

JOURNAL OF **AVIATION**



-edit
PUBLISHING

VOLUME **9**
ISSUE **3**
OCTOBER **2025**

www.javsci.com
dergipark.gov.tr/jav
e-ISSN 2587-1676

Editor- in-Chief

Ph.D Vedat Veli Çay (Dicle University), Türkiye

Associate Editors

Ph.D İnan Eryılmaz (Süleyman Demirel University), Türkiye
Ph.D Vildan Durmaz (Eskişehir Technical University), Türkiye
Ph.D Yasin Şöhret (Süleyman Demirel University), Türkiye
Ph.D Fatih Koçyiğit (Dicle University), Türkiye
Ph.D Gülaçtı Şen (Balıkesir University), Türkiye
Ph.D Ömer Osman Dursun (Fırat University), Türkiye
Ph.D Bahri Baran Koçak (Dicle University), Türkiye
Ph.D Yusuf Er (Fırat University), Türkiye

Language Editors

Ph.D Seçil Ulufer Kansoy, Department of Aviation Management in Lüleburgaz Faculty of Aeronautics and Astronautics (Kırklareli University)Türkiye
Lecturer İbrahim Çapar, School of Foreign Languages (Dicle University), Türkiye

EDITORIAL BOARD

Mohd Razif İdris, Ph.D

Kuala Lumpur University, Malaysian

Simone Sarmento, Ph.D

Federal Do Rio Grab De Unv. Brazil

Sukumar Senthilkumar, Ph.D

Chon Buk National University, South Korea

Nicolas Avdelidis, Ph.D

Universite Laval, Canada

Tarcisio Saurin, Ph.D

Federal do Rio Grande do Sul Unv. Brazil

Mary Johnson, Ph.D

Purdue University, United States

Özlem Atalık, Ph.D

Anadolu University, Türkiye

Faruk Aras, Ph.D

Kocaeli University, Türkiye

Sermin Ozan, Ph.D

Fırat University, Türkiye

Mustafa Sabri Gök, Ph.D

Bartın University, Türkiye

Ahmet Topuz, Ph.D

Yıldız Technical University, Türkiye

Mustafa Boz, Ph.D

Karabük University, Türkiye

Melih Cemal Kuşhan, Ph.D

Eskişehir Osmangazi University, Türkiye

Önder Altuntaş, Ph.D

Anadolu University, Türkiye

Ferhan Kuyucak Şengür, Ph.D

Anadolu University, Türkiye

Uğur Soy, Ph.D

Sakarya University, Türkiye

Matilde Scaramucci, Ph.D

Estadual Campinas Unviversity, SP, Brazil

Seçil Ulufer Kansoy, Ph.D

Kırklareli University, Türkiye

Ümit Deniz Göker, Ph.D

Astronomical Institute of Czech Academy of Sciences, Czech Republic

Kumar Shanmugam, Ph.D

*Masdar Institute of Science &
Technology, Abu Dhabi, UAE*

Sonjoy Das, Ph.D

Buffalo University, United States

Fatih Koçyiğit, Ph.D

Dicle University, Türkiye

Kasım Kiracı, Ph.D

Iskenderun Technical University, Türkiye

Hüseyin Tamer Hava, Ph.D

Milli Savunma University, Türkiye

Haşim Kafalı, Ph.D

Muğla University, Türkiye

Mustafa Yeniad, Ph.D

Yıldırım Beyazıt University, Türkiye

Tolga Tüzün İnan, Ph.D

Gelişim University, Türkiye

Bahri Baran Koçak, Ph.D

Dicle University, Türkiye

Murat Düzgün, Ph.D

İstanbul Medipol University, Türkiye

Filiz Mızrak, Ph.D

İstanbul Medipol University, Türkiye

Mehmet Konar, Ph.D

Erciyes University, Türkiye

Tuğrul Oktay, Ph.D

Erciyes University, Türkiye

Ceyda Aktan, Ph.D

*Türk Hava Kurumu University,
Türkiye*

Akansel Yalçınkaya, Ph.D

Medeniyet University, Türkiye

Cengiz Mesut Bükeç, Ph.D

Bahçeşehir University, Türkiye

Salvatore Brischetto, Ph.D

Polytechnic University of Turin, Italy

Hikmat Asadov, Ph.D

Azerbaijan National Aerospace Agency

Bilal Kılıç, Ph.D

Ozyegin University, Türkiye

Gülaçtı Şen, Ph.D

Balıkesir University, Türkiye

Ramazan Çoban, Ph.D

Malatya Turgut Özal University, Türkiye

Nalan Gelirli, Ph.D

Cyprus Science University, Cyprus

Marco Linz, Ph.D

EBS University, Germany

Donald Costello, Ph.D

United States Naval Academy, United States

Sezer Çoban, Ph.D

Iskenderun Technical University, Türkiye

İnan Eryılmaz, Ph.D

Süleyman Demirel University, Türkiye

Serdar Alnıpak, Ph.D

Nişantaşı University, Türkiye

JOURNAL INFORMATION

Journal Name	Journal of Aviation
Abbreviation	J. Aviat.
Subjects	Aviation, Aircraft, Aerospace
e-ISSN	2587-1676
Publisher	Edit Publishing; Edit Teknoloji ARGE San. Tic.Ltd. Şti. Diyarbakır, Türkiye
Owner	Vedat Veli Cay
Language	English
Frequency	Tri-annual (January, June, October)
Type of Publication	International, Scientific, Open Access, Double blinded peer review, Widely distributed periodical
Manuscript Submission and Tracking System	JAV uses the submission system of TUBITAK ULAKBİM JournalPark Open Journal Systems - http://dergipark.gov.tr/jav
Licence	Journal is licensed under a Creative Commons Attribution 4.0 International License
Legal Responsibility	Authors are responsible for content of articles that were published in Journal
Indexed and Abstracted in	TÜBİTAK ULAKBİM TR Dizin, Crossref, Directory of Open Access Journal (DOAJ), WorldCat, Google Scholar, SOBIAD, Scilit, ROAD (Directory of Open Access Scholarly Resources), Neliti, International Citation Index, ROOT Indexing, ResearchBib, Index Copernicus International, ESJİ, ResearchGate, Microsoft Academic
Address	Edit Teknoloji Arge Sanayi ve Ticaret Limited Şirketi Dicle Teknokent Dicle Üniversitesi Kampüsü Yiğit Çavuş Mah. Silvan Yolu Üzeri Kat:2 No:26, Diyarbakır, Türkiye
Contact	Ph.D Vedat Veli Cay Phone: +90 532 567 95 97 E-Mail: journalofaviation@gmail.com - info@editteknoloji.com Web: www.javsci.com - dergipark.gov.tr/jav

AIM AND SCOPE

Journal of Aviation (JAV) established in 2017. It is a peer-reviewed international journal to be of interest and use to all those concerned with research in various fields of, or closely related to, Aviation science. Journal of Aviation (JAV) aims to provide a highly readable and valuable addition to the literature which will serve as an indispensable reference tool for years to come. The coverage of the journal includes all new theoretical and experimental findings in the fields of Aviation Science or any closely related fields. The journal also encourages the submission of critical review articles covering advances in recent research of such fields as well as technical notes.

The scopes include:

- Accounting
- Acoustics
- Aerospace communications
- Air cargo, logistics, and supply-chain management
- Air pollution
- Air traffic management and control
- Air transport policy, regulation, and law
- Airport planning and management
- Airworthiness, reliability, and safety
- Atmospheric flight mechanics
- Attitude dynamics
- Autonomous and unmanned air vehicles
- Big data and data mining
- Brand management
- Business management and strategy
- Combustion and fuels
- Complex systems
- Design and manufacturing
- Dynamics and control of large flexible space structures
- Economics and finance
- Electrical systems in air vehicles
- Electromagnetism and radar
- Environmental issues
- Flight mechanics
- Flight performance
- Fluid dynamics
- History of aviation
- Human and system interaction
- Human factors
- Information processing
- Innovation in aerospace and astronautical technology
- Maintenance, repair, and overhaul
- Management of route, terminal, airspace, and airport operations
- Maneuvering flight vehicles
- Marketing
- Materials and structures
- Navigation, guidance, and control
- Noise
- Novel and trend technologies in aerospace
- Numerical and computational methods
- Optics
- Orbit determination
- Organizational behavior and commitment
- Propulsion systems
- Robotics and intelligent systems
- Safety management system (SMS)
- Signal and image processing
- Space mission analysis
- Standards, procedures, training, and certification in aviation
- Sustainable technologies and development
- System design and development for air vehicles
- Test, instrumentation, and validation
- Trajectory optimization
- Vehicle conceptual design
- Weather and meteorology

Abstracting & Indexing

 TR Dizin	 Index Copernicus	 CrossRef	 ASOS Index
 Google Scholar	 International Scientific Indexing	 DRJI	 Bielefeld Academic Search Engine BASE
 Journal Factor	 JIFACTOR	 i2or	 Rootindexing
 Science Library Index	 Academic Keys	 Eurasian Scientific Journal Index	 COSMOS IF
 Scientific Indexing Services	 OpenAIRE EXPLORE		

CONTENTS

-Research Article-

1.	Design and Implementation of a UAV Control System Using the Airbus A320 Side-Stick Controller Hüseyin Gülhan, Ömer Kemerlioğlu, Aydın Türkmen, Sümeyra Tuna and Mehmet Konar	497
2.	Performance Maximization of Longitudinal Flight Stability of Fixed Wing Unmanned Aerial Vehicles with Double Dihedral Angle Variation Tolunay Dağ, Tuğrul Oktay	503
3.	Analysis of LTE Network Connection Parameters at Legal Maximum UAV Flight Altitudes and Comparison with Ground Emin Tugay Kekeç, Mustafa Samet Gençay, Köksal Boyalı	508
4.	A TRIZ-Axiomatic Design Framework with Semantic Rmp Mapping for Material Selection: Application to Aircraft Brake Disks Ömer Yaman	516
5.	Factors of Human Interaction on the Path to Passenger Satisfaction, Perceived Value, and Intention to Recommend in Airlines Sadiye Oya Işıkcı	528
6.	Aviation Focused Sustainability Analysis in EU Countries with CRITIC Based MABAC Method Sümeyye Yavuz, Tuğba Akbıyık, Eda Çınaroğlu	538
7.	Strategic Pathways to Aviation Sustainability: Insights from Turkish Experts on Regulatory, Technological, and Market Responses Tuncel Öz	548
8.	The Effect of Perceived Level of Institutionalization on Organizational Trust: A Study on Aviation Sector Murat Sucu, Mustafa Kemal Yılmaz	564
9.	Environmental Sustainability Performance in Aviation: An Analysis Based on Stakeholders' Sustainability Reports Güzide Karakuş	578
10.	Breaking the Barriers: Accessibility Challenges for Disabled Passengers in Aviation Kübra Nur Cingoz, Vildan Durmaz	590
11.	The Impact of ESG Performance on Financial Profitability: Evidence from the Aviation Sector in EU Countries Burcu Zengin	600
12.	Machine Learning-Based Approach for Predicting Hard Landings in Commercial Aircraft Hatice Doğan Kuzey, Fatma Yıldırım Dalkıran	609
13.	Hot Air Balloon Accidents in Turkish Airspace: Human Factors Through RCA and HFACS Derya Azık Özkan	614
14.	The Impact of Brand Communication on Consumer Attitudes: Example in the Airlines Industry Oguzcan Yerli, Belis Gülay	623
15.	The Mediating Role of Trust in Coworker In The Effect Of Perceived Overqualification On Job Passion: A Study On Aircraft Maintenance Technicians Tugay Öney, Nida Palabıyık, Seçil Ulufer Kansoy	630
16.	Panopticon Perceptions and Work Engagement Among Airline Employees: The Role of Surveillance in Employee Motivation Ahmet Selim Süzer	640

17.	Resistance to Change, Self-Efficacy, and Organizational Agility in Civil Aviation Seray Toksöz	648
18.	The Mediating Role of Occupational Stress in the Impact of Digital Leadership on Open Innovation Capability in the Aviation Sector Ethem Topçuoğlu, Onur Oktaysoy, Yaşar Şahin	658
19.	Shift Planning with Artificial Intelligence within the Scope of Strategic Decision-Making Approach in Airport Ground Handling Operations Mine Değirmencioğlu, Armağan Macit	669
20.	Multidimensional Seat Comfort and Its Influence on Passenger Recommendation Behavior: Insights from Skytrax Reviews Şahap Akan	676
21.	Bibliometric Analysis of Sustainable Aviation Fuels Using Biblioshiny Vurgun Topçuoğlu, Mevlüt Üzülmaz	684
22.	Flying Towards Equality: The Role of Female Employees in Enhancing Airline Performance Mehmet Şahin Durak	694
23.	An Analysis of Commercial Aircraft Accidents Using the Human Factors Analysis and Classification System (HFACS): The Case of The United States Münevver Aysel Kaya, Didem Göçmen	703
24.	Financial Sustainability of European Air Navigation Service Providers and the Impact of the COVID-19 Pandemic Orkun Bayram	714
25.	Examining The Impact of General Competency Belief on Crisis Management: The Mediating Roles of Perceived Insider Status in The Airline Industry Semra Erener Özalçın, Nurdan Çolakoğlu	725
26.	Financial Repercussions of the Pandemic Shock in OECD Countries: An Analysis of the Airline and Healthcare Industries Çağatay Mirgen, Yunus Emre Kahraman	735
27.	Investigating the Relationships Between Oil Prices and Airline Stock Values Eşref Kuloğlu	745
28.	Examination of Human Factors in Civilian Unmanned Aerial Vehicles Accidents with PEAR Model: United Kingdom Sample Ramazan Çoban	751
29.	From Check-in to Take-off: How Digitalization Reshapes Airport Service Quality Sinem Büyüksaatçı Kiriş, Binnur Akıf	768
30.	A Tool for Fleet and/or Aircraft Assignment in Demand Optimization in Airline Operations Ali Akbaba	780
31.	Post-Pandemic Trends in Corporate Risk Management: A Bibliometric Review in the Context of the Aviation Industry Tuğçe Çopur, Ayşe Küçük Yılmaz	797
32.	Towards International Standardization in UAS Pilot Licensing: A Comparative Analysis of EASA and FAA Frameworks Anastasia Tsotra	808
33.	Comparison Of Customer Reviews Between Traditional Airlines and Low-Cost Carriers: A Case Study from Türkiye Nursel Çebişli, Kemal Enes, Mustafa Öztürkel	816

Design and Implementation of a UAV Control System Using the Airbus A320 Side-Stick Controller

Hüseyin Gülhan¹, Ömer Kemerlioğlu^{2*}, Aydın Türkmen^{3*}, Sümeyra Tuna^{4*} and Mehmet Konar⁵

¹Erciyes University, Graduate School of Natural and Applied Science, Aviation Electrical and Electronics (MSC) Program, 38039, Kayseri, Türkiye. (gulhann.huseyin@gmail.com)

²Turkish Aerospace Industries Inc. Principal Technical Logistics Engineer, After Sale Product Support, 06980, Ankara, Türkiye. (okemerlioglu@gmail.com)

³Kahramanmaraş İstiklal University Airbus TUSAŞ Aviation Vocational School, Department of Motor Vehicles and Transportation Technologies, 46000, Kahramanmaraş, Türkiye. (aydin.turkmen@istiklal.edu.tr)

⁴Erciyes University, Graduate School of Natural and Applied Science, Aviation Electrical and Electronics (MSC) Program, 38039, Kayseri, Türkiye. (sumeyratuna@erciyes.edu.tr)

⁵Erciyes University, Faculty of Aeronautics and Astronautics, Aviation Electrical and Electronics, 38039, Kayseri, Türkiye. (mkonar@erciyes.edu.tr)

Article Info

Received: 14 August 2025

Revised: 17 September 2025

Accepted: 22 September 2025

Published Online: 09 October 2025

Keywords:

Side-stick

Fly-by-wire

Simulator

Control Surfaces

UAV

A320

Corresponding Author: Mehmet Konar

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1768620>

Abstract

Air transportation has become a rapidly expanding and widely preferred mode of international and intercontinental travel. In line with this growth, aircraft manufacturers continuously strive to enhance both flight safety and comfort for passengers as well as flight crews. One of the most significant examples of these efforts is the side-stick controller employed in Airbus aircraft, which plays a vital role in improving flight safety and operational efficiency. The side-stick is a fundamental control device that facilitates the pilot's handling of the aircraft. Pilot inputs made in the cockpit are transmitted via the side-stick and used as reference signals for the actuation of the flight control surfaces. These signals are then processed by the flight control computers, which determine the corresponding movements of the control surfaces. In this way, cockpit commands are converted into electrical signals, enabling precise aircraft control through the flight control system.

This study presents a reverse-engineering analysis of the co-pilot's side-stick controller in the Airbus A320 series passenger aircraft. The research begins with a comprehensive examination of the A320 side-stick control system, focusing on the interaction of its mechanical and electronic components and the generation of control commands. Based on this analysis, the operational limitations of the side-stick controller were identified. The findings indicate that the A320 side-stick controller has an electromechanical structure. Building on this result, an Arduino-based circuit was designed within the scope of the study to control the flight surfaces of an Unmanned Aerial Vehicle (UAV) using the A320 side-stick controller.

1. Introduction

Simulations are widely recognized as technological tools, typically based on computer models, that replicate real-world events, processes, or systems. By creating digital representations of physical systems, they allow users to analyze and evaluate scenarios in safe and controlled environments. Although simulations are used across numerous industries, they have become particularly critical in aviation, where they play a fundamental role in reducing costs and enhancing safety across aircraft design, pilot training, maintenance, and certification processes (Fellah et al. 2016; Tselegkaridis and Sapounidis 2021; Farmer et al. 2017; Basdogan et al. 2007; Saia et al. 2013).

In the context of aircraft design, several studies emphasize the role of simulations in reducing both cost and time. The

development of a new aircraft requires numerous tests and evaluations, and conducting these tests on physical prototypes has traditionally been expensive and time-consuming. Computer-based simulations, however, enable engineers to design, test, and optimize new models in a virtual environment. According to previous research, this approach minimizes the need for physical prototypes, reduces testing costs, and allows for the early detection and correction of potential design flaws, ultimately contributing to improved safety and efficiency (Hancock et al. 2008, Saia et al. 2013; Bilgin and Konar 2022; Karaburun et al. 2024; Konar et al. 2024; Karaburun et al. 2025).

Pilot training represents another area in which simulations have proven indispensable. Real aircraft training flights are both costly and potentially hazardous. As highlighted by Bell and Waag, military flight simulators have demonstrated

significant potential in complementing conventional training, particularly in the development of combat skills. However, their study also pointed out that evaluations are often limited in scope and recommended further experimental research to expand their effectiveness (Bell and Waag 1998). In civilian aviation, modern simulators provide highly realistic environments, allowing trainees to practice emergency procedures, diverse weather conditions, and all phases of flight operations with remarkable accuracy. This ensures that trainee pilots are better prepared for real-world operations, enhancing both the safety and efficiency of training programs (Farmer et al. 2017; Hegg et al. 1994).

Simulations have also been applied effectively in aviation maintenance and certification processes. Farmer et al. concluded that simulation-based training can offer substantial educational benefits, particularly when real systems are either unavailable or impractical for training purposes (Farmer et al. 2017). Maintenance technicians, for example, are able to practice complex repair and inspection procedures in a risk-free environment, thereby increasing both skill acquisition and confidence. Furthermore, simulations play an essential role in the certification of new aircraft models. By enabling performance and safety testing in virtual environments, they complement physical trials and contribute to more efficient and cost-effective certification processes.

Another field of research highlights the role of simulations in educational robotics and skill development. Tselegkaridis and Sapounidis, for instance, investigated how simulators in educational robotics support knowledge acquisition and skill-building among students. Their study demonstrated that simulators not only provided valuable virtual experience but also enabled preparation for robotics competitions without the limitations imposed by hardware availability (Tselegkaridis and Sapounidis 2021).

Collectively, these studies demonstrate that simulations have become an indispensable component of aviation and related fields. Their effectiveness, however, is strongly linked to the accuracy and reliability of the systems, models, and control devices employed. Advanced hardware, high-performance computing, and realistic control systems are essential to ensure both fidelity and effectiveness. Consequently, continuous development and improvement of simulation technologies remain vital for their sustained success in aviation and other domains (Tselegkaridis and Sapounidis 2021; Basdogan et al. 2007; Coban and Oktay 2023; Bilgin and Konar 2022).

2. Simulators

Simulators are technological systems that replicate real-world events, processes, or environments through physical and/or digital models. They are employed across a wide range of fields, including education, research, planning, and entertainment, with the purpose of preparing users for real-world situations. In aviation, flight simulators play a central role in the training of pilots, engineers, and technicians. These systems realistically replicate aircraft cockpits, flight dynamics, and environmental conditions, thereby providing a safe and controlled training environment. Beyond aviation, simulator technologies have also been applied in other domains. Driving simulators, for instance, enable drivers to train under various road and traffic conditions by replicating the dynamics of cars, trucks, and trains. In the medical field, simulators—ranging from patient mannequins to virtual reality (VR) applications—allow healthcare professionals to practice

procedures and emergency responses in risk-free environments (Hancock et al. 2008). Similarly, military simulators enable personnel to engage in realistic combat and operational scenarios by integrating battlefield tactics, weapons systems, and mission planning exercises (Farmer et al. 2017). In addition, educational and research simulators are utilized for scientific training and experimentation, replicating diverse scientific and engineering processes for instructional and investigative purposes (Hosman et al. 1990.; Farmer et al. 2017; Dechow and Nurcombe 2005; Hegg et al. 1992).

The architecture of simulators generally consists of three key components: hardware, software, and immersive technologies such as virtual reality (VR) and augmented reality (AR). The hardware comprises the physical elements, including control panels, displays, seats, and motion platforms. Software represents the algorithms and programs that govern system operation, managing both environmental dynamics and user interactions. Meanwhile, VR and AR technologies enhance realism and interactivity, making simulation-based experiences more immersive and effective (Saia et al. 2013).

Simulators have become essential tools in professional training, research, entertainment, and planning. They provide critical opportunities for skill development among pilots, drivers, doctors, and military personnel, while also being widely applied in video games and amusement parks to create immersive user experiences. In scientific and engineering research, simulators are employed to test new systems and technologies, while in urban planning and emergency management they serve as valuable tools for analysis and decision-making. Their advantages include risk reduction, cost-effectiveness, reusability, and realistic training opportunities. By enabling the safe replication of potentially hazardous real-world conditions, simulators reduce risks, lower costs compared to real-world testing, allow for repeated experimentation across diverse scenarios, and facilitate experiential learning through practice.

With the continuous advancement of technology, simulators are becoming increasingly realistic and effective. Innovations in artificial intelligence, machine learning, and advanced graphics have significantly improved the fidelity and interactivity of simulations. Consequently, simulators are now regarded as indispensable tools across diverse domains, from education and research to professional training and planning. By enhancing preparedness for real-world situations, they contribute directly to improvements in safety, efficiency, and overall performance outcomes.

3. Aircraft controllers

Aircraft controllers are integral systems designed to manage an aircraft's movements and overall performance during flight, assisting pilots in navigating safely and efficiently. These systems can be categorized into manual control systems, fly-by-wire (FBW) systems, and automatic flight control systems (AFCS). Manual control systems rely on traditional mechanical linkages and hydraulic actuators, whereas FBW systems transmit pilot inputs to control surfaces via electronic signals. AFCS, which include autopilot, auto-steer, and auto-landing systems, enable automatic aircraft control according to predefined parameters (McLean 1999; Bağış and Konar 2008).

Aircraft control systems comprise several key components, including cockpit controls, control surfaces, sensors, actuators,

and flight computers (Bailey 1963). Cockpit controls—such as joysticks, pedals, and buttons—serve as the primary interface through which pilots issue flight commands. Control surfaces, including ailerons, rudder, and elevators, govern the aircraft's orientation and stability by adjusting the aerodynamic forces acting on the wings and tail. Sensors and actuators collect and relay information regarding the aircraft's state, facilitating precise adjustments of the control surfaces. Flight computers process this data, calculate necessary flight parameters, and execute control commands accordingly.

The applications of aircraft control systems encompass guidance, altitude regulation, speed management, and autopilot functionalities. By managing bank, pitch, and yaw movements, adjusting altitude, and controlling engine power and air brakes, these systems ensure stable and efficient flight operations. Autopilot functions further reduce pilot workload and improve operational efficiency, particularly during extended flights. Overall, aircraft control systems contribute significantly to flight safety, precision, comfort, and efficiency.

Future developments in aircraft control systems are expected to leverage artificial intelligence (AI) and machine learning to create more intelligent and predictive control capabilities. Advanced sensor technologies will provide higher precision and reliability in data acquisition, further enhancing flight safety. Moreover, the ongoing development of autonomous aircraft represents a significant evolution in aircraft control systems.

The specific system relevant to this study is the Fly-by-Wire (FBW) system, a digital control architecture that enables aircraft maneuvering via electronic signals. In FBW systems, pilot inputs through control levers and pedals are detected by electronic sensors and converted into electrical signals. These signals are transmitted to the flight computers, which subsequently command the actuators to adjust the positions of the control surfaces, ensuring accurate and responsive aircraft control (Lucena et al. 2007).

4. Control surfaces

Aircraft control surfaces are movable components that govern an aircraft's direction and stability. These surfaces are located on the wings and tail sections and respond directly to pilot control commands (Tischler 1996; Karaburun et al. 2024; Hatipoğlu and Özcan 2025).

Ailerons are small, movable surfaces situated on the outer portions of the wings. They control the aircraft's roll (bank) by moving the wings up or down. When the aileron on one wing moves upward, the aileron on the opposite wing moves downward, causing the aircraft to tilt laterally. This mechanism enables pilots to manage and steer the aircraft's bank angle effectively.

The rudder is a movable surface positioned on the vertical stabilizer of the tail. It regulates yaw by directing the aircraft's nose to the left or right and is operated via pedals. By pressing the pedals, pilots adjust the rudder's angle, controlling the aircraft's lateral direction. Yaw control is particularly important for executing turns and maintaining directional stability during flight.

Elevators are movable surfaces located on the horizontal stabilizer of the tail. They control the aircraft's pitch by moving the nose up or down and are operated through the yoke or side-stick. Pitch adjustments are essential for regulating altitude, allowing the aircraft to climb or descend safely.

Flaps and spoilers are additional movable surfaces located on the wings. Flaps, positioned along the trailing edges, increase lift during takeoff and landing, enabling safe operations at lower speeds. Spoilers, located on the upper wing surfaces, reduce lift by disrupting airflow, assisting in deceleration during landing and enhancing overall control.

Each of these control surfaces plays a critical role in maneuvering and safely operating the aircraft. They are specifically designed to execute different flight maneuvers and are utilized effectively by pilots under a wide range of flight conditions.

5. Basics of Using Side-Sticks and Components

The primary reason for selecting this Airbus component, rather than other types of controllers, in this study is that it operates as a fly-by-wire (FBW) system rather than a traditional mechanical system. Because the system functions through the transmission of electronic signals, all necessary pilot feedback, including gradient zones and points of increased resistance, is inherently integrated into the side-stick. This characteristic enables the collection of precise feedback corresponding to in-flight conditions when using the controller (Summers et al. 1987; Corps 1986; Hegg et al. 1994; McLean 2003).

The study commenced with a detailed examination of the mechanical and electronic components of the sidestick controller. During this phase, key parameters such as the sidestick's range of motion, sensitivity, and response time were measured and analyzed. These measurements are essential for understanding the operational characteristics of the sidestick and how it transmits commands to the flight control surfaces (Coyle 1993; Alford 2004).

Integration tests of the sidestick with the flight control system revealed a direct connection to the Flight Control Computers (FCC) (Figure 1). This connection is crucial for flight safety and overall system performance, as the FCC serves as the primary processor of aircraft control commands, transmitting them to the control surfaces. To replicate this process in a model aircraft without using the FCC, potentiometers were employed to convert sidestick movements into precise electrical signals. These signals were transmitted to an Arduino platform, which then converted them into digital commands to control servo motors and actuate the model aircraft's control surfaces. This methodology allows for accurate tracking of sidestick movements and their translation into control surface actions (Collinson 2012; Lucena et al. 2007; Alford 2004; Aguilar et al. 2019).

The integration process involves converting the mechanical movements of the sidestick into electrical signals via potentiometers, processing these signals with the Arduino, and transmitting commands to the servo motors. This enables precise tracking of movements along the x, y, and z axes. The Arduino continuously processes the incoming signals, adjusting the servo motors' positions to ensure accurate movement of the model aircraft's control surfaces. This system effectively simulates the operation of the sidestick under real-world flight conditions, demonstrating how pilot inputs are transmitted to the flight control surfaces.

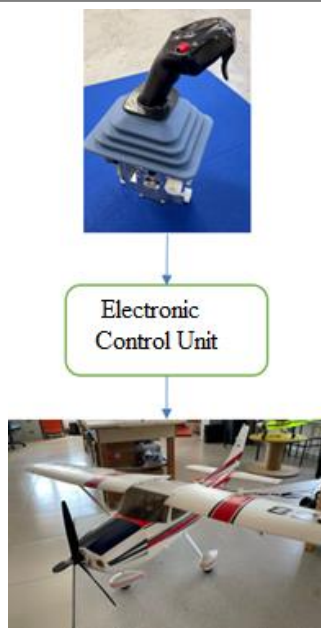


Figure 1. Block diagram of the A320 side-stick controller integration with a UAV via the electronic control unit.

The measurement results confirmed that the sidestick could be successfully connected to the FCC and integrated into the model aircraft using potentiometers, Arduino, and servo motors. This approach provides a valuable method for understanding the principles of flight control systems and serves as an educational tool for aeronautical engineering students and professionals. The Arduino platform, with its flexible and programmable architecture, is particularly well-suited for this application, as it allows analog signals from the sidestick to be accurately converted into digital commands for the servo motors.

Customized software, written in the Arduino IDE, converts the sidestick movements into commands compatible with the servo motors, ensuring precise positioning of the model aircraft's control surfaces. The final phase of the study involved assembling all components and conducting performance tests on the model aircraft. The movement of the control surfaces was monitored, and the system's performance was evaluated (Figure 2).



Figure 2. Integration of A320 Side-Stick Controller with UAV via Electronic Control Unit

This demonstration on the model aircraft enables users to observe and understand the operating principles and structural characteristics of real aircraft systems on a scaled-down platform. It serves as a significant educational tool in the design, testing, and training of engineers and technicians, bridging the gap between theoretical knowledge and practical application.

6. Discussion

Simulation technologies play a critical role in education, research, and development across aerospace, automotive, healthcare, and numerous other sectors. The integration of sidesticks with the Arduino platform to create a simulation stand demonstrates the potential benefits of combining these technologies. However, while this approach offers significant advantages, it also presents certain challenges that must be addressed.

One of the primary benefits of this integration is its flexibility and customizability. The Arduino platform allows users to tailor the simulation stand to specific applications and requirements. This adaptability enables the design of simulation scenarios for a wide range of purposes. Moreover, Arduino is an affordable and widely accessible platform, reducing project costs and expanding user access. Its user-friendly programming environment and extensible architecture support rapid prototyping and iterative design processes, accelerating innovation and enabling users to implement their ideas efficiently.

Despite these advantages, several technical challenges exist. Accurately detecting and transferring sidestick movements is essential for realistic simulation. The precision of potentiometers and the Arduino platform is therefore critical; insufficient accuracy can compromise the simulation experience and potentially produce misleading results in training or research contexts. Integrating multiple components—including sidesticks, potentiometers, and servo motors—requires careful technical coordination to ensure harmonious operation. This integration process demands both technical expertise and experience to achieve reliable performance.

The use of high-quality materials and components is also vital for maintaining durability and reliability under continuous and intensive use. Substandard materials can lead to system failures, increased maintenance requirements, and a diminished user experience. By carefully addressing these technical, integration, and reliability considerations, a sidestick and Arduino-based simulation stand can provide an accessible, flexible, and customizable platform for simulation technologies.

Several key operational considerations further enhance the effectiveness of such a simulation stand:

- **Calibration and Testing:** Regular calibration and testing should be conducted to ensure proper data flow and accurate operation of sidesticks, potentiometers, and servo motors.
- **Training and User Support:** Comprehensive training materials, user manuals, and support documentation should be provided to enable effective use of the simulation stand.
- **Spare Parts and Maintenance:** Stocking spare components and implementing periodic maintenance routines helps prevent malfunctions and wear during intensive use.
- **Updating and Improvement:** In a rapidly advancing technological environment, regular updates and improvements

should be planned to enhance the stand's performance and capabilities.

- **User Feedback:** Collecting and evaluating user feedback is essential for assessing the stand's design, functionality, and performance, informing future developments.

The integration of sidesticks with the Arduino platform offers a flexible, customizable, and cost-effective approach to simulation technologies, enabling broad applicability in education and research. While this method provides significant advantages in terms of accessibility and adaptability, it also poses challenges related to accuracy, component integration, and system reliability. Ensuring precise signal detection, employing high-quality materials, and implementing calibration, maintenance, and user support measures are essential to achieve realistic performance. Addressing these considerations will allow sidestick-Arduino simulation stands to evolve into robust and practical tools for long-term use.

For future work, efforts can be directed toward developing dedicated calibration software, integrating more advanced sensor technologies, and enhancing user interfaces to improve system usability. Additionally, implementing modular architectures may enable scalability and broader applicability across various UAV and simulation platforms, further extending the impact of this study.

7. Conclusion

The most significant finding of this study is that used, end-of-life aircraft components can be effectively repurposed as training materials. Students, technicians, and engineers can gain hands-on experience with real aircraft parts before entering their professional careers. This principle is not limited to the sidestick; many control surfaces and aircraft components can be utilized for educational purposes.

Using a force gauge as a measurement criterion, the study quantitatively demonstrated the difference in force feedback between traditional joysticks and the Airbus sidestick. While joystick measurements remained at 25 in/lb and were largely unaffected by applied force, sidestick measurements reached 40 in/lb and increased proportionally with applied force. In gradient zones, this value was measured at 55 in/lb, highlighting the variable resistance inherent to the sidestick design.

Simulation stands created by integrating sidesticks with Arduino platforms offer notable advantages, including flexibility, customizability, and cost-effectiveness. Such systems expand access to simulation technologies and allow their application across diverse educational and research settings. However, technical challenges exist, including the precise detection and transmission of sidestick movements, accurate programming of the Arduino, and the integration of various hardware components. Additionally, the use of high-quality materials and components is essential to ensure durability and reliability under continuous and intensive use.

The study involved a detailed examination of the mechanical and electronic components of the Airbus sidestick controller and the creation of a simulation stand using the Arduino platform. Initial testing focused on parameters such as range of motion, sensitivity, and response time, which are critical for understanding how the sidestick issues commands to the flight control surfaces. Integration tests demonstrated the sidestick's direct connection to the Flight Control Computers

(FCCs), highlighting its importance for flight safety and overall system performance.

In later stages, potentiometers were used to convert sidestick movements into precise electrical signals, which were transmitted to the Arduino platform. The Arduino converted these signals into digital commands, controlling servo motors and accurately actuating the model aircraft's control surfaces. This process enabled precise tracking of sidestick movements along the x, y, and z axes and their translation to the flight control surfaces. The system effectively simulated the operation of the sidestick under real-world flight conditions, demonstrating how pilot commands are transmitted and executed.

Overall, the study demonstrated that the sidestick can be successfully connected to the FCC and integrated into a model aircraft using potentiometers, Arduino, and servo motors. This project provides an effective approach to making simulation technologies more accessible, flexible, and customizable. Successful implementation, however, requires careful attention to technical details, integration challenges, and system reliability. Future projects that continue to refine and expand such simulation technologies are expected to make substantial contributions to education and research in aeronautical engineering.

In addition to the current findings, future studies will focus on the development of a dedicated calibration system or software to enhance the accuracy and reliability of the proposed platform. Such a system would enable automatic adjustment of sensor deviations, improve long-term stability, and provide user-friendly interfaces for broader application in training and research environments. By integrating calibration capabilities, the platform can evolve into a more robust and practical tool for real-world applications.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

This study was supported by the Scientific Research Projects Unit of Erciyes University with the FYL-2024-13287 project code. Thank you for support.

References

- Aguilar, G. P., Binet, L., & Rakotomamonjy, T. (2019, July). Design methodology of force feedback laws for active side stick interface. In *World Haptics Conference*.
- Alford, L. D. (2004). Fly-by-wire T & E challenge [aircraft test pilot handling compensation]. *IEEE Aerospace and Electronic Systems Magazine*, 19(2), 3-7.
- Arik, S., Turkmen, I. and Oktay, T. (2018). Redesign of Morphing UAV for Simultaneous Improvement of Directional Stability and Maximum Lift/Drag Ratio. *Advances in Electrical and Computer Engineering*. 18(4), 57-62.
- Bağış, A., & Konar, M., (2008). Elektronik Uçuş Kontrol Sistemleri. VII. Havacılık Sempozyumu (HaSeM'08) (pp.155-159). Kayseri, Turkey
- Bailey, Jr, A. (1963). Development of a Side-Stick Controller for Aerospace Vehicles. In *Testing of Manned Flight Systems Conference* (p. 1806).
- Basdogan, C., Sedef, M., Harders, M., & Wesarg, S. (2007). VR-based simulators for training in minimally invasive

- surgery. *IEEE Computer Graphics and Applications*, 27(2), 54-66.
- Bell, H. H., & Waag, W. L. (1998). Evaluating the effectiveness of flight simulators for training combat skills: A review. *The international journal of aviation psychology*, 8(3), 223-242.
- Bilgin, M. and Konar, M. (2022). Investigation of Visual Disappearance by Intelligent Illumination of Exterior Surfaces of Unmanned Aerial Vehicles. *Journal of Aviation*. 6(1), 26-32.
- Coban, S. and Oktay, T. (2023). Innovative Morphing UAV Design and Manufacture. *Journal of Aviation*. 7(2), 184-189.
- Collinson, R. P. (2012). *Introduction to avionics* (Vol. 11). Springer Science & Business Media.
- Corps, S. G. (1986). Airbus A320 Side Stick and Fly by Wire—An Update. *SAE Transactions*, 1263-1275.
- Coyle, S. (1993). *Automatic flight control*. Blackwell Scientific Publications.
- De Lucena, S. E., & Suzuki, E. Y. (2007, May). Electro-hydraulic actuator tester for fly-by-wire aircrafts. In *2007 IEEE Instrumentation & Measurement Technology Conference IMTC 2007* (pp. 1-3). IEEE.
- Dechow, M., & Nurcombe, C. A. H. (2005). Aircraft environmental control systems. In *Air quality in airplane cabins and similar enclosed spaces* (pp. 3-24). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Ersen, M and Konar, M. (2023). Obtaining Condition Monitoring Data for the Prognostics of the Flight Time of Unmanned Aerial Vehicles. *Journal of Aviation*. 7(2), 209-214.
- Farmer, E., Van Rooij, J., Riemersma, J., & Jorna, P. (2017). *Handbook of simulator-based training*. Routledge.
- Fellah, K., Guiatni, M., Ournid, A. K., & Boulahlib, M. A. (2016). Fuzzy-PID side-stick force control for flight simulation. *The Aeronautical Journal*, 120(1227), 845-872.
- Hancock, P. A., Vincenzi, D. A., Wise, J. A., & Mouloua, M. (2008). *Human factors in simulation and training*. CRC Press.
- Hatipoğlu, S. A., & Özcan, B. (2025). Estimating of UAV Battery Status with BSA Based Sugeno Type Fuzzy System. *Journal of Aviation*, 9(2), 382-387.
- Hegg, J. W., Smith, M. P., & Yount, L. (1992, October). Sidestick controllers for advanced aircraft cockpits. In *[1992] Proceedings IEEE/AIAA 11th Digital Avionics Systems Conference* (pp. 491-499). IEEE.
- Hegg, J. W., Smith, M. P., Yount, L., & Todd, J. (1994, October). Features of active sidestick controllers. In *AIAA/IEEE Digital Avionics Systems Conference. 13th DASC* (pp. 305-308). IEEE.
- Hosman, R. J., Benard, B., & Fourquet, H. (1990, November). Active and passive side stick controllers in manual aircraft control. In *1990 IEEE International Conference on Systems, Man, and Cybernetics Conference Proceedings* (pp. 527-529). IEEE.
- Karaburun, N. N., Hatipoğlu, S. A., & Konar, M. (2024). SOC estimation of Li-Po battery using machine learning and deep learning methods. *Journal of Aviation*, 8(1), 26-31.
- Karaburun, N. N., Hatipoğlu, S. A., & Konar, M. (2025). Aircraft takeoff speed prediction with machine learning: parameter analysis and model development. *The Aeronautical Journal*, 129(1336), 1534-1549.
- Konar, M., Hatipoğlu, S. A., & Akpınar, M. (2024). Improvement of UAV thrust using the BSO algorithm-based ANFIS model. *The Aeronautical Journal*, 128(1328), 2364-2373.
- McLean, D. (1999). Aircraft flight control systems. *The Aeronautical Journal*, 103(1021), 159-166.
- McLean, D. (2003). Automatic flight control systems. *Measurement and Control*, 36(6), 172-175.
- Samia, H., Khan, S., Lawrence, J., & Delaney, C. P. (2013). Simulation and its role in training. *Clinics in colon and rectal surgery*, 26(01), 047-055.
- Summers, L. G., Shannon, J. H., White, T. R., & Shiner, R. J. (1987). Fly-by-wire sidestick controller evaluation (No. 871761). SAE Technical Paper.
- Tischler, M. B. (1996). *Advances in aircraft flight control*. crc press.
- Tselegkaridis, S., & Sapounidis, T. (2021). Simulators in educational robotics: A review. *Education Sciences*, 11(1), 11.

Cite this article: Gulhan, H., Kemerlioglu, O., Turkmen, A., Tuna, S., Konar, M. (2025). Design and Implementation of a UAV Control System Using the Airbus A320 Side-Stick Controller. *Journal of Aviation*, 9(3), 497-502.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Performance Maximization of Longitudinal Flight Stability of Fixed Wing Unmanned Aerial Vehicles with Double Dihedral Angle Variation

Tolunay Dağ^{1*}, Tuğrul Oktay²

¹Iskenderun Technical University, Aerospace Engineering Department, 31200, Iskenderun, Hatay, Türkiye. (tolunay.dag@iste.edu.tr)/ Erciyes University /Institute of Science/Aircraft Engineering.

²Erciyes University, Aircraft Engineering Department, Kayseri, Türkiye. (oktay@erciyes.edu.tr)

Article Info

Received: 29 May 2025
Revised: 07 August 2025
Accepted: 25 August 2025
Published Online: 09 October 2025

Keywords:

Dihedral
Morphing
Stability and Control
PID

Corresponding Author: Tolunay Dağ

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1708776>

Abstract

As a result of the continuous development of technology, autonomous control and stability of UAVs are of critical importance. Stability, which is a product of the flight performance of aircraft, has been the subject of intensive study and different methods have been put forward to improve it.

The aim of this study is to investigate the importance of the change in the longitudinal stability response of an UAV with a morphing wing. The effect of a 1.25 meter wingspan unmanned aerial vehicle with two different dihedral angles on its longitudinal stability is investigated. Longitudinal stability derivative coefficients were obtained. With the stability derivatives obtained separately for nine different wing geometries, the state space model of the UAV was obtained.

The resulting state-space model is controlled by a PID controller and the longitudinal stability response is analyzed. As a result, the variation of the return time of the UAV to the equilibrium position with respect to the dihedral angle is obtained.

1. Introduction

Air vehicles are important tools used in both commercial and military fields today. These vehicles, which are included in the inventory in two classes, manned and unmanned, can fly at high or low speeds. Depending on their mission profile, they are capable of high maneuverability, stable flight, high altitude or low altitude flight. Aircrafts can also be classified by rotary wing, fixed wing or VTOL concepts (Özen & Oktay, 2024; Tanyeri et al., 2022). The performance expected from all these classes may vary according to their mission profiles (Dündar et al., 2020; Gatti et al., 2015).

The most common class of aircraft is fixed-wing aircraft, which can be described in the traditional concept of fuselage, wings, propulsion system and tail assembly. The propulsion system provides acceleration, the wings generate lift, the fuselage carries payload and the tail assembly provides control and stability of the aircraft. During flight, an aircraft may deviate from its flight path due to environmental conditions or external factors. One such factor is the occurrence of pitching movement during level flight. This movement causes the aircraft to perform sinusoidal pitching, which has a negative effect on fuel consumption and flight comfort. In such cases, a stable aircraft design or control system design is of critical importance.

The stability and control of aircraft has been the focus of many studies (Ducard & Carughi, 2024; Oktay et al., 2016). The behavior of the aircraft is important in terms of its stability in the event that it deviates or deviates from the flight route as a result of environmental factors during flight (Wang et al., 2024). There are many parameters that affect the stability of the aircraft, such as passenger comfort in commercial aircraft and safety of the payload in cargo aircraft.

The movement of the air vehicle takes place in three axes. The pitch, roll and yaw movements affect the longitudinal and lateral stability of the air vehicle, which makes moment in these three axes. While the pitching moment is controlled by the elevator, the roll and yaw movements are realized by the aileron and rudder elements.

Another factor affecting stability is that the air vehicle has surface elements that can change shape. These structures, called morphing, have a great impact on stability (Ye et al., 2025). For example, longitudinal and lateral stability can be improved by actively and passively changing parameters such as wing span, dihedral, swept angle, wing incidence angle or twist angle in the wing geometry.

Many different methods have been used for the stability and control of aircraft. Traditional methods such as Proportional-Integral-Derivative (PID) control, Linear Quadratic Regulator (LQR), Model Predictive Control (MPC)

and Adaptive Control are the most preferred methods. In addition to these, artificial intelligence techniques, which have been developing in recent years, are of critical importance in the field of control. There are many studies that have been done with a hybrid method by combining traditional methods with various artificial intelligence techniques. In this way, the performance of traditional methods has been improved with artificial intelligence techniques and the diversity has increased with the introduction of new methods (K. Guo et al., 2025; Hakeem et al., 2024; Richter et al., 2024).

Çoban (2020) used artificial intelligence techniques to improve the longitudinal and lateral stability of the autonomous flight system of the mini-UAV he designed in his study (Çoban, 2020). Çopur et al. used multiple artificial intelligence methods to improve the performance of PID coefficients affecting the flight performance of a rotary-wing UAV (Çopur et al., 2025).

Uzun et al. aimed to improve the aerodynamic performance of a morphing UAV in different situations by analyzing the changes in aerodynamic performance and the data obtained as a result of these changes with the ANFIS approach. In addition, various artificial intelligence techniques were also included to improve performance. Data was obtained by simulating various analysis conditions with the change of swept angle, speed and angle of attack (Uzun et al., 2024).

Pan and Pi. worked with a dual-stage controller algorithm to ensure stable behavior of the aircraft during landing. By synthesizing Proportional-Integral-Derivative (PID) and Model Predictive Control (MPC) type controllers, they optimized the stable landing of the aircraft in case of meteorological or extreme conditions (Pan & Pi, 2025).

It is known that active or passive variability of aerodynamic surfaces improves stability performance. It is known that stability performance improves when the wing geometry has a morphing feature. The effect of the dihedral angle on stability has been studied in many works. However, there are not enough studies that examine the change in stability performance of UAVs with two different dihedral angles on the wing.

In this study, the variation of the longitudinal stability response of a UAV in level flight as a result of disturbance with respect to the dihedral angle is investigated. For this purpose, nine different combinations of dihedral angles were created for the UAV, each with a 5° increase. The effect of the double dihedral change on the response is evaluated by means of a closed loop system created.

2. Materials and Methods

Stability analyses were performed to obtain the stability parameters of the UAV. The change in the stability parameters of the UAV at different dihedral angles was determined. The wing is modeled with dihedral angles of 5, 10, and 15° at the first dihedral point and 15, 20, and 25° at the second dihedral point. Figure 1 shows the CAD drawing of the UAV with a dihedral position of (15°, 25°).



Figure 1. CAD modeling of the UAV

The UAV with a mass of 1.2 kg with a double dihedral was dimensioned considering the cruise flight. For cruise flight, Equations 1 and 2 are used for calculation (Dağ et al., 2022; Uzun et al., 2022).

$$W = L = 0.5\rho V^2 SC_L \quad (1)$$

$$T = D = 0.5\rho V^2 SC_D \quad (2)$$

The geometric properties of the UAV designed according to Equations 1 and 2 are given in Table 1.

Table 1. Specifications of the UAV

Parameter	Symbol	Value
Wingspan	b_w	1.25 m
Wing Chord	c_w	0.17 m
Wing Area	S_w	0.21 m ²
Aspect Ratio	AR	7.35
Vertical Tail Span	b_{vt}	0.17 m
Vertical Tail Chord	c_{vt}	0.11 m
Vertical Tail Area	S_{vt}	0.019 m ²
Horizontal Tail Span	b_{ht}	0.29 m
Horizontal Tail Chord	c_{ht}	0.11 m
Horizontal Tail Area	S_{ht}	0.033 m ²

Figure 1 shows the UAV modeling created with CAD software. The UAV has dihedrals at two different points, one at the fuselage attachment and one at the wing center. Figure 2 shows the 3D model on which the stability analysis is applied.

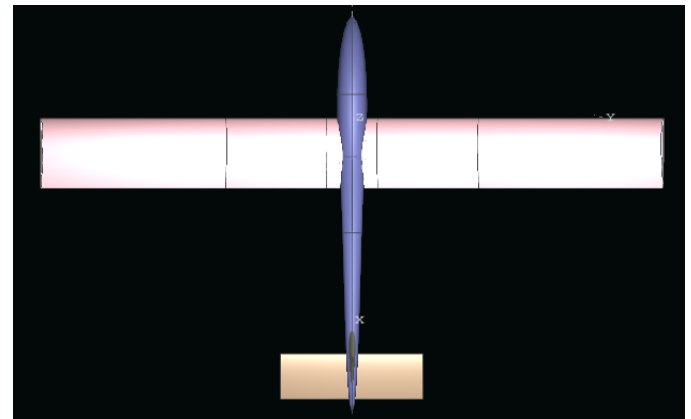


Figure 2. 3D model created for stability analysis

Table 2. Moment of inertia values

(Γ_1, Γ_2)	I_{xx} [kg*m ²]	I_{yy} [kg*m ²]	I_{zz} [kg*m ²]
(5°,15°)	0.042279106	0.05925	0.097125
(5°,20°)	0.04370085	0.059779	0.098034
(5°,25°)	0.046261586	0.060605	0.099984
(10°,15°)	0.043013996	0.060048	0.096959
(10°,20°)	0.044494143	0.06068	0.097826
(10°,25°)	0.046394809	0.061487	0.098947
(15°,15°)	0.044210464	0.061135	0.097081
(15°,20°)	0.045726603	0.061868	0.097883
(15°,25°)	0.047884318	0.062823	0.09912

The longitudinal state-space model of the UAV was created using the parameter data obtained from the stability analysis of the UAV.

$$\begin{bmatrix} \Delta \dot{u} \\ \Delta \dot{w} \\ \Delta \dot{q} \\ \Delta \dot{\theta} \end{bmatrix} = \begin{bmatrix} X_u & X_w & 0 & -g \\ Z_u & Z_w & u_0 & 0 \\ M_u + M_w Z_u & M_w + M_w Z_w & M_q + M_w u_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \Delta u \\ \Delta w \\ \Delta q \\ \Delta \theta \end{bmatrix} + \begin{bmatrix} X_{\delta_e} & X_{\delta_T} \\ Z_{\delta_e} & Z_{\delta_T} \\ M_{\delta_e} + M_w Z_{\delta_e} & M_{\delta_T} + M_w Z_{\delta_T} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta \delta_e \\ \Delta \delta_T \end{bmatrix} \quad (3)$$

Table 3. Longitudinal Stability Derivatives

$X_u = C_{x_u} \frac{QS}{mu_0}$	$X_w = (C_{L_0} - C_{D_0}) \frac{QS}{mu_0}$
$Z_u = C_{z_u} \frac{QS}{mu_0}$	$Z_w = -(C_{L_\alpha} + C_{D_0}) \frac{QS}{mu_0}$
$M_u = C_{M_u} \frac{QSc}{I_{yy}u_0}$	$M_w = C_{M_\alpha} \frac{QSc}{I_{yy}u_0}$
$M_q = C_{M_q} \frac{c}{2u_0} \frac{QSc}{I_{yy}}$	$Z_{\delta_e} = C_{z_{\delta_e}} \frac{QS}{m}$
$M_w = C_{M_\alpha} \frac{c}{2u_0} \frac{QSc}{I_{yy}}$	$M_{\delta_e} = C_{M_{\delta_e}} \frac{QSc}{I_{yy}}$

$$Q = 0.5\rho V^2 \quad (4)$$

In the longitudinal state-space model given in Equation 3, the effect of the UAV on stability as a result of elevator deflection is included, while the effect of the engine is neglected (Aldosari & Feron, 2025).

The state-space model calculated for 9 different cases of the double dihedral wing structure was simulated with MATLAB Simulink software.

The controller installed to control the disturbance is controlled by PID debuggers. Proportional-integral-derivative (PID) control is the preferred method for many different systems with a very low error rate (J. Guo et al., 2022; Surur et al., 2025; Xu & Qi, 2024). The error signal (e(t)) and gain values (K_p , K_i and K_d) are the parameters that help to improve the system. The mathematical expression of the PID controller is given in Equation 4 (Richter et al., 2024).

$$u(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{d}{dt} e(t) \quad (4)$$

The parameters K_p , K_i and K_d were set by default to 50, 5 and 50, respectively (Uzun, 2024). These values were changed according to the response of the system to obtain the best correction coefficients. Table 4 shows the change in longitudinal stability derivative coefficients for nine different dihedral positions.

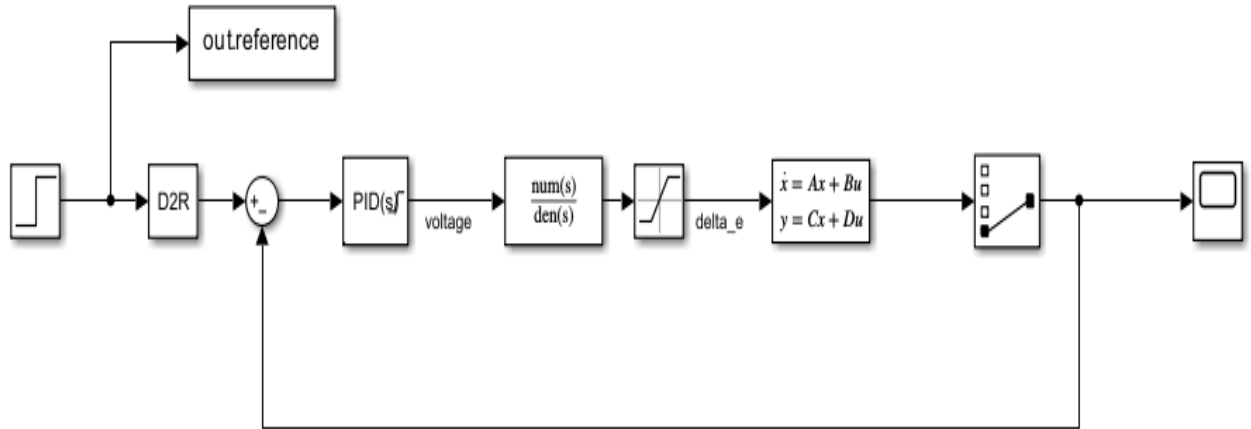


Figure 3. Simulink schematic of the controller model

Table 4. Longitudinal Stability Derivatives Coefficient

(Γ_1, Γ_2)	(5°,15°)	(5°,20°)	(5°,25°)	(10°,15°)	(10°,20°)	(10°,25°)	(15°,15°)	(15°,20°)	(15°,25°)	(5°,15°)
C_{L_α}	4.6274	4.58132	4.52442	4.61686	4.56976	4.6274	4.5984	4.55019	4.4911	4.6274
C_{M_α}	-0.97185	-0.9859	-1.00341	-0.98847	-1.00346	-0.97185	-1.00847	-1.0246	-1.04477	-0.97185
C_{M_u}	-0.00637	-0.00712	-0.00789	-0.00706	-0.00778	-0.00637	-0.00767	-0.01156	-0.01269	-0.00637
C_{M_q}	-9.748	-9.9059	-10.1147	-9.8039	-9.9631	-9.748	-9.8833	-10.0401	-10.2528	-9.748
C_{x_u}	-0.02461	-0.02486	-0.02521	-0.02386	-0.0241	-0.02461	-0.02319	-0.02884	-0.02937	-0.02461

3. Results and Discussion

In this study, the longitudinal stability of a drone with 9 different dihedral positions is simulated. The effect of dihedral angle on the stability of the aircraft is analyzed. The obtained

stability derivatives and state space matrices are controlled by PID method and the disturbance response is evaluated.

Table 4 shows the stability derivative coefficients for 9 different dihedral angles. These coefficients obtained as a result of stability analysis are the parameters affecting the longitudinal stability.

The default values for K_p , K_i and K_d were set to 50, 5 and 50 respectively and the response of the aircraft was tried to converge (Çoban, 2025). Figure 4 shows the response of the aircraft to disturbance as a result of default PID gain values. For 9 different dihedral states, this curve converges towards instability.

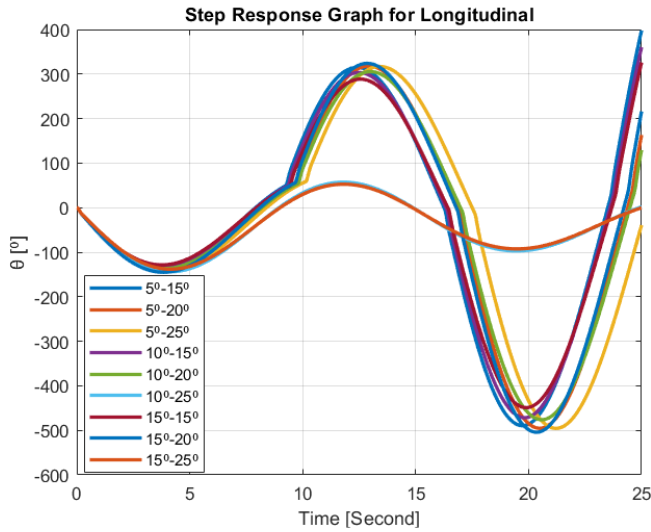


Figure 4. UAV response with default PID gain values

It was realized that a simple algorithm can improve the time it takes for the UAV to return to its equilibrium position. The PID gain coefficients will be changed according to the response of the UAV to return to its natural position (Li et al., 2024). For this purpose, an iterative algorithm was created and the variation of the settling time parameter of the drone was analyzed. The settling time parameter was chosen as the most important evaluation criterion. The reason for this is to ensure that the aircraft reaches the equilibrium position quickly with minimal oscillation. Figure 5 shows the result of PID coefficients where the aircraft settles to the equilibrium position for 20 seconds. $K_p=-0.175$, $K_i=-0.015$ and $K_d=-0.2180$. The B matrix given in Equation 3 models the effect of control surfaces on motion. Since the mathematical models calculated in this matrix are defined with negative coefficients, the PID values are negative.

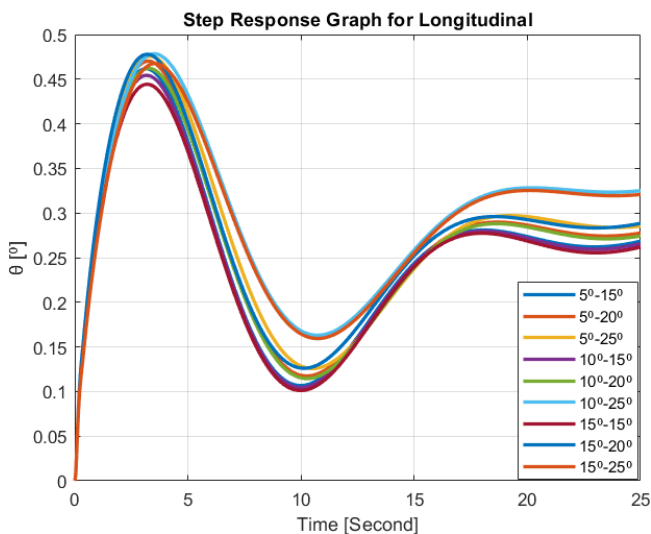


Figure 5. UAV response with $K_p=-0.175$, $K_i=-0.015$ and $K_d=-0.2180$

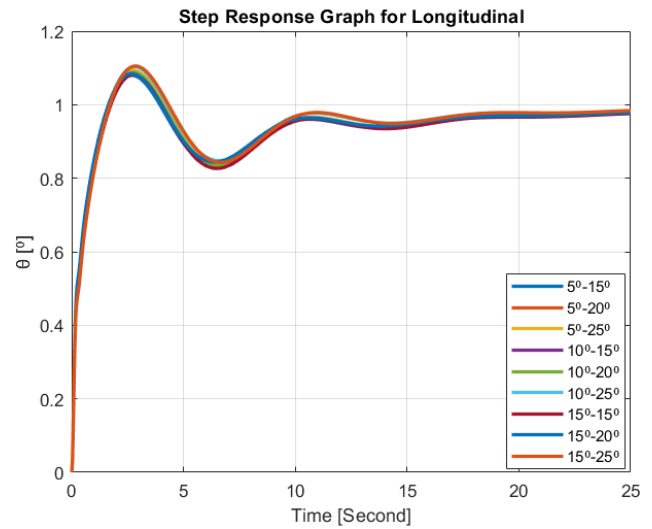


Figure 6. UAV response with $K_p=-1$, $K_i=-1$ and $K_d=-1$

As corrections are made to the PID gain values, it is seen that the response of the UAV improves. By minimizing the oscillation motion of the UAV in the longitudinal axis, it is ensured that it reaches the equilibrium position earlier.

4. Conclusion

The control of unmanned aerial vehicles has a significant effect on their performance. UAV are optimized to have a stable flight. In this study, the longitudinal stability behavior of a fixed wing UAV with double dihedral angle is investigated. Stability analysis of the modeling of the UAV in cruise flight is performed, stability derivative coefficients are obtained and state-space models are created using these coefficients.

The response of the aircraft to the disturbance was controlled by the PID controller and approximate gain coefficients (K_p , K_i , and K_d) were obtained. By changing the default values of 50, 5 and 50 for the K_p , K_i and K_d coefficients, respectively, we tried to converge to the maximum performance values in the equilibrium position.

Table 3. System response

(Γ_1, Γ_2)	Rise Time [s]	Settling Time [s]	Overshoot [%]
$(5^\circ, 15^\circ)$	1.7	19.68	8.00
$(5^\circ, 20^\circ)$	1.72	19.32	8.09
$(5^\circ, 25^\circ)$	1.76	19.34	8.15
$(10^\circ, 15^\circ)$	1.68	19.40	8.71
$(10^\circ, 20^\circ)$	1.7	19.14	8.81
$(10^\circ, 25^\circ)$	1.648	19.24	8.43
$(15^\circ, 15^\circ)$	1.667	19.44	9.35
$(15^\circ, 20^\circ)$	1.76	18.64	10.33
$(15^\circ, 25^\circ)$	1.71	18.48	10.51

The time it takes for the aircraft to return to the equilibrium position after being subjected to disturbance shows the stability behavior. Considering this situation, it is seen that the aircraft with dihedral position $(15^\circ, 25^\circ)$ returns to the equilibrium position earlier than the other variants.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Aldosari, M. N., & Feron, E. (2025). Acceleration Flight Control for Reduced Gravity Flight in Large Fixed-Wing Aircraft. *Microgravity Science and Technology*, 37(3), 27.
- Çoban, S. (2020). Autonomous performance maximization of research-based hybrid unmanned aerial vehicle. *Aircraft Engineering and Aerospace Technology*, 92(4), 645–651.
- Çoban, S. (2025). Optimization of PID Controllers for UAVs Using SPSA Algorithm for Enhanced Flight Performance. *Journal of Aviation*, 9(1), 28–33.
- Çopur, E. H., Balta, E., & Bilgic, H. H. (2025). Tuning of cascade PID controller gains of quadcopter under bounded disturbances using metaheuristic based research algorithm. *The Aeronautical Journal*, 1–23.
- Dağ, T., Ünler, T., Çopur, E. H., & Çakın, U. (2022). Kentsel Hava Taşımacılığında Kullanılacak Dikey İniş-Kalkış Kabiliyetine Sahip Bir Hava Aracının Kavramsal Tasarımı ve Menzil Hesabı. *Konya Journal of Engineering Sciences*, 10(3), 649–664.
- Ducard, G., & Carughi, G. (2024). Neural Network Design and Training for Longitudinal Flight Control of a Tilt-Rotor Hybrid Vertical Takeoff and Landing Unmanned Aerial Vehicle. *Drones*, 8(12), 727.
- Dündar, Ö., Bilici, M., & Ünler, T. (2020). Design and performance analyses of a fixed wing battery VTOL UAV. *Engineering Science and Technology, an International Journal*, 23(5), 1182–1193.
- Gatti, M., Giulietti, F., & Turci, M. (2015). Maximum endurance for battery-powered rotary-wing aircraft. *Aerospace Science and Technology*, 45, 174–179.
- Guo, J., Lu, Y., & Li, Z. (2022). PID parameter tuning algorithm of rotor UAV Based on Improved Particle Swarm Optimization. 2022 IEEE 6th Information Technology and Mechatronics Engineering Conference (ITOEC), 1251–1255.
- Guo, K., Li, H., Bai, Z., Li, B., & Wang, S. (2025). Robust optimal hybrid fuzzy tuned dual-stage fractional-order PI (1 + PDF) control of fixed-wing aerial robot. *Mechanics Based Design of Structures and Machines*, 1–19.
- Hakeem, B., Taimoor, M., & Tahir, M. A. (2024). A Review of Fixed Wing Unmanned Aerial Vehicles: Control Methodologies for Rejecting Unwanted Disturbances during Landing. 2024 4th International Conference on Digital Futures and Transformative Technologies (ICoDT2), 1–8.
- Li, J., Xu, S., Wu, Y., & Zhang, Z. (2024). Automatic Landing Control for Fixed-Wing UAV in Longitudinal Channel Based on Deep Reinforcement Learning. *Drones*, 8(10), 568.
- Oktay, T., Konar, M., Onay, M., Aydin, M., & Mohamed, M. A. (2016). Simultaneous small UAV and autopilot system design. *Aircraft Engineering and Aerospace Technology*, 88(6), 818–834.
- Özen, E., & Oktay, T. (2024). Maximization of Flight Performance of Eight-Rotor Multirotor with Differentiated Hub Angle. *Journal of Aviation*, 8(3), 206–213.
- Pan, Z., & Pi, Y. (2025). Design of an automatic landing strategy for fixed-wing aircraft based on longitudinal and lateral collaborative hierarchical control. *Aerospace Science and Technology*, 163, 110217.
- Richter, D. J., Calix, R. A., & Kim, K. (2024). A Review of Reinforcement Learning for Fixed-Wing Aircraft Control Tasks. *IEEE Access*, 12, 103026–103048.
- Surur, K., Kabir, I., Ahmad, G., & Abido, M. A. (2025). Optimal Gain Scheduling for Fault-Tolerant Control of Quadrotor UAV Using Genetic Algorithm-Based Neural Network. *Arabian Journal for Science and Engineering*.
- Tanyeri, B., Ural Bayrak, Z., & Uçar, U. U. (2022). The Experimental Study of Attitude Stabilization Control for Programmable Nano Quadcopter. *Journal of Aviation*, 6(1), 1–11.
- Uzun, M. (2024). Autonomous flight performance maximization for slung load carrying rotary wing mini unmanned aerial vehicle. *Aircraft Engineering and Aerospace Technology*, 96(4), 593–603.
- Uzun, M., Bilgic, H. H., Çopur, E. H., & Çoban, S. (2024). The aerodynamic force estimation of a swept-wing UAV using ANFIS based on metaheuristic algorithms. *The Aeronautical Journal*, 128(1322), 739–755.
- Uzun, M., Özdemir, M., Yıldırım, Ç. V., & Çoban, S. (2022). A Novel Biomimetic Wing Design and Optimizing Aerodynamic Performance. *Journal of Aviation*, 6(1), 12–25.
- Wang, W., Zhang, J., & Jiao, R. (2024). Optimized Fractional-Order Type-2 Fuzzy PID Attitude Controller for Fixed-Wing Aircraft. *Journal of Optimization Theory and Applications*, 203(3), 2592–2616.
- Xu, L., & Qi, G. (2024). Function observer based on model compensation control for a fixed-wing UAV. *Aerospace Science and Technology*, 152, 109325.
- Ye, Z., Cai, G., Xu, H., Shang, Y., & Hu, C. (2025). Prescribed Performance Sliding Mode Fault-Tolerant Tracking Control for Unmanned Morphing Flight Vehicles with Actuator Faults. *Drones*, 9(4), 292.

Cite this article: Dağ, T., Oktay, T. (2025). Performance Maximization of Longitudinal Flight Stability of Fixed Wing Unmanned Aerial Vehicles with Double Dihedral Angle Variation *Journal of Aviation*, 9(3), 503-507.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License

Copyright © 2025 *Journal of Aviation* <https://javsci.com> - <http://dergipark.gov.tr/jav>

Analysis of LTE Network Connection Parameters at Legal Maximum UAV Flight Altitudes and Comparison with Ground

Emin Tugay Kekeç^{1*}, Köksal Boyalı², Mustafa Samet Gençç³

^{1*}Cappadocia University, Aircraft Technology, 50400, Mustafapasa, Nevşehir, Türkiye. (tugay.kekec@kapadokya.edu.tr)

²Argela Yazılım ve Bilişim Teknolojileri A.Ş., Sarıyer, 34467, İstanbul, Türkiye. (koksall.boyali@argela.com.tr)

³Cappadocia University, Aircraft Technology, 50400, Mustafapasa, Nevşehir, Türkiye. (samet.gencag@kapadokya.edu.tr)

Article Info

Received: 22May 2025

Revised: 21 July 2025

Accepted: 07 August 2025

Published Online: 09 October 2025

Keywords:

Unmanned Aerial Vehicles

UAV Traffic Management systems

UAV Communication

Mobile Network Long Term Evolution

UTM

Corresponding Author: *Emin Tugay Kekeç*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1662688>

Abstract

Recently, Unmanned Aerial Vehicles (UAVs) and UAV Traffic Management (UTM) systems have gained attention, particularly for applications such as aerial mapping and agriculture. Due to the widespread use of applications and the increasing number of UAVs, air traffic poses a danger to the public and the inability to track UAVs causes a security vulnerability. The European U-Space concept and the Next GEN concept in the USA implement the Air corridor and UTM system for Tracking of UAVs and Commercial UAVs services. It is desired to use new generation communication infrastructures for UAVs to communicate with UTM uninterruptedly and safely. In this study, flights were conducted at the maximum legal altitude limit of 120 meters to test the usability of the UAV and UTM communication infrastructures of the Long-Term Evolution (LTE) communication infrastructures of Mobile Operators in Turkey. In the study, an LTE-supported UAV was connected to the Türk Telekom Corporation (Türk Telekomünikasyon A.Ş.) Mobile LTE network, log telemetry information was sent to the UTM server on the ground via the UAV from an altitude of 120 meters, and the connection quality of the Mobile Operator was determined. In addition, the signal quality and strength measured from the ground on the same route as the highway were compared with the signal quality and strength received by the UAV at an altitude of 120 meters. Successful results were achieved and it was proven that communication can be achieved using the Mobile Operator's LTE network even at the maximum legal UAV altitude limit.

1. Introduction

With today's technological advancement, Unmanned Aerial Vehicles (UAVs) are widely used in various sectors to increase efficiency and offer new possibilities. These UAVs are equipped with advanced electronic systems and software technologies, and are produced in different concepts and designed to be flexible enough to meet various needs (Gupta et al., 2015). To ensure safe flights, they are supported by reliable flight control systems and constantly developed software support. However, the use of UAVs is becoming increasingly diversified and widespread (Konar et al., 2021; Lin et al., 2018). While they are used in tasks such as detection of plant diseases, field monitoring and fire control in fields such as agriculture and forestry, they also play an important role in the security and defense sector for reconnaissance, surveillance and target identification (Dalkiran et al., 2021; Oktay et al., 2016). The fast and flexible maneuvering capabilities of UAVs provide different advantages over traditional aircraft and human-powered vehicles (Ding et al., 2017). Therefore, with the advancement of UAV technologies and the expansion of their usage areas, these vehicles are expected to gain even more importance in the future.

Unmanned Aerial Vehicles (UAVs) are flown autonomously by users, either remotely controlled directly from the ground station or via predetermined routes and missions (Gharib et al., 2021). In recent years, the increase in demand for UAVs has led to the expansion of their usage areas. UAVs, which were initially used in military operations, later became widespread in civilian areas due to their low operating costs and ease of use. Civilian (hobby and commercial) and professional use of scientific applications is rapidly increasing worldwide (Amorim et al., 2017; Sae et al., 2019). Examples of civilian purposes include intelligence and security activities, weather monitoring, creating three-dimensional models of cities, monitoring fires, monitoring coastal areas, conducting search and rescue operations, analyzing agricultural areas, monitoring natural disasters and infrastructure (Sundaresan et al., 2018; Hellaoui et al., 2020). UAVs are also used for various purposes such as conducting archaeological studies, examining urban transformation and detecting pollution through cartography (Militaru et al., 2020; Nguyen et al., 2017).

Despite the developing UAV and UAV technologies, their usage areas are increasingly diversifying (Watts et al., 2012). However, the rapid increase in the number of UAVs poses a

serious security concern for air traffic, and the inability to track them poses a major risk to commercial airspace and people (Qazi et al., 2015). Therefore, various organizations at the international level have seen the need to make new regulations for the registration and monitoring of UAVs. In this context, institutions such as ICAO, FAA in the USA and EASA in the EU have taken steps to regulate UAVs (Ranjan et al., 2018).

In order for UAVs to be recorded and monitored by the Unmanned Aircraft System Traffic Management (UTM) system, the importance of the services provided by mobile GSM operators and therefore mobile networks is increasing (Batistatos et al., 2018; Horani et al., 2018). The concept of recording and tracking drones in UTM by connecting to the mobile network with UAV communication support based on LTE standards stands out as a forward-looking approach (Lee et al., 2019).

For UAVs to be registered and monitored by UTM, the services provided by Mobile GSM Operators and therefore mobile networks have gained importance (Karamchedu, 2020). With the UAV communication support that comes with LTE standards, the concept of registering and following the drones to the UTM by connecting to the mobile network has been established (Miao et al., 2019; Ding et al., 2017; Stanczak et al., 2018; Reingruber et al., 2022).

In a previous study, the effects on network performance were investigated in terms of data outputs that would be possible with realistic deployment and mobility models encountered in a simulated environment in Aerial UAV-based building surveillance networks but in real-world UAV-based environments (Watts et al., 2012). Another study investigated realistic propagation and mobility models present in real-world UAV-based environments. It examined the effects of these models on the network performance of Airborne UAV-based building surveillance networks in a simulated environment, in terms of possible data outputs (Qazi et al., 2015). Another study examined the impact of the base station's maximum capacity, cell's automatic switching performance, and UAVs' range of action on the communication performance of the system. The research suggests that implementing LTE private network technology in a group of UAVs is viable and provides considerable benefits, such as great versatility, affordability, and excellent signal quality (Ding et al., 2017). Unmanned aerial vehicles function as airborne relay stations, providing tele-communications services to areas with limited connectivity. Furthermore, they serve as backup data gateways when base stations become overloaded due to increased traffic. The study presents representative findings obtained through a two-year measurement campaign that utilized quadcopters in various operational scenarios. This examination evaluated the strength of the Long-Term Evolution (LTE) signal and the Signal-to-Interference-plus-Noise Ratio (SINR) in the atmosphere across two different configurations. The study area consisted of an underserved rural region and the urban centre of a town. High SINR levels (>10 dB) were recorded at certain heights in the rural scenario, allowing for an expansion of the network coverage. In the urban environment, the ascending UAV captures more cells, leading to an influence on the SINR values. Nonetheless, it has the potential to promote diversity on a larger scale (Batistatos et al., 2018). Another study has developed a visualization tool for LTE based surveillance of UAVs in an urban area (Lee et al., 2019). This study developed a tool to visualize the estimation of UAV positions using LTE signals in an urban area. The visualization tool displays true positions of UAVs and evolved Node Bs (eNodeBs), as well as estimated positions of UAVs, and calculated horizontal and vertical protection levels (HPLs and VPLs) on a 3D city map (Lee et al., 2019). The other study analysed 4G/LTE coverage

by implementing a virtual environment simulation of a terrestrial cellular network. This method allowed for the identification and analysis of potential issues when setting up a UAV datalink over 4G networks. This study concludes that an increasing amount of research on unmanned aerial vehicles (UAVs) indicates that terrestrial mobile networks offer the most suitable means of supporting UAV communications at low altitudes. These networks can provide suitable traffic management capabilities to ensure the safe and secure operation of the UAV (Militaru et al., 2020). Another study examines the key features of Direct Communications or Device-to-Device (D2D) communications, as they apply to communication between UAVs (Karamchedu, 2020). Another study investigated the change in performance of a commercially available multi-band LTE antenna when used near a UAV fuselage. This study provides a more thorough comprehension of antenna performance near a UAV. Moreover, these out-comes will assist in enhancing antenna management, mitigating adverse impacts on drone operations at high altitudes exceeding typical cell tower height (Reingruber et al., 2022). Previous studies on UAV telemetry over LTE networks can be broadly categorized into simulation-based research, controlled laboratory studies, and real-world field experiments. Simulation-based studies (e.g., Ding et al., 2017; Karamchedu, 2020) allow for controlled parameter testing but lack terrain-induced variability. Field tests in urban areas (e.g., Lee et al., 2019) often highlight interference and signal congestion, whereas rural-focused studies (e.g., Nguyen et al., 2017) typically rely on ideal flat landscapes. Moreover, a distinction exists between studies using commercial LTE infrastructure and those using private or purpose-built networks.

Despite this progress, there remains a lack of empirical field data under actual regulatory constraints and with real commercial LTE networks in semi-rural environments. Our study addresses this gap by conducting legal-altitude UAV telemetry measurements using Turkey's live LTE infrastructure, in a topographically diverse region (Cappadocia). This approach helps assess signal viability in mixed-use terrains and informs national airspace integration strategies for similar geographies.

While the feasibility of LTE-based UAV telemetry has been explored in previous studies across various international contexts, our study provides a unique real-world validation within Turkey's regulatory and geographic framework. The test corridor between Mustafapaşa and Ürgüp presents semi-rural topography with non-uniform coverage, offering insights into the LTE network's viability under less idealized conditions. Unlike simulations or urban-focused field tests, our study evaluates commercial LTE performance in a real-use scenario reflecting operational constraints common in many countries adopting similar UAV flight ceilings and regulatory models.

This study is motivated by the expected exponential growth of advanced and autonomous aircraft in the upcoming years. In the future, air traffic management is expected to face increased complexity due to the growing number of aircraft occupying both low and high-altitude airspace. This study is to investigate the usability of communication between UAV and UTM over Türk Telekom Corporation (Türk Telekomünikasyon A.Ş.) Mobile LTE Communication infrastructure. For this purpose, within the scope of the study, flight tests were carried out at 120 meters, which is the legal altitude limit of UAVs determined by the Directorate General of Civil Aviation in Turkey. Flight tests were carried out approximately 5 kilometers between Mustafapaşa and Ürgüp.

Data from 120-meter flight tests and ground tests were compared.

2. Materials and Methods

In this study, flights were made with a specially developed quadcopter that can fly for 10-12 minutes. Pixhawk Cube Black, an advanced and open-source code-supported autopilot, was used for the UAV with its light and strong body and 7000 mAh capacity 4S battery. Data received during the UAV flight can be received with the telemetry module and the TEMS phone placed directly on the UAV.

During the test flights with the UAV, a Samsung S10 TEMS phone, whose placement on the UAV is shown in Figure-1, was used for signal measurement and efficiency tests. Additionally, the Ground control station interface and the UAV route are shown in Figure-1. In addition, the Raspberry Pi 4 Model B control card, which has a wide user base and flexibility of use in different projects, was used. Sixfab 3G/4G LTE Base LINE and Quetel EC 25 Mini PCI 4G/LTE GSM

modem were preferred for the UAV to transmit telemetry information via broadband LTE base station.

A total of 4 flight missions were conducted along the same predefined 5 km route between Mustafapaşa and Ürgüp at a legal altitude of 120 meters. Each mission was performed under similar environmental conditions: clear weather, wind speed below 5 m/s, and temperatures ranging from 18°C to 24°C, between 09:00 and 13:00 local time. The drone flew the identical autonomous route in each mission to ensure consistency. Data collection was performed using a Samsung S10 TEMS phone mounted on the UAV, configured via TEMS Pocket software. The sample rate was set to 1 Hz, generating approximately 3,000 data points per flight (totaling around 12,000 samples). Ground tests were performed on the same route by placing the TEMS phone in a stationary vehicle at four designated points (start, 1.5 km, 3 km, end point). The devices used for testing, including the TEMS phone, were verified using standard calibration procedures provided by the manufacturer, and the LTE modem settings were configured to standard operating parameters (Band 20 and Band 3 activation with automatic frequency switching).



Figure 1. TEMS phone, Ground control station interface and UAV route

2.1. Test Methods & Test Scenarios

The tests were carried out in Nevşehir Cappadocia, on the route determined between Mustafapaşa and Ürgüp District. The total route length is 5 km. 3G and LTE infrastructures, different bands and frequencies are available in the test area. LTE band frequencies are 1800-20 MHz, 800-10 MHz and WCDMA band frequencies are 900 MHz, 2100 MHz.

The UAV and LTE network communication Architecture is planned for the tests to be carried out within the scope of UAV

innovation tests. The intended architecture is presented in detail in Figure 2. Within the scope of the architecture, it is aimed to connect the LTE communication kit on the UAV to the LTE Base Stations in a healthy way.

The LTE-supported UAV was connected to Türk Telekom LTE base stations with the Architecture used in the project and successfully sent the telemetry information to the UAV Tracking system at Cappadocia University.

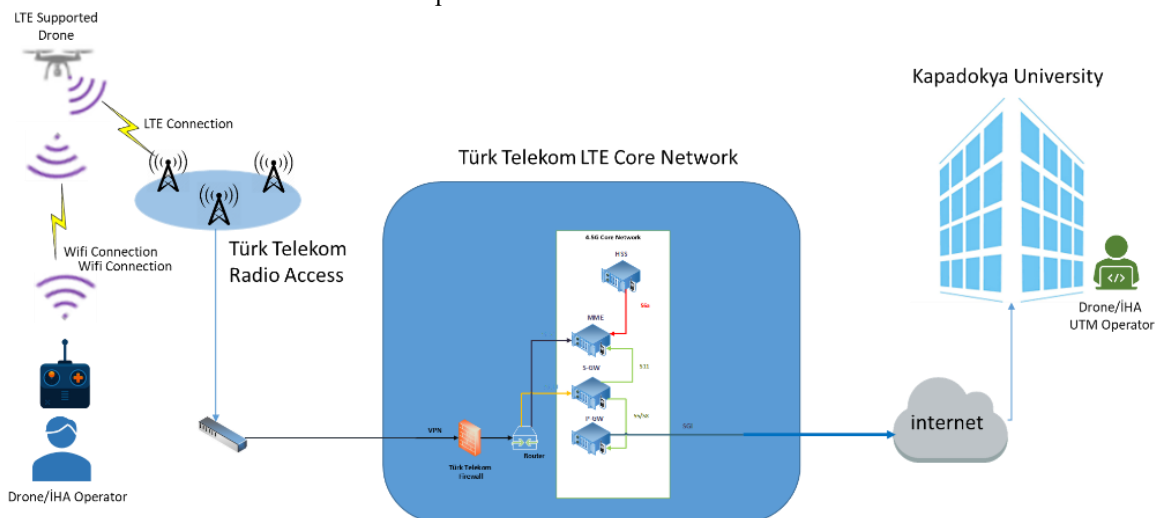


Figure 2. System Architecture

The main purpose of the uplink test is to transfer the telemetry information on the drone to the log server at Cappadocia University over the LTE network. The tests were carried out by generating data traffic over Tems phone and Raspberry pi at the same time with LTE modem support. First of all, with this test, the transmission of the telemetry information of the drone to the on-site server over the LTE network and the throughput scenario were realized.

It was connected to Türk Telekom Mobile communication system with LTE-supported UAV. Then, the drone successfully transferred the telemetry information to the Server at Cappadocia University via Türk Telekom LTE base stations. Uplink throughput test topology details can be seen in Figure 3.

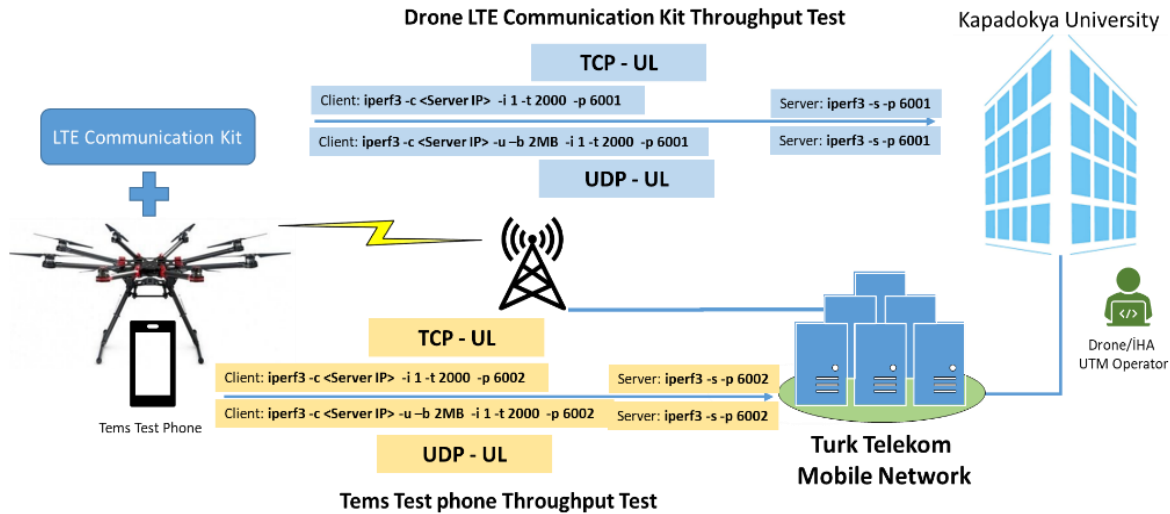


Figure 3. UL Throughput Test Topology

UAV and LTE network communication Architecture is planned for the tests to be carried out within the scope of UAV innovation tests. Within the scope of the architecture, it is aimed to connect the LTE communication kit on the UAV to the LTE Base Stations in a healthy way. The LTE-supported UAV was connected to Türk Telekom LTE base stations with the Architecture used in the project and successfully sent the telemetry information to the UAV Tracking system at Cappadocia University.

3. Result and Discussion

The primary aim of this study was to evaluate the feasibility and basic signal viability of LTE-based telemetry at the legal UAV flight altitude using commercially available infrastructure in a real-world test scenario. As such, the scope of analysis was focused on visual comparison of key LTE parameters (RSRP, RSRQ, SINR) rather than on statistical generalization. The number of flights (n=4) was sufficient for preliminary insights but not intended for robust statistical treatment. In the study, the drone connected to Türk Telekom live mobile LTE network was flown on the determined route and test scenarios were realized. The tests were carried out in Nevşehir Cappadocia on a total of 5 km route determined between Mustafapaşa and Ürgüp District. The drone was tested with 4 different flights (UL-TCP/UDP and DL-TCP/UDP) at an altitude of 120 meters. UDP and TCP test throughput results satisfying for the drone to provide Control Channel information and other metrics.

Within the scope of the regulations issued in Europe and America, UAV Traffic Management Systems were started to be used to manage and expand Commercial UAV air operations. The basic requirement of these systems is the two-way transfer of TCP/UDP Telemetry, which is required for the management and control of UAVs, to ground control systems. This transmission requires reliable and comprehensive wireless communication infrastructures. By this way, UAVs are integrated and managed with UAV Monitoring, Control

and Traffic Management Systems (UTM) serving on the Cloud.

In the studies carried out, it has been seen that 4G / LTE communication technologies support the necessary communication infrastructure for UAVs. Especially within the scope of U-Space studies carried out in the European Union, 4G supported UAVs have started to serve commercially in an integrated manner with UTM systems running on the cloud. The 3Gpp standard community has started to publish Mobile Communication systems standards for UAVs that will work with UTM systems.

In the UAV Innovation Project study, a UAV with 4G Mobile Communication kit integration was flown in connection with Türk Telekom live mobile network, UAV Telemetry information was transferred to Cappadocia University servers over Türk Telekom 3G/4G Mobile network and the usability of the network for UAV connected to Türk Telekom Mobile network was tested.

The UAV completed its flight on the highway and by being constantly monitored from the ground in Auto mode. During the flight, flight information was constantly monitored via the ground control station and necessary emergency scenarios (Fail Safe) were planned to avoid accidents. For autonomous flight, an altitude value of 120 meters has been determined, which is the maximum flight altitude determined by the General Directorate of Civil Aviation (SHGM). This value is set in Terrain Following/Holding mode, which can follow the land surface via QGroundControl, an open-source ground control station software.

Some values determining the signal level and quality of the signal for LTE networks obtained as a result of test flights at an altitude of 120 meters are discussed. During one of the test missions, a brief degradation in SINR was observed near the 3.8 km mark of the route, where the SINR temporarily dropped below 0 dB for approximately 6 seconds. Although no complete connection loss occurred, such variations highlight the sensitivity of UAV telemetry to local network coverage and environmental factors. These observations are consistent

with the expected fluctuations in semi-rural LTE deployments. Reference-Signal-Receive-Power (RSRP) and Reference Signal Received Quality (RSRQ) values are two different parameters aimed in this study. While RSRP defines the strength of LTE Reference Signals spanning full bandwidth and narrow band, RSRQ defines the quality of the received

signal. In addition, the parameters that determine the signal level and quality of the signal for LTE networks were compared with ground tests. As a result of the tests performed at a flight altitude of 120 meters and on the ground, the RSRP value for the LTE infrastructure is shown in Figure 4.

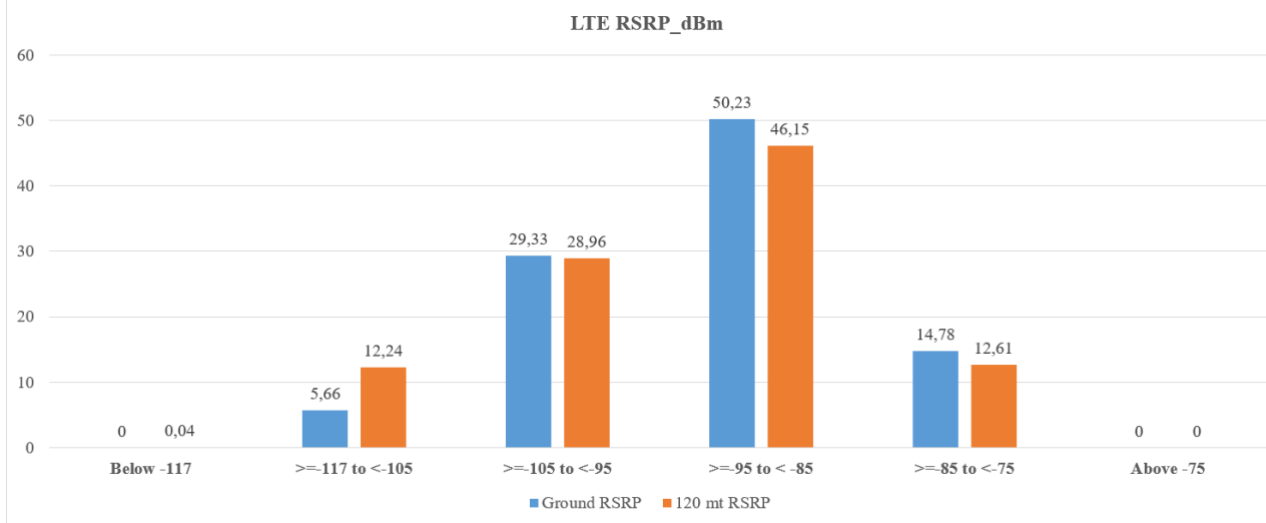


Figure 4. LTE Reference Signal Receive Power (RSRP) at 120 m and Ground,

Flights at 120 meters were carried out at different altitudes with the mobile device used for communication in the free mode of the commercial 3G and 4G network. In addition, the tests were carried out on LTE technology because the mobile network had 3G technology in the test area, there was UDP in the test area and the LTE coverage area was sufficient. Türk Telekom Turkey has 10 MHz spectrum in the 800MHz band, which can provide maximum efficiency of approximately 75Mb/s in the downlink and 25Mb/s in the uplink. In addition, Türk Telekom uses 20 MHz spectrum in the 1800 MHz band, and this spectrum can provide maximum efficiency of approximately 150 Mbps in the downlink and 50 Mbps in the uplink. Reaching such a high speed is a rare occurrence. The testing tool used to determine throughput without enabling any additional features or optimizations on the network is a Tems Pocket mobile tester that is pre-configured to emulate common device interaction patterns with the mobile network. As a result of the tests, it was seen that Türk Telekom 4G Communication infrastructure successfully supports UAV-TCP data traffic. RSRP, RSRQ and SINR values for Uplink and Downlink are presented for the UAV monitored and managed using the TCP-DL connection. In this study, the results including UAV flight test RSRP, RSRQ and SINR data for cell signal quality serving TCP-DL LTE at an altitude of 120 meters are discussed. In addition, the UAV, which was tested at 120 meters, performed its entire flight over the highway. In this way, continuous visual tracking of the UAV was ensured throughout the flight. In addition, the highway was used for UAV ground tests and the test was aimed to give more accurate results by following the same route. While the overall telemetry performance was within acceptable levels, some edge cases may pose operational risks in real-world scenarios. For instance, LTE signal strength and SINR can degrade sharply due to terrain obstructions, sudden weather changes (e.g., precipitation or high humidity), or network congestion during peak hours. Although no critical failures were observed in our tests, a brief SINR drop below 0 dB near the 3.8 km mark highlights the potential for intermittent telemetry disruptions. In practical UAV deployments, such

interruptions may impact command-and-control reliability, particularly in beyond visual line-of-sight (BVLOS) operations. These caveats suggest the need for fail-safe procedures and redundancy mechanisms when relying solely on commercial LTE networks.

Compared to UTM pilot projects in Europe (e.g., SESAR U-space trials) and the USA (e.g., NASA's UTM initiative), our study is limited in scope but provides practical insight from a localized operational context. Unlike those projects which involve multi-layer airspace integration and often rely on custom communication infrastructure, our test used standard commercial LTE service without priority access or UAV-specific tuning. This reflects a "worst-case" scenario and helps assess LTE viability without specialized support. Future work should involve multi-operator testing, UAV-specific LTE QoS modifications, and integration with cloud-based dynamic UTM platforms. Regulatory bodies may also need to explore spectrum reservation or slicing for UAV operations to ensure real-time communication quality and predictability.

Many measurements and evaluations can be made to evaluate the quality of the wireless communication signal. In this study, the most basic indicators RSRQ, RSRP and SINR were examined and compared. Figure 4 shows the RSRP values measured in 120 meter flight and ground tests. The blue indicator represents ground tests and the orange indicator represents 120 meter flight tests.

RSRP plays a crucial role in evaluating the quality of cellular connections and is an important indicator for optimizing network performance. Reference Signal Received Power (RSRP) represents how strong the connection between the cell and the base station is in wireless communication. RSRP expresses power in decibels (dBm). It can take values between -130 dBm and -50 dBm, and less negative values indicate stronger signal strength. RSRP is an important parameter for network operators to evaluate the quality and coverage of their cellular networks. Figure 4 shows the quality of cellular networks at the UAV maximum legal altitude of Türk Telekom LTE Mobile communication infrastructure.

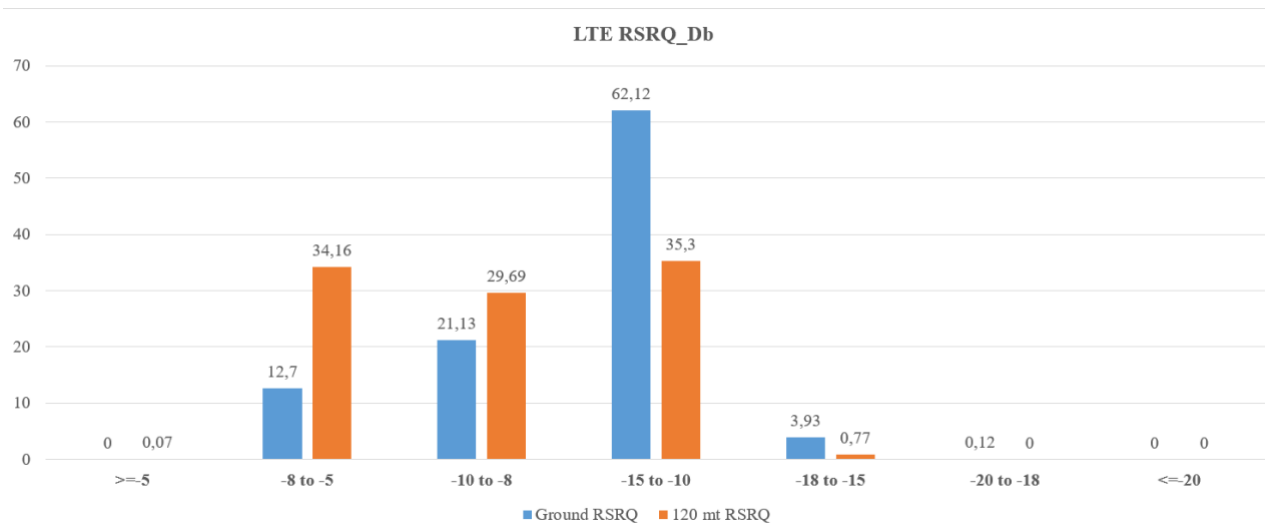


Figure 5. LTE Reference Signal Received Quality (RSRQ) at 120 m and Ground

RSRQ, which is an important parameter in wireless communication systems, especially in cellular networks such as 4G LTE and 5G, measures the quality of the signal that a serving cell receives from the base station. While the RSRP value measures the signal strength, the RSRQ value evaluates the level of interference and noise in the received signal. RSRQ values obtained in the tests are shown in Figure 5. Here, blue color represents ground tests and orange color represents values obtained from 120 meter flights. RSRQ operating values range from -3 dB to -18 dB, with higher values indicating a more suitable RSRQ and better signal quality. RSRQ provides a comprehensive analysis of signal quality by combining both signal strength (RSRP) and the level of interference from other nearby cells. RSRQ data provides crucial information for network operators to optimize their

cellular networks. Thus, operators can easily identify areas where interference may occur by analyzing RSRQ values in different locations. In addition to all this, RSRQ helps mobile devices select cells for the best communication.

An important parameter in the wireless communication system for mobile operators is Signal-to-Interference-plus-Noise Ratio (SINR). This measurement parameter represents the quality of the RF channel. SINR indicates the ratio between received power and interference in Decibels (dB). SINR shows the signal quality depending on Signal Power (S), Interference Power (I) and Noise Power (N) values. Figure 6 shows the SINR values obtained in this study. SINR values obtained in ground tests are shown in blue and SINR values obtained after 120 meters flight are shown in orange.

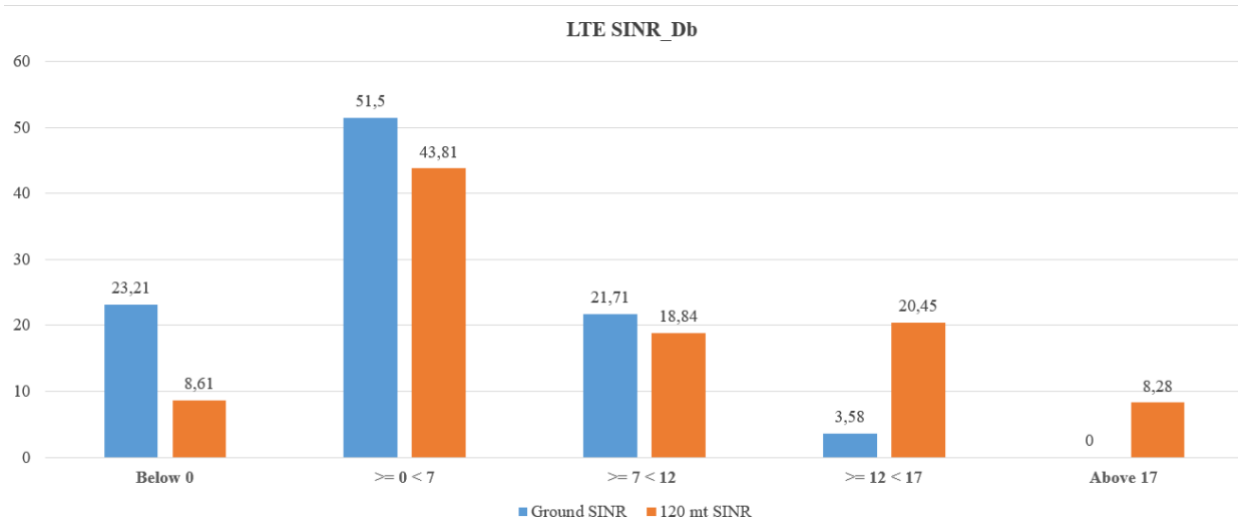


Figure 6. LTE Signal-to-Interference-plus-Noise Ratio (SINR) at 120 m and Ground

SINR describes mobile network throughput and network coverage and capacity. Mobile network operators can reduce network load by improving SINR values. The value scale is presented in Figure 7 to understand how the RSRP, RSRQ and SINR parameters are specified according to their levels.

	RSRP (dBm)	RSRQ (dB)	SINR (dB)
BAD	< -105	< -15	< 5
FAIR	-95 to -105	-10 to -15	5 to 20
GOOD	> -95	> -10	> 20

Figure 7. Scale of parameters RSRP, RSRQ and SINR

Within the scope of the study, flight tests were carried out with the Tems Phone placed on the UAV at a legal altitude of 120 meters. RSRP, RSRQ and SINR parameters were recorded for

examination throughout the flights. Figures 4, 5, and 6 showed the results of RSRP, RSRQ, and SINR, respectively. In addition, one of the main purposes of the study is to measure RSRP, RSRQ and SINR values by monitoring the route followed on the ground during the flight. Thus, the signal values of base stations normally developed for ground level wireless communication were tested. Considering these values, the main purpose of this study is to see how they change during flights at 120 meters. For this purpose, in order to compare the measurements, both the maximum UAV flight altitude and the minimum flight altitude were made within acceptable limits in the graphics.

4. Conclusion

UAV Traffic Management Systems are being tested in many regions, especially in Europe and America, in order to manage UAV air operations, which are becoming more widespread day by day in the world. The basic requirement of these systems is the two-way transfer of TCP/UDP Telemetry, which is required for the management and control of UAVs, to ground control systems. This transmission requires reliable and comprehensive wireless communication infrastructures.

In this study, it has been proven that the infrastructure of 4G/LTE communication technologies supports the tests carried out at ground level and at 120 meters, which is the legal altitude limit specified in Turkey for UAV systems. Tests were carried out at minimum and maximum legal altitude to determine how communication capability would change. As a result of the tests carried out within the scope of the UAV Innovation Project carried out in partnership with Türk Telekom, Argela and Cappadocia University, the UAV with 4G Mobile Communication kit integration in connection with the Türk Telekom live mobile network successfully performed flights. Telemetry information was transferred and made available to Cappadocia University servers via Türk Telekom 3G/4G Mobile network. The study proved that UAV Traffic Management Systems can be used successfully at the legal minimum and maximum UAV altitudes in Turkey and that RSRQ, RSRP and SINR parameters will support this telemetry communication. Although the experiments were conducted within the Turkish regulatory environment, the findings are relevant to regions with comparable LTE infrastructure and regulatory limits on UAV altitudes. The results may guide policy decisions and infrastructure assessments in similar semi-urban or rural geographies where LTE-based UTM integration is being considered. Within the scope of the UAV Innovation Project, it aims to strengthen its background by carrying out similar studies at certain altitudes between 0 and 120 meters in the following phases. One limitation of the present study is the lack of statistical generalization and the exclusive use of a single operator. Future studies will aim to include a larger number of flights, multiple LTE service providers, diverse terrain types, and statistical treatment of signal performance to further strengthen the generalizability of the findings.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

This research was funded by the Türk Telekomünikasyon A.Ş., ARGELA Technologies and Scientific Research Projects Unit

of Cappadocia University, grant number KÜN.2021-BAGP-029. The APC was funded by the Scientific Research Projects Unit of Cappadocia University. The authors would like to thank the Scientific Research Projects Unit of Cappadocia University, and the Türk Telekomünikasyon A.Ş., ARGELA Technologies. The authors would like to extend their gratitude to Emel Uzun Subaş, Furkan Açık, Serkan Yıldız, Sezer Erkli, Erhan Lokman, and Onur Altunbaş for their valuable contributions to this study.

References

- Amorim, R., Nguyen, H., Mogensen, P., Kovács, I. Z., Wigard, J., & Sørensen, T. B. (2017). Radio channel modeling for UAV communication over cellular networks. *IEEE Wireless Communications Letters*, 6(4), 514-517.
- Batistatos, M. C., Athanasiadou, G. E., Zarbouti, D. A., Tsoulos, G. V., & Sagias, N. C. (2018). LTE ground-to-air measurements for UAV-assisted cellular networks.
- Dalkıran, F. Y., & Gençay, M. S. (2021). Küresel Seyrüsefer Uydu Sistemleri Kullanılmayan Alanlarda İnsansız Hava Aracının Stabilizasyonunun Artırılması. *Journal of Aviation*, 5(1), 36-44.
- Ding, X., Yin, D., Zhou, Y., Lai, J., & Wang, Y. (2017, December). Joint communication quality assurance algorithm for UAVs flying over urban LTE networks. In *2017 3rd IEEE International Conference on Computer and Communications (ICCC)* (pp. 490-496). IEEE.
- Gharib, M., Nandadapu, S., & Afghah, F. (2021, June). An exhaustive study of using commercial lte network for uav communication in rural areas. In *2021 IEEE International Conference on Communications Workshops (ICC Workshops)* (pp. 1-6). IEEE.
- Gupta, L., Jain, R., & Vaszkun, G. (2015). Survey of important issues in UAV communication networks. *IEEE communications surveys & tutorials*, 18(2), 1123-1152.
- Hellaoui, H., Chelli, A., Bagaa, M., & Taleb, T. (2020, June). UAV communication strategies in the next generation of mobile networks. In *2020 International Wireless Communications and Mobile Computing (IWCMC)* (pp. 1642-1647). IEEE.
- Horani, M., & Hasna, M. O. (2018, October). Latency analysis of UAV based communication networks. In *2018 International Conference on Information and Communication Technology Convergence (ICTC)* (pp. 385-390). IEEE.
- Karamchedu, V. P. (2020, November). A Path from Device-to-Device to UAV-to-UAV Communications. In *2020 IEEE 92nd Vehicular Technology Conference (VTC2020-Fall)* (pp. 1-5). IEEE.
- Konar, M., & Kekeç, E. T. (2021). İnsansız hava araçlarının uçuş süresinin termal hava akımları kullanılarak artırımı. *Avrupa Bilim ve Teknoloji Dergisi*, (23), 394-400.
- Lee, H., Kang, T., & Seo, J. (2019, October). Development of confidence bound visualization tool for LTE-based UAV surveillance in urban areas. In *2019 19th International Conference on Control, Automation and Systems (ICCAS)* (pp. 1187-1191). IEEE.
- Lin, X., Yajnanarayana, V., Muruganathan, S. D., Gao, S., Asplund, H., Maattanen, H. L., ... & Wang, Y. P. E. (2018). The sky is not the limit: LTE for unmanned aerial vehicles. *IEEE Communications Magazine*, 56(4), 204-210.

- Miao, W., Luo, C., Min, G., Wu, L., Zhao, T., & Mi, Y. (2019, May). Position-based Beamforming Design for UAV communications in LTE networks. In ICC 2019-2019 IEEE International Conference on Communications (ICC) (pp. 1-6). IEEE.
- Militaru, L. G., Popescu, D., & Ichim, L. (2020, October). 4G/LTE Issues of Low Altitude UAV Flying Systems. In 2020 24th International Conference on System Theory, Control and Computing (ICSTCC) (pp. 874-879). IEEE.
- Nguyen, H. C., Amorim, R., Wigard, J., Kovacs, I. Z., & Mogensen, P. (2017, September). Using LTE networks for UAV command and control link: A rural-area coverage analysis. In 2017 IEEE 86th Vehicular Technology Conference (VTC-Fall) (pp. 1-6). IEEE.
- Oktay, T., Konar, M., Onay, M., Aydin, M., & Mohamed, M. A. (2016). Simultaneous small UAV and autopilot system design. *Aircraft Engineering and Aerospace Technology*, 88(6), 818-834.
- Qazi, S., Siddiqui, A. S., & Wagan, A. I. (2015, December). UAV based real time video surveillance over 4G LTE. In 2015 International Conference on Open Source Systems & Technologies (ICOSST) (pp. 141-145). IEEE.
- Ranjan, A., Panigrahi, B., Rath, H. K., Misra, P., & Simha, A. (2018, April). LTE-CAS: LTE-based criticality aware scheduling for UAV assisted emergency response. In IEEE INFOCOM 2018-IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS) (pp. 894-899). IEEE.
- Reingruber, P., Langwieser, R., Berisha, T., & Mecklenbräuker, C. F. (2022, March). Measured radiation behaviour of a UAV-attached LTE antenna. In 2022 16th European Conference on Antennas and Propagation (EuCAP) (pp. 1-5). IEEE.
- Sae, J., Wirén, R., Kauppi, J., Maattanen, H. L., Torsner, J., & Valkama, M. (2019, April). Public LTE network measurements with drones in rural environment. In 2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring) (pp. 1-5). IEEE.
- Stanczak, J., Kovacs, I. Z., Koziol, D., Wigard, J., Amorim, R., & Nguyen, H. (2018, June). Mobility challenges for unmanned aerial vehicles connected to cellular LTE networks. In 2018 IEEE 87th Vehicular Technology Conference (VTC Spring) (pp. 1-5). IEEE.
- Sundaresan, K., Chai, E., Chakraborty, A., & Rangarajan, S. (2018). SkyLiTE: End-to-end design of low-altitude UAV networks for providing LTE connectivity. *arXiv preprint arXiv:1802.06042*.
- Watts, A. C., Ambrosia, V. G., & Hinkley, E. A. (2012). Unmanned aircraft systems in remote sensing and scientific research: Classification and considerations of use. *Remote sensing*, 4(6), 1671-1692.

Cite this article: Kekec, E.T., Boyali, K., Gencag, M.S.. (2025). Analysis of LTE Network Connection Parameters at Legal Maximum UAV Flight Altitudes and Comparison with Ground. *Journal of Aviation*, 9(3), 508-515.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

A TRIZ-Axiomatic Design Framework with Semantic RMp Mapping for Material Selection: Application to Aircraft Brake Disks

Ömer Yaman¹ 

¹Istanbul Medeniyet University, Department of Aeronautical Engineering, Istanbul, Türkiye. (omer.yaman@medeniyet.edu.tr)

Article Info

Received: 24 June 2025
Revised: 07 August 2025
Accepted: 25 August 2025
Published Online: 09 October 2025

Keywords:

TRIZ
Axiomatic Design
Material Selection
Aircraft Brake Disk
Design Requirements

Corresponding Author: Ömer Yaman

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1726595>

Abstract

The selection of materials for aerospace purposes requires rigorous mapping between design requirements and material properties, especially for critical safety components like aircraft brake disks. Traditional selection methods like Ashby charts or tabulated property databases often struggle with conflicting vague, fuzzy, or high-performance requirements. This study proposes an integrated approach combining the Theory of Inventive Problem Solving (TRIZ), Axiomatic Design (AD), and information modelling (IM) principles to map functional and non-functional product requirements to material properties systematically. TRIZ resolves contradictions between requirements, while Axiomatic Design deals with functional independence and traceability towards the design parameters. Information model enables structured traceability from high-level requirements to quantifiable material properties to support semantic consistency and cross-domain reasoning. The methodology is validated through a case study on aircraft brake discs, where carbon-carbon composite is identified as the most suitable material based on a quantitative Requirement-Material property (RMp) evaluation that prioritizes safety and thermal resilience over cost. The results highlight the potential of the proposed framework to support traceable, structured, and safety-driven decisions in complex engineering design. The integration of TRIZ, Axiomatic Design, and structured information modelling for traceable, safety-driven material selection is the core novelty of this work, and has not been previously formalized into a reusable framework for aerospace applications.

1. Introduction

At the outset of product design, immediately after the function-to-form mapping activity, designers must choose materials whose properties align with the performance and functional requirements of the product. Traditionally, this selection relies on databases of mechanical, physical, and chemical properties. However, in complex products such as aircraft, designers often face challenging and conflicting demands such as lightweight versus strength or thermal resilience versus manufacturability. These challenges require more than just matching numerical properties; they necessitate a systematic method for understanding and resolving contradictions in design requirements.

To support this, structured information models are introduced to provide traceable links between product requirements and material properties, enabling consistent decomposition and knowledge-based decision making throughout the design process.

Historical examples, such as the evolution from steel to carbon-carbon composites in aircraft braking systems, illustrate how external drivers like thermal capacity, fatigue resistance, and safety standards heavily influence material selection beyond conventional metrics. In many cases, terms like “durability” are context-sensitive and rely on the

designer’s judgment and knowledge of material behavior within high-temperature and cyclic loading environments. Issues related to thermal shock resistance, structural reliability, oxidation control, and lifecycle requirements must be addressed through the proper choice of materials.

To find out how these performance criteria are directly or indirectly related to material properties, this paper integrates two powerful frameworks: the Theory of Inventive Problem Solving (TRIZ) and Axiomatic Design (AD). TRIZ provides tools such as contradiction matrices and 40 inventive principles to resolve technical conflicts during early-stage design (Altshuller, 1984). Axiomatic Design, developed by Suh (1990), offers a structured methodology for decomposing functional requirements and mapping them to design parameters while maintaining independence between functions.

By integrating TRIZ with Axiomatic Design, this study proposes a robust and traceable approach to material selection. This method enables the identification and resolution of design conflicts, the decomposition of complex requirements into measurable attributes, and the formation of uncoupled or decoupled design matrices that link functional requirements to quantifiable material properties. A case study on aircraft brake disk material selection is presented to demonstrate the practical value of this combined approach.

Despite various advances in material selection methods, a significant gap remains in addressing traceable, requirement-driven selection for safety-critical aerospace components. Traditional tools do not handle cross-domain reasoning or provide support for contradictory and evolving design goals. This study addresses that gap by proposing a layered, semi-formal model that integrates problem structuring, traceability, and performance evaluation using RMP logic.

Our framework, while demonstrated on aircraft brake disks, is readily extensible to broader aerospace material selection problems. In particular, it can support advanced composite systems and thermoset-thermoplastic tape development where conflicting thermal-mechanical requirements must be resolved traceably. Within this context, the integration of TRIZ is especially valuable, as its contradiction-resolution principles are well-suited to composite material selection processes, where designers frequently encounter tradeoffs between thermal resistance, structural strength, and manufacturability.

2. Literature Review

Material selection methods have evolved from simple look-up tables to more sophisticated tools that incorporate computational and knowledge-based techniques. One of the most prominent frameworks is Ashby's material selection methodology, which utilizes graphical performance indices to identify optimal materials based on mechanical and physical criteria (Ashby, 1999; Ashby, 2005). Although effective for quantifiable properties, these charts struggle to address qualitative factors or complex trade-offs between competing requirements, particularly prevalent in aerospace applications where weight, thermal resistance, and durability must be carefully balanced.

Axiomatic Design (AD), introduced by Suh (1990), provides a systematic way to decompose functional requirements (FRs) and relate them to design parameters (DPs) through the construction of design matrices. AD emphasizes the Independence Axiom, which asserts that each FR should be satisfied by a unique DP, and the Information Axiom, which encourages solutions with minimal uncertainty. AD have been applied in various engineering domains, including manufacturing systems and mechanical components by researchers such as Kulak et al. (2010) and Cochran et al. (2000). They demonstrate its effectiveness in structuring design problems. However, AD assumes that FRs are already well defined and decoupled, a condition often unmet in early-stage aerospace design.

To address this challenge, the Theory of Inventive Problem Solving (TRIZ) developed by Altshuller (1984), has gained traction as a complementary framework. TRIZ is grounded in the resolution of technical contradictions and proposes a set of 40 inventive principles that guide design creativity. TRIZ excels at identifying and addressing situations where improvement in one parameter leads to deterioration in another, such as increasing strength at the cost of weight. Studies by Mann (2002) and Savransky (2000) have extended TRIZ theory to product design and innovation engineering, enhancing early-stage contradiction analysis even in high-stakes domains such as aerospace and defense.

Recent studies have begun integrating TRIZ with AD to improve early-stage design modeling and conflict resolution buildig on the mentioned complementarity. For example, Zhang et al. (2016) demonstrated how TRIZ can preprocess design problems to create more effective and uncoupled AD matrices. Similarly, Shirwaiker (2008) showed that TRIZ-

enhanced requirement decomposition results in more functionally consistent material selection outcomes. Additional work by Yoon and Park (2005) proposed hybrid design models that benefit from the structured reasoning of AD and the inventive capabilities of TRIZ.

Separately, Roy and colleagues developed several models to bridge requirements, product structures, and material data using semantic information models and ontologies (Roy & Sarigecili, 2013; Yaman et al., 2014; Roy & Yaman, 2014; Zhang et al., 2015). These studies underline the need for structured models that support bidirectional traceability between product needs and material attributes.

Despite these advancements, the integration of TRIZ and Axiomatic Design in the context of material selection, particularly in mapping design requirements to specific material properties, remains underexplored. Moreover, the practical implementation of such integrated models in real-world engineering development is still limited. This study addresses this gap by leveraging TRIZ for systematic contradiction analysis and Axiomatic Design for formalizing the requirement-material property relationship through design matrices. While previous studies have applied TRIZ or Axiomatic Design independently to engineering problems, and others have explored material selection methods in aerospace, to the best of our knowledge, no previous work has formally integrated TRIZ, Axiomatic Design, and a semantic requirement-material mapping framework for safety-critical components such as aircraft brake disks.

Despite these advancements, the integration of TRIZ and Axiomatic Design in the context of material selection, particularly in mapping design requirements to specific material properties, remains underexplored. Moreover, the practical implementation of such integrated models in real-world engineering development is still limited. This study addresses this gap by leveraging TRIZ for systematic contradiction analysis and Axiomatic Design for formalizing the requirement-material property relationship through design matrices. While previous studies have applied TRIZ or Axiomatic Design independently to engineering problems, and others have explored material selection methods in aerospace, to the best of our knowledge, no previous work has formally integrated TRIZ, Axiomatic Design, and a semantic requirement-material mapping framework for safety-critical components such as aircraft brake disks. Traditional methods such as Ashby charts and weighted property indices focus primarily on quantitative property matching; however, they lack the ability to systematically resolve contradictory goals, a gap addressed directly by the proposed TRIZ-AD-RMP framework.

3. Methodology

This study proposes a comprehensive methodology for the systematic mapping of product requirements to material properties by integrating TRIZ-based contradiction resolution with Axiomatic Design theory and multi-layered information modeling. The method addresses challenges such as vague or conflicting requirements, lack of traceability, and inconsistency in property linkage by establishing a robust reasoning structure that extends from requirement capture to quantifiable material parameters. Although the case study presented in this paper focuses on brake disk materials, the methodology is structured to be applicable to a wide range of aerospace components, including advanced composites and thermoplastic tapes. The framework proposed in this study

systematically resolves contradictions while preserving functional independence, and ensuring traceability across multiple design layers. By these means, the introduced approach differs from the conventional ones which emphasize direct property matching such as Ashby charts or weighted property indices. Therefore, the outlined steps in the upcoming sections are general in nature, with domain-specific adjustments possible based on the application.

At its core, the methodology uses information models to ensure traceable mappings among various entities: requirements, functions, design parameters, product features, and material properties. This integrated approach builds upon the Open Assembly Model (OAM) architecture (Baysal et al., 2005), which captures design rationale, constraints, and assumptions at varying abstraction levels. By embedding the requirement-property relationship into this model, designers can trace how material properties support specific functional and non-functional objectives over the product lifecycle.

The approach also utilizes a knowledge base driven RMP matrix model, supported by standardized vocabularies and taxonomies. These include goal templates that classify requirements into performance, processability, serviceability, environmental, and constraint goals. This layered mapping is further enhanced by using UML representations for product-material relationships based on ISO 10303-45 (Part 45), enabling integration into PLM platforms and future automation.

The methodology progresses through requirement classification, contradiction resolution using TRIZ, functional decomposition using Axiomatic Design, and finally a formalized mapping into the RMP structure. The following sections describe each stage in detail.

3.1. Classification of Requirements

The foundation of requirement-property mapping lies in the precise and structured classification of product requirements. Such classification is particularly important for clarifying vague or conflicting requirements, which, if left unresolved, can undermine later stages of design. In this study, we adopt a taxonomy that divides product requirements into two main categories: Functional Requirements (FRs) and Non-Functional Requirements (NFRs), in alignment with the taxonomy established in prior work by Roy and Sarigecili (2013). This step also establishes explicit traceability, ensuring that each requirement can be systematically followed through TRIZ-based contradiction analysis and Axiomatic Design decomposition.

Functional Requirements include the demands directly associated with a product's operational behavior and technical performance. These are typically decomposed into:

- **Performance Requirements:** Related to load-bearing capacities (e.g., tensile, compression, bending, torsion), thermal behavior, and mechanical endurance.
- **Serviceability Requirements:** Cover reliability, maintainability, and reparability under operating conditions.
- **Processability Requirements:** Encompass manufacturability metrics such as machinability, weldability, castability, formability, and heat treatability.

Non-Functional Requirements encapsulate broader constraints and design goals:

- **Objectives:** Cost, weight, emission, and efficiency targets.
- **Constraints:** Recyclability, use of hazardous materials, regulatory compliance.
- **Geometric Constraints:** Design-related specifications such as mass, length, volume, section area, and other dimensional limits.

This classification schema not only enhances traceability during design but also facilitates the downstream decomposition of requirements into quantifiable entities suitable for matrix-based mapping to material properties. It provides a consistent vocabulary across lifecycle stages and enables integration with semantic models, information systems, and standardized PLM platforms (ISO 10303). To a further extent, the offered classification, with its strong structure, lays the ground for resolving contradictions using TRIZ, where conflicts are addressed and discussed, such as thermal resistance versus manufacturability, and creates the foundation for subsequent formal mapping in Axiomatic Design and RMP models.

3.2. TRIZ-Driven Conflict Resolution

After the requirements are classified, the next step for the study is to identify conflicts tending to show up, such as between processability and performance. In the early stages of product development, design requirements often conflict; improving one aspect of performance may degrade another. For instance, increasing thermal conductivity to dissipate heat might compromise dimensional stability due to thermal expansion. To address these issues, the TRIZ methodology is employed to identify and resolve such contradictions systematically.

TRIZ (Teoriya Resheniya Izobretatelskikh Zadach), developed by Altshuller (1984), offers a contradiction matrix and 40 inventive principles derived from an extensive analysis of global patents. It helps designers resolve both technical and physical contradictions by reformulating problems into inventive challenges.

In this methodology, TRIZ is applied immediately after requirement classification. Technical contradictions, such as high stiffness versus lightweight, are identified and analyzed using the TRIZ contradiction matrix. Appropriate inventive principles, such as segmentation (Principle #1), local quality (Principle #3), and composite materials (Principle #40) are then selected to propose innovative solutions that satisfy conflicting requirements simultaneously.

In the composite-based aerospace components, the main contradictions stand out as weight versus thermal resistance, or structural integrity versus repairability, which are addressed through the studied principles that can be evaluated as inventive (Parveez et al., 2022). This structured contradiction analysis enhances the design process by enabling early resolution of trade-offs, reducing the risk of coupled functions, and paving the way for more effective decomposition in the Axiomatic Design phase. For example, instead of choosing a single compromise material, TRIZ may suggest using functionally graded materials or modular assemblies to resolve contradictions without compromising key requirements.

By integrating TRIZ at this stage, the methodology assures that the requirements which enter the design matrix are uncoupled or at least minimally coupled, technically feasible, and optimized in terms of the context for mapping to material properties. At the end of this stage, contradiction-resolved

requirements stand out as an output, serving as the input for functional decomposition using Axiomatic Design.

3.3. Axiomatic Design Framework

After resolving contradictions using TRIZ, the next step in the methodology is to employ Axiomatic Design (AD) to systematically decompose functional requirements (FRs) into design parameters (DPs) and ensure clarity and independence in their implementation. Axiomatic Design, developed by Suh (1990), is based on two core principles: the Independence Axiom, which emphasizes that each functional requirement should be satisfied without affecting others, and the Information Axiom, which promotes designs with the minimum information content. This strategy has even been effectively used in aerospace structures such as the redesign of the Beech Baron 58 aircraft's empennage (Ashtiany et al., 2016).

The mapping between the functional and physical domains is expressed through the design equation: $[FR]=[A][DP]$ where $[FR]$ represents the vector of functional requirements, $[DP]$ represents the vector of design parameters, and $[A]$ is the design matrix that defines the relationships between them. The structure of the matrix reveals whether the design is:

- Uncoupled: If $[A]$ is a diagonal matrix, where each FR is satisfied by an independent DP.
- Decoupled: If $[A]$ is a triangular matrix, where DPs satisfy FRs in a sequential, non-interfering order.
- Coupled: If $[A]$ is a complete matrix, where interdependencies exist among FRs and DPs, indicating that changes in one DP affect multiple FRs that require redesign or decoupling.

To illustrate the transition from TRIZ to AD, consider a contradiction such as maximize stiffness while minimizing weight, which is typical in aerospace material design. TRIZ may propose inventive principles like segmentation or composite materials to resolve this conflict, leading to the adoption of functionally graded composites. Within the AD framework, this resolution is then expressed as FRs (provide structural stiffness and minimize overall mass), mapped to DPs (layered composite architecture and optimized fiber orientation), which ensures the design matrix remains uncoupled or minimally coupled.

Applying the axiomatic framework ensures a modular and traceable decomposition of complex requirements, which is critical for linking each FR to quantifiable material properties. For instance, in the case of a brake rotor, the FR "reduce speed controllably" can be translated into DPs such as friction coefficient and surface hardness, which are then directly associated with specific material attributes.

Moreover, AD supports hierarchical decomposition, enabling designers to refine higher-level FRs into sub-requirements until the associated DPs become measurable physical or chemical properties. This feature makes Axiomatic Design particularly suitable for multi-layered problems where functional performance is influenced by multiple interdependent material traits.

By structuring the FR-DP relationships explicitly, Axiomatic Design serves as a critical foundation for populating the RMp matrix, facilitating the eventual mapping between material properties and design intent.

3.4. Layered Information Models for RMp Mapping

This study adopts a dual-layered information modeling approach to help structure and trace the mapping between design requirements and material properties. These models support a consistent, scalable, and traceable methodology for translating high-level product objectives into concrete material selection criteria across the product lifecycle.

As illustrated in Figure 1, the integrated model combines the Requirement Information Model, Material Information Model, and Product Information Model, forming a comprehensive semantic framework. This structure builds on prior ontology-based research in requirement modeling (Yaman et al., 2014), material information modeling (Roy & Yaman, 2014), and integrated product-process-material representation (Roy & Sarigecili, 2013). It is further supported by the process-oriented product model presented by Zhang et al. (2015), which emphasizes the role of system structure in sustainable manufacturing environments.

The Requirement Information Model categorizes both functional and non-functional requirements, including aspects such as performance, serviceability, lifecycle goals, and compliance constraints. These are contextualized across different product states (Beginning-of-Life, Middle-of-Life, End-of-Life) and linked to specific actors, environments, and manufacturing processes. For instance, in the brake rotor case, the FR, maintain friction under high thermal load is contextualized as a performance requirement linked to the DP, friction coefficient stability, which maps directly to the thermal-mechanical material properties of carbon-carbon composites and ceramic matrix composites. This layered taxonomy supports knowledge-based interpretation of ambiguous or high-level design intents.

The Material and Product Information Model represents relationships among materials, parts, and final products, incorporating material composition, properties (mechanical, chemical, thermal, electrical, environmental), manufacturing constraints, and application contexts. The information model follows ISO 10303-45 standards for consistency and extensibility in material data representation. By modeling validation, behavior, and composition alongside requirement classes, this semantic framework supports traceable RMp (Requirement-Material Property) mapping.

The output of this stage is a structured RMp mapping table, where each requirement (classified and contradiction-resolved) is explicitly linked to one or more material properties, forming the basis for candidate material evaluation in Section 4.

This unified architecture enables recursive reasoning from functional requirements to material selection by allowing both top-down and bottom-up inference. It facilitates traceability across system abstraction levels and provides a formalized path for aligning material attributes with engineering intent thereby enhancing the clarity, transparency, and reusability of decisions made throughout the product lifecycle. By embedding requirements, material attributes, and lifecycle states in a unified model, the approach ensures complete traceability from stakeholder intent to material choice, addressing the need for transparent decision pathways highlighted in design for sustainability research (Zhang et al., 2015).

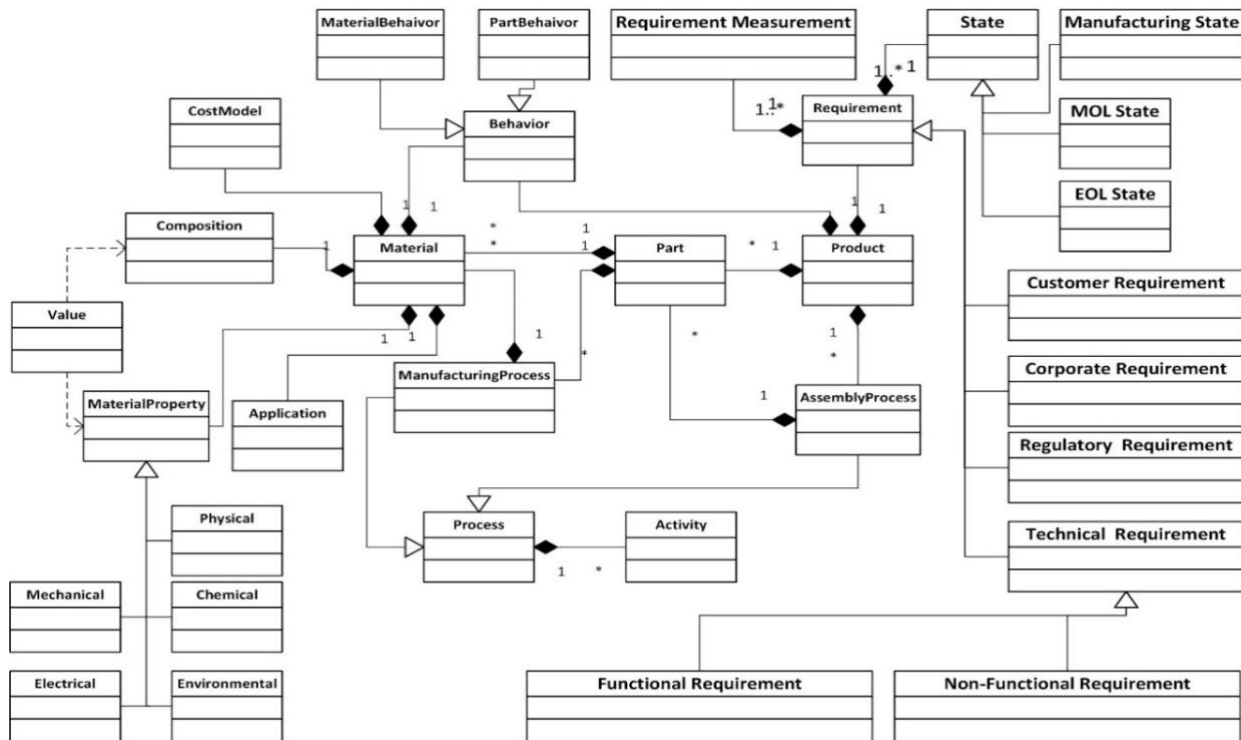


Figure 1. Unified Product, Material, and Requirement Information Model.

3.5. Relationship Mapping Between Design Requirements and Material Properties (RMP)

At the core of the methodology lies the RMP (Requirement-Material Property) relationship framework, which establishes a matrix-based mapping between decomposed requirements and material properties. As shown in Figure 2, this mapping is implemented within the Product Information Model. This is accomplished by first forming two binary matrices:

- Requirement-to-Product matrix (RP) maps requirements (FRs) to product functions or features.
- Product-to-Material Property matrix (PMp) maps those product features to relevant material properties.

Multiplying these yields the matrix: Each cell in this matrix represents the relevance or strength of the relationship between

a specific requirement and a material property. For example, the processability requirement 'formability' can be broken down further into 'drawability' and 'stretchability', which are then linked to specific measurable properties such as elongation and yield strength. The flexibility of this framework supports varying levels of granularity based on context and application.

The composite RMP matrix is defined as: $RMP = RP \times PMp$
Each RMP cell is binary or weighted according to a 5-point scale that quantifies the intensity of the relationship:

- 0: No relationship
- 0.1: Weak relationship
- 0.4: Moderate relationship
- 0.7: Strong relationship
- 1.0: Very strong relationship

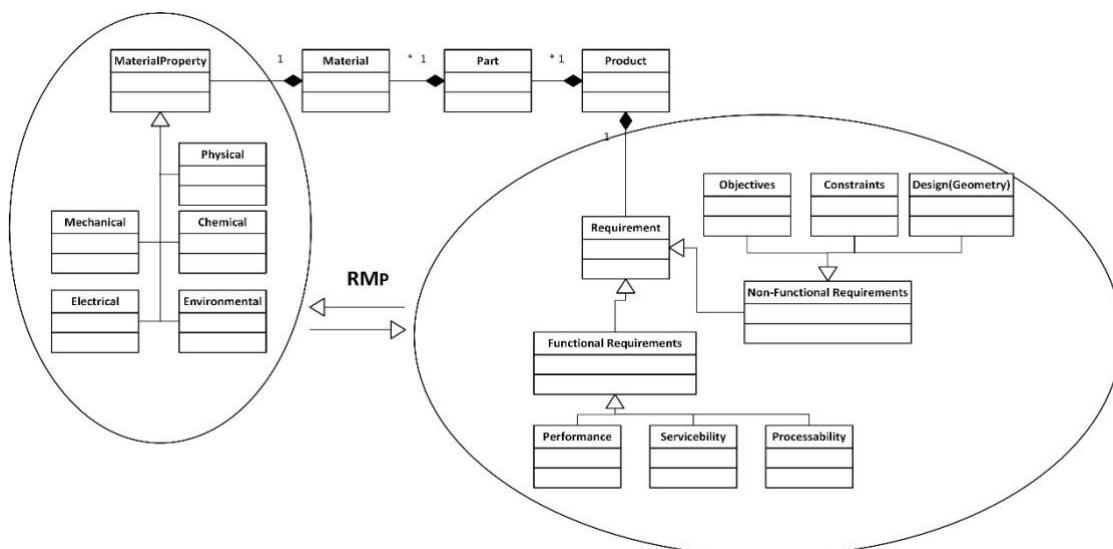


Figure 2. Representation of Requirement-Material Property (RMP) Relationships within the Product Information Model

This scale supports fuzzy evaluation and AI-compatible inference. It enables both bottom-up reasoning (property $\rightarrow$ requirement) and top-down mapping (requirement $\rightarrow$ property) for decision-making.

We adopt a rule-based reasoning process, integrated with TRIZ logic, to sequence functional requirements and their dependent design parameters:

- FR1 $\rightarrow$ DP1 $\rightarrow$ MP1: Initiates braking via friction
- DP1 $\rightarrow$ FR2: Friction generates heat $\rightarrow$ thermal management
- FR2 $\rightarrow$ DP2 $\rightarrow$ MP2: Heat dissipation and structural load handling
- DP2 $\rightarrow$ FR3, and so on

TRIZ principles are employed before matrix formation to resolve inherent contradictions that emerge during the decomposition of Functional Requirements (FRs) to Design Parameters (DPs) and subsequently to other downstream FRs. For instance, the initial requirement to generate sufficient friction (FR1) may lead to the need for high thermal conductivity in the brake rotor to manage heat (FR2), while simultaneously necessitating low thermal expansion to preserve structural stability creating a classical contradiction. TRIZ inventive principles such as Local Quality and Composite Materials are used to address such conflicts. These principles guide the reformulation of the problem space (e.g., introducing functionally graded materials or layered architectures) before these requirements are formalized in the RMP matrix. Thus, TRIZ not only mitigates conflicts but also informs how FRs are logically sequenced and refined through the FR-DP-MP hierarchy. These shape how functional requirements are decomposed or reformulated before being entered into the RMP model.

Once decomposed, Axiomatic Design principles are used to construct an uncoupled matrix that ensures independence between FRs and their associated DPs, maintaining system traceability and design clarity. These DPs are then mapped to material properties, resulting in a structured RMP matrix in which each requirement-property link is quantified using a 5-point relationship strength scale. This weighting allows for refined, fuzzy logic-based evaluation of candidate materials under uncertainty, supporting top-down and bottom-up reasoning in the material selection process.

This approach ensures traceable reasoning from high-level requirements to low-level property selections by integrating Requirement and Material models within a unified Product Information Model. The semantic and modular structure of these models supports reuse, knowledge transfer, and potential integration with AI-driven material selection platforms and PLM systems.

3.6. Quantitative RMP Evaluation Using Normalized Material Scores

To improve the transparency and reproducibility of candidate material evaluation, a quantitative method is incorporated into the RMP framework. This method computes scores for each material by identifying all relevant material properties (MPs) that correspond to a given functional requirement (FR), normalizing each property independently, and then averaging their normalized values to obtain a single RMP score per FR. This approach ensures that the RMP matrix is populated through a consistent, data-driven process rather than relying solely on qualitative judgment. To formalize this process and enable reproducible computation, the following notation is adopted.

Let:

- $MP_{(i, j)}$ denotes the value of the j^{th} material property associated with functional requirement FR_i .
- $M_{(c, j)}$ denotes the value of the j^{th} property for candidate material c .
- $S_{(i, c, j)}$ represents the normalized score of material c for property j .

Normalization is applied according to the desirability direction of the property:

$$S_{i,c,j} = \begin{cases} \frac{M_{c,j}}{\max(M_{*,j})}, & \text{if higher values – preferred} \\ \frac{\min(M_{*,j})}{M_{c,j}}, & \text{if lower values – preferred} \end{cases} \quad (1)$$

For each functional requirement FR_i composed of n contributing material properties, an average normalized score is calculated as:

$$S_{i,c} = \frac{1}{n} \sum_{j=1}^n S_{i,c,j} \quad (2)$$

The overall suitability score for a candidate material c is then determined by aggregating the weighted scores across all functional requirements, where w_i denotes the predefined importance weight of FR_i :

$$Total\ Score_c = \sum_{i=1}^m w_i * S_{i,c} \quad (3)$$

This quantitative RMP scoring approach enables comparative evaluation of candidate materials using objective property data and supports traceable decision-making in high-performance design scenarios. A similar normalization and weighting strategy have been utilized in prior work on brake disk material selection by Maleque et al. (2010), further validating the relevance of this methodology to engineering domains where functional trade-offs must be addressed with numerical rigor.

As an important note, the application of this quantitative scoring method will be discussed in Section 4 through the case study on brake rotor, where material scores after being normalized are going to be applied to compare and select suitable candidates as the material.

4. Case Study: Material Selection for an Aircraft Brake Disk

To demonstrate the practical application of the integrated TRIZ and Axiomatic Design-based RMP methodology, this section presents a case study focused on selecting appropriate material properties for an aircraft brake disk. Aircraft brake disks are critical safety components exposed to intense thermal, mechanical, and environmental stresses during repeated landing and taxiing operations. The material used must endure high-energy braking events, resist thermal shock and fatigue, and meet stringent reliability and regulatory standards.

Unlike automotive applications, where cost may be a more significant factor, material selection for aircraft brake disks prioritizes performance, safety, and lifecycle durability over economic constraints. Therefore, this case study emphasizes performance-critical properties such as thermal conductivity, fatigue resistance, oxidation resistance, and dimensional stability under high temperatures. The objective is to

demonstrate how TRIZ and Axiomatic Design, supported by a structured information model, can effectively guide the decision-making process for material selection in high-performance aerospace systems.

This case study explicitly follows the methodological sequence established in Section 3: requirement classification, contradiction resolution via TRIZ, functional decomposition through Axiomatic Design, layered information modeling, RMP mapping, and quantitative evaluation. By demonstrating the full cycle, the study highlights how contradictions can be systematically addressed and traced through FR-DP-MP relationships. The goal is not only to identify a suitable material but also to illustrate the transparency, traceability, and robustness of the integrated TRIZ-AD-RMP framework.

4.1. Requirement Decomposition, Design Coupling, and Traceability

The initial step involves identifying and decomposing the high-level product requirements into functional requirements (FRs), design parameters (DPs), and their associated material properties (MPs).

The traceable FR-DP-MP structure begins with the identification of the system's main function: to provide a controllable and reliable reduction of speed during landing operations. Applying rule-based TRIZ decomposition, this function is translated into the primary functional requirement (FR1: enable braking via friction), which maps to the design parameter DP1: generate friction. The frictional process generates considerable heat, leading to the subsequent requirement (FR2: manage heat), fulfilled by DP2: dissipate thermal energy effectively. This logic cascade continues through durability under cyclic loads (FR3), thermal shock resistance (FR4), and sustainability and reusability objectives (FR5). Each functional requirement is linked to quantifiable material properties through well-defined design parameters. This TRIZ-guided hierarchy ensures that all system-level demands are grounded in engineering logic.

The decomposition from high-level goals to specific properties, driven by domain knowledge and rule-based logic is structured into three levels:

- **FR-to-DP Cascading Rules (Function-Driven):** These rules define how high-level Functional Requirements (FRs) emerge and relate to Design Parameters (DPs) through physical and product-level logic.
 - Rule 1 (FR1 → FR2): Friction enables deceleration but generates heat → Need to dissipate heat.
 - Rule 2 (FR2 → FR3): Heat and pressure → Wear and fatigue → Require durability.
 - Rule 3 (FR3 → FR4): Repeated stress cycles → Resist thermal shock and expansion effects
 - Rule 4 (FR4 → FR5): Performance and material stability → Support sustainable operation and reusability.

These are realized in the design domain as:

- FR1: Enable braking → DP1: Generate friction
- FR2: Manage heat → DP2: Dissipate thermal stress
- FR3: Resist wear and fatigue → DP3: Ensure high endurance
- FR4: Withstand thermal shock → DP4: Control thermal expansion

- FR5: Meet lifecycle/sustainability goals → DP5: Support reusability and environmental compatibility

This first layer of reasoning forms the foundation for functional traceability. It ensures that each design parameter originates from a specific, performance-driven product requirement and can be logically followed downstream.

- **{DP-to-DP Propagation Rules (Design-Coupling Logic):** While an uncoupled axiomatic matrix is ideal, in real-world cases DPs may logically influence one another.
 - Rule A (DP1 → DP2): Frictional force results in heat → DP2 must address this by managing thermal load.
 - Rule B (DP2 → DP3): Poor heat management accelerates fatigue and wear → DP3 ensures durability.
 - Rule C (DP3 → DP4): Durable materials under cyclic heat may expand irregularly → DP4 addresses thermal shock.
 - Rule D (DP4 → DP5): Materials optimized for thermal shock may affect recyclability and cost → DP5 ensures lifecycle alignment.

These intermediate rules reveal how the satisfaction of one design parameter can condition or constrain the definition of another, forming a logical chain within the design space. This chain of dependencies not only refines the design strategy but also ensures that downstream parameters inherit the implications of upstream decisions, preparing the basis for property-level material matching.

- **DP-to-MP Mapping Rules (Material Translation Logic):** Design Parameters are translated to measurable Material Properties (MPs) using engineering knowledge.
 - Rule E (DP1): Generate friction → Coefficient of friction, Surface roughness, Wear rate
 - Rule F (DP2): Dissipate heat → Thermal conductivity, Specific heat, Thermal diffusivity
 - Rule G (DP3): Ensure durability → Hardness, Fatigue strength, Oxidation resistance, Creep resistance
 - Rule H (DP4): Withstand thermal shock → Thermal expansion coefficient, Thermal diffusivity, Fracture toughness (thermal cycling)
 - Rule I (DP5): Sustainability → Reusability, Repairability, Environmental compliance, Lifecycle traceability

Contradictions frequently emerge during the decomposition of functional requirements in the context of aircraft brake disks, especially due to the extreme thermal and mechanical conditions they endure. These conflicts are not only technical such as heat dissipation vs. structural stability but also manifest in trade-offs between performance and manufacturability.

To illustrate how TRIZ resolves such domain-specific conflicts in aerospace material selection, Table 1 presents examples of technical contradictions encountered in brake disk design, along with the TRIZ principles used to resolve them and their corresponding design implications.

Table 1. TRIZ-Based Contradiction Resolution Examples in Brake Disk Material Selection

Technical Contradiction	TRIZ Principle(s)	Design Implication / Reformulation
High thermal conductivity (for cooling) vs. Low thermal expansion (for dimensional stability)	#3 Local Quality, #40 Composite Materials	Use carbon-carbon composites with layered or functionally graded architectures to decouple thermal roles
High surface hardness (wear resistance) vs. Machinability	#1 Segmentation, #35 Parameter Change	Apply hard coatings or localized surface treatments while keeping the core material machinable
High strength and fatigue resistance vs. Low weight	#2 Taking Out, #40 Composite Materials	Use advanced composites or hybrid architectures to reduce weight without sacrificing performance
Thermal shock resistance vs. High thermal mass	#19 Periodic Action, #28 Mechanics Substitution	Introduce vented or functionally graded materials to dynamically manage heat and expansion
High friction (for braking) vs. Surface stability (wear, oxidation)	#10 Preliminary Action, #32 Color Changes	Integrate protective coatings or oxidation-resistant layers to prolong surface performance

By applying these TRIZ principles early, the methodology enables proactive resolution of design trade-offs and informs material candidate evaluation in the subsequent Rmp mapping phase.

To reinforce decision traceability, these FR-DP-MP relationships are also represented in a system-level dependency diagram (Figure 1), which complements the Rmp matrix by showing how requirement propagation and design coupling occur visually. This graphical mapping, combined with the uncoupled design matrix, makes explicit how each contradiction is resolved and how the decision logic flows from system-level goals to material properties.

Simultaneously, Axiomatic Design principles guide the mapping process by enforcing the Independence Axiom, which states that functional requirements should be satisfied independently. This is achieved by constructing an uncoupled design matrix, where each Functional Requirement (FR) is directly associated with a single Design Parameter (DP).

Hence, changes made to one DP will not affect the fulfillment of other FRs, thus reducing the risk of unintended design trade-offs and ensuring traceability throughout the system. The structure promotes clarity and design robustness

by enabling systematic decomposition and hierarchical representation of functional logic. This mapping approach provides a rigorous foundation for translating abstract system requirements into specific, quantifiable material needs.

$$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \\ FR_4 \\ FR_5 \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 \\ 0 & 0 & x & 0 & 0 \\ 0 & 0 & 0 & x & 0 \\ 0 & 0 & 0 & 0 & x \end{bmatrix} = \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \\ DP_5 \end{bmatrix}$$

This uncoupled matrix ensures that each Functional Requirement (FR) is independently satisfied by its corresponding Design Parameter (DP). Once established, each DP is then linked to specific Material Properties (MPs), which define the columns of the Rmp matrix.

The strength of each FR-MP relationship is quantified using a 5-point scale in the Rmp matrix: 1.0 (very strong), 0.7 (strong), 0.4 (moderate), 0.1 (weak), and 0.0 (none). These weights reflect both the physical dependency and the relative design priority, enabling nuanced decision-making under multi-objective constraints.

Table 2. Rule-Based FR-DP-MP Mapping with Rmp Weights and Requirement Metadata

FR	Req. Type	State	Actor	DP	Mapped MPs	Rules	Weight
Enable braking	Functional	MOL	Part, Material	DP1: Generate friction	Coefficient of friction, Surface roughness	Rule 1, A, E	1.0
Manage heat	Functional	MOL	Material	DP2: Dissipate thermal stress	Thermal conductivity, Heat capacity	Rule 2, B, F	0.7
Resist wear	Functional	MOL	Part surface, Material	DP3: Ensure durability	Hardness, Fatigue strength, Corrosion resistance	Rule 3, C, G	0.7
Thermal shock resistance	Functional	MOL	Material	DP4: Stability under gradients	Low thermal expansion, Thermal diffusivity	Rule 4, D, H	0.6
Lifecycle goals	Non-Functional	EOL	Material	DP5: Support sustainability	Recyclability, Embodied energy	Rule D, I	0.4

To highlight the utility of the proposed information modeling framework, it is important to note that each FR can be instantiated and managed within the unified Product Information Model, as depicted in Figure 1. This model contextualizes FRs across requirement types, lifecycle states, associated actors, and domain-specific constraints, while maintaining semantic links to the corresponding DPs and MPs. Since DPs and MPs are embedded within the same model, organized under part and material classes respectively, this structure ensures full traceability across design, engineering, and decision-making domains.

The Table 2 operationalizes this modeling strategy, illustrating how functional and non-functional requirements are instantiated with specific actors, lifecycle states, and measurable characteristics, and are ultimately linked to material properties. This traceability model supports Rmp logic by showing how abstract requirements throughout the product lifecycle, from manufacturing feasibility to in-use performance and end-of-life sustainability, can be decomposed, validated, and transformed into quantifiable material selection criteria. This process bridges abstract system-level functions to quantifiable selection criteria,

facilitating traceability, comparability, and rational evaluation in material selection decisions.

4.2. Interpreting and Using the RMp Framework for Candidate Material Selection

The RMp framework not only provides traceable decomposition from design intent to material traits, but also serves as a structured tool for evaluating and comparing real-world candidate materials. Once the FR-DP-MP structure is defined and weighted, it becomes feasible to shortlist materials that align with the required material properties through quantitative analysis.

Candidate materials are selected based on key mechanical, thermal, and environmental properties matched to the defined MPs. Selection also considered aerospace availability, property data from CES EduPack (Granta Design, 2023) and MatWeb (2023), and usage history in brake disk manufacturing.

The following five materials were shortlisted:

- **Carbon-Carbon Composite:** Widely used in aircraft brake systems due to its exceptional high-temperature strength, thermal shock resistance, and lightweight nature.
- **Ceramic Matrix Composite (CMC):** Offers superior thermal stability, wear resistance, and low density, making it suitable for high-energy landings.
- **Titanium Alloy (Ti-6Al-4V):** Known for its excellent strength-to-weight ratio, corrosion resistance, and reasonable thermal conductivity.

- **High-Strength Steel (e.g., Maraging Steel):** Offers high toughness and fatigue resistance under extreme mechanical loads.
- **Gray Cast Iron:** Common in automotive applications for its good castability and damping, included here for comparative purposes despite weight limitations.

For each Functional Requirement (FR), material property values are extracted from public databases and normalized as described in Section 3.6. When a single FR was associated with multiple MPs, each property was normalized individually according to its desirability direction—either maximizing or minimizing—and the resulting scores were averaged to obtain a single normalized score for that FR. The RMp weight defined in Table 2 was then applied to this score to determine its weighted contribution to the total RMp score of each candidate.

To ensure full transparency in how the RMp scores were derived, the actual material property values associated with each functional requirement (FR) are compiled in Table 3. Each FR is supported by one or more measurable material properties (MPs), including mechanical, thermal, and sustainability indicators. These raw values serve as the basis for the normalization and weighted scoring procedure defined in Section 3.6. By structuring the data in FR-MP format, the traceability from design intent to material data is preserved, enabling reproducibility and comparative benchmarking.

Table 3. Material Property Values by Functional Requirement (FR)

Material	FR1: Enable Braking		FR2: Heat Mgmt		FR3: Durability		FR4: Shock Res.		FR5: Lifecycle	
	μ	Ra (μm)	Cond	Cp ($\text{J/kg}\cdot\text{K}$)	Hardn.	Fatigue	α	Toughn.	Recycl.	E_emb
Carbon-Carbon Comp.	0.9	0.8	30	710	90	60	1.5	5.5	0.6	150
CMC	0.8	0.9	20	750	130	75	4.5	7	0.5	120
Ti-6Al-4V	0.7	1.4	6.7	560	349	620	9	55	0.9	100
Maraging Steel	0.6	1.2	25	460	540	900	10.4	100	0.85	85
Gray Cast Iron	1	1	54	460	210	260	11	20	1	25

To demonstrate how the scoring equations from Section 3.6 are applied, consider the example of Carbon-Carbon Composite under FR1 (Enable Braking). According to Table 3 the highest friction coefficient (μ) among candidates is 1 (Gray Cast Iron), and the lowest surface roughness (Ra) is 0.8 (Carbon-Carbon Composite). Applying the normalization rules:

$$S_{1,CCC,\mu} = \frac{0.9}{1} = 0.9$$

$$S_{1,CCC,Ra} = \frac{0.8}{0.8} = 1$$

Taking the average:

$$S_{1,CCC} = \frac{0.9 + 1}{2} = 0.95$$

This normalized score is then multiplied by the FR1 weight (1.0), resulting in a weighted RMp contribution of 0.95 for Carbon-Carbon Composite. This same process is applied to all other FRs and materials.

The individual normalized scores for FR1 across all candidate materials are computed and summarized in Table 4, showing the contribution of each relevant MP to the final RMp score for FR1.

Table 4. Computation of Normalized RMp Scores for FR1 Across Candidates

Material	μ	Ra (μm)	Norm. μ	Norm. Ra	RMp (FR1)
Carbon-Carbon Composite	0.9	0.8	0.9	1	0.95
Ceramic Matrix Composite (CMC)	0.8	0.9	0.8	0.89	0.845
Titanium Alloy (Ti-6Al-4V)	0.7	1.4	0.7	0.57	0.635
Maraging Steel	0.6	1.2	0.6	0.67	0.635
Gray Cast Iron	1	1	1	0.8	0.9

Following the same procedure for all functional requirements, Table 5 presents the aggregated RMp scores for each material. These scores are computed by multiplying each material's normalized score for a given FR by the corresponding weight, and then summing across all FRs. For example, the Carbon-Carbon Composite achieved normalized scores of 0.95 for FR1, 1 for FR2, 0.9 for FR3, 1 for FR4, and 0.4 for FR5. Given the FR weights (1, 0.7, 0.7, 0.6, 0.4), the total RMp score is calculated as:

$$RMp_{Total} = (1 * 0.95) + (0.7 * 1) + (0.7 * 0.9) + (0.6 * 1) + (0.4 * 0.4) = 3.04$$

This example illustrates how the weighted aggregation quantitatively evaluates each candidate's suitability with respect to the prioritized design requirements.

Table 5. RMp-Based Weighted Evaluation of Candidate Materials Using Normalized Material Property Scores

Material	FR1 (1.0)	FR2 (0.7)	FR3 (0.7)	FR4 (0.6)	FR5 (0.4)	RMp Total
Carbon-Carbon Composite	0.95	1	0.9	1	0.4	3.04
Ceramic Matrix Composite (CMC)	0.845	0.9	0.85	0.95	0.3	2.75
Maraging Steel	0.635	0.85	0.9	0.85	0.3	2.49
Gray Cast Iron	0.9	0.7	0.8	0.4	0.4	2.35
Titanium Alloy (Ti-6Al-4V)	0.635	0.7	0.8	0.7	0.5	2.31

To assess the robustness of the RMp-based material evaluation framework, a sensitivity analysis is also conducted by varying the weight of the most critical functional requirement: FR1 (Enable Braking). All other weights were held constant (as in Table 2), while FR1's weight was adjusted by ± 20 .

Table 6. Effect of Varying FR1 Weight on Final RMp Scores

Material	FR1 = 0.8	FR1 = 1.0	FR1 = 1.2
Carbon-Carbon Composite	2.88	3.04	3.2
Ceramic Matrix Composite (CMC)	2.68	2.75	2.82
Maraging Steel	2.42	2.49	2.56
Gray Cast Iron	2.27	2.35	2.43
Titanium Alloy	2.21	2.31	2.41

The results in Table 6 show that Carbon-Carbon Composites consistently score highest, regardless of small variations in FR1 weighting. This indicates the model's robustness and supports the reliability of the ranking even when design priorities shift moderately.

The updated evaluation in Table 5 demonstrates that Carbon-Carbon Composites achieve the highest RMp score due to superior thermal stability, mechanical strength, and fatigue resistance, making them the most suitable material under the defined functional requirements for aircraft brake disks. Ceramic Matrix Composites and Maraging Steel also show strong performance, offering favorable trade-offs in thermal resilience, wear, and structural integrity.

Gray Cast Iron, though not traditionally used in aerospace contexts, was included for benchmarking due to its widespread automotive usage. The quantitative results confirm that it performs competitively in frictional and manufacturability-

related metrics (FR1), but its lower scores in thermal shock resistance (FR4) and lifecycle durability (FR5) highlight its limitations for high-performance aviation environments. In Maleque et al. (2010), Gray Cast Iron was selected for automotive brake rotors based on a combination of performance and cost considerations. However, the present analysis prioritizes performance and reliability under extreme thermal and mechanical conditions, making carbon-based composites more appropriate for aerospace applications. Therefore, economic factors were excluded from the RMp total calculation to ensure alignment with the safety-centric priorities of aerospace systems. Notably, inclusion of cost would likely improve the relative score of Gray Cast Iron but would not meet the performance thresholds necessary for aircraft applications.

Although this study focuses on aircraft brake disks, the proposed TRIZ Axiomatic Design-RMp framework is inherently modular and domain independent. Its logic-based mapping of requirements to material properties via contradiction resolution and design matrices can be readily adapted to other safety-critical aerospace components, such as turbine blades, thermal protection systems, or structural panels. These components often exhibit similarly complex, conflicting functional demands, making them well suited for extension of the methodology.

5. Study Limitations and Future Extensions

While the proposed methodology demonstrates strong potential for systematic material selection in critical engineering domains, it currently faces limitations in scalability and automation. The framework assumes that functional requirements (FRs) and material properties (MPs) are discretely defined and manually mapped, which becomes

labor-intensive in large-scale systems involving hundreds of requirements and parameters. Furthermore, the current implementation relies on expert-defined rules and weights, limiting its flexibility in dynamic or data-scarce design environments.

To overcome these constraints, future research should explore:

- Integration of natural language processing (NLP) tools for automated extraction of requirements from engineering documents.
- AI-based reasoning engines to infer RMP relationships and assign weights based on design context.
- Semantic linking to existing PLM systems using standardized ontologies and ISO-compliant data models.
- Development of a software prototype to operationalize the TRIZ-AD-RMP framework, supporting visual modeling, scoring automation, and traceable design evaluation.
- Incorporation of lifecycle performance data such as maintenance logs, failure histories to refine material selection dynamically within a closed-loop PLM environment.
- Integration of rule-based semantic reasoning frameworks, such as OWL ontologies or SWRL rule engines, to automate RMP generation and conflict resolution through inference-based traversal from functional requirements to material properties. This would support scalable, knowledge-based PLM implementation across domains.

Overall, these extensions would strengthen the framework's adaptability, enabling its broader deployment in aerospace and other safety-critical engineering applications.

6. Conclusion

This study presents an integrated methodology combining TRIZ and Axiomatic Design. It addresses the complex challenges of material selection in engineering design while specifically focusing on aircraft brake disks. Selection methods proposed in prior studies for material selection often struggle to resolve conflicting requirements or establish traceable links between product functions and material properties. The methodology systematically identifies and resolves contradictions by implementing TRIZ, while AD provides functional independence through structured decomposition into measurable design parameters.

The methodology is further enlarged by the use of layered information models aiding semantic traceability across functional requirements, design parameters, and material properties. This structured reasoning framework improves design clarity and consistency. It also enhances the potential for integration into digital engineering platforms such as PLM and CAD/CAM systems.

A case study on aircraft brake disks illustrates the practical applicability of the methodology. The RMP (Requirement-Material Property) framework made it possible to do quantitative evaluations by allowing score-based mapping between requirements and material data. By using normalized material property values and weighted aggregation, candidate materials were systematically evaluated across multiple functional dimensions. The results showed that Carbon-Carbon Composites has the highest total RMP score (3.04). It

provides better thermal performance, mechanical durability, and structural stability. Other materials, like Ceramic Matrix Composites and Maraging Steel, also did well in some areas, which supports trade-off analysis.

The method further clarified that Gray Cast Iron, while effective in cost-sensitive automotive applications, falls short under the thermal and durability constraints required in aerospace systems. The case study reinforces that cost-based decisions, such as those highlighted by Maleque et al. (2010), must be re-evaluated in high-performance engineering contexts where safety and reliability dominate.

The RMP-based evaluation builds up established industry practices as well as introducing a transparent and reproducible principle for material selection within constraints regarding aerospace standards. Robustness of the approach was further evidenced through sensitivity analysis showing that material rankings remained largely consistent under moderate variations in requirement weightings.

More broadly, the integrated TRIZ-AD-RMP framework illustrates potential scalability to other safety-critical systems beyond brake disks, such as turbine blades, heat shields, and structural composites, where trade-offs between thermal, mechanical, and environmental requirements must be explicitly managed.

Finally, by demonstrating traceability from high-level requirements to measurable material traits, the methodology contributes to the development of explainable, data-driven material selection processes. With further integration of AI-assisted tools and lifecycle data, it can support dynamic and adaptive decision-making in next-generation digital engineering environments.

The novelty of this work lies in bridging qualitative contradiction resolution via TRIZ with quantitative, database-driven evaluation via RMP, creating a unified, transparent, and extendable framework for material selection that has not been previously operationalized in aerospace design.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Altshuller, G. (1984). *Creativity as an exact science: The theory of the solution of inventive problems*. Gordon and Breach Science Publishers.
- Altshuller, G. (1999). *The innovation algorithm: TRIZ, systematic innovation and technical creativity*. Technical Innovation Center.
- Ashby, M. F. (1999). *Materials selection in mechanical design* (2nd ed.). Butterworth-Heinemann.
- Ashby, M. F. (2005). *Materials selection in mechanical design* (3rd ed.). Elsevier.
- Ashtiany, M. S., Dastmalchi, A., & Azghadi, M. R. (2016). Integration of axiomatic design with quality function deployment and sustainable design for the satisfaction of airplane tail stakeholders. *Procedia CIRP*, 53, 144-149.
- Baysal, M. M., Roy, U., Sudarsan, R., Sriram, R. D., & Lyons, K. W. (2005). Product information exchange using open assembly model: Issues related to representation of geometry information. In *Proceedings of ASME IMECE*.
- Cochran, D. S., Eversheim, W., Kubin, G., & Sesterhenn, M. L. (2000). The application of axiomatic design and lean management principles in the scope of production

- system segmentation. *International Journal of Production Research*, 38(6), 1377-1396.
- Granta Design. (2023). CES EduPack material database. Granta Design Ltd. Retrieved from <https://www.grantadesign.com>
- Kulak, O., Cebi, S., & Kahraman, C. (2010). Applications of axiomatic design principles: A literature review. *Expert Systems with Applications*, 37(9), 6705-6717.
- Maleque, M. A., Dyuti, S., & Rahman, M. M. (2010). Material selection method in design of automotive brake disc. In *Proceedings of the World Congress on Engineering 2010 (WCE 2010)*.
- Mann, D. (2002). *Hands-on systematic innovation*. CREA Press.
- MatWeb. (2023). MatWeb material property data. Retrieved from <https://www.matweb.com>
- Roy, U., & Sarigecili, M. I. (2013). Development of an integrated product, process and material information model. In *Proceedings of ASME IDETC/CIE*.
- Parveez, B., Kittur, M. I., Badruddin, I. A., Kamangar, S., Hussien, M., & Umarfarooq, M. A. (2022). Scientific Advancements in Composite Materials for Aircraft Applications: A Review. *Polymers*, 14(22), 5007.
- Roy, U., & Yaman, O. (2014). Development of material information model to support the powder metallurgical product and processes. *Transactions of the North American Manufacturing Research Institution of SME*, 42, 256-265.
- Savransky, S. D. (2000). *Engineering of creativity: Introduction to TRIZ methodology of inventive problem solving*. CRC Press.
- Shirwaiker, R. and Kremer, G., (2008). TRIZ and axiomatic design: A review of case-studies and a proposed synergistic use, *Journal of Intelligent Manufacturing*, 19(1), pp. 33-47.
- Suh, N. P. (1990). *The principles of design*. Oxford University Press.
- Yaman, O., Zhu, B., & Roy, U. (2014). Towards the development of an ontology-based product requirement model. In *Proceedings of the ASME International Mechanical Engineering Congress and Exposition American Society of Mechanical Engineers*.
- Yoon, B., & Park, Y. (2005). A systematic approach for identifying technology opportunities: Keyword-based morphological analysis. *Technological Forecasting and Social Change*, 72(2), 145-160.
- Zhang, H., Zhu, B., Li, Y., Yaman, O., & Roy, U. (2015). Development and utilization of a process-oriented information model for sustainable manufacturing. *Journal of Manufacturing Systems*, 37, 459-466.
- Zhang, Y., Luo, X., Zhao, Y., & Zhang, H. (2015). An ontology-based knowledge framework for engineering material selection. *Advanced Engineering Informatics*, 29(4), 985-1000.

Cite this article: Yaman, Ö. (2025). A TRIZ-Axiomatic Design Framework with Semantic RMP Mapping for Material Selection: Application to Aircraft Brake Disks. *Journal of Aviation*, 9(3), 516-527.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License

Factors of Human Interaction on the Path to Passenger Satisfaction, Perceived Value, and Intention to Recommend in Airlines

Sadiye Oya Işıkcı ¹ 

¹ İstanbul Kültür University Vocational School, İstanbul, Türkiye. (s.isikci@iku.edu.tr)

Article Info

Received: 14 June 2025

Revised: 25 August 2025

Accepted: 12 September 2025

Published Online: 18 October 2025

Keywords:

Airline industry

Human factors

Intention to recommend

Passenger satisfaction

Perceived value

Corresponding Author: Sadiye Oya Işıkcı

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1320102>

Abstract

Intense competition, high costs, and elevated customer expectations characterise civil aviation passenger transportation. It is widely accepted that passenger satisfaction is one of the key achievements in gaining a competitive advantage in this industry. While various factors influence passenger satisfaction, the airline industry inherently requires intensive interaction and communication between cabin crew and passengers, as services are delivered on an individual basis. Cabin services, therefore, play a significant role in the emergence of this satisfaction.

This study focuses on four dimensions of human interaction points during service delivery in the cabin: individual care, helpfulness, politeness, and promptness. The aim is to determine domestic passengers' opinions regarding these variables. Additionally, the study aims to statistically determine the impact of each of these variables on passenger satisfaction and the effects of passenger satisfaction on perceived value and intention to recommend. To achieve these objectives, an online survey was conducted using a quantitative research method, and a convenience sampling technique provided access to 405 respondents' answers. The collected data were coded and analysed using the SPSS software.

The empirical findings obtained through statistical analysis emphasise the importance of airline companies focusing on human factors to enhance customer satisfaction. The research statistically confirms the positive effect of human interaction points such as individual attention, helpfulness, courtesy, and promptness by cabin crew members on passenger satisfaction, as well as the audience of passenger satisfaction on perceived value and intention to recommend. Despite the increasing interest in service quality in the airline industry, the effects of various aspects of human interaction on passenger satisfaction, perceived value, and recommendation intention have been limitedly examined. Therefore, this study aims to fill this gap by addressing the interpersonal interaction dynamics between cabin crew and passengers. Based on these findings, the study provides some assessments that can contribute to the literature and the aviation industry.

A section of this study was presented at the 7th International Eurasian Social Sciences Congress (ICOESS) held in Bodrum, Muğla, Turkey, on April 27-30, 2023.

1. Introduction

The airline industry operates in a competitive business environment where retaining existing customers and attracting new ones is the key to success. Air travel has become more widespread, and customers now have numerous service provider options (Law, 2018), putting significant pressure on commercial enterprises in the civil aviation transportation sector. To succeed in a highly competitive market, an airline must understand customer needs and meet them with high-quality services that provide positive experiences (Robledo, 2001; Law et al., 2022: 741). While matching competitors in pricing, meal options, flexibility, and loyalty programs are important for staying competitive and enhancing passenger satisfaction, the most critical factor for long-term success in civil aviation is delivering high-quality service and creating a positive passenger experience (Gibbs et al., 2017: 57).

Various factors can shape passengers' experiences and influence their satisfaction in the airline industry. Services, by their nature, involve intense interaction between customers and the company, making various touchpoints between passengers and the airline crucial in shaping the overall experience. Therefore, understanding the various aspects of these touchpoints is critical for service providers in the airline industry to gain a competitive advantage.

Many studies in the literature evaluate a passenger's overall assessment of an airline's quality based on the airline's general service quality, which is more visible in terms of service quality (For example Namukasa, 2013; Brochado et al., 2019; Hamid et al., 2021; Banjarnahor et al., 2025). This includes aspects such as physical appearance, reliability, and trust. However, on the other hand, the most common and visible face of the service encountered by service recipients is the employees who deliver the service and the one-on-one

interactions established with them. In other words, it is the human touch.

This research focuses on human and humane factors in the airline industry, examining the human interactions (personal touches) between passengers and airline personnel, considering them as human touchpoints. In this context, individual attention, helpfulness, courtesy, and promptness are human touchpoints contributing to passenger satisfaction. The aim is to determine the impact of these variables on passenger satisfaction and the influence of passenger satisfaction on the perceived value of passengers and intention to recommend to others. The research aims to contribute to the literature by providing findings highlighting the importance of human touchpoints, separate from service quality.

2. Conceptual Framework

2.1. Human Interactions in Airlines

Air transportation is one of the most essential dynamics that constitute passenger transportation and tourism; with the advancements in civil aviation since the 1950s, fast, safe, and economical transportation to distant destinations has been made possible. Globalisation and liberalisation have paved the way for intense competition in air transportation by allowing numerous private airlines to enter the market. One of the most crucial tools for airlines to gain a competitive advantage is the ability to provide a high-quality service experience and thus differentiate themselves from their competitors (Akpur & Zengin, 2019: 29).

Due to the intangible nature of services, how the service is delivered becomes a significant determinant of service quality (Grönroos, 1984). This confirms the need to understand better and measure the role of employees who directly interact with and have contact with customers in shaping customer satisfaction. Communication and customer interactions are essential in designing and delivering air transportation services. Interestingly, since service quality is more visible, customers can evaluate the overall quality of an airline by using their service experience with airline employees, in other words, their interactions, as a basis (Rhoades & Waguespack, 1999). Human interactions are defined as direct encounters between a customer (passenger in the context of civil aviation) and a service provider (i.e., the airline) that co-occur and have the potential for interaction (Babbar & Koufteros, 2008: 805).

Service employees are vital in providing service excellence and productivity, which can be a significant competitive advantage. However, among the most challenging tasks in service businesses are the additional duties/expectations/requests that include being efficient and quick in operational tasks and being polite, friendly, and helpful in relationships with passengers. From the perspective of a service business, the level of service and the way it is frontline employees deliver it a significant source of competitive advantage as well as differentiation (Wirtz et al., 2008: 5). Therefore, various interactions between employees and passengers, especially between employees and the airline's customers, are of great importance.

Employees providing services in the field of air transportation (check-in personnel, cabin crew, etc.) and physical evidence (the comfort of seats, food and beverages provided) significantly impact the perception of service quality. In airlines, cabin crew members—who have the most direct and frequent interaction with passengers—are commonly portrayed in advertisements as smiling and hospitable figures, reflecting the airline's commitment to

service quality (Akpur & Zengin, 2019: 30). In this regard, it is possible to argue that individual attention (such as active listening to passengers, showing individual attention on passengers, understanding their unique needs), helpfulness (occasionally checking if passengers need anything, making efforts to find solutions to their problems, voluntarily providing information on flight-related issues), courtesy (being kind to passengers, providing service with a smile), and promptness (instantly responding to passengers' questions, quickly fulfilling their requests) as factors discussed by Babbar & Koufteros (2008) could be crucial in the communication and interaction between cabin crew members and passengers during service delivery.

In industries like civil aviation, where competing companies offer similar services, creating positive service experiences plays a central role in fostering passenger satisfaction, which in turn contributes to customer loyalty, positive word-of-mouth, and long-term competitive advantage (Auvinen & Malinen, 2022: 19).

2.2. Passenger Satisfaction, Perceived Value, and Intention to Recommend

Satisfying the customer in any business is the ultimate goal of any enterprise. In aviation, the consumer of transportation services is the passenger. Therefore, the concept of "customer satisfaction" is referred to as "passenger satisfaction" in the aviation industry (Auvinen & Malinen, 2022: 18). Excellent passenger satisfaction is one of the greatest assets for an airline in today's competitive environment. Therefore, passenger satisfaction is a fundamental objective for every airline that provides passenger services. Passenger satisfaction occurs when an airline can deliver benefits to passengers that exceed their expectations and are considered as added value. If passengers are satisfied with the products and services an airline offers are more likely to choose that airline again (Kumar et al., 2012).

On the other hand, the flight experience is a unique experience for a passenger from start to finish. Today's airline passenger is a discerning customer with high expectations and demands. Since passengers have a wide range of options based on their needs, satisfying them is more challenging and crucial than ever. Therefore, airline companies continuously work on in-flight product development and innovation to differentiate themselves from competitors, and passenger services and satisfaction can be decisive factors in the overall success of an operation (Sanyal & Hisam, 2016: 354-355).

Understanding passengers' expectations is crucial in the airline service industry because passengers evaluate their performance by comparing it to their expectations. Passenger satisfaction can be achieved when the outcome of this comparison favours the passenger. In the airline industry, passenger satisfaction can be defined as complex customer knowledge and experience, serving as a passenger assessment (Tahanisaz & Shokuhyar, 2020; Noviantoro & Huang, 2022: 2).

Customers evaluate service quality by comparing what they require or expect with what they perceive they have received. Customers are the sole judges of service quality regardless of the industry. Suppose a customer perceives a business's service as poor. In that case, it is considered poor for that individual. Negative service experiences can result in customer dissatisfaction, which may lead to lower repurchase intention, reduced perceived value, and decreased willingness to engage in positive word-of-mouth (Nejati et al., 2009: 249).

Perceived value is the difference between the highest price consumers are willing to pay for a product or service and the

actual amount they pay. From a quality standpoint, value can be seen as the gap between the amount of money spent on a product and the quality it offers (Bishop, 1984). Essentially, when a high-quality product is purchased at a lower cost, it results in a high perceived value. From a utility perspective, value involves an overall assessment of the perceived benefits compared to the perceived sacrifices (Zeithaml, 1988). This means consumers mentally weigh what they receive against what they give up—both in monetary terms and non-monetary aspects like transaction, search, and negotiation efforts, as well as the time invested in the purchasing process (Kuo et al., 2009: 888). The evaluation of perceived value stems from the cognitive integration of a customer's perceived benefits with perceived costs. Perceived value refers to what a customer can obtain or achieve from a service provider (Jen et al., 2010: 326-327). In civil aviation, it represents passengers' evaluation of the quality of service received relative to the monetary and non-monetary costs incurred. High levels of passenger satisfaction are positively associated with increased perceived value, which in turn can lead to favorable word-of-mouth recommendations (Jen et al., 2010: 326-327).

Intention to recommend refers to the willingness of a customer to share, communicate, and guide their experience with a business's product or service with individuals or groups in their close circle whom they perceive as trustworthy. It refers to the motivation to suggest a company's service to trusted individuals, such as friends or family. In contrast, word-of-mouth communication involves the casual exchange of information between consumers who have experienced a product or service and who then share their favorable or unfavorable opinions with others considering a purchase (Suki, 2014: 27). This communication can occur between existing or potential customers and product or service providers, independent experts, or members of one's personal network, such as family and friends. Generally, it involves transferring information about a business that a customer has purchased from or consumed. In this sense, it enables other customers to make more informed choices (Chaniotakis & Lympieropoulos, 2009: 229-230). In the service sector, word-of-mouth communication is considered to have a significant impact on both retaining existing customers and acquiring new customers. Additionally, it is argued that interactions between customers and service employees can meaningfully influence word-of-mouth communication (Macintosh, 2007: 150). Perceived high service quality in customer interactions with service providers can enhance the perceived value of existing customers and lead to actions such as word-of-mouth recommendations (Choudhury, 2013: 154; Gürlér & Erturgut, 2018: 234).

It is widely acknowledged that the opinions of satisfied and dissatisfied passengers quickly spread within a business, with satisfied customers enhancing profitability and dissatisfied customers damaging the business's reputation and affecting its economic aspects (Prentice et al., 2017). Previous research findings also support the notion that satisfied customers exhibit loyalty and provide positive communication and recommendations within their social circles for the spread of good services received (Ellinger et al., 1999; Kim et al., 2006; Ladhari et al., 2011; Marcos et al., 2022; Singh et al., 2023). Therefore, providing high-quality service to passengers can be critical for an airline to survive, compete, maintain profitability, and achieve long-term growth in a highly competitive environment (Bakır et al., 2022: 21). Consequently, given the service-oriented nature of the aviation industry, there is a need to identify and analyse the relevant

factors to enhance customer satisfaction in the aviation industry from the perspective of passengers in order to understand the consequences and precursors of satisfaction (Ringle et al., 2011; Walia et al., 2021: 137). Although prior studies have emphasized the role of service quality and satisfaction, limited research has focused specifically on the human interaction dimension -particularly the impact of interpersonal dynamics between cabin crew and passengers-within the civil aviation context. This study aims to fill this gap by examining how key aspects of human interaction affect perceived value, satisfaction, and recommendation intention, thereby contributing to a more comprehensive understanding of service experiences in airline settings.

3. Materials and Methods

3.1. Research Model and Hypotheses

This study is based on a quantitative research method and has a correlational survey nature. The correlational model of the study includes seven variables. In this study, interpersonal interaction between passengers and airline flight attendants is conceptualized as a multi-dimensional construct comprising four sub-dimensions: individual attention, helpfulness, courtesy and promptness. Perceived value and intention to recommend are considered outcome variables. Customer satisfaction is forming the study's independent variable in relation to interpersonal interactions, perceived value, and intention to recommend. The research model representing these variables, the relationships between them, and the hypotheses formulated regarding these relationships are presented below.

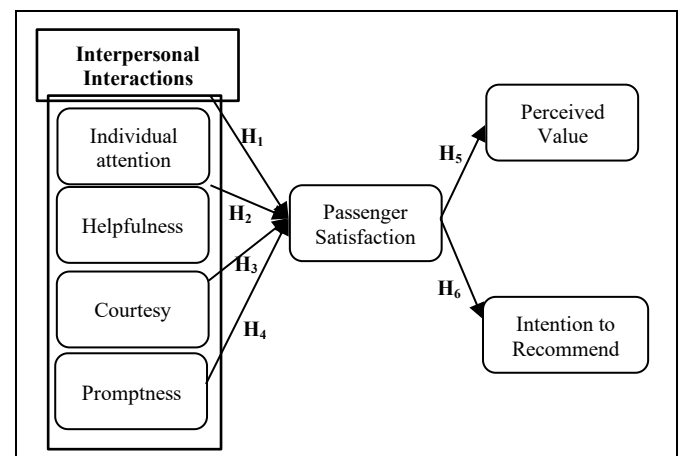


Figure 1. Research Model

The hypotheses proposed regarding the relationships between variables in the research are as follows:

- H₁.** There is a significant relationship between individual attention and customer satisfaction.
- H₂.** There is a significant relationship between helpfulness and customer satisfaction.
- H₃.** There is a significant relationship between courtesy and customer satisfaction.
- H₄.** There is a significant relationship between promptness and customer satisfaction.
- H₅.** There is a significant relationship between passenger satisfaction and perceived value.

H₆. There is a significant relationship between passenger satisfaction and intention to recommend.

3.2. Data Collection Tools

In order to gather the opinions of passengers, a survey method was employed in the study. The survey forms were distributed to participants through the online survey platform Google Forms, and the data was collected accordingly. The data collected on this platform were analysed using Microsoft Excel and then transferred to the SPSS software.

The survey form provided to respondents consisted of two main sections. The first section included questions related to participants' gender, marital status, age, education level, personal income, and personal (demographic) information. Additionally, this section contained questions aimed at identifying flight habits, such as frequency of air travel, reasons for air travel, and the most frequently used airline. The second section of the survey comprised items adapted from validated psychometric scales, and all variables were measured using a 5-point Likert scale. The scales used in the study are as follows:

Human Interactions Scale: This scale, developed by Babbar & Koufteros (2008), focuses on the human element in airline service quality. The development of the scale involved a comprehensive literature review covering various disciplines such as marketing, operations management, hospitality management, and healthcare management. While drawing insights from the widely used SERVQUAL measurement tool for measuring service quality, the scale focuses explicitly on interpersonal interactions during service delivery. The scale has four dimensions: individual attention, helpfulness, courtesy, and promptness. Through factor analyses conducted as part of the scale's development, it was found that the identified four dimensions were supported by various goodness-of-fit indices. The original scale comprised 21 statements; however, in this study, some statements that showed similarities when translated into Turkish were excluded to avoid issues like multicollinearity. Therefore, 17 statements were used, including 4 for individual attention, 3 for helpfulness, 5 for courtesy, and 5 for promptness. The original study reported acceptable levels of internal consistency, with Cronbach's alpha values ranging from .784 (individual attention) to .946.

Passenger Satisfaction Scale: This scale is adapted from the structure used in Babbar & Koufteros' (2008) research specific to the airline industry. It is designed to evaluate passengers' satisfaction with the airline company. The scale consists of 6 statements, measured on a 5-point Likert scale. The scale demonstrated reliability with a Cronbach's alpha coefficient of $\alpha = .946$.

Perceived Value Scale: Perceived value refers to the balance between perceived benefits and costs. This scale, developed by Jen et al. (2010), assesses whether passengers perceive the service they receive as valuable. The scale consists of 3 statements on a 5-point Likert scale, demonstrating a reliability coefficient of $\alpha = .823$.

Intention to Recommend Scale: This scale, developed initially by Karatepe & Ekiz (2004) for the accommodation sector and adapted by Suki (2014) for airline passengers, measures passengers' intention to recommend. Similarly, this scale is designed on a 5-point Likert scale. The variable was assessed through a scale consisting of three items. It has been reported that the structural equation modelling confirmed the consistency of the data with the model and demonstrated measurement capability. The reliability coefficient of the scale was calculated as $\alpha = .772$.

3.3. Sampling

The study's target population consists of all consumers aged 18 and above who travel by airline. The sampling method was employed due to the impossibility of obtaining information about the entire population and the inaccessibility as well as the unnecessary nature of such a population method was employed. In cases where it is not possible to determine the exact population of the sample, non-random sampling methods are used, where the sample is determined by the researcher's judgment within the population (Gegez, 2010). In this study, convenience sampling (Haşiloğlu, 2015) was used, where the sample is selected from the population based on ease of access because it is impossible to identify the entire sample that constitutes the population.

In quantitative research conducted in the field of social sciences, when the population that constitutes the target population of the study is very large or not fully known, a sample size of 384 is considered sufficient and valid with a 95% confidence interval and a 5% error tolerance (Bartlett et al., 2001; Sekaran, 2003). Therefore, a sample size of 384 is considered to have the ability to represent the population (Baştürk & Taştepe, 2013). Accordingly, the aim was to reach at least 384 survey forms. At the end of the data collection process, 421 survey forms were obtained, out of which 16 were excluded due to incomplete or incorrect filling. Thus, the study's data on the responses were obtained from 405 participants over a period of three months.

Data collecting process was conducted in accordance with the principles of research ethics. Participation in the study was entirely voluntary, and informed consent was obtained from all participants prior to data collection. Participants were clearly informed about the purpose of the study, their right to withdraw at any time without penalty, and how their data would be used. All responses were collected anonymously. The data were securely stored in password-protected digital files accessible only to the researchers. Ethical approval for this research was obtained (Approval was given at the end of the study).

4. Result and Discussion

Reliability and normal distribution analysis were performed as preliminary tests before conducting the analyses on the data obtained in the quantitative study. The obtained Cronbach's Alpha (α) and Kaiser-Meyer-Olkin (KMO) coefficients, as well as skewness and kurtosis coefficients, are presented in Table 1.

Table 1. Reliability and normal distribution of research scales

Scales	Items	α	KMO	Skewness	Kurtosis
Individual Attention	4	.878	.834	-1.038	1.046
Helpfulness	3	.781	.706	-.951	1.058
Courtesy	5	.849	.741	-.552	.403
Promptness	5	.894	.827	-.328	-.552
Passenger Satisfaction	6	.865	.882	-.544	.311
Perceived Value	3	.883	.722	-.999	1.400
Intention to Recommend	3	.884	.736	-.570	-.279
TOTAL	29	.960	.952	-	-

Upon examining the coefficients presented in Table 1, it can be concluded that all scales used in the research are reliable based on Cronbach's Alpha coefficients obtained. The KMO coefficients indicate the adequacy of sample measurement. Skewness and Kurtosis coefficients demonstrate that the data for each scale follow a normal distribution. In light of these findings, it is understood that the data is suitable for parametric analysis. The participants' demographic characteristics and travel habits are presented in Table 2.

Table 2. Demographic characteristics of the participants

Gender	n	%
Female	211	52.1
Male	194	47.9
Marital Status	n	%
Single	273	67.4
Married	132	32.6
Age Range	n	%
18-26	107	26.4
27-36	117	28.9
37-49	110	27.2
50 and above	71	17.5
Education Level	n	%
High School	50	12.3
Associate Degree	37	9.1
Bachelor's Degree	236	58.3
Graduate Degree	82	20.2
Personal Income	n	%
8506 TL and below	166	41.0
8506-20.000 TL	124	30.6
20.001 TL and above	115	28.4
Travel Frequency	n	%
Once a year or less	64	15.8
Several times a year	180	44.4
Once a month	100	24.7
Several times a month or more	61	15.1
Travel Purpose	n	%
Tourism, vacation, visit	285	70.4
Business or trade	120	29.6
Travel Type	n	%
Domestic	252	62.2
International	153	37.8

As can be observed from the values in Table 2, the distribution of participants can be summarised as follows: in terms of gender, there were 211 females (52.1%) and 194 males (47.9%); regarding marital status, 273 participants were single (67.4%), and 132 were married (32.6%); concerning age range, there were 107 participants aged 18-26 (26.4%), 117 aged 27-36 (28.9%), 110 aged 37-49 (27.2%), and 71 participants aged 50 and above (17.5%); in terms of education level, 50 participants had completed high school (12.3%), 37 had an associate degree (9.1%), 236 had a bachelor's degree (58.3%), and 82 had a graduate degree (20.2%); regarding personal income, 166 participants earned 8500 TL or below (41.0%), 124 earned between 8501-20,000 TL (30.6%), and 115 earned 20,001 TL or above (28.4%).

Analysing the participants' travel characteristics, it can be seen that in terms of travel frequency, 64 participants travelled once a year or less (15.8%), 180 travelled several times a year (44.4%), 100 travelled once a month (24.7%), and 61 travelled several times a month or more (15.1%); concerning travel purpose, 285 participants travelled for tourism, vacation, or visit purposes (70.4%), while 120 travelled for business or trade purposes (29.6%); in terms of travel type, 252 participants travelled domestically (62.2%), and 153 travelled internationally (37.8%).

A correlation analysis was conducted to determine the strength and direction of the relationships between individual attention, helpfulness, courtesy, promptness, passenger satisfaction, perceived value, and intention to recommend. The findings of this analysis are presented in Table 3.

Table 3. Results of correlation analysis on relationships between variables

	1	2	3	4	5	6	7
1 Individual Attention	1						
2 Helpfulness	.803**	1					
3 Courtesy	.627**	.653**	1				
4 Promptness	.455**	.509**	.731**	1			
5 Passenger Satisfaction	.575**	.622**	.649**	.640**	1		
6 Perceived Value	.720**	.692**	.562**	.437**	.770**	1	
7 Intention to Recommend	.659**	.668**	.618**	.596**	.697**	.823**	1

** Correlation statistically significant at the $p < 0.001$ level (two-tailed)

According to the findings obtained from the correlation analysis, there are statistically significant positive linear relationships between the variables. The correlation

coefficients indicate strong relationships between passenger satisfaction and individual attention ($r = .575$, $p < 0.01$), helpfulness ($r = .622$, $p < 0.01$), courtesy ($r = .649$, $p < 0.01$), and

promptness ($r=.640$, $p<0.01$), based on the criterion that correlations above 0.50 indicate a strong relationship (Cohen, 2013). Moreover, there are very strong positive relationships between perceived value and passenger satisfaction ($r=.770$, $p<0.01$), and between intention to recommend and passenger satisfaction ($r=.697$, $p<0.01$). These results suggest positive and meaningful associations between individual attention, helpfulness, courtesy, promptness, passenger satisfaction, and perceived value. Furthermore, all service quality factors and perceived value show strong positive correlations with the intention to recommend.

These findings indicate that there are significant positive linear relationships between the variables. However, it should be noted that correlation coefficients only provide information about the strength and direction of the relationship between two variables and do not establish a cause-and-effect relationship. In other words, although a correlation analysis

may reveal a strong relationship between two variables, it does not provide information about whether this relationship is a cause-and-effect relationship. Therefore, regression analysis was conducted to determine whether there is a causal relationship among these variables.

In the research, the first regression model was constructed based on the hypothesised relationships, with individual attention, helpfulness, courtesy and promptness as independent variables and passenger satisfaction as the dependent variables. This model aimed to test the relational hypotheses (H_1 , H_2 , H_3 , and H_4). Subsequently, regression models were constructed with passenger satisfaction as the independent variable and perceived value and intention to recommend as the dependent variables to test hypotheses H_5 and H_6 . The results of the simple linear regression analysis conducted using the enter method within the scope of these regression models are presented in Table 4.

Table 4. Results of regression analysis

Model 1	Beta	Standard Error	Standard Beta	t	R ²	p
Constant	1.625	.157		10.322		.000*
Individual Attention	.549	.039	.575	14.114	.331	.000*
Dependent Variable: Passenger Satisfaction						
Model 2	Beta	Standard Error	Standard Beta	t	R ²	P
Constant	1.480	.149		9.944		.000*
Helpfulness	.592	.037	.622	15.930	.386	.000*
Dependent Variable: Passenger Satisfaction						
Model 3	Beta	Standard Error	Standard Beta	t	R ²	P
Constant	1.465	.140		10.499		.000*
Courtesy	.630	.037	.649	17.122	.421	.000*
Dependent Variable: Passenger Satisfaction						
Model 4	Beta	Standard Error	Standard Beta	t	R ²	P
Constant	2.121	.105		20.247		.000*
Promptness	.499	.030	.640	16.731	.410	.000*
Dependent Variable: Passenger Satisfaction						
Model 5	Beta	Standard Error	Standard Beta	t	R ²	P
Constant	1.156	.123		9.414		.000*
Passenger Satisfaction	.766	.032	.770	24.196	.592	.000*
Dependent Variable: Perceived Value						
Model 6	Beta	Standard Error	Standard Beta	t	R ²	P
Constant	.780	.161		4.843		.000*
Passenger Satisfaction	.810	.042	.697	19.506	.486	.000*
Dependent Variable: Intention to Recommend						

* Statistically significant at the $p<0.001$ level

According to the regression results, the independent variables have a statistically significant effect on the dependent variable, with the magnitude of the effect varying across variables. All regression models are significant at the $p<0.001$ level. The coefficient of determination (R^2) values indicate that the models have moderate to high explanatory power, meaning that the independent variables explain a substantial proportion of the variance in passenger satisfaction, consistent with commonly accepted benchmarks (Hair et al., 2019). Specifically, individual attention has a significant positive effect on passenger satisfaction ($p<0.001$), accounting for 33.1% of its variance ($R^2=.331$). Similarly, helpfulness exerts a significant positive effect ($p<0.001$), explaining 38.6% of the variance ($R^2=.386$). Courtesy also significantly influences passenger satisfaction ($p<0.001$), with an R^2 of

0.421, while promptness has a significant positive effect as well ($p<.001$), accounting for 41.0% of the variance ($R^2=.410$).

Regarding the hypotheses testing the relationships between passenger satisfaction and perceived value, as well as the intention to recommend, the findings from the regression models indicate statistically significant results ($p<0.001$) for both models. Passenger satisfaction explains 59.2% ($R^2=.592$) of the variation in perceived value and 48.6% ($R^2=.486$) of the variation in intention to recommend. These results support all the hypotheses (H_1 , H_2 , H_3 , H_4 , H_5 , and H_6) proposed in the study.

In conclusion, the regression analysis demonstrates that the independent variables significantly impact the dependent variable, with varying degrees of influence. The findings validate the research hypotheses and highlight the importance of factors such as individual attention, helpfulness, courtesy,

promptness, perceived value and intention to recommend in shaping passenger satisfaction in the study context.

5. Conclusion

Passengers tend to evaluate airline companies based on their satisfaction with the flight service experience (Park et al., 2004). Given the highly competitive nature of the aviation industry, passenger satisfaction is considered a critical factor in the selection of both the airline and the airport of travel (Vokáč et al., 2017; Park et al., 2019; Auvinen & Malinen, 2022). It is known that passenger satisfaction can be influenced by various factors to varying extents. However, one primary determinant can be the interpersonal interactions between passengers and cabin crew members during service delivery. Empirical evidence in the literature indicates that flight crew members are the airline employees with the most frequent and prolonged communication and interaction with passengers, making various aspects of interpersonal contact during the in-flight service critical. While some factors affecting passenger satisfaction may occasionally be beyond the control of the airline (such as cancellations and delays due to weather conditions), certain factors can be controlled and improved upon (Gibbs et al., 2017: 58). Elements such as individual attention, helpfulness, courtesy and promptness serve as critical factors in the interactions between cabin crew members and passengers, and they possess a highly controllable aspect.

The pandemic crisis, travel restrictions, followed by an economic crisis, and on the other hand, changes in passenger behaviour in the aftermath of market liberalisation, high technology, and restructuring have also brought about changes in airline services. Airlines must adapt quickly and effectively to such a competitive environment, which is crucial for success in the highly competitive aviation industry (Noviantoro & Huang, 2022: 1). When evaluating the service, a passenger will consider all the interactions throughout the entire process, from the check-in counter to baggage delivery, with a holistic perspective. However, in terms of service, the most visible face of an airline in civil aviation is the passenger services provided in the cabin. Therefore, the interactions between cabin crew members and passengers can influence perceptions, attitudes, and behaviours in a passenger's overall evaluation of the airline.

This study focuses on the human factors in airlines, explicitly examining the interpersonal interactions between passengers and cabin crew members and the related factors. The study aims to determine the impact of individual attention, helpfulness, courtesy and promptness as human service contact points between cabin crew members and passengers on passenger satisfaction, as well as the influence of passenger satisfaction on perceived value and intention to recommend the airline to others. To achieve these objectives, statistical analyses were conducted using the responses obtained from 405 participants aged 18 and above who travelled by air, collected through an online survey conducted via the Google Forms platform.

The results obtained in the study indicate positive relationships between individual attention, helpfulness, courtesy, and promptness as human service contact factors between cabin crew members and passengers and passenger satisfaction and perceived value. Furthermore, passenger satisfaction is strongly and positively linearly related to perceived value and intention to recommend. These findings

demonstrate the importance of each human service contact point in enhancing passenger satisfaction and suggest that passenger satisfaction can increase perceived value and passengers' intention to recommend the airline. Specifically, positive passenger perceptions regarding individual attention, helpfulness, courtesy and promptness as human service contact points within the cabin services framework significantly impact satisfaction formation. As a result, passenger satisfaction can positively affect perceived value and intention to recommend. These findings indicate that airline companies must focus on these factors to enhance service quality. The significant impact of these factors on passenger satisfaction also suggests that they can increase the likelihood of customers recommending the airline.

The findings presented in the study regarding the significant positive correlations between service quality dimensions—such as individual attention, helpfulness, courtesy, and promptness—and passenger satisfaction align well with prior literature in the domain of service quality and customer satisfaction, particularly within transportation and airline services. For example, Park et al. (2004) found that courteous and responsive service significantly predicted overall passenger satisfaction in the airline sector. In the context of low-cost carriers, Kim and Lee (2011) further noted that when passengers perceive a high value from the service—considering both price and quality—they tend to report higher levels of satisfaction. Ali et al. (2015) demonstrated that airline passengers' perceptions of employee helpfulness and personalized attention strongly influence their satisfaction levels and loyalty intentions. A major meta-analysis conducted by Eshaghi et al. (2024) confirms that perceived service quality and perceived value significantly and positively impact passenger satisfaction in air transport contexts. Rezaei and Keynezhad (2024) provide evidence from a public tourism transport study in Iran that similarly confirms the role of service quality and its dimensions—particularly interpersonal elements like friendliness and responsiveness—in enhancing passenger satisfaction and perceived value. Rather (2024), in a broader conceptual analysis of brand relationships in tourism, emphasizes the central role of service experiences—including individual attention and emotional engagement—in building satisfaction and subsequent advocacy behaviors. Moreover, Al Hattali et al. (2025) analyzes tourism services in Oman and conclude that cleanliness, prompt responses, and courteous behavior have a tangible effect on overall satisfaction and perceived value.

In line with the established literature, this research emphasises the importance of focusing on human factors in airlines to enhance customer satisfaction. The study statistically confirms the impact of human service contact points by cabin crew members on passenger satisfaction and the influence of passenger satisfaction on perceived value and intention to recommend. According to the study's results, the qualities displayed by cabin crew members at these human service contact points play a significant role in passenger satisfaction. These human factors are practical tools that airline companies can utilize to enhance customer satisfaction. Additionally, it highlights the significant impact of passenger satisfaction on perceived value and intention to recommend the airline to others. Therefore, by focusing on human service contact points to enhance customer satisfaction, airline companies can increase passengers' intention to recommend and loyalty to the business. In conclusion, the findings of this study highlight the importance for airline companies to focus

on human factors to enhance customer satisfaction. Understanding the critical role that airline employees play in shaping passengers' experiences is valuable information for service providers. These results can guide airline companies towards adopting a more human-centered approach to increase customer satisfaction and achieve positive outcomes.

These results can guide airline companies towards adopting a more human-centered approach to increase customer satisfaction and achieve positive outcomes. In line with these findings, airline companies are encouraged to implement concrete strategies to strengthen human service contact points. For instance, comprehensive training programs focusing on emotional intelligence, communication skills, cultural sensitivity, and service recovery can help cabin crew members enhance the quality of their interactions with passengers. Additionally, establishing structured customer feedback mechanisms, such as post-flight surveys or digital feedback platforms, can provide real-time insights into passenger experiences and help identify areas for improvement. Airlines can also consider recognition and reward systems for cabin crew members who consistently deliver high levels of service, thus reinforcing a culture of customer-centric behaviour. By investing in these initiatives, airline companies can better leverage human factors to not only increase customer satisfaction but also foster stronger and more meaningful passenger–employee interactions, which are essential for building lasting relationships, enhancing brand loyalty, and improving overall business performance.

Understanding the critical role played by airline employees in shaping passengers' experiences is valuable information for service providers (Babbar & Koufteros, 2008). The empirical findings obtained in this study support the results provided by Babbar & Koufteros (2008), indicating that individual care, helpfulness, politeness, and speed as human service contact points in the interactions between businesses and customers offer valuable opportunities for service provider airline companies to meet customers' needs and achieve positive outcomes such as satisfaction.

However, it is essential to note that, like any research, this study has certain limitations, and the results should be interpreted within the context of these limitations. Most notably, the use of convenience sampling constitutes a significant limitation that may affect the generalizability of the findings. Since participants were not selected through random sampling, the sample may not fully represent the broader population, and thus, caution should be exercised when attempting to generalize the results to other contexts. Since the online survey method used in the research only includes individuals with internet access, the representativeness of the data obtained through this method may be limited. The focus of the study on human service contact factors between passengers and cabin crew members may overlook other factors. For example, other services provided by the airline or other experiences during the flight may also influence passenger satisfaction.

On the other hand, conducting similar studies on specific airline companies in future research could allow for a broader perspective in evaluating the results. Diversifying data collection methods and collecting data from different demographics could be substantial. This would enable the examination of satisfaction profiles of passengers with different demographic characteristics. More comprehensive research could be conducted by considering other factors influencing passenger satisfaction. This would help clarify

which areas airline companies need to improve and contribute to the literature. Additionally, conducting qualitative research methods or mixed qualitative-quantitative methods to examine the interpersonal contacts between passengers and cabin crew members and their relationships with antecedents or outcomes in more detail could contribute to the literature.

Ethical approval

The research has been evaluated for its ethical considerations by the Ethics Committee Presidency of İstanbul Arel University Rectorate, and it has been determined to be ethically appropriate based on the decision with reference number E-52857131-050.06.04-284137 and the document issued on 30.05.2023.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Akpur, A., ve Zengin, B. (2019). İç ve dış müşteriler açısından kabin hizmetleri kalite algısını ölçmeye yönelik karşılaştırmalı bir araştırma. Çanakkale Onsekiz Mart Üniversitesi Uluslararası Sosyal Bilimler Dergisi, 4(1), 29-50.
- Al Hattali, L. K. K., Al-Bakari, J. H. N., Al Rasheedi, J. S. H., Al Hatmi, H. A. S., & Al Salami, S. N. A. (2025). Investigating customer satisfaction with tourism services in Oman. *Jamal Academic Research Journal: An Interdisciplinary*, 6(1), 35-49.
- Ali, F., Dey, B. L., & Filieri, R. (2015). An assessment of service quality and resulting customer satisfaction in Pakistan International Airlines: Findings from foreigners and overseas Pakistani customers. *International Journal of Quality & Reliability Management*, 32(5), 486-502.
- Auvinen, T., & Malinen, M. (2022). Passenger satisfaction studies in global aviation context: trends and best practices. Bachelor's Thesis Haaga-Helia University of Applied Sciences, Helsinki, Finland.
- Babbar, S., & Koufteros, X. (2008). The human element in airline service quality: Contact personnel and the customer. *International Journal of Operations & Production Management*, 28(9), 804-830.
- Bakır, M., Akan, Ş., Özdemir, E., Nguyen, P. H., Tsai, J. F., & Pham, H. A. (2022). How to achieve passenger satisfaction in the airport? Findings from regression analysis and necessary condition analysis approaches through online airport reviews. *Sustainability*, 14(4), 21-51.
- Banjarnahor, A. R., Simarmata, J., Gugat, R. M. D., Prakoso, O. S., & Yosafat, A. (2025). Understanding customer perception of airline service quality and brand image: A pathway to loyalty and repurchase intentions. *Indonesian Interdisciplinary Journal of Sharia Economics (IJSE)*, 8(1), 923-955.
- Bartlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, 19(1), 43-50.
- Baştürk, S., ve Taştepe, M. (2013). Evren ve örneklem. *Bilimsel araştırma yöntemleri içinde. Vize Yayıncılık*, Ankara, 129-159.

- Bishop, W. R. Jr., (1984). Competitive intelligence. *Progressive Grocer*, 63(3), 19-20.
- Brochado, A., Rita, P., Oliveira, C., & Oliveira, F. (2019). Airline passengers' perceptions of service quality: Themes in online reviews. *International Journal of Contemporary Hospitality Management*, 31(2), 855-873.
- Chaniotakis, I. E., & Lymperopoulos, C. (2009). Service quality effect on satisfaction and word of mouth in the health care industry. *Managing Service Quality: An International Journal*, 19(2), 229-242.
- Choudhury, K. (2011). Service quality and WOM (word-of-mouth): A study of the Indian banking sector. *International Journal of Customer Relationship Marketing and Management (IJCRM)*, 2(2), 63-87.
- Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge.
- Ellinger, A. E., Daugherty, P. J., & Plair, Q. J. (1999). Customer satisfaction and loyalty in supply chain: The role of communication. *Transportation Research Part E: Logistics and Transportation Review*, 35(2), 121-134.
- Eshaghi, M. S., Afshardoost, M., Lohmann, G., & Moyle, B. D. (2024). Drivers and outcomes of airline passenger satisfaction: A meta-analysis. *Journal of the Air Transport Research Society*, 3, 100034.
- Gegez, A. E. (2010). *Pazarlama araştırmaları*. Beta Basım Yayım, İstanbul.
- Gibbs, L., Slevitch, L., & Washburn, I. (2017). Competency-based training in aviation: The impact on flight attendant performance and passenger satisfaction. *Journal of Aviation/Aerospace Education & Research*, 26(2), 55-80.
- Gronroos, C. (1984). A service quality model and its marketing implications. *European Journal of Marketing*, 18(4), 36-44.
- Gürler, H. E., ve Erturgut, R. (2018). Hizmet kalitesinin müşteri tatmini ve ağızdan ağıza iletişim üzerindeki etkisi: Havayolu endüstrisinde cinsiyet temelli bir araştırma. *İşletme Araştırmaları Dergisi*, 10(1), 229-253.
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate Data Analysis* (8th ed.). Cengage Learning.
- Hamid, M. S. B. S., Baxter, G., & Wild, G. (2021). Passenger perceptions towards service quality of airlines based in Singapore. *International Review of Management and Marketing*, 11(1), 78.
- Haşiloğlu, S. B., Baran, T., & Aydın, O. (2015). Pazarlama araştırmalarındaki potansiyel problemlere yönelik bir araştırma: Kolayda örnekleme ve sıklık ifadəli ölçek maddeleri. *Pamukkale İşletme ve Bilişim Yönetimi Dergisi*, 1, 19-28.
- Jen, W., Tu, R., & Lu, T. (2010). Managing passenger behavioral intention: an integrated framework for service quality, satisfaction, perceived value, and switching barriers. *Transportation*, 38(2), 321-342.
- Karatepe, O. M., & Ekiz, E. H. (2004). The effects of organizational responses to complaints on satisfaction and loyalty: A study of hotel guests in Northern Cyprus. *Managing Service Quality: An International Journal*, 14(6), 476-486.
- Kim, Y. K., & Lee, H. R. (2011). Customer satisfaction using low cost carriers. *Tourism Management*, 32(2), 235-243.
- Kim, W. G., Lee, Y. K., & Yoo, Y. J. (2006). Predictors of relationship quality and relationship outcomes in luxury restaurants. *Journal of Hospitality & Tourism Research*, 30(2), 143-169.
- Kumar, R., & Deshpande, M. (2012). *E-banking*. Pacific Books International, New Delhi.
- Kuo, Y. F., Wu, C. M., & Deng, W. J. (2009). The relationships among service quality, perceived value, customer satisfaction, and post-purchase intention in mobile value-added services. *Computers in Human Behavior*, 25(4), 887-896.
- Ladhari, R., Souiden, N., & Ladhari, I. (2011). Determinants of loyalty and recommendation: The role of perceived service quality, emotional satisfaction and image. *Journal of Financial Services Marketing*, 16(2), 111-124.
- Law, C. C. (2018). *A practical guide to airline customer service: From airline operations to passenger services*. BrownWalker, Irvine, CA.
- Law, C. C., Zhang, Y., & Gow, J. (2022). Airline service quality, customer satisfaction, and repurchase intention: Laotian air passengers' perspective. *Case Studies on Transport Policy*, 10, 741-750.
- Macintosh, G. (2007). Customer orientation, relationship quality, and relational benefits to the firm. *Journal of Services Marketing*, 21(3), 150-159.
- Marcos, A. M. B. D. F., & Coelho, A. F. D. M. (2022). Service quality, customer satisfaction and customer value: holistic determinants of loyalty and word-of-mouth in services. *The TQM Journal*, 34(5), 957-978.
- Namukasa, J. (2013). The influence of airline service quality on passenger satisfaction and loyalty: The case of Uganda airline industry. *The TQM Journal*, 25(5), 520-532.
- Nejati, M., Nejati, M., & Shafaei, A. (2009). Ranking airlines' service quality factors using a fuzzy approach: study of the Iranian society. *International Journal of Quality & Reliability Management*, 26(3), 247-260.
- Noviantoro, T., & Huang, J. P. (2022). Investigating airline passenger satisfaction: Data mining method. *Research in Transportation Business & Management*, 43, 1-13.
- Park, E., Jang, Y., Kim, J., Jeong, N. J., Bae, K., & Del Pobil, A. P. (2019). Determinants of customer satisfaction with airline services: An analysis of customer feedback big data. *Journal of Retailing and Consumer Services*, 51, 186-190.
- Park, J.-W., Robertson, R., & Wu, C.-L. (2004). The effect of airline service quality on passengers' behavioural intentions: A Korean case study. *Journal of Air Transport Management*, 10(6), 435-439.
- Prentice, C., Maria, S., & Loureiro, C. (2017). An asymmetrical approach to understanding configurations of customer loyalty in the airline industry. *Journal of Retailing and Consumer Services*, 38, 96-107.
- Rather, R. A., & Rafi, A. (2024). Consumer-brand relationships in tourism and hospitality research. In *Tourism, hospitality and event management* (pp. 1-14). (Tourism, Hospitality and Event Management; Vol. Part F3652). Springer Nature.
- Rezaei, M., & Keynezhad, M. A. (2024). Explanation of the sociability urban tourism model with an Islamic realism approach: A case study of Tabriz. *Geographical Research*, 39(4), 1001-1013.
- Rhoades, D. L., & Waguespack, B. (1999). Better safe than service? The relationship between service and safety quality in the US airline industry. *Managing Service Quality: An International Journal*, 9(6), 396-400.

- Ringle, C. M., Sarstedt, M., & Zimmermann, L. (2011). Customer satisfaction with commercial airlines: The role of perceived safety and purpose of travel. *Journal of Marketing Theory and Practice*, 19(4), 459-472.
- Robledo, M. A. (2001). Measuring and managing service quality: Integrating customer expectations. *Managing Service Quality: An International Journal*, 11, 22-31.
- Sanyal, S., & Hisam, M. W. (2016). An analysis of the impact of service quality and passenger satisfaction on passenger preference for airlines: A study of the indian aviation sector. *International Review of Management and Marketing*, 6(2), 354-357.
- Sekaran, U. (2003). *Research methods for business: A skill-building approach*. Wiley, New York.
- Singh, V., Sharma, M. P., Jayapriya, K., Kumar, B. K., Chander, M. A. R. N., & Kumar, B. R. (2023). Service quality, customer satisfaction and customer loyalty: A comprehensive literature review. *Journal of Survey in Fisheries Sciences*, 10(4), 3457-3464.
- Suki, N. M. (2014). Passenger satisfaction with airline service quality in Malaysia: A structural equation modeling approach. *Research in Transportation Business & Management*, 10, 26-32.
- Tahanisaz, S. (2020). Evaluation of passenger satisfaction with service quality: A consecutive method applied to the airline industry. *Journal of Air Transport Management*, 83, 101764.
- Vokáč, R., Lánský, M., & Szabo, S. (2017). The dependence of airport profit on passenger satisfaction and operational efficiency. *MAD-Magazine of Aviation Development*, 5(2), 11-14.
- Walia, S., Sharma, D., & Mathur, A. (2021). The impact of service quality on passenger satisfaction and loyalty in the Indian aviation industry. *International Journal of Hospitality and Tourism Systems*, 14(2), 136-143.
- Wirtz, J., Heracleous, L., & Pangarkar, N. (2008). Managing human resources for service excellence and cost effectiveness at Singapore Airlines. *Managing Service Quality: An International Journal*, 18(1), 4-19.
- Zeithaml, V. A. (1988). Consumer perceptions of price, quality and value: A means- end model and synthesis of evidence. *Journal of Marketing*, 52(3), 2-22.

Cite this article: Isikci, S.O. (2025). Factors of Human Interaction on the Path to Passenger Satisfaction, Perceived Value, and Intention to Recommend in Airlines. *Journal of Aviation*, 9(3), 528-537.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Aviation Focused Sustainability Analysis in EU Countries with CRITIC Based MABAC Method

Sümeyye Yavuz¹ , Tuğba Akbıyık^{2*} , Eda Çınaroğlu³ 

¹Erciyes University, Aviation Management Graduate Student, Kayseri, Türkiye. (sumeyyeyvz5885@gmail.com)

^{2*}TarsusUniversity, Aviation Management Department, Mersin, Türkiye. (tugbaakbiyik@tarsus.edu.tr)

³Erciyes University, Aviation Management, Kayseri, Türkiye. (ecinaroglu@erciyes.edu.tr)

Article Info

Received: 20 July 2025
Revised: 25 August 2025
Accepted: 31 August 2025
Published Online: 09 October 2025

Keywords:

CRITIC
MABAC
Sustainability
Performance Analysis

Corresponding Author: *Tuğba Akbıyık*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1519579>

Abstract

The objective of this study is to assess the environmental and economic sustainability of the European Union (EU) countries that have the highest air transportation density. In this particular case, the CRITIC-based MABAC approach is used as the analysis methodology. The study is conducted using the following criteria: total number of commercial passenger flights, total number of cargo and mail flights, percentage share of R&D expenditures in the state budget, innovation index, urbanization rate, gross domestic product, recycling amount per capita, and amount of carbon dioxide emissions from air transport measured in tons. CRITIC method is used to assign weights to the criteria, and it is found that the level of air transportation emissions (CO₂) significantly influences the environmental and economic sustainability of countries. On the other hand, the least important criteria is the percentage of R&D expenditures in the state budget. Using the MABAC method, the ranking analysis revealed Sweden, Denmark, and Norway as the top three countries in terms of environmental and economic sustainability during the five years period from 2018 to 2022. In contrast, it is found that France, Ireland, and Germany are the bottom three countries in this regard.

1. Introduction

The aviation sector is not just of interest to individuals who dream of flying or have vacation memories; it also plays a crucial role in modern economies. This industry encompasses significant and intricate investments, such as the development of airports, the procurement of aircraft and the implementation of control systems. Aside from the inherent risks involved in these investments, the sector also presents significant business prospects. The aviation industry contributes substantially to the economy and creates employment opportunities by overseeing several industries, including airports, airlines and aircraft manufacturing. The sector's robust and efficient operation is critical for countries that rely on it. Furthermore, several elements that impact the industry, such as rules, agreements, ownership structures and strategic decisions made at the corporate level, have a significant influence on developing the market. The connection and appeal of cities and countries that have a strong aviation infrastructure, together with the benefits they provide in terms of tourism, business, and other economic sectors, are highly significant to national leaders. Country managers gain a substantial edge in optimizing economic potential (Lo, 2019).

The aviation industry, which plays a crucial role in transportation, relies on finite fossil fuels that not only contribute to pollution but also render the business

unsustainable. To address this issue, the industry has redirected its attention towards sustainable aviation fuels (Degirmenci et al., 2023). While a universally agreed-upon definition of sustainability does not exist, there are specific definitions for sustainable development and sustainable transportation. Sustainable development, with a specific focus on sustainable transportation, entails achieving a suitable equilibrium between present and future considerations of the environment, society, and economy. Despite numerous attempts, there is currently no established set of indicators that effectively encompass the environmental, social, and economic dimensions of sustainable transportation (Steg and Gifford, 2007). The concept of sustainable development has progressed from an early emphasis solely on resource consumption to a more comprehensive definition that encompasses economic and social welfare, fairness, human health and ecological soundness. A strict interpretation of sustainable mobility stresses specific technological remedies, whereas more comprehensive interpretation centers on integrated solutions that encompass enhanced travel choices, economic incentives, institutional reforms, land use modifications and technological advancements. Sustainability planning necessitates a shift in mindset and problem-solving approaches when it comes to transportation issues (Litman and Burwell, 2006).

Advancements in technology have significantly enhanced the significance of air transportation in comparison to other modes of transportation. The primary factors driving the desire for air transportation are its speed, time efficiency and enhanced security compared to other means of transport. The demand for air transportation, previously limited by high costs and inadequate technical infrastructure, has grown in recent years, primarily due to the decrease in expenses. This has enhanced the accessibility of air transportation and allowed a broader population to reap the benefits of these advantages (Keles, 2022). In the past five decades, the airline sector has experienced substantial transformations as a because of deregulation and liberalization in the United States and Europe, along with the implementation of "Open Skies" laws in Asia and Latin America. These worldwide advancements have sparked a significant transformation in air transportation. According to data provided by the International Air Transport Association (IATA), there was a significant surge in worldwide air passenger traffic between 1970 and 2019, with the number of passengers increasing from 300 million to an astonishing 4.5 billion. IATA reported a twofold increase in airline revenue over the same timeframe, culminating in a total of 507 billion dollars in 2023. Nevertheless, in tandem with this expansion, airlines have encountered increasingly intricate commercial landscapes and escalating expenses. Airlines have faced financial difficulties due to substantial pressures from increasing fuel prices, human costs and infrastructure expenditures. According to studies, fuel and labor expenditures are the primary expenses in the global aviation sector. The global airline market has undergone major changes in its structure and competitive dynamics, mostly due to rising rivalry, particularly with the advent of low-cost airlines. The intense competition in the market has compelled airlines to enhance their efficiency and competitiveness, leading to a transformation in their business practices. The future of the airline business hinges on the implementation of novel strategies that prioritize sustainability, cost efficiency and customer-centric innovation (Cui and Yu, 2021). The airline sector's dynamic nature necessitates an increase in operational efficiency. Within this particular framework, numerous academics have employed diverse methodologies to evaluate the efficacy of airlines.

According to the Kyoto Protocol, the world's carbon content grows by 2% per year. Modern transportation alternatives primarily cause climate change, contributing about 27% of greenhouse gas emissions. The aviation transport industry accounts for around 12% of carbon dioxide (CO₂) emissions. Several recent studies have examined the effects of air traffic on the atmosphere. The environmental impact of air travel is significant in relation to the duration of time individuals spend on airplanes. Despite the widespread environmental concerns and general acknowledgement of the imperative to address global climate change, the growth of air travel is happening at a fast pace. Projections predict a 5% increase in air travel by 2030 (Degirmenci et al., 2023; Breidenich et al., 1998).

This study used the CRITIC (Criteria Importance Through Intercriteria Correlation) and MABAC (Multi-attributive Border Approximation Area Comparison) methods to analyse the economic and environmental sustainability of European countries with the most air transport density. The aim is to comprehensively assess the economic and environmental sustainability of these countries, which are experiencing significant growth in aviation activities. The sustainability performance evaluation challenge, which involves the

simultaneous analysis of multiple factors, is regarded as a significant multi-criteria decision-making (MCDM) problem. The study consists of five chapters. The study provides a comprehensive analysis of existing literature on the subject after the introduction section. The third section provides a comprehensive account of the methodology employed, while the fourth section outlines the stages involved in the analysis. The last section comprises findings and assessments.

2. Literature Review

The research examines the literature from two distinct perspectives. The first perspective encompasses research that specifically examines sustainability in the aviation industry, while the second perspective provides an overview of studies completed utilizing the CRITIC and MABAC techniques.

Arjomandi and Seufert (2014) conducted an analysis of 48 prominent airlines, including low-cost and full-service, using the regional classification system of the IATA. Using data envelope analysis (DEA) models, the researchers assessed the environmental and technical effectiveness of the chosen airlines. According to the report, European airlines are predominantly the ones with the highest environmental performance. Additionally, the report found that low-cost carriers continue to be more ecologically sustainable, despite the growing presence of environmentally focused full-service airlines.

Chang et al. (2014) conducted a study using DEA to assess the economic and environmental efficiency of 27 worldwide airlines in the year 2010. The investigation revealed that Asian-based airlines had higher levels of efficiency, followed by European and American carriers.

Alameeri et al. (2017) conducted a study to evaluate the effectiveness of sustainability practices in airlines operating in the United Arab Emirates (UAE). They established eight primary criteria and three sub-criteria for their assessment. The study employed the Analytic Hierarchical Process (AHP) methodology. The study concluded that the three most crucial sustainability sub-criteria in the airline industry are adherence to legislative requirements, marketing innovation and innovation and development.

Karaman et al. (2018) conducted a study to analyze the impact of sustainability reporting, based on the Global Reporting Initiative (GRI), on companies operating in the aviation industry. The study specifically focused on the timeframe from 2006 to 2015. The study assessed the impacts by applying various analytical techniques such as logistic regression, poisson regression, ordered logistic regression and ordinary least squares regression. The study's findings show a direct correlation between sustainability reporting and a corporation's size and leverage. However, the study observed a negative correlation with ownership. In addition, the paper asserts that sustainability reporting has no positive impact on the performance of companies in the aviation industry. The argument suggests that firms' performance does not significantly benefit from sustainability measures. This discovery significantly contributes to the examination of how sustainability reporting impacts the financial performance of the airline industry.

In their study, Dhingra et al. (2018) examined how policy decisions informed by environmental impact assessments contribute to achieving sustainable development in different transportation modes.

In their study, Lo (2019) investigated the economic advantages of air transportation and specifically explored the function of air freight transportation in relation to sustainability and environmental expenses within the aviation industry. Amankwah-Amoah (2020) found that the worldwide aircraft industry's response to the challenges posed by COVID-19 has resulted in a neglect of environmental sustainability measures. Within this framework, the study investigated airline firms'

sustainability endeavors, including the adoption of eco-friendly aircraft, compensation for their emissions impact, and involvement in other corporate activities. The study revealed that certain airlines tend to eschew ecologically conscious obligations as a result of existential risks, fiscal constraints, and a lack of emphasis on programs promoting environmental sustainability.

Table 1. Literature review of studies employing CRITIC and MABAC methodologies.

The Authors	Sample	Period	Method	Findings
Pamucar, Petrovic and Cirovic (2018)	Serbia		BWM, MABAC, COPRAS and VIKOR	The investigation revealed that the IVFRN-BWM-MABAC model is a highly useful tool for decision-making and yields accurate results.
Yalcin and Karakas (2019)	Energy companies traded on BIST	2010-2018	CRITIC and EDAS	The analysis revealed that the companies' corporate sustainability performance was initially unstable but had a resurgence in 2018. The findings generated from the integration of the EDAS method with other criterion weighting methods were examined, and it was concluded that the current strategy was suitable.
Kiraci and Bakır (2018)	13 Airline companies	2005-2012	CRITIC and EDAS	The analysis indicated that prior to the crisis, companies like DAL, UAL, AFR, and SIA showed superior performance, whereas companies such as UAL, DAL, CES, and CSN demonstrated greater effectiveness during the crisis.
Stojanovic and Puska (2021)	Gulf Cooperation Countries	2012, 2014, 2016, 2018	CRITIC and MABAC	The analysis indicated that prior to the crisis, companies like DAL, UAL, AFR, and SIA showed superior performance, whereas companies such as UAL, DAL, CES, and CSN demonstrated greater effectiveness during the crisis.
Cinaroglu (2021)	EU countries	2020	CRITIC, CODAS and ROV	Denmark was determined to have the highest degree of quality of life. Greece has the lowest standard of living among all countries.
Oksuzkaya and Atan (2022)	Banks in Turkey	2016-2021	CRITIC and MABAC	The Development and Investment Bank of Turkey has achieved the highest financial performance, as determined by the criteria established for the 2016–2021 timeframe using the MABAC technique. Conversely, Iller Bank has demonstrated the lowest financial performance.
Akandere and Zerenler (2022)	Eastern European Countries	2022	CRITIC and TOPSIS	In the study, Romania demonstrated the highest environmental and economic performance, while Bosnia and Herzegovina exhibited the lowest performance value.
Keles (2022)	THY	2016-2021	CRITIC and MABAC	THY achieved its peak performance in 2019, but its lowest performance occurred in 2016.
Durmuscelebi and Kiraci (2022)	Airports operated by DHMI	2013-2019	CRITIC and EDAS	The study assessed the efficacy of airports using 15 criteria and observed a noteworthy enhancement in the performance of certain airports, particularly during the 2015–2018 timeframe.
Esiyok, Aris and Antmen (2023)	G7 Countries and Turkey	2010-2020	ENTROPİ, CRITIC and EDAS	Turkey's environmental performance is inferior to that of wealthy countries.

Aytekin and Gündoğdu (2021) employed the SWARA and TOPSIS-Sport-B methodologies, a type of MCDM approach, to assess the variations in sustainable governance levels among OECD and EU member nations. The survey concluded that the top tier included nations like Sweden, Norway, Denmark, Finland, Germany and Switzerland, while the bottom tier included countries like Romania, Hungary, and Turkey.

Corrente et al. (2021) employed the hierarchical-SMAA-PROMETHEE approach, to assess the sustainability levels of 20 European cities from 2015 to 2021. The evaluation process considered macro-criteria related to the environment, society, and economy. Using this approach, the strengths and weaknesses of each city were identified and the effects of the adopted policies were examined.

In their study, Ahmad et al. (2021) investigated the production methods of sustainable aviation fuels (SAF). The study involved the categorization of 24 variables into environmental, social, economic, and technical effect categories. PROMETHEE, TOPSIS, and VIKOR techniques are used to rate 11 distinct SAF manufacturing pathways. The survey revealed that the categories of environmental and economic impact received the highest priority, followed by technical and social factors.

Senir and Büyükkelik (2022) assessed the environmental sustainability of road transportation networks in OECD countries by examining their greenhouse gas emissions and air pollution levels.

Barke et al. (2022) conducted a study to assess the environmental and economic effects of four alternative fuel options in comparison to fossil kerosene. The study's findings demonstrate that the use of sustainable aviation fuels has the potential to reduce the ecological repercussions of aircraft operations. Nevertheless, it is crucial to transition to a power combination reliant on sustainable energy sources in order to attain substantial reductions. It is determined that, from an economic perspective, using fossil kerosene is more financially beneficial than the other alternatives.

Brodny and Tutak (2023) used the five most prevalent methodologies (CODAS, EDAS, TOPSIS, VIKOR, and WASPAS) to assess the sustainable energy and climate progress of 27 European Union countries. The investigation identified Sweden and Denmark as the countries with the greatest and most consistent levels of sustainable economic development.

Tanrıverdi et al. (2023) conducted a study on 56 airlines in the airline industry from 2017 to 2021, focusing on the aspects of reducing carbon emissions and ensuring long-term financial stability. For this specific objective, the aviation industry created and employed the MEREC-CoCoSo/Borda model, a novel multi-criterion measuring approach. The analysis revealed that sustainable performance placed greater emphasis on operational results during the pandemic, while financial performance gained more significance in 2020. Furthermore, it is found out that the decarbonization criteria experienced a decline in importance.

Durmaz et al. (2023) employed SWARA and WASPAS techniques to assess the significance of the United Nations' 17 Sustainable Development Goals (SDGs) for airports and to evaluate airports within this framework. The study findings indicate that SDG 8 holds the most significance for airports; however, SDG 14 falls beyond the purview of airport sustainability. Dallas/Fort Worth International Airport is chosen as the most appropriate alternative due to its effective strategies and documented achievements that align with the Sustainable Development Goals.

In their study, Kara et al. (2024) employed the MEREC-AROMAN methodology to evaluate Turkey's sustainable and competitive position. The study revealed that resource efficiency and intensity requirements are of utmost significance for Turkey.

The CRITIC approach is commonly employed in literature, often in conjunction with other methods, to ascertain the weight of criteria in the solution procedures. These integrations demonstrate the successful use of CRITIC in the process of ranking criteria based on their importance. Table 1 provides a summary of current research that has utilized the CRITIC and MABAC techniques for analysis.

The study employed the CRITIC-based MABAC technique. Firstly, the importance levels of the criteria are determined using the CRITIC technique. Then, the performance rankings of the countries are calculated using the MABAC approach.

3.1. CRITIC Method

Diakoulaki et al., (1995) proposed the CRITIC (Criteria Importance Through Intercriteria Correlation) approach. It is an objective weighting method to determine the weights or significance of criteria. The solution procedure consists of the following steps (Kiracı & Bakır, 2018, pp. 160–161):

Step 1: Creating the Decision Matrix

The initial step of the process involves constructing a decision matrix, as depicted in Equation (1). The matrix comprises n criteria and m alternatives.

$$X = [X_{ij}] = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

Step 2: Normalization of the Decision Matrix

In the second stage, standardization is done to eliminate any variations resulting from discrepancies in units of measurement. In this step, we employ Equation (2) for benefit-oriented criteria and Equation (3) for cost-oriented criteria.

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (2)$$

$$r_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (3)$$

In equations (2) and (3), $x_j^{\max}$ represents the highest values among the columns of the decision matrix, while $x_j^{\min}$ represents the lowest values among the columns of the choice matrix.

Step 3: Calculation of Binary Correlation Values

Equation (4) calculates the correlation coefficients between the criteria in this step of the method to assess the strength of the relationship between the criteria.

$$P_{jk} = \frac{\sum_{i=1}^m (r_{ij} - \bar{r}_j)(r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^m (r_{ij} - \bar{r}_j)^2 \sum_{i=1}^m (r_{ik} - \bar{r}_k)^2}} \quad (4)$$

Step 4: Calculating the Amount of Information

During this stage, the quantity of information encompassed in the criteria is computed utilizing the variable (as denoted by Equation (5)). The quantity of information is calculated using the formula presented below.

$$c_{ij} = \sigma_{ij} \sum_{k=1}^n (1 - p_{jk}) \quad (5)$$

Step 5: Determining the weights of the criteria

Equation (6) is used to calculate the weight values for each criterion in the last phase of the process.

$$w_j = \frac{c_j}{\sum_{k=1}^n c_k} \quad (6)$$

This calculation method identifies the criterion with the highest weight value as the one with the greatest level of significance.

3.2. MABAC Method

Multi-attribute Boundary Adjacency Area Comparison, or MABAC, is a method for MCDM analysis. It specifically aims to calculate the distances of different alternatives to the boundary proximity areas of the criteria functions (Pamučar and Čirović, 2015). This approach assesses and prioritizes different options based on the proximity of the criteria employed in the decision-making process to the border approximation areas (Alinezhad & Khalil, 2019, p. 194). The MABAC approach consists of a six-stage solution process. The following steps are as outlined by Cınaroğlu (2020):

Step 1: Creating the Decision Matrix

The first step of the process entails constructing an initial decision matrix that includes m alternatives with n criteria for applying the MABAC approach. Equation (7) represents this matrix.

$$X = [X_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (7)$$

Step 2: Normalization of the Decision Matrix

The matrix's normalization stage adjusts the data to conform to a standardized range of values between 0 and 1, depending on the specific criterion under consideration. The normalization method is executed by employing Equation (8) for benefit criteria and Equation (9) for cost criteria.

$$n_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (8)$$

$$n_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (9)$$

In Equations (8) and (9), $x_j^{\max}$ represents the highest values of the columns in the decision matrix, while $x_j^{\min}$ represents the lowest values of the columns in this matrix.

$$N = \begin{bmatrix} n_{11} & n_{12} & \dots & n_{1n} \\ n_{21} & n_{22} & \dots & n_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ n_{m1} & n_{m2} & \dots & n_{mn} \end{bmatrix} \quad (10)$$

Step 3: Acquiring a weighted decision matrix

At this point, Equation (11) incorporates the weight values that indicate the criterion's degree of significance into the application process.

$$v_{ij} = w_i * (n_{ij} + 1) \quad (11)$$

Step 4: Creating a Proximity Area Matrix

Equation (12) is used to determine the boundary proximity area values of the criteria at this step.

$$g_i = (\prod_{j=1}^m v_{ij})^{1/m} \quad (12)$$

The v_{ij} in Equation (12) correspond to the weighted values computed in the preceding phase, whereas m denotes the number of decision alternatives. Once the g_i value has been computed for each criterion, the boundary proximity area matrix (G) is generated using Equation (13).

$$G = [g_1 \ g_2 \ \dots \ g_n] \quad (13)$$

Step 5: Calculating the Alternatives' Distance (Q) from the Boundary Proximity Area

Equation (14) is used to determine the difference between the weighted decision matrix elements (v_{ij}) and the boundary proximity matrix elements (g_i) at this step. The disparity between the two entities creates the distance matrix (Q) derived from the boundary proximity region, as depicted in Equation (15).

$$Q = V - G = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \dots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \dots & v_{2n} - g_n \\ \vdots & \vdots & \ddots & \vdots \\ v_{m1} - g_1 & v_{m2} - g_2 & \dots & v_{mn} - g_n \end{bmatrix} \quad (14)$$

$$Q = \begin{bmatrix} q_{11} & q_{12} & \dots & q_{1n} \\ q_{21} & q_{22} & \dots & q_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ q_{m1} & q_{m2} & \dots & q_{mn} \end{bmatrix} \quad (15)$$

Equation (16) is used to determine the cases related to the boundary proximity area for each of the alternatives.

$$A_i \in \begin{cases} G^+ \text{ if } q_{ij} > 0 \\ G \text{ if } q_{ij} = 0 \\ G^- \text{ if } q_{ij} < 0 \end{cases} \quad (16)$$

A choice of alternative can be found within the Boundary Proximity Zone (G), the Upper Proximity Zone (G^+) or the Lower Proximity Zone (G^-). For the alternative decision problem, an option that closely aligns with the criteria values in Upper Proximity Zone (G^+) is typically the best choice. In other words, if ($g_i > 0$) is more than zero, it means that alternative is close to the ideal alternative. Conversely, if ($g_i < 0$) is less than zero, it means that alternative A_i is close to the negative ideal alternative.

Step 6: Calculation and Ranking of Criteria Functions for Alternatives:

In this stage, the criterion functions S_i are calculated by using the distance values (g_i) of the alternatives from the boundary proximity region. The ranking for the choice issue is then obtained. The criterion function is calculated by summing the distance values from the boundary proximity area for each possibility. Equation (17) is used to carry out this calculation.

$$S_i = \sum_{j=1}^n q_{ij}, \quad i=1, 2, \dots, m, \quad j=1, 2, \dots, n \quad (17)$$

The optimum alternative is established by ranking the alternatives in descending order based on their criteria function

values and selecting the alternative with the highest criterion function value.

This section of the research examines the 15 European countries with the greatest overall aircraft traffic. It employs an approach to analyze the aviation industry, with a specific emphasis on environmental and economic sustainability. The sustainability evaluation procedure is based on eight criteria, and details about these criteria can be found in Table 2. The data is acquired from the European Statistical Office (Eurostat) and the Organization for Economic Co-operation and Development Statistical Database (OECD).

Table 2. Assessment Criteria

Code of the criterion	Type of Criteria	Explanation of the criterion
KK1	Max	Total number of commercial passenger departures
KK2	Max	Total number of cargo and mail departures
KK3	Max	R&D expenditures (Percentage share in government expenditures)
KK4	Max	Innovation Index
KK5	Max	Urbanization Rate
KK6	Max	Gross Domestic Product
KK7	Max	Waste management (Recycling (kilograms per capita))
KK8	Min	Air Transportation Emissions CO2 (Tons)

In this phase, we established the weights of the criteria using the CRITIC technique. We recommend this method because

Table 4. Initial Decision Matrix

Alt./Crit. Direct.	Max	Max	Max	Max	Max	Max	Max	Min
Crit.	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
Alt1.	1194079	130390	2.18	58.69	0.37	3564000	410	22443066
Alt2.	200536	5801	1.54	52902	0.94	406600	414	3491422
Alt3.	201036	47151	1.27	51.28	0.58	493000	296	2334976
Alt4.	215437	9893	1.8	57708	0.61	3375649	394	2050253
Alt5.	132669	4213	1.62	60066	0.26	254800	232	2429179
Alt6.	929772	46025	1.16	56008	0.64	2566000	220	14691275
Alt7.	406983	20300	1.7	61162	1.05	845000	290	10187540
Alt8.	184553	6769	0.9	54442	1.68	415000	224	12020612
Alt1.	1170540	33054	1.23	48276	0.81	1274000	170	10074928
Alt9.	233792	12703	1.51	64124	1.14	557000	186	1589008
Alt10.	859832	45253	1.13	47366	-0.11	1886000	232	4269119
Alt11.	304625	8782	0.78	45836	1.04	217800	136	3653650
Alt12.	269701	8431	0.92	41894	-0.61	581600	111	2042987
Alt13.	332526	9401	1.96	53274	1.1	415400	274	2603313
Alt14.	125556	6081	0.43	37698	-0.36	218400	29	327238

Step 2. Equations (2) and (3) are used to normalize the decision matrix for the benefit and cost criterion, respectively. The resulting normalized matrix can be found in Table 4.

subjective weighing approaches accurately represent decision-makers' evaluations, often involving uncertainty and challenging to quantify. We employed the MABAC technique to rank countries based on their environmental and economic sustainability in relation to aviation.

Table 3. Countries included in the analysis

	Countries
Alt1.	Germany
Alt2.	Austria
Alt3.	Belgium
Alt4.	Denmark
Alt5.	Finland
Alt6.	France
Alt7.	Netherlands
Alt8.	Ireland
Alt9.	Spain
Alt10.	Sweden
Alt11.	Italy
Alt12.	Portugal
Alt13.	Poland
Alt14.	Norway
Alt15.	Romania

4.1. Calculation of Criteria Weights With CRITIC Method

Step 1. Based on these data, the initial decision matrix depicted in Table 4 is created.

Table 5. Normalized Decision Matrix

COUNTRY	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
Alt1.	1	1	1	0	0.4	1	0.99	0
Alt2.	0.07	0.01	0.64	0.82	0.7	0.06	1	0.86
Alt3.	0.07	0.34	0.48	0	0.5	0.08	0.69	0.91
Alt4.	0.08	0.05	0.78	0.9	0.5	0.04	0.95	0.92
Alt5.	0.01	0	0.68	0.94	0.4	0.01	0.53	0.9
Alt6.	0.75	0.33	0.41	0.87	0.6	0.7	0.5	0.35
Alt7.	0.26	0.13	0.72	0.95	0.7	0.19	0.68	0.55
Alt8.	0.06	0.02	0.27	0.85	1	0.06	0.51	0.47
Alt9.	0.98	0.23	0.46	0.75	0.6	0.32	0.37	0.56
Alt10.	0.1	0.07	0.62	1	0.8	0.1	0.41	0.94
Alt11.	0.69	0.33	0.4	0.74	0.2	0.5	0.53	0.82
Alt12.	0.17	0.04	0.2	0.71	0.7	0	0.28	0.85
Alt13.	0.13	0.03	0.28	0.65	0	0.11	0.21	0.92
Alt14.	0.19	0.04	0.87	0.83	0.8	0.06	0.64	0.9
Alt15.	0	0.01	0	0.59	0.1	0	0	1
σ_j	0.36	0.26	0.27	0.31	0.27	0.30	0.29	0.28

Table 5 includes not only the normalized decision matrix values, but also the standard deviation (σ_j) values needed to determine the quantity of information (C_j) for the criteria.

Step 3. The Pearson correlation coefficient values, which quantify the relationship between the criteria, are calculated using Equation (4) and are shown in detail in Table 6.

Table 6. Correlation Coefficients between Criteria

Crit.	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
KK1	1	0.76	0.23	-0.27	-0.09	0.88	0.15	-0.74
KK2	0.76	1	0.41	-0.72	-0.15	0.9	0.4	-0.76
KK3	0.23	0.41	1	-0.06	0.28	0.32	0.81	-0.32
KK4	-0.3	-0.72	-0.06	1	0.3	-0.41	-0.19	0.31
KK5	-0.1	-0.15	0.28	0.3	1	-0.16	0.34	-0.23
KK6	0.88	0.9	0.32	-0.41	-0.16	1	0.3	-0.83
KK7	0.15	0.4	0.81	-0.19	0.34	0.3	1	-0.34
KK8	-0.7	-0.76	-0.32	0.31	-0.23	-0.83	-0.34	1

Step 4. Equation (5) is used to calculate the quantity of information contained in each criteria (C_j) in the next phase. This calculation is based on the standard deviation (σ_j) values provided in Table 5.

Step 5. Following this stage, the criteria weights (w_j) are calculated using Equation (6) by allocating the (C_j) value of each criterion in proportion to the total (C_j) value of all the criteria. The detailed information regarding the criteria and the corresponding determined weight values are provided in Table 7.

Table 7. Information Amount of Criteria (C_j) and Criteria Weights (w_j)

	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
C_j	2.17	1.61	1.45	2.48	1.81	1.77	1.58	2.81
w_j	0.14	0.1	0.09	0.16	0.12	0.11	0.1	0.18

The CRITIC method shows that the amount of carbon dioxide (CO₂) emissions from aviation should be the main thing that is looked at when judging a country's environmental and economic sustainability (KK8). The least significant criterion is the percentage of government funding dedicated to research and development (KK3). These weight values will be used in the MABAC approach.

4.2. Determining The Performance Ratings of Countries Using The MABAC Method

After determining the criterion weights, we employed the MABAC technique to assess the environmental and economic sustainability of the countries. The procedure followed in the application process of this technique is as follows:

Step 1. The initial decision matrix is displayed in Table 4.

Step 2. Equation (8) and Equation (9) are utilized to normalize the decision matrix in this particular stage. The criteria being considered are geared towards both benefit and cost. The resulting normalized matrix can be found in Table 8.

Table 8. Normalized decision matrix according to MABAC method

Alt./Crit.	Max	Max	Max	Max	Max	Max	Max	Min
Direction	Max	Max	Max	Max	Max	Max	Max	Min
Criteria	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
Crit. Weig.	0.14	0.1	0.09	0.16	0.12	0.11	0.1	0.18
Alt1.	1	1	1	0	0.43	1	0.99	0
Alt2.	0.07	0.013	0.635	0.825	0.679	0.056	1	0.857
Alt3.	0.071	0.34	0.476	0	0.519	0.082	0.694	0.909
Alt4.	0.084	0.045	0.783	0.89	0.534	0.036	0.948	0.922
Alt5.	0.007	0	0.68	0.937	0.378	0.011	0.527	0.905
Alt6.	0.753	0.331	0.414	0.873	0.547	0.702	0.496	0.351
Alt7.	0.263	0.127	0.723	0.954	0.724	0.187	0.678	0.554
Alt8.	0.055	0.02	0.269	0.849	1	0.059	0.506	0.471
Alt9.	0.978	0.229	0.457	0.753	0.619	0.316	0.366	0.559
Alt10.	0.101	0.067	0.618	1	0.766	0.101	0.408	0.943
Alt11.	0.687	0.325	0.398	0.738	0.219	0.499	0.527	0.822
Alt12.	0.168	0.036	0.2	0.715	0.72	0	0.278	0.85
Alt13.	0.135	0.033	0.278	0.653	0	0.109	0.213	0.922
Alt14.	0.194	0.041	0.871	0.831	0.749	0.059	0.636	0.897
Alt15.	0	0.015	0	0.588	0.11	0	0	1

Step 3. In this phase, the weighted normalized decision matrix is created by combining the weight values that represent the levels of importance of the criteria. This is done using Equation (11) and the resulting matrix is displayed in Table 9.

Table 9. Weighted normalization decision matrix according to MABAC method

Alt./Crit.	Max	Max	Max	Max	Max	Max	Max	Min
Direc.	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
Crit.	0.14	0.1	0.09	0.16	0.12	0.11	0.1	0.18
Crit. Weigh.	0.277	0.205	0.185	0.158	0.165	0.226	0.201	1.179
Alt1.	0.148	0.104	0.151	0.289	0.193	0.119	0.202	2.036
Alt2.	0.148	0.137	0.137	0.158	0.175	0.122	0.171	2.088
Alt3.	0.15	0.107	0.165	0.3	0.177	0.117	0.197	2.101
Alt4.	0.14	0.102	0.155	0.306	0.159	0.114	0.154	2.084
Alt5.	0.243	0.136	0.131	0.296	0.178	0.192	0.151	1.53
Alt6.	0.175	0.115	0.159	0.309	0.199	0.134	0.169	1.733
Alt7.	0.146	0.104	0.117	0.292	0.23	0.12	0.152	1.65
Alt8.	0.274	0.126	0.135	0.277	0.187	0.149	0.138	1.738
Alt9.	0.153	0.109	0.15	0.316	0.204	0.124	0.142	2.122
Alt10.	0.152	0.109	0.149	0.316	0.203	0.124	0.142	2.12
Alt11.	0.234	0.136	0.129	0.275	0.14	0.169	0.154	2.001
Alt12.	0.162	0.106	0.111	0.271	0.198	0.113	0.129	2.029
Alt13.	0.157	0.106	0.118	0.261	0.115	0.125	0.122	2.102
Alt14.	0.165	0.107	0.173	0.289	0.202	0.12	0.165	2.076
Alt15.	0.139	0.104	0.093	0.251	0.128	0.113	0.101	2.179

Step 4. In this step, the task is to establish the boundary proximity area values for each criterion. The boundary proximity area matrix (G) generated using Equation (12) to obtain the border proximity values presented in Table 9.

Table 10. Boundary proximity area matrix (G)

	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8
<i>g_{it}</i>	0.175	0.118	0.139	0.265	0.174	0.134	0.154	1.887

Step 5. The distance values from the boundary proximity area are obtained by subtracting the components of the weighted decision matrix from the elements of the boundary proximity area matrix.

Step 6. Equation (17) is utilized to determine the criteria functions of the alternatives in the last step, employing the distance values from the boundary proximity area. The options are ordered in descending order based on their criterion function values, and the alternative with the highest criterion function value is identified as the optimal choice. The analysis findings are displayed in Table 11, which showcases the ranking of countries based on their environmental sustainability and economic sustainability, with a specific emphasis on criteria functions and aviation.

Table 11. Distance matrix, criteria functions (*St*) and ranking values of the alternatives from the boundary proximity area

Crit.	KK1	KK2	KK3	KK4	KK5	KK6	KK7	KK8	<i>St</i>	Rank
Alt1.	0.102	0.087	0.047	-0.107	-0.009	0.092	0.047	-0.71	-0.45	15
Alt2.	-0.027	-0.014	0.013	0.024	0.02	-0.015	0.048	0.15	0.197	4
Alt3.	-0.027	0.019	-0.002	-0.107	0.001	-0.012	0.017	0.2	0.091	7
Alt4.	-0.025	-0.011	0.026	0.036	0.003	-0.017	0.043	0.21	0.269	2
Alt5.	-0.036	-0.016	0.017	0.041	-0.015	-0.02	0	0.2	0.169	6
Alt6.	0.068	0.018	-0.008	0.031	0.004	0.058	-0.003	-0.36	-0.188	13
Alt7.	0	-0.003	0.021	0.044	0.025	0	0.015	-0.15	-0.051	12
Alt8.	-0.029	-0.014	-0.021	0.028	0.057	-0.014	-0.002	-0.24	-0.232	14
Alt9.	0.099	0.008	-0.004	0.012	0.013	0.015	-0.016	-0.15	-0.022	11
Alt10.	-0.023	-0.009	0.011	0.051	0.03	-0.01	-0.012	0.24	0.274	1
Alt11.	0.059	0.018	-0.009	0.01	-0.033	0.035	0	0.11	0.193	5
Alt12.	-0.013	-0.012	-0.027	0.006	0.024	-0.021	-0.025	0.14	0.074	8
Alt13.	-0.018	-0.012	-0.02	-0.003	-0.059	-0.009	-0.032	0.21	0.062	9
Alt14.	-0.01	-0.012	0.0346	0.025	0.028	-0.014	0.011	0.19	0.252	3
Alt15.	-0.037	-0.014	-0.046	-0.014	-0.046	-0.021	-0.053	0.29	0.061	10

According to the rankings calculated with the CRITIC-supported MABAC method and shown in Table 10, Sweden, Denmark and Norway are the top performing countries. These countries exhibit the highest performance in terms of environmental sustainability and economic sustainability, specifically in the aviation context. Germany, Ireland, and France have the lowest performance rankings among these countries.

European nations have made notable progress by implementing efficient policies and methods to promote environmental and economic sustainability. Under the guidance of the EU, this framework has successfully implemented a range of comprehensive measures, including energy efficiency, waste management, climate change

mitigation, and biodiversity conservation. The EU has set ambitious goals for 2030 and 2050 to enhance environmental sustainability. These goals include achieving zero carbon emissions and promoting a circular economy. Moreover, the social market economy model embraced in Europe offers a structure to foster economic expansion while guaranteeing social equity. This paradigm advocates for an approach that promotes the harmonization of social and environmental responsibilities within business operations. European businesses have been urged to embrace sustainability concepts, which have gained significance among customers, investors, and other stakeholders.

The aviation business is experiencing growth due to technical advancements and increasing global demand for mobility.

However, it has been criticized for its significant carbon emissions and negative environmental effects. Nevertheless, significant advancements in the industry have prompted progress towards a more environmentally friendly future for aviation. Efforts to mitigate environmental concerns are evident in the development of new generations of aircraft, which boast substantial improvements in fuel efficiency and emissions reductions.

This study investigates the fifteen European countries with the most significant aviation traffic, focusing on their environmental and economic sustainability. During the procedure, eight criteria are used the weight values of each criterion are determined using the CRITIC approach. The results obtained using the CRITIC method indicate that the primary factor in the analysis of environmental and economic sustainability in countries with a focus on aviation is the level of air transportation emissions (CO₂). On this basis, it may be advisable for EU countries to expand their carbon taxation systems to reduce emissions from air transport and to differentiate these taxes according to aircraft type, flight distance, and fuel type. Furthermore, ways to promote the widespread usage of SAF should be explored. Conversely, the findings suggest that the least significant factor is the proportion of government budgets allocated for research and development (R&D). Countries should increase their R&D budgets and prioritize the share of these budgets allocated to research into sustainable aviation technologies. This could facilitate the development of more innovative solutions.

The MABAC findings revealed that Scandinavian countries - Sweden, Denmark, and Norway - occupy the top three positions, while Germany, France, and Ireland are at the bottom of the list. These countries, which score lowest in the rankings, have extremely high CO₂ emission values from aviation. In this context, improvement proposals including the usage of renewable energy sources in air transportation can be implemented.

Future research can employ other MCDM approaches and supplementary criteria to conduct more analysis. The acquired results will be critical for assessing European nations' sustainability endeavors from various perspectives and formulating more efficient strategies. Moreover, employing Necessary Condition Analysis (NCA) to determine the necessary but not sufficient conditions for countries' environmental and economic sustainability performance levels can also provide deep insights and spark new scientific discussions.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Ahmad, S., Ouenniche, J., Kolosz, B. W., Greening, P., Andresen, J. M., Maroto-Valer, M. M., & Xu, B. (2021). A stakeholders' participatory approach to multi-criteria assessment of sustainable aviation fuels production pathways. *International Journal of Production Economics*, 238, 108156.
- Akandere, G., & Zerenler, M. (2022). Evaluation of the environmental and economic performance of Eastern European countries with the integrated CRITIC-TOPSIS method. *Selcuk University Journal of Social Sciences Vocational School*, 25(Special Issue), 524-535.
- Alameeri, A., Ajmal, M. M., Hussain, M., & Helo, P. T. (2017). Sustainability practices in the aviation sector: A study of UAE-based airlines. *International Journal of Sustainable Society*, 9(2), 119-147.
- Alinezhad, A., & Khalili, J. (2019). New methods and applications in multiple attribute decision making (MADM) (Vol. 277, pp. 103-108). Cham: Springer.
- Amankwah-Amoah, J. (2020). Stepping up and stepping out of COVID-19: New challenges for environmental sustainability policies in the global airline industry. *Journal of Cleaner Production*, 271, 123000.
- Arjomandi, A., & Seufert, J. H. (2014). An evaluation of the world's major airlines' technical and environmental performance. *Economic Modelling*, 41, 133-144.
- Aytekin, A., & Gündoğdu, H. G. (2021). Investigation of OECD and EU member countries by SWARA-based TOPSIS-SORT-B and WASPAS methods according to sustainable governance levels. *Journal of Social Sciences*, 16(56), 943-971.
- Barke, A., Bley, T., Thies, C., Weckenborg, C., & Spengler, T. S. (2022). Are sustainable aviation fuels a viable option for decarbonizing air transport in Europe? An environmental and economic sustainability assessment. *Applied Sciences*, 12(2), 597.
- Breidenich, C., Magraw, D., Rowley, A., & Rubin, J. W. (1998). The Kyoto Protocol to the United Nations Framework Convention on Climate Change. *American Journal of International Law*, 92(2), 315-331.
- Brodny, J., & Tutak, M. (2023). Assessing the energy and climate sustainability of European Union member states: an MCDM-based approach. *Smart Cities*, 6(1), 339-367.
- Chang, Y. T., Park, H. S., Jeong, J. B., & Lee, J. W. (2014). Evaluating economic and environmental efficiency of global airlines: A SBM-DEA approach. *Transportation Research Part D: Transport and Environment*, 27, 46-50.
- Corrente, S., Greco, S., Leonardi, F., & Słowiński, R. (2021). The hierarchical SMAA-PROMETHEE method applied to assess the sustainability of European cities. *Applied Intelligence*, 51(9), 6430-6448.
- Cui, Q., & Yu, L. T. (2021). A review of data envelopment analysis in airline efficiency: State of the art and prospects. *Journal of Advanced Transportation*, 2021, 1-13.
- Cınaroğlu, E. (2020). Evaluation of activities of innovative initiatives by entropy-based MABAC method. *Journal of Entrepreneurship and Innovation Management*, 9(1), 111-135.
- Cınaroğlu, E. (2021). Analysis of life quality of EU countries with CRITIC-based CODAS and ROV methods. *Bingöl University Journal of Economics and Administrative Sciences*, 5(1), 337-364.
- Degirmenci, H., Uludag, A., Ekici, S., & Karakoc, T. H. (2023). Analyzing the hydrogen supply chain for airports: Evaluating environmental impact, cost, sustainability, viability, and safety in various scenarios for implementation. *Energy Conversion and Management*, 293, 117537.
- Dhingra, S. L., Rao, K. V. K., & Tom, V. M. (2003). Environmental impact assessment for sustainable transport. In *Handbook of Transport and the Environment* (pp. 309-329). Emerald Group Publishing Limited.
- Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria

- problems: The CRITIC method. *Computers & Operations Research*, 22(7), 763-770.
- Durmaz, V., Yazgan, E., Derice, E. K., & Çelem, B. P. (2023). Evaluating airports' sustainable development goals by using multi-criteria decision making methodologies. *Work* (Preprint), 1-14.
- Esiyok, S., Erhan, Ar İ. S., & Antmen, F. (2023). Ranking and evaluation of G7 countries and Turkey according to GGGI indicators using entropy, CRITIC, and EDAS methods. *Çukurova University Journal of Engineering Faculty*, 38(3), 647-660.
- Geurs, K. T., & Van Wee, G. P. (2000). Environmentally sustainable transport: Implementation and impacts for the Netherlands for 2030.
- Kisa, A. C. G., & Ayçin, E. (2019). Evaluation of the Logistics Performance of OECD Countries with EDAS Method Based on SWARA. *Cankırı Karatekin University Journal of the Faculty of Economics and Administrative Sciences* 9(1), 301-325.
- IATA. (2023). Retrieved from <https://www.iata.org/contentassets/59454a254aa0417395e5065b73c6ad41/2023-06-05-01-tr.pdf>
- Kara, K., Yalçın, G. C., Acar, A. Z., Simic, V., Konya, S., & Pamucar, D. (2024). The MEREC-AROMAN method for determining sustainable competitiveness levels: A case study for Turkey. *Socio-Economic Planning Sciences*, 91, 101762.
- Karaman, A. S., Kilic, M., & Uyar, A. (2018). Sustainability reporting in the aviation industry: Worldwide evidence. *Sustainability Accounting, Management and Policy Journal*, 9(4), 362-391.
- Keshavarz Ghorabae, M., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). *Informatica*, 26(3), 435-451.
- Keles, M. K. (2022). Evaluation of Turkish Airlines' performance by years with the CRITIC-based MABAC method. *Mehmet Akif Ersoy University Journal of Applied Sciences*, 6(1), 53-67.
- Kiracı, K., & Bakır, M. (2018). Application of performance measurement in airlines with CRITIC-based EDAS method. *Pamukkale University Journal of Social Sciences Institute*, (35), 157-174.
- Kiracı, K., & Durmuscelebi, C. (2022). Analysis of ventilation in Turkey using the CRITIC total EDAS method. *Anemon Muş Alparslan University Journal of Social Sciences*, 10(2), 837-856.
- Litman, T., & Burwell, D. (2006). Issues in sustainable transportation. *International Journal of Global Environmental Issues*, 6(4), 331-347.
- Lo, P. (2019). Sustainability and economics of aviation industry.
- Oksuzkaya, M., & Atan, M. (2023). Financial efficiency of development and investment banks in Turkey in the period 2016-2021: An application with CRITIC method and MABAC method. *Journal of Banking and Financial Research*, 10(1), 14-32.
- Pamuçar, D., & Ćirović, G. (2015). The selection of transport and handling resources in logistics centers using multi-attributive border approximation area comparison (MABAC). *Expert Systems with Applications*, 42(6), 3016-3028.
- Pamuçar, D., Petrović, I., & Ćirović, G. (2018). Modification of the Best–Worst and MABAC methods: A novel approach based on interval-valued fuzzy-rough numbers. *Expert Systems with Applications*, 91, 89-106.
- Tanrıverdi, G., Merkert, R., Karamaşa, Ç., & Asker, V. (2023). Using multi-criteria performance measurement models to evaluate the financial, operational, and environmental sustainability of airlines. *Journal of Air Transport Management*, 112, 102456.
- Senir, G., & Büyükkelik, A. (2023). Measuring sustainability performance in road transport: A comparative analysis. *Business & Management Studies: An International Journal*, 11(1), 10-30.
- Steg, L., & Gifford, R. (2007). Sustainable transport and quality of life. In *Building blocks for sustainable transport: Obstacles, Trends, Solutions* (pp. 183-202). Emerald Group Publishing Limited.
- Stojanović, I., & Puška, A. (2021). Logistics performances of Gulf Cooperation

Cite this article: Yavuz, S. Akbiyik, T., Cinaroglu, E. (2025). Aviation Focused Sustainability Analysis in EU Countries with CRITIC Based MABAC Method. *Journal of Aviation*, 9(3), 538-547.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Strategic Pathways to Aviation Sustainability: Insights from Turkish Experts on Regulatory, Technological, and Market Responses

Tuncel Öz¹ 

¹Istanbul Commerce University, Aviation Management Department, 34445, Beyoğlu, İstanbul, Türkiye. (toz@ticaret.edu.tr)

Article Info

Received: 17 March 2025

Revised: 21 July 2025

Accepted: 21 August 2025

Published Online: 09 October 2025

Keywords:

Aviation sustainability

Sustainable aviation fuels (SAF)

Corporate social responsibility (CSR)

Airline sustainability strategies

Corresponding Author: Tuncel Öz

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1659395>

Abstract

As the global aviation sector faces increasing pressure to meet decarbonization targets, transitional economies like Türkiye—positioned between emerging and developed markets—must navigate the complex intersection of international environmental mandates, evolving technological capabilities, and domestic implementation challenges. This study investigates the strategic and operational dimensions of sustainable aviation in Türkiye through four key lenses: regulatory adaptation (RQ1), challenges in Sustainable Aviation Fuel (SAF) adoption (RQ2), the role of artificial intelligence (AI) in enhancing operational efficiency (RQ3), and the influence of Corporate Social Responsibility (CSR) and Environmental, Social, and Governance (ESG) practices (RQ4). Based on semi-structured interviews with 14 aviation experts and thematic analysis, the findings reveal that Türkiye's carriers face regulatory asymmetries between ICAO's CORSIA and the EU ETS, limited SAF infrastructure and incentives, fragmented digital systems for AI integration, and inconsistent CSR adoption. The study contributes to the literature by highlighting how sustainability frameworks are adapted within transitional economies, where global mandates must be reconciled with national capabilities. It also provides actionable policy and managerial implications for harmonizing environmental governance, scaling clean energy infrastructure, and fostering digital transformation in aviation. These insights offer value for both domestic policymakers and international stakeholders seeking to enable sustainable transitions in complex regulatory environments.

1. Introduction

The aviation industry plays a pivotal role in facilitating global mobility and economic activity; however, it remains one of the fastest-growing sources of greenhouse gas (GHG) emissions. As concerns over climate change intensify, the environmental implications of air travel—including carbon emissions, noise pollution, and excessive resource consumption—have come under increasing scrutiny (Rupčić et al., 2023; Sher et al., 2021). In response, a combination of global regulatory instruments and technological innovations has emerged to guide the industry's sustainability transformation. Initiatives such as the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and the European Union Emissions Trading System (EU ETS) aim to curb emissions through market-based mechanisms. At the same time, advancements such as Sustainable Aviation Fuels (SAF), artificial intelligence (AI)-enabled fuel optimization, and digitized operational efficiencies are reshaping how airlines approach environmental performance (Amankwah-Amoah, 2020; Wang, Ting, & Zhao, 2024).

However, significant challenges persist. High implementation costs, infrastructure gaps, and regulatory

inconsistencies across jurisdictions complicate the effective adoption of sustainable practices (Karaman, Kilic, & Uyar, 2018; Lai et al., 2022). These obstacles are particularly pronounced in emerging aviation markets, such as Türkiye, where regulatory maturity and technological integration vary considerably compared to the European Union. Despite rapid growth in its civil aviation sector over the past two decades, Türkiye continues to face systemic barriers to sustainability. While the country has aligned itself with ICAO's CORSIA and issued emissions monitoring guidelines through the Directorate General of Civil Aviation (DGCA), more robust enforcement mechanisms and integration of advanced solutions like SAF and AI are still in early development stages (DGCA, n.d.-a; n.d.-b). These conditions make Türkiye a compelling context for investigating how regional aviation sectors interpret and operationalize global sustainability mandates. Rather than positioning Türkiye as an outlier, this study presents it as a representative case for exploring how emerging aviation markets contend with evolving international pressures, domestic regulatory capacities, and technological innovations. The European Union's comparatively advanced systems—such as the binding EU ETS framework and national roadmaps from airlines like Lufthansa and Air France-KLM—

offer critical reference points for contrast and contextualization (European Commission, 2023).

Existing literature provides substantial coverage of sustainability challenges in aviation, often focusing on either technological advancements (e.g., electric propulsion, SAF) or global policy frameworks (e.g., CORSIA, ETS) in isolation (Kim, Lee, & Ahn, 2019; Pereira, Lohmann, & Houghton, 2021). Few studies integrate these domains or examine how sustainability strategies unfold within specific national contexts. This study addresses this gap by offering a multi-dimensional analysis grounded in the perspectives of aviation experts based in Türkiye. Drawing on insights from sustainability managers, environmental policy advisors, and analysts, it examines how airline sustainability strategies are shaped by international regulation, technological capacity, and stakeholder expectations-including those of passengers, investors, and regulators.

Accordingly, the study seeks to answer the following research questions:

- How do airlines in Türkiye adapt to global and regional sustainability regulations, including CORSIA and the EU ETS?
- What are the challenges and opportunities associated with Sustainable Aviation Fuel (SAF) adoption and other low-emission technologies?
- How do AI and operational efficiency strategies contribute to fuel consumption and emissions reduction in Türkiye?
- What role does corporate social responsibility (CSR) play in shaping sustainability strategies in Türkiye's aviation sector, and how does it influence investor confidence and passenger preferences?

To address these questions, a qualitative research design was employed. Semi-structured interviews were conducted with 14 industry experts in Türkiye, and thematic analysis was performed using NVivo software (Braun & Clarke, 2006; Nowell et al., 2017). Sentiment analysis and word cloud visualizations complemented this process by capturing expert attitudes and highlighting key discussion themes (Liu, 2012; McNaught & Lam, 2010). Secondary data from international and national sources-such as the Air Transport Action Group (2023), airline sustainability reports, the World Economic Forum Net-Zero Tracker (2023), and Türkiye's Directorate General of Civil Aviation-provided additional context.

The remainder of this paper is organized as follows: Section 2 reviews relevant literature on aviation sustainability strategies, including regulatory compliance, SAF development, AI applications, and CSR engagement. Section 3 details the methodology. Section 4 presents findings from the thematic and sentiment analyses. Section 5 discusses implications for policy and practice. Section 6 concludes with recommendations for advancing sustainability in Türkiye's aviation sector while aligning with global objectives.

2. Literature Review

To contextualize Türkiye's position in the broader sustainability landscape, this literature review includes international examples of sustainability strategies from leading global aviation companies. The inclusion of U.S.-based carriers (such as American Airlines and Delta) and European leaders (such as Lufthansa, KLM, and IAG) enables a comparative understanding of how regulatory frameworks, fuel transition efforts, and digital innovations are approached

across different policy environments. This comparative lens is especially relevant given that Türkiye operates at the intersection of EU-aligned obligations and ICAO's global frameworks without being fully integrated into either. The review is structured around four key themes reflecting the research questions: (1) global and regional regulatory mechanisms and their implications for airlines, (2) the evolving landscape of Sustainable Aviation Fuel (SAF) and its economic and logistical barriers, (3) the integration of digital technologies, particularly artificial intelligence, in enhancing operational efficiency and emissions reduction, and (4) the role of Corporate Social Responsibility (CSR) and Environmental, Social, and Governance (ESG) initiatives in shaping stakeholder perceptions and sustainability performance. By synthesizing recent studies, regulatory reports, and corporate sustainability disclosures from multiple regions, the literature review establishes a comprehensive foundation for analyzing Türkiye's national responses within the global shift toward sustainable aviation.

2.1. Environmental Impact of the Aviation Industry

Aviation is a significant contributor to global greenhouse gas (GHG) emissions, playing a critical role in climate change and environmental degradation. The industry's environmental footprint extends beyond carbon emissions, encompassing fuel consumption, contrail formation, and noise pollution, which collectively impact air quality, global warming, and community well-being (Rupcic et al., 2023). The aviation sector accounts for approximately 2–3% of global CO₂ emissions, a figure that is expected to rise as demand for air travel continues to grow (Air Transport Action Group, 2023). Despite efforts to introduce carbon-neutral technologies and improve operational efficiency, the industry's reliance on fossil fuels remains a substantial barrier to achieving sustainable aviation (Lai et al., 2022).

Fuel consumption is a central factor in aviation's environmental impact, with kerosene-based jet fuels producing high levels of carbon dioxide, nitrogen oxides, and particulate matter that contribute to climate change and local air pollution (Sher et al., 2021). The increased adoption of alternative energy sources such as sustainable aviation fuels (SAFs) has shown promise, but their large-scale implementation remains hindered by production costs and infrastructure limitations (Wang, Ting, & Zhao, 2024). In response, several leading European airlines have taken concrete steps to advance SAF usage. Lufthansa Group, for instance, has committed to reducing its net CO₂ emissions by 50% by 2030 and achieving net-zero by 2050, in line with the Science Based Targets initiative (SBTi). Lufthansa is one of Europe's largest SAF purchasers and has launched customer-facing initiatives such as the Compensaid platform and Green Fares, which allow passengers to directly fund SAF usage or offset emissions (Lufthansa Group, 2024).

Similarly, KLM Royal Dutch Airlines has been at the forefront of sustainable fuel innovation, operating the world's first commercial flight using synthetic SAF in 2021 and launching partnerships with SkyNRG and Neste to increase fuel availability. The airline also participates in the Destination 2050 coalition, aligning with the EU's climate roadmap (KLM, 2023). Air France, supported by France's SAF blending mandates, has partnered with TotalEnergies for SAF demonstration flights using up to 30% SAF content. These airlines' efforts underscore the growing recognition that

sustainability requires long-term strategic investments and multi-stakeholder cooperation.

Contrail effects are another critical environmental concern, as the condensation trails produced by aircraft engines at high altitudes contribute to atmospheric warming by trapping outgoing infrared radiation (Yang & O'Connell, 2020). These contrails can evolve into cirrus clouds that exacerbate radiative forcing, further intensifying aviation's impact on global temperatures. Studies suggest that altering flight altitudes or optimizing air traffic routes can mitigate contrail formation, yet such adjustments often conflict with fuel efficiency goals and airline operational priorities (Lai et al., 2022). Several EU carriers have expressed interest in integrating artificial intelligence (AI) into air traffic optimization to both reduce contrail formation and enhance route efficiency—an area where further investment and regulatory coordination are still needed.

Noise pollution remains a persistent issue, particularly for communities located near airports. Aircraft operations generate substantial noise emissions that can adversely affect human health, leading to sleep disturbances, cognitive impairment, and cardiovascular issues (Torija & Self, 2018). Regulatory efforts have led to technological advancements in quieter engine designs and operational noise abatement strategies, but the rapid expansion of global air traffic continues to challenge mitigation efforts (Kılıç, Uyar, & Karaman, 2019). In the EU, airports such as Charles de Gaulle and Schiphol have adopted operational noise restrictions, nighttime curfews, and collaborative decision-making frameworks with local communities, demonstrating a more inclusive and environmentally responsive airport governance approach (Karaman, Kılıç, & Uyar, 2018).

The aviation industry's commitment to sustainability is increasingly reflected in corporate sustainability reports and environmental policies. Airlines such as American Airlines, Delta Air Lines, and United Airlines have outlined sustainability goals, including carbon neutrality targets and improved fuel efficiency programs (American Airlines, 2023; Delta Air Lines, 2023; United Airlines, 2023). However, this study initially focused more heavily on U.S.-based carriers. To create a more balanced global view, the inclusion of European airlines like Lufthansa, KLM, and Air France offers important comparative insights. These EU carriers have generally shown greater alignment with governmental policies on climate change, especially given the EU's commitment to the 2050 Net-Zero Aviation goal and stronger environmental regulations compared to the U.S., which withdrew from the Paris Agreement between 2017–2021. Consequently, EU airlines appear to have adopted more aggressive sustainability practices, partly driven by mandatory national and EU-level SAF mandates, public scrutiny, and participation in collaborative climate initiatives. Efforts to reduce aviation's environmental footprint also extend to aircraft manufacturing and material recycling. The potential for closed-loop recycling of carbon fiber composites offers an opportunity to minimize waste and improve resource efficiency, but challenges related to cost and technological feasibility remain (Meng et al., 2020). Additionally, energy and environmental assessments of turbofan engines highlight the need for improved fuel efficiency and emissions reductions in future engine designs (Tuzcu, Sohret, & Caliskan, 2021).

Despite ongoing challenges, the aviation industry continues to explore pathways toward sustainability through technological innovation, regulatory adaptation, and corporate

responsibility initiatives. The transition to greener aviation will require a combination of policy interventions, financial incentives, and industry-wide collaboration to achieve meaningful reductions in emissions and environmental impact. The development of strategic sustainability plans for airports, such as those implemented at Istanbul Airport, demonstrates the potential for localized solutions that integrate environmental priorities with operational efficiency (Mizrak, Polat, & Tasar, 2024). The push for sustainable aviation remains a complex and evolving challenge, necessitating a holistic approach that balances economic growth with environmental stewardship.

2.2. Global and Regional Environmental Regulations

Global and regional environmental regulations play a crucial role in guiding the aviation industry's sustainability agenda. At the international level, frameworks such as the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), the European Union Emissions Trading System (EU ETS), and sustainability initiatives championed by the International Air Transport Association (IATA) form the backbone of emissions control in global aviation. CORSIA, implemented by ICAO, seeks to cap the net carbon emissions of international flights by mandating that airlines offset excess emissions through certified carbon reduction projects (Baledón & Kosoy, 2018). However, ensuring consistent compliance and standardization across jurisdictions remains a challenge (European Commission, 2023). In parallel, the EU ETS imposes a cap-and-trade mechanism on airlines operating within the European Economic Area, requiring them to purchase carbon allowances proportional to their emissions. This system is designed to incentivize the adoption of low-emission technologies and sustainable aviation fuels (Gudmundsson, 2019). Complementing these regulatory efforts, IATA promotes voluntary industry-wide commitments to carbon neutrality, operational efficiency, and SAF integration, although the actual implementation varies significantly across regions due to disparities in cost, infrastructure, and policy support (Amankwah-Amoah, 2020).

At the national level, regulatory approaches vary across key aviation markets such as the European Union, the United States, and Türkiye. The EU has been at the forefront of aviation sustainability policies, implementing stringent regulations that require airlines to integrate SAFs and adopt emissions monitoring programs (Linden, 2021). The U.S. Federal Aviation Administration (FAA) has prioritized research into hybrid-electric propulsion technologies and air traffic management innovations to reduce fuel consumption and environmental impact (Rendón et al., 2021). However, regulatory enforcement in the U.S. has faced challenges, particularly as airlines resist more aggressive emissions reduction mandates due to financial constraints.

Türkiye, emerging as a strategic aviation hub, has progressively aligned its environmental policies with European standards by implementing sustainability measures across its aviation infrastructure—most notably at Istanbul Airport, which incorporates energy-efficient technologies and green design principles (De Neufville, 2020). The Directorate General of Civil Aviation (Türkiye) has formalized national compliance with international emissions frameworks by integrating ICAO's CORSIA guidelines into domestic regulations, as outlined in the SHT-CORSIA Implementation Guidelines (Directorate General of Civil Aviation, n.d.-b).

Furthermore, Türkiye's "Green Airport" certification program incentivizes airports to reduce carbon emissions, optimize energy use, and improve environmental performance in ground operations, contributing to broader climate goals and signaling a growing commitment to sustainable aviation development (Directorate General of Civil Aviation, n.d.-b).

Despite these advancements, Türkiye faces challenges in integrating SAFs into its fuel supply chain and meeting international emissions reduction targets. While Turkish Airlines (THY) has begun incorporating SAFs into its operations as part of its sustainability strategy, the widespread adoption of these fuels remains limited due to high production costs and inadequate supply infrastructure (Türk Hava Yolları, n.d.). Efforts to expand the SAF market have been supported by national initiatives promoting research and development in sustainable fuel alternatives (Türkiye Yüzyılı, n.d.), yet the country's SAF production capacity remains insufficient to meet long-term demand. The Turkish Standards Institute (TSE) has also introduced ICAO CORSIA verification programs to ensure that airlines adhere to global emissions reporting requirements, further integrating international environmental standards into national policy (Türk Standartları Enstitüsü, n.d.).

Regulatory adaptation continues to be a challenge as governments and industry stakeholders attempt to balance economic growth with environmental sustainability. The aviation sector's transition toward digitalized operations and smart airport technologies is expected to play a critical role in enhancing emissions monitoring and improving air traffic efficiency (Zaharia & Pietreanu, 2018). However, the industry must also address long-term resilience strategies following the disruptions of the COVID-19 pandemic, ensuring that sustainability measures are incorporated into financial recovery plans (Amankwah-Amoah, 2020). The success of these initiatives will depend on the harmonization of international and national regulations, increased investment in SAFs, and the development of comprehensive green aviation policies. While Türkiye has made significant progress in aligning its aviation sector with global environmental standards, continued advancements in regulatory compliance, alternative fuel integration, and emissions monitoring will be necessary to achieve long-term sustainability goals (TFS Akaryakıt Hizmetleri A.Ş., n.d.; Yeşil Ekonomi, 2018).

2.3. Sustainability Strategies in Aviation

Sustainability strategies in aviation have become a central focus for the industry as it seeks to mitigate its environmental impact while maintaining operational efficiency. The aviation sector has introduced multiple approaches to achieving sustainability, including fuel efficiency programs, carbon offsetting mechanisms, and technological innovations. These strategies aim to reduce greenhouse gas emissions, optimize resource utilization, and align aviation operations with international sustainability goals.

Fuel efficiency programs have played a crucial role in minimizing the aviation industry's environmental footprint. Airlines have increasingly invested in new-generation aircraft that feature improved aerodynamics, lightweight materials, and more efficient engines designed to reduce fuel consumption (Qiu et al., 2021). Optimized flight routes and advanced air traffic management systems have also contributed to fuel savings, allowing airlines to minimize unnecessary fuel burn by reducing flight times and congestion at airports (Pereira et al., 2021). The introduction of

Sustainable Aviation Fuels (SAFs) has been another key element in reducing carbon emissions, offering an alternative to conventional jet fuel with significantly lower life-cycle emissions. However, challenges remain in scaling up SAF production and integrating it into the global aviation fuel supply chain due to cost and infrastructure limitations (Kim, Lee, & Ahn, 2019). Airlines such as Air France-KLM have been actively seeking partnerships to expand SAF production in an effort to align with sustainability commitments, but logistical and economic barriers continue to hinder widespread adoption (Air France-KLM, 2025). Despite these challenges, major carriers like Delta Air Lines, American Airlines, and United Airlines have included SAF as a core component of their sustainability strategies, as reflected in their recent environmental reports (Delta Air Lines, 2023; American Airlines, 2023; United Airlines, 2023).

Carbon offsetting initiatives have emerged as a widely adopted measure for airlines seeking to achieve carbon neutrality. Many carriers have introduced voluntary offset programs that allow passengers to contribute to environmental projects designed to absorb or prevent emissions equivalent to those produced by their flights (Rajani & Kot, 2018). Airlines have also pledged to participate in global offset mechanisms, such as ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which mandates that airlines compensate for their emissions by investing in carbon reduction projects (Gössling & Lyle, 2021). Despite these efforts, the effectiveness of carbon offsetting remains a subject of debate, as critics argue that it serves as a temporary solution rather than a long-term emissions reduction strategy. The success of these programs depends on their credibility, transparency, and ability to generate verifiable emissions reductions (Jahanger et al., 2024). The World Economic Forum (2023) has tracked progress on aviation net-zero commitments, highlighting that while offsetting is widely used, a shift toward direct emissions reductions through SAFs and technology adoption is essential for long-term sustainability.

Technological innovations have been pivotal in accelerating the transition toward greener aviation. Developments in electric and hydrogen-powered aircraft have the potential to transform the industry by eliminating direct emissions from flight operations (Thummala & Hiremath, 2022). Several manufacturers and research institutions are actively working on hybrid-electric propulsion systems, which combine traditional jet engines with battery-powered electric motors to reduce fuel dependency and emissions (Bridgellall, 2024). Additionally, artificial intelligence (AI) has been leveraged to enhance operational efficiency, particularly in flight planning and route optimization, helping airlines reduce unnecessary fuel consumption and streamline air traffic management (Jayabal, 2024). However, the large-scale deployment of these emerging technologies remains in the early stages, with further research and investment required to overcome technical, regulatory, and financial barriers. Some airlines, including Frontier Airlines and Alaska Airlines, have outlined commitments to researching and piloting new technologies that enhance fuel efficiency and reduce emissions (Frontier Airlines, 2023; Alaska Airlines, 2023).

While these sustainability strategies offer promising pathways to reducing aviation's environmental impact, their successful implementation relies on coordinated efforts between governments, industry stakeholders, and technological innovators. Public awareness and consumer

willingness to support greener aviation initiatives have also been identified as key factors in driving sustainability adoption. Studies indicate that passengers who possess a greater understanding of aviation's environmental challenges are more likely to support and pay for sustainable flight options (Ragbir et al., 2021). Moving forward, the aviation industry must continue to balance economic viability with its commitment to sustainability, integrating fuel efficiency measures, carbon offsetting mechanisms, and technological advancements to achieve a more environmentally responsible future. The Air Transport Action Group (2023) has emphasized the importance of international collaboration in addressing aviation's sustainability challenges, noting that airlines, airports, and policymakers must work together to ensure the long-term viability of green aviation. Similarly, recent reports on European aviation emissions stress the need for stronger regulatory frameworks to drive sustainable innovation and reduce reliance on fossil fuels (Transport & Environment, 2023). These efforts highlight the critical role that both corporate sustainability commitments and regulatory action will play in shaping the future of aviation.

2.4. Corporate Social Responsibility (CSR) in Airlines

Corporate social responsibility (CSR) has become an essential component of the airline industry's sustainability strategy, reflecting commitments to environmental protection, social equity, and ethical governance. As airlines navigate increasing regulatory pressures and consumer expectations, CSR initiatives play a crucial role in shaping their corporate image and financial performance. Airlines have progressively integrated CSR policies that emphasize emissions reductions, operational efficiency, and investment in sustainable aviation fuels (SAFs) to mitigate their environmental impact (Kuo, Chen, & Meng, 2021). The implementation of CSR strategies is no longer just a voluntary ethical consideration but a competitive necessity, particularly as stakeholders, including governments, consumers, and investors, demand greater accountability and transparency in airline operations (Streimikiene et al., 2021).

Airlines' commitments to sustainability have expanded beyond environmental efforts to include social initiatives such as diversity and inclusion, community engagement, and fair labor practices. Research indicates that companies with strong CSR programs often experience enhanced corporate reputation and increased customer loyalty, particularly in the highly competitive aviation industry (Vuong et al., 2024). Budget airlines, which historically prioritized cost efficiency over sustainability, have increasingly incorporated CSR into their business models to enhance brand trust and attract environmentally conscious consumers (Streimikiene et al., 2021). Furthermore, strategic CSR initiatives have been linked to improved financial performance, as passengers are more likely to choose airlines with demonstrated commitments to sustainability and corporate responsibility (Phillips, Thai, & Halim, 2019). This shift has encouraged airlines to align their CSR objectives with long-term profitability by integrating green technologies, reducing operational waste, and investing in carbon offsetting programs (Karaman & Akman, 2018).

Public perception and stakeholder pressure have significantly influenced the adoption and expansion of CSR programs in the airline sector. Airlines frequently report their sustainability efforts on corporate websites and annual reports to improve transparency and engage with environmentally conscious stakeholders (Okumus et al., 2020). However, the

credibility of such reports has been questioned, as some airlines engage in "greenwashing" practices—exaggerating their environmental contributions while continuing high-emission operations (Peeters et al., 2019). Consumers have become increasingly discerning, expecting airlines to demonstrate tangible sustainability efforts rather than relying on corporate rhetoric. Studies suggest that passengers' willingness to pay for greener flights is contingent upon their trust in an airline's sustainability claims, highlighting the importance of authenticity in CSR communication (Sorsa & Bona-Sánchez, 2024).

CSR trends in the airline industry are also influenced by regulatory frameworks and industry-wide sustainability goals. Green human resource management (HRM) has emerged as a key factor in integrating CSR into airline operations, fostering a sustainability-oriented corporate culture that aligns with passenger expectations (Wang et al., 2024). Additionally, cross-country studies have demonstrated that airports with strong CSR commitments experience higher passenger satisfaction, reinforcing the importance of CSR in enhancing customer experience and brand loyalty (Alam et al., 2024). Case studies of airlines such as Singapore Airlines have shown that both qualitative and quantitative CSR disclosures play a role in shaping investor confidence and industry positioning (Boulesnam et al., 2025).

As the aviation industry continues to evolve, CSR will remain a fundamental driver of corporate sustainability and competitive advantage. Airlines that successfully integrate environmental, social, and governance (ESG) principles into their operations will not only improve their public perception but also ensure long-term financial stability in an era where sustainability is increasingly linked to profitability (Upadhaya et al., 2018). Moving forward, the effectiveness of airline CSR programs will depend on their ability to implement meaningful environmental initiatives, engage with stakeholders transparently, and adapt to evolving consumer and regulatory expectations.

2.5. Technological Innovations in Aviation Sustainability

Technological innovation is emerging as a critical pillar in aviation sustainability, complementing regulatory and market-driven efforts to reduce environmental impact. Central to this transformation are digital technologies and AI-enabled systems that enhance fuel efficiency, optimize route planning, and support predictive maintenance. According to Belobaba, Cooper, and Seabridge (2023), recent advances in aircraft design, engine efficiency, and digital flight operations have the potential to significantly reduce carbon emissions per passenger-kilometer. These innovations include real-time data analytics for load and trajectory optimization, integration of AI for minimizing fuel burn, and the application of machine learning algorithms in air traffic control to mitigate unnecessary holding patterns. However, the authors note that despite the availability of these technologies, their adoption varies widely across regions, often due to infrastructural limitations and inconsistent investment in digital transformation. For emerging markets like Türkiye, the gradual incorporation of such tools offers both opportunity and challenge—providing environmental gains while requiring systemic modernization of aviation infrastructure and governance frameworks.

Parallel to operational advancements, sustainable aviation fuels (SAFs) represent a foundational technological innovation with direct implications for carbon neutrality. As emphasized

by Ershov et al. (2023), innovation in SAF production processes—including thermochemical conversion, power-to-liquid synthesis, and algae-based feedstocks—is rapidly evolving to overcome economic and scalability barriers. SAFs are considered a near-term solution to decarbonize aviation without requiring massive changes to aircraft engines or airport fueling infrastructure. However, their broader deployment is hindered by high production costs, limited feedstock availability, and policy uncertainty, especially in countries where state incentives or mandatory blending requirements are absent. Khujamberdiev and Cho (2024) further explore the technical compatibility of SAFs with existing aircraft engines, confirming that drop-in fuels can reduce lifecycle emissions by up to 80%, but they stress the need for regionally tailored policies to support large-scale adoption. In Türkiye's context, experts echo these concerns, pointing to the absence of domestic SAF production facilities and insufficient policy alignment with international sustainability targets as key obstacles to progress.

Aligning SAF research with global sustainability goals has also gained momentum, highlighting the need for multi-dimensional frameworks that consider environmental, economic, and social impacts. A recent thematic analysis by Raman et al. (2024) underscores the evolving research landscape, identifying key clusters related to feedstock optimization, emissions reduction, and integration into existing supply chains. The study emphasizes that to effectively contribute to Sustainable Development Goals (SDGs), SAF research must not only focus on technical feasibility but also engage with questions of equity, access, and global cooperation. This broader systems-level thinking is echoed in Raihan's (2025) critical review, which calls for stronger alignment between technological innovation and long-term policy instruments. Raihan argues that countries with emerging aviation markets—such as Türkiye—must adopt a dual-track strategy: building technical capacity for SAF production and engaging in international policy dialogues to harmonize sustainability benchmarks. These findings suggest that Türkiye's SAF roadmap, while currently underdeveloped, could benefit from collaborative regional efforts and lessons learned from more advanced markets like the EU and the U.S.

Beyond fuel technologies, the digital transformation of aviation enterprises plays a vital role in embedding sustainability into core business models. According to Smerichevskiy et al. (2024), digital technologies such as blockchain, Internet of Things (IoT), and big data analytics are increasingly used to monitor environmental indicators, streamline operations, and enhance transparency in sustainability reporting. The integration of digital dashboards for emissions tracking, AI-driven scheduling tools, and simulation-based carbon forecasting are some of the practices identified to boost the innovative potential of aviation firms. These tools not only contribute to environmental performance but also foster stakeholder trust and institutional readiness for future regulatory shifts. In Türkiye, where digital maturity remains uneven across aviation actors, such technologies offer a path to leapfrog traditional inefficiencies and align more closely with international standards.

Finally, the broader relationship between business sustainability and information technology has become even more prominent in the post-COVID aviation landscape. Trivedi, Negi, and Tiwari (2024) highlight how IT systems can reinforce the triple bottom line—people, planet, and profit—

by enabling responsive decision-making, enhancing energy efficiency, and supporting remote operational capabilities. Their findings indicate that IT-driven sustainability strategies not only mitigate environmental risks but also improve long-term financial resilience, particularly during periods of volatility. This intersection of digital resilience and ecological responsibility is particularly salient for Turkish airlines navigating post-pandemic recovery while facing increasing environmental scrutiny from both domestic regulators and international stakeholders. In this regard, the strategic integration of technological tools—from AI to SAF—offers a multifaceted approach to achieving sustainability in aviation that is both operationally viable and ethically aligned.

3. Materials and Methods

3.1. Research Design

This study employs a qualitative research design to investigate sustainability strategies, regulatory adaptation, and technological innovation in the aviation industry, with a particular focus on the Turkish civil aviation context. Qualitative inquiry is well-suited for examining complex, evolving issues such as environmental sustainability in aviation, as it facilitates deep exploration of stakeholder perceptions, strategic responses, and institutional challenges (Creswell & Poth, 2018). By drawing on expert insights, the study captures the nuanced interplay between policy mandates, market pressures, and organizational practices. Figure 1 presents a flowchart of the data collection and analysis process. The flowchart outlines the sequential stages of the research—from expert identification and interview scheduling to transcription, coding, and cross-comparison with secondary sources. It also highlights the tools and procedures used in thematic analysis, including the application of NVivo software for coding and visualization. This structured representation supports methodological rigor and helps readers understand how empirical data were systematically gathered and interpreted within the study.

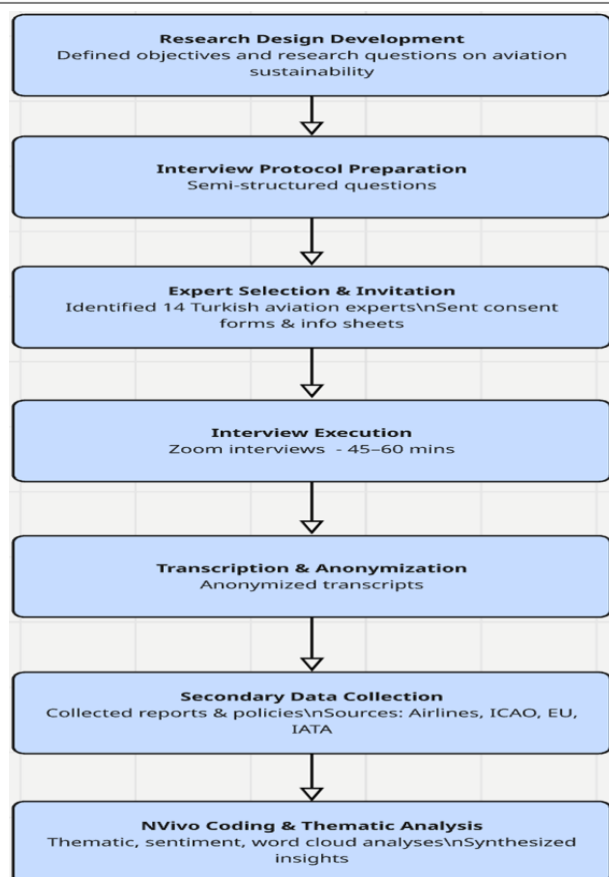


Figure 1. Flowchart of the Data Collection and Analysis Process

3.2. Data Collection Methods

This study adopts a qualitative research design grounded in semi-structured interviews to explore sustainability strategies, regulatory adaptation, and technological innovation within the aviation industry. A total of 14 participants were purposefully selected based on their roles as sustainability managers, environmental policy advisors, aviation analysts, and other experts actively engaged in Türkiye's civil aviation sector. This purposive sampling approach enabled access to individuals with deep, experience-based knowledge of airline sustainability practices and policy engagement (Patton, 2015). The primary data collection method was semi-structured interviews, which allowed for consistency in addressing core themes while also offering the flexibility to explore unanticipated insights raised by participants (Braun & Clarke, 2006). Interviews were structured around three thematic domains:

- (1) Airline sustainability strategies, such as SAF deployment, carbon offsetting efforts, and fuel efficiency initiatives;
- (2) Regulatory adaptation, with a focus on ICAO's CORSIA, the EU ETS, and national environmental compliance mechanisms;
- (3) Technological innovation, particularly in digital transformation, AI-based optimization, and emerging propulsion systems.

The interview protocol consisted of open-ended questions designed to encourage rich, narrative responses and capture nuanced perspectives on sustainability implementation and policy alignment. This format enabled participants to elaborate on strategic priorities, operational challenges, and future directions in their own words, thereby enhancing the depth of

thematic analysis. Interviews were conducted online via Zoom to facilitate logistical accessibility and international scheduling flexibility. Each session lasted between 45 and 60 minutes, was recorded with informed consent, and transcribed using Zoom's built-in transcription feature. All transcripts were carefully reviewed for accuracy and anonymized to ensure ethical compliance and participant confidentiality. Digital recordings and transcripts were securely stored in encrypted research folders.

In parallel with interview data, secondary sources were analyzed to triangulate findings and contextualize expert perspectives. These sources included ESG reports, sustainability disclosures, and regulatory documents from major global airlines—such as Delta Air Lines, United Airlines, and Air France-KLM—as well as publications from international organizations like IATA and the World Economic Forum. Türkiye-specific regulatory documents and environmental guidelines issued by the Directorate General of Civil Aviation were also incorporated to validate national policy references. This dual-layered approach ensured a comprehensive foundation for comparing expert insights with broader policy trends and corporate strategies.

3.3. Sampling Strategy

The study employs purposive sampling to ensure that participants represent airlines with significant sustainability initiatives. Expert selection is based on their professional involvement in aviation sustainability, regulatory compliance, or strategic decision-making. The participant group includes sustainability managers, environmental policy experts, aviation analysts, and industry consultants to capture diverse perspectives on sustainability challenges and best practices in the airline sector.

3.4. Data Analysis

The data collected from the interviews undergoes thematic analysis, a qualitative research method used to identify, analyze, and interpret patterns within the data (Braun & Clarke, 2006). The purpose of thematic analysis in this study is to structure expert insights into recurring patterns, challenges, and strategies related to airline sustainability, facilitating a comparative understanding of regulatory adaptation, technological innovations, and corporate social responsibility (CSR) efforts. This method ensures that both anticipated and emerging themes are captured, allowing for a comprehensive examination of how airlines navigate sustainability challenges (Nowell et al., 2017).

To conduct the thematic analysis, NVivo software is used to organize, code, and interpret the qualitative data systematically. The process begins with data preparation, where all interviews are transcribed verbatim to preserve accuracy and detail. These transcripts are then imported into NVivo, where preliminary readings help identify key discussion points, and memos document early observations. During the coding phase, NVivo's node structure allows for the segmentation of text into meaningful units, ensuring that themes are captured at various levels of granularity. Thematic analysis follows both inductive and deductive approaches. Deductive coding categorizes responses based on predefined themes such as regulatory compliance, sustainable aviation fuels (SAF), and emissions reduction, while inductive coding allows new themes to emerge organically from the expert discussions. As coding progresses, NVivo's hierarchical structure enables the formation of broader categories and sub-

themes, refining the analysis. For example, regulatory adaptation includes sub-themes such as compliance challenges, financial implications, and policy harmonization, reflecting the complexities of adhering to sustainability mandates across different regulatory environments.

To further enhance the thematic analysis, NVivo's Matrix Coding Query tool is used to identify relationships between themes. This enables a comparative analysis of sustainability strategies across airlines, revealing differences and similarities in regulatory responses, SAF adoption strategies, and the integration of technological solutions (Castleberry & Nolen, 2018). The matrix analysis also helps to cross-reference expert responses, ensuring internal consistency and thematic saturation in the findings.

In addition to thematic analysis, sentiment analysis is performed to evaluate experts' perceptions of key sustainability challenges and initiatives. This technique, commonly used in qualitative research, assesses the polarity of responses (positive, neutral, or negative) toward sustainability regulations, SAF adoption, and operational strategies (Liu, 2012). The sentiment analysis is conducted using NVivo's sentiment scoring function, which assigns quantitative sentiment values to qualitative text. For instance, while CORSIA received predominantly positive responses, EU ETS was frequently criticized for its financial burden, providing a quantifiable measure of expert attitudes toward regulatory frameworks. The sentiment scores help contextualize expert feedback, revealing areas where sustainability policies are perceived as effective versus areas where concerns remain prominent.

To complement the analysis, a word cloud visualization is generated using NVivo's word frequency analysis tool. The purpose of the word cloud is to highlight the most frequently mentioned terms in expert discussions, providing a quick visual representation of dominant topics (McNaught & Lam, 2010). Words such as SAF, AI, emissions, fuel efficiency, regulatory compliance, and ESG reporting appear most frequently, reinforcing the key thematic areas identified in the coding process. The word cloud not only validates thematic findings but also reveals which sustainability topics are most emphasized by industry experts, offering additional insight into priority areas for airlines and policymakers. By integrating thematic analysis, sentiment analysis, and word cloud visualization, this study ensures a holistic and structured examination of airline sustainability strategies. The use of NVivo software enhances the efficiency, accuracy, and transparency of qualitative data analysis, allowing for a deeper understanding of expert perspectives and industry trends.

3.5. Ethical Considerations

The study adhered to strict ethical guidelines to safeguard the anonymity, confidentiality, and privacy of all interview participants. Prior to participation, all experts received a detailed informed consent form outlining the purpose of the research, the nature of their involvement, and their rights, including the option to withdraw at any stage without consequences. Their identities remained undisclosed, with all personally identifiable information either anonymized or

excluded from the final reporting to protect both their professional reputations and personal interests. The data collection process was conducted in a transparent and ethically responsible manner, ensuring that all interviews were accurately documented, securely stored, and analyzed without bias or misinterpretation. Findings were reported objectively, adhering to rigorous ethical and methodological standards. This study received formal ethical approval from the Ethics Committee of Istanbul Ticaret University, confirming its compliance with institutional and international research ethics standards.

4. Findings

This section presents the key findings derived from thematic analysis, word cloud visualization, and sentiment analysis. These analyses provide insights into how airlines navigate sustainability challenges, implement technological innovations, and respond to regulatory pressures.

4.1. Thematic Analysis

The thematic analysis revealed five key themes aligned directly with the research questions, reflecting core dimensions of sustainability in Türkiye's aviation sector. These themes are: (1) Regulatory Adaptation and Compliance, (2) Sustainable Aviation Fuels (SAF), (3) AI and Operational Efficiency, (4) Corporate Social Responsibility (CSR) and Stakeholder Expectations, and (5) Emerging Technological Innovations. Table 1 summarizes the results.

Sustainable Aviation Fuels (SAF) are widely recognized as essential for decarbonization, yet challenges persist in their adoption. One respondent noted Türkiye's ambition: *"Our airline is committed to achieving a 10% blend of SAF by 2030, though limited supply continues to hinder our efforts."* Another stated, *"There is minimal airport infrastructure to support SAF blending, which complicates operational rollout."* These insights reflect Türkiye's dual status as both a committed participant in SAF dialogues and a nation contending with cost, supply, and infrastructural readiness issues. National programs, including the Türkiye Yüzyılı vision, highlight the state's interest in SAF development, but industry professionals stress that scalable implementation remains a significant hurdle.

Operational efficiency, particularly through AI integration, is also gaining momentum. Turkish experts confirmed that AI applications are actively being adopted for real-time fuel optimization and route planning. As one expert explained, *"We are leveraging AI for real-time route optimization, which significantly reduces fuel burn and enhances efficiency."* Yet, constraints such as airspace congestion were also emphasized: *"Despite advanced technology, congested airspace often forces us into less efficient routing, which increases emissions."* These accounts mirror global trends while emphasizing Türkiye's particular infrastructural bottlenecks, such as regional ATC coordination and older airport logistics systems.

Table 1. Thematic Analysis Results

Theme	Subtheme	Code	Frequency	Example Quotes
Regulatory Adaptation and Compliance(RQ1)	Compliance with ICAO's CORSIA	CORSIA	12	E5: "The CORSIA framework has provided a baseline for our carbon offsetting strategy, but the cost of compliance is a persistent concern."E11: "ICAO's CORSIA program plays a key role in standardizing emissions reduction globally, although its real impact is still debated within the industry."
	Challenges with EU ETS	EU ETS Challenges	9	E3: "The EU ETS introduces financial burdens that complicate our ability to expand sustainability investments."E9: "While carbon pricing via the EU ETS is effective in theory, it puts European airlines at a competitive cost disadvantage."
	National Sustainability Policies	Local Regulations	7	E7: "The inconsistency of national sustainability regulations makes compliance challenging for international airlines."E14: "Incentives for SAF use vary across countries, with some offering strong support and others providing no clear direction."
Sustainable Aviation Fuels (SAF) (RQ2)	Adoption of SAF	SAF Adoption	10	E2: "Our airline is committed to achieving a 10% blend of SAF by 2030, though limited supply continues to hinder our efforts."E12: "SAF represents a revolutionary step forward for aviation sustainability, but we still lack consistent regulatory backing for full-scale integration."
	Cost and Production Barriers	SAF Costs	8	E6: "Currently, SAF is between three to five times more expensive than traditional jet fuel, which slows its broader adoption."E10: "Although investing in SAF production is critical, most airlines cannot compete with fossil fuel pricing structures."
	Infrastructure Challenges	SAF Infrastructure	6	E8: "There is minimal airport infrastructure to support SAF blending, which complicates operational rollout."E13: "Even when SAF is secured, the absence of adequate supply chain infrastructure in key regions restricts its practical use."
AI and Operational Efficiency (RQ3)	Fuel Efficiency Optimization	AI Fuel Optimization	11	E4: "We are leveraging AI for real-time route optimization, which significantly reduces fuel burn and enhances efficiency."E9: "Our smart fuel management systems have achieved an 8% reduction in fuel waste over the past two years."
	Air Traffic Constraints	Congested Airspace	7	E1: "Despite advanced technology, congested airspace often forces us into less efficient routing, which increases emissions."E14: "Enhanced coordination among air traffic control agencies would allow for much more efficient routing and energy savings."
	Fleet Modernization	Fleet Renewal	8	E3: "Renewing our fleet with next-generation aircraft is currently our most effective approach to reducing emissions."E12: "Although fleet modernization is essential, the capital required for it is not available to every airline."
CSR and Stakeholder Expectations(RQ4)	Stakeholder Pressure	Investor Expectations	10	E6: "We are increasingly pressured by institutional investors who demand stronger ESG policies and measurable commitments."E11: "Clients now evaluate us based on the strength and transparency of our sustainability reporting."
	Passenger Engagement	Carbon Offsetting Programs	6	E7: "Passengers are making choices based on whether we offer carbon offsetting as part of our ticketing."E13: "Our brand loyalty is being influenced by the visibility and credibility of our sustainability programs."
	Transparency in ESG Reporting	ESG Accountability	5	E2: "Being transparent in our ESG reporting is fundamental to maintaining regulatory and consumer trust."E9: "There is a growing concern around greenwashing; our claims must be backed by real, auditable data."
Emerging Technological Innovations(extension of RQ2 & RQ3)	AI for Route Optimization	AI-based Flight Efficiency	9	E4: "AI-driven flight scheduling has led to measurable reductions in fuel usage across our routes."E12: "Our predictive analytics tools allow us to proactively reduce flight delays and emissions simultaneously."
	Hydrogen and Electric Aircraft	Hydrogen Aircraft Development	8	E1: "Hydrogen-powered aircraft offer great promise, but the infrastructure to support them remains severely lacking."E10: "Although we're closely monitoring hydrogen aircraft, making them cost-effective for commercial use is still far off."
	Smart Airport Technologies	AI-Driven Airport Operations	7	E5: "Our smart airport systems use AI automation to streamline ground operations and minimize emissions."E8: "Energy-efficient and intelligent airport infrastructure is fundamental for achieving long-term sustainability targets."

This thematic framework directly addresses each research question by mapping the experiences and reflections of Turkish aviation professionals to global trends and localized challenges. The consistency between expert responses and international benchmarks underscores Türkiye's evolving role in aligning with—and at times diverging from—broader sustainability mandates. The inclusion of direct quotes not only illustrates these dynamics vividly but also anchors the findings in the grounded experiences of industry professionals navigating complex transitions in policy, technology, and stakeholder engagement.

The word cloud (Figure 2) provides a visual representation of the most frequently occurring terms in expert discussions, offering insights into which topics dominate aviation sustainability conversations. The most prominent words include Sustainable Aviation Fuels (SAF), AI, emissions, fuel efficiency, regulatory compliance, passenger engagement, and ESG reporting. The size and frequency of these words indicate their significance in shaping airline sustainability strategies, policy discussions, and technological advancements.

Finally, the word cloud visually captures the intersectionality of sustainability drivers in Türkiye—economic, regulatory, technological, and stakeholder-based. The relative size and proximity of words across these categories reinforce that aviation decarbonization in Türkiye is not led by a single factor but is shaped by the convergence of international standards, domestic capabilities, and market pressures. The word cloud analysis thus enhances the study's thematic insights by offering a frequency-based lens through which the research questions are both visually and conceptually validated.



Figure 2. Word Cloud

4.3. Sentiment Analysis

The sentiment analysis (Table 2) reveals mixed perceptions regarding regulatory policies, reflecting both support and criticism from industry experts. CORSIA received predominantly positive responses, with several experts acknowledging its role as a global baseline mechanism for emissions offsetting. One expert emphasized, “ICAO’s

CORSIA program has significantly shaped our carbon offset strategy” (E1), suggesting that it provides a structured approach to emissions reduction without imposing excessive financial burdens on airlines. Additionally, some experts highlighted that CORSIA allows airlines flexibility by offering carbon offsetting options rather than enforcing direct emission reduction quotas.

Table 2. Sentiment Analysis Results

Theme	Subtheme	Example Quote	Sentiment Score	Sentiment Label
Regulatory Compliance	Compliance with ICAO’s CORSIA	E1: “ICAO’s CORSIA program has significantly shaped our carbon offset strategy.”	0.38	Positive
Regulatory Compliance	Challenges with EU ETS	E2: “The EU ETS has been a financial challenge, requiring airlines to purchase carbon credits.”	0.00	Neutral
Regulatory Compliance	National Sustainability Policies	E3: “National sustainability policies vary, making compliance complex for international airlines.”	-0.15	Negative
Sustainable Aviation Fuels (SAF)	Adoption of SAF	E4: “Our airline has begun blending SAF with conventional jet fuel on long-haul flights.”	-0.14	Negative
Sustainable Aviation Fuels (SAF)	Cost and Production Barriers	E5: “SAFs are still 2-5 times more expensive than conventional jet fuel, making large-scale adoption difficult.”	-0.16	Negative
Sustainable Aviation Fuels (SAF)	Infrastructure Challenges	E6: “Limited SAF blending infrastructure at major airports is slowing adoption.”	-0.20	Negative
Operational Efficiency	Fuel Efficiency Optimization	E7: “We use AI-driven flight route optimization and real-time weather analytics to improve fuel efficiency.”	0.45	Positive
Operational Efficiency	Air Traffic Constraints	E8: “Air traffic congestion sometimes forces inefficient routing, reducing fuel savings from optimization.”	-0.12	Negative
Operational Efficiency	Fleet Modernization	E9: “Investing in newer, fuel-efficient aircraft is one of our long-term sustainability strategies.”	0.32	Positive
Corporate Social Responsibility (CSR)	Stakeholder Pressure	E10: “Institutional investors increasingly prioritize ESG performance, influencing airline sustainability commitments.”	0.28	Positive
Corporate Social Responsibility (CSR)	Passenger Engagement	E11: “Passengers are more likely to fly with airlines that offer carbon offset options.”	0.35	Positive
Corporate Social Responsibility (CSR)	Transparency in ESG Reporting	E12: “Transparency in ESG reporting is key to maintaining credibility with stakeholders and regulators.”	0.22	Positive
Technological Innovations	AI for Route Optimization	E13: “AI-powered real-time flight scheduling enhances operational efficiency and reduces emissions.”	0.40	Positive
Technological Innovations	Hydrogen and Electric Aircraft	E14: “Hydrogen-powered aircraft could eliminate emissions, but infrastructure limitations remain a challenge.”	-0.18	Negative

The sentiment analysis complements the thematic findings by providing nuanced insights into how Turkish aviation professionals emotionally and strategically respond to sustainability challenges. These perceptions—ranging from frustration to cautious optimism—offer an important interpretive layer that connects directly to the study’s research questions.

For RQ1 (Regulatory Influence), sentiment around the EU ETS and CORSIA reveals a dichotomy. While CORSIA is generally viewed neutrally to positively as a global standard-setting mechanism, the EU ETS elicits predominantly negative sentiment. As one Turkish airline executive (E3) stated, “The EU ETS imposes financial burdens, making it harder for airlines to scale sustainability investments.” Another remarked, “Carbon pricing through the EU ETS is effective but places European airlines at a cost disadvantage” (E9). These quotes reflect widespread concern that Türkiye, aiming to harmonize with the EU, risks inheriting cost-intensive policies that may not match its current economic and infrastructural capacity. The negative sentiment indicates that

regulatory compliance is not just a procedural hurdle but a strategic and financial risk, particularly when incentives do not offset associated costs.

Additionally, neutral to slightly negative sentiment appeared regarding regulatory fragmentation, with one expert noting: “National sustainability policies vary, making compliance complex for international airlines” (E7). This aligns with Türkiye’s current position—straddling international obligations (e.g., ICAO and EU directives) and domestic implementation gaps. These views reinforce the need for regulatory harmonization, a key finding from the thematic analysis, and highlight how sentiment reflects underlying structural issues faced by the country’s aviation stakeholders. With respect to RQ2 (SAF enablers and barriers), sentiment ranged from positive strategic alignment to economic frustration. SAF was described as an “essential component of aviation’s decarbonization future,” but experts expressed disappointment over high costs, limited local production, and inadequate infrastructure. One professional (E10) commented: “Although investing in SAF production is critical, most

airlines cannot compete with fossil fuel pricing structures.” This view captures a recurring tension in Turkish aviation: alignment with global green innovation versus domestic feasibility constraints. Positive sentiment toward the concept of SAF exists, but its implementation in Türkiye is clouded by cost and logistical realities.

Regarding RQ3 (digitalization and AI integration), sentiment was generally positive, with several experts expressing enthusiasm about the role of AI in fuel management, predictive analytics, and route optimization. As one stated, “We are leveraging AI for real-time route optimization, which significantly reduces fuel burn” (E4). However, subtle frustrations emerged when discussing external limitations, such as restricted airspace or limited inter-agency coordination, which impeded the full impact of these tools. Thus, sentiment here reflects optimism tempered by operational barriers, a theme consistent with Türkiye’s current modernization trajectory in aviation infrastructure.

For RQ4 (stakeholder expectations and CSR), sentiment skewed positively but cautiously, particularly around ESG transparency and passenger influence. Experts acknowledged the growing importance of ESG disclosure, with one emphasizing, “Clients now evaluate us based on the strength and transparency of our sustainability reporting” (E11). However, concerns around greenwashing and accountability were evident. This duality reflects the Turkish aviation sector’s attempt to balance reputational expectations with meaningful performance, especially as investor scrutiny intensifies. The sentiment analysis validates the shift from voluntary CSR to stakeholder-driven sustainability.

5. Result and Discussion

This study investigated sustainability strategies in global aviation with a particular focus on Türkiye’s aviation sector, guided by four research questions: regulatory adaptation (RQ1), SAF challenges and opportunities (RQ2), the role of digital technologies such as AI (RQ3), and the influence of CSR and stakeholder engagement (RQ4). Drawing on thematic analysis of interviews with 14 experts, this section interprets the findings in relation to each research question and compares them to relevant academic literature.

RQ1 – Regulatory Adaptation and Compliance Experts highlighted the tension between international commitments—particularly ICAO’s CORSIA—and regional obligations such as the EU ETS. While CORSIA was broadly seen as a baseline for global compliance, it was criticized for depending heavily on offsetting mechanisms rather than real emissions reductions. This reflects concerns from Baledón and Kosoy (2018), who argue that offset-centric policies dilute the transformative potential of sustainability mandates. The EU ETS was perceived more negatively due to its financial burden and perceived inequity for Turkish carriers operating outside the EU bloc, echoing Scheelhaase et al. (2020) regarding non-EU airline disadvantages. Experts emphasized the need for harmonized national policies and clearer long-term roadmaps, including domestic carbon pricing strategies and SAF-related incentives, to bridge the gap between ambition and implementation.

RQ2 – Sustainable Aviation Fuels (SAF) SAF was seen as both a necessary and highly constrained solution for decarbonizing aviation. While major Turkish carriers have initiated SAF trials, cost barriers, limited production, and inadequate infrastructure continue to inhibit meaningful scale-up. These

concerns align with studies by Gegg et al. (2020) and Wang et al. (2024), which argue that supportive ecosystems—including feedstock logistics, blending mandates, and economic incentives—are essential for SAF viability. Unlike the EU’s ReFuelEU strategy, Türkiye lacks structured policy tools and dedicated SAF development zones. Experts recommended exploring regional SAF production near agricultural hubs and aligning infrastructure investment with airport capacity expansion, resonating with suggestions from Pavlenko and Searle (2021) and IRENA (2023).

RQ3 – AI and Digital Operational Efficiency Participants expressed cautious optimism about the growing use of AI in sustainability efforts. AI applications in predictive routing, fuel optimization, and fleet management are gaining momentum, mirroring global practices (Tu et al., 2022; Schäfer et al., 2023). However, implementation in Türkiye is impeded by airspace congestion, fragmented data systems, and outdated traffic management infrastructure. These limitations correspond with Liu et al. (2021), who argue that digital aviation innovation requires strong institutional coordination. Türkiye’s lack of a national AI strategy for aviation stands in contrast to digital leaders such as Singapore and Germany, underscoring the need for cross-agency collaboration and public-private partnerships to fully leverage AI’s potential.

RQ4 – CSR and Stakeholder Expectations CSR and ESG frameworks are becoming more influential in Türkiye’s aviation sector, with investor expectations, passenger behavior, and global reporting norms driving adoption. Larger airlines are aligning with international ESG frameworks and tapping into green finance instruments, consistent with Kolk and Pinkse (2020) and Eccles et al. (2014), who highlight finance-sector pressure as a catalyst for CSR. However, the absence of a standardized national ESG reporting requirement creates disparities in implementation and opens the door to greenwashing. Smaller carriers and service providers struggle to keep pace, lacking the financial and organizational resources to execute robust CSR policies. Experts called for clear regulatory frameworks and third-party audits to enhance credibility and stakeholder trust, echoing findings from Alonso-Almeida et al. (2015).

Collectively, the findings indicate that Türkiye’s aviation sector is increasingly attuned to global sustainability priorities, but it faces significant gaps in policy coherence, technological integration, and resource allocation. The insights from this study suggest that progress depends not only on technical innovation but also on systemic reforms and strategic alignment. Compared to leading countries with integrated aviation sustainability frameworks, Türkiye’s approach remains fragmented. However, its willingness to engage in SAF trials, invest in digital solutions, and respond to ESG pressures reflects a growing maturity.

6. Conclusion

The transition toward sustainable aviation is an urgent and global undertaking, yet its implementation unfolds unevenly across national contexts. This study contributes to the growing literature by examining how Türkiye’s aviation sector navigates regulatory mandates, SAF limitations, digital transformation, and CSR engagement. By drawing on expert insights, the research provided a comprehensive view of the opportunities and constraints faced by the sector as it strives to align with global sustainability norms. Regulatory asymmetries—particularly between ICAO’s CORSIA and the

EU ETS—illustrate the challenges Turkish carriers face in reconciling international frameworks with limited national policy support. These disparities highlight the urgent need for harmonized domestic strategies to reduce compliance burdens and ensure coherence in environmental governance.

From a practical standpoint, the findings suggest several targeted interventions that can enhance the sustainability performance of Türkiye's aviation sector. First, the government should develop a comprehensive national aviation sustainability roadmap that includes binding targets, sector-specific emissions guidelines, and financial instruments aligned with international mechanisms like the EU ETS and ICAO's CORSIA. This roadmap must address SAF barriers by incentivizing production through tax breaks, feedstock subsidies, and infrastructure investments at major airports. Policymakers could explore creating regional SAF innovation clusters, particularly near agricultural and industrial byproduct zones, leveraging Türkiye's geographical diversity for localized fuel sourcing. Moreover, aviation authorities and digital transformation agencies in Türkiye must collaborate to create a unified strategy for AI deployment in air traffic management, route planning, and fuel optimization. Public-private partnerships could support technology infrastructure modernization, while funding mechanisms like green aviation grants or AI innovation funds could encourage airline and airport investment. Strengthening ESG regulations through mandatory disclosure standards and independent audits would also raise accountability and trust among consumers and investors. Such reforms would empower not only flag carriers but also smaller service providers to adopt meaningful sustainability and CSR strategies.

At the global level, these insights underline the importance of harmonizing international regulatory frameworks to avoid competitive imbalances—particularly for countries like Türkiye that operate across both EU and non-EU airspaces. Global aviation authorities should work toward integrating CORSIA, EU ETS, and other carbon pricing schemes into a more cohesive model that accounts for varying national capabilities. Similarly, international cooperation on SAF R&D, technology transfer, and blended finance solutions could enable developing and transitional economies to contribute to decarbonization without facing prohibitive entry barriers. Finally, global aviation actors—whether regulators, technology providers, or international carriers—must recognize the role of contextual adaptation. The lessons from Türkiye underscore that sustainability strategies cannot be one-size-fits-all. Instead, they require flexible frameworks that accommodate national infrastructure realities, governance capacities, and socio-economic conditions. Only through coordinated but adaptive implementation can the aviation sector globally meet its emissions reduction targets and deliver on its sustainability promise.

Limitations of the study include the scope of participants, which was limited to 14 experts operating primarily in Türkiye. This scope may not fully reflect the experiences of all stakeholders, particularly low-cost carriers, regional airports, or global regulators. Moreover, while word clouds and sentiment analysis supplemented the findings, the absence of statistical modeling or longitudinal data restricts the generalizability and depth of the insights. Future research should integrate cross-national comparisons and quantitative modeling of sustainability impacts to validate and deepen these qualitative findings. Areas such as lifecycle emissions of SAF, financial returns on digital investment, and public

perception of ESG in aviation remain ripe for further exploration.

In conclusion, Türkiye stands at a pivotal crossroads in the global push toward aviation sustainability. With targeted policy reform, technological investment, and stakeholder coordination, the country can move from fragmented compliance to proactive leadership. Achieving this requires a multi-dimensional strategy—one that unites regulation, innovation, finance, and social accountability into a cohesive sustainability agenda for aviation. By embracing such an integrated approach, Türkiye has the potential to shape not only its national aviation trajectory but also contribute meaningfully to the global effort in achieving climate-resilient air transport systems.

Ethical approval

Approval for this research was authorized by İstanbul Ticaret University Ethics Committee under decision number 02-09 and dated 28.02.2025.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Air France-KLM. (2025, January 28). Air France-KLM seeks partners for sustainable fuel in Portugal ahead of TAP sale. Reuters. Retrieved from <https://www.reuters.com/sustainability/climate-energy/air-france-klm-seeks-partners-sustainable-fuel-portugal-ahead-tap-sale-2025-01-28/>
- Air France-KLM. (2025). Air France-KLM Sustainability Strategy 2025. Retrieved from <https://www.airfranceklm.com>
- Air Transport Action Group. (2023). Aviation: Benefits beyond borders. Retrieved from <https://aviationbenefits.org/environmental-efficiency/climate-impact/>
- Alam, F., Yang, Q., Bandara, Y. M., Ahmad, N., & Chiwaridzo, O. T. (2024). The nexus between corporate social responsibility of airports and passenger satisfaction: A cross-country study. *Corporate Social Responsibility and Environmental Management*, 31(3), 2454-2473.
- Alaska Airlines. (2023). Sustainability report 2023. Retrieved from <https://news.alaskaair.com/investor-relations/events-presentations/wp-content/uploads/2024/08/Alaska-Airlines-Sustainability-Report-2023.pdf>
- Amankwah-Amoah, J. (2020). Stepping up and stepping out of COVID-19: New challenges for environmental sustainability policies in the global airline industry. *Journal of Cleaner Production*, 271, 123000.
- American Airlines. (2023). Sustainability report 2023. Retrieved from <https://s202.q4cdn.com/986123435/files/images/esg/American-Airlines-Sustainability-Report-2023.pdf>
- Baledón, M. S., & Kosoy, N. (2018). "Problematising" carbon emissions from international aviation and the role of alternative jet fuels in meeting ICAO's mid-century aspirational goals. *Journal of Air Transport Management*, 71, 130-137.

- Belobaba, P., Cooper, J., & Seabridge, A. (2023). Sustainable Aviation Technology and Operations: Research and Innovation Perspectives. John Wiley & Sons.
- Boulesnam, M., Hocini, O., Rezazi, I., & Boukhors, A. (2025). Quantitative and Qualitative Disclosure of Corporate Social Responsibility in the Aviation Sector: Case Study of Singapore Airlines 2018-2024. In Sustainable Marketing Practices in the Aviation Industry (pp. 77-114). IGI Global Scientific Publishing.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101.
- Bridgelall, R. (2024). Aircraft innovation trends enabling advanced air mobility. *Inventions*, 9(4), 84.
- Castleberry, A., & Nolen, A. (2018). Thematic analysis of qualitative research data: Is it as easy as it sounds? *Currents in Pharmacy Teaching and Learning*, 10(6), 807-815.
- De Neufville, R. (2020). Airport systems planning, design, and management. In *Air Transport Management* (pp. 79-96). Routledge.
- Delta Air Lines. (2023). Environmental, social, and governance (ESG) report 2023. Retrieved from <https://esghub.delta.com/content/dam/esg/2023/pdf/Delta-2023-ESG-Report.pdf>
- Directorate General of Civil Aviation (Türkiye). (n.d.-a). Environment and climate change. Republic of Türkiye, Ministry of Transport and Infrastructure. Retrieved from <https://web.shgm.gov.tr/tr/kurumsal/6277-cevre>
- Directorate General of Civil Aviation (Türkiye). (n.d.-b). SHT-CORSIA implementation guidelines. Republic of Türkiye, Ministry of Transport and Infrastructure. Retrieved from <https://web.shgm.gov.tr/documents/sivilhavacilik/files/mevzuat/sektorel/taslaklar/2018/SHT-CORSIA.pdf>
- Ershov, M. A., Savelenko, V. D., Burov, N. O., Makhova, U. A., Mukhina, D. Y., Aleksanyan, D. R., ... & Abdelkareem, M. A. (2023). An incorporating innovation and new interactive technology into obtaining sustainable aviation fuels. *Energy*, 280, 128156.
- European Commission. (2023). The EU Emissions Trading System (EU ETS). Retrieved August 2, 2025, from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en
- Frontier Airlines. (2023). Environmental, social, and governance (ESG) report 2023. Retrieved from <https://ir.flyfrontier.com/news-releases/news-release-details/frontier-airlines-releases-2023-environmental-social-and>
- Gössling, S., & Lyle, C. (2021). Transition policies for climatically sustainable aviation. *Transport Reviews*, 41(5), 643-658.
- Gudmundsson, S. V. (2019). European air transport regulation: achievements and future challenges. In *Airline economics in Europe* (Vol. 8, pp. 9-56). Emerald Publishing Limited.
- Heyes, G., Urquhart, C., Hooper, P., & Thomas, C. (2023). Comprehensive Strategic Analysis for Sustainability: An Aviation Industry Case Study. *Sustainability*, 15(11), 8806.
- Jahanger, A., Ozturk, I., Onwe, J. C., Ogwu, S. O., Hossain, M. R., & Abdallah, A. A. (2024). Do pro-environmental interventions matter in restoring environmental sustainability? Unveiling the role of environmental tax, green innovation and air transport in G-7 nations. *Gondwana Research*, 127, 165-181.
- Jayabal, R. (2024). Towards a carbon-free society: innovations in green energy for a sustainable future. *Results in Engineering*, 103121.
- Karaman, A. S., & Akman, E. (2018). Taking-off corporate social responsibility programs: An AHP application in airline industry. *Journal of Air Transport Management*, 68, 187-197.
- Karaman, A. S., Kilic, M., & Uyar, A. (2018). Sustainability reporting in the aviation industry: worldwide evidence. *Sustainability Accounting, Management and Policy Journal*, 9(4), 362-391.
- Khujamberdiev, R., & Cho, H. M. (2024). Biofuels in aviation: Exploring the impact of sustainable aviation fuels in aircraft engines. *Energies*, 17(11), 2650.
- Kim, Y., Lee, J., & Ahn, J. (2019). Innovation towards sustainable technologies: A socio-technical perspective on accelerating transition to aviation biofuel. *Technological Forecasting and Social Change*, 145, 317-329.
- Kılıç, M., Uyar, A., & Karaman, A. S. (2019). What impacts sustainability reporting in the global aviation industry? An institutional perspective. *Transport Policy*, 79, 54-65.
- KLM. (2023). KLM Sustainability Report 2023. Retrieved from <https://www.klm.com/en/about-klm/newsroom/klm-sustainability-report-2023-is-now-available>
- Kuo, T. C., Chen, H. M., & Meng, H. M. (2021). Do corporate social responsibility practices improve financial performance? A case study of airline companies. *Journal of Cleaner Production*, 310, 127380.
- Lai, Y. Y., Christley, E., Kulanovic, A., Teng, C. C., Björklund, A., Nordensvärd, J., ... & Urban, F. (2022). Analysing the opportunities and challenges for mitigating the climate impact of aviation: A narrative review. *Renewable and Sustainable Energy Reviews*, 156, 111972.
- Linden, E. (2021). Pandemics and environmental shocks: What aviation managers should learn from COVID-19 for long-term planning. *Journal of Air Transport Management*, 90, 101944.
- Liu, B. (2022). *Sentiment analysis and opinion mining*. Springer Nature.
- Lufthansa Group. (2024). Climate protection: Our path to CO₂ neutrality. Retrieved from <https://www.lufthansagroup.com/en/responsibility/climate-environment/climate-protection.html>
- McNaught, C., & Lam, P. (2010). Using Wordle as a supplementary research tool. *The Qualitative Report*, 15(3), 630-643.
- Meng, F., Cui, Y., Pickering, S., & McKechnie, J. (2020). From aviation to aviation: Environmental and financial viability of closed-loop recycling of carbon fibre composite. *Composites Part B: Engineering*, 200, 108362.
- Mizrak, F., Polat, L., & Tasar, S. A. (2024). Applying Entropy Weighting and 2-Tuple Linguistic T-Spherical Fuzzy MCDM: A Case Study of Developing a Strategic Sustainability Plan for Istanbul Airport. *Sustainability*, 16(24), 11104.
- Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the

- trustworthiness criteria. *International Journal of Qualitative Methods*, 16(1), 1-13.
- Okumus, F., Kuyucak Sengur, F., Koseoglu, M. A., & Sengur, Y. (2020). What do companies report for their corporate social responsibility practices on their corporate websites? Evidence from a global airline company. *Journal of Hospitality and Tourism Technology*, 11(3), 385-405.
- Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage publications.
- Peeters, P., Bouwer, J., Bongaerts, R., & Eijgelaar, E. (2019). Airlines and corporate responsibility: Issues and challenges. *Corporate sustainability and responsibility in tourism: A transformative concept*, 163-180.
- Pereira, B. A., Lohmann, G., & Houghton, L. (2021). Innovation and value creation in the context of aviation: a Systematic Literature Review. *Journal of air transport management*, 94, 102076.
- Pettersen, K. A., & Schulman, P. R. (2019). Drift, adaptation, resilience and reliability: toward an empirical clarification. *Safety science*, 117, 460-468.
- Phillips, S., Thai, V. V., & Halim, Z. (2019). Airline value chain capabilities and CSR performance: The connection between CSR leadership and CSR culture with CSR performance, customer satisfaction and financial performance. *The Asian Journal of Shipping and Logistics*, 35(1), 30-40.
- Qiu, R., Hou, S., Chen, X., & Meng, Z. (2021). Green aviation industry sustainable development towards an integrated support system. *Business Strategy and the Environment*, 30(5), 2441-2452.
- Ragbir, N. K., Rice, S., Winter, S. R., & Choy, E. C. (2021). Emotions and caring mediate the relationship between knowledge of sustainability and willingness to pay for greener aviation. *Technology in Society*, 64, 101491.
- Raihan, A. (2025). Sustainable Aviation: A Critical Review of Policies, Technologies, and Future Pathways. *Journal of the Air Transport Research Society*, 100080.
- Rajiani, I., & Kot, S. (2018). The prospective consumers of the Indonesian green aviation initiative for sustainable development in air transportation. *Sustainability*, 10(6), 1772.
- Raman, R., Gunasekar, S., Dávid, L. D., Rahmat, A. F., & Nedungadi, P. (2024). Aligning sustainable aviation fuel research with sustainable development goals: Trends and thematic analysis. *Energy Reports*, 12, 2642-2652.
- Rendón, M. A., Sánchez R, C. D., Gallo M, J., & Anzai, A. H. (2021). Aircraft hybrid-electric propulsion: Development trends, challenges and opportunities. *Journal of Control, Automation and Electrical Systems*, 32(5), 1244-1268.
- Rupcic, L., Pierrat, E., Saavedra-Rubio, K., Thonemann, N., Ogugua, C., & Laurent, A. (2023). Environmental impacts in the civil aviation sector: Current state and guidance. *Transportation Research Part D: Transport and Environment*, 119, 103717.
- Schultz, M., Evler, J., Asadi, E., Preis, H., Fricke, H., & Wu, C. L. (2020). Future aircraft turnaround operations considering post-pandemic requirements. *Journal of Air Transport Management*, 89, 101886.
- Science Based Targets initiative. (n.d.). Companies taking action: Lufthansa Group. Retrieved from <https://sciencebasedtargets.org>
- Sher, F., Raore, D., Klemeš, J. J., Rafi-ul-Shan, P. M., Khzouz, M., Marintseva, K., & Razmkhah, O. (2021). Unprecedented impacts of aviation emissions on global environmental and climate change scenario. *Current Pollution Reports*, 1-16.
- Smerichevskiy, S., Poberezhna, Z., Mykhalchenko, O., Petrova, Y., & Smilyanets, V. (2024). Ensuring the sustainable development of the aviation enterprise in the context of forming innovative potential using digital technologies. In *CEUR Workshop Proceedings (Vol. 3732, pp. 174-185)*.
- Sorsa, K., & Bona-Sánchez, C. (2024). Corporate Social Responsibility Trends in the Airline Industry: A Bibliometric Analysis. *Sustainability*, 16(7), 2709.
- Streimikiene, D., Lasickaite, K., Skare, M., Kyriakopoulos, G., Dapkus, R., & Duc, P. A. (2021). The impact of corporate social responsibility on corporate image: evidence of budget airlines in Europe. *Corporate Social Responsibility and Environmental Management*, 28(2), 925-935.
- TFS Akaryakıt Hizmetleri A.Ş. (n.d.). SAF (Sürdürülebilir Havacılık Yakıtları). Retrieved from <https://turkishfuel.com/tr/anasayfa/surdurulebilirli/saf-surdurulebilir-havacilik-yakitlari/>
- Thummala, V., & Hiremath, R. B. (2022). Green aviation in India: Airline's implementation for achieving sustainability. *Cleaner and Responsible Consumption*, 7, 100082.
- Torija, A. J., & Self, R. H. (2018). Aircraft classification for efficient modelling of environmental noise impact of aviation. *Journal of Air Transport Management*, 67, 157-168.
- TotalEnergies. (2023). TotalEnergies and Air France: SAF partnerships in aviation. Retrieved from <https://totalenergies.com/media/news/news/air-france-and-totalenergies-join-forces-sustainable-aviation-fuel>
- Transport & Environment. (2023). Above the clouds: European aviation emissions in 2023. Retrieved from https://www.transportenvironment.org/uploads/files/Europe_Aviation_2023_file.pdf
- Trivedi, S., Negi, S., & Tiwari, S. (2024). Business sustainability in aviation industry in post-COVID era through information technology and triple bottom line perspective. *International Journal of Sustainable Aviation*, 10(1), 43-59.
- Türk Hava Yolları. (n.d.). Sürdürülebilir havacılık yakıtı (SAF) nedir?. Retrieved from <https://www.turkishairlines.com/tr-tr/surdurulebilir-hava-yakiti/>
- Türk Standartları Enstitüsü. (n.d.). ICAO CORSIA Doğrulama. Retrieved from <https://www.tse.org.tr/icao-corsia-dogrulama/>
- Türkiye Yüzyılı. (n.d.). Sürdürülebilir Havacılık Yakıtları. Retrieved from <https://www.turkiyeyuzyili.com/proje-surdurulebilir-havacilik-yakitlari>
- Tuzcu, H., Sohret, Y., & Caliskan, H. (2021). Energy, environment and enviroeconomic analyses and assessments of the turbofan engine used in aviation industry. *Environmental Progress & Sustainable Energy*, 40(3), e13547.
- United Airlines. (2023). Corporate responsibility report 2023. Retrieved

- from <https://crreport.united.com/documents/United-2023-CR-Report.pdf>
- Upadhaya, B., Munir, R., Blount, Y., & Su, S. (2018). Diffusion of corporate social responsibility in the airline industry. *International Journal of Operations & Production Management*, 38(4), 1020-1040.
- Vuong, B. N., Voak, A., Hossain, S. F. A., Phuoc, N. T., & Dang, L. H. (2024). The Impact of Corporate Social Responsibility on Customer Loyalty through Brand Trust and Brand Reputation: Evidence from Low-Cost Airlines. *Transportation Research Procedia*, 80, 111-118.
- Wang, B., Ting, Z. J., & Zhao, M. (2024). Sustainable aviation fuels: Key opportunities and challenges in lowering carbon emissions for aviation industry. *Carbon Capture Science & Technology*, 13, 100263.
- Wang, C., Zhang, T., Tian, R., Wang, R., Alam, F., Hossain, M. B., & Illés, C. B. (2024). Corporate social Responsibility's impact on passenger loyalty and satisfaction in the Chinese airport industry: The moderating role of green HRM. *Heliyon*, 10(1).
- World Economic Forum. (2023). Aviation industry net-zero tracker. Retrieved from <https://www.weforum.org/publications/net-zero-industry-tracker-2023/in-full/aviation-industry-net-zero-tracker/>
- Xu, C., Liao, X., Tan, J., Ye, H., & Lu, H. (2020). Recent research progress of unmanned aerial vehicle regulation policies and technologies in urban low altitude. *Ieee Access*, 8, 74175-74194.
- Yang, H., & O'Connell, J. F. (2020). Short-term carbon emissions forecast for aviation industry in Shanghai. *Journal of cleaner production*, 275, 122734.
- Yesil Ekonomi. (2018, March 8). ICAO CORSIA. Retrieved from <https://yesilekonomi.com/icao-corsia/>
- Zaharia, S. E., & Pietreanu, C. V. (2018). Challenges in airport digital transformation. *Transportation research procedia*, 35, 90-99.

Cite this article: Oz, T. (2025). Strategic Pathways to Aviation Sustainability: Insights from Turkish Experts on Regulatory, Technological and Market Responses. *Journal of Aviation*, 9(3), 548-563.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

The Effect of Perceived Level of Institutionalization on Organizational Trust: A Study on Aviation Sector

Murat Sucu^{1*} , Mustafa Kemal Yılmaz² 

^{1*}Independent Researcher, Istanbul, Türkiye. (mur.sucu34@gmail.com)

^{2*}Samsun University, Aviation Management Department, Samsun, Türkiye. (kemal.yilmaz@samsun.edu.tr)

Article Info

Received: 16 April 2025
Revised: 07 August 2025
Accepted: 25 August 2025
Published Online: 09 October 2025

Keywords:

Aviation
Organizational Trust
Institutionalization

Corresponding Author: Murat Sucu

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1677305>

Abstract

Organizational trust is the climate of trust that exists within an organization and can be defined as the positive expectations that organizational members have about the intentions and behaviour of individuals based on relationships and experiences. Institutionalization is defined as the process of transition from the initial structure of a newly established enterprise to the stage where it gains stability. However, institutionalization is defined as a process in which the enterprise gains value and stability through formative practices and increased internal capabilities. Institutionalization is a radical change process that brings change and eliminates routine activities. During this process, people may fear losing their jobs or being unable to succeed in their jobs due to changes and may become silent. Therefore, it is thought that the perceived level of institutionalization influences organizational trust. The population of this study consists of employees working in the civil aviation sector. In the civil aviation sector, there are enterprise such as airlines, ground handling services, catering services and representation services. The employees of these enterprises were tried to be reached via e-mail, WhatsApp groups and social media (linked in, Instagram, Facebook). Data were collected by sending a 5-point Likert-type questionnaire form to the participants. As a result of the analyses, it was determined that there is a significant relationship between perceived level of institutionalization and organizational trust. In addition, perceived level of institutionalization has a significant impact on organizational trust.

1. Introduction

Institutionalization ensures the establishment of a better organization structure by writing the rules and procedures of the enterprises. A strong business structure helps to be more competitive than competitors. Therefore, enterprises that want to become more competitive, increase their market share, and make their operations more efficient are progressing towards institutionalization. Institutionalization brings change and innovation. Change and innovation should be managed well by enterprise managers. Managers should especially focus on the resistance to change and the fear of losing their jobs that may arise due to change.

Employees may be resistant to change due to fear of losing their jobs during the institutionalization process. For this reason, the causes, benefits, and functioning of the change process should be shared with employees, and employees should be involved in the change process. Clearly explaining institutionalization to employees by enterprise managers is of critical importance in preventing possible resistance. In addition, the differences between institutionalized enterprises and enterprises that are not yet institutionalized should be highlighted. If employees trust the enterprise, they will show more performance and make extra effort to achieve the goals of the enterprise. Thus, institutionalization and organizational trust are two concepts that are influenced by each other.

The aviation sector is rapidly growing and developing due to technological advances. This growth and development have led to an increase in the number of employees working in the aviation sector. Due to the large number of employees working in the aviation industry and the nature of the risks involved in this sector, business processes must be clear and rule-based. For this reason, aviation companies must complete their institutionalization processes. Aviation employees must have specific experience in this high-risk sector. Experience is gained through many years of working in the same company. Employees are able to work for many years if they feel confident in their company. Therefore, companies with clear rules and a strong sense of trust among their employees will be preferred. However, competition in the aviation sector is increasing. Companies that have completed their institutionalization processes and have a strong team will be a step ahead of their competitors.

This study is an important reference for companies operating in the aviation sector that have not yet completed their institutionalization processes. A study examining the relationship between institutionalization and organizational trust in the aviation sector has not been found. Therefore, it is expected to make an important contribution to aviation literature.

2. Institutionalization

In the research on enterprises from Scientific Management to the post-World War II period, enterprises were generally considered as rationally constructed instruments to produce goods and services. However, the impact of political and non-rational factors on the results obtained has been repeatedly demonstrated in various studies. Despite this evidence, one of the most important reasons for the continuation of a rational approach in institutionalization studies is the issue of legitimacy. In this context, policies, procedures and structures established by enterprises can be rapidly institutionalized, i.e. they can be widely accepted as the accepted social structures of corporate life. As a result of the policies, procedures, and structures implemented, behaviors in enterprises become predictable. However, since institutionalized practices and procedures are resistant to change, they can also impose significant constraints on the flexibility and adaptability of organizations (Tolbert & Arthur, 1990). It is suggested that resistance to change can bring rigidity to businesses and thus successful organizations may lose their competitive advantage over time (Fleck, 2007). Resistance to change, together with environmental conditions, is recognized as an important factor in the survival and legitimacy of organizations. Faced with long-term changes in environmental conditions, older businesses with institutionalized procedures and policies are at high risk of failure. Any change in the environmental conditions that contribute to institutionalization (disruption in inter-firm relations, reduced environmental capacity and changes in external factors affecting the business) leads to the deterioration of Institutionalization (Tolbert & Arthur, 1990). Therefore, resistance to change and environmental factors stand out as factors that will affect institutionalization.

Before proceeding to the concept of institutionalization, it is necessary to address the concept of institution. Institutions are defined as social structures that have acquired a high degree of resilience. Institutions consist of cultural-cognitive, normative and regulatory elements that provide stability and meaning to social life with their activities and resources (Wiseman, 2007). Institutions can be defined as elements that reduce uncertainty by setting rules in daily life, determining and limiting the preferences of individuals and serving as a guide for human interaction. An institution refers to an organization that has been formed over many years and has a culture that can only change very slowly and has formed a unique culture. For this reason, institutional means the state of having these characteristics and institutionalization means the process of moving towards possessing these characteristics (İşçi, Taştan & Kozal, 2013). Institutionalization is one of the innovation activities in enterprises. Barley and Tolbert (1997) used the concept of institutionalization in structuration theory to better understand 'the processes by which existing institutions are maintained and modified'. According to the authors, organization have a structure in which new practices are continuously introduced and developed, while institutional principles are related to environmental events. Because of this structure, this structuration approach to institutionalization in business provides critical predictions about how practices (routine actions) contribute to the ongoing formation of social structures (institutions) and systems. As institutionalization is considered an innovation activity, it provides enterprises with important information in terms of competitiveness. Innovation activities represent major organizational changes, occurring in radical or disruptive ways. For example, with the emergence of companies such as Uber, a radically changed mode of

transport has emerged and changed the competitive elements in the market (Akaka, Vargo & Wieland, 2017). Besides the competitiveness ability that emerges with institutionalization, economic scientists state that there should be 'non-market strategies' that aim to change the rules of the game to the advantage of the business (Tworek & Buschow, 2016). Among these strategies, institutionalization has an important place. Therefore, it can be said that institutionalization has a structure that aims to gain competitive advantage by developing out-of-market activities in the direction of innovative activities. However, DiMaggio and Powell (1983) mention three mechanisms that lead to institutionalization. These mechanisms are listed as coercive, normative and imitative pressures.

These concepts have been analysed by Scott (1995) as 'three institutional pillars' and by Powell (1991) as 'pathways of institutional reproduction'. Coercive pressure is usually associated with the state and refers to the threat or actual use of force by a powerful actor. Normative pressure often arises as a result of cultural expectations that are felt to be honoured. Imitative pressure refers to the creation of value by imitating behaviour from other actors. Scott (1995) stated that among these three concepts, coercive pressure brings about 'regulatory processes', normative pressure brings about 'normative processes' and imitative pressure brings about 'cognitive processes' (Lawrence, Winn & Jennings, 2001). The coercive, normative and imitative pressures have given rise to the concept of strategic institutionalization and combined them within the framework of new institutionalism. For example, Armenakis et al. (1999) mentioned the empowerment strategy that supports change in institutionalization models (Mugenyi et al., 2022). Strategic institutionalization includes the following elements (Tworek & Buschow, 2016).

- *Economic*: Building alliances with powerful and affluent actors,
- *Effective*: Defining boundaries, memberships, standards and creating identities,
- *Political*: Collaborating with politicians, lobbying,
- *Legal*: It is defined as pressing for new laws and creating new legal institutions.

Strategic institutionalization is analysed within the framework of new institutionalism. Old and new institutionalization are two frequently used concepts among institutionalization theories. Both concepts are claimed to provide structural forms of institutionalization, stability and continuity of behaviours. According to the old institutionalization theory, institutions shape the formation of units in the market, their functions and the relations between units. In addition, institutions employ personnel to create the work to be done and to fulfil the work to be done. Employment and work to be done include financing, managing, training and motivating organizational actions by the personnel in the enterprise. The employment of the personnel who will fulfil these tasks constitutes the basis of the previous institutionalization (Kurt, 2016).

New institutionalization adopts a more holistic approach rather than an in-depth investigation of human activity throughout the institutionalization process (Fleck, 2007). Therefore, it is emphasised that holistic change is necessary before investigating people's behaviour. While human behaviour is an element in holistic change, it is critical how broadly and deeply institutionalization is accepted by

individuals. Institutions with a relatively short history or that have not yet gained widespread acceptance are more vulnerable to being challenged by pressures (Barley & Tolbert, 1997). However, the new institutionalization assumes that businesses play a role in implementing the expectations, values and rules of society. This sociological stream of institutional theory has been used to explain how businesses respond to the pressures of their institutional environment (Jorge, Nogueira & Ribeiro, 2021).

In the literature, some studies that examine the relationship between professionalization and institutionalization processes. These studies discuss the role of professionals in the institutionalization process and the determination of institutional spaces and the establishment of rules because of coercive, normative and imitative pressures (Bresnen, 2013). Thus, it can be said that there is a significant relationship between professionals and institutionalization efforts. In addition, the enterprises that desire competitive advantage and initiate the process of institutionalization against pressures will result in major changes within the enterprise because of cooperation with professionals.

There are different definitions of the concept of institutionalization in the literature. Some of these definitions are as follows. Institutionalization is generally used to describe the process by which social roles, values, norms or behavioural patterns are established within enterprise or societies. According to Huntington, institutionalization is the process by which enterprise and their procedures gain value and stability (Tolbert & Zucker, 1999). Institutionalization is defined as organizational stability, legitimacy, regular, stable and socially integrated structure into the corporate environment and the acceptance of this structure by all employees and managers (İşçi, Taştan & Kozal, 2013). Angelo Panebianco defines institutionalization as the process of transition from the initial structure of a newly established enterprise to a stable stage. Palanza, Scartascini, and Tommasi define institutionalization as a process through which an enterprise gains value and stability through a series of investments, shaping practices, and increasing internal capacities (Palanza, Scartascini & Tommasi, 2016). Institutionalization is defined as a conscious effort to disseminate knowledge at the organizational level and the process by which this knowledge is learned by individuals and groups and the organization's systems, structures and procedures are designed according to this knowledge (Wiseman, 2007). According to Berger and Luckmann (1967), institutionalization define as the mutual harmonisation of actor and action, i.e. the transfer of activities to practices and their subsequent realisation by harmonised actors as part of social roles (Meyer, et al. 2018). Based on these definitions, institutionalization can be defined as the creation of a system in which businesses establish their own standards and procedures independently of individuals, closely follow the changing environmental conditions and have their own culture. Although institutionalization is handled independently of individuals, the process of institutionalization and the survival of corporate identity are still possible with individuals. Thus, it cannot be said that individuals are completely outside the institutionalization system.

2.1. Institutionalization Process

Studies for many years have focused on the characteristics of environmental factors affecting the behaviour of businesses. Lawrence and Lorsch (1967) argued that environmental uncertainty is an important factor in the field of organization. Hannan and Freeman (1977) investigated population density

as the main indicator of organizational survival. Pfeffer and Salancik (1978) argued that the external reliance of enterprise to access valuable resources is important for their survival (Jang, Lee, & Nelson, 2014). Barley and Tolbert (1977) investigate the dynamics of institutionalization and mentioned 4 dynamics. They listed these dynamics as identifying an organization that is under the risk of change during the study period; creating action plans and deriving scenarios; analysing scenarios of change; and linking findings from observational data with other sources of data on changes in the business (Barley & Tolbert, 1997). Goodman and Dean (1982), in their study to determine the degree of institutionalization of enterprises, mentioned that the following issues should be examined for enterprises to be institutionalised (Mugenyi et al., 2022).

- Socialisation or transfer of knowledge about beliefs, preferences, norms and values within the organization,
- Management commitment to people,
- Transferring changes from one subsystem to another to reinforce change,
- The existence of systems to detect deviations from desired behaviour and to take corrective action.

Cummings and Worley (2009), Goodman and Dean (1982) and Jacobs (2002) argued that some characteristics of organizations affect the institutionalization process. The authors mentioned three dimensions in particularly. These dimensions are listed as adaptation, environmental and technological stability and personnel. It is stated that harmonious interventions, stable environments and non-resistant personnel groups within the enterprise are important elements for institutionalization. Clausen and Kragh (2019) stated that a strong and stable business management will support the sustainability of change by providing the necessary resources (Mugenyi et al., 2022). As a result of these studies, it can be stated that internal and external dynamics have a direct impact on the success of the institutionalization process and that the institutionalization process should be carried out within a certain plan.

Institutionalization process is listed as pre-Institutionalization, semi-institutionalization and complete Institutionalization. Pre-institutionalization is defined as the phase in which businesses try to gain social existence. This process, which is also defined as the reflection of the ideas of the business to the society, is a process in which the business attracts attention and consensus is achieved (Meyer, et al. 2018). For example, Zucker (1987) defined this process as the first stage of partial acceptance. After this stage, he said that there is a rapid diffusion stage of institutionalization and finally saturation and full legitimation stages (Lawrence, Winn & Jennings, 2001). At this stage, the structure is not yet a social structure as ideas have not yet turned into actions (Tolbert & Zucker, 1999). It can also be said that at this stage, not all negotiations that take place in enterprises are subject to institutionalization. Decision-making processes can cause different problems within the organization. For example, the unexpected development of new technology and the decision to adopt it or not may require intensive negotiations (Tolbert & Arthur, 1990). Semi-institutionalization refers to a moderate level of institutionalization, where the values and rules that constitute the activity are implemented. There is a gradual transition from an informal to a formal organizational structure. It is defined as the stage in which responsibilities and

authorities, procedures, rules and common organizational values are discussed and tried to be implemented in order to increase the efficiency and effectiveness of the company (Serbest, 2024). After successful pre-institutionalization, existing ideas begin to be experienced beyond individuals. Ideas become theories and begin to spread further (Meyer, et al. 2018). In the process of full institutionalization, it is the stage where the corporate culture is strengthened, and activities are carried out systematically according to the rules, procedures and values determined in writing by all employees (Tur, 2019). In addition, ideas are fully institutionalized at this stage.

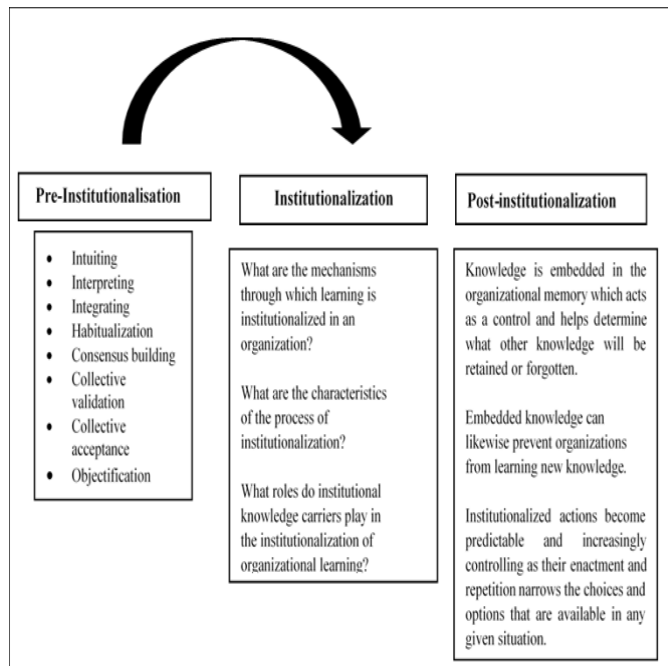


Figure 1. Model of the Institutionalization Process and its Components. Wiseman, 2007:1131.

As seen in Figure 1, in the pre-institutionalization process, ideas, intuitions and interpretations have not yet entered the action stage. At this stage, habituation to the concept of institutionalization, consensus on ideas, acceptance and objectification of the concept come to the fore. In the institutionalization stage, the process of acting by fully understanding the institutionalization process with various questions is expressed. After institutionalization, it is the stage where institutional memory is formed, and actions become predictable and planned thanks to this memory. Zaheer et al. (1999) addressed the concept of time in the process of institutionalization and drew attention to the institutionalization of new practices, rules or technologies and the duration of institutionalization (Dinç & Karakaya, 2014). It is stated that the length of this period increases the efficiency of institutionalization. However, there is also the view that institutionalization does not provide long-term efficiency due to rigidity and resistance to change.

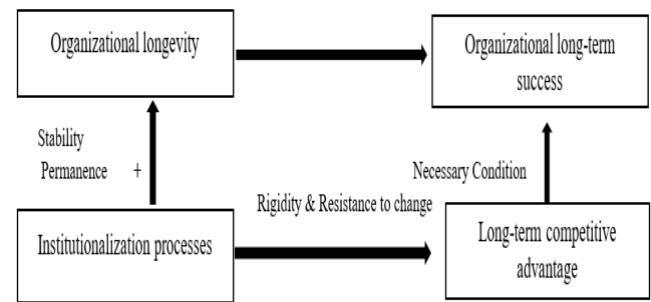


Figure 2. The Effect of Institutionalization Processes on Long-term Success Fleck, 2007: 65.

Figure 2 indicates the impact of institutionalization processes on the long-term success of an enterprise (Fleck, 2007). While institutional life can be long with stability and permanence, rigidity and resistance to change can negatively affect long-term competitive advantage. Long-term success and competitive advantage can be achieved by providing the necessary conditions for institutionalization. Therefore, factors such as competition, resistance to change, rigidity and necessary conditions should not be ignored in the success of the institutionalization process. In this context, institutionalization is a process with advantages and disadvantages that businesses may encounter with obstacles. The obstacles to institutionalization can be listed as insufficient level of professionalization, conflicts between stakeholders, inadequate control processes, conflicts between managers and business partners, tendency to continue old habits, insufficient level of authority given to managers, lack of clear written rules and working based on trust, resistance to change by employees, differences of opinion (Gül, 2012). Possible problems of institutionalization can be listed as employees focusing only on their own work, prolonged decision-making processes, lack of coordination, inability to handle the business at the macro level, and the prominence of the functional structure (Alkış & Temizkan, 2010). The positive aspects of institutionalization in terms of enterprises are as follows: institutionalized enterprises gain a different identity, have a democratic structure, the continuity of the enterprise is ensured, the brand value of the enterprise increases, financial data are positively affected, legitimacy is gained, areas of authority are determined, expert opinions are valued and decision-making processes are more effective (Gül, 2012).

2.2. Human Factor in Institutionalization

Various studies on institutionalization can be found in literature. These studies are general studies that examine the strategy and competitive capabilities of enterprises and the concept of institutionalization. There are few studies on institutionalization and organizational behaviour.

Gül (2012) determined in his study that the managers of accommodation enterprises stated that the institutionalization levels of their enterprises were generally high and accordingly, they stated that their performance was better / higher than that of rival enterprises. Kobanoğlu (2013) determined that there is a strong positive relationship between the institutionalization levels of family businesses and strategic management practices. Furthermore, it was determined that there is a strong positive relationship between the institutionalization levels of family businesses and human resources practices. Temelli (2014) found that institutionalization and organizational capabilities are related. In addition, it was determined that

these two variables have significant relationships with customer value. Kurt (2016) found that as the level of institutionalization increases in hotel enterprises, the use of strategic management tools also increases. Işkın (2017) determined that the increase in the level of institutionalization causes a significant increase in competitive advantage. Duran (2019) determined that the level of institutionalization has a positive effect on job satisfaction. Tur (2019) concluded in his study that there is a significant negative relationship between institutionalization and abusive management. As a result, the employee may consider reacting negatively to their behavior toward them. Ay (2017) found that there is a negative and high-level relationship between institutionalization level and organizational silence.

The impact of human resources, which is the most important element of institutionalization, should not be forgotten, as mentioned in some of the above studies. Due to a lack of institutional awareness, small enterprise structures, and similar reasons, there are situations where the human factor is considered unnecessary. However, the adoption of the idea of institutionalization and the survival of institutionalization is possible with the human factor. For institutionalization to be realized, business owners, managers and employees should perceive institutionalization as a culture (Alkış & Temizkan, 2010). Institutionalized enterprises should give importance to the feelings and thoughts of their employees, must give them clear information about the institutionalization processes. If employees are informed in this way, they will feel more responsible towards the organization and their trust in the business will increase. As the level of institutionalization increases, employees' tolerance for uncertainty increases, and therefore, due to the strong trust in the organization, their efforts to develop positive reactions even in uncertainty increase (Halis & Ay, 2017). The conduct of institutionalization processes by business owners and managers via providing necessary information to their employees also gives an idea about the flexibility dimension of the enterprise. In a study conducted in Konya, it was found that the flexibility dimension of institutionalization is effective on both financial and non-financial performance of the enterprise, while the dimensions of professionalism, simplicity, transparency and consistency are effective only on the non-financial performance of the enterprise (Yurdakul & Bayraktar, 2022). It has been stated that human resources management practices are different between institutionalized enterprises and enterprises that have not yet been institutionalized, and some studies indicate that there is a negative relationship between human resources practices and institutionalization (Akkuş & Bilen, 2020). However, in some studies, the relationship between institutionalization level and organizational silence has been examined and it has been shown that institutionalization levels have a positive and significant effect on organizational silence (Kuşcu, 2019). Within this context, institutionalization processes are closely related to the human factor in enterprise. The effect of the human factor should be taken into consideration in time from the emergence of the institutionalization process as an idea to the realization of the process. Institutionalization is a radical change process that brings change and ends routine activities. In this process, people may be afraid of losing their jobs or failing in the business due to the change and may become silent. Emotions such as organizational silence and fear of losing their jobs may also reduce people's trust in the organization. In this context, the aim of the study is to examine

the effects of the level of institutionalization perceived by employees on their trust in the organization.

3. Organizational Trust

Structural reforms, revised functions and processes that have been taking place in enterprises for a long time have led to significant changes in the behavior of employees. It is stated that due to organizational policies and structural arrangements, trust in the organization among employees has generally decreased. Shaw (1997) argues that employee trust is a critical component for the success of an organization (Singh & Srivastava, 2016). Thus, the importance of trust-based relationships within the organization comes to the surface. Since the mid-1990s, trust has been posited as a source of competitive advantage for businesses. Trust between people and groups within an organization is considered as a critical component for long-term stability and well-being of its members (Guinot, Chiva & Mallén, 2013). In the literature, it is generally emphasized that trust is an important element for individual welfare, organizational performance and socio-economic development of the country. From an organizational perspective, trust is emphasized to ensure successful teamwork through effective communication between colleagues and managers and thus increase employee commitment and productivity (Pučėtaitė, Lāmsā & Novelskaitė, 2010). Due to insufficient individual specialization, complementary knowledge, resources and skills are needed. These needs are fulfilled by individuals transferring information to each other and sharing their experiences. Furthermore, according to Luhmann (1995, 112), every system first tests the bond of trust and then begins to function. Therefore, trust is seen as a necessary premise for co-operation (Blomqvist & Ståhle, 2000). Co-operation requires trusting other people to achieve goals. In this context, trust is considered as a psychological state that indicates the expectation that the behaviour or intentions of another person will be positive (Eroğlu, 2014). Schoorman, Mayer and Davis (2007) mentioned the relationship between trust and risk taking. They stated that trust is the willingness to take risk, and the level of trust is an indicator of the amount of risk that a person is willing to take. If the risk is greater than the feeling of trust (and therefore the willingness to take risk), a management system should be established. For example, in an organization with a culture of transparency, perceived risk levels will be lower. However, if there is a very strong control system in an organization, it is thought that this will prevent the development of trust.

It is possible to find some definitions of trust in philosophy, psychology, sociology and economics. According to Herzberg, trust means having confidence in another person and having a trusting attitude towards the other person. Philosophers emphasized that trust is an attitude and part of the basic behaviour of life, usually at a subconscious level (Paliszkievicz, et al. 2014). According to Mayer, Davis and Schoorman (1995), trust can be defined as the state of being vulnerable to the other party when the other party cannot be controlled or monitored. Therefore, the situation that the person cannot control will put the person in a vulnerable situation and take a risk (Guinot, Chiva & Mallén, 2013). Mishra (1996) argues that trust is the voluntary behaviour of the other party that the person is trustworthy (Eroğlu, 2014). According to Wiersema, trust is based on three components. These components are reliability (the expectation that partners will act in the best interests); predictability (consistency of actions) and belief (that partners will not behave

opportunistically). In the light of these components, trust is generally expressed as an optimistic expectation of a person's behaviour. However, trust is dependent on other people's behaviour and trust is usually associated with voluntary, rather than forced, cooperation and the benefits arising from this cooperation (Paliszkievicz, et al. 2014). At the macro level, trust is expected to emerge in a society where there is honesty, cooperation and shared values. If this situation, which we think is valid for society, is examined at the organizational level, we come across the concept of organizational trust. Organizational trust is the climate of trust within organization and can be defined as the positive expectations of individuals based on relationships and experiences (Türköz, Polat & Coşar, 2013). Vakola & Bouradas (2011) define organizational trust as a psychological state that provides feedback on how employees perceive problems when the organization is in danger (Fard & Karimi, 2015). There is a significant difference between trust in management and trust in the organization. Trust is a framework of interaction influenced by both personality and social system. The definition of managerial trust focuses on the actions of a manager towards a relatively vulnerable employee. Organizational trust, on the other hand, is emphasized to be related to aspects such as acceptance of organizational goals and values and the desire to establish a strong relationship with the organization (Perry & Mankin, 2007). In another definition, organizational trust is the feeling of trust and support within the enterprise and refers to the belief that the employer will be open and will fulfil its commitments. It is thought that trust will keep people together and give them a sense of confidence (Taşkın & Dilek, 2010).

Organizational trust refers to the importance of both individuals and groups in the functioning of an organization. Different findings have been obtained in studies on the formation and development of organizational trust. For example, Anderson et al. (2012) classified organizational trust into five dimensions.

- Organizational trust is considered as an individual psychological issue,
- Organizational trust is considered as perceived experiences,
- Organizational trust refers to positive expectations and trust in the characteristics of the other party,
- Organizational trust is the intention to actively take risks,
- Organizational trust will vary according to the situation.

The importance of both individuals and groups is divided into two as trust with colleagues and managers and trust in the whole organization. As a result of this distinction, two different concepts are introduced. The first of these is called cognitive-based trust. Cognitive-based trust refers to the intention to trust the other party after understanding the evidence that the person is trustworthy. Such evidence is evaluated according to personality, background, intention, ability and promises. The second concept of trust is called emotion-based trust. Emotion-based trust refers to the willingness to trust a person based on emotional attachment to that person. The emotional exchange in interpersonal trust deepens the trust between both parties (Jiang & Chen, 2017). The cognitive component of organizational trust usually refers to a certain level of experience and knowledge about the other actor. Cognition-based trust is based on predictions and calculations, such as the likelihood of the other party's behaviour. This perception of trust implies that one party trusts

the other party because they both follow the same ethical principles and have acted in a trustworthy, competent manner in the past and are expected to behave in the same way in the future. The emotional component is related to the emotional side of trust. For example, Flores and Solomon (1998) stated that trust is first and foremost an effect and involves the reasoning of an emotion. This form of trust usually results from an interaction over a long period of time (Puçetait, Lämsä & Novelskaitė, 2010). Zaheer et al. (1998) argue that interpersonal and organizational trust are related but they are different structures. It is also stated that there may be situations where people trust each other but do not trust their organizations (Blomqvist & Ståhle, 2000). Organizational trust has also been defined as horizontal and vertical. According to McCauley and Kuhnert (1992), horizontal trust refers to the trust that can exist between colleagues or equals who share a similar employment position. Vertical trust, on the other hand, refers to the trust between employees and their immediate superiors, subordinates, top management or organizations as a whole. Therefore, organizational trust includes both types of trust in the organization (Guinot, Chiva & Mallén, 2013).

4. Relationship Between Organizational Trust and Institutionalization

In the literature, there is not found any study examining the relationship between the perceived level of institutionalization and organizational trust in the civil aviation sector. However, it is possible to come across studies in which common elements are addressed in the studies conducted for both concepts. In this section, the studies in which similar elements are discussed will be analyzed.

In today's world, organizations expect their employees to be involved in innovation due to increasing competition and high customer expectations. For organizations to survive, they need people who respond to environmental challenges well, who are not afraid to share knowledge and information, and who strive for their team's beliefs. Although these items emphasized empowerment and open communication channels, most of the employee's state that their organizations have failed in change processes due to communication and information sharing. In addition, one of the biggest obstacles to changing plans is lack of knowledge and trust. However, another factor that prevents change is job satisfaction. Job satisfaction is a person's general attitude towards his/her job. When employees participate in an organization, a series of desires and needs emerge and as a result, job expectations are formed. These needs can be listed as education, learning, information exchange, promotion, security and appropriate work (Fard & Karimi, 2015). Callaway et al. (2007) examined the relationship between organizational trust and job satisfaction and found that trust in the organization positively affects employees' job satisfaction (Fard & Karimi, 2015). According to Gambetta (1988), organizational trust is the confidence of employees that the organization will take meaningful or at least non-harmful action for them. The belief in management, assurance about their actions, honesty and positive expectations are some of the similar components of the construction (Singh & Srivastava, 2016). Institutionalization is a radical change process that brings about change and ends routine activities. In this process, people may become fearful of losing their jobs or failing in the enterprise due to change and may become silent. Another element of institutionalization is the establishment of systems

that will enable information dissemination and learning at the organizational level (Wiseman, 2007). Therefore, in the institutionalization process, the need for information of employees should be met, the fear of losing their jobs should be prevented, management should feel that they will refrain from actions that will harm employees, and employees should be encouraged to take an active role in changing processes. Guchait et al. (2012) suggested that organizational trust is an important dimension in organizational creativity.

Weng et al. (2010) stated that trust in the organization is the basis of the innovation climate and can be developed through the relationship between managers and subordinates (Jiang & Chen, 2017). Institutionalization process is also considered as an innovation activity. Innovation activities represent major institutional changes by emerging in a radical or disruptive way (Akaka, Vargo & Wieland, 2017). In this context, it can be stated that there cannot be innovation in organizations where there is no organizational trust and therefore obstacles may arise in institutionalization processes.

Kobanoğlu (2013) found that there is a strong positive relationship between the level of institutionalization of organizations and human resources practices. Paliszkiewicz, et al. (2014) argue that human resources policies and practices will affect employees' perceptions of trust. Thus, enterprise that want to institutionalize should have human resources policies and practices that both create trust and provide services for institutionalization processes.

Tur (2019) concluded in his study that there is a significant negative relationship between institutionalization and abusive management. As a result, the employee thinks of responding negatively to the behaviors done to him/her. Although it is accepted that trust is a variable that positively affects organizational performance, some researchers have also mentioned the possible harmful effects of trust. For example, Dirks and Ferrin (2001) state that trust can create negativity as well as positivity (Guinot, Chiva & Mallén, 2013). In addition, it has been determined that organizational cynicism can play a mediating role in the relationship between organizational trust and organizational commitment (Türköz, Polat & Coşar, 2013). In this context, the wrong management style in the process of institutionalization may cause employees to respond negatively and organizational trust and business performance may be negatively affected. The purpose of this study is to determine the effect of the perceived level of institutionalization in civil aviation operations on organizational trust, thereby filling a gap in literature.

5. Research Method

5.1. Purpose and Importance of the Research

The purpose of this study is to determine the effect of perceived level of institutionalization on organizational trust in enterprises in the aviation sector. In the literature review, no study dealing with these two variables and conducted in the civil aviation sector was found.

Nowadays, it can be said that institutionalization is essential for businesses to sustain their existence and gain competitive power. Institutionalization of enterprises means that all business and management processes in an organization are linked to rules. Institutionalization means change for enterprises. Changes in business processes, management styles and organizational structure may adversely affect employees. This negative impact can lead to the success or failure of the institutionalization process. Change may be seen as a danger by people and a resistance may develop with the threat of

losing their jobs. Resistance to change may result in slowing down or even stopping the institutionalization process. Therefore, the human factor should not be forgotten in the success of the institutionalization process. If employees trust their organization during the institutionalization process, they may not feel that change is a threat. Therefore, it can be said that organizational trust plays an important role in the success of the institutionalization process.

5.2. Sample and Methodology of the Study

The population of this study consists of employees working in the civil aviation sector. In the civil aviation sector, there are businesses such as airlines, ground handling services, catering services and representation services. The employees of these enterprises were trying to be reached via e-mail, WhatsApp groups and social media (linked in, Instagram, Facebook). Data was collected by sending a 5-point Likert-type questionnaire form to the participants. In the research, a sample that can represent the population was selected from the population, and random sampling was applied with the idea that the sample has a higher power to represent the population. The random sampling method carries the rule of randomness since the probabilities of sampling units to be selected to the sample are equal and independent. However, random sampling methods are stronger than other sampling methods in ensuring representation and the power of the sample to represent the universe is higher (Büyükoztürk et al., 2014:85). In this study, 374 people were reached and included in the analyses.

Hypotheses of the study:

- H₁: There is a significant relationship between perceived level of institutionalization and organizational trust.
- H₂: Perceived level of institutionalization has a significant impact on organizational trust.
- H₃: Perceived level of institutionalization differs according to gender, age, marital status, education, revenue level, work experience, field of work in aviation and job title.
- H₄: Organizational trust differs according to gender, age, marital status, education, revenue level, work experience, field of work in aviation and job title.

5.3 Tools and Data Analysis

In the first part of the questionnaire form, demographic questions were asked to determine the gender, age, marital status, monthly salary, educational status, position in the organization, the field of service in which they work and their total work experience. In the second part, the institutionalization scale used by Aksoy (2021) in his master's thesis was used, which consists of 24 statements and five sub-dimensions: formalization, professionalization, cultural strength, clarity and consistency. For the answers to the statements in the scale, 5-point Likert type (1= Strongly Disagree - 5= Strongly Agree) was used. In the third part of the questionnaire form, the organizational trust scale developed by Adams (2004), adapted into Turkish by Kanten (2012) and used by Apaydın (2023) in his master's thesis was used. The scale consists of 16 statements belonging to the dimensions of trust to manager, trust to colleagues and trust to the organization. For the answers to the statements in the scale, 5-point Likert type (1= Strongly Disagree - 5= Strongly Agree) was used.

The data were analyzed with SPSS v30 statistical data analysis package programme. Correlation analysis was used to measure the relationships between variables, linear regression

analysis was used to determine the effect of variables on each other, and ANOVA and t-tests were used to determine the differences. The conformity of the data obtained within the scope of the research to the normal distribution was examined before the analysis. In order to decide which analysis methods will be used within the scope of the research, it is necessary to examine whether the data show normal distribution. For this purpose, skewness & kurtosis values were examined and as seen Table 1, they were between -1.5 & +1.5. Based on these results, it was concluded that the distribution was normal (Tabachnick & Fidell, 2007: 80-81).

Table 1. The Analysis of Normality (Kurtosis & Skewness)

	Institutionalization	Organizational Trust
n	374	374
Mean	4.07	3.99
Std. Deviation	.6888	.7441
Skewness	-.355	-.146
Kurtosis	-1.075	-1.414

5.4. Findings

As seen in Table 2, the participants consisted of 265 (70.9%) males. The number of female participants is 109 (29.1%). The age group of participants is 36-45 years old with 149 participants (39.8%). The revenue level has the highest rate (31.3%) with 80.001-100.000 TL.

Table 2. Demographic Characteristics of the Population

Gender		
	n	%
Male	265	70.9
Female	109	29.1
Age		
18-25	96	25.7
26-35	88	23.5
36-45	149	39.8
46-55	41	11.0
Revenue Level		
20.000 - 40.000TL	61	16.3
40.001 - 60.000TL	83	22.2
60.001 - 80.000TL	72	19.3
80.001 - 100.000TL	117	31.3
More than 100.000TL	41	11.0
Field of Work in Aviation		
Ground Handling	285	76.2
Airport	36	9.6
Airline	53	14.2
Marital Status		
Married	241	64.4
Single	133	35.6
Education		
Associate degree	20	5.3
Undergraduate	253	67.6
Postgraduate	101	27.0
Length of Work Experience		
Less than 5 years	130	34.8
5-10 years	45	12.0
11-15 years	134	35.8
16-20 years	48	12.8
More than 20 years	17	4.5
Job Title		
Upper-Level Manager (Director and above)	65	17.4
Middle-Level Manager (Chief. Shift Manager. etc.)	141	37.7
Lower-Level Employee (Expert. Officer. etc.)	168	44.9

Analyses results applied to calculate the factor loadings of institutionalization scale and organizational trust scale are shown in Table 3. The KMO value of the factor analysis results

related to institutionalization scale was calculated as 0.791. The KMO value for the organizational trust scale was calculated as 0.856. This shows that the sample size is adequate.

Table 3. KMO and Bartlett Test Result

Sampling Adequacy of Institutionalization Scale			
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.			0.791
Bartlett's Test of Sphericity	Approx. Chi-Square	12500.330	
	df	276.000	
	p*	0.000	
* p<0,01			
Sampling Adequacy of Organizational Trust Scale			
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.			0.856
Bartlett's Test of Sphericity	Approx. Chi-Square	7781.482	
	df	120.000	
	p*	0.000	
* p<0,01			

The results of the factor analysis of institutionalization are shown in Table 4. Cronbach's Alpha value for the institutionalization scale is 0.964. If Cronbach's Alpha value is $0.80 \leq \alpha < 1.00$, the scale is highly reliable (Terzi, 2019:13). Explained variance is %78.

Table 4. Factor Analysis of the Institutionalization Scales

	n	Mean	Std. Deviation	Variance %	Cronbach's Alpha
Q1	374	4.45	.559		
Q2	374	4.48	.561		
Q3	374	4.46	.665		
Q4	374	4.17	.988		
Q5	374	4.36	.864		
Q6	374	4.07	1.016		
Q7	374	3.79	1.136		
Q8	374	3.90	.958		
Q9	374	4.03	.929	.784	.964
Q10	374	3.85	1.054		
Q11	374	3.72	1.146		
Q12	374	3.65	1.282		
Q13	374	4.03	.893		
Q14	374	4.15	.914		
Q15	374	3.94	.980		
Q16	374	3.93	1.010		
Q17	374	3.85	1.084		
Q18	374	4.12	0.865		
Q19	374	4.01	0.922		
Q20	374	4.43	0.495		
Q21	374	4.23	0.752		
Q22	374	4.11	0.783		
Q23	374	4.21	0.787		
Q24	374	3.85	1.142		

The results of the factor analysis of organizational trust are shown in Table 5. Cronbach's Alpha value for the institutionalization scale is 0.953. If Cronbach's Alpha value

is $0.80 \leq \alpha < 1.00$, the scale is highly reliable (Terzi, 2019:13). Explained variance is %78.

Table 5. Factor Analysis of the Organizational Trust

	n	Mean	Std. Deviation	Variance %	Cronbach's Alpha
Q1	374	4.26	0.761	.786	.953
Q2	374	4.05	0.904		
Q3	374	4.35	0.784		
Q4	374	4.23	0.940		
Q5	374	4.07	1.016		
Q6	374	4.16	0.763		
Q7	374	3.76	1.148		
Q8	374	3.81	1.148		
Q9	374	4.35	0.597		
Q10	374	3.91	1.088		
Q11	374	3.63	1.166		
Q12	374	3.80	1.021		
Q13	374	3.90	1.113		
Q14	374	4.04	0.786		
Q15	374	4.15	0.760		
Q16	374	3.39	1.281		

The Pearson correlation analysis conducted for the first hypothesis of our research. Pearson correlation analysis in Table 6 shows that there is a strong and positive relationship ($r = .856$; $p < 0.01$) between institutionalization and the organizational Trust. In this context, H_1 : "There is a significant relationship between perceived level of institutionalization and organizational trust" is confirmed.

Table 6. The Relationship Institutionalization and Organizational Trust

	Organizational Trust	
Institutionalization	Pearson Correlation	.856
	p*	.000
	n	374

* $p < 0.05$

The regression analysis conducted for the second hypothesis of our research. Regression analysis in Table 7 shows that R^2 value, which is the explanatory power of the model: 0.733 and significance level $p < .001$ ($\beta = 0.925$; $R^2 = 0.733$; $p < 0.01$). This value shows that 73.3% of the dependent variable (variance) of the organizational trust is explained by the independent variable in the model and $\beta = 0.925$. In this context, it is seen that institutionalization has a significant impact on the organizational trust. Thus, our hypothesis H_2 : "Perceived level of institutionalization has a significant impact on organizational trust" is confirmed.

Table 7. The Effect of Institutionalization on Organizational Trust

	β	R^2	t	p*
Institutionalization	.925	.733	31.985	.000

Dependent Variable: Organizational Trust

* $p < 0.05$

The results of the ANOVA test are shown in Table 8 (Table 8 is given on page 576). It is seen that the perceived level of institutionalization differs in the 46-55 age group ($x = 4.56$) compared to other age groups. Also, associate degree ($x = 4.87$); revenue level in the range of 80.001-100.000 TL ($x = 4.67$); 5-10 years of employment ($x = 4.62$); employees working at the airport as their field of work ($x = 4.23$) and finally middle level managers ($x = 4.45$) differences according to their groups.

As seen in Table 9, according to the t-test result, married ($x = 4.20$) and male ($x = 4.15$) participants show a difference in the perception of institutionalization compared to other groups.

Table 9. T test Results of Institutionalization

The Relationship of Institutionalization and Gender - T Test					
	n	Mean	Std. Deviation	t	p
Male	265	4.1591	0.65800	3.794	.000
Female	109	3.8670	0.72052		

The Relationship of Institutionalization and Marital Status- T Test					
	n	Mean	Std. Deviation	t	p
Married	241	4.2061	0.55771	5.162	.000
Single	133	3.8346	0.82793		

* $p < .05$

The results of the ANOVA test are shown in Table 10 (Table 10 is given on page 577). It is seen that the perceived level of organizational trust differs in the 46-55 age group ($x = 4.61$) compared to other age groups. Also, associate degree ($x = 4.87$); revenue level in the range of 80.001-100.000 TL ($x = 4.74$); more than 20 years of employment ($x = 4.68$) and finally middle level managers ($x = 4.39$) differences according to their groups.

As seen in Table 11, according to the t-test result, married ($x = 4.11$) and male ($x = 4.15$) participants show a difference in the perception of institutionalization compared to other groups.

Table 11. T test Results of Organizational Trust

The Relationship of Organizational Trust and Gender - T Test					
	n	Mean	Std. Deviation	t	p
Male	265	4.1507	0.63122	6.902	.000
Female	109	3.5998	0.84925		

The Relationship of Organizational Trust and Marital Status - T Test					
	n	Mean	Std. Deviation	t	p
Married	241	4.1172	0.69721	4.563	.000
Single	133	3.7599	0.77319		

* $p < 0.05$

According to the results of ANOVA and t-test on institutionalizations, gender, age, marital status, education, revenue level, work experience, field of work in aviation and job title were found to be differentiated. Thus, our hypothesis H_3 : "Perceived level of institutionalization differs according to gender, age, marital status, education, revenue level, work experience, field of work in aviation and job title" is accepted.

According to the results of ANOVA and t-test on organizational trust, marital status, education, revenue level, work experience and job title were found to be differentiated. However, no difference was found in the field work in aviation. Thus, our hypothesis H₄: “Organizational trust differs according to gender, age, marital status, education, revenue level, work experience, field of work in aviation and job title” is partial accepted.

6. Discussion

The purpose of this study is to determine the effect of perceived level of institutionalization on organizational trust in enterprises in the aviation sector. In the literature review, no study dealing with these two variables and conducted in the civil aviation sector was found. The findings of the study reveal important results in terms of understanding the impact of institutionalization on the trust of employees in enterprises which are in the process of institutionalization or have already been institutionalized. By encouraging a culture of trust and empowering employees, organizations can create an environment that fosters creativity, innovation and ultimately organizational success.

The study's findings align with previous research. Callaway et al. (2007) examined the relationship between organizational trust and job satisfaction and found that trust in the organization positively affects employees' job satisfaction (Fard & Karimi, 2015). Institutionalization is a radical change process that brings about change and ends routine activities. In this process, people may become fearful of losing their jobs or failing in the enterprise due to change and may become silent. Another element of institutionalization is the establishment of systems that will enable information dissemination and learning at the organizational level (Wiseman, 2007). Also, In the literature, it is generally emphasized that trust is an important element for individual welfare and organizational performance. According to organizational perspective, trust is emphasized to ensure successful teamwork through effective communication between colleagues and managers and thus increase employee commitment and productivity (Pučetaitė, Lāmsā & Novelskaitė, 2010). These studies suggest that, in order to meet the demand for skilled and experienced workers in the aviation sector, it is essential that employees are satisfied with their jobs. Employee satisfaction is achieved through trust in the company. Organizational trust provides an environment in which employees can work without fear of losing their jobs and can continue their careers based on their performance. Furthermore, it can be said that employees in companies that have completed the institutionalization process experience less fear of job loss. In addition, institutionalized companies try to develop their employees through continuous training. These training programs and information help create experienced and skilled employees who are needed in the aviation sector. As a result, specialized employees will work with less fear of job loss and improve their performance. Enterprises with high-performing teams will be more competitive than their competitors in a competitive environment.

The aviation sector is rapidly changing and needs new ideas due to changes in passenger demands, new aircraft models, and the diversity of services offered at airports. For this reason, the aviation sector has become open to innovation. There are studies on the relationship between institutionalization and innovation. For example, Akaka, Vargo & Wieland (2017) emphasize that, institutionalization process is also considered as an innovation activity. Therefore, institutionalized

companies in the aviation sector will be able to generate innovation.

Studies in the literature and this study show that the perceived level of institutionalization has an impact on employees' trust in the enterprise. However, perceived institutionalization and organizational trust differ according to the age, education, revenue, gender, length of work experience, job title and marital status of the employees. It is thought that these findings will be a guide in determining the groups that enterprises will focus on in order to increase the perception of trust.

6.1. Implications

Theoretical Implications:

This study is an empirical study to determine the perceived level of institutionalization and organizational trust of the employees in the civil aviation sector. These findings provide a better understanding of the concepts of perceived institutionalizations level and organizational trust.

Practical Implications:

Aviation Industry Managers: The findings indicate the trust of employees towards institutionalized organizations. Managers should do the necessary work to prevent employees' fear of job loss and increase organizational trust in the process of institutionalization and should be in close communication with employees.

Aviation Sector Organizations: Enterprises that are in the process of institutionalization or have completed the process of institutionalization should take the necessary actions to protect the trust of employees in the organization. In the process of institutionalization, the feelings of the employees should not be ignored. In the process of institutionalization, demographic differences among employees may cause the process to be prolonged or difficult. For this reason, aviation sector enterprises should get to know their employees more closely.

6.2. Limitations and Future Research Directions

This study has some limitations even though it has important findings. Among the limitations are part-time and shift work of aviation sector employees. In addition, most of the enterprises operating in the civil aviation sector have completed their institutionalization processes. Therefore, future studies can be conducted in enterprises that have not yet been institutionalized and in different sectors.

7. Conclusion

This study provides valuable insights into the impact of aviation employees' perceptions of institutionalization level on organizational trust. The results show that the perceived level of institutionalization is effective on employees' trust in their organizations. For this reason, enterprises in the civil aviation sector and their managers should pay attention to prevent loss of employees' trust in institutionalization processes. In addition, the fact that employees have a voice in managerial decisions can easily present their ideas about change and do not fear job loss increases their trust in the organization.

Ethical approval

Approval for this research was authorized by Samsun University Ethics Committee under decision number 2024/92 and dated 11.12.2024.

Conflicts of Interest

The authors declare that there are no conflicting interests associated with the publication of this document.

References

- Akaka, M. A., Vargo, S. L. & Wieland, H. (2017). Extending the Context of Innovation: The Co-Creation & Institutionalization of Technology & Markets. *Innovating in Practice: Perspectives & Experiences*. 43-57.
- Akkus, B. and Bilen, A. (2020). Investigating the Relationship Between Human Resource Management Practices and Institutionalization in Organizations. *Munzur University Journal of Social Sciences*, 9(1), 38-55.
- Alkis, H. and Temizkan, V. (2010). Determining the Institutionalization Levels of Businesses: (Rolling Mills) The Case of the Karabuk Iron and Steel Sector. *Journal of Economic Approach*, C, 21, 73-92.
- Kuşcu, F. N. (2019). Yönetimde Profesyonelleşme Algısının Kurumsallaşma Üzerine Etkisi: Sağlık Çalışanlarında Bir Uygulama. Yüksek Lisans Tezi. T.C. Kahramanmaraş Sütçü İmam Üniversitesi Sosyal Bilimler Enstitüsü Sağlık Yönetimi Ana Bilim Dalı. Kahramanmaraş.
- Ay, A. D. (2017). Örgütsel Sessizlik ve Kurumsallaşma Düzeyi Arasındaki İlişki: Kastamonu Üniversitesi Örneği. T.C. Kastamonu Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı İşletme Bilim Dalı. Yüksek Lisans Tezi. Kastamonu.
- Barley, S. R. & Tolbert, P. S. (1997). Institutionalization & Structuration: Studying The Links Between Action & Institution. *Organization Studies*, 18(1), 93-117.
- Blomqvist, K. & Stähle, P. (2000). Building Organizational Trust. In 16th Annual IMP Conference, Bath, UK (7-9).
- Büyükköztürk Ş., Çakmak, E., Akgün, Ö., E., Karadeniz, Ş. ve Demirel, F. (2014). *Bilimsel Araştırma Yöntemleri*, 15. Baskı, Pegem, Ankara.
- Dinc, E. and Karakaya, A. (2014). A Study on the Relationship Between Accounting Information Systems and Institutionalization Level. *Selcuk University Faculty of Economics and Administrative Sciences Journal of Social and Economic Research*, 14 (27), 21-50.
- Duran, A. (2019). Kurumsallaşma Düzeyi İle İş Tatmini, Açıkça Konuşma İsteği ve İşten Ayrılma Niyeti Arasındaki İlişki: Otel Çalışanları Üzerinde Bir Araştırma. Doktora Tezi. Mersin Üniversitesi Sosyal Bilimler Enstitüsü Turizm İşletmeciliği Anabilim Dalı. Mersin.
- Eroglu, S. G. (2014). The Effects of Employees' Perceptions of Organizational Justice on Organizational Trust. *Pamukkale Journal of Business and Information Management*, (1), 53-66.
- Fard, P. G. & Karimi, F. (2015). The Relationship Between Organizational Trust & Organizational Silence with Job Satisfaction & Organizational Commitment of the Employees of University. *International Education Studies*, 8(11), 219-227.
- Fleck, D. (2007). Institutionalization & Organizational Long-Term Success. *BAR-Brazilian Administration Review*, 4, 64-80.
- Guinot, J., Chiva, R. & Mallén, F. (2013). Organizational Trust & Performance: Is Organizational Learning Capability a Missing Link? *Journal of Management & Organization*, 19(5), 559-582.
- Gül, H. (2012). İşletmelerdeki Kurumsallaşma Düzeyinin İşletme Performansına Etkisi: Konaklama İşletmelerinde Bir Uygulama. Yüksek Lisans Tezi. T.C. Nevşehir Üniversitesi Sosyal Bilimler Enstitüsü. Nevşehir.
- Halis, M. and Ay, D. A. (2017). The Effect of Institutionalization Level on Organizational Silence: A Research. *Cumhuriyet University Journal of Economics and Administrative Sciences*, 18(2), 43-62.
- Işkın, M. (2017). Kurumsallaşma Düzeyinin Rekabet Üstünlüğü ve Markalaşma Üzerine Etkisi: Sivas Sanayi İşletmeleri Üzerine Bir Araştırma. Doktora Tezi. Cumhuriyet Üniversitesi Sosyal Bilimler Enstitüsü İşletme Ana Bilim Dalı Yönetim Organizasyon Bilim Dalı. Sivas.
- Isci, E., Tastan, S. B., & Kozal, M. A. (2013). Examining the Effect of Institutionalization Level in Organizations on Nepotism: The Case of Hospital Employees. *Journal of Political, Economic, and Management Studies*, 1(3), 61-83.
- Jang, S. H., Lee, B. K. & Nelson, S. A. (2014). Institutionalization Strategy Enhancing Firm Resources: Isomorphism from Firms & its Strategic Implications. *Journal of Management & Strategy*, 5(3), 1.
- Jiang, Y. & Chen, W. K. (2017). Effects of Organizational Trust on Organizational Learning & Creativity. *Eurasia Journal of Mathematics, Science & Technology Education*, 13(6), 2057-2068.
- Jorge, S., Nogueira, S. P. & Ribeiro, N. (2021). The Institutionalization of Public Sector Accounting Reforms: The Role of Pilot Entities. *Journal of Public Budgeting, Accounting & Financial Management*, 33(2), 114-137.
- Kobanoğlu, S. M. (2013). Aile İşletmelerinde Kurumsallaşma Düzeyi ile Stratejik Yönetim ve İnsan Kaynakları Yönetimi Uygulamaları Arasındaki İlişkinin İncelenmesi: Erzurum Alt Bölgesinde Bir Uygulama. Doktora Tezi. Atatürk Üniversitesi Sosyal Bilimler Enstitüsü İşletme Ana Bilim Dalı. Erzurum.
- Kurt, S. (2016). Otel İşletmelerinde Stratejik Yönetim Araçları Kullanımı ile Kurumsallaşma Düzeyi Arasındaki İlişki. Yüksek Lisans Tezi. Gazi Üniversitesi Sosyal Bilimler Enstitüsü Turizm İşletmeciliği Anabilim Dalı Turizm İşletmeciliği Bilim Dalı. Ankara.
- Lawrence, T. B., Winn, M. I. & Jennings, P. D. (2001). The Temporal Dynamics of Institutionalization. *Academy of Management Review*, 26(4), 624-644.
- Meyer, R. E., Jancsary, D., Höllerer, M. A. & Boxenbaum, E. (2018). The Role of Verbal & Visual Text in The Process of Institutionalization. *Academy of Management Review*, 43(3), 392-418.
- Bresnen, M. (2013) Advancing a 'New Professionalism': Professionalization, Practice & Institutionalization. *Building Research & Information*, 41:6, 735-741.
- Mugenyi, A. R., Karemera, C., Wesana, J. & Dooms, M. (2022). Institutionalization of Organizational Change Outcomes in Development Cooperation Projects: The Mediating Role of Internal Stakeholder Change-Related Beliefs. *Administrative Sciences*, 12(2), 60.
- Palanza, V., Scartascini, C. & Tommasi, M. (2016). Congressional Institutionalization: A Cross-National Comparison. *Legislative Studies Quarterly*, 41(1), 7-34.

- Paliszkiewicz, J., Koohang, A., Gołuchowski, J. & Horn Nord, J. (2014). Management Trust, Organizational Trust, & Organizational Performance: Advancing & Measuring A Theoretical Model. *Management & Production Engineering Review*, 5(1), 32-41.
- Perry, R. W. & Mankin, L. D. (2007). Organizational Trust, Trust in The Chief Executive & Work Satisfaction. *Public Personnel Management*, 36(2), 165-179.
- Pučetaitė, R., Lämsä, A. M. & Novelskaitė, A. (2010). Building Organizational Trust in a Low-Trust Societal Context. *Baltic Journal of Management*, 5(2), 197-217.
- Schoorman, F. D., Mayer, R. C. & Davis, J. H. (2007). An Integrative Model of Organizational Trust: Past, Present, & Future. *Academy of Management Review*, 32(2), 344-354.
- Serbest, A. (2024). Kurumsallaşma Düzeyi İle Örgütsel Bağlılık İlişkisinde İşten Ayrılma Niyetinin Aracılık Rolü: İstanbul'da Beyaz Yakalılar Üzerinde Bir Araştırma. Doktora Tezi. T.C. İstanbul Kültür Üniversitesi İşletme Anabilim Dalı Lisansüstü Eğitim Enstitüsü. İstanbul.
- Singh, U. & Srivastava, K. B. (2016). Organizational Trust & Organizational Citizenship Behaviour. *Global Business Review*, 17(3), 594-609.
- Tabachnick, B. G. & Fidell, L. S. (2007). *Using Multivariate Statistics* (Vol. 5). Boston, MA: Pearson.
- Taskin, F. and Dilek, R. (2010). A Field Study on Organizational Trust and Organizational Commitment. *Journal of Organization and Management Sciences*, 2(1), 37-46.
- Temelli, E. U. (2014). Kurumsallaşma Düzeyinin Örgütsel Yetenekler Açısından İnşaat Sektöründe Algılanan Müşteri Değerine Etkisi. Doktora Tezi. T.C. İstanbul Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı İşletme Yönetimi ve Organizasyon Bilim Dalı. İstanbul.
- Terzi, Y. (2019). Questionnaire, Reliability-Validity Analysis. Ondokuz Mayıs University, Samsun https://Personnel.Omu.Edu.Tr/Ders_Dokumanlari/1030_32625_1500.Pdf, 21, 2023.
- Tolbert, P. S. & Zucker, L. G. (1999). The Institutionalization of Institutional Theory. *Studying Organization. Theory & Method*, 1, 169-184.
- Tolbert, P. S. & Arthur, J. B. (1990). Institutionalization & Negotiations in Organizations.
- Tur, Ç. T. (2019). İşletmelerde Kurumsallaşma Düzeyi, İstismarcı Yönetim ve Üretkenlik Karşısı İş Davranışı İlişkisi. Yüksek Lisans Tezi. T.C. Balıkesir Üniversitesi Sosyal Bilimler Enstitüsü İşletme Ana Bilim Dalı. Balıkesir.
- Turkoz, T., Polat, M., & Coşar, S. (2013). The Role of Employees' Organizational Trust and Cynicism Perceptions on Their Organizational Commitment. *Journal of Management and Economics*, 20(2), 285-302.
- Tworek, H. J. & Buschow, C. (2016). Changing the Rules of the Game: Strategic Institutionalization & Legacy Companies' Resistance to New Media. *International Journal of Communication*, 10, 21.
- Yazıcıoğlu, Y. ve Erdoğan, S. (2004). *SPSS Uygulamalı Bilimsel Araştırma Yöntemleri*. Ankara: Detay Yayıncılık.
- Yurdakul, S. and Bayraktar, O. (2022). Examining the Relationship Between Institutionalization Level and Organizational Performance in Family Businesses. *Istanbul Commerce University Journal of Social Sciences*, 21(43), 504-527.
- Wiseman, E. (2007). The Institutionalization of Organizational Learning: A Neo-Institutional Perspective. *Proceedings of OLKC*, 1114.

Cite this article: Sucu, M., Yilmaz, M.K. (2025). The Effect of Perceived Level of Institutionalization on Organizational Trust: A Study on Aviation Sector. *Journal of Aviation*, 9(3), 564-577.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Table 8. ANOVA Test Results of Institutionalization

The Relationship of Institutionalization and Age- ANOVA					
Institutionalization	n	Mean	Std. Deviation	F	p**
18-25	96	3.7240	0.72546	20,198	.000**
26-35	88	4.2618	.72196		
36-45	149	4.0529	.61319		
46-55	41	4.5671	.16321		
Total	374	4.0740	0.68878		
The Relationship of Institutionalization and Education - ANOVA					
Institutionalization	n	Mean	Std. Deviation	F*	p**
Associate Degree	20	4.8750	.09559	15.561	.000**
Undergraduate	253	4.0412	.71567		
Postgraduate	101	3.9975	.58327		
Total	374	4.0740	.68878		
The Relationship of Institutionalization and Revenue - ANOVA					
Institutionalization	n	Mean	Std. Deviation	F*	p**
20.000 - 40.000TL	61	3.4146	0.70096	87.919	.000**
40.001 - 60.000TL	83	4.0025	0.66155		
60.001 - 80.000TL	72	3.6181	.43968		
80.001 - 100.000TL	117	4.6788	0.23399		
More than 100.000TL	41	4.2744	0.35927		
Total	374	4.0740	0.68878		
The Relationship of Institutionalization and Length of Work Experience - ANOVA					
Institutionalization	n	Mean	Std. Deviation	F	p**
Less than 5 years	130	3.8458	.81917	13.890	.000**
5-10 years	45	4.6204	0.19507		
11-15 years	134	4.0525	0.61956		
16-20 years	48	4.0938	.54608		
More than 20 years	17	4.4853	0.17613		
Total	374	4.0740	.68878		
The Relationship of Institutionalization and Field of Work in Aviation - ANOVA					
Institutionalization	n	Mean	Std. Deviation	F	p**
Ground Handling	285	4.1127	.69031	7.356	.001**
Airport	36	4.2361	.54591		
Airline	53	3.7555	.68563		
Total	374	4.0740	.68878		
The Relationship of Institutionalization and Job Title - ANOVA					
Institutionalization	n	Mean	Std. Deviation	F	p**
Upper-Level Manager (Director and above)	65	4.2885	.39089	73.753	.000**
Middle-Level Manager (Chief. Shift Manager. etc.)	141	4.4533	.44094		
Lower-Level Employee (Expert. Officer. etc.)	168	3.6726	0.73256		
Total	374	4.0740	.68878		

* According to the variance equality; (p<0.01 and p<0.05) Tukey or Tamhane Tests were applied. ** p<.01 and p<.05

Table 10. ANOVA Test Results of Organizational Trust

The Relationship of Organizational Trust and Age - ANOVA					
Organizational Trust	n	Mean	Std. Deviation	F	p**
18-25	96	3.5000	0.62907	36.027	.000**
26-35	88	4.2855	.64158		
36-45	149	3.9606	0.75258		
46-55	41	4.6113	.25522		
Total	374	3.9901	0.74410		
The Relationship of Organizational Trust and Education - ANOVA					
Organizational Trust	n	Mean	Std. Deviation	F	p**
Associate Degree	20	4.8594	.18348	15.587	.000**
Undergraduate	253	3.9340	0.75160		
Postgraduate	101	3.9585	0.68933		
Total	374	3.9901	0.74410		
The Relationship of Organizational Trust and Revenue - ANOVA					
Organizational Trust	n	Mean	Std. Deviation	F	p**
20.000 - 40.000TL	61	3.2982	0.69310	61.810	.000**
40.001 - 60.000TL	83	3.6483	0.60633		
60.001 - 80.000TL	72	3.4896	0.31135		
80.001 - 100.000TL	117	4.7415	0.25267		
More than 100.000TL	41	4.4466	.20802		
Total	374	3.9901	0.74410		
The Relationship of Organizational Trust and Length of Work Experience - ANOVA					
Organizational Trust	n	Mean	Std. Deviation	F	p**
Less than 5 years	130	3.7188	0.72680	20.568	.000**
5-10 years	45	4.6389	0.25937		
11-15 years	134	4.0005	0.72760		
16-20 years	48	3.8438	0.76122		
More than 20 years	17	4.6801	0.08806		
Total	374	3.9901	.74410		
The Relationship of Organizational Trust and Field of Work in Aviation - ANOVA					
Organizational Trust	n	Mean	Std. Deviation	F	p**
Ground Handling	285	4.0002	.82489	1.265	.283**
Airport	36	3.8125	.31481		
Airline	53	4.0566	.40212		
Total	374	3.9901	.74410		
The Relationship of Organizational Trust and Job Title - ANOVA					
Organizational Trust	n	Mean	Std. Deviation	F	p**
Upper-Level Manager (Director and above)	65	4.3048	0.5563	86.862	.000**
Middle-Level Manager (Chief. Shift Manager. etc.)	141	4.3972	0.6287		
Lower-Level Employee (Expert. Officer. etc.)	168	3.5268	0.6263		
Total	374	3.9901	0.7441		

* According to the variance equality; (p<0.01 and p<0.05) Tukey or Tamhane Tests were applied. ** p<.01 and p<.05

Environmental Sustainability Performance in Aviation: An Analysis Based on Stakeholders' Sustainability Reports

Güzide Karakuş¹ 

¹Necmettin Erbakan University, Faculty of Aviation and Space Sciences / Department of Aviation Management, Meram, Konya, Türkiye.
(gkarakus@erbakan.edu.tr)

Article Info

Received: 21 April 2025
Revised: 07 August 2025
Accepted: 25 August 2025
Published Online: 09 October 2025

Keywords:

Aviation industry
Environmental sustainability
Green aviation
Sustainable aviation
Sustainability reporting

Corresponding Author: [Güzide Karakuş](mailto:Guzide.Karakus@erbakan.edu.tr)

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1681077>

Abstract

As global sustainability efforts gain momentum, large-scale enterprises across various industries increasingly disclose their environmental impacts, goals, and improvement initiatives through sustainability reports. The aviation industry, characterized by continuous growth in parallel with the global economy, plays a complex role in sustainability, contributing both positively and negatively across its dimensions. Understanding the performance of industry stakeholders in reducing environmental impacts is therefore of critical importance and serves as the main motivation for this study.

This research aims to evaluate the environmental sustainability performance of key stakeholders in the aviation sector. An exploratory case study methodology was employed, analyzing the sustainability reports of selected aviation companies in Turkey for the years 2021 and 2022. Using descriptive analysis, data disclosed under environmental sustainability categories were examined on a company basis, summarized, converted into comparative tables, and evaluated across eight key indicators.

The findings reveal that İGA achieved improvements in three out of eight indicators, TAV in five, Turkish Airlines (THY) in one, while Pegasus did not show any improvement in the indicators examined. Overall, the results indicate that the environmental performance of aviation stakeholders in Türkiye is insufficient in terms of reducing their environmental impacts.

1. Introduction

As the impacts of climate change increasingly escalate to a crisis level, governments continue to extend their preventive measures against global warming toward long-term targets. However, every delayed action negatively affects the right to a sustainable life that we promise to future generations. Sustainability, in its simplest definition, refers to the transfer of existing resources to future generations. It involves the continued use and management of life-sustaining resources without their complete depletion or irreversible damage (Ballı, 2019).

Constructed upon three main pillars—environmental, social, and economic—sustainability encompasses a complex structure that requires examination at multiple levels involving stakeholders such as governments, businesses, employees, the public, civil society organizations, and resource managers (Dil & Talaş, 2021). Although all dimensions of sustainability are critically important, the environmental dimension is the most frequently addressed topic in the scientific literature (Adubor, Adeniji, Salau, Olajugba & Onibudo, 2022).

Environmental sustainability is often referred to in the literature as environmentally conscious business practices, green management, or ecological management. It reflects an understanding whereby businesses consider environmental impacts throughout their entire production and support

processes, provide environmental awareness training to employees, adopt technologies that do not harm the environment, and aim to minimize environmental effects in their operational activities (Karakuş, Karşıgil & Polat, 2018). The intensification of climate change impacts and the rising environmental awareness have exerted pressure on businesses worldwide to restructure their strategic orientations and capabilities in line with sustainable development (Roxas & Coetzer, 2012). This pressure has also prompted the aviation industry to take action.

Aviation is one of the fastest-growing and most innovative sectors in the world and holds a significant place within the global economy. While the sector continues to progress economically in response to increasing customer demand, it also aims to maintain a balance with regard to social development and environmental responsibility (Karakuş, 2023). Although aviation fosters economic growth by facilitating the global movement of people and goods, concerns persist regarding its impact on noise pollution, air and water quality, biodiversity, and climate change (Marais & Waitz, 2009). Despite its positive influence on global trade, the sector's environmentally unsustainable nature positions it as a priority area for green transformation (Sak & Karakuş, 2024).

It is crucial to identify the environmental sustainability indicators used by stakeholders operating in the aviation sector, to determine areas requiring improvement, and to

contribute to the dissemination of best practices. Considering the importance of the issue, this study aims to reveal the environmental impact indicators resulting from the operations of aviation industry stakeholders and their performance in relation to these indicators through a descriptive analysis method. Within this context, the study seeks to answer the following research questions:

- *What are the environmental impacts generated by the operations of stakeholders in the aviation industry?*
- *What is the current state of environmental sustainability performance among aviation industry stakeholders?*

In this study, following the introduction, the concepts of environmental sustainability and environmental sustainability in aviation are addressed, along with a review of related studies in the existing literature. In the application section, data disclosed in the sustainability reports of selected aviation companies were analyzed using a descriptive analysis method. The findings were organized into tables to allow for comparison. Finally, in the discussion section, the environmental sustainability performance of industry stakeholders was evaluated based on the findings, and several recommendations were proposed.

2. Theoretical Framework

2.1. Environmental Sustainability

Industrial activities contribute to global warming, climate change, drought, forest fires, ecological degradation, and environmental damage (Ghoni & Ginting, 2023), while environmental pollution and climate change continue to evolve into serious global issues affecting human health (Khalid, Harun, Noor, & Hashim, 2021; Mi, Zhang, Yu, Zhang, Xu & Qiao, 2024). As climate change intensifies and current resources become increasingly depleted, the need for sustainable industries becomes even more critical (Afonso et al., 2023). In order to prevent the planet from becoming uninhabitable, the manufacturing and service industries must adopt green practices that reduce environmental pollution and protect existing natural resources (Gill, Ahmad & Kazmi, 2021).

Although individuals bear some responsibility in ensuring environmental sustainability, the magnitude of industrial impact necessitates even greater accountability on the part of industry. Education and awareness-raising are essential for establishing a sustainable quality of life (Haron, Paim & Yahaya, 2005). It is imperative for businesses to foster a green organizational culture and make greater efforts to protect the environment, thereby promoting behavioral changes such as green consumerism, the use of eco-friendly products, and the development of environmentally conscious attitudes. In this context, green strategies and practices at the macro level are a powerful driver for fostering individual-level efforts (Darvishmotevali & Altinay, 2022). Otherwise, the continuous and increasing consumption of natural resources will pose a serious threat to humanity and the planet (Fransson & Gärling, 1999).

As a result of the destruction of natural habitats and the reckless use of resources, deadly issues such as food and water shortages, hunger, disease, and poverty have begun to emerge in many parts of the world (Atmaca, Kiray & Pehlivan, 2019). At this point, businesses must be aware that they can contribute to sustainable development by managing their operations in a way that enhances economic growth and competitiveness, while also protecting the environment and promoting social

responsibility, including the interests of consumers (Amaeshi & Crane, 2006).

According to Roxas & Coetzer (2012), environmental sustainability orientation for businesses consists of three dimensions: knowledge of environmental issues, sustainable practices, and commitment to environmental sustainability. Therefore, businesses must generate knowledge on practices that minimize environmental impact, adapt all their operations to be environmentally responsible, and ensure the continuity of these efforts. In this regard, managerial leadership and commitment are of critical importance. While conducting economic activities, businesses must consider the costs associated with environmental practices as part of their fundamental expenses. The financial resources that were previously withheld from environmental protection due to profit-oriented strategies must now be allocated to repair the environmental damage that has been done. Thus, companies are expected to compromise some of their profits in favor of environmental restoration.

2.2. Environmental Sustainability in Aviation

The aviation sector is a strategically significant industry that plays a vital role in global urbanization and long-term economic growth (Eid, Salah, Barakat, & Obrecht, 2022). It consists of a broad range of stakeholders, including aircraft manufacturers, airline operators, ground handling providers, airport service operators, and various support services (Aydin, 2024). Most of these actors are large-scale enterprises operating on an international level.

Aviation activities generate considerable environmental impacts at local, regional, and global scales. From airport construction to aircraft manufacturing, from airline operations to ground services, all stages contribute to air, water, and noise pollution and adversely affect biodiversity (Hooper & Greenall, 2005; Oto, 2011). Airport surroundings are particularly vulnerable due to multiple risk factors such as emissions from aircraft, de-icing fluid runoff, fuel spills, and waste treatment and disposal (Marais & Waitz, 2009). Additionally, environmental impacts arising from passengers and aviation personnel further amplify the overall ecological burden.

Hence, a holistic approach involving all stakeholders is essential for achieving environmental sustainability in the aviation sector. Developing inclusive strategies can enhance the sector's overall environmental performance. Teoh and Khoo (2016), in their review of environmental issues in aviation, emphasize that all stakeholders have equally important roles in achieving a greener air transport system. Improvements are needed in areas such as research and development, flight planning, and operational management to advance environmental sustainability.

Environmentally sustainable airport infrastructure is also a key requirement in the pursuit of green aviation (Ramakrishnan, Liu, Yu, Seshadri, & Gou, 2022). Such infrastructures not only support eco-conscious passenger behavior but also contribute to raising environmental awareness among employees. Effective leadership and commitment to green human resource policies are therefore critical success factors.

Furthermore, compliance with environmental regulations and engagement with environmental management systems and certification programs are essential mechanisms for institutionalizing environmental sustainability within the aviation sector (Mańkowska, Tłoczyński, Wach-Kłoskowska, & Bulczak, 2023). Encouraging companies to participate in

these programs can significantly accelerate the green transformation of the industry.

2.3. Literature

In recent years, the publication of sustainability reports—documents that enable companies to transparently disclose their environmental impacts—has increased significantly. This development has also led to a growing body of academic literature addressing sustainability reporting. For instance, Dil and Talaş (2021) examined the perspectives of the top 100 successful companies in Turkey regarding environmental sustainability through their sustainability reports. Their findings revealed a lack of standardization in voluntary reporting practices, limited corporate transparency, and vague or insufficient statements on environmental issues.

Similarly, Gökçen and Kayacan (2024) analyzed the environmental sensitivity of companies operating in Turkey's automotive sector using content analysis of their sustainability reports. The study found that these companies demonstrated high awareness regarding environmental and climate change issues and provided satisfactory levels of disclosure to their stakeholders. These results indicate progressive improvements in sustainability reporting practices over time.

The aviation industry, characterized predominantly by large-scale multinational enterprises, has emerged as a leader in sustainability reporting—just as it has in many other areas. Consequently, the sector has also drawn academic attention. Turkish Airlines (THY), Turkey's national flag carrier, has been the subject of several scholarly studies. For example, Güney and Dinler (2021) analyzed THY's 2018 and 2019 sustainability reports in line with the Global Reporting Initiative (GRI) standards. Although the reports covered various topics across different sections, the researchers noted the absence of information on certain indicators. They recommended that such indicators be included in future reports to enhance the company's transparency. In a similar vein, Karakuş (2023) conducted a content analysis of THY's sustainability reports from 2014 to 2021. While recognizing the reports as pioneering in the industry, the study also identified certain deficiencies and inconsistencies. The author recommended that future reports should be improved based on the principles of reliability, transparency, traceability, and auditability.

Among the three pillars of sustainability—environmental, social, and economic—the environmental dimension tends to receive the greatest focus in academic research. This trend also applies to studies within the aviation sector. Hooper and Greenall (2005), in their investigation of environmental reporting practices in the airline industry, noted an increase in quantitative data over time. However, they emphasized that variations in indicators made it difficult to conduct performance comparisons across companies in the sector.

In a systematic review of 108 academic articles and technical reports, Greer, Rakas, and Horvath (2020) evaluated the environmental sustainability of airports. They found that scholarly interest in this area has grown over the years, yet highlighted the need for further research. The authors recommended a comprehensive evaluation of all relevant parameters, such as ground services, airport infrastructure, and flight operations, when assessing environmental impacts.

Similarly, Zieba and Johansson (2022) explored the current state of scientific research on sustainability reporting in the airline industry. In their findings, they emphasized the limited number of studies in the aviation sector and the inconsistency observed across sustainability reports. Accordingly, they

called for increased academic attention and more systematic research on the topic.

3. Materials and Methods

3.1. Research Aim

A review of the literature on environmental sustainability in the aviation industry highlights the sector's significant role in the global economy and its considerable environmental impact, while also pointing out a lack of sufficient academic research on the topic. Considering that only 10% of aviation operations take place in the air and the remaining 90% on the ground, achieving sustainability in aviation requires a comprehensive understanding and application of sustainability principles across all subsystems (Karakuş, 2023). Given that operations in the sector are managed by different stakeholders, it is essential to accurately define each stakeholder's environmental impacts in order to assign responsibilities and develop effective strategies for reducing environmental harm.

In this context, the aim of the study is to identify the environmental impacts and performance levels of aviation industry stakeholders based on their operational activities. Accordingly, the study seeks to answer the following research questions:

- *What are the environmental impacts generated by the operations of stakeholders in the aviation industry?*
- *What is the current level of environmental sustainability performance of these stakeholders?*

The study aims to evaluate the environmental impacts of aviation stakeholders based on their sustainability reports. A sustainability report is a document that provides stakeholders with information about a company's role and contribution to society, presenting its performance in economic, environmental, social, and governance areas (www.kgk.gov.tr, Accessed: 02.08.2024). These reports also present a clear overview of companies' environmental activities. By enhancing transparency and accountability, sustainability reports not only inform the public about corporate attitudes towards environmental responsibility but also serve to legitimize their practices (Dil & Talaş, 2021).

For this purpose, a multiple exploratory case study design was adopted, allowing for an in-depth understanding of the phenomenon under investigation (Yin, 2018). In the analysis of qualitative data, the method developed by Walcott (1994), consisting of description, analysis, and interpretation categories, was employed. This approach emphasizes the importance of narrating events in a systematic order and providing readers with a direct understanding of the subject matter (Walcott, 1994; Özdemir, 2010). According to Yıldırım and Şimşek (2003), the goal of descriptive analysis is to present the findings in a summarized and interpreted form. In line with this approach, the current study analyzed the data obtained from sustainability reports, summarizing and tabulating the findings for each stakeholder to ensure comparability.

No similar study addressing this specific topic was found in the national or international literature, which highlights the originality and contribution of this research.

3.2. Population and Sample

In the determination of the sample for this study, the purposeful sampling method (Maxwell, 1996), which allows for in-depth data collection on the phenomenon being studied, was employed. The following steps were taken to identify the aviation industry stakeholders to be examined:

The companies operating in the aviation sector in Turkey were identified using the General Directorate of Civil Aviation (SHGM) website (www.web.shgm.gov.tr/, Accessed: 08.06.2024) and the Public Disclosure Platform (KAP) website (www.kap.org.tr, Accessed: 12.06.2024). Subsequently, the websites of the companies operating in the sector were individually reviewed to determine whether they

publish sustainability reports and the years in which these reports were published. The collected data is presented in Table 1. Since these companies publicly share their reports on their corporate websites, the company names and the disclosed information are available and transparently shared.

Table 1. Sustainability Reports of Aviation Sector Stakeholders

Aviation Enterprises		Published Sustainability Reports								
IGA (İstanbul Grand Airport)	2021 - 2022	2020	2019	2017 - 2019	2016					
TAV Airports	2022					2015 - 2016	2014 - 2015		2013	
TGS - Ground Services Inc.	2023	2022								
PEGASUS Airlines	2023	2022	2021	2020						
THY (Turkish Airlines)	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.tgs.aero/kurumsal/cysp, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

As seen in Table 1:

- **IGA (İstanbul Grand Airport)** is an airport infrastructure contractor company established on October 7, 2013, with the purpose of constructing and operating Istanbul Airport for 25 years. Istanbul Airport, which is planned to reach a capacity of 150 million passengers and 5.5 million tons of cargo, is the largest airport built under one roof in the world. IGA has published a total of five sustainability reports for the years 2016, 2017-2019, 2019, 2020 and 2021-2022 (www.igairport.aero/sustainability, Accessed: 10.07.2024).
- **TAV Airports** was established in 1997 and, through its subsidiaries, provides services at every point of the airport value chain. It operates in 8 countries at 15 airports (www.tavhavalimanlari.com.tr, Accessed: 21.07.2024). TAV has published a total of four sustainability reports covering the years 2013, 2014-2015, 2015-2016 and 2022 (www.gelecekicinhalimanlari.org/index.html, Accessed: 21.07.2024).
- **TGS (Turkish Ground Services)**, established in 2010, is a ground services company that provides all activities (ramp, operations, cargo, and passenger services) for domestic and foreign airlines in accordance with international standards. TGS has published a total of two sustainability reports for the years 2022 and 2023 (www.tgs.aero/kurumsal/cysp, Accessed: 24.07.2024).
- **Pegasus Airlines** was established in 1990 as Turkey's first "low-cost" airline. Pegasus has published a total of four sustainability reports for the years 2020, 2021, 2022 and 2023 (www.flypgs.com/sustainability, Accessed: 24.07.2024).
- **Turkish Airlines (THY)**, established in 1933, is Turkey's flag carrier airline. THY has published a total of ten sustainability reports covering the years 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 and 2023 (www.turkishairlines.com/en-tr/sustainability, Accessed: 24.07.2024).

Upon reviewing the reports, it is observed that the most recent sustainability reports for all selected companies in the sample are from the year 2022 (Table 1). Therefore, the

sustainability reports for the year 2022 have been included in the scope of the study.

4. Result and Discussion

4.1. The 'Environment' Section in Sustainability Reports

Upon reviewing the 2022 and 2023 reports of **TGS Ground Services**, it was observed that the reports do not qualify as sustainability reports. Instead, under the title of the report, the company has submitted a "Sustainability Compliance Report" to the Public Disclosure Platform (KAP). The relevant report includes key sustainability-related items, and the company responds to these items with "yes," "no," and "partially," providing brief explanations. All of TGS's responses to the environmental items in the report are either "partially" or "no." The company holds an ISO 14000 Environmental Management System Certificate, and references to this certification are made in some of the items where a "partially" response was given.

The report states that the company has not defined environmental objectives, has not collaborated with any stakeholders on the subject, has not provided public data on environmental indicators (such as greenhouse gas emissions, air quality, energy management, water and wastewater management, waste management, biodiversity impacts, etc.), and has not developed a strategy to combat the climate crisis. Additionally, for items under headings such as greenhouse gas emissions, renewable energy production and usage, energy efficiency projects, water consumption reduction, and carbon pricing, the company answered "no" to all, providing the explanation, "As our company operates in the service sector, there is no need for such initiatives." This report serves as a declaration that the company has not undertaken any activities in the scope of environmental sustainability and is also an indication that the company lacks environmental awareness. Therefore, due to the absence of any environmental activities or data, **TGS** has been excluded from the scope of the study.

While examining the environmental impact indicators of the companies in the sample, considering the differences in the types of energy and waste used in their core operations, as well as the differences in the size and operations of the companies, no comparison was made between the companies. The data provided by the companies regarding their environmental

performance indicators were calculated by comparing the years 2021 and 2022. The performance of the companies in terms of the indicators was determined by calculating the rate of change in the values.

General information related to environmental sustainability in the 2022 sustainability reports of İGA, TGS, Pegasus and Turkish Airlines (THY) is presented in Table 2.

Table 2. General information on environmental sustainability

Aviation Enterprises	İGA (İstanbul Grand Airport)	TAV Airports	PEGASUS Airlines	THY (Turkish Airlines)
Years Covered by the Report	1 January - 31 December 2022	1 January - 31 December 2022	1 January - 31 December 2023 (2022 data provided in the report has been used)	1 January - 31 December 2022
Total Number of Pages	84	142	103	98
Number of Pages on Environmental Sustainability Relevant Standard	14	25	10	13
	GRI	GRI	GRI	GRI
Title	We focus on preserving the integrity of the environment	Respect for the environment for the future	Our route to a clean future	Responsible company
Titles Related to Environmental Sustainability	➤ Compliance with the climate law: Targeting carbon neutrality by 2050 - Energy - Facilities ➤ Our emission distributions ➤ Our emission reduction targets ➤ Zero waste ➤ Resource usage - Water and wastewater management & water security ➤ Energy efficiency ➤ Biodiversity ➤ Noise	➤ Fighting the climate crisis ➤ Carbon footprint and emissions ➤ Energy management ➤ Waste management ➤ Water management ➤ Biodiversity	➤ Climate change and our net zero journey ➤ Environmental management system - Waste management - Noise management - Biodiversity ➤ Energy management - Fleet transformation and investments in next-generation aircraft - Transformation in ground operations - Energy monitoring system and energy efficiency - Our steps towards renewable energy	➤ Fighting climate change - Energy and emissions management - Energy policy - Fuel efficiency - Carbon offset practices - Sustainable aviation fuels ➤ Environmental management - Environmental policy - Resource efficiency • Water consumption • Reduction in chemical usage • Reduction in paper consumption • Preference for environmentally friendly materials • Cabin modification projects • Green building practices • Waste management • Aircraft body disposal - Responsible catering - Fleet modernization • Noise management

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik

As shown in Table 2, each of the sustainability reports examined within the scope of this study uses a distinct title for the environmental sustainability section, shaped by the respective company's corporate vision. Among the reports, TAV's report is the most extensive in terms of length, comprising 142 pages, and also devotes the largest proportion (17%) of its content to environmental sustainability. In contrast, Pegasus allocates the least space proportionally (9.7%) to environmental sustainability.

Although Pegasus's 2022 report was reviewed, it was found not to comply with the GRI (Global Reporting Initiative) standards. The company prepared its first GRI-compliant report in 2023, which also included data from 2022. Therefore, for the purpose of comparability across companies, the 2022

reports of İGA, TAV, and THY were used, while Pegasus's 2023 report was included.

THY, Pegasus, and TAV provided numerical data related to environmental sustainability within the body of their reports and also presented these data as annexed tables at the end of the documents. During the analysis, data from these sections were cross-verified for accuracy. Since İGA's report did not include annexed tables, relevant data were extracted directly from the textual content for the purposes of this study.

4.2. Energy Consumption in Sustainability Reports

The data on energy consumption presented in the sustainability reports are summarized in Table 3.

Table 3. Total energy consumption of aviation enterprises

Aviation Enterprises	Total energy consumption			Explanation
	2021	2022	Change	
IGA (İstanbul Grand Airport)	209.722.336,89 kw = 755.000,41 GJ	233.369.458,41 kw = 840.130,05 GJ	11.3% increase	The total energy consumption data was not provided, and the energy consumption per passenger was calculated by multiplying the passenger count. However, the resulting figure appears to be lower than the total electricity consumption. The report presents data on consumed diesel, natural gas, and gasoline in numerical terms, but due to unit differences, they were not included in the calculations. The energy values were converted from kilowatts (kW) to gigajoules (GJ).
TAV Airports (Antalya, Esenboğa, İzmir, Gazipaşa, Bodrum)	942.598,59 GJ	817.711,59 GJ	13.3% decrease	While data for all regions, except Gazipaşa, was presented in GJ units, Gazipaşa's data was provided in kW. A unit conversion was performed by proportionally comparing it to the other data, and the total value was approximately calculated.
PEGASUS Airlines	24.674.938,79 GJ	34.536.795,1 GJ	40% increase	Aviation fuel, natural gas, petrol, diesel
THY (Turkish Airlines)	187.326.898 GJ	252.648.196 GJ	35% increase	Aviation fuel, natural gas, petrol, diesel

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

The change in total energy consumption of businesses is an important indicator for comparing their environmental performance. As shown in Table 3, with the exception of TAV, the other stakeholders have increased their total energy consumption in 2022 compared to 2021. The total energy consumption has increased by 11.3% at IGA, decreased by

13.3% at TAV, increased by 40% at Pegasus, and increased by 35% at Turkish Airlines (THY).

In the next phase of the study, a performance evaluation was conducted regarding the electricity consumption per employee (Table 4).

Table 4. Electricity consumption per employee in aviation enterprises

Aviation Enterprises	Electricity consumption per employee (kw/employees)		
	2021	2022	Change
IGA (İstanbul Grand Airport)	210.947.457 kw / 7031 employees = 30.002.5 kw/employees	234.167.578 kw / 8.032 employees = 29.154.3 kw/employees	2.8% decrease
TAV Airports (Antalya, Esenboğa, İzmir, Gazipaşa, Bodrum)	140.784.641 kw / 15.738 employees = 8.945.5 kw/employees	167.379.301 kw / 17.088 employees = 9.795.14 kw/employees	9.5% increase
TAV Airports - Total	230.575.666 kw / 15.738 employees = 14.650.9 kw/ employees	270.479.470 kw / 17.088 employees = 15.828.5 kw/employees	8.03% increase
PEGASUS Airlines	29.583.45 GJ (conventional) / 5.824 employees = 5.08 GJ /employees	26.560.14 (conventional) + 15.271.20 (renewable) = 41.831.34 GJ / 6.754 employees = 6.2 GJ /employees	22% increase
THY (Turkish Airlines) The value calculated based on the reported "total electricity consumption"	326.487 GJ (conventional) / 33.191 employees = 9.83 GJ/employees	394.003 (konvansiyonel) + 63.921 (yenilenebilir) = 457.924 GJ / 37.379 employees = 12.25 GJ/employees	24.6% increase
The "electricity consumption per employee" reported in the report	8.09 GJ/employees	8.89 GJ/employees	9.9% increase

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

In the case of TAV Airports, since the report does not explicitly state the value of electricity consumption per employee, this figure was estimated by dividing the total electricity consumption by the number of employees. Although the report provides detailed electricity usage for each airport operated in Turkey, the exact number of employees per

location or in total is not disclosed. Therefore, two estimations are presented in the table: one reflecting electricity consumption per employee based on domestic operations in Turkey, and another based on TAV's entire operational scope using an estimated total workforce.

In the sustainability reports of Turkish Airlines (THY), both total electricity consumption and electricity consumption per employee are provided. However, discrepancies were identified when comparing the product of reported per capita electricity usage and the total number of employees with the reported total electricity consumption, suggesting inconsistencies in data presentation. Consequently, Table 4 includes both the recalculated electricity consumption per employee (derived from dividing total electricity usage by the number of employees) and the figure officially reported by the company.

Furthermore, both THY and Pegasus Airlines reported their electricity consumption from conventional and renewable energy sources separately for the year 2022, which provides a more detailed view of their energy profiles.

As shown in Table 4, among the aviation stakeholders examined in this study, only İGA (Istanbul Grand Airport) reported a reduction in electricity consumption per employee. In contrast, increases were observed in TAV (8.03%), Pegasus (22%), and THY (24.6% based on recalculated value / 9.9% based on declared figure). However, the partial shift toward renewable electricity by THY and Pegasus indicates that a portion of their increased energy demand was met through more sustainable sources, which can be interpreted as a positive development in terms of environmental performance.

4.3. Emission Disclosures in Sustainability Reports

Following the analysis of electricity consumption data, the study proceeds with an examination of the greenhouse gas emissions disclosed by aviation stakeholders. The classification of carbon emissions is as follows (www.semtrio.com/blog/karbon-ayak-izi-nedir, Accessed: 27.09.2024):

- **Scope 1:** Direct emissions from sources that are owned or controlled by the organization.
- **Scope 2:** Indirect emissions from the generation of purchased electricity, heating, and steam consumed by the organization.
- **Scope 3:** All other indirect emissions not covered in Scope 2 that occur in the value chain of the organization, including both upstream and downstream activities.

As seen table 5, in the sustainability report of Pegasus Airlines, Scope 3 emissions are defined as those arising from employee commuting and business travel, the consumption of purchased services, and waste-related emissions.

Table 5. Greenhouse gas emissions of aviation enterprises

Aviation enterprises	Greenhouse Gas Emissions (Tons of CO ₂ e)		
	2021	2022	Change
İGA (Istanbul Grand Airport) (Scope 1 + 2)*	147.434	140.537	4.7% decrease
Scope 1 (Direct Emissions)	30.358	27.199	10.4% decrease
Scope 2 (Indirect Emissions)	117.076	113.338	3.2% decrease
TAV Airports (Scope 1+2+3)	616.281,65	572.610,25	7.1% decrease
Scope 1 (Combustion-related emissions)	27.820,41	18.868,71	32.2% decrease
Scope 2 (Emissions from purchased electricity consumption)	14.514,49	28.760,60	98.2% increase
Scope 3 (Scope 1 and Scope 2 emissions of airport-wide stakeholders)	573.946,75	524.980,94	8.5% decrease
PEGASUS Airlines (Scope 1+2+3)	2.252.569,1	3.165.299,9	40.5% increase
Scope 1 (Direct greenhouse gas emissions)	1.791.368,05	2.507.472,39	40% increase
Scope 2 (Indirect greenhouse gas emissions)	4.559,14	10.337,24	126.7% increase
Scope 3 (Other indirect greenhouse gas emissions)	456.641,91	647.490,33	41.8% increase
THY (Turkish Airlines) (Scope 1+2+3)	16.591.244	22.983.093	38.5% increase
Scope 1 (Direct greenhouse gas emissions)	13.462.858	18.170.030	35% increase
Scope 2 (Indirect greenhouse gas emissions)	56.377	64.219	13.9% increase
Scope 3 (Other greenhouse gas emissions)	3.072.009	4.748.844	54.6% increase

* Within the scope of efforts to reduce Scope 3 greenhouse gas emissions, the airport stakeholder contributions have been identified in percentage terms (airline fuel consumption: 84.7% – public transportation: 9.6% – heating: 2.2% – ground handling: 2.3% – staff shuttle services: 1.2%). However, no quantitative data regarding the current status have been provided in the report.

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

When examining Table 5, it is observed that airport operators reduced their greenhouse gas emissions in 2022 compared to the previous year. However, the airline operators contributed to a significant increase in emissions. Although İGA had higher direct emissions, it achieved a 4.7% reduction in total greenhouse gas emissions. Upon reviewing TAV Airports' greenhouse gas emissions, it is evident that a significant portion of emissions occurred under Scope 3. TAV caused a 98.2% increase in emissions under Scope 2, while achieving a 7.1% reduction in total greenhouse gas emissions.

Pegasus Airlines and Turkish Airlines (THY) have experienced significant increases in greenhouse gas emissions across all scopes. Pegasus Airlines' greenhouse gas emissions in 2022 showed a 40.5% increase compared to the previous year, while THY's emissions increased by 38.6%.

Following the examination of the greenhouse gas emissions data, it was deemed appropriate to analyze the companies' carbon offset practices (Table 6).

Table 6. Carbon offset practices of aviation enterprises

Aviation enterprises	Carbon offset practices (Tons CO ₂ e)		
	2021	2022	Change
IGA (Istanbul Grand Airport)	No data available	No data available	--
TAV Airports	No data available	No data available	--
PEGASUS Airlines	---	7.860	--
THY (Turkish Airlines)	13.968	8.968	35.8% decrease

Source: www.igairport.aero/surdurulebilirlik,
www.tavairports.com/surdurulebilirlik,
www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik

In TAV Airports' sustainability report, references to pages 70, 77, and 130 are made in the table of contents and annexed tables under the heading **Carbon Footprint and Emissions**. The company declares that it has achieved carbon neutrality at three airports through carbon credit purchases and sets forth the goal of “*achieving carbon neutrality by 2030 and net-zero emissions by 2050*”. Additionally, it is stated that a “*Carbon Management System Procedure is in place to calculate the carbon footprint and set targets for reducing carbon emissions*”. Specific goals are outlined for each airport in which the company operates. The report notes that 3,634.56 tCO₂ of carbon credits were acquired in 2022 for Scope 1 emissions offsetting. However, apart from the qualitative information presented in these sections, no concrete numerical data regarding carbon offset applications for the years 2021 and 2022 is provided.

In IGA Airport's sustainability report, pages 46–51 are referenced for data related to “**Compliance with Climate Law: Target Carbon Neutrality by 2050**”. Within these pages, the company outlines a 45% reduction target for Scope 1 emissions and sets a long-term goal of achieving net-zero emissions by 2050. It is also stated that afforestation efforts are expected to create approximately 1,258,554 tons of CO₂ sinks over a 25-year period. The report highlights the following achievement: “*In 2022, as a result of our efforts to manage and reduce our carbon footprint within the framework of our sustainability policy, we successfully upgraded our Level 1 certificate to Level 3 within a short period of time under the same program*”. However, no data is provided for the years 2021 and 2022 that would allow for a comparative analysis of carbon offset practices.

Pegasus Airlines, on the other hand, reported carbon offsetting for the first time in its 2022 report, declaring a total of 7,860 tons of CO₂e.

In Turkish Airlines' (THY) sustainability reports, carbon offset figures have been disclosed starting from the year 2020. As shown in Table 6, the amount of carbon offset by THY in 2022 decreased by 35.8% compared to the previous year.

4.4. Resource Efficiency in Sustainability Reports

This section analyzes the environmental performance indicators related to water consumption and water consumption per employee.

Table 7. Total water consumption of aviation enterprises

Aviation enterprises	Total water consumption (m ³)		
	2021	2022	Change
IGA (Istanbul Grand Airport)	1.013.776	1.330.820	31.3% increase
TAV Airports	906.212	977.367	7.9% increase
PEGASUS Airlines	9.986	15.520	55.4% increase
THY (Turkish Airlines)	255.238	364.508	42.8% increase

Source: www.igairport.aero/surdurulebilirlik,
www.tavairports.com/surdurulebilirlik,
www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik

Upon examining Table 7, it is observed that all aviation stakeholders in the sample increased their water consumption in 2022 compared to the previous year. According to the reported data, water consumption amounts have increased by the following percentages compared to the previous year: TAV by 7.9%, IGA by 31.3%, THY by 42.8%, and Pegasus by 55.4%. When examining the water consumption per employee of the aviation stakeholders, it is noted that while the other companies provided the relevant figures, TAV did not. To calculate TAV's water consumption per employee, since the total number of employees at the airports operating in Turkey was unknown, the total water consumption was divided by the total number of employees to obtain an estimate (Table 8).

Table 8. Water consumption per employee of aviation enterprises

Aviation enterprises	Water consumption per employee (m ³ /person)		
	2021	2022	Change
IGA (Istanbul Grand Airport)	144.18	165.69	14.9% increase
TAV Airports	57.58	57.20	0.66% decrease
PEGASUS Airlines	1.71	2.30	34.5% increase
THY (Turkish Airlines)	23.70	13.42	43.4% decrease

Source: www.igairport.aero/surdurulebilirlik,
www.tavairports.com/surdurulebilirlik,
www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

When Table 8 is examined, it is notable that Pegasus's water consumption per employee is significantly lower compared to the other companies. When evaluating the performance in terms of water consumption savings per employee, it is observed that THY reduced its water consumption by a high rate of 43.4%, while TAV reduced it by 0.66%. On the other hand, IGA increased its water consumption per employee by 14.9% in 2022 compared to the previous year, while Pegasus's water consumption per employee increased by 34.5%.

4.5. Waste Quantities in Sustainability Reports

This section examines the waste quantities and recycling rates reported by aviation stakeholders, which are important indicators of environmental performance, under the topic of waste management and presented in Table 9.

Table 9. Waste quantities of aviation enterprises

Aviation enterprises	Waste Quantities (tons)			
	2021	2022	Change	Explanation
IGA (Istanbul Grand Airport)	25.372	43.507	71.5% increase	The waste quantities have been presented without classification.
TAV Airports	18.969.60	18.621.85	1.8% decrease	The quantities of hazardous and non-hazardous waste are inconsistent with the total amount. There are undefined waste present.
Hazardous waste	42.69	77.61		
Non-hazardous waste	9.888.98	10.570.22		
PEGASUS Airlines	185.4	242.2	30.6% increase	The enterprise has not included electronic and packaging waste in the total waste amount stated in the report. In the analysis, the reported values have been used.
Hazardous waste	88.6	107.8		
Non-hazardous waste	96.9	135.0		
Electronic waste	0.269	0.345		
Packaging waste	21.51	48.23		
THY (Turkish Airlines)	1.608	2.313	43.8% increase	The enterprise has included packaging waste when reporting the total waste amount.
Hazardous waste	105.50	128.9		
Non-hazardous waste	1.449	2.103		
Packaging waste	53.50	81		

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

As seen in Table 9, there are notable proportional differences in the waste quantities reported by the aviation stakeholders. When analyzing the data in terms of waste reduction performance, it is observed that only TAV Airports reduced its waste in 2022 compared to the previous year, though the reduction was minimal (1.8%). On the other hand, IGA increased its waste by 71.5%, Pegasus by 30.6%, and Turkish Airlines (THY) by 43.8% in the same period.

Table 10. Waste recycling rates of aviation enterprise

Aviation enterprises	Waste recycling rates (%)		
	2021	2022	Change
IGA (Istanbul Grand Airport)	31	34	9.7% increase
TAV Airports	63.80	79.70	25% increase
PEGASUS Airlines	99.97	99.76	0.2% decrease
THY (Turkish Airlines)	---	---	---

Source: www.igairport.aero/surdurulebilirlik, www.tavairports.com/surdurulebilirlik, www.flypgs.com/surdurulebilirlik, www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik.

While Turkish Airlines (THY) provides data on the amount of recycled waste in its sustainability reports, it does not disclose a specific waste recycling rate, making direct evaluation impossible. However, in its 2022 sustainability report, the total amount of recovered non-hazardous waste, recovered hazardous waste, disposed hazardous waste, and recycled packaging waste equals the reported amount of solid waste. Therefore, it can be inferred that, aside from 0.90 tons of hazardous waste that was disposed of, THY recycles all of the solid waste generated through its operations.

As seen in Table 10, İstanbul Grand Airport (IGA) and TAV Airports increased their waste recycling rates by 9.7% and 25%, respectively. Although Pegasus Airlines experienced a minor decline of 0.2%, its overall recycling rate of 99.76% demonstrates the company's strong performance in this area.

5. Discussion

The aim of this study is to compare the environmental sustainability performance of aviation sector stakeholders that publish sustainability reports. In the performance evaluation, the differences in stakeholders' operational scopes and scales were taken into consideration; therefore, direct comparisons between stakeholders were avoided. Instead, proportional comparisons were made based on the change in their reported environmental impacts. The environmental impacts of IGA, TAV, Pegasus, and Turkish Airlines (THY)—including total energy consumption, electricity consumption per employee, greenhouse gas emissions, carbon offset practices, water consumption per employee, total waste generation, and waste recycling rate—were analyzed using data from the years 2021 and 2022.

The main challenges encountered during the implementation phase include discrepancies in the content of sustainability reports, the use of different units in numerical data, and internal inconsistencies within the data itself. These issues hinder traceability and comparability. Similar challenges have been highlighted in previous studies by Hooper & Greenall (2005), Chen & Lin (2009), Battal (2018), Zieba & Johansson (2022), and Karakuş (2023), all of which emphasize the need for a standardized framework specifically tailored for the aviation sector. This issue is not exclusive to aviation; it is also evident in other sectors. For instance, in a study by Talaş (2021), which investigated the environmental sustainability perspectives of Turkey's top 100 companies, it was noted that there is a lack of standardization in reporting, that companies tend to avoid full transparency, and that the disclosures related to environmental themes are often vague. In line with the global implementation of green transformation initiatives, sector-specific reporting standards should be established both worldwide and in Türkiye. Customizing the globally most widely adopted GRI standards within the context of individual sectors, and collaborating with sector representatives for this purpose, would address a significant need and fill an existing gap.

Firstly, the study sought to address the initial research question: “*What are the environmental impacts generated by the operations of aviation industry stakeholders?*” As evidenced in the reviewed reports, each stakeholder generates environmental impacts of varying magnitude depending on the nature of their operations. In general, the aviation sector contributes to greenhouse gas emissions primarily through energy and electricity consumption, and in response, partially implements carbon offset initiatives. The sector also generates water consumption and undertakes efforts to reduce per capita

water usage among employees. Furthermore, stakeholders produce hazardous, non-hazardous, electrical, and packaging waste, and set targets related to waste reduction and recycling.

At this stage, the second research question “*What is the performance of aviation industry stakeholders in terms of environmental sustainability?*” was examined. Quantitative data disclosed by companies in their sustainability reports were analyzed, and the findings obtained are summarized in Table 11.

Table 11. Comparative analysis of environmental indicators of aviation enterprises

Aviation enterprises	IGA (Istanbul Grand Airport)	TAV Airports	PEGASUS Airlines	THY (Turkish Airlines)
Headline	We are committed to preserving the integrity of the environment	Respect for the environment for a sustainable future	Our course is a cleaner future	Responsible company
Total energy consumption	11,3% increase (-)	13,3% decrease (+)	40% increase (-)	35% increase (-)
Electricity consumption per employee	2,8% decrease (+)	8,03% increase (-)	22% increase (-)	9,9% increase (-)
Greenhouse gas emissions	4,7% decrease (+)	7,1% decrease (+)	40,5% increase (-)	38,5% increase (-)
Carbon Offset Practices	-- (-)	-- (-)	-- (-)	35,8% decrease (-)
Total water consumption	31,3% increase (-)	7,9% increase (-)	55,4% increase (-)	42,8% increase (-)
Water Consumption per employee	14,9% increase (-)	0,66% decrease (+)	34,5% increase (-)	43,4% decrease (+)
Waste amounts	71,5% increase (-)	1,8% decrease (+)	0,6% increase (-)	43,8% increase (-)
Waste recycling rate	9,7% increase (+)	25% increase (+)	0,2% decrease (-)	-- --

Source: Author

When examining the total energy consumption of the companies, it is observed that, with the exception of TAV, all other companies increased their energy consumption in 2022 compared to 2021. Notably, Pegasus (40%) and Turkish Airlines (35%) demonstrated significant increases in their energy consumption. In terms of electricity consumption per employee, while IGA achieved a modest reduction of 2.8%, TAV (8.03%), Pegasus (22%), and Turkish Airlines (9.9%) all reported increases in electricity consumption per employee.

Greenhouse gas (GHG) emissions are a critical issue for the aviation sector, and it is evident from the reports that companies have set important targets in this regard. As presented in Table 11, IGA (4.7%) and TAV (7.1%) managed to reduce their GHG emissions, whereas Pegasus (40.5%) and Turkish Airlines (38.5%) experienced substantial increases. In relation to carbon offsetting efforts undertaken to compensate for the emissions generated, it is noteworthy that IGA and TAV did not report any data within this scope. Pegasus included carbon offset data for the first time in its 2022 report, while Turkish Airlines has disclosed offset emission figures in its reports since 2020. However, Turkish Airlines' carbon offset volume decreased by 35.8% in 2022 compared to the previous year.

An analysis of total water consumption data reveals that all aviation stakeholders included in the sample increased their water usage in 2022 compared to the previous year—TAV by 7.9%, IGA by 31.3%, Turkish Airlines (THY) by 42.8%, and Pegasus by 55.4%. In terms of water consumption per employee, THY achieved a significant reduction of 43.4%, while TAV reported a marginal decrease of 0.66%. Conversely, IGA increased its per capita water consumption by 14.9%, and Pegasus showed a considerable rise of 34.5%.

When evaluating the waste reduction performance of aviation stakeholders, it is observed that only TAV managed

to reduce its waste in 2022 compared to the previous year, albeit by a modest 1.8%. In contrast, IGA (71.5%), Pegasus (30.6%), and THY (43.8%) all reported increases in their waste generation.

The amount of waste recycled is also a key indicator of an enterprise's environmental performance. With respect to recycling rates, IGA and TAV increased their recycling by 9.7% and 25%, respectively. Although Pegasus experienced a slight decline of 0.2%, its reported recycling rate of 99.76% demonstrates notable success in this area. THY did not disclose its recycling rate in the report; therefore, it could not be included in the comparative evaluation.

As shown in Table 11, the companies present their environmental impacts under eight main categories and set targets accordingly. Based on the findings, IGA demonstrated improvements in three of the eight categories, TAV in five, and THY in one, while Pegasus did not achieve performance improvement in any of the categories. This indicates that none of the companies has attained full success in terms of environmental sustainability performance. Furthermore, it is noteworthy that the performance of airline companies appears to be more negative compared to airport operators.

Given the significant environmental impact associated with airline operations, it is recommended that such companies intensify their efforts to mitigate these effects. Additionally, enhanced collaboration among stakeholders within the sector is advised to foster progress in environmental sustainability initiatives.

Limitations and Recommendations for Future Research

In this study, the environmental performance of aviation sector stakeholders operating in Türkiye was analyzed based on the disclosures provided in their sustainability reports. To the best of the author's knowledge, no similar study was

encountered in the existing literature. Consequently, a comparative evaluation of the findings could not be conducted.

Future research should aim to examine the environmental performance of companies from different countries and sectors to expand the existing body of literature. Such efforts will not only contribute to fostering an environmentally conscious business perspective but may also generate societal pressure on companies to accelerate their green transformation efforts.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Adubor, N. V., Adeniji, A. A., Salau, O. P., Olajugba, O. J., & Onibudo, G. O. (2022). Exploring green human resource adoption and corporate sustainability in Nigerian manufacturing industry. *Sustainability*, 14(19), 12635.
- Afonso, F., Sohst, M., Diogo, C. M., Rodrigues, S. S., Ferreira, A., Ribeiro, I., ... & Suleman, A. (2023). Strategies towards a more sustainable aviation: A systematic review. *Progress in Aerospace Sciences*, 137, 100878.
- Amaeshi, K. M., & Crane, A. (2006). Stakeholder engagement: a mechanism for sustainable aviation. *Corporate Social Responsibility and Environmental Management*, 13(5), 245-260.
- Atmaca, A. C., Kıray, S. A., & Pehlivan, M. (2019). Development of a measurement tool for sustainable development awareness. *International Journal of Assessment Tools in Education*, 6(1), 80-91.
- Aydın S. (2024). Sustainable airport management and airline marketing. *Black Sea Journal of Engineering and Science*, 7(3): 478-487.
- Ballı, A. (2019). Sürdürülebilirlik, sürdürülebilir girişimcilik ve Türkiye’de sürdürülebilir girişimcilik. Mehmet Akif Ersoy Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 11(29), 464-483.
- Battal, Ü. (2018). Sürdürülebilirlik raporlaması ve entegre raporlama: Türk Hava Yolları ve Güney Afrika Hava Yolları incelemesi. *Journal of Accounting and Taxation Studies*, 11(3), 393-424.
- Chen, F. & Lin, Y. (2009). Corporate social responsibility initiatives of major Asian Airlines. *ICEB 2009 Proceedings (Macau, SAR China)*, 80.
- Darvishmotevali, M., & Altinay, L. (2022). Green HRM, environmental awareness and green behaviors: The moderating role of servant leadership. *Tourism Management*, 88, 104401.
- Dil, E., Talaş, Z. (2021). Türkiye’de faaliyet gösteren başarılı şirketlerin çevresel sürdürülebilirlik yaklaşımlarına dair bir araştırma. *İş Ahlakı Dergisi*, 14(2), 201- 241
- Eid, A., Salah, M., Barakat, M., & Obrecht, M. (2022). Airport sustainability awareness: A theoretical framework. *Sustainability*, 14 (19), 11921.
- Eid, A., Obrecht, M., Ali, A. H., & Barakat, M. (2024). Does environmental knowledge and performance engender environmental behavior at airports? A moderated mediation effect. *Business Process Management Journal*, 30(3), 671-698.
- Fransson, N., & Gärling, T. (1999). Environmental concern: Conceptual definitions, measurement methods, and research findings. *Journal of Environmental Psychology*, 19(4), 369-382.
- Ghoni, I. A., & Ginting, J. G. (2023). The effect of green human resource management on environmental performance: Systematic literature review, *Asian Journal of Economics and Business Management*, 2(2), 522-527.
- Gill, A., Ahmad, B., & Kazmi, S. (2021). The effect of green human resource management on environmental performance: The mediating role of employee eco-friendly behavior. *Management Science Letters*, 11(6), 1725-1736.
- Gökçen, B. A., & Kayacan, A. (2024). BİST sürdürülebilirlik 25 endeksinde yer alan otomotiv şirketlerinin çevresel sürdürülebilirlik performanslarının içerik analizi ile değerlendirilmesi. *Öneri Dergisi*, 19(61), 77-94.
- Greer, F., Rakas, J., & Horvath, A. (2020). Airports and environmental sustainability: a comprehensive review. *Environmental Research Letters*, 15(10), 103007.
- Güney, S., & Dinler, S. (2021). Sustainability Reports Frames & GRI-Specific Standard Disclosures Series: Evaluation of the Turkish Airlines 2018-2019 Sustainability Reports. *Anadolu University Journal of Faculty of Economics*, 3(2), 100-118.
- Haron, S. A., Paim, L., & Yahaya, N. (2005). Towards sustainable consumption: an examination of environmental knowledge among Malaysians. *International Journal of Consumer Studies*, 29(5), 426-436.
- Hooper, P. D., & Greenall, A. (2005). Exploring the potential for environmental performance benchmarking in the airline sector. *Benchmarking: An International Journal*, 12(2), 151-165.
- IGA. (2024). Sustainability. from <https://www.igairport.aero/sustainability>, Accessed: 10.07.2024.
- KAP (Public Disclosure Platform). from www.kap.org.tr, Accessed: 12.06.2024.
- Karakuş, G., Karşıgil, E., & Polat, L. (2018). A Research on environmental sustainability practices in the aviation sector. *Sosyal Bilimler Araştırma Dergisi*, 7(4), 155-171.
- Karakuş, G. (2023). Türk Hava Yolları sürdürülebilirlik raporları üzerine bir araştırma. *Aerospace Research Letters (ASREL)*, 2(2), 86-113.
- Khalid, H. A. M., Harun, H., Noor, A. M., & Hashim, H. M. (2021). Green human resource management, perceived organizational support and organizational citizenship behavior towards environment in Malaysian petroleum refineries. In *SHS Web of Conferences*, 124, p. 11001. EDP Sciences.
- KGK, Soru ve Cevaplarla Sürdürülebilirlik Raporlaması, https://www.kgk.gov.tr/Portalv2Uploads/files/Sustainability/Soru_ve_Cevaplarla_Surdurulebilirlik_Raporlamasi_30_05_2023-.pdf, Accessed: 02.08.2024.
- Mańkowska, M., Tłoczyński, D., Wach-Kłoskowska, M., & Bulczak, G. (2023). Factors determining the implementation of green practices in airport management. The case study of Polish airports. *Journal of Air Transport Management*, 111, 102438.
- Marais, K., & Waitz, I. A. (2009). Air transport and the environment. *The Global Airline Industry* (Edited By

- Peter Belobaba, Amedeo Odoni and Cynthia Barnhart), John Wiley & Sons, 405-440.
- Maxwell, J. A. (1996). *Qualitative Research Design: An Interactive Approach*. California: SAGE Publications.
- Mi, L., Zhang, W., Yu, H., Zhang, Y., Xu, T., & Qiao, L. (2024). Knowledge mapping analysis of pro-environmental behaviors: research hotspots, trends and frontiers. *Environment, Development and Sustainability*, 1-35.
- Oto, N., (2011), Çevresel Sürdürülebilirlik ve Havaalanları: Esenboğa Havalimanı Örneği. Ankara Üniversitesi, Sosyal Bilimler Enstitüsü, Sosyal Çevre Bilimleri Anabilim Dalı, Doktora Tezi, Ankara.
- Özdemir, M. (2010). Nitel veri analizi: Sosyal bilimlerde yöntemibilim sorunsalı üzerine bir çalışma. *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi*, 11(1), 323-343.
- Pegasus Airlines. (2024). Sustainability Reports. from www.flypgs.com/surdurulebilirlik, Accessed: 24.07.2024
- Ramakrishnan, J., Liu, T., Yu, R., Seshadri, K., & Gou, Z. (2022). Towards greener airports: Development of an assessment framework by leveraging sustainability reports and rating tools. *Environmental Impact Assessment Review*, 93, 106740.
- Roxas, B., & Coetzer, A. (2012). Institutional environment, managerial attitudes and environmental sustainability orientation of small firms. *Journal of Business Ethics*, 111, 461-476.
- Sak, F. S., & Karakuş, G. (2024). Airline companies in green transformation: A comparison through websites. *Marketing and Resource Management for Green Transition in Economies*, (Edited By Jean-Vasile Andrei, Mile Vasić, Luminita Chivu, Boris Kuzman), IGI Global, 236-265, DOI: 10.4018/979-8-3693-3439-3.
- SHGM (General Directorate of Civil Aviation), from www.web.shgm.gov.tr/, Accessed: 08.06.2024.
- TAV Havalimanları. (2024). Sürdürülebilirlik Raporu (Gelecek için Havalimanları). from <https://www.gelecekicinhalimanlari.org/index.html>, Accessed: 21.07.2024
- Teoh, L. E., & Khoo, H. L. (2016). Green air transport system: An overview of issues, strategies and challenges. *KSCE Journal of Civil Engineering*, 20, 1040-1052.
- TGS, Sustainability Reports. www.tgs.aero/kurumsal/cysp, Accessed: 24.07.2024
- Turkish Airlines. (2024). Sustainability Reports. from www.turkishairlines.com/tr-tr/turk-hava-yollarinda-surdurulebilirlik, Accessed: 24.07.2024.
- Zieba, M., & Johansson, E. (2022). Sustainability reporting in the airline industry: Current literature and future research avenues. *Transportation Research Part D: Transport and Environment*, 102, 103133.
- Walcott, H. F. (1994). *Transforming qualitative data: Description, analysis and interpretation*. London: SAGE Publications.
- www.semtrio.com/blog/karbon-ayak-izi-nedir, Accessed: 27.09.2024.
- Yıldırım, A., & Şimşek, H. (2003). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*. Seçkin Yayınları, Ankara.
- Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). Los Angeles, CA: SAGE.

Cite this article: Karakuş, G. (2025). Environmental Sustainability Performance in Aviation: An Analysis Based on Stakeholders' Sustainability Reports. *Journal of Aviation*, 9(3), 578-589.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Breaking the Barriers: Accessibility Challenges for Disabled Passengers in Aviation

Kübra Nur Cingöz^{1*}, Vildan Durmaz²

^{1*}Gaziantep University, Aviation Management Department, Gaziantep, Türkiye. (kcingoz@gantep.edu.tr)

²Eskisehir Technical University, Aviation Management Department, Eskisehir, Türkiye. (vkorul@eskisehir.edu.tr)

Article Info

Received: 21 April 2025

Revised: 19 August 2025

Accepted: 15 September 2025

Published Online: 18 October 2025

Keywords:

Accessibility

Mobility

Inclusion

Passenger with disabilities

Challenges for disabled passengers

Corresponding Author: Kübra Nur Cingöz

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1681239>

Abstract

The global number of passengers with disabilities (PWDs) has increased significantly, with passengers with reduced mobility (PRMs) rising at a rate far exceeding overall passenger growth. Yet, despite this growing demand, substantial barriers to accessible air travel persist, resulting in lower participation rates among passengers with disabilities compared to other traveler groups. Existing challenges include insufficient infrastructure, fragmented services, inconsistent implementation of accessibility measures, and limited awareness of available accommodations. Furthermore, inadequate staff training, communication gaps, and persistent risks associated with mobility equipment exacerbate these difficulties, while passengers with mental health conditions encounter additional complexities. This study aims to systematically examine the challenges faced by passengers with disabilities in air transportation through a thematic approach. By employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model, the research analyzes recent developments and identifies persistent barriers within both airports and aircraft. The findings highlight the need for harmonized procedures across airlines and airports, comprehensive staff education, inclusive infrastructure, and the integration of assistive technologies. Additionally, the study emphasizes the importance of involving passengers with disabilities in policy development and decision-making processes. Finally, several targeted recommendations are presented for regulators, airlines, and designers to foster a more accessible, equitable, and inclusive air travel experience.

1. Introduction

There has been a notable global rise in the number of passengers with disabilities (PWDs) (Rady & Wahab, 2022). In some airports, the proportion of passengers with reduced mobility (PRM) has increased at a pace nearly six times faster than the overall growth in passenger numbers. However, despite this sharp rise, substantial barriers to accessible air travel persist, leading to lower participation rates in air travel among passengers with disabilities compared to other groups of travelers (Budd & Ison, 2020). This situation reveals a critical paradox: while the demand for accessible air travel is rapidly expanding, the actual travel experience of passengers with disabilities remains hindered by persistent obstacles. Despite airport design focusing on accessibility and preventive measures, passengers with disabilities still face significant challenges when navigating airports (Yeğnidemir, 2013). Indeed, similar issues exist globally; research indicates that accessibility barriers persist at airports in various countries (Santos et al., 2024; Erickson, 2016; Chang & Chen, 2012; Saari, 2015; Wang & Cole, 2014). According to da Silva et al. (2021), passengers with disabilities experience a wide range of challenges throughout their air travel journey. These include situations where families neglect their responsibilities or

where travel is denied due to stringent medical documentation requirements. Communication gaps among professionals, coupled with passengers' feelings of embarrassment, often result in inadequate follow-up. Furthermore, insufficient infrastructure and limited staffing exacerbate accessibility barriers. Conflicts may also emerge when passengers with disabilities resist complying with security procedures. Wheelchair users are particularly vulnerable, frequently facing accidents during boarding, while auxiliary equipment remains at risk of being damaged or lost. Additionally, aviation staff encounter further complexities when managing cases involving individuals with mental disorders. In light of these ongoing challenges, regulatory bodies and aviation stakeholders have undertaken several initiatives over the past decades to address accessibility barriers in air travel. Efforts to improve accessibility in air travel date back several decades. In 1979, the Federal Aviation Administration (FAA) in the United States established a working group to investigate accessibility challenges and propose solutions. The committee's recommendations emphasized the importance of specialized staff training for emergency evacuations involving elderly and disabled passengers, the provision of accessible toilets in both terminals and aircraft, the availability of wheelchairs and other mobility devices, and the installation of

ramps or lifts at changes in level (Chang & Chen, 2012). However, despite these early initiatives, studies indicate that implementation has been inconsistent, with considerable variation across airlines and airports in terms of available services and accommodations. Furthermore, information for passengers with disabilities is typically confined to airline websites, where accessibility resources remain fragmented and lack standardization. Despite the introduction of such measures, many accessibility challenges remain unresolved, as recent studies point to persistent barriers within airport environments. Moreover, limited awareness of available services within airports remains one of the most pressing challenges faced by people with disabilities (Nur & Acar, 2017; Evliyaoğlu & Tezel, 2017).

Building on these ongoing challenges, the primary aim of this study is to examine the difficulties encountered by passengers with disabilities in air transportation through a thematic approach. The study particularly focuses on analyzing issues that have emerged in recent years and seeks to develop practical recommendations to improve accessibility in the aviation sector. Special emphasis is placed on crafting targeted recommendations for key stakeholder groups, including airlines, regulators, and designers. These groups play a vital role in advancing accessibility efforts, and by signaling this early, readers can anticipate practical guidance tailored to their roles. To achieve this comprehensive objective, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model was employed, and the resulting findings are presented in the corresponding section.

2. Method

This article reviews the social science literature on disabled passengers, with a particular focus on the aviation sector. The study aimed to examine how disabled passengers are studied from a social science perspective, considering the issues addressed and the recommendations made for their development. To achieve this, a systematic literature review was conducted in accordance with the PRISMA guidelines. This framework comprises 27 items and outlines the key stages of a systematic review, including establishing eligibility criteria, identifying information sources, defining search strategies, describing study selection procedures, and presenting outcomes and data synthesis. Guided by the research question, “What kind of knowledge is produced in social science studies of disabled passengers?”, the review systematically identified and analyzed studies that address the challenges faced by disabled passengers during travel, as well as how these challenges have been investigated and addressed in the literature (Kojonsaari & Palm, 2023; Ortiz-Martínez et al., 2019).

2.1. Eligibility Criteria

The present systematic review applied clearly defined eligibility criteria to ensure consistency and relevance in the selection of studies. The inclusion criteria comprised peer-reviewed journal articles published between 2015 and 2025 in English or Turkish, focusing on the challenges faced by disabled passengers from a social science perspective. Exclusion criteria removed non-academic materials, such as dissertations, conference proceedings, editorials, and studies focusing solely on technical or

non-social science aspects. The authors collectively determined these criteria to establish clear boundaries for the review, which were consistently applied during the database search and study selection processes.

Articles were retrieved from two major databases, Scopus and Web of Science (WoS), using the search terms “disabled passenger” (WoS) and “disabled and passenger” (Scopus), with search fields, categories, and document types tailored to capture relevant studies within social sciences and related disciplines. After removing duplicates and applying language, time, and category restrictions, a total of 104 records remained. Initial screening was performed by reading abstracts and introductions, followed by full-text assessment. Studies that did not address disabled passengers from a social science perspective were excluded. After removing duplicates and irrelevant studies, 19 articles were included in the final review. The selected articles were subsequently classified thematically using an inductive, data-driven approach, organizing the literature based on emerging concepts, themes, and geographical context (Kojonsaari & Palm, 2023). Observations from the authors were incorporated into a dedicated coding category to enhance the analysis.

2.2. Study Selection

In accordance with the PRISMA methodology, the review team consisted of two authors who independently screened titles, abstracts, and full texts of all retrieved articles to minimize random errors and potential bias at each stage of the review. Screening was conducted based on the predefined inclusion and exclusion criteria outlined in the Eligibility Criteria section. After the initial database search, 104 records were identified from Scopus and Web of Science, which were merged and cross-checked for duplicates. Abstracts of the remaining works were then carefully reviewed, and studies relevant to disabled passengers in a social science context were selected. Full texts were downloaded for further assessment whenever the review team was uncertain about a study’s eligibility. Following full-text assessment, a total of 19 articles met the eligibility criteria and were included in the systematic review.

3. Findings

As shown in Fig. 1, a total of 569 works were initially retrieved from the Scopus and WoS databases, with 18 works identified in WoS and 551 in Scopus. After merging the results and applying restrictions based on language (English and Turkish), document type (articles and reviews), and publication period (2015–2025), the total number of records was reduced to 107. These 107 records were then screened through abstract reading, introduction reviews, and, when necessary, quick scanning of full texts. Following this screening process, 33 records were excluded because they were unrelated to the aviation industry, focusing instead on areas such as healthcare, history, or other modes of transportation. Ultimately, 19 studies were deemed relevant and included in the final synthesis. This reduction from 569 to 19 articles highlights critical gaps in airport operations and policy discussions. The missing studies highlight blind spots, particularly in operational areas such as emerging technological solutions, inclusivity practices, and the detailed regulatory impacts. This gap suggests the need for more comprehensive research to

address these oversight areas strategically and provide practitioners with insights that could enhance accessibility efforts in air travel. The remaining 19 works were included in the analysis (See Figure 1).

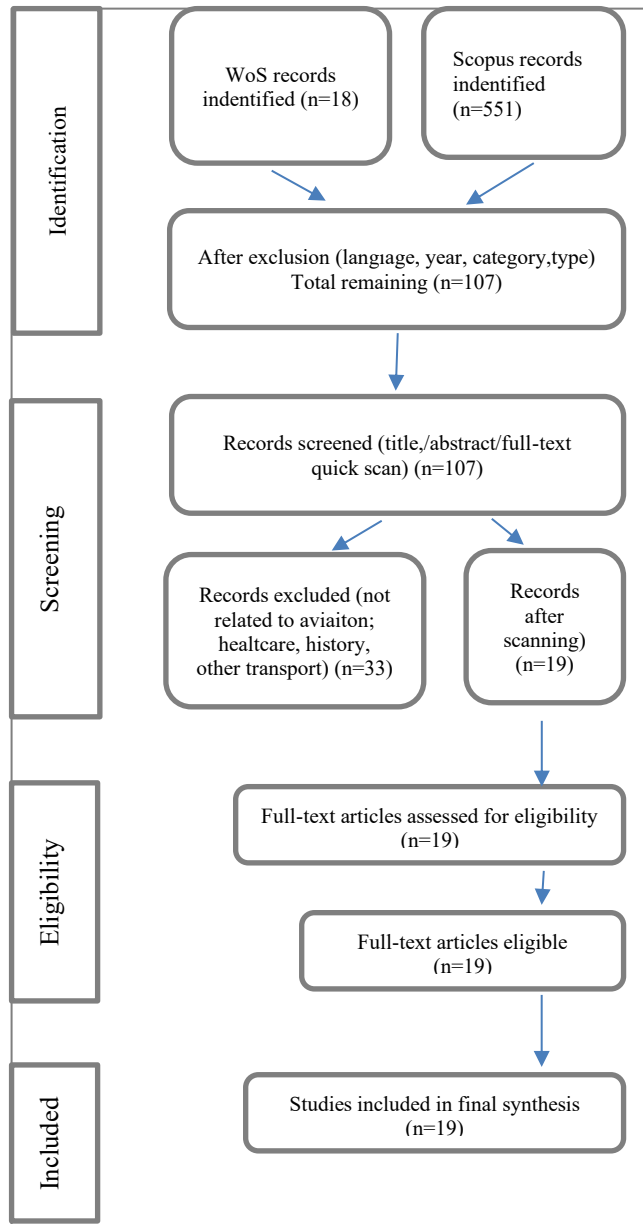


Figure 1. Flow Diagram of the Study Selection Process
Source: Developed by the authors, inspired by Ortiz-Martínez et al. (2019), Keskin and İşler, 2023; and Filiz (2022)

These works were classified based on their themes, geographical contexts, methods, and the aim of identifying emerging narratives and patterns related to disabled As seen in Table 1, technological solutions and ergonomic design are increasingly explored to enhance accessibility. For instance, Maurya et al. (2019) investigated digital human modeling (DHM) to enhance work environments for the elderly and individuals with disabilities, emphasizing the importance of inclusive design principles. Żydek et al. (2021) applied simulation models to the evacuation and movement of people with disabilities, while Ma et al. (2024) modeled aircraft cabin evacuations, considering passenger diversity that includes people with disabilities, and highlighted the impact on evacuation efficiency.

passengers from a social science perspective. The study was exploratory in nature, and the inductive analysis involved creating data-driven categories. Observations made by the review team were incorporated into a dedicated coding category.

As shown in Table 1, the analysis results are systematically organized according to the identified themes, including Title, Author, Year, Themes, Geographical Context, Aim, and Method. Although studies from 2015 to 2025 were initially filtered during the identification stage (see Figure 1), the included studies date from 2017 onwards. Notably, research conducted in 2024–2025 addressing the challenges faced by passengers with disabilities is more abundant compared to earlier years.

The categories presented in Table 1 are discussed in detail below.

3.1. Thematic Analysis of Results

As shown in Table 1, The literature on accessibility and inclusivity in air travel and related domains highlights several recurring themes. Experiences and barriers faced by disabled passengers are well documented. Davies and Christie (2017) explored the experiences of wheelchair users as aircraft passengers, identifying barriers and suggesting improvements. Similarly, Dos Santos et al. (2024) focused on passengers with hidden disabilities, highlighting accessibility challenges and offering recommendations for better assistance in air travel. Gotti et al. (2024) examined the dehumanizing aspects of air travel for people with disabilities, noting both barriers and facilitators within international airports. Martín-Domingo et al. (2024) extended this discussion by systematically reviewing barriers and proposed solutions for passengers with specific access requirements, including persons with disabilities (PwDs) and passengers with reduced mobility (PRMs). Booth (2024) further emphasized the importance of accessibility for children with disabilities, highlighting confidence-building and preparatory initiatives for inclusive travel. Castro et al. (2025) examined airport accessibility for neurodivergent passengers, underlining hidden disabilities and support programs.

Ageing passengers and inclusivity constitute another significant theme. Graham et al. (2019) analyzed the air travel experiences of the aging population in the UK, focusing on airports and the needs of aging passengers, as well as the accessibility of airport services and technologies. Graham et al. (2023) further investigated perceptions of ground access journeys, demonstrating how older passengers experience airport travel differently and suggesting ways to enhance accessibility.

Kurbatova and Aisner (2021) examined technology as a compensatory tool to protect the rights of vulnerable individuals in criminal proceedings, demonstrating the broader application of technological interventions beyond transport contexts.

Legal frameworks and social protection also emerge as important considerations. Colker (2022) critiqued the Americans with Disabilities Act for its narrow individual-focused approach, while Aliabieva and Kerymov (2022) reviewed international standards regarding social protection rights of persons with disabilities, highlighting

systemic and policy-level factors that affect accessibility. Beyond these legal and policy frameworks, the practical implementation of accessibility also relies on inclusive and universal design principles. Bęczkowska and Grabarek (2024) discussed the distinction between universal and inclusive design in public utility and transportation infrastructure, emphasizing the importance of designing services that cater to diverse needs. At the same time, communication and functional challenges must be addressed to ensure accessibility in operational contexts. Giguere et al. (2020) investigated the effects of hearing loss and language proficiency on speech intelligibility over radio communication, illustrating the importance of communication accessibility. Collectively, these studies highlight that legal rights, design practices, and communication strategies are all interrelated in creating truly accessible environments.

3.2. Results Presented Within a Geographical Framework

Understanding the geographical distribution of research on accessibility and inclusion provides insight into the contexts in which challenges are studied and solutions are proposed. The following analysis categorizes existing studies according to their geographical focus, highlighting both country-specific investigations and broader, internationally oriented research.

While some studies focus on specific countries, such as the United Kingdom (Davies & Christie, 2017; Graham et al., 2019; Graham et al., 2023; Booth, 2024), the United States (Colker, 2022), Ukraine (Aliabieva & Kerymov, 2022), and Russia and Kazakhstan (Abilkassimova et al., 2025), other research adopts a more general or international perspective, addressing accessibility and inclusive practices without being tied to a particular geographic context (Maurya et al., 2019; Giguere et al., 2020; Żydek et al., 2021; Kurbatova & Aisner, 2021; Tuli et al., 2023; Ma et al., 2024; Bęczkowska & Grabarek, 2024; Dos Santos et al., 2024; Gotti et al., 2024; Martín-Domingo et al., 2024; Castro et al., 2025). This variation in geographical focus highlights not only the diverse contexts in which accessibility challenges are studied but also the universal relevance of inclusive practices, providing a foundation for examining both policy frameworks and practical implementation strategies in subsequent discussions.

3.3 Results Organized According to Study Objectives

The reviewed studies encompass a diverse range of research aims, including accessibility, inclusion, ergonomics, policy evaluation, and service improvement. By examining these aims, it is possible to identify patterns in the focus areas of current research and the strategies employed to address challenges faced by individuals with disabilities.

Davies and Christie (2017) aimed to understand the experiences of wheelchair users and develop policy recommendations for air passengers. In contrast, Graham et al. (2019, 2023) investigated airport use by older travelers and ground access journeys, with the goal of informing future airport policy and management for air transport. Booth (2024) assessed the impact of the "Try Before You Fly" initiative on family confidence and anxiety in navigating airports for children with disabilities who travel

by air.

Other studies concentrate on developing or evaluating technical solutions. Maurya et al. (2019) aimed to improve ergonomics and accessibility using digital human modeling (DHM), whereas Żydek et al. (2021) developed evacuation simulations for individuals with disabilities. Ma et al. (2024) modeled aircraft cabin evacuation processes, analyzing passenger attributes and cabin structures, including air passengers. Kurbatova & Aisner (2021) examined the role of technological tools in protecting the rights of vulnerable individuals.

Several studies aim to analyze or critique policy and legal frameworks. Colker (2022) argued that the Americans with Disabilities Act's requirement for individuals to claim disability status undermines broader structural reforms, proposing a shift toward proactive societal inclusion. Aliabieva and Kerymov (2022) examined social protection rights for persons with disabilities.

Some works focus on analyzing accessibility and service delivery. Tuli et al. (2023) examined service experiences of disabled users, while Dos Santos et al. (2024) analyzed literature to identify recommendations for air passengers with hidden disabilities. Gotti et al. (2024) evaluated accessibility and inclusion practices in airports for air travel, and Martín-Domingo et al. (2024) systematically reviewed challenges and solutions for air passengers with specific access requirements. Castro et al. (2025) examined accessibility strategies for neurodivergent air passengers and analyzed their implementations. Finally, some studies address educational and developmental outcomes. Abilkassimova et al. (2025) investigated the effects of school-based physical activity programs on academic performance, social relationships, and attention development for students with disabilities.

Overall, these studies demonstrate that research efforts are driven by the goal of enhancing accessibility and inclusion, whether through understanding user experiences, developing technical solutions, evaluating policies, or improving service delivery, all aimed at better meeting the varied needs.

3.4. Results Organized According to Research Methods

Within the framework of social science research methodologies, the reviewed studies employed a diverse array of approaches, encompassing qualitative methods such as interviews, thematic analyses, and exploratory observations, as well as quantitative techniques including surveys, statistical analyses, and mixed-methods strategies that integrate both qualitative and quantitative data. Additionally, several studies utilized modeling and simulation approaches, computational analyses, and experimental designs to examine accessibility, inclusion, and ergonomic issues.

Building on these diverse methodological approaches, the findings from the literature reveal persistent challenges in air travel accessibility, highlighting how physical, infrastructural, communication, and service-related barriers continue to affect passengers with disabilities, ageing travelers, and neurodivergent individuals.

Accessibility in air travel remains constrained by persistent challenges affecting passengers with disabilities, ageing travelers, and neurodivergent individuals. Across studies, multiple barriers have been identified, highlighting critical gaps in infrastructure, procedures, communication, and

staff preparedness.

Physical and infrastructural barriers are among the most frequently reported challenges. Davies and Christie (2017) found that wheelchair users face difficulties with boarding, seating, and using onboard facilities due to inadequate airport layouts and limited accessible infrastructure. Graham et al. (2019) and Graham et al. (2023) Edwards et al. (2025) highlighted mobility difficulties faced by older passengers, including challenges with signage, ground access, and navigation within airports. Dos Santos et al. (2024) also noted that passengers with hidden disabilities encounter disorientation and sensory overload in complex airport spaces.

Evacuation and safety management present additional challenges. Żydek et al. (2021) demonstrated that passengers with disabilities require tailored evacuation procedures to prevent delays and ensure safety. Ma et al. (2024) found that passenger density and the proportion of passengers with disabilities significantly affect cabin evacuation times, underscoring the need for optimized seating distribution and emergency protocols.

Communication and service barriers further limit accessibility. Dos Santos et al. (2024) highlighted that insufficient staff training and a lack of awareness about hidden disabilities reduce passengers' comfort and ability to navigate airports effectively. Martin-Domingo et al. (2024) demonstrated that inconsistent staff responses and insufficient service processes significantly hinder passengers with specific access needs. Their analysis further identifies nuanced sub-categories of accessibility obstacles. It emphasizes practical solutions, including regulatory measures, facility upgrades, digitalization, cabin accessibility improvements, and targeted staff training, highlighting the necessity of coordinated stakeholder efforts to foster greater inclusivity in air travel. Castro et al. (2025) highlighted that airport accessibility for neurodivergent passengers remains limited and fragmented, with information scattered across multiple platforms and a lack of centralized resources. The study emphasizes that neurodivergent individuals face unique challenges, and current initiatives are often inconsistent, underscoring the urgent need for inclusive policies, staff training, and research that incorporates the perspectives of neurodivergent passengers to improve their air travel experiences. Booth (2024) demonstrated that preparatory programs, such as "Try Before You Fly," can mitigate anxiety and increase confidence, revealing that the lack of such initiatives is a significant challenge for families traveling with children with disabilities.

Overall, these findings highlight that the primary obstacles to accessible air travel stem from insufficient infrastructure, gaps in emergency preparedness, communication shortcomings, limited staff training, and fragmented service initiatives. Effectively addressing these challenges through coordinated infrastructure enhancements, comprehensive staff education, streamlined procedures, and inclusive program development is crucial for creating air travel experiences that are safe, equitable, and comfortable for all passengers.

4. Conclusion and Recommendations

Accessibility in air travel remains a significant global

challenge. Overall, numerous obstacles have been identified for passengers with disabilities, older travelers, and neurodivergent individuals, including inadequate infrastructure, insufficient emergency planning, communication gaps, and limited staff preparedness. Physical and structural barriers notably impede boarding, seating, wayfinding, and mobility within airports for wheelchair users, older passengers, and individuals with hidden disabilities.

Emergency and safety management also represent critical areas, as tailored evacuation procedures are required for passengers with disabilities, and cabin density and the proportion of passengers with disabilities directly influence evacuation times.

Communication and service shortcomings, combined with insufficient staff training and limited awareness of specific passenger needs, further hinder effective navigation of airport environments. Initiatives for neurodivergent passengers remain limited and fragmented, with scattered information and inconsistent practices emphasizing the need for inclusive policies and targeted staff training.

These findings underscore the importance of coordinated measures, including infrastructure enhancements, comprehensive staff education, standardized procedures, and inclusive program development, to improve accessibility in air travel. Collectively, such efforts are crucial for ensuring safe, equitable, and comfortable travel experiences, underscoring the need for future research to address existing knowledge gaps in this field.

Building on these insights, the following recommendations outline concrete strategies for the aviation industry to translate accessibility research into effective practices, ensuring that passengers with disabilities experience safe, equitable, and inclusive air travel.

Airlines and airports should adopt standardized procedures across the industry to ensure disabled passengers receive consistent and high-quality service, no matter where they travel. This includes uniform protocols for boarding assistance, communication of flight changes, and handling medical equipment. Regular and comprehensive training for airline and airport staff on disability awareness and customer service is essential. This training should cover a variety of disabilities, emergency evacuation procedures, and effective communication techniques to ensure that passengers with disabilities feel respected, understood, and safe.

To further enhance accessibility, airlines and airports should integrate more technologies, such as improved navigation apps, real-time assistance via virtual assistants, and intuitive in-flight systems designed for passengers with hearing, vision, or mobility impairments. Clear and timely communication regarding flight changes, delays, and gate information is crucial. Airlines should implement systems to proactively inform disabled passengers of any disruptions and offer alternative options, ensuring that all passengers, including those with hearing impairments, are informed effectively.

Disabled travelers should be actively involved in the development of new policies and services. Engaging them in focus groups or surveys will provide valuable insights into the specific challenges they face and help design solutions that cater to their needs. Information campaigns should promote the rights of disabled passengers and educate them on how to access available services. Such initiatives can empower

travelers to seek the assistance they need and ensure they are fully informed about the services available to them.

The accessibility of air travel still faces significant challenges that need to be addressed. To overcome these obstacles, the aviation industry should focus on standardizing services, enhancing staff training, improving communication systems, and integrating more technology. By implementing these measures, the industry can create a more inclusive and equitable travel experience for all passengers. The ultimate goal is to ensure that disabled passengers can travel with the same comfort and convenience as non-disabled travelers, promoting full inclusion and equality within the aviation sector. Addressing these recommendations will ensure that disabled individuals are not just accommodated but can also enjoy the same high level of service as all other passengers.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abilkassimova, G., Baigabylov, N., Chernova, O., Litvinov, A., & Koneeva, E. (2025). Improving academic outcomes through accessible physical activity for students with disabilities. *Retos*, 67, 1202-1115.
- Aliabieva, N., & Kerymov, L. (2022). The right to social protection of persons with disabilities according to international standards. *Social and Legal Studios*, 5(1), 63-69.,
- Bęczkowska, S., & Grabarek, I. (2024). Accessible Transportation—Universal or Inclusive Design?. *Zeszyty Naukowe. Transport-Politechnika Śląska*, (125).
- Booth, N. (2024). Try before you fly: Perspectives of parents and their children with disabilities on a natural environment teaching airport event. An exploratory study. *Annals of Tourism Research Empirical Insights*, 5(2), 100162.
- Budd, L., & Ison, S. (2020). Supporting the needs of special assistance (including PRM) passengers: An international survey of disabled air passenger rights legislation. *Journal of Air Transport Management*, 87, 101851.
- Castro, R. T. D., Batista, M. M., & Andrada, M. E. S. (2025). Airport accessibility for neurodivergent passengers: a global survey of initiatives and its implications. *Revista Brasileira de Pesquisa em Turismo*, 19, e-3077.
- Chang, Y. C., & Chen, C. F. (2012). Meeting the needs of disabled air passengers: Factors that facilitate help from airlines and airports. *Tourism Management*, 33(3), 529–536.
- Chang, Y. C., & Chen, C. F. (2012). Meeting the needs of disabled air passengers: Factors that facilitate help from airlines and airports. *Tourism Management*, 33(3), 529–536.
- Colker, R. (2021). The Americans with Disabilities Act's Unreasonable Focus on the Individual. *U. Pa. L. Rev.*, 170, 1813.
- da Silva, F. H. M., Sticca, M. G., da Silva, T. N. R., Vidotti, H. G. M., & Menegon, N. L. (2021, May). Analyzing the activity of Brazilian airline industry professionals in assisting passengers with disabilities. In *Proceedings of the 21st Congress of the International Ergonomics Association (IEA 2021) Volume I: Systems and Macroergonomics* (pp. 288–295). Cham: Springer International Publishing.
- Davies, A., & Christie, N. (2017). An exploratory study of the experiences of wheelchair users as aircraft passengers—implications for policy and practice. *IATSS research*, 41(2), 89-93.
- Dos Santos, I., Da Silva, S. L., Camarotto, J. A., & Vidotti, H. G. M. (2024). Accessibility for passengers with hidden disabilities in air transport: A literature review. *Journal of the Air Transport Research Society*, 3, 100033.
- Edwards, C., Love, A. M., Ying Cai, R., Tutton, T., Beardsley, E., & Gibbs, V. (2025). Autistic-led insights on airport accessibility: A retrospective analysis of environmental assessments. *Autism*, 13623613251337200.
- Erickson, K. C. (2016). Able to fly: Temporality, visibility, & the disabled airline passenger. In *Handbook of Anthropology in Business* (pp. 412–428). Routledge.
- Evliyaoğlu, D., & Tezel, E. (2017). Havalimanlarının görme ve bedensel engellilerin erişebilirliği üzerinden değerlendirilmesi: İstanbul Atatürk Havalimanı örneği. *Mühendislik Bilimleri ve Tasarım Dergisi*, 5, 95–108.
- Filiz, M. (2022). Sağlık çalışanların ihbarcılık eğilimlerini belirlemeye yönelik yapılan çalışmaların sistematik derleme yöntemi ile analizi. *Artvin Çoruh Üniversitesi Uluslararası Sosyal Bilimler Dergisi*, 8(1), 74-86.
- Giguere, C., Vaillancourt, V., & Laroche, C. (2020). Effects of hearing loss and language proficiency on speech intelligibility over radio transmission with tactical communication devices. *International Journal of Audiology*, 59(sup1), S31-S39.
- Gotti, D., Morales, E., Routhier, F., Riendeau, J., & Hadj Hassen, A. (2024). Dehumanizing air travel: a scoping review on accessibility and inclusion of people with disabilities in international airports. *Frontiers in Rehabilitation Sciences*, 5, 1305191.
- Graham, A., Budd, L., Ison, S., & Timmis, A. (2019). Airports and ageing passengers: A study of the UK. *Research in Transportation Business & Management*, 30, 100380.
- Graham, A., Budd, L., Ison, S., & Timmis, A. (2019). Airports and ageing passengers: A study of the UK. *Research in Transportation Business & Management*, 30, 100380.
- Graham, A., Kruse, W., Budd, L., Kremarik, F., & Ison, S. (2023). Ageing passenger perceptions of ground access journeys to airports: A survey of UK residents. *Journal of Air Transport Management*, 107, 102338.
- Keskin, M., & İşler, E. K. (2023). Dijital şeffaflık kavramı: Uluslararası literatürün PRISMA yöntemiyle sistematik incelenmesi. *Türk Kütüphaneciliği*, 37(2), 109-136.
- Kojonsaari, A. R., & Palm, J. (2023). The development of social science research on smart grids: A semi-structured
- Kurbatova, S. M., & Aisner, L. Y. (2021). Modern technologies as compensatory means of ensuring the rights of vulnerable persons in criminal proceedings. *Kutafin Law Review*, 8(4), 546-572.
- Ma, Y., Yuan, J., Tan, L., Liu, Q., & Li, M. (2024). A model for aircraft cabin evacuation considering passenger type. *Journal of Safety Science and Resilience*, 5(1), 83-90.
- Martín-Domingo, L., Adiloğlu-Yalçınkaya, L., Ertürk, M., & Farkić, J. (2024). Existing barriers and suggested solutions for dealing with air passengers with specific

- access requirements: A systematic literature review. *Research in Transportation Business & Management*, 53, 101104.
- Maurya, C. M., Karmakar, S., & Das, A. K. (2019). Digital human modeling (DHM) for improving work environment for specially-abled and elderly. *SN Applied Sciences*, 1(11), 1326.
- Nur, R., & Acar, N. (2017). Havalimanında sunulan hizmetlerin engelli yolcular tarafından değerlendirilmesi: Ankara Esenboğa Havalimanı örneği (Master's thesis, Nevşehir Hacı Bektaş Veli Üniversitesi).
- Ortiz-Martínez, V. M., Andreo-Martínez, P., García-Martínez, N., de los Ríos, A. P., Hernández-Fernández, F. J., & Quesada-Medina, J. (2019). Approach to biodiesel production from microalgae under supercritical conditions by the PRISMA method. *Fuel processing technology*, 191, 211-222.
- Rady, A., & Wahab, H. A. (2022). Assessing air services and facilities provided to passengers with disabilities at EgyptAir. *International Journal of Heritage, Tourism and Hospitality*, 15(2), 115-127.
- Saari, S. (2015). Taking over the world in a wheelchair: The difficulties and challenges when travelling by air transportation.
- Santos, I., Silva, S., Camarotto, J. A., & Vidotti, H. G. M. (2024). Accessibility for passengers with hidden disabilities in air transport: A literature review. *Journal of the Air Transport Research Society*, 100033.
- Tuli, N., Srivastava, R., & Kumar, H. (2023). Navigating services for consumers with disabilities: a comprehensive review and conceptual framework. *Journal of services marketing*, 37(9), 1132-1150.
- Wang, W., & Cole, S. (2014). Perceived onboard service needs of passengers with mobility limitations: An investigation among flight attendants. *Asia Pacific Journal of Tourism Research*, 19(11), 1239-1259.
- Żydek, K., Król, M., & Król, A. (2021). RETRACTED: Evacuation Simulation Focusing on Modeling of Disabled People Movement. *Sustainability*, 13(4)

Cite this article: Cingoz, K.N, Durmaz, V. (2025). Breaking the Barriers: Accessibility Challenges for Disabled Passengers in Aviation. *Journal of Aviation*, 9(3), 590-599.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Table 1. Studies on Challenges Faced by Passengers with Disabilities

Title	Author	Year	Themes	Geographical Context	Aim	Method
An exploratory study of the experiences of wheelchair users as aircraft passengers – implications for policy and practice	Davies and Christie	2017	Experiences of wheelchair users as aircraft passengers, barriers, and improvement suggestions	United Kingdom	To understand the experiences of wheelchair users and develop policy recommendations	Qualitative research, interviews, thematic analysis
Airports and ageing passengers: A study of the UK	Graham et al.	2019	Ageing population and air travel Accessibility of airport services and technologies	United Kingdom	To investigate the use of UK airports by older travellers using publicly available data and provide recommendations for future airport policy and management	Qualitative research, survey, data analysis
Digital human modeling (DHM) for improving work environment for specially-abled and elderly	Maurya et al.	2019	Digital human modeling (DHM) for ergonomic design Inclusive design for elderly and disabled individuals	General	To improve ergonomics and accessibility using DHM techniques	Qualitative research, digital modeling, simulation
Effects of hearing loss and language proficiency on speech intelligibility over radio transmission with tactical communication	Giguere et al.	2020	Effects of hearing loss and language proficiency on communication	General (study sample-based)		Experimental study, communication testing
Evacuation simulation focusing on modeling of disabled people movement	Żydek et al.	2021	Simulation of evacuation and movement models of disabled people	General (emergencies)	To develop evacuation simulations for disabled individuals	Computer simulation, modeling
Modern Technologies as Compensatory Means of Ensuring the Rights of Vulnerable Persons in Criminal Proceedings	Kurbatova and Aisner	2021	Use of technology to protect the rights of vulnerable individuals	General (legal processes)	To examine the role of technological tools in protecting rights	Legal analysis, technology evaluation
The Americans with Disabilities Act's Unreasonable Focus on the Individual	Colker	2022	Disability justice and legal frameworks	United States	To critique the ADA's focus on disability claims and promote a shift from reactive accommodations to proactive societal inclusion.	Legal analysis, critical approach

Title	Author	Year	Themes	Geographical Context	Aim	Method
The Right to Social Protection of Persons with Disabilities According to International Standards	Aliabieva and Kerymov	2022	Social protection rights of persons with disabilities under international standards	Ukraine	To examine social protection rights	Qualitative research , analysis of international documents
Ageing passenger perceptions of ground access journeys to airports: A survey of UK residents	Graham et al.	2023	Ageing population and airport ground Access	United Kingdom	To investigate airport access from the perspective of aging passengers	Qualitative, survey, data analysis
Navigating services for consumers with disabilities: a comprehensive review and conceptual framework	Tuli et al.	2023	Navigation of services for disabled consumers and a conceptual framework	General	To examine the service experiences of disabled users	Qualitative, literature review, and conceptual model development
A model for aircraft cabin evacuation considering passenger type	Ma et al.	2024	Passenger evacuation dynamics in aircraft cabins, Impact of passenger diversity, including disabled passengers, on evacuation efficiency	General	To model cabin evacuation processes, develop and analyze a cellular automaton model for different passenger types	Mathematical modeling, simulation
Accessible Transportation – Universal or Inclusive Design?	Bęczkowsk & Grabarek	2024	Accessibility and universal design in public utility and transportation infrastructure	General (transportation systems)	To compare accessibility designs in transportation and propose design strategies for inclusive and universal accessibility	Literature analysis, design comparison
Accessibility for passengers with hidden disabilities in air transport: A literature review	Dos Santos et al.	2024	Accessibility challenges for passengers with hidden disabilities in air transport	General (air transport)	To identify accessibility recommendations for improving air travel experiences for passengers with disabilities	Systematic literature review
Dehumanizing air travel: a scoping review on accessibility and inclusion of people with disabilities in international airports	Gotti et al	2024	Accessibility barriers and facilitators for people with disabilities in air travel	General (International airports)	To evaluate accessibility and inclusion practices in airports	Scoping review, systematic analysis
Existing barriers and suggested solutions for dealing with air passengers with specific access requirements: A systematic literature review	Martín-Domingo et al.	2024	Barriers faced by passengers with disabilities (PwDs) and passengers with reduced mobility (PRMs) in air transport	General (international literature)	To systematically review literature addressing accessibility challenges and solutions for PwDs and PRMs in air travel	Systematic literature review

Title	Author	Year	Themes	Geographical Context	Aim	Method
Try before you fly: Perspectives of parents and their children with disabilities on a natural environment teaching airport event. An exploratory study	Booth	2024	Air travel accessibility for children with disabilities Confidence-building and preparatory initiatives for inclusive travel	United Kingdom (regional airport)	To explore the impact of the "Try Before You Fly" initiative on the confidence of families with disabled children in navigating the airport experience	Exploratory study, observation, survey
Airport Accessibility for Neurodivergent Passengers: A Global Survey of Initiatives And Its Implications	Castro et al	2025	Airport accessibility for neurodivergent passengers; hidden disabilities; support programs	General (Global)	To examine accessibility strategies for neurodivergent passengers and analyze implementations	Survey, compilation of case examples
Improving Academic Outcomes Through Accessible Physical Activity For Students With Disabilities	Abilkassimova et al.	2025	Physical activity; accessible education; disabled students; academic achievement; attention development; social relations	Russia and Kazakhstan	To examine the effects of school-based physical activity programs on academic performance and social relationships	12-week single-blind randomized controlled trial; comparison of 3 groups (MVPA, MPA, NPA)

Source: Developed by Authors

The Impact of ESG Performance on Financial Profitability: Evidence from the Aviation Sector in EU Countries

Burcu Zengin¹ 

¹Ankara Hacı Bayram Veli University, Business Department, 06500, Yenimahalle, Ankara, Türkiye. (burcu.zengin@hbv.edu.tr)

Article Info

Received: 18 April 2025
Revised: 12 September 2025
Accepted: 15 September 2025
Published Online: 09 October 2025

Keywords:

Aviation
Airline
ESG score
Sustainability
Stakeholder theory
Triple bottom line theory

Corresponding Author: [Burcu Zengin](mailto:burcu.zengin@hbv.edu.tr)

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1768349>

Abstract

This study investigates the impact of environmental, social, and governance (ESG) practices on the financial performance of airlines, with profitability measured by return on assets (ROA). While the ESG–performance nexus has been widely explored in the finance literature, empirical evidence specific to the airline industry remains limited, despite the sector’s significant contribution to global emissions and its unique regulatory and competitive pressures. Drawing on stakeholder theory and the triple bottom line framework, the study examines whether ESG engagement serves as a strategic driver of financial outcomes alongside its social and environmental objectives.

Using a panel dataset of European Union airlines covering an eleven-year period, the analysis employs Random-Effects estimators with cluster-robust standard errors, complemented by Feasible Generalized Least Squares (FGLS) estimation as a robustness check against heteroskedasticity and autocorrelation. Regression results, reported across four model specifications, reveal a consistently positive and statistically significant association between ESG performance and ROA. This relationship indicates that higher ESG scores enhance firm profitability. Disaggregated findings further demonstrate that each ESG sub-dimension—environmental (E), social (S), and governance (G)—exerts a positive and statistically significant effect on ROA, underscoring that diverse sustainability-related practices collectively strengthen financial outcomes.

The study contributes to the literature by offering sector-specific evidence on the ESG–performance relationship in aviation. By integrating stakeholder and triple bottom line perspectives, it highlights that ESG practices are not merely compliance-oriented but represent a strategic pathway to profitability, competitive advantage, and long-term value creation.

1. Introduction

Sustainability practices have become increasingly salient in the airline industry, as the sector is widely recognized as a major contributor to global carbon emissions and climate change. According to EU Climate Action (2022), direct emissions from aviation account for 3.8–4% of the European Union’s total greenhouse gas emissions and 13.9% of transport-related emissions, positioning aviation as the second-largest source of transport emissions after road transport. This environmental footprint underscores the importance of developing strategies to mitigate the sector’s contribution to climate change while ensuring continued competitiveness and growth.

With the rapid expansion of air travel, airlines face the dual challenge of reducing operational costs while maintaining fair labor conditions and addressing environmental responsibilities. Scholars emphasize that companies should not compromise social well-being—including environmental protection and labor rights—for short-term profitability (Kao et al., 2022). This responsibility extends to a wide range of initiatives, including reducing greenhouse gas emissions,

ensuring employee welfare, fostering community engagement, and adhering to ethical business practices (Sorsa and Bona-Sánchez, 2024). Such efforts are not only integral to advancing societal welfare but also critical to the survival and long-term growth of firms. For airlines in particular, consumer loyalty, compliance with increasingly stringent government regulations, and the financial perceptions of investors and partners depend heavily on the successful management of sustainability practices.

In line with stakeholder theory, companies must balance the expectations of diverse stakeholder groups with financial imperatives. Failure to do so may expose firms to risks such as increased costs or accusations of greenwashing. At the same time, triple bottom line theory posits that firms create value not solely through financial returns but also through their contributions to social and environmental well-being. Within this framework, sustainability practices must be assessed holistically, recognizing both their potential benefits and limitations for firm performance.

Although the relationship between ESG practices and financial outcomes has been widely studied in the broader corporate finance literature, research focusing specifically on

airlines remains limited. This study seeks to address this gap by examining the impact of ESG performance on airline profitability. Previous studies investigating the role of corporate social responsibility and sustainability in the airline sector generally adopt two perspectives. The first focuses on improvements in financial and accounting-based indicators, documenting a positive association between ESG performance and financial outcomes (Yang and Baasandorj, 2017; Lee et al., 2013). The second emphasizes the role of intangible assets, arguing that sustainability initiatives enhance brand value and corporate image, thereby fostering consumer trust and favorable customer attitudes (Vo et al., 2019; Chen et al., 2012; Kim et al., 2020). While both perspectives provide valuable insights, the present study concentrates primarily on the financial dimension, assessing how ESG and its sub-components—environmental (E), social (S), and governance (G)—affect profitability as measured by return on assets (ROA). A comprehensive assessment of these sub-dimensions is essential to reveal their relative contributions to firm performance.

Guided by stakeholder theory and triple bottom line theory, the study posits that financial performance is positively influenced by sustainability achievements. To test these hypotheses, 11 years of panel data from airline companies operating within the European Union are analyzed. This empirical focus is particularly relevant given the EU's strong emphasis on sustainability regulation and support for corporate responsibility in aviation. By doing so, the study contributes to both theory and practice. For financial managers, it offers insights into how ESG strategies can simultaneously advance profitability and sustainability goals. For academics, it provides evidence on the complex and multifaceted relationship between corporate sustainability and economic viability (Kaffash et al., 2024).

The structure of the study is as follows: the first section presents the introduction; the second provides a literature review and hypotheses; the third outlines the data and methodology; the fourth presents the results; the fifth provides robustness checks; the sixth offers a discussion; and the final section addresses limitations and directions for future research.

2. Literature Review and Hypothesis Development

2.1. Literature Review

While the broader finance literature provides substantial evidence on the interplay between corporate financial performance and sustainability, empirical investigations focusing on the airline industry are relatively limited. Addressing this gap is particularly important, as airlines operate under unique structural constraints and competitive pressures that may shape both the effectiveness and the perception of sustainability strategies.

Abdi et al. (2020), for example, analyzed data from 27 airlines worldwide between 2013 and 2019 and reported results broadly consistent with the wider finance literature. Their findings revealed that environmental (E) and governance (G) scores were positively associated with market-to-book ratios and Tobin's Q, suggesting that sustainability practices enhance firm value and financial performance. However, the social (S) dimension was negatively related to financial outcomes, a result attributed to the relatively high costs of social initiatives compared with their immediate financial benefits.

Extending this line of inquiry, Abdi et al. (2022) examined 36 airlines globally over the period 2008–2019 and reached

somewhat different conclusions. Their study identified a significant negative relationship between financial performance and ESG engagement, indicating that financially stronger airlines were less likely to invest in sustainability practices. Importantly, they also demonstrated that state ownership moderated this relationship, underscoring the role of government involvement in shaping sustainability strategies in the aviation sector.

By contrast, Gangi et al. (2021) presented evidence more consistent with the dominant view in the broader literature, finding that sustainable practices contribute to higher profitability, greater recognition among financial stakeholders, and enhanced competitive advantage and market value. These results highlight the strategic importance of sustainability initiatives as mechanisms to safeguard the interests of both financial and non-financial stakeholders.

Similarly, Kaffash et al. (2024) examined panel data from nine U.S. passenger airlines between 2010 and 2019 to assess the influence of financial performance and efficiency on environmental sustainability outcomes. Their findings indicate that financially stronger airlines possess greater resources to mitigate their environmental footprint, underscoring the resource-dependency of sustainability practices in aviation.

Kao et al. (2022) also contributed to this discussion, showing that both energy efficiency and wealth creation efficiency are positively associated with ESG scores, and that overall production efficiency improves with higher levels of ESG engagement. They further noted that full-service airlines tend to achieve slightly higher ESG scores compared to low-cost carriers. More importantly, their results highlight the necessity for airlines to adopt sustainability-oriented practices in order to secure long-term and stable financial benefits, thereby providing empirical support for the resource-based view (RBV) of the firm.

From a governance perspective, Weber et al. (2025) argued that ESG practices affect both costs and revenues in the airline industry, a dynamic that can be explained through good governance theory. Their study emphasized that such initiatives ultimately contribute positively to financial performance.

Karaman and Akman (2018) stressed the pivotal role of corporate social responsibility (CSR) in enhancing company quality, strategy, sustainability, and brand image by addressing the expectations of social stakeholders. Their findings delineated the subcomponents of CSR and their relative importance, recommending that aviation managers in Türkiye design CSR strategies that prioritize economic, social, and environmental dimensions, respectively. The strong emphasis on economic considerations highlights the dual need for financial performance alongside long-term sustainability.

Nonetheless, not all studies report uniformly positive results. Kuo et al. (2021), for example, identified a U-shaped relationship between corporate social responsibility and firms' ROA. They showed that in the initial stages of CSR initiatives, both public and private airlines experienced a decline in ROA, but following the implementation and integration phases, profitability gradually improved.

In a more recent study, Yıldız et al. (2024) examined the impact of ESG scores on operational efficiency, risk reduction, and financial performance for 32 airlines between 2018 and 2023. Their findings suggest that while strong governance practices may effectively reduce risks, they can also increase costs and therefore do not necessarily lead to higher short-term firm value. This outcome may be explained by high levels of

transparency that do not necessarily capture the quality of disclosed information. Furthermore, the absence of statistically significant relationships between ESG and the environmental or social dimensions was attributed to the complex and difficult-to-assess structure of the airline industry.

Taken together, these studies illustrate that while ESG practices in the airline industry have the potential to enhance financial performance, firm value, and long-term competitiveness, the evidence remains mixed and often contingent upon contextual factors such as state ownership, governance quality, and the temporal horizon of benefits. In particular, the contrasting findings suggest that the relationship between ESG engagement and financial outcomes is neither straightforward nor uniform. These discrepancies may stem from variations in sample composition, time horizons, measurement of ESG dimensions, or institutional and regulatory environments across studies. This ambiguity underscores the need for further investigation through theoretical frameworks such as stakeholder theory and the triple bottom line (TBL), which provide a structured lens for examining the multifaceted link between ESG performance and financial outcomes.

2.2. Hypothesis Development

Studies examining the relationship between ESG performance and financial outcomes predominantly draw upon

stakeholder theory as their explanatory framework. More recent research has also employed the triple bottom line (TBL) theory, which posits that firms should pursue objectives that extend beyond profit to include social and environmental dimensions (Gupta et al., 2020; Elkington, 1998). Often summarized as the 3Ps—people, planet, and profit—this perspective emphasizes that sustainable value creation requires businesses to integrate economic performance with social responsibility and environmental stewardship (Li et al., 2023; Crace and Gehman, 2022).

Airlines, operating in an industry that is highly visible and sensitive to societal expectations, are increasingly aligning their strategies with both stakeholder theory and the TBL framework. By addressing stakeholder concerns while simultaneously pursuing profitability, airlines can differentiate themselves from competitors, strengthen long-term relationships with passengers and investors, and enhance firm value (Gupta et al., 2020; Zieba and Johansson, 2022). Empirical evidence suggests that ESG practices in the aviation sector can generate wide-reaching impacts, improve competitive positioning, and positively influence both profitability and firm valuation.

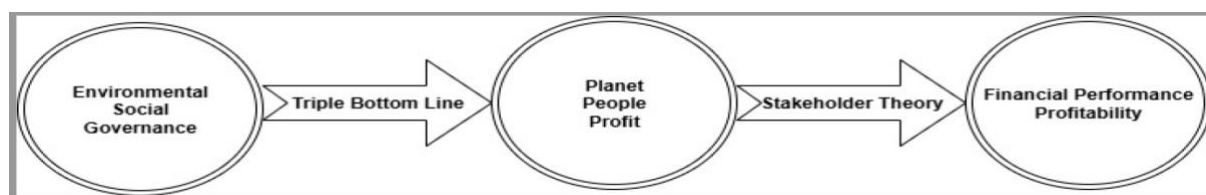


Figure 1. Research Framework (own elaboration)

As depicted in the conceptual framework (Figure 1), ESG is expected to contribute positively to firm performance, consistent with the assumptions of stakeholder and TBL theories. While shareholder theory traditionally emphasizes profit maximization as the sole objective, recent scholarship underscores the need to incorporate the financial relevance of social and environmental initiatives.

Within this context, ESG performance may be viewed as an intangible asset—enhancing brand equity, consumer trust, and overall firm reputation—thereby influencing both market-based and accounting-based measures of financial performance (Chung et al., 2022).

Although debates remain regarding the precise direction and magnitude of the ESG–financial performance nexus, the preponderance of empirical studies suggests a positive association. Building on this literature, the present study examines whether airlines with stronger sustainability performance, as reflected by higher ESG scores, achieve superior profitability. Accordingly, the following hypotheses are proposed:

H1: There is a positive relationship between ESG and ROA.

H2: There is a positive relationship between Environmental (E) and ROA.

H3: There is a positive relationship between Social (S) and

ROA.

H4: There is a positive relationship between Governance (G) and ROA.

3. Data and Methodology

3.1. Data

The study aims to present an assessment based on 11 years of data from 10 airlines in the European Union for which data is available. The data in the study, which examines the relationship between ESG and the financial performance of airlines, was obtained from Thomson Reuters DataStream. A panel data model was used to evaluate these relationships.

The airline sector was selected because environmental, social, and corporate sustainability practices are a significant element in companies in this sector. Companies prioritize these practices because they believe these practices significantly impact a company's value for consumers, regulators, investors, and creditors. The European Union, one of the regulatory bodies, has also emphasized this issue. This sector is specifically addressed in the European Union's climate-neutrality by 2050 and GHG emissions reduction target of at least 55% by 2030 targets (European Union, 2022).

The study will draw conclusions based on how ESG activities, both holistically and through their subcomponents, impact companies' financial performance, as reflected in ROA.

Therefore, ROA was used as the dependent variable, while ESG scores, E, S, and G scores were used as explanatory variables.

Control variables included intangible assets, debt/asset ratio, cash flow from operating, firm size measured by the logarithm of assets, and firm age. Table 1 shows all variables and data sources below:

Table 1. Definitions of the Variables

Variable Name	Variable
ROA	Return on Assets – Dependent Variable
ESG	Environmental, Social and Governance Score– Explanatory variable
E	Environmental Score - Explanatory variable
S	Social Score - Explanatory variable
G	Governance Score - Explanatory variable
IA	Intangible Assets – Control variable
DA	Debt/Assets – Control variable
CFO	Cash flow from Operating – Control variable
log _Assets	Firm Size – Control variable
Age	Firm Age - Control variable

3.2. Methodology

The main research question of this study is to examine how the ESG practices of firms in the airline industry influence Return on Assets (ROA), a widely used indicator of financial performance. Given the European Union’s strong policy orientation toward sustainability, and in particular its support for environmentally and socially responsible practices in the airline sector, this study focuses specifically on airlines operating within the EU. The analysis relies on data from only 10 EU-based airlines over an 11-year period, which represents a relatively small and geographically constrained sample. While this focus allows for an in-depth examination of EU-specific dynamics, it also limits the generalizability of the findings to broader global contexts and other segments of the aviation industry.

A panel data methodology was employed, with ROA as the dependent variable and the aggregate ESG score as well as its three sub-dimensions—environmental (E), social (S), and governance (G)—as the main explanatory variables. Since correlations among these explanatory variables and their potential cross-sectional dependence are found to be relatively high, four separate model specifications are developed. To strengthen the reliability of the estimation, several control variables commonly used in the literature were incorporated: intangible assets (IA), debt-to-assets ratio (DA), cash flow from operating (CFO), firm size (log of total assets), and firm age (Age).

The general specification of the four panel models can be expressed as follows:

$$ROA_{it} = \beta_0 + \beta_1 ESG_{it} + \beta_2 IA_{it} + \beta_3 DA_{it} + \beta_4 CFO_{it} + \beta_5 \log(Assets_{it}) + \beta_6 Age_{it} + \varepsilon_{it} \quad (1)$$

$$ROA_{it} = \beta_0 + \beta_1 E_{it} + \beta_2 IA_{it} + \beta_3 DA_{it} + \beta_4 CFO_{it} + \beta_5 \log(Assets_{it}) + \beta_6 Age_{it} + \varepsilon_{it} \quad (2)$$

$$ROA_{it} = \beta_0 + \beta_1 S_{it} + \beta_2 IA_{it} + \beta_3 DA_{it} + \beta_4 CFO_{it} + \beta_5 \log(Assets_{it}) + \beta_6 Age_{it} + \varepsilon_{it} \quad (3)$$

$$ROA_{it} = \beta_0 + \beta_1 G_{it} + \beta_2 IA_{it} + \beta_3 DA_{it} + \beta_4 CFO_{it} + \beta_5 \log(Assets_{it}) + \beta_6 Age_{it} + \varepsilon_{it} \quad (4)$$

To ensure the robustness and validity of the panel data estimations, a series of diagnostic tests were conducted, including checks for multicollinearity, autocorrelation, and heteroskedasticity. Following these diagnostic results, a Random-Effects model with Cluster-Robust Standard Errors was employed as the primary estimation method, as it accounts for firm-level heterogeneity and corrects for potential violations of classical assumptions. In addition, to further validate the robustness of the results, the Feasible Generalized Least Squares (FGLS) estimator was applied as an alternative model, and its results were compared with those obtained from the random-effects regressions.

4. Conclusion

Descriptive statistics for the variables used in the analysis are presented in Table 2.

Table 2. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
ROA	4.256	4.243	-9.509	14.331
ESG	57.444	18.224	23	89
E	60.348	22.269	21	95
S	54.513	18.582	20	90
G	58.023	17.045	20	92
IA	3068287	4303844	77441	15996142
DA	.305	.161	.025	.632
CFO	1854522	2443091	-3226748	11819514
log _Asset	16.306	1.158	13.439	18.118
Age	83.5	44.85	19	194

The Return on Assets (ROA) results indicate that, on average, aviation sector companies in the European Union generated a return of 4.26% on their assets. The relatively large standard deviation and negative minimum value point to substantial variability in operational efficiency, with some firms experiencing significant losses in certain years. The mean Environmental, Social, and Governance (ESG) score is 57.44 (SD = 18.22), ranging from 23 to 89. This suggests a moderate level of sustainability performance overall, but with considerable dispersion, reflecting differences in sustainability strategies, reporting standards, and regulatory compliance. Across ESG sub-dimensions, the mean Environmental (E) score (60.35) exceeds both the Social (S) score (54.51) and the Governance (G) score (58.02), likely reflecting the direct impact of EU-level environmental regulations—such as the EU Emissions Trading System (EU ETS)—on aviation emissions. Intangible Assets (IA), representing factors such as brand equity, patents, and route rights, display substantial heterogeneity across firms. The high standard deviation suggests that while some companies possess extensive intangible resources, others operate with minimal intangible assets. The average Debt-to-Assets ratio (DA) of 30.5% (SD = 16.1%) indicates diverse capital structures, likely linked to varying strategic and operational models within the sector. The mean Cash Flow from Operating (CFO) is €1.85 million, with notable variance and the presence of negative values, underscoring the cyclical volatility and operational challenges in the industry—such as demand shocks, fluctuating fuel costs, and seasonality. The average log of total assets is 16.31, consistent with the large-scale asset base characteristic of aviation companies.

Overall, these statistics reveal considerable heterogeneity in size, age, capital structure, and ESG performance among EU aviation companies. The moderate average ESG score,

coupled with its wide dispersion, suggests that while some firms have fully integrated ESG principles into their business models, others remain in the early stages of adoption. Meanwhile, negative values in ROA and CFO highlight the financial and operational risks inherent to the sector,

particularly in the context of post-pandemic recovery.

Table 3 reports the Pearson correlation coefficients for all variables included in the analysis.

Table 3. Matrix of Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) ROA	1.000									
(2) ESG	-0.091 (0.347)	1.000								
(3) E	-0.113 (0.238)	0.950 (0.000)	1.000							
(4) S	-0.089 (0.356)	0.964 (0.000)	0.877 (0.000)	1.000						
(5) G	-0.040 (0.675)	0.955 (0.000)	0.871 (0.000)	0.878 (0.000)	1.000					
(6) IA	0.064 (0.507)	0.256 (0.007)	0.281 (0.003)	0.261 (0.006)	0.181 (0.058)	1.000				
(7) DA	-0.665 (0.000)	0.060 (0.535)	0.158 (0.099)	0.037 (0.703)	-0.013 (0.894)	-0.030 (0.754)	1.000			
(8) CFO	0.156 (0.103)	0.287 (0.002)	0.291 (0.002)	0.322 (0.001)	0.187 (0.051)	0.646 (0.000)	-0.068 (0.482)	1.000		
(9) log Assets	-0.409 (0.000)	0.528 (0.000)	0.532 (0.000)	0.498 (0.000)	0.464 (0.000)	0.558 (0.000)	0.294 (0.002)	0.620 (0.000)	1.000	
(10) Age	0.110 (0.251)	0.621 (0.000)	0.576 (0.000)	0.670 (0.000)	0.528 (0.000)	0.522 (0.000)	-0.277 (0.003)	0.441 (0.000)	0.331 (0.000)	1.000

The return on assets (ROA), a measure of firm profitability, exhibits a negative correlation with the ESG composite score and each of its sub-dimensions -Environmental (E), Social (S), and Governance (G). However, these coefficients are small in magnitude and statistically insignificant, indicating that any potential relationship between financial performance and sustainability should be further investigated through regression analysis. As expected, ESG is highly and positively correlated with its sub-components: E ($r = 0.950$, $p < 0.01$), S ($r = 0.964$, $p < 0.01$), and G ($r = 0.955$, $p < 0.01$). Furthermore, E, S, and G are strongly intercorrelated ($p < 0.01$), reflecting either conceptual overlap in measurement or consistent firm performance across sustainability dimensions. This is indicated by asterisks in the table. This high degree of intercorrelation raises concerns regarding multicollinearity when ESG and its sub-dimensions are entered simultaneously in regression models. To mitigate this risk, subsequent analyses will estimate separate models for ESG and each of its sub-components.

The Debt-to-Asset ratio (DA) demonstrates a strong negative correlation with ROA, suggesting that higher leverage is generally associated with lower profitability within the sampled firms. Cash flow from operating (CFO) is positively correlated with ROA, consistent with the

expectation that stronger internal cash generation supports higher returns. Firm size (log_Assets) is positively associated with ESG, implying that larger firms may have greater capacity and institutional pressure to invest in sustainability initiatives. Firm age also shows a positive correlation with ESG and its sub-dimensions, suggesting that more established firms tend to have more formalized sustainability practices. However, age does not exhibit a significant correlation with ROA, indicating that longevity alone does not necessarily translate into superior profitability in the European Union aviation sector.

Because ESG and its sub-dimensions (E, S, and G) are included in separate models, all correlation coefficients in the Pearson matrix fall within the acceptable range, remaining below the 0.80 threshold (Gujarati and Porter, 2008). To further assess the potential for multicollinearity, Variance Inflation Factor (VIF) tests are conducted, with the results presented in Table 4. VIF values below 10 –and, more conservatively, below 5– are considered indicative of an acceptable level of collinearity among explanatory variables. Across all model specifications, the observed VIF values remain well below these thresholds, confirming that multicollinearity is not a concern in this study.

Table 4. Variance Inflation Factor (VIF)

ESG		E		S		G	
log_Assets	2.946	log_Assets	2.705	Age	3.099	log_Assets	2.973
Age	2.752	Age	2.518	log_Assets	2.744	CFO	2.359
ESG	2.478	CFO	2.253	S	2.661	IA	2.258
IA	2.318	E	2.227	IA	2.391	Age	2.239
CFO	2.276	IA	2.208	CFO	2.23	G	1.966
DA	1.41	DA	1.473	DA	1.425	DA	1.406
Mean VIF	2.363	Mean VIF	2.231	Mean VIF	2.425	Mean VIF	2.2

F Test, LM Test and Hausman Test are used as pre-tests before panel data analysis. The specification test results are reported in Table 5. The F-tests for individual effects are statistically significant at the 1% level across all model specifications, providing strong evidence of unobserved firm-level heterogeneity. Conversely, the time effects are statistically insignificant in most models, suggesting the absence of systematic year-to-year variation in the dependent variable once the explanatory variables are accounted for. The sole exception is the Environmental (E) model, where the time effect attains marginal significance at the 5% level; however, the magnitude of this effect is likely negligible.

Table 5. Model Selection

	(1) ESG p-value	(2) E p-value	(3) S p-value	(4) G p-value
F Test				
Individual effect	0.0000	0.0000	0.0000	0.0000
Time effect	0.0989	0.0355	0.0699	0.1190
Breusch-Pagan LM Test				
Individual effect	0.0000	0.0000	0.0000	0.0000
Time effect	0.2288	0.0625	0.2351	0.2760
Cluster-Robust Hausman Test	0.4519	0.0947	0.6935	0.6193

The diagnostic test results are reported in Table 6. To verify the validity of the random-effects panel data models, diagnostic tests are conducted on key assumptions. The modified Wald test for groupwise heteroskedasticity indicates the presence of heteroskedasticity across entities in all model specifications ($p < 0.01$).

Table 6. Diagnostic Tests

	Wald Test	Durbin-Watson	Pesaran	Heteroskedasticity	Autocorrelation	Cross-sectional Dependence	Estimation Method
ESG	0.0000	1.4302	0.2003	YES	YES	NO	RE + Cluster Robust SE
E	0.0000	1.4696	0.1750	YES	YES	NO	RE + Cluster Robust SE
S	0.0000	1.4321	0.2328	YES	YES	NO	RE + Cluster Robust SE
G	0.0000	1.4280	0.2773	YES	YES	NO	RE + Cluster Robust SE

In light of the detected heteroskedasticity and serial correlation, the adoption of random-effects estimators with cluster-robust standard errors is considered appropriate to obtain consistent and efficient inference.

Regression results presented in four model specifications are reported in Table 7. The regression results reveal a consistently positive and statistically significant association between ESG performance and ROA. This relationship, significant at the 5% level, indicates that enhancements in ESG scores are associated with improved firm profitability.

When examining the ESG sub-dimensions -environmental (E), social (S), and governance (G)- each dimension shows a positive and statistically significant relationship with ROA. These results reinforce the conclusion that diverse sustainability-related practices collectively contribute to enhancing firm profitability.

Regarding the control variables, the Debt-to-Asset Ratio (DA) exhibits a strong and negative relationship with ROA in all specifications. The magnitude of the coefficients, coupled with their significance at the 1% level, suggests that higher leverage exerts a detrimental effect on profitability.

Cash Flow from Operating (CFO) displays a positive and statistically significant association with ROA at the 1% level

Consistent with the F-test findings, the Breusch-Pagan Lagrange Multiplier (LM) test also indicates the presence of significant individual effects, while time effects remain statistically insignificant across all specifications. The cluster-robust Hausman test fails to reject the null hypothesis in all cases ($p > 0.05$), implying no systematic differences between the fixed-effects and random-effects estimators. Accordingly, the random-effects model is deemed appropriate for the analysis, as it adequately captures unobserved firm-specific heterogeneity without compromising estimator efficiency.

The Durbin-Watson statistics, consistently below the benchmark value of 2, suggested the existence of positive first-order serial correlation in the residuals. With respect to cross-sectional dependence, the Pesaran CD test failed to reject the null hypothesis of cross-sectional independence in all models, as the p-values exceeded the 5% significance threshold.

across all models, underscoring the importance of robust operational cash flows in sustaining firm performance.

Firm size, proxied by the natural logarithm of total assets, consistently demonstrates a negative and significant effect on ROA, implying that larger firms may experience diminishing returns to scale or heightened operational inefficiencies.

Similarly, firm age exhibits a negative and statistically significant coefficient in all specifications, indicating that older firms may encounter structural rigidities or reduced growth potential relative to their younger rivals.

Beyond the statistical significance of these findings, the results have important managerial implications. The positive role of ESG performance highlights that investments in sustainability are not merely symbolic or reputational tools, but rather mechanisms that can generate tangible financial benefits. Managers and decision-makers in the aviation sector may thus perceive ESG initiatives as strategic investments that enhance long-term value creation. At the same time, the adverse effect of excessive leverage warns against over-reliance on debt financing, suggesting that maintaining financial flexibility is essential for profitability in capital-intensive industries such as aviation.

Furthermore, the evidence that firm size and age negatively influence profitability provides an important perspective for policymakers and investors. These findings imply that younger and relatively smaller firms may be more agile in adopting innovative practices, while mature and large-scale firms could face efficiency losses. Policymakers aiming to foster competitiveness in the aviation industry should therefore

consider frameworks that support innovation and structural adaptation among established firms. For investors, the results indicate that ESG performance can be a meaningful screening criterion when evaluating firms, while also emphasizing the risks associated with high leverage and operational inefficiencies.

Table 7. Random-Effects Estimators with Cluster-Robust Standard Errors

	ROA (1)	ROA (2)	ROA (3)	ROA (4)
ESG	0.0493** (0.0311)			
IA	0.0000 (0.3337)	0.0000 (0.2534)	0.0000 (0.4049)	0.0000 (0.3323)
DA	-16.1587*** (0.0000)	-15.8311*** (0.0000)	-16.7326*** (0.0000)	-15.9625*** (0.0000)
CFO	0.0000*** (0.0000)	0.0000*** (0.0000)	0.0000*** (0.0000)	0.0000*** (0.0000)
log_Assets	-2.4452** (0.0392)	-2.5143** (0.0107)	-2.3232* (0.0668)	-2.3751** (0.0414)
Age	-0.0077*** (0.0068)	-0.0069** (0.0100)	-0.0079*** (0.0082)	-0.0071*** (0.0058)
E		0.0401*** (0.0019)		
S			0.0437* (0.0620)	
G				0.0454** (0.0444)
_cons	45.0497** (0.0122)	46.4513*** (0.0024)	43.7716** (0.0243)	43.9005** (0.0116)
R-squared	0.584	0.646	0.545	0.579

5. Robustness Check

The Feasible Generalized Least Squares (FGLS) estimation is employed to assess the robustness of the regression results across the four model specifications.

Table 8. Feasible Generalized Least Squares (FGLS) Regression Results

	(1) ROA	(2) ROA	(3) ROA	(4) ROA
ESG	0.0502*** (0.0097)			
IA	0.0000*** (0.0011)	0.0000*** (0.0023)	0.0000*** (0.0023)	0.0000*** (0.0027)
DA	-13.3595*** (0.0000)	-13.6979*** (0.0000)	-13.7853*** (0.0000)	-13.0336*** (0.0000)
CFO	0.0000*** (0.0000)	0.0000*** (0.0000)	0.0000*** (0.0000)	0.0000*** (0.0000)
log_Assets	-3.6704*** (0.0000)	-3.5372*** (0.0000)	-3.5235*** (0.0000)	-3.4987*** (0.0000)
Age	-0.0094*** (0.0000)	-0.0090*** (0.0001)	-0.0092*** (0.0001)	-0.0083*** (0.0002)
E		0.0345** (0.0163)		
S			0.0396** (0.0258)	
G				0.0401** (0.0273)
_cons	64.6543*** (0.0000)	63.4189*** (0.0000)	63.1897*** (0.0000)	62.1738*** (0.0000)
N	110	110	110	110

The findings, which are consistent with those obtained from Random-Effects estimations with cluster-robust standard errors, reveal a strong, positive, and statistically significant association between ESG performance and ROA. The ESG coefficient, significant at the 1% level in all specifications, indicates that higher ESG scores are systematically associated with increased firm profitability. Furthermore, when the ESG score is decomposed into its environmental (E), social (S), and governance (G) components, each dimension exhibits a positive and statistically significant relationship with ROA, thereby reinforcing the study's overall conclusions.

Among the control variables, the Debt-to-Asset Ratio (DA) emerges as a particularly influential determinant. DA demonstrates a strong negative relationship with ROA, significant at the 1% level, suggesting that greater leverage substantially diminishes profitability. This result is consistent with the earlier regression findings. Likewise, Cash Flow from Operating (CFO) maintains a positive and significant association with ROA at the 1% level across all models, underscoring the critical role of operational cash flows in sustaining firm performance. By contrast, intangible assets (IA) diverge from the earlier regression outcomes, displaying a small but positive and highly significant effect on ROA. This finding suggests that investment in intangible assets is systematically linked to enhanced financial performance. The results for firm size and firm age also align with prior findings. Both variables are negatively and significantly associated with ROA across all models, implying that larger and older firms may be less profitable, potentially due to structural rigidities, diseconomies of scale, or reduced adaptability.

6. Discussion

The empirical findings of this study provide robust evidence that ESG performance exerts a positive and significant effect on firm profitability, as measured by ROA, across all model specifications. Both the Random-Effects estimations with cluster-robust standard errors and the Feasible Generalized Least Squares (FGLS) analyses converge on this result, underscoring the stability and reliability of the findings. Moreover, the decomposition of ESG into its environmental, social, and governance dimensions confirms that each subcomponent independently contributes to enhancing financial performance.

These results are well aligned with the stakeholder theory, which posits that companies generate long-term value not solely by maximizing shareholder wealth but by addressing the needs and expectations of multiple stakeholder groups (Freeman, 1984; Gupta et al., 2020). Airlines that adopt sustainability practices and improve their ESG performance enhance their relationships with passengers, employees, regulators, and local communities, thereby fostering customer loyalty and strengthening brand reputation (Chung et al., 2022). This effect is consistent with the interpretation of ESG as an intangible asset, which contributes to both market-based outcomes, such as brand equity, and accounting-based measures of profitability.

The results also resonate with the triple bottom line theory (Elkington, 1998), which emphasizes the balance of economic, environmental, and social goals—the “3Ps” of people, planet, and profit. The positive impact of ESG and its dimensions on ROA demonstrates that airlines can achieve financial gains while simultaneously addressing environmental sustainability and social responsibility concerns. This finding provides

evidence that sustainability-oriented strategies not only improve stakeholder relations but also enhance operational efficiency and resource allocation, thereby contributing to firm performance. In the specific context of the airline industry, these results should also be understood against the strong regulatory environment in the European Union. Ambitious policies such as the climate-neutrality target for 2050 and the “Fit for 55” plan, which aims to cut emissions by 55% by 2030, create significant pressure on airlines to strengthen their ESG performance (European Commission, 2021; European Union, 2022). At the same time, these policies provide incentives for companies to align with sustainability goals, which may help explain why ESG practices show a positive link with financial outcomes in this study. Given the capital-intensive and highly visible nature of the sector, compliance with such regulations and proactive engagement in ESG are not only regulatory requirements but also strategic tools for competitiveness and legitimacy.

The control variables further enrich the interpretation of the results. The strong negative association between leverage (DA) and profitability suggests that financial sustainability remains a crucial determinant of firm performance in the airline sector, a finding consistent with the capital structure literature. By contrast, the positive impact of cash flow from operating (CFO) on profitability highlights the fundamental role of liquidity in supporting long-term sustainability initiatives. The significance of intangible assets in the FGLS estimations suggests that investments in non-physical resources such as innovation, digitalization, and reputation management may generate additional value in line with the resource-based theory (Kao et al., 2022; Kaffash et al., 2024).

In addition, the analysis reveals that both firm size and firm age are negatively associated with profitability. This suggests that larger airlines may suffer from diseconomies of scale, operational inefficiencies, or increased stakeholder pressures, while older firms may face structural rigidities and reduced adaptability compared to younger competitors. From the perspectives of stakeholder theory and the triple bottom line framework, these results indicate that the broader social and environmental responsibilities of larger and older firms can generate additional costs, which may constrain short-term profitability despite potential long-term legitimacy benefits.

7. Literature Limitations and Future Research

While the findings of this study offer strong empirical support for the positive association between ESG performance and firm profitability in the airline sector, several limitations warrant caution. First, the analysis is restricted to airlines operating within the European Union. Although this focus is justified given the EU's strong sustainability agenda, it limits the generalizability of the results to other geographical contexts, particularly regions with less stringent sustainability regulations. Future research should expand the scope by incorporating airlines from North America, Asia, and emerging markets to explore potential regional heterogeneity.

Second, the study employs profitability (ROA) as the primary measure of financial performance. While this indicator captures market accounting-based outcomes, it does not fully reflect market-based valuations such as Tobin's Q or stock returns. Integrating both market-based and accounting-based measures in future research could provide a more holistic understanding of the ESG–financial performance nexus. Finally, due to potential endogeneity concerns, such as

reverse causality, future research could address this issue by employing dynamic panel estimators, such as system GMM.

In conclusion, this study contributes to the growing literature by demonstrating that ESG performance is positively and significantly associated with firm profitability in the airline sector, consistent with stakeholder theory and the triple bottom line framework. Future research building on these findings may provide deeper insights into the mechanisms through which ESG practices create value, particularly in industries where sustainability is both a regulatory necessity and a strategic opportunity.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abdi, Y., Li, X., & Càmara-Turull, X. (2020). Impact of sustainability on firm value and financial performance in the air transport industry. *Sustainability*, 12(23), 9957.
- Abdi, Y., Li, X., and Càmara-Turull, X. (2022). How financial performance influences investment in sustainable development initiatives in the airline industry: The moderation role of state-ownership. *Sustainable Development*, 30(5), 1252–1267.
- Chen, F.-Y., Chang, Y.-H. and Lin, Y.-H. (2012). Customer perceptions of airline social responsibility and its effect on loyalty. *Journal of Air Transport Management*, 20, 49–51.
- Chung, S., Park, J.-W. and Lee, S. (2022). The influence of CSR on airline loyalty through the mediations of passenger satisfaction, airline brand, and airline trust: Korean market focused. *Sustainability*, 14, 4548.
- Crace, L. and Gehman, J. (2022). What really explains ESG performance? disentangling the asymmetrical drivers of the triple bottom line. *Organization & Environment*, 36(1), 150-178.
- Elkington, J. (1997). *The triple bottomline of sustainable development*. Capstone Publishing, Oxford.
- European Commission. (2021). Fit for 55: Delivering the EU's 2030 climate target on the way to climate neutrality. COM(2021) 550 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0550>
- European Union. (2022). EU Climate Action. <https://climate.ec.europa.eu/eu-action/transport-decarbonisation/reducing-emissions-aviation>
- Freeman, R.E. (1984). *Strategic management: a stakeholder approach*. Pitman, Boston (MA).
- Gangi, F., Mustilli, M., Daniele, L. M., and Coscia, M. (2022). The sustainable development of the aerospace industry: Drivers and impact of corporate environmental responsibility. *Business Strategy and the Environment*, 31(1), 218–235. <https://doi.org/10.1002/bse.2883>
- Gujarati, D. and Porter, C. (2008). *Basic Econometrics* (5th ed.). McGraw-Hill Education. New York.
- Gupta, I., Mishra, N. and Tandon, D. (2020). Triple Bottom Line: Evidence from aviation sector, *International Journal of Business Ethics and Governance (IJBEG)*, 3(1), 71-80.
- Kaffash, S., Chomachaei, F. and Aktaş, E. (2024). Environmental sustainability performance of US airlines: implications of financial performance and technical efficiency, *Journal of the Operational Research Society*, 1-22.
- Kao, F.-C., Ting, I.W.K., Chou, H.-C. and Liu, Y.-S. (2022). Exploring the influence of corporate social responsibility on efficiency: an extended dynamic data envelopment analysis of the global airline industry. *Sustainability*, 14, 12712, 1-21.
- Karaman, A. S. and Akman, E. (2018). Taking-off corporate social responsibility programs: An AHP application in airline industry. *Journal of Air Transport Management*, Elsevier, 68(C), 187-197.
- Kim, Y., Lee, S. S., and Roh, T. (2020). Taking another look at airline CSR: how required CSR and desired CSR affect customer loyalty in the airline industry. *Sustainability*, 12(10), 4281.
- Kuo, T.-C., Chen, H.-M. and Meng, H.-M. (2021). Do corporate social responsibility practices improve financial performance? A case study of airline companies. *Journal of Cleaner Production*, 310,
- Lee, S., Seo, K., and Sharma, A. (2013). Corporate social responsibility and firm performance in the airline industry: The moderating role of oil prices. *Tourism Management*, 38, 20–30.
- Li, W., Cui, J., Gao, J. and Xiong, J. (2023). Corporate social responsibility in China's airline industry: A longitudinal content analysis of related reports. *Journal of Air Transport Management*, Elsevier, 111(C).
- Sorsa, K. and Bona-Sánchez, C. (2024). Corporate social responsibility trends in the airline industry: a bibliometric analysis. *Sustainability*, 16, 2709, 1-18.
- Vo, T.T., Xiao, X. and Ho, S.Y. (2019). How does corporate social responsibility engagement influence word of mouth on twitter? evidence from the airline industry. *Journal of Business Ethics*, 157, 525–542.
- Weber, O., Jones, D. and Makinde, A. (2025). The connection between sustainability ratings and financial performance in the aviation industry (June 02, 2025).
- Yang, A. S. and Baasandorj, S. (2017). Exploring CSR and financial performance of full-service and low-cost air carriers. *Finance Research Letters*, Elsevier, 23(C), 291-299.
- Yıldız, F., Dayi, F., Yücel, M. and Çilesiz, A. (2024). The impact of esg criteria on firm value: a strategic analysis of the airline industry. *Sustainability*, 16, 8300.
- Zieba, M. and Johansson, E. (2022). Sustainability reporting in the airline industry: current literature and future research avenues. *Transportation Research Part D: Transport and Environment*, 102, Article ID: 103133.

Cite this article: Zengin, B. (2025). The Impact of ESG Performance on Financial Profitability: Evidence from the Aviation Sector in EU Countries. *Journal of Aviation*, 9(3), 600-608.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Machine Learning-Based Approach for Predicting Hard Landings in Commercial Aircraft

Hatice Doğan Kuzey^{1,2} , Fatma Yıldırım Dalkıran^{3*} 

¹National Defence University, Air NCO Vocational HE School, Gazimir, İzmir, Türkiye. (haticedogan.kuzey@msu.edu.tr)

²Erciyes University, Graduate School of Natural and Applied Sciences, Kayseri, Türkiye.

^{3*}Erciyes University, Faculty of Aviation and Astronautics, Kayseri, Türkiye. (fatmay@erciyes.edu.tr)

Article Info

Received: 28 April 2025
Revised: 12 September 2025
Accepted: 22 September 2025
Published Online: 09 October 2025

Keywords:

Hard Landing
Logistic Regression
Random Forest
Flightradar
Flight Safety

Corresponding Author: Fatma Yıldırım
Dalkıran

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1683966>

Abstract

The landing phase, one of the flight phases, is considered the most critical phase due to its significantly higher accident rate compared to other flight phases. A large portion of accidents occurring during the landing phase consists of hard landings. A hard landing is a landing incident defined as the main landing gear impacting the ground with a greater vertical speed and force than a normal landing. The severity of hard landings can vary from minor passenger discomfort to serious aircraft damage, structural failure, or even loss of life. In this study, the decision-making process regarding go-around maneuvers based on hard landing prediction is addressed using Machine Learning methods, specifically Logistic Regression and Random Forest models. Modeling was conducted using a dataset composed of real-time flight parameters, aiming to prevent hard landing incidents and even landing accidents. The calculation results indicate that the developed models provide accurate predictions for hard landing events.

1. Introduction

Aircraft follow a five-phase flight process when traveling from a departure point to a destination. These phases include arrival, initial approach, intermediate approach, final approach, and go-around. Following the plane crash that occurred in Diyarbakır on January 8, 2003, Boeing prepared a report analyzing commercial aircraft accidents from 1959 to 2001. According to this report, 54% of aircraft accidents took place during the final approach phase (Cavcar et al., 2003). Additionally, accident statistics reported by Boeing indicate that although the landing phase accounts for only 24% of the total flight duration, it alone was responsible for 1% of fatal accidents between 2007 and 2016 (Kong et al., 2022). Studies conducted in 2017 also revealed that the deadliest accidents in Turkish airspace mostly occurred during the approach phase (Donmez, 2017; Yanaz, 2017).

In the 2020 study titled “An Evaluation on the Concept of Aviation Accidents and Pilot Error”, statistical data on aircraft accidents revealed that most accidents occur during the landing and approach phases (Meltem, 2020).

The reason for this is that the final approach and landing phases present pilots with a high workload, requiring them to perform multiple operations and make relatively quick decisions. Research findings indicate that hard landings

significantly impact flight safety and account for 8% of all accidents (IATA, 2015).

According to the International Air Transport Association (IATA) report, hard landings ranked fourth among aircraft accidents between 2016 and 2020. In 2020, this rate increased, making hard landings the second most common type of accident after runway/taxiway incidents (IATA, 2021).

A hard landing is defined as the main landing gear impacting the ground with a greater vertical speed and force than a normal landing (Wang et al., 2014). In Boeing's training and maintenance manuals, a hard landing is considered an event where the aircraft's vertical acceleration exceeds the threshold limit for that aircraft type during landing (Hu et al., 2016).

If not detected and addressed, hard landings can lead to stress accumulation in the aircraft structure, potentially resulting in fatal accidents. Therefore, it is crucial to determine with certainty whether a hard landing has occurred (Jeong et al., 2023).

Despite the severe consequences of accidents occurring during the landing phase and the extensive research in the literature aimed at enhancing flight safety during approach and landing, relatively fewer studies focus on hard landings, which account for a significant portion of these accidents.

One such study from 2009 involved a system installed on the aircraft to reconstruct landing incidents, allowing for the measurement of aircraft conditions and accelerations, including position, speed, and acceleration data (Schmidt, 2009).

In the same year, Xu and his research colleagues developed a decision support system to assist in detecting hard landings using the Least-Squares Support Vector Machine (LS-SVM) classifier (Xu-Hui et al., 2009).

Another study conducted by P. Sartor and his team identified hard landings based on the regulatory definition set by EASA Certification Specification (CS) 25 and Federal Aviation Regulations (FAR) 25, which considers a landing with a vertical descent rate exceeding 10 ft/s as a hard landing (Sartor et al., 2010). While vertical speed is the primary factor influencing hard landings, the researchers also developed a Flight Parameter Sensor Simulation (FPSS) model to evaluate the persistence of landing gear loads by considering parameters such as aircraft weight, pitch, roll, yaw angles, and tire-runway friction coefficient (Sartor et al., 2010).

Wang and his colleagues aimed to analyze hard landing incidents and operational characteristics using regression modeling, incorporating parameters such as vertical speed, pitch-roll angles and flap degree (Wang et al., 2014).

Chen Hu and his team developed a hard landing prediction model using the Support Vector Machine (SVM) method. The input parameters for their model included vertical speed, roll, pitch angles, and flap degree (Hu et al., 2016).

Pia Sartor and her team investigated the sensitivity of varying input parameters in their flight parameter sensor simulation model to the differences between real and simulated loads in both symmetric and asymmetric two-point landings. Parameters affecting the aircraft's landing included vertical speed, center of gravity position, ground speed, and pitch-roll angles (Sartor et al., 2016).

Geoffrey Holmes and his colleagues explored the feasibility of using machine learning algorithms to predict loads experienced by the landing gear during landing. A Gaussian Process Regression model was applied to estimate the stress on the landing gear (Holmes et al., 2016).

Chao Tong and his team proposed an innovative deep learning architecture for aircraft hard landing prediction based on QAR data. In their study, an LSTM-based efficient RNN model was developed to predict whether a hard landing would occur by calculating the vertical acceleration (VRTG) value before landing (Tong et al., 2018).

Debora Gil and her colleagues researched a deployable machine learning-based decision support system in the cockpit to assist flight crews in deciding on a go-around based on hard landing predictions. Their study enabled early detection of hard landing events and provided go-around recommendations for the cockpit crew (Gil et al., 2021).

Seon Ho Jeong and his team applied the anomaly detection technique using an Autoencoder (AE) to flight parameters during the landing phase to identify hard landings. The Autoencoder, an artificial neural network model, was used to detect outliers in landing data obtained from high-quality landing simulations. Their study developed a precise landing simulation model capable of replicating real landing scenarios and generating landing simulation data for various landing conditions classified as abnormal landing data (Jeong et al., 2023).

A review of the literature indicates that the key parameters influencing hard landings include vertical speed, approach

speed, aircraft weight, roll-pitch angles, wind direction, and landing altitude. Flight data was obtained using the Flightradar application, and the parameters most strongly correlated with hard landings were identified as approach speed and vertical speed. Data collection focused on flights arriving at Sabiha Gökçen Airport (SAW), one of the busiest airports. During this study, Boeing 737 aircraft were observed, and aircraft weight was not included as an input parameter; instead, the hard landing conditions for the same aircraft type were examined.

During the landing phase, machine learning is used to predict whether a hard landing would occur based on appropriate parameters, allowing for a decision on a go-around. By utilizing suitable data and selecting an appropriate machine learning algorithm, an analysis of flight parameters was conducted.

2. Machine Learning

Various systems have been developed to enhance flight safety, efficiency, and performance in aviation. In cases where flight parameters cannot be provided to the flight crew due to a malfunction, the recently developed digital twin technology ensures continuous data availability while also enabling aircraft health and performance monitoring. Instead of relying on backup hardware systems in aircraft, using this software-based system is both more convenient and cost-effective.

Machine learning has played a significant role in many industries in recent years. This technology stands out for its ability to analyze complex datasets and recognize patterns. The aviation industry has also benefited significantly from the capabilities provided by machine learning.

There are three primary learning systems used to solve machine learning problems: supervised learning, unsupervised learning, and reinforcement learning (Bonaccorso, 2017).

2.1. Supervised Learning

In supervised learning, the output values corresponding to the input values are known. A predictive model is created using various techniques based on existing examples. Once this model is tested using different evaluation criteria and demonstrates high prediction performance, it can be used to classify new, previously unseen data. Supervised learning includes classification and regression methods.

Classification aims to develop a model that distinguishes between two or more different classes. Some popular classification techniques include k-nearest neighbors (KNN), logistic regression, support vector machines (SVM), decision trees and random forests, artificial neural networks (ANNs).

If the dataset's output consists of continuous numerical values rather than discrete classes, the problem falls under regression analysis. In regression analysis, the goal is to understand how the variation in one or more input variables (independent variables) affects the output variable (dependent variable).

Some popular regression techniques include linear regression, polynomial regression, support vector regression (SVR), decision tree regression, multiple linear regression, non-random regression.

2.2. Unsupervised Learning

In unsupervised learning problems, the dataset consists of unlabeled data. This method is preferred when the goal is to group a set of elements based on their similarities or distance measures. The primary objective of unsupervised learning is

to uncover hidden relationships among unlabeled data in a dataset. Unsupervised learning is categorized into two main tasks. These are clustering and dimensionality reduction.

Clustering is based on measuring similarities between data points in a dataset where class labels are unknown. Some common clustering techniques include k-Means Algorithm and Hierarchical Clustering Analysis.

Dimensionality Reduction is essential as modern datasets often contain a large number of features. Working with such datasets can be computationally intensive, especially when dealing with vectors and matrices. Dimensionality reduction transforms the dataset into a lower-dimensional space while preserving useful information. Some popular dimensionality reduction techniques include principal component analysis (PCA), Kernel PCA (Uguz, 2019).

2.3. Reinforcement Learning

Even without a direct supervisor, reinforcement learning relies on feedback provided by the environment. The goal is to develop a system that improves its performance based on interactions with its surroundings. This performance enhancement follows a reward-punishment system. Algorithms operating under this learning model function similarly to how a student is encouraged with high grades for correct answers and penalized for mistakes (Bonaccorso, 2017; Uguz, 2019).

Monte Carlo Simulation, a technique based on random sampling and statistical modeling, is often used to approximate mathematical functions and mimic the operations of complex systems. This simulation is particularly useful for problems that are analytically challenging, time-consuming, costly, or impractical to experiment with directly (Harrison, 2010).

Some popular reinforcement learning techniques include Q-learning, State-Action-Reward-State-Action (SARSA), Deep Q Network (DQN)

3. Method

This study has been presented a hard landing prediction model using the Logistic Regression and Random Forest methods to assist pilots in deciding whether to execute a go-around or proceed with landing during the approach and landing phases. Flight data was obtained from the Flightradar application. During the data collection, flights to Istanbul Sabiha Gökçen Airport (SAW), one of the busiest airports, were monitored. Only Boeing 737 aircraft landing at the airport were considered. A total of 500 data points from these aircraft were used in this study.

In this study, the **approach speed** and **vertical speed** were selected as the input parameters that affect hard landing.

- **Approach Speed:** The final approach speed of the aircraft negatively impacts the landing distance. This condition can prevent the aircraft from remaining stable, indicating that the landing phase may be dangerous (Ruzgarin Ucaklar Uzerindeki Etkisi, 2020).
- **Vertical Speed:** At higher vertical descent speeds (and consequently higher vertical accelerations), the likelihood of deviation from vertical acceleration increases, which is associated with greater peak amplitudes (Sartor et al., 2016). The input-output operations of the model are performed in Figure 1.

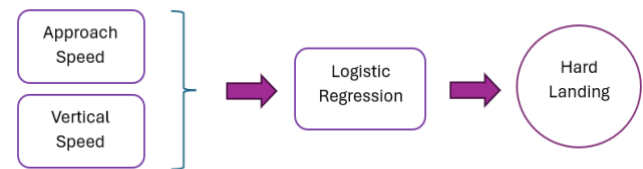


Figure 1. Input-Output parameters of the model

The correlation coefficient, a statistical calculation used to examine the relationship between two datasets, was determined between the input and output parameters using Python programming. The correlation coefficients between all input variables and the output variables are provided in Table 1.

Table 1. Correlation coefficients of the selected parameters

Input parameter	Output Parameter
	Hard Landing
Ground Speed	0.40
Vertical Speed	-0.77

When aircraft enter the approach phase, it is possible to detect whether a hard landing will occur and make a decision regarding go-around. Based on this hypothesis, a model prediction was made for the study, and upon reviewing the optimal conditions for the model, the data was analyzed using the Logistic Regression and Random Forest models, which is widely used in the literature and provides the most accurate results.

When examining the suitability of the dataset for Logistic Regression and Random Forest, it is observed that the dependent variable HL consists of binary (0,1) values. The steps related to Logistic Regression are presented in Figure 2. This workflow is largely applicable to Random Forest as well (Korkem,2013).

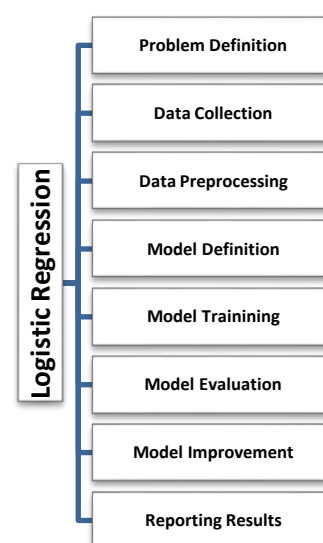


Figure 2. Steps of logistic regression (James et al., 2013).

After selecting the appropriate model as Logistic Regression, the model training step was carried out. The data was split into 70% training and 30% testing sets. As a result, the accuracy obtained from the Logistic Regression and

Random Forest models was determined to be 99% and 98%, respectively.

Logistic regression and Random Forest enable the detection of the likelihood of a hard landing based on the aircraft's approach speed and vertical speed. The classification of landing conditions into normal or hard landing categories is required. This classification is achieved using the Confusion Matrix. Through the Confusion Matrix, the model's sensitivity and specificity values are also calculated, and the logistic regression evaluation is performed. An example of a Confusion Matrix table is shown in Figure 3. Here, TP represents true positive values, FP represents false positive values, FN represents false negative values, and TN represents true negative values. Based on this matrix, the model's sensitivity (SE) and specificity can be determined (Singh et al., 2021).

		Actual Values	
		Positive (1)	Negative (0)
Predicted Values	Positive (1)	TP	FP
	Negative (0)	FN	TN

Figure 3. Example of confusion matrix table

$$\begin{aligned} \text{Sensitivity} &= \text{TP}/(\text{TP}+\text{FN}) & (1) \\ \text{Specificity} &= \text{TN}/(\text{TN}+\text{FP}) & (2) \end{aligned}$$

In this study, according to the results of Logistic Regression, the sensitivity of the hard landing model was calculated as 97% and the specificity as 99%, whereas according to the results of the Random Forest model, the sensitivity was calculated as 98% and the specificity again as 99%, based on the confusion matrix. The confusion matrix determines the threshold value to predict a hard landing event for values above or below this threshold. Each threshold value corresponds to a different confusion matrix result, which can lead to significant confusion. To eliminate this confusion, the Receiver Operating Characteristic (ROC) curve is used (Park et al., 2004). This graph summarizes all the information and presents it in a clear and understandable way. The ROC curve illustrating the impact of the model's input parameters on hard landing conditions is presented in Figure 4 for the Logistic Regression results and in Figure 5 for the Random Forest results. In this graph, the y-axis represents the true positive rate (sensitivity), and the x-axis represents the false positive rate (1- specificity). Thus, the ROC curve summarizes all the confusion matrix tables produced by each threshold.

4. Conclusion

Hard landings are a major problem that poses a safety threat to aircraft and passengers during the landing phase. While previous studies in the literature have developed models related to hard landing by considering flight parameters at various flight times, this study aims to make more accurate detections by accessing the flight data of a specific aircraft type arriving at one of the busiest airports in a shorter time and

at a lower cost. Therefore, the flight parameters of B-737 aircraft landing at Istanbul Sabiha Gökçen Airport were analyzed, and Logistic Regression and Random Forest, among Machine Learning methods, were applied to determine whether the landing condition was hard or normal. The model results were compared with the aim of identifying the approach that achieved the best performance. This allows the decision to be made regarding whether to go around in the face of a potential hard landing during the landing phase. With real-time performance monitoring and alert systems, the landing condition will be determined, potentially reducing the accident rate during the landing phase.

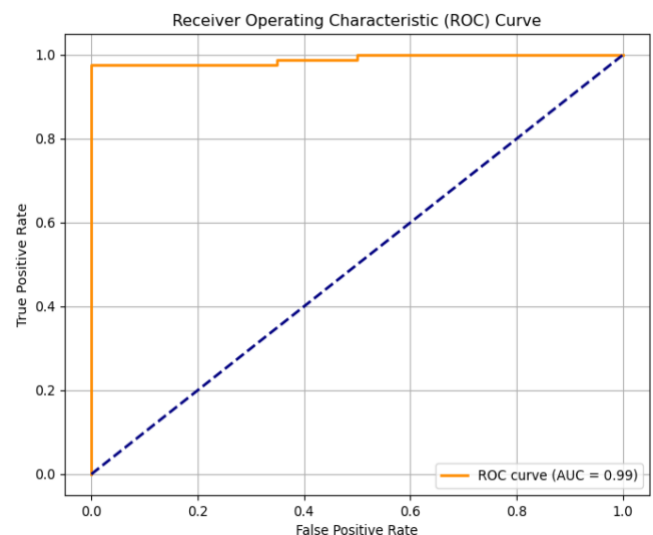


Figure 4. The impact of the model's input parameters on hard landing condition using Logistic Regression

Finally, in future studies on hard landing, factors such as runway condition and pilot experience, which were not addressed in this study, may be included as input parameters. In an industry that requires safety such as aviation, more work needs to be done to overcome the problem of hard landings.

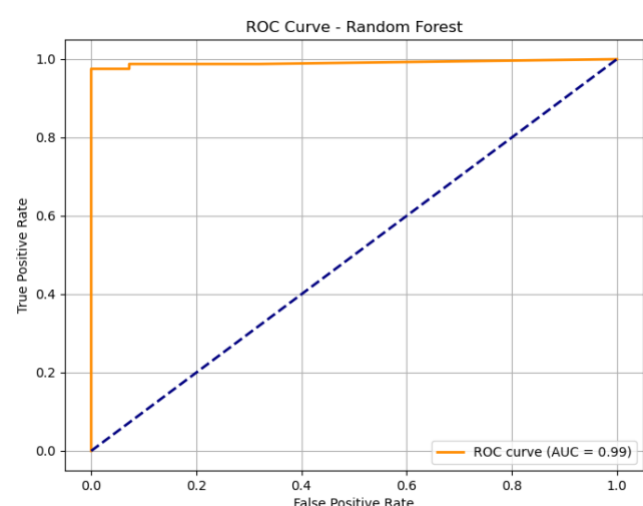


Figure 5. The impact of the model's input parameters on hard landing condition using Random Forest

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Bonaccorso, G. (2017). *Machine Learning Algorithms*, Packt Publishing, Birmingham.
- Cavcar, M. and Cavcar, A. (2003). Türkiye Hava Sahası Ticari Hava Taşımacılığı Kazalarına Genel Bakış: 1950-2003. *Mühendis ve Makine*, 44(518), 21-29.
- Donmez, K. (2017). Türk Hava Sahasında Meydana Gelen Ölümcül Uçak Kazalarına İnsan Faktörleri Analiz Ve Sınıflandırma Sisteminin (HFACS) Uygulanması. *The Journal of Academic Social Science Studies*, 6(59), 229-253.
- Gil, D., Hernandez-Sabate, A., Enconniere, J., Asmayawati, S., Folch, P., Borrego-Carazo, J. and Piera, M. A. (2021). E-pilots: A System to Predict Hard Landing During The Approach Phase of Commercial Flights. *IEEE Access*, 10, 7489-7503.
- Harrison, R. L. (2010). Introduction to Monte Carlo Simulation. *AIP Conference Proceedings*, 1204(1), 17-21.
- Holmes, G., Sartor, P., Reed, S., Southern, P., Worden, K. and Cross, E. (2016). Prediction of Landing Gear Loads Using Machine Learning Techniques. *Structural Health Monitoring*, 15(5), 568-582.
- Hu, C., Zhou, S. H., Xie, Y. and Chang, W. B. (2016). The Study on Hard Landing Prediction Model with Optimized Parameter SVM Method. 35th Chinese Control Conference (CCC), July 27-29, 2016, Chengdu, China, 4283-4287.
- IATA. (2015). 2010–2014 Runway Safety Accident Analysis Report, Int. Air Transp. Assoc., Montreal, QC, Canada. <https://www.iata.org/contentassets/7a5cd514de9c4c63ba0a7ac21547477a/rsar-1st-2015-final-version.pdf> (Accessed on April 22, 2025)
- IATA. (2021). Safety Report 2020. <https://libraryonline.erau.edu/online-full-text/iata-safety-reports/IATA-Safety-Report-2020.pdf> (Accessed on April 22, 2025)
- James, G., Witten, D., Hastie, T. and Tibshirani, R. (2013). *An Introduction to Statistical Learning with Applications in R*, Springer, New York.
- Jeong, S. H., Park, E. G., Cho, J. Y. and Kim, J. H. (2023). Development of Automatic Hard Landing Detection Model Using Autoencoder. *International Journal of Aeronautical and Space Sciences*, 24(3), 778-791.
- Kong, Y., Zhang, X. and Mahadevan, S. (2022). Bayesian Deep Learning for Aircraft Hard Landing Safety Assessment. *IEEE Transactions on Intelligent Transportation Systems*, 23(10), 17062-17076.
- Korkem, E. (2013). Mikroarray Gen Ekspresyon Veri Setlerinde Random Forest ve Naive Bayes Sınıflama Yöntemleri Yaklaşımı. Yüksek Lisans Tezi, Hacettepe Üniversitesi, Ankara, 65p.
- Meltem, A. (2020). Havacılık Kazası ve Pilot Hatası Kavramı Üzerine Bir Değerlendirme. *The Journal of Social Science*, 4(7), 251-264.
- Park, S. H., Goo, J. M. and Jo, C. H. (2004). Receiver Operating Characteristic (ROC) Curve: Practical Review for Radiologists. *Korean Journal of Radiology*, 5(1), 11-18.
- Sartor, P., Becker, W., Worden, K., Schmidt, R. K. and Bond, D. (2016). Bayesian Sensitivity Analysis of Flight Parameters in a Hard-Landing Analysis Process. *Journal of Aircraft*, 53(5), 1317-1331.
- Sartor, P., Schmidt, R., Becker, W., Worden, K., Bond, D. A. and Staszewski, W. J. (2010). Conceptual Design of a Hard Landing Indication System Using a Flight Parameter Sensor Simulation Model. 27th Congress of the International Council of the Aeronautical Sciences, September 19-24, 2010, Nice, France, 3515-3526.
- Schmidt, R.K. (2009). System and Method for Determining Aircraft Hard Landing Events from Inertial and Aircraft Reference Frame Data. (7,589,645), U.S. Patent.
- Singh, K. K., Elhoseny, M., Singh, A. and Elngar, A. A. (2021). *Machine Learning and The Internet Of Medical Things in Healthcare*. Academic Press.
- Tong, C., Yin, X., Li, J., Zhu, T., Lv, R., Sun, L. and Rodrigues, J. J. (2018). An Innovative Deep Architecture for Aircraft Hard Landing Prediction Based on Time-Series Sensor Data. *Applied Soft Computing*, 73, 344-349.
- Uguz, S. (2019). Makine Öğrenmesi Teorik Yönleri ve Python Uygulamaları ile Bir Yapay Zekâ Ekolü, Nobel Akademik Yayıncılık.
- Ruzgarin Ucaklar Uzerindeki Etkisi. (2020). <https://seyruseferim.com/ruzgarin-ucaklar-uzerindeki-etkisi/> (Accessed on April 22, 2025)
- Wang, L., Wu, C., Sun, R. and Cui, Z. (2014). An Analysis of Hard Landing Incidents Based on Flight QAR Data. International Conference on Engineering Psychology and Cognitive Ergonomics (EPCE 2014), June 22-27, 2014, Heraklion, Crete, Greece, 398-406.
- Xu-Hui, W., Ping, S., Xiang, R. and Lei, N. (2009). A Decision Support System Based on Support Vector Machine for Hard Landing of Civil Aircraft. International Forum on Computer Science-Technology and Applications, December 25-27, 2009, Chongqing, China, 66-70.
- Yanaz, E. (2017). Ekip Kaynak Yönetimi ve SHELL Model Anlayışının Havayolu İşletmelerinde Uçuş Emniyeti ve Zamanında Kalkış Performansına Etkileri. Yüksek Lisans Tezi, Arel Üniversitesi, İstanbul, 143p.

Cite this article: Kuzey, H.D. and Dalkiran, F.Y. (2025). Machine Learning-Based Approach for Predicting Hard Landings in Commercial Aircraft. *Journal of Aviation*, 9(3), 609-613.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Hot Air Balloon Accidents in Turkish Airspace: Human Factors Through RCA and HFACS

Derya Azık Özkan¹ 

¹Turkish National Police Academy, Traffic Institute, 06570, Ankara, Türkiye. (derya.azikozkan@pa.edu.tr, deryaazik@gmail.com)

Article Info

Received: 11 May 2025

Revised: 15 June 2025

Accepted: 08 July 2025

Published Online: 09 October 2025

Keywords:

Hot air balloon

Human factors

Human Error in Aviation

Root Cause Analysis (RCA)

HFACS

Corresponding Author: Derya Azık Özkan

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1697241>

Abstract

Hot air balloons play a significant role in tourism in Türkiye. Despite offering a unique experience, they are also associated with a relatively high risk of accidents. According to the Turkish Ministry of Transport and Infrastructure (2024), hot air balloon accidents account for 36% of aviation incidents, highlighting the need for closer examination of these occurrences. Since human factors constitute the dominant contributory element in aviation accidents, it is crucial to analyze hot air balloon incidents from this perspective.

This study examines two serious hot air balloon accidents in Türkiye that occurred between 2021 and 2024, focusing on the human factors involved. Using a mixed methodology, including the 5 Whys Root Cause Analysis (RCA) and the Human Factors Analysis and Classification System (HFACS), the research investigates systemic issues. Data were collected from official accident reports published by the Transport Safety Investigation Center under the Ministry of Transport and Infrastructure of the Republic of Türkiye. The analysis reveals significant patterns in decision-making errors, insufficient meteorological assessments, inadequate training, and organizational shortcomings.

The findings show that both accidents were driven by systemic failures rather than pilot error alone. These included issues with organizational processes, supervisory oversight, and safety culture. The study emphasizes the need for improved meteorological systems, better training for adverse weather conditions, and enhanced safety management practices that stress the importance of a proactive safety culture and stronger operational planning to address human factors and reduce risks in hot air balloon operations.

1. Introduction

Hot air balloon flights, categorized as non-scheduled private and commercial civil aviation, transcend conventional transportation to become vibrant marketing tools and centerpieces of aerial tourism (Novotná & Kunc, 2022). Since its 1991 inception in Türkiye, balloon tourism has flourished into a crucial tourism segment with Cappadocia and Pamukkale as flagship destinations. The remarkable growth of balloon tourism is evidenced by the presence of more than 50 companies registered with the Directorate General of Civil Aviation (2024). These operators, with Cappadocia-based companies dominating the sector, collectively transport hundreds of thousands of passengers annually (Nevşehir Investment Support Office, 2017).

Despite their prominence as an enthralling tourism activity, hot air balloon flights carry notable safety considerations that often receive insufficient attention relative to their growing popularity. The frequency of accidents per journey presents a concerning risk profile for this mode of aerial transportation. According to the Turkish Ministry of Transport and Infrastructure (2024), hot air balloon accidents account for 36% of all aviation incidents investigated and reported in Türkiye. Compared to other aviation segments, this constitutes an alarmingly high proportion, far exceeding the rates

observed in general aviation (29%), training flights (28%), and commercial airline operations (7%). (Transport Safety Investigation Center [Ulaştırma Emniyeti İnceleme Merkezi (UEİM)], 2024). The disproportionate representation of balloon incidents raises serious questions about current safety protocols and risk management strategies in the sector. Given that thousands of tourists participate in these flights annually, often with minimal understanding of the inherent risks, hot-air balloon tour safety in regions like Cappadocia warrants far greater scrutiny than it currently receives (Aslaner, 2019).

Although not extensively documented in the literature, several studies have been conducted to understand the causality of these balloon accidents. Research investigating accident causes - beyond injury and trauma assessments - has identified various contributing factors. Filtress et al. (2014) categorized these as attributes, crew resource management, equipment, errors, instructors, organizational factors, physical environment, regulatory bodies, and violations. Their study concluded that “weather,” “inexperience,” and “poor/inappropriate decisions” presented the greatest perceived associated risks. Similarly, Cowl et al. (1998) found that pilot error or incapacitation was subjectively determined by crash investigators to contribute to 85.1% of balloon crashes. However, these studies lack a systematic approach to understanding the complex interplay of factors involved in

balloon accidents. They often identify some human factors as the primary cause without thoroughly analyzing the underlying systemic issues, and most are outdated or conducted at widely spaced intervals.

Although the precise proportion for hot air balloon incidents specifically remains undetermined, aviation safety experts and human factors researchers consistently find that human involvement appears in approximately 70-80% of all aviation accident causal sequences, highlighting the critical role of human performance in flight safety outcomes (Shappell et al., 2007; Wiegmann & Shappell, 2003). A recent Türkiye-based study also highlights the prominence of human factors. Ercan and Avcı (2022), who analyzed Turkish civil aviation accidents between 2003 and 2017, concluded that "human factors are still major contributing factors in aviation accidents." Although this study also focuses on general aviation accidents, this observation is particularly significant given the persistent lack of structured methodologies in the field. Among the few studies offering methodological depth, Kılıç's (2020) research stands out for applying the Human Factors Analysis and Classification System (HFACS) to hot-air balloon accidents, revealing that environmental factors were the most significant contributors, followed by skill-based errors. However, systematic investigations into balloon-specific accident causation remain scarce.

Given this context, there is a compelling need to employ a systematic and layered analysis of human factors in hot air balloon accidents that have occurred in Turkish airspace in recent years. The HFACS methodology offers a hierarchical framework to trace accident causes from organizational influences down to unsafe acts (Wiegmann & Shappell, 2003). Yet to uncover deeper root causes and enable more effective interventions, this study integrates HFACS with Root Cause Analysis (RCA). RCA has been widely applied across high-risk industries and healthcare systems to investigate adverse events through a structured interrogation of systemic origins (Wu et al., 2008). As Vincent and Amalberti (2016) highlight, RCA enables investigators to look past the superficial elements of an incident and systematically explore the deeper organizational and systemic vulnerabilities that created conditions for failure.

The integration of HFACS with RCA - specifically the "5 Whys" technique - creates a powerful methodology that captures both organizational failures and causal chains simultaneously. This approach is particularly effective for the complex operational environment of balloon tourism where environmental variability, decision-making under uncertainty, and organizational dynamics interact in ways that demand sophisticated analysis. The successful application of similar integrated frameworks in healthcare settings for preventing medical errors (Lee et al., 2025) suggests that this approach can be effectively adapted to identify and mitigate contributing factors in aviation contexts as well.

While alternative root cause analysis tools such as fishbone diagrams (Ishikawa diagrams) are commonly used in conjunction with the "5 Whys" technique (Barsalou & Starzyńska, 2023), this study employed the "5 Whys" method to complement the analysis provided by HFACS. Since HFACS inherently provides a structured categorization of organizational factors to a certain depth, the "5 Whys" technique was specifically utilized to penetrate deeper into the causal chains and simultaneously explore the detailed investigative report findings along a single coherent pathway. This approach allows for a more focused interrogation of identified factor within the HFACS framework, tracing specific causal sequences from the rich detail available in the official accident reports without the need for additional

categorization tools that might duplicate HFACS's existing organizational structure.

By applying this integrated methodology to examine hot air balloon accidents in Turkish airspace between 2021 and 2024, this study aims to generate nuanced insights into the human factors contributing to these incidents. The ultimate goal is to develop evidence-based recommendations that can enhance safety protocols, improve training practices, and strengthen the safety culture within Türkiye's growing balloon tourism industry.

2. Materials and Methods

In this study, qualitative document analysis examined hot air balloon accidents in Türkiye through a human factors lens. The research employed a retrospective mixed methodology, combining 5 Whys Root Cause Analysis with Human Factors Analysis and Classification System (HFACS) to analyze official accident investigation reports.

2.1. Data Gathering

The study data were obtained from official aircraft accident investigation reports published by the Transport Safety Investigation Center [Ulaştırma Emniyeti İnceleme Merkezi (UEİM)] under the Ministry of Transport and Infrastructure of the Republic of Türkiye (T.C. Ulaştırma ve Altyapı Bakanlığı, 2025). These data were compiled through systematic screening of publicly accessible reports on Transport Safety Investigation Center's official website (<https://ulasimemniyeti.uab.gov.tr/hava-araci>). Since all data used in the study were obtained from publicly available official reports, ethics committee approval was not required. However, within the framework of research ethics, information that the names of crew members, passengers, balloon operators, and specific companies regarding the accidents was presented anonymously. Any details that could indirectly reveal the identities of individuals or commercial entities (e.g., registration marks traceable to operators, personnel initials, or location-specific company identifiers) were either generalized or omitted to maintain anonymity and protect privacy.

Specific criteria were considered in case selection. These included: the aircraft being only a hot air balloon, the event being classified as an accident, being reported between 2021-2024, having its investigation completed and official report published by Transport Safety Investigation Center, and containing sufficient detail to enable human factors analysis (i.e., the presence of descriptive narratives, documented decision-making processes, operational context, and identifiable contributory factors across organizational levels). The 2021–2024 time frame was chosen because only within this period are full-text accident reports for hot air balloons publicly available on the Center's official website. The identified cases occurred in different regions of Türkiye, particularly in areas with intensive balloon tourism such as Cappadocia and Pamukkale, forming a sample that reflects various dimensions of human factors. Among the seven balloon cases reported between 2021 and 2024, only two were officially classified as accidents according to the Transport Safety Investigation Center. The other five were categorized as serious incidents. For methodological consistency and in line with international safety analysis standards, this study focused exclusively on accidents—as these events involve more severe outcomes (e.g., injury, major damage) and typically include more comprehensive investigation reports. Furthermore, accident reports tend to provide richer detail regarding operational context, environmental conditions, human decision-making, and organizational responses, all of

which are essential for conducting a robust human factors analysis using HFACS and the 5 Whys Root Cause Analysis. Therefore, this study specifically focused on 2 cases classified as accidents.

The data collection process was carried out in three stages. In the first stage, all aircraft accident reports between 2021-2024 in the Transport Safety Investigation Center database were screened and hot air balloon cases were identified. In the second stage, the identified reports were downloaded in PDF format and organized digitally for analysis. In the third stage,

each report was examined in detail, and basic information about the accident, accident process descriptions, findings, and conclusions were systematically recorded. At this stage, the report of the TC-BBF registered balloon accident that occurred on July 31, 2022, in Aktepe village, Avanos district, Nevşehir province, which was categorized as a serious incident, could not be accessed (see Table 1). Finally, the most recently accessible accident reports were processed as primary sources to make them suitable for analysis.

Table 1. Hot Air Balloon Cases Within the Study Scope (2021-2024)

Accident Date	Registration Mark	Event Type	Location	Damage Status	Fatalities	Injuries	Report Date
June 26, 2022	TC-BDJ	Serious Incident	Nevşehir/ Göreme/ Love Valley	Minor	-	1	April 22, 2024
October 18, 2022	TC-BOT	Accident	Nevşehir/ Çardak Village	Major	0	4	March 18, 2024
July 31, 2022*	TC-BBF	Serious Incident	Nevşehir/ Avanos District/ Aktepe Village	-	-	-	March 18, 2024
July 25, 2022	TC-GDC	Serious Incident	Nevşehir Cappadocia Airport	Minor	-	-	February 19, 2024
April 19, 2022	TC-BIN	Accident	Denizli/ Pamukkale/Irliğanlı Region	Minor	-	1	December 26, 2022
April 22, 2022	TC-UEG	Serious Incident	Nevşehir Cappadocia Airport	Minor	-	-	September 19, 2022
November 13, 2021	TC-GDR	Serious Incident	Nevşehir/ Cappadocia	Minor	-	-	February 28, 2022

Note. Compiled from Ministry of Transport and Infrastructure of the Republic of Türkiye, Transport Safety Investigation Center, 2025. (<https://ulasimemniyeti.uab.gov.tr/hava-araci>). Retrieved May 4, 2025.

2.2. Research Instruments and Analysis Framework

This study employed a sequential mixed-method approach integrating the "5 Whys" Root Cause Analysis with the Human Factors Analysis and Classification System (HFACS). The three-stage analysis process included individual case examinations, cross-case pattern identification, and findings integration to reveal systemic issues. ATLAS.ti software (ATLAS.ti, 2023) facilitated systematic coding and relationship mapping between factors. The following sections detail these analytical frameworks and their implementation.

The 5 Whys Root Cause Analysis:

The 5 Whys technique is an iterative interrogative method developed by Sakichi Toyoda at Toyota Motor Corporation (Serrat, 2017). This deceptively simple but powerful approach aims to identify the root cause of a problem by repeatedly asking "why" questions, typically five times or until reaching a satisfactory systemic explanation (Dunn, 2004). Each question forms the basis for the next, creating a chain of causal relationships that extends beyond superficial symptoms to reveal fundamental issues (Al-Rifai, 2025).

In this study, the 5 Whys methodology was applied through a systematic procedure. Initially, the immediate cause of each accident (e.g., hard landing, basket impact) was clearly established as the starting point for analysis. For the first inquiry level, researchers identified direct technical or operational failures by asking why the immediate event

occurred, uncovering factors such as unexpected wind conditions or inability to control descent rates. The process continued with subsequent "why" questions for each answer, with responses progressively revealing more systemic issues—moving from technical factors to human performance limitations, supervisory decisions, and organizational influences. This iterative questioning continued until reaching a root cause representing a fundamental systemic or organizational issue that, if addressed, would prevent recurrence of similar incidents.

Human Factors Analysis and Classification System (HFACS):

The Human Factors Analysis and Classification System (HFACS) is a comprehensive taxonomy for identifying and categorizing human factors that contribute to accidents and incidents. Developed by Wiegmann and Shappell (2003) based on James Reason's "Swiss Cheese" model of accident causation, HFACS provides a structured approach to understanding how failures at different organizational levels combine to create accident conditions.

The HFACS framework employs a four-level hierarchical structure to analyze human factors in accidents. At Level 1 Unsafe Acts, the model examines frontline operator failures, categorizing them as either errors (unintentional actions

including decision, skill-based, and perceptual errors) or violations (deliberate procedural deviations, either routine or exceptional). Level 2 Preconditions for Unsafe Acts addresses contributing conditions, including environmental factors (physical and technological), operator conditions (mental states, physiological states, and limitations), and personnel factors (crew resource management and personal readiness). Level 3 Unsafe Supervision focuses on oversight failures such as inadequate supervision, inappropriate operations planning, failure to correct known problems, and supervisory violations. Level 4 Organizational Influences examines systemic factors including resource management, organizational climate, and organizational processes that create the context for accidents (Shappell & Wiegmann, 2000).

For this study, HFACS implementation followed a rigorous analytical process. Researchers first reviewed each accident report to identify relevant actions, decisions, and contextual factors. These elements were then coded according to the HFACS taxonomy and assigned to appropriate categories. The analysis included calculating frequencies of factors across categories to identify recurring patterns. ATLAS.ti software facilitated this process by enabling systematic organization, visualization, and relationship mapping between factors at different hierarchical levels.

3. Result and Discussion

This section first presents critical information about the accidents, root cause determination using the 5 Whys technique, and particularly HFACS categorization to examine human factors, listed sequentially for Case 1 and then Case 2. Subsequently, common patterns were identified through general cross-comparisons, and findings were discussed within the literature framework.

3.1. Case 1: TC-BIN Registered Hot Air Balloon Accident (19.04.2022)

On April 19, 2022, the TC-BIN registered Ultramagic N-425 type hot air balloon crashed in the Irlıanlı Region of Denizli/Pamukkale. The aircraft took off from Cemile Region (29°7'37"E, 37°55'23"N) at 03:39:22 UTC (06:39 local time) and was conducting a tourist flight with 20 passengers when it made a hard landing in Irlıanlı Region (29°13'3"E, 37°54'50"N) at 04:22:12 UTC (07:22 local time). In his statement, the pilot-in-command reported arriving at the field for launch site selection at 05:45 (local time) in the morning, checking meteorological data and deciding on a green flag before setting up the balloon in Cemile Region. He stated that they took off at 06:40 (local time), gained altitude due to wind while passing over the travertines, and planned to land in an area called "Ağıl" but bypassed it due to high-voltage power lines. He reported that wind speed varied between 17-22 km/h, they found a safe area in Irlıanlı Region, but experienced a hard landing due to wind speeds of 17-18 km/h during landing. Analysis of GPS data revealed that the aircraft, carried by winds, landed outside the designated area D of the LTB2 (Pamukkale) designated airspace (the area between D-C zones designated as an emergency landing area) according to Turkish Aeronautical Information Publication (AIP), dated January 13, 2022, reference 03/22, AIC B Series. It was determined that the Airgram issued by the Slot Service Center did not cover the takeoff time. The upper right corner of the Airgram indicated it was valid from 12:00 on Tuesday, April 19, 2022. One passenger suffered a collarbone fracture in the accident due to failure to assume proper landing position, and the

aircraft sustained minor damage. According to GPS data, the flight duration was 45 minutes 20 seconds, with the speed at the time of the accident recorded as 16 km/s.

The root cause analysis employed the 5 Whys technique, systematically asking "Why?" questions to trace the causal chain from the immediate cause (hard landing) to the underlying systemic issues. This iterative questioning process revealed that the hard landing was caused by the balloon encountering strong winds (17–18 km/h) during approach to an unauthorized landing area. This occurred because the pilot could not find a suitable alternative landing site due to the presence of high-voltage power lines and approaching mountainous terrain. Further inquiry revealed that the flight had deviated from its planned route and exited the designated Area D, primarily due to changing meteorological conditions. The deviation itself stemmed from insufficient pre-flight meteorological assessment and a lack of contingency planning. Ultimately, the root cause was found to be the pilot's reliance on an Airgram not valid at the time of the flight (valid from 12:00, while the flight began at 06:39) and insufficient knowledge of airspace restrictions, where Areas D–C are designated only for emergency landings. The details of the procedure and findings for the TC-BIN registered hot air balloon accident are illustrated in Figure 1.

1st Why - Why did the hard landing occur?

Because the aircraft encountered strong winds (17-18 km/h) during landing approach unauthorized area

2nd Why - Why did the pilot attempt landing in strong winds?

Because there were no suitable alternative landing sites due to high-voltage power lines and approaching mountainous terrain

3rd Why - Why were there no alternative landing sites available within permitted airspace?

Because the flight had deviated from its planned route and exited the designated Area D due to changing meteorological condition.

4th Why - Why did the route deviation occur outside permitted airspace boundaries?

Because of insufficient pre-flight meteorological assessment and lack of contingency planning for maintaining operations

5th Why - Why was the meteorological and airspace assessment insufficient?

Because the pilot relied on an AIRGRAM that was not valid for the flight time (valid from 12:00, flight at 06:39) and had insufficient knowledge of LTB2 airspace restrictions where Area D-C is designated only for emergency landings

Root-Cause: Organizational deficiencies in standard operating procedures for verifying current meteorological information and ensuring pilots' knowledge of airspace restrictions before flight operations

Figure 1. Root Cause Analysis Stages for TC-BIN Registered Hot Air Balloon Accident

Following the root cause analysis, the HFACS framework was applied to categorize human factors contributing to the TC-BIN hot air balloon accident. The analysis showed that errors clustered around poor decision-making and supervisory failures, with organizational influences playing a significant role. At the Unsafe Acts level, the pilot made a decision error by continuing the flight despite worsening weather, and a skill-based error during landing. A passenger injury occurred due to not assuming the correct landing position. Violations included landing outside Area D without declaring an emergency and using invalid meteorological data. Preconditions included

strong winds, limited landing options due to terrain and power lines, reduced situational awareness, and inadequate weather preparation. Supervisory issues involved failing to enforce airspace restrictions, ignoring invalid weather data, and lack of emergency procedures. At the organizational level, there were gaps in training, policy, and weather verification systems, enabling flights to proceed without complete or timely information. Detailed classifications are presented in Table 2.

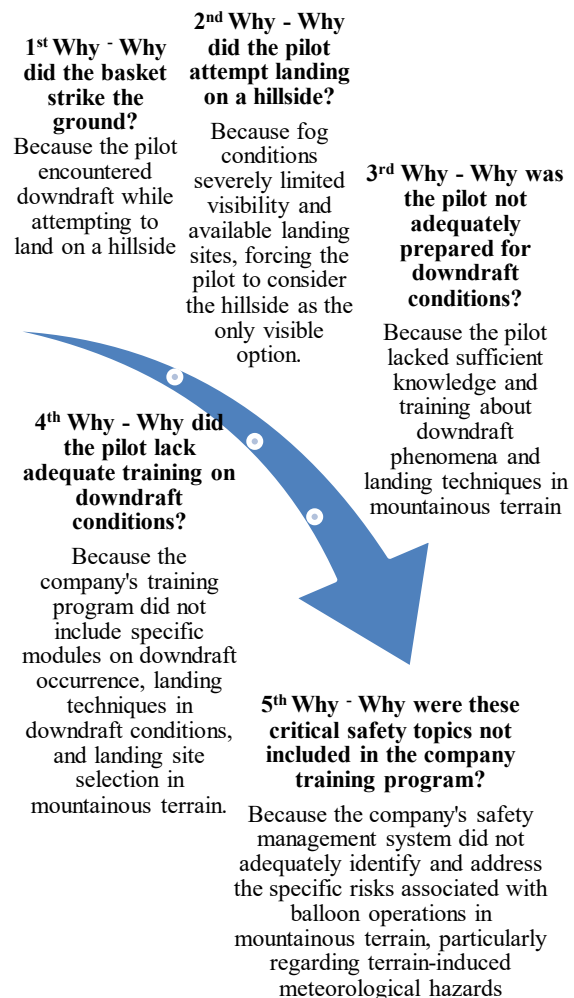
Table 2. HFACS Classification of Human Factors in TC-BIN Hot Air Balloon Accident

HFACS Level	Category	Identified Factors
Level 1: Unsafe Acts	Errors	<i>Decision error:</i> Decision to continue flight despite changing meteorological conditions <i>Skill-based error:</i> Hard landing technique <i>Passenger error:</i> Failure to assume proper landing position resulting in injury
	Violations	<i>Exceptional violation:</i> Landing outside designated Area D due to deteriorating meteorological conditions without declaring emergency <i>Routine violation:</i> Using Airgram not valid for flight time (Airgram valid from 12:00, flight commenced at 06:39). Insufficient meteorological assessment - failed to obtain weather information covering the actual flight time
Level 2: Preconditions for Unsafe Acts	Environmental Factors	<i>Physical environment:</i> Increasing wind speed and variable meteorological conditions. Mountainous terrain limiting landing options within permitted airspace <i>Technological environment:</i> Presence of high-voltage power lines
	Condition of Operator	<i>Adverse mental state:</i> Decision-making under deteriorating weather conditions <i>Physical/Mental limitations:</i> Insufficient situational awareness of airspace boundaries during weather-related route changes
	Personnel Factors	<i>Personal readiness:</i> Inadequate preparation regarding weather-contingency operations within airspace restrictions
Level 3: Unsafe Supervision	Inadequate Supervision	<i>Planned inappropriate operation:</i> Failure to ensure compliance with LTB2 airspace restrictions during adverse weather <i>Failed to correct known problem:</i> Allowing operations with invalid AIRGRAM timing <i>Inadequate guidance:</i> Insufficient procedures for defining emergency situations warranting D-C zone usage <i>Supervisory violations:</i> Failure to verify meteorological information validity for actual flight time
	Inappropriate Operations Planning	Lack of risk management weather-related airspace deviations. Inadequate contingency planning for operations within restricted airspace during changing weather conditions
Level 4: Organizational Influences	Resource Management	<i>Human resources:</i> Inadequate training on airspace restrictions during weather-related route changes <i>Equipment/Facility resources:</i> Lack of systems to verify AIRGRAM validity for specific flight times
	Organizational Climate	<i>Structure:</i> Operational environment allowing flights with incomplete meteorological data <i>Policies:</i> Insufficient procedures for verifying airspace compliance during adverse weather conditions
	Organizational Process	<i>Operations:</i> Inadequate oversight of flight planning within restricted airspace
		<i>Procedures:</i> Ambiguous definitions of "emergency" situations warranting D-C zone usage <i>Procedures:</i> Lack of standardized checks for AIRGRAM validity and appropriate time coverage

3.2. Case 2: TC-BOT Registered Hot Air Balloon Accident (18.10.2022)

On October 18, 2022, the TC-BOT registered Ultramagic N-500 type hot air balloon crashed near Çardak Village in Nevşehir. The planned takeoff time was 03:20 UTC (06:20 local time) with a planned flight duration of 01:00 hour, but the actual takeoff occurred at 04:25 UTC (07:25 local time). The aircraft took off from Göreme at 04:25 UTC and was operating with 28 passengers when it made a hard landing at the foot of a hill at 05:14:01 UTC (08:14:01 local time). In his statement, the pilot-in-command reported that they initially descended to the İbrahimpaşa Region, then gained altitude due to fog. He stated that their flight direction was completely covered with fog and their speed reached 30-35 km/h. When they attempted to land at a point where the fog cleared, during the approach to the hillside, the pilot decided to abort the landing but encountered downdraft from the hill. He reported that while attempting to climb by firing all four burners, the basket struck the ground hard. The observer pilot confirmed that they were searching for a suitable landing area in foggy conditions and encountered the downdraft. In the accident, four passengers were injured. Medical examination revealed that one passenger suffered a cheekbone fracture, another had an ankle fracture, and two passengers sustained minor injuries. The aircraft sustained major damage with welding cracks in the basket, rattan damage, and panel damage to the envelope.

The root cause analysis employed the 5 Whys technique, systematically asking "Why?" questions to trace the causal chain from the immediate cause (basket impact during an aborted landing) to deeper systemic failures. The analysis revealed that the pilot attempted a hillside landing due to limited visibility and lack of alternative landing sites, ultimately leading to a downdraft-induced impact. Further questioning uncovered that the pilot lacked training on downdraft conditions and safe landing techniques in mountainous terrain. This deficiency was traced back to gaps in the company's training program, which did not include critical safety topics related to terrain-induced meteorological hazards. At the root, the company's safety management system failed to identify and address risks specific to balloon operations in mountainous areas. The findings and procedural steps for the TC-BOT registered hot air balloon accident are illustrated in Figure 2.



Root-Cause: Inadequate company training programs on critical safety topics including downdraft phenomena, emergency landing techniques in adverse conditions, and proper landing site selection in mountainous terrain, leading to insufficient pilot knowledge to handle terrain-induced meteorological hazards.

Figure 2. Root Cause Analysis Stages for TC-BOT Registered Hot Air Balloon Accident

Following the root cause analysis, the HFACS framework was applied to classify the contributing human factors in the TC-BOT hot air balloon accident across four organizational levels. The analysis revealed that errors were primarily related to poor decision-making in challenging terrain-induced weather conditions, compounded by inadequate supervision of safety-critical training programs. At the organizational level, significant issues included insufficient training on downdraft phenomena, non-compliance with alcohol testing protocols, and a weak safety management system. These systemic shortcomings left the pilot unprepared to identify and respond to downdraft risks in mountainous terrain, ultimately contributing to the accident. The detailed classification of these human factors is presented in Table 3.

Table 3. HFACS Classification of Human Factors in TC-BOT Hot Air Balloon Accident

HFACS Level	Category	Identified Factors
Level 1: Unsafe Acts	Errors	<i>Decision error:</i> Attempted landing approach to hillside in foggy conditions <i>Skill-based error:</i> Insufficient response time to downdraft during landing approach <i>Perceptual error:</i> Late recognition of terrain-induced downdraft hazard <i>Judgment error:</i> Inadequate assessment of terrain risks during site selection
	Violations	<i>Exceptional violation:</i> Attempting landing at an unsuitable location in foggy conditions
Level 2: Precondition s for Unsafe Acts	Environmental Factors	<i>Physical environment:</i> Fog, high wind speeds (30-35 km/h), terrain-induced downdraft. Mountainous terrain creating unpredictable meteorological hazards
	Condition of Operator	<i>Adverse mental state:</i> Pressure to find suitable landing site in deteriorating conditions <i>Physical/Mental limitations:</i> Reduced situational awareness due to fog
	Personnel Factors	<i>Crew resource management:</i> Inadequate pre-flight risk assessment <i>Training deficiencies:</i> Lack of specific training on downdraft conditions and emergency procedures
Level 3: Unsafe Supervision	Inadequate Supervision	<i>Inadequate training:</i> Failure to provide effective training on downdraft phenomena and mountain flying hazards <i>Supervisory violations:</i> Alcohol testing conducted by untrained personnel
Level 4: Organization al Influences	Resource Management	<i>Human resources:</i> Inadequate allocation of training resources for mountain-specific hazards <i>Equipment/facility resources:</i> Lack of weather monitoring systems for real-time mountain conditions
	Organizational Process	<i>Oversight:</i> Failure to ensure compliance with alcohol testing procedures (separate issue)

3.3. Cross-Case Results and Discussions: Systemic Deficiencies and High-Risk Areas

The investigation into the TC-BIN and TC-BOT hot air balloon accidents revealed multiple systemic deficiencies that contributed to these incidents. Through the application of Root Cause Analysis (RCA) and the Human Factors Analysis and Classification System (HFACS), shortcomings were identified across individual decision-making, supervisory practices, and broader organizational processes.

In both accidents examined, sudden weather changes played a significant role, with pilots failing to anticipate or effectively respond to terrain-induced atmospheric conditions. This failure was compounded by the absence of real-time weather updates and poor communication with meteorological services. Numerous studies have emphasized the critical role weather plays in ballooning. For instance, Cowl et al. (1998) found that pilot error was implicated in 85.1% of balloon crashes, with wind misjudgment contributing to 19.0% of cases. Moreover, 57% of these crashes occurred in relatively moderate winds of 5 to 10 knots, highlighting the inherent susceptibility of balloons -due to their limited directional control- to even modest meteorological shifts. These findings underscore the urgent need for more advanced weather forecasting systems, localized weather monitoring stations, and robust communication protocols particularly in geographically complex areas such as Cappadocia (Cowl et al., 1998; Filtiness et al., 2014).

A second critical deficiency was the insufficiency of pilot training. The pilots involved lacked the skills required to manage high-risk scenarios like downdrafts or mountainous terrain landings. Kılıç (2020) also identified weather-related events and mid-air collisions as major contributors to balloon accidents, with perceptual errors such as poor environmental scanning or fixation on unsuitable landing areas accounting for 16% of cases. Our analysis builds on this by showing how such perceptual errors become more hazardous under dynamic weather conditions. The current training framework does not sufficiently equip pilots to interpret the nuanced interactions between terrain and rapidly shifting weather. To address this, training programs must incorporate scenario-based modules that replicate complex environmental conditions, improving pilots' situational awareness and decision-making under pressure, especially when conventional landing options are not viable.

Another significant factor was the weak organizational safety culture. The success of any safety management system depends not only on its formal components but also on the organizational culture that supports it. Key et al. (2023) argue that although many organizations acknowledge the importance of a positive safety culture, they often struggle to translate this awareness into actionable insights or measurable improvements. In both balloon accidents, commercial pressures and poor oversight led to a deprioritization of critical safety tasks such as thorough weather briefings and validation of pilot readiness. This illustrates that unless safety is deeply embedded as a core organizational value, even robust procedural systems may be ignored or circumvented in practice.

Moreover, the analysis revealed a pattern of procedural neglect at the organizational level. Consistent with the principles of complex human-machine systems, safe operation depends on rigorous adherence to established protocols (Degani & Wiener, 1997). However, in both cases, essential procedures particularly those concerning weight and balance calculations were either overlooked or executed superficially. This systemic disregard points to deeper organizational failures beyond individual pilot behavior. To address this, balloon operators must implement stringent internal auditing mechanisms and provide practical, procedure-focused training. Without such institutional safeguards, formal safety protocols risk becoming symbolic rather than functional defenses against accidents.

Lastly, these findings align with the principles of the Safe System Approach, which emphasizes that human errors are inevitable, and safety must be ensured by designing systems that anticipate and mitigate these errors (OECD/ITF, 2016;

Reason, 1997). Rather than attributing blame solely to individual actors, this approach underscores the shared responsibility across all levels — from pilots to organizational leadership and regulatory frameworks. By addressing systemic weaknesses such as inadequate training, insufficient weather integration, and weak safety culture, the ballooning industry can move toward a more resilient and error-tolerant operational model.

In conclusion, preventing future hot air balloon accidents requires a shift from reactive responses to proactive, systemic interventions. Integrating real-time meteorological data into operational planning, enhancing scenario-based pilot training, and fostering a genuinely safety-oriented organizational culture are essential steps. Drawing on layered safety models from sectors like aviation and healthcare, the balloon tourism industry can mitigate key risks and significantly enhance overall operational safety. However, it is important to acknowledge that these findings are based on two case studies, which limits their generalizability to the broader balloon tourism sector. Future research should expand this analysis to include a larger sample of balloon accidents across different regions and operational environments to validate these preliminary findings and develop more comprehensive safety frameworks for the industry.

4. Conclusion

This study aimed to investigate human factors in hot air balloon accidents in Turkish airspace using an integrated methodological approach combining RCA and HFACS. Analysis of two serious accidents revealed that balloon incidents stem from complex interactions between immediate operator actions, environmental conditions, supervisory decisions, and organizational influences.

Key findings revealed that while pilot decision-making errors appeared as immediate causes, deeper systemic issues were significant contributors, including: inadequate meteorological assessment systems, insufficient terrain-specific pilot training, weak organizational safety cultures, and procedural failures in operational planning. The integration of RCA with HFACS proved particularly effective in identifying these layered causal relationships.

Based on these findings, implementing real-time local meteorological monitoring systems in high-traffic balloon regions; developing specialized pilot training modules for terrain-induced weather phenomena and emergency decision-making; strengthening regulatory oversight of balloon operator safety management systems; and creating standardized pre-flight risk assessment protocols specifically addressing meteorological uncertainties could be recommended.

For the balloon tourism industry to enhance safety while maintaining operational viability, a shift from reactive to proactive safety management is essential. Future research should focus on developing balloon-specific human factors taxonomies, conducting comparative analyses across different regulatory environments, and examining the effectiveness of targeted interventions in reducing accident rates in this rapidly growing tourism sector.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

References

- ATLAS.ti Scientific Software Development GmbH. (2023). ATLAS.ti (Version 23) [Qualitative data analysis software]. <https://atlasti.com>
- Aslaner, M.A. (2019). Hot-air balloon tour accidents in the Cappadocia region. *Aerospace Medicine and Human Performance*, 90(2), 123-127.
- Barsalou, M., & Starzyńska, B. (2023). Inquiry into the use of five whys in industry. *Quality Innovation Prosperity*, 27(1), 62-78.
- Cowl, C.T., Jones, M.P., Lynch, C.F., Sprince, N.L., Zwerling, C., & Fuortes, L.J. (1998). Factors Associated With Fatalities and Injuries From Hot-Air Balloon Crashes. *JAMA*, 279(13), 1011-1014.
- Degani, A., & Wiener, E. L. (1997). Procedures in complex systems: The airline cockpit. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, 27(3), 302-312.
- Directorate General of Civil Aviation. (2024). Balloon operations and flight statistics. Retrieved from <https://web.shgm.gov.tr/tr/arama?searchkey=balon>
- Dunn, A. (2004), "Getting root cause analysis to work for you", ICOMS, available at: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.172.914&rep=rep1&type=pdf>
- Ercan, E., & Avcı, A.U. (2022). Analysis of Turkish Civil Aviation Accidents Between 2003 And 2017. *Journal of Aviation*, 6(2), 148-154.
- Filtress, A.J., Goode, N., & Cook, R.W. (2014). Causal factors of hot air ballooning incidents: identification, frequency, and potential impact. *Aviation, Space, and Environmental Medicine*, 85(12), 1190-1198.
- Key, K., Hu, P., Choi, I., & Schroeder, D. (2023). Safety culture assessment and continuous improvement in aviation: A literature review. Federal Aviation Administration.
- Kılıç, B. (2020). The analysis of hot-air balloon accidents by human factor analysis and classification system. *Journal of Aeronautics and Space Technologies*, 13(1), 17-24.
- Lee, J.-Y., Huang, C.-H., Sie, Y.-A., Yang, P.-C., Su, C.-C., & Chang, J.-T. (2025). Applying the Human Factors Analysis and Classification System within root cause analysis to prevent medical errors and enhancing patient safety culture: insights from a medical center. *International Journal for Quality in Health Care*, 37(1), mzaf009.
- Nevşehir Investment Support Office. (2017). Hot-air balloon industry report. Retrieved from https://www.ahika.gov.tr/assets/upload/dosyalar/ahika_2017_nevsehir-sicak-hava-balonu_sektor-raporu.pdf
- Novotná, M. & Kunc, J. (2022). Balloon Tourism. In D. Buhalis (Ed.), *Encyclopedia of Tourism Management and Marketing*. Edward Elgar Publishing Ltd., Cheltenham, UK.
- OECD/ITF. (2016). Zero road deaths and serious injuries: Leading a paradigm shift to a Safe System. OECD Publishing.
- Reason, J. (1997). *Managing the risks of organizational accidents*. Ashgate.
- T.C. Ulaştırma ve Altyapı Bakanlığı. (2025). Hava aracı kaza ve olay raporları [Aircraft accident and incident reports].

- Ulaşım Emniyeti İnceleme Merkezi.
<https://ulasimemniyeti.uab.gov.tr/hava-araci>
- Al-Rifai, M. (2025), "Unlocking insights: evaluating 5Whys methodology for root cause analysis and employee problem-solving skills in 91 case studies", International Journal of Lean Six Sigma, Vol. ahead-of-print No. ahead-of-print.
- Serrat, O. (2017). The Five Whys Technique. In: Knowledge Solutions. Springer, Singapore.
- Shappell, S. A., & Wiegmann, D. A. (2000). The Human Factors Analysis and Classification System -- HFACS. Retrieved from <https://commons.erau.edu/publication/737>
- Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A., & Wiegmann, D. A. (2007). Human Error and Commercial Aviation Accidents: Analysis Using the Human Factors Analysis and Classification System. Human Factors: The Journal of the Human Factors and Ergonomics Society, 49(2), 227–242.
- Ulaşım Emniyeti İnceleme Merkezi. (2024). Hava aracı kazaları istatistikleri: 2024 yılı verileri. T.C. Ulaştırma ve Altyapı Bakanlığı. <https://ulasimemniyeti.uab.gov.tr/uploads/pages/istatistikler/hava-2024-istatistik.pdf>
- Vincent, C., & Amalberti, R. (2016). Safer Healthcare: Strategies for the Real World. Springer Open.
- Wiegmann, D. A., & Shappell, S. A. (2003). A human error approach to aviation accident analysis: The human factors analysis and classification system. Ashgate Publishing Company.
- Wu, A.W., Lipshutz, A.K., & Pronovost, P.J. (2008). Effectiveness and efficiency of root cause analysis in medicine. JAMA, 299(6), 685-687.

Cite this article: Azik Ozkan, D (2025). Hot Air Balloon Accidents in Turkish Airspace: Human Factors Through RCA and HFACS. Journal of Aviation, 9(3), 614-622.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

The Impact of Brand Communication on Consumer Attitudes: Example in the Airlines Industry

Oğuzcan Yerli^{1*}, Belis Gülay²

^{1*}Maltepe University PhD Student in Interdisciplinary Communication Studies, Turkey, (oguzcan.yerli@gmail.com).

²Maltepe University, Assistant Professor, Vocational School, Civil Aviation Cabin Services Program, Turkey, (belisgulay@maltepe.edu.tr)

Article Info

Received: 13 May 2025

Revised: 08 July 2025

Accepted: 10 July 2025

Published Online: 09 October 2025

Keywords:

Rossiter-Percy Grid Theory
Brand communication strategies
Airlines industry

Corresponding Author: Oğuzcan Yerli

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1698378>

Abstract

This study drew insights from the Rossiter-Percy Grid Theory, which provides a framework for understanding brand communication strategies based on consumer motivation and involvement levels. The theory was applied to examine the effect of brand communication on the preference of airline companies in Kenya, focusing on social media as a branding tool. The study employed a survey research design, collecting data from a sample of 412 airline consumers through an online questionnaire distributed via Google Forms. Data analysis involved both descriptive and inferential statistics, assessing the association between social media usage for brand communication and airline preference. Findings revealed that there was no statistically significant association between social media brand communication and airline preference. However, this does not imply that social media lacks a role in brand communication. Instead, the study highlighted that while social media alone may not directly influence airline preference, it remains an essential tool for enhancing brand awareness, engagement, and consumer perception. The study suggested that airline companies should integrate social media with other rational and emotional brand communication strategies, as outlined in the Rossiter-Percy Theory. This includes leveraging functional benefits, emotional appeal, and brand personality to create a more comprehensive and effective brand positioning strategy.

Produced from the unpublished doctoral dissertation titled "The Impact of Brand Communication on Airline Companies' Brand Perception and Demographic Variables," prepared within the Interdisciplinary Communication Sciences Doctoral Program, Institute of Social Sciences, Maltepe University, Republic of Türkiye, dated July 8, 2025.

1. Introduction

Branding is the cornerstone of business identity and consumer engagement, shaping how a product, service, or organization is perceived in the marketplace. It involves creating a unique identity for a product, service, or organization through elements such as name, logo, design, and messaging. It serves to differentiate offerings from competitors while shaping consumer perceptions and preferences. A brand is more than just a name or a symbol; it encompasses the emotional and psychological associations that consumers develop with a product or company over time. Strong branding builds trust, enhances recognition, and influences purchasing decisions by creating a distinctive image in the minds of consumers (Keller, 2013).

Branding has existed since ancient times as a way to denote ownership, authenticity, and quality. Evidence suggests that branding practices date back to BC, with symbols used on cave walls to represent ownership or usage. Ancient Egyptians branded livestock to signify ownership, while Mesopotamian merchants used distinctive seals to mark their goods (Moore & Reid, 2008). In the Old Sumerian period, seals functioned as a form of branding, ensuring product authenticity and traceability. Similarly, Roman merchants stamped wine jars, pottery, and cheese distinguishing

their products from others (Keller & Swaminathan, 2020) finalised by section Conclusions. Continuation of the Study the modern concept of branding emerged during the Industrial Revolution in the late 19th century. Mass production and increased competition led companies to develop unique brand identities to differentiate their products. The rise of advertising, cinema, and mass communication in the 20th century further reinforced the importance of branding (Aaker, 2011). With the advent of digital platforms and e-commerce, branding has evolved into a crucial strategy for businesses seeking to establish a strong presence in a competitive marketplace. Today, branding is not just about product differentiation; it is a key factor in shaping consumer behavior and fostering brand loyalty (Kapferer, 2012). Brands provide numerous benefits to both consumers and businesses. For consumers, branding plays a crucial role in product identification and promotion. A brand serves as a guarantee of quality, ensuring that consumers can differentiate products and purchase with confidence. Furthermore, a branded product often comes with a warranty, protecting consumer rights even after purchase (Kotler & Keller, 2016). A brand is a symbolic identity that exists in the minds of consumers and influences their purchasing decisions.

2. Theory Development

Rossiter-Percy Grid Model, Brand Communication and

Consumer Preference Consumer behavior, especially in terms of brand selection and purchasing tendencies, is substantially shaped by how brand communication is formulated and delivered. The strategic strength of such communication determines a company's ability to solidify its brand identity, stand apart from its competitors, and secure customer loyalty. Numerous conceptual models have been introduced to articulate the relationship between brand messaging and consumer reactions. Central to this study is the Rossiter-Percy Grid Model, which classifies advertising approaches based on the type of consumer motivation and their level of involvement (Rossiter & Percy, 1987). This model presents a systematic framework for analyzing brand value communication and interpreting how consumers engage with such messaging—rendering it highly relevant for evaluating brand strategies in Kenya's aviation sector. Developed by John Rossiter and Larry Percy in 1987, the Rossiter-Percy Grid Model delineates brand communication based on two primary axes: consumer motivation (informational vs. transformational) and degree of involvement (high vs. low). Informational motives are rooted in rational problem-solving and utilitarian needs, while transformational motives rely on emotional resonance and lifestyle enhancement. Additionally, the model distinguishes between purchases that require extensive decision-making (high-involvement) and those made with minimal cognitive effort (low-involvement) (Rossiter et al., 1991). This dichotomy assists marketers in crafting tailored communication strategies that align with both product type and target audience psychology. Informational branding approaches are commonly employed in sectors where functional benefits are paramount. In aviation, this includes communications that emphasize safety standards, timeliness, affordability, and operational performance (Batra et al., 1996). Airlines adopting this strategy appeal predominantly to business travelers and price-sensitive passengers by underscoring attributes such as reliability and efficiency. Conversely, transformational branding strategies seek to forge emotional and symbolic connections. These are often found in industries driven by lifestyle and aspirational value. Within Kenya's airline sector, carriers applying this model highlight luxury, superior service, comfort, and exclusivity—attributes that attract premium clientele and leisure travelers. The underlying message in such communications is designed to associate the flying experience with prestige, relaxation, and personalized service. One of the notable strengths of the Rossiter-Percy framework is its balanced integration of logical and affective appeals, allowing it to be adapted across a wide array of industries (Rossiter et al., 1991). Furthermore, it aids businesses in effectively segmenting their audiences by aligning distinct brand narratives with specific consumer motivations (Yılmaz, 1999), thus enhancing message retention and consumer engagement. Nonetheless, the model is not without limitations. A primary critique is its binary segmentation of consumer motives, which may oversimplify the complex interplay of rational and emotional drivers in real-world purchasing behavior (Batra et al., 1996). Moreover, it presumes a linear decision-making pathway, whereas actual consumer behavior is often nonlinear and influenced by external variables such as peer influence, market trends, or competitive actions. Additionally, the model's primary emphasis on advertising and mass communication does not adequately account for emerging forms like digital marketing, public relations, and personalized engagement channels (Rossiter et al., 1991). In the context of this study, the model served as a valuable analytical lens to explore branding

strategies in Kenya's airline industry. By classifying airline communications into informational and transformational categories, it became evident that consumer segments diverge in response depending on their expectations and involvement levels. Business and frequent travelers prioritized efficiency and cost, favoring informational appeals, while leisure and high-end travelers gravitated toward transformational messages emphasizing comfort and exclusivity (Rossiter & Percy, 1987). Ultimately, brand communication emerges as a pivotal force in shaping consumer preferences. Airlines that skillfully blend both rational and emotional messaging are more likely to foster brand loyalty and engage a broad consumer base. This study affirms that utilizing the Rossiter-Percy Grid can assist airlines in refining their communication strategies, optimizing their brand positioning, and sustaining long-term competitive advantages in an increasingly dynamic market.

3. Methodology

This section describes the study's chosen research methodology, including the research design, sampling strategy, tools used for data collecting, data analysis techniques, and ethical issues. The study employed a quantitative research approach, utilizing the general survey model to examine the influence of brand communication on airline preferences. The general survey model is widely used in research that seeks to collect structured data from a large population or a selected sample to derive generalizable conclusions (Büyükoztürk, 2013). This approach was suitable for analyzing consumer perceptions and behaviors related to brand communication in the airline industry. Additionally, demographic factors were examined to assess variations in consumer perceptions regarding brand communication and airline selection (Bahtiyar & Can, 2016).

4. Study Design

A descriptive and correlational research design was used in the study, which aimed to describe consumer attitudes toward brand communication while also examining the relationships between brand communication strategies and airline preferences. The descriptive aspect of the study focused on identifying key consumer perceptions, while the correlational component sought to determine the extent to which brand communication influences consumer choices (Yıldırım & Şimşek, 2016). Furthermore, the study sought to establish whether demographic traits including age, sex, degree of education, and income significantly influenced consumer responses to brand communication strategies in the airline industry.

5. Sampling Procedure and Sample Size

The study adopted both purposive and random sampling techniques, ensuring that participants were chosen on the basis of their applicability to the research issue. Purposive sampling is a non-random technique that enables researchers to select individuals who meet predefined criteria suitable for the study objectives (Gürbüz & Şahin, 2016), while random sampling procedure ensures representativeness in the study. The research population comprised individuals who had previous experience using airline services, as they are the primary decision-makers in airline selection. The sample was drawn from this population to ensure representativeness and

reliability. The study involved 412 respondents, who were selected to provide insights into the relationship between brand communication and airline preferences. The sample was composed of individuals from diverse demographic backgrounds, ensuring representation of various age groups, professions, income levels, and travel frequencies. The inclusion of these varied demographics ensured that the study captured a broad spectrum of consumer perspectives on brand communication and airline preferences.

6. Data Collection Instruments

The study utilized a structured survey instrument, which was separated into two primary parts. Age, gender, education level, income, occupation, use of social media, and preferred airline carrier were among the demographic data collected in the first section. This demographic data was essential in segmenting consumer groups and analyzing variations in brand communication preferences. The second section consisted of a brand communication scale, which measured consumer perceptions of brand messaging, brand image, and communication effectiveness. Based on earlier studies on the efficacy of brand communication, the survey was designed on a Likert scale, with 1 denoting "strongly disagree" and 5 denoting "strongly agree" (Aaker, 2011; Keller, 2013). The questionnaire was distributed online via Google Forms, thus ensuring broad reach and diverse respondent participation.

7. Data Analysis Procedure

To find trends and connections between airline choices and brand communication, the gathered data was examined using SPSS (Statistical Package for the Social Sciences). To give a thorough examination of the research problem, a number of statistical approaches were used. An overview of customer attitudes toward brand communication was obtained by analyzing the frequency distributions, mean scores, and standard deviations of consumer responses using descriptive statistics (Büyüköztürk, 2013). To find out if there were any notable variations in consumer attitudes according to gender, age, and income level, independent samples t-tests were used (Field, 2018). To determine the direction and degree of the links between consumer airline choices and the efficacy of brand communication, correlation analysis was used (Pallant, 2020). Regression analysis was used to determine the predictive power of brand communication through social media use on airline preference.

8. Ethical Considerations

Ethical considerations were a crucial aspect of the study to ensure compliance with research integrity and participant protection. All participants provided informed consent before participating in the study, and their responses were handled with strict confidentiality and anonymity, ensuring that personal data was not disclosed or misused (Kiral, 2021). The study adhered to ethical guidelines by ensuring that participants were fully aware of the purpose of the research, the voluntary nature of their participation, and their right to withdraw at any time without consequences. Additionally, no personally identifiable information was collected, and all data was stored securely to prevent unauthorized access or breaches of privacy.

9. Results

This section outlines the empirical findings of the study, focusing on participants' demographic data, descriptive statistical evaluations, and inferential hypothesis testing. The primary objective was to explore the extent to which branding activities, particularly brand communication, influence consumer preferences within the airline industry. Data were gathered from a sample of 412 respondents, each of whom provided detailed information regarding their travel behaviors, brand-related perceptions, airline preferences, and use of social media as a platform for brand interaction. The results are systematically presented, beginning with a demographic overview, followed by descriptive insights into airline preferences, and concluding with inferential analyses to test the proposed research hypotheses.

10. Demographic Characteristics of the Respondents

The gender composition of the respondents revealed that 55% identified as male and 45% as female, indicating a moderate gender imbalance in favor of male participants. Age-wise, the sample predominantly comprised individuals aged 40 or below, accounting for approximately 75.2% of total participants, with the 31–40 age bracket being most heavily represented. Conversely, the lowest response rate came from individuals aged 51 and older. Educational attainment among respondents was generally high. A majority—64.3%—held undergraduate degrees, followed by 18% who possessed postgraduate qualifications (master's or doctoral degrees), and 17.5% who were high school graduates. Only 0.2% of participants had completed only primary education, highlighting an overall well-educated sample. Occupationally, the private sector dominated, with 59.2% of participants employed in private enterprises. Other categories included miscellaneous occupations (15.8%) and laborers (13.3%). Government employees made up the smallest group at 11.7%.

11. Participants' Responses on Brand Communication and Airline Preference

The research also sought to capture participants' attitudes toward various dimensions of brand communication and how these influenced their airline preferences. Variables examined included social media usage, brand perception, advertisement impact, travel frequency, travel purpose, and perceptions of corporate social responsibility (CSR). These factors were evaluated to determine their role in shaping consumer decision-making processes within the airline sector. The quantitative findings—summarized in Table 1—offer insight into how branding elements such as digital engagement, messaging strategies, and corporate values affect consumer airline selection behavior.

Table 1. Participants’ Response on Brand Communication and Airline Preference

Symbol	Quantity	Gaussian and CGS EMU to SI
1	Social Media Use for Brand Communication	86.2%
2	Airline Preference	Turkish Airlines: 45.4%, Kenya Airways: 34.1%, Qatar Airways & Emirates: ~10% each
3	Air Travel Frequency (Last 12 Months)	1-2 times: 43.9%; ≤5 times: 71.1%; >6 times: 18.7%
4	Purpose of Travel	Business: 42.2%, Vacation/Family: 40.6%, Education: 7.3%
5	Channels for Airline Advertisements	Social Media: 67.0%, Internet Ads: 15.3%, TV: 9.7%, Newspapers: 1.9%, Radio: 0.7%
6	Impact of Advertisements on Airline Choice	85.9%
7	Most Attractive Airline Brand Image	Turkish Airlines: 61.7%, Emirates: 16.7%, Qatar Airways: 11.2%, Kenya Airways: 8.5%
8	Influence of Corporate Social Responsibility (CSR)	CSR Influences Choice: 79.9%, CSR Not a Factor: 20.1%

Source: Field Data, 2024

12.Descriptive Findings on Brand Communication and Airline Preference

An analysis of social media engagement revealed that a significant majority of participants (86.2%) utilize social media platforms to engage with brands. This finding underscores the growing relevance of digital communication tools in shaping consumer-brand interactions and fostering engagement. With regard to brand preference in the airline sector, Turkish Airlines emerged as the most favored carrier, garnering 45.4% of the total responses. Kenya Airways followed with 34.1%, while Qatar Airways and Emirates each accounted for roughly 10% of the participants' preferences. Interestingly, a substantial number of respondents reported utilizing multiple airlines, indicating a relatively low degree of brand loyalty in airline selection behavior. In terms of travel frequency over the preceding year, 71.1% of the participants reported flying no more than five times, with 43.9% indicating they traveled only once or twice annually. Only 18.7% of the sample qualified as frequent flyers (traveling more than six times in the year), suggesting that most respondents were infrequent air travelers. The study also explored the primary purposes behind air travel. Business-related travel constituted 42.2% of the responses, while leisure and family visits collectively represented 40.6%. A smaller portion (7.3%) reported travel for educational purposes, illustrating that commercial and personal motivations dominate airline usage patterns. When identifying the most effective advertising channels, social media stood out as the predominant medium (67.0%). It was followed by internet advertisements (15.3%) and television (9.7%). Traditional media such as newspapers and radio had a minimal impact, with only 1.9% and 0.7% respectively indicating them as influential in airline brand communication. Moreover, 85.9% of participants acknowledged that advertising played a role in shaping their airline choices, highlighting the persuasive power of strategic brand messaging in influencing consumer behavior. Regarding

brand image, Turkish Airlines was again rated most favorably, with 61.7% of participants identifying it as having the most appealing brand identity. Emirates and Qatar Airways followed with 16.7% and 11.2%, respectively. Kenya Airways received the lowest brand image rating at 8.5%, suggesting a competitive disadvantage in brand perception. Finally, corporate social responsibility (CSR) initiatives were shown to significantly influence consumer preferences. Approximately 79.9% of respondents stated that CSR activities impacted their airline choice, while 20.1% reported that such initiatives had no substantial bearing on their decisions. These findings highlight the growing importance of socially responsible branding in consumer evaluation processes.

13. Hypothesis Testing

Evaluating the Relationship Between Social Media Usage for Brand Communication and Airline Preference
The following hypothesis was formulated to assess the impact of social media on airline selection behavior:
Ho: There is no significant relationship between participants’ use of social media for brand communication and their airline preferences.
To test this hypothesis, a Chi-Square Test for Independence was employed to determine whether a statistically significant association exists between social media engagement for branding purposes and consumer airline preference. This non-parametric test evaluated whether users’ interactions with airline brands via social platforms influence their decisions when selecting an airline.

Table 2. Chi-square for Independence Results

Symbol	Quantity	Gaussian and CGS EMU to SI
Pearson Chi-Square	3.769a	df = 4, Sig = .438
Likelihood Ratio	3.808	df = 4, Sig = .433
Linear-by-Linear Association	0.107	df = 1, Sig = .743
N of Valid Cases	409	—

As shown in Table 2, the Pearson Chi-Square statistic yielded a value of $\chi^2(4, N = 409) = 3.769$ with a corresponding p-value of .438. Given that the significance level exceeds the conventional alpha threshold of 0.05, the null hypothesis cannot be rejected. This outcome indicates that there is no statistically significant association between social media usage for brand communication and airline preference among the participants in the study. The findings suggest that while social media platforms serve as critical tools for brand visibility and consumer engagement, their direct influence on consumer choice—specifically in the context of airline selection—may be limited. Consumers may engage with airline content online without allowing such interactions to dictate their purchasing decisions. Instead, practical considerations such as ticket pricing, service quality, safety record, and schedule convenience appear to play a more decisive role. This underscores the necessity for airline companies operating in Kenya to adopt a comprehensive marketing strategy that goes beyond digital interaction. Integrating social media branding with traditional advertising channels, loyalty programs, and competitive pricing structures could enhance brand influence and strengthen customer acquisition and retention efforts in a competitive aviation market.

14. Discussion

The present study's findings demonstrate that the utilization of social media for brand communication does not exert a statistically significant influence on consumer airline preferences. As evidenced by the Chi-Square Test for Independence, no meaningful correlation was found between consumers' engagement with airline brands via social media platforms and their ultimate airline choices. This suggests that factors beyond social media communication—such as pricing, service reliability, and convenience—are more decisive in shaping purchasing decisions, particularly in industries driven by rational, cost-sensitive behaviors such as air travel (Gössling et al., 2019; Kaplan & Haenlein, 2021). Despite this limited direct impact, social media remains a crucial channel for brand interaction, awareness, and engagement. The study revealed that 86.2% of participants reported engaging with airline brands on social platforms, consistent with literature highlighting the centrality of digital platforms in modern airline marketing (Hudson & Hudson, 2020). Nonetheless, such interactions often serve informational or service-related functions rather than fostering strong brand loyalty or preference. It is important to recognize that brand communication extends well beyond digital channels. Traditional media, word-of-mouth, CSR initiatives, and direct marketing all contribute significantly to consumer perceptions. The study found that 85.9% of respondents acknowledged the influence of airline advertising on their brand preferences, and 79.9% indicated that CSR efforts shaped their airline choices. These findings emphasize the necessity of integrated marketing communication strategies that combine emotional branding and functional value propositions across multiple platforms, including social media, television, influencer partnerships, and customer experience initiatives. While social media alone may not trigger purchasing decisions, it remains an effective tool for emotional branding. Airlines that successfully share compelling narratives and showcase service excellence through social media may foster stronger brand associations over time. These emotional connections, when complemented by tangible service benefits, can enhance long-term consumer loyalty.

14.1 Implications of the Rossiter-Percy Grid Theory

The results are congruent with the Rossiter-Percy Grid Theory, which classifies purchasing decisions as being primarily rational or emotional in nature (Rossiter & Percy, 1997). Within the airline industry, the study suggests that rational drivers—such as cost efficiency, safety, convenience, and reliability—tend to outweigh emotional appeals. The preference for Turkish Airlines (45.4%), followed by Kenya Airways (34.1%), supports this notion, indicating that practical considerations take precedence in consumer decision-making. Nevertheless, emotional factors—including brand image and CSR initiatives—play a reinforcing role. Turkish Airlines, which also ranked highest in perceived brand image (61.7%), illustrates that emotional engagement complements rational evaluation. The Rossiter-Percy model reinforces this interplay, arguing that emotional advertising and brand communication can influence consumer attitudes even in logic-driven purchasing environments. Additionally, the study shows that CSR initiatives had a measurable impact on preferences, aligning with theories that advocate for the integration of ethical and emotional brand strategies to build consumer trust. Therefore, the evidence points to the effectiveness of a dual-branding strategy—combining rational marketing (e.g.,

pricing, punctuality) with emotional messaging (e.g., CSR, premium experience)—as a means to optimize brand positioning and consumer influence in the competitive airline sector.

14.2 Managerial and Policy Implications

From a managerial perspective, airline companies should not over-rely on social media engagement alone. While digital interaction is important, it is not sufficient to drive preference or loyalty in isolation. Airlines should focus on delivering core value through competitive pricing, high service reliability, and customer satisfaction. These should be complemented with personalized offers, loyalty rewards, and a cohesive brand narrative across platforms. Marketing strategies should also be diversified. The study confirms the continuing relevance of traditional advertising and CSR as influential tools. A multi-channel approach—utilizing both digital and conventional outlets—is vital for reaching a broader demographic and strengthening brand resonance.

At the policy level, regulatory bodies must uphold transparency in airline pricing and promotional content. Since cost is a major factor in airline selection, fair competition policies and consumer protection regulations are essential. Moreover, given the positive reception of CSR, authorities might consider incentivizing sustainability, ethical labor practices, and local development projects in the airline industry to drive both consumer confidence and environmental responsibility.

14.3. Limitations of the Study

Although the study provides meaningful insights, it is not without limitations. First, it focuses solely on consumers within the Kenyan aviation market, potentially limiting its external validity. Second, reliance on self-reported survey data introduces the possibility of social desirability bias. Lastly, the research concentrates broadly on social media usage rather than dissecting the nuanced impact of rational versus emotional components of brand communication. These gaps create opportunities for more detailed future investigations.

14.4. Directions for Future Research

Subsequent studies should explore other brand communication dimensions influencing airline preference, including customer satisfaction, corporate ethics, and direct engagement initiatives. Additionally, examining behavioral variations across demographic groups may uncover distinct patterns—such as digital responsiveness among younger travelers versus service reliability prioritization among older cohorts. A particularly valuable area of inquiry would involve evaluating the synergy between rational and emotional elements of brand communication. While this study identified the dominance of rational decision-making, a deeper understanding of how storytelling, CSR, and emotional branding interplay with logic-driven factors could enhance airline marketing frameworks. Future research might also compare airlines employing integrated marketing strategies to assess their effectiveness in cultivating long-term brand loyalty and customer retention.

15. Conclusion

The findings of this research indicate that while social media constitutes a vital component of brand communication for Kenyan airlines, its direct impact on consumer preference remains minimal. Although user engagement with airline

brands on digital platforms is high, consumer decisions are predominantly influenced by pragmatic factors such as pricing, service reliability, and overall flight experience. These insights are congruent with the Rossiter-Percy Grid Theory, which positions airline services within the high-involvement informational category, where consumer decisions are guided more by functional evaluations than emotional resonance. Consequently, brand communication, although crucial, is insufficient on its own to drive preference unless supported by operational excellence and value-based offerings. The study also identifies a notable lack of brand loyalty within the sector. Most respondents reported flying with multiple airlines rather than exhibiting allegiance to a single carrier. This reflects a consumer mindset driven more by comparative utility than emotional attachment. However, in line with the Rossiter-Percy framework, airlines may benefit from enhancing their high-involvement transformational appeal through emotional branding tools such as corporate social responsibility (CSR). Given that CSR initiatives were found to significantly influence preference, investment in socially and environmentally responsible practices could create stronger emotional bonds and differentiate airlines in a competitive market.

Ethical approval

Approval for this research was authorized by Maltepe University Ethics Committee under decision number 2024/14 and dated 25. .2024.

Acknowledgments

This article is derived from the doctoral research conducted by the lead author as part of the academic fulfillment requirements at Maltepe University. The authors would like to express sincere appreciation to Dr. Belis Gülay for her expert guidance, mentorship, and continuous support throughout the research process. Gratitude is also extended to the management of Maltepe University for providing institutional and academic support. The authors acknowledge with thanks the contribution of survey participants—particularly airline passengers—whose insights substantially enriched the empirical findings. The study also benefited from the valuable input of academic and industry professionals who contributed constructive feedback on the research design and instrumentation. Further appreciation is extended to airline companies, regulatory authorities, and personnel at Jomo Kenyatta International Airport (JKIA), whose logistical support and data access enabled the successful execution of the study.

Funding

This study forms part of the doctoral research project of the first author at Maltepe University. No external funding bodies were involved in supporting the research. The project was fully self-financed by the authors, as part of their commitment to advancing empirical scholarship in branding and consumer behavior, with a specific focus on emerging market contexts such as Kenya's aviation industry.

References

Aaker, D.A. (2011). *Brand relevance: Making competitors irrelevant*. John Wiley & Sons.
 Aaker, D.A. (2011). *Building strong brands*. Free Press.
 Aaker, D.A. and Joachimsthaler, E. (2000). *Brand leadership*. Free Press.

Bahtiyar, A. and Can, A. (2016). *Research methods in social sciences*. Ankara: Nobel Publications.
 Basu, P., Rudoy, D. and Wolfe, P.J. (2009). A nonparametric test for stationarity based on local Fourier analysis. *IEEE International Conference on Acoustics, Speech and Signal Processing*, first and last page 3005–3008.
 Batra, R., Myers, J.G. and Aaker, D.A. (1996). *Advertising management*. Prentice Hall.
 Bigné, E., Chatzipanagiotou, K. and Ruiz, C. (2019). The impact of digital marketing on consumer behavior in the airline industry. *Journal of Marketing Communications*, 25(3), 312–330.
 Bozkurt, İ. (2014). *İşletmelerde marka yönetimi ve önemi*. İstanbul: Beta Yayınları.
 Büyüköztürk, Ş. (2013). *Data analysis handbook for social sciences*. Ankara: Pegem Academy.
 Canpolat, Ö. (2001). *Elektronik ticaret ve işletmelere sağladığı faydalar*. İstanbul: Der Yayınları.
 Carroll, A.B. and Shabana, K.M. (2019). The business case for corporate social responsibility: A review of concepts, research, and practice. *International Journal of Management Reviews*, 21(2), 85–105.
 Chen, H., Wang, C. and Li, J. (2021). Examining factors influencing airline selection in emerging markets. *Transportation Research Part A: Policy and Practice*, 145, 27–39.
 Chernatony, L. de and Riley, F.D. (1998). Defining a "brand": Beyond the literature with experts' interpretations. *Journal of Marketing Management*, 14(5), 417–443.
 Cochran, W.G. (1977). *Sampling techniques*. John Wiley & Sons.
 Çakır, H. (2004). *Medya ve iletişim araçları*. Ankara: Nobel Yayınları.
 Field, A. (2018). *Discovering statistics using SPSS*. SAGE Publications.
 Gössling, S., Cohen, S. and Higham, J. (2019). Why social media marketing does not drive airline brand loyalty. *Journal of Travel Research*, 58(5), 678–692.
 Gürbüz, S. and Şahin, F. (2016). *Qualitative and quantitative research methods in social sciences*. Ankara: Seçkin Publishing.
 Hair, J.F., Hult, G.T.M., Ringle, C.M. and Sarstedt, M. (2014). *A primer on partial least squares structural equation modeling (PLS-SEM)*. SAGE Publications.
 Hudson, S. and Hudson, D. (2020). *Social media marketing in the airline industry: Challenges and opportunities*. *Tourism Management*, 81, 104160.
 Kapferer, J.N. (2012). *The new strategic brand management: Advanced insights and strategic thinking*. Kogan Page Publishers.
 Kaplan, A.M. and Haenlein, M. (2021). Rethinking airline branding in the digital age. *Business Horizons*, 64(1), 47–59.
 Keller, K.L. (2013). *Strategic brand management: Building, measuring, and managing brand equity*. Pearson Education.
 Keller, K.L. (2016). Reflections on customer-based brand equity: Perspectives, progress, and priorities. *Academy of Marketing Science Review*, 46(1), 36–45.
 Keller, K.L. and Lehmann, D.R. (2006). Brands and branding: Research findings and future priorities. *Marketing Science*, 25(6), 740–759.
 Keller, K.L. and Swaminathan, V. (2020). *Strategic brand management*. Pearson.

- Kenya Civil Aviation Authority. (2022). Annual report on airline industry performance. Nairobi.
- Kıral, B. (2021). Ethical considerations in social science research. İstanbul: Nobel Publishing.
- Kotler, P. and Keller, K.L. (2016). Marketing management. Pearson.
- Moore, K. and Reid, S. (2008). The birth of brand: 4000 years of branding history. *Business History*, 50(4), 419–432.
- Mutai, J.K. and Ombui, K. (2021). Influence of brand communication on airline consumer preference in Kenya. *African Journal of Business Management*, 15(5), 145–159.
- Pallant, J. (2020). SPSS survival manual: A step-by-step guide to data analysis using IBM SPSS. McGraw-Hill Education.
- Park, J. and Zhang, Y. (2022). The role of digital marketing in airline brand perception: A comparative study. *International Journal of Tourism Research*, 24(4), 512–528.
- Rossiter, J.R. and Percy, L. (1987). Advertising and promotion management. McGraw-Hill.
- Rossiter, J.R. and Percy, L. (1997). Advertising and promotion management. McGraw-Hill.
- Rossiter, J.R., Percy, L. and Donovan, R.J. (1991). A better advertising planning grid. *Journal of Advertising Research*, 31(5), 11–21.
- Temporal, P. (2011). Advanced brand management: Managing brands in a changing world. Singapore: John Wiley & Sons.
- Ünlü, H. (1987). Reklamcılığın temel ilkeleri ve uygulamaları. İstanbul: Alfa Yayınları.
- Yayınoğlu, B. (2006). Bütünleşik pazarlama iletişimi: Marka yönetiminde yeni yaklaşımlar. Ankara: Gazi Kitabevi.
- Yıldırım, A. and Şimşek, H. (2016). Qualitative research methods in social sciences. Seçkin Publishing.
- Yılmaz, H. (1999). Marketing communication and consumer behavior. İstanbul: Beta Publishing.

Cite this article: Oguzcan, Y., Gulay, B. (2025). The Impact of Brand Communication on Consumer Attitudes: Example in the Airlines Industry. *Journal of Aviation*, 9(3), 623-629.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

The Mediating Role of Trust In Coworker In The Effect Of Perceived Overqualification On Job Passion: A Study On Aircraft Maintenance Technicians

Tugay Öney^{1*}, Nida Palabıyık², Seçil Ulufer Kansoy³

^{1*} Tarsus University, Faculty of Aviation and Astronautics, Mersin, Türkiye (tugayoney@tarsus.edu.tr)

² Yozgat Bozok University, Vocational School of Health Services, Management and Organization, Yozgat, Türkiye. (nida.palabıyık@bozok.edu.tr)

³ Kırklareli University, Faculty of Aviation and Astronautics, Kırklareli, Türkiye. (secululuferkansoy@klu.edu.tr)

Article Info

Received: 14 May 2025

Revised: 15 June 2025

Accepted: 10 July 2025

Published Online: 09 October 2025

Keywords:

Aviation

Perceived overqualification

Job passion

Trust in a coworker

Aircraft technicians

Corresponding Author: Tugay Öney

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1699071>

Abstract

This study examines how perceived overqualification defined as employees' perception that their qualifications exceed job requirements affects job passion. Grounded in Optimal Distinctiveness Theory, which suggests that individuals seek a balance between belonging to a group and maintaining personal uniqueness, the study investigates two forms of job passion: harmonious passion (a balanced, self-directed engagement with work) and obsessive passion (a rigid, uncontrollable attachment to one's job). Additionally, the study explores the mediating role of trust in coworkers in the relationship between perceived overqualification and job passion. Data were collected from 227 aircraft maintenance technicians working in the Turkish aviation sector. Analyses were conducted using confirmatory factor analysis, multiple regression, and mediation analysis through SPSS 25.0 and Jamovi software. The results indicate that the misfit dimension of overqualification negatively predicts obsessive passion, while the simplicity dimension has a detrimental effect on harmonious passion. Moreover, trust in coworkers partially mediates both relationships. These findings offer theoretical contributions to understanding the emotional consequences of overqualification and provide actionable insights for HR practices in aviation and similar high-skill sectors.

1. Introduction

The evolving global economic and social dynamics have led to an increasing misfit between employees' qualifications and the positions in which they are employed. This growing disparity has prompted employees to develop the perception that their jobs do not fully utilize their capabilities and that their knowledge, skills, and experience exceed the requirements of their current roles. This perception, commonly referred to in the literature as perceived overqualification, is primarily shaped by subjective evaluations and social comparisons (Erdogan & Bauer, 2009; Johnson, Morrow & Johnson, 2002). When individuals perceive their work as intellectually or professionally inadequate, or when they feel overqualified compared to their coworkers, the sense of overqualification becomes more pronounced.

Perceived overqualification has been identified as a significant factor influencing employees' psychological attitudes in organizational contexts, such as job satisfaction and job passion (Harari, Manapragada & Viswesvaran, 2017; Tomás et al., 2023). However, the literature has yet to reach a clear consensus on the direction of this relationship. While some studies indicate that overqualification leads to negative work outcomes, others suggest that individuals may transform their perceived uniqueness into a source of positive motivation

(Erdogan, 2011). These contradictions imply that the effects of perceived overqualification may be shaped by contextual factors such as the employee's social environment. In particular, the nature of interpersonal relationships with coworkers and the level of trust within these relationships emerges as a critical determinant of the work experience.

In this regard, job passion is defined as a strong psychological connection, enthusiasm, and dedication that an individual feels toward their job (Vallerand et al., 2003). The formation of such passion is influenced not only by individual motivation but also by the social relationships and trust-based environment within the organization. When individuals feel accepted within the organization, their sense of belonging can be reinforced, and they may be better able to reframe their differences constructively. At this point, trust in coworker may increase one's sense of group belonging and help mitigate potential negative outcomes or, in some cases, make one's distinctiveness more visible, thereby weakening the sense of inclusion.

This research examines the effect of perceived overqualification on job passion and investigates the mediating role of trust in coworker within the framework of Optimal Distinctiveness Theory (ODT). According to ODT, individuals strive to balance two fundamental needs in their social lives: the need for belonging and the need for

distinctiveness (Brewer, 1991). When an individual perceives themselves as overqualified, this balance may be disrupted, enhancing the need for differentiation. In such cases, trust-based relationships with coworkers may help to neutralize the negative effects of this perceived difference or, conversely, may amplify the visibility of one's distinctiveness, thus reducing the sense of belonging. Within this framework, the study presents conceptual explanations of the variables based on existing literature, followed by the methodology and findings.

2. Conceptual framework

This section provides information about the concepts forming the research model and explains the research hypotheses.

2.1. Perceived Overqualification

The concept of qualification can be defined as an individual's possession of the knowledge, skills, and abilities required to perform a specific job or task. Fine and Cronshaw (1999) described qualification as a structure that reflects an individual's professional competence and encompasses their technical skills, problem-solving abilities, communication skills, and personal attributes in the workplace. This approach, which points to the alignment between the individual and the job, necessitates an evaluation of the extent to which the individual's knowledge and skills match the demands of the current job. In this context, Kulkarni et al. (2015, p. 544) stated that since employees may have different levels of knowledge, skills, and abilities, their level of qualification may also vary. They classified qualification levels as underqualified, adequately qualified, and overqualified. Accordingly, underqualified employees fall below the required competencies of the job, while adequately qualified employees fully meet the job requirements. Overqualification, on the other hand, refers to the perception that one possesses higher levels of knowledge, skills, and experience than what is required for the current job. However, the literature emphasizes that overqualification can be assessed based on both objective data and personal perceptions (Johnson, Morrow, & Johnson, 2002, p. 427). Objective evaluation involves comparing an individual's qualifications with job requirements based on standardized criteria, while subjective evaluation is based on the individual's perception of their own competence. For example, if a university graduate works in a position that only requires a high school diploma, this individual is objectively overqualified. If the same person believes that their skills exceed the job requirements, they may perceive themselves as subjectively overqualified. However, since it is not always possible to determine the exact knowledge and skills a job requires (Acaray, 2019, p. 448), subjective evaluations are frequently used, particularly in explaining employee attitudes and behaviors.

Subjective evaluation should not be considered merely a narrow perspective in which employees compare their current job with their qualifications. Employees can also evaluate their current job by comparing it with their expectations and what they hope to gain from it. Indeed, educated individuals with a wide range of knowledge and skills tend to have high expectations regarding their job status (Yu, Yang, Wang, Sun, & Hu, 2019, p. 6068). When such individuals compare their current job situation with the position they desire and believe they deserve, and find that their job roles do not meet their

expectations, this discrepancy may lead them to feel deprived. This feeling can become even more pronounced if the individual perceives that their coworkers are not at the same level of competence. In other words, the gap between objective working conditions and subjective expectations may lead to a perception of overqualification, which in turn can make employees feel deprived (Yu, Yang, Wang, Sun, & Hu, 2019, p. 6069). In this sense, perceived overqualification can also arise through social comparisons among employees. In this framework, Johnson and Johnson (2000, p. 167) state that the perception of overqualification stems from two main reasons: (1) the employee's belief that there are limited opportunities for development, and (2) misfit dimension between the person and the job. Especially in low-meaning, routine, and repetitive jobs, the individual may feel mentally or professionally understimulated and perceive their job as significantly beneath their capabilities. This may reinforce the feeling of "doing a job beneath my abilities," thus strengthening the perception of overqualification.

In light of these explanations, it can be said that perceived overqualification is a powerful psychological perception that may shape an individual's approach to their job. Particularly in work environments defined by strict rules and high levels of regulation, the formation of this perception may become a determining factor in how psychologically engaged employees are with their work.

2.2. Job Passion

This is a concept that refers to employees' levels of dedication, enthusiasm, and commitment to their work. It represents a psychological state in which employees direct their time, mental capacity, intelligence, energy, excitement, emotions, and concentration toward their work roles (Kossyva, Theriou, Aggelidis, & Sarigiannidis, 2023, p. 725). Therefore, it is closely related to employees' interest in and motivation for their work (Nursanti & Lestari, 2024, p. 1224). Employees with high levels of job passion are fully devoted to their tasks in terms of ideas and energy, which can result in increased enthusiasm and productivity (Pangestu, Wiradendi-Wolor, & Usman, 2024, p. 1330). Factors such as the alignment of employees' efforts with organizational strategy, empowerment through delegated authority, collaboration and teamwork, opportunities for self-development, receiving support and recognition, job satisfaction, and organizational commitment determine the level of employee engagement (Agustiani, Mora, & Ibad, 2024, p. 379).

Most studies in the literature have revealed that perceived overqualification has a negative direct or indirect relationship with work-related attitudes such as organizational commitment, job satisfaction, and job passion (Tomás et al., 2023; Zhang, Bolino, & Yin, 2022; Harari, Manapragada, & Viswesvaran, 2017). Perceived overqualification, which reflects an individual's belief that they possess more qualifications than required for the job (Liu & Wang, 2012), may highlight job inadequacy for employees who prioritize their personal career development. Based on this perspective, the current study investigates this relationship through the lens of Optimal Distinctiveness Theory (ODT). ODT posits that individuals strive to balance their needs for inclusion within a social group and for differentiation from it (Brewer, 1991). In other words, employees seek to feel accepted by the group (a sense of belonging) while also wanting to assert their uniqueness (a sense of distinctiveness). An imbalance between these two needs can significantly influence individuals' organizational behaviors.

Perceived overqualification refers to a situation in which individuals believe that their knowledge, skills, and experience exceed the requirements of their current job. This perception may weaken the sense of belonging to the group while simultaneously amplifying the desire to emphasize one's distinctiveness. Consequently, it may influence both the psychological bond with the organization and the type of motivation toward the job. In this study, perceived overqualification is examined in three dimensions: qualification, misfit, and simplicity. Each of these dimensions may have different impacts on individuals' needs for distinctiveness and belonging.

The qualification dimension pertains to the perception that one's capabilities exceed job requirements. Individuals who consider themselves "overqualified" compared to others may find it difficult to feel a sense of belonging to the group, potentially weakening their organizational ties. As a result, such individuals may struggle to develop harmonious job passion and may also avoid developing obsessive job passion. In this context, it is assumed that job passion may diminish due to the lack of fulfillment in a job that does not match one's needs, leading to the following hypotheses:

- **H1a:** Qualification dimension has a negative effect on employees' harmonious job passion
- **H1b:** Qualification dimension has a negative effect on employees' obsessive job passion

The misfit dimension reflects the perception that the job is not a good fit for the individual. This may lead to psychological disengagement from both the job and the organization. According to ODT, the need for belonging may be undermined under these circumstances. Consequently, a decrease in both harmonious and obsessive job passion is expected. To investigate this assumption, the following hypotheses are proposed:

- **H2a:** Misfit dimension has a negative effect on employees' harmonious job passion
- **H2b:** Misfit dimension has a negative effect on employees' obsessive job passion.

The simplicity dimension refers to the perception that the job fails to provide sufficient intellectual or professional challenge. When employees feel that their uniqueness is not appreciated and their abilities are underutilized, they may perceive the job as meaningless and lacking value. This could prevent the development of a healthy connection with the job. Accordingly, the following hypotheses are developed:

- **H3a:** Simplicity dimension has a negative effect on employees' harmonious job passion.
- **H3b:** Simplicity dimension has a negative effect on employees' obsessive job passion.

2.3. Trust in Coworker

Trust in coworker is a fundamental psychological construct that develops within the context of interpersonal relationships and influences cooperation, performance, and commitment in organizational life. Trust is defined as the willingness to be vulnerable based on positive expectations about another individual's intentions and behavior (Rousseau et al., 1998, p. 395). This definition underscores the importance of considering trust both as a cognitive evaluative process and as an emotional state of attachment. Indeed, McAllister (1995, pp. 25–26) conceptualizes trust in two forms: cognitive and affective. Cognitive trust is grounded in rational assessments

of another person's competence, reliability, and integrity. In contrast, affective trust evolves over time through social interactions and reflects emotional bonds based on mutual care, concern, and sincerity. In this regard, cognitive trust is often seen as a prerequisite for the development of affective trust; that is, the individual must first perceive the coworker as "worth investing in emotionally," which is rooted in cognitive appraisals (McAllister, 1995, p. 30).

Research highlights the critical role of affective trust in fostering positive social exchange relationships among coworkers. Employees with high levels of affective trust are more inclined to cooperate, exhibit prosocial behaviors, and engage in organizational citizenship behaviors (Patrick & Kumar, 2019, p. 126). Therefore, trust in coworker plays a significant role in building social capital within the organization. Moreover, the presence of trust in the work environment has substantial implications for organizational outcomes. Studies in the literature indicate that trust enhances employees' engagement and contributes to improved performance and productivity (as cited in Patrick & Kumar, 2019, p. 127). Thus, trust in coworker should not be viewed merely as an interpersonal attitude but also as a strategic organizational resource.

In the context of job passion, trust in coworker is believed to foster a sense of psychological safety and nourish motivational resources such as autonomy, meaningfulness, and belonging (Nešić, Mitrović Veljković, Meško, & Bertonecel, 2020, pp. 1284–1286). Accordingly, it can be posited that trust in coworker may serve as a mediating variable in the relationship between individual perceptions such as perceived overqualification and motivational outcomes like job passion. Especially within the framework of the Overqualification Attribution Theory (OAT), perceived overqualification may lead individuals to feel socially disconnected from their groups, thereby triggering a need for belonging. However, restoring this balance requires the strengthening of social bonds. At this point, Social Identity Theory (Tajfel & Turner, 2001) offers valuable insights into how individuals define themselves through membership in organizational groups. According to this theory, people derive part of their self-concept from their identification with social groups, and this identification significantly contributes to the development of self-esteem, belongingness, and interpersonal trust (Tajfel & Turner, 2001, pp. 104–106). When individuals perceive themselves as more qualified than other group members but are unable to identify with the group, they may experience an increased sense of social distance, making it more difficult to develop trust in their coworkers (van Knippenberg, 2000, p. 367). In this context, trust while inherently interpersonal can also be understood as an outcome of intragroup identity dynamics. Thus, group identity shapes emotional and cognitive perceptions of trust, but it can also act as a stabilizing mechanism to restore the motivational balance disrupted by overqualification. Within the scope of these theories, establishing trust-based relationships in the organizational environment becomes a critical factor supporting social integration. Trust in coworker can help employees reinforce their social ties and foster a sense of belonging within the group. Particularly, an employee who perceives themselves as more qualified than their peers may not view this difference as a threat if trustful relationships are in place. On the contrary, feeling accepted by the group may strengthen their sense of inclusion and help reconstruct their job passion.

From this perspective, the emphasis of Social Identity Theory on group belonging complements the explanatory structure of ODT, which highlights the balance between uniqueness and inclusion. When considered together, these two theoretical frameworks offer a more comprehensive understanding of how the sense of being accepted within a group interacts with trust dynamics to shape individuals' motivational orientations toward their work. In this framework, trust in coworker may function as a mediating variable in the relationship between perceived overqualification and work passion. This indirect effect suggests that an individual's psychological commitment to their work can be shaped—both in direction and intensity—through social bonds within the group. Based on this theoretical framework, the following hypothesis is proposed:

H4: Trust in coworker mediates the relationship between perceived overqualification and employees' job passion.

3. Method

The aim of this study is to examine the effect of perceived overqualification on job passion among aircraft maintenance technicians and to determine whether trust in coworker mediates this effect. To test the hypotheses and analyze the anticipated relationships, SPSS 25 and JAMOVI 2.3.28 statistical software were used. Data were collected between November 11 and December 7, 2024, after receiving approval from the Yozgat Bozok University Social and Human Sciences Ethics Committee dated October 23, 2024 with approval number 18/38.

3.1. Sample

The population of the study consists of aircraft maintenance technicians. Due to time and budget constraints, the minimum number of participants required for factor analysis was considered. According to the literature, a sample size five times greater than the number of variables to be analyzed is generally considered sufficient for reliable results (Streiner, 1994; Tabachnick & Fidell, 2019). In this context, a non-random sampling method was employed, and a questionnaire developed by the researchers was applied online to 227 participants who worked as aircraft maintenance technicians in the provinces of Isparta, Antalya, Ankara, and Malatya.

The reason for selecting aircraft maintenance technicians for the sample is that the qualified human factor forms the backbone of the aircraft maintenance system. Therefore, examining the factors that could impact this profession is considered crucial for the sustainability of the aviation industry.

3.2. Measurement Tools

The scales used in the research using the survey technique are given below.

Perceived Overqualification Scale:

The Perceived Overqualification Scale, which was developed by Johnson and Johnson (1996) and later translated into Turkish by Uçar and Zengin, consists of 13 items across 3 dimensions. The three dimensions of the Perceived Overqualification Scale are: Qualification Dimension (5 items), Misfit Dimension (4 items), and Simplicity Dimension (4 items). The two-factor structure of the scale was confirmed without item removal. The goodness-of-fit values for the factor

analysis are $\chi^2/sd = 2.491$, RMSEA = 0.081, CFI = 0.988, TLI = 0.984. In this study, the reliability coefficient for the Qualification Dimension subscale was found to be 0.850, for the Misfit Dimension subscale it was 0.879, and for the Simplicity Dimension subscale it was 0.697.

Trust in Coworkers Scale:

The three-item scale developed by Cook and Wall (1980) and adapted into Turkish by Çetinceli (2023) was used to measure trust in coworkers' reliable intentions. The scale is a 5-point Likert type (1 = Strongly Disagree; 5 = Strongly Agree), and it includes statements such as "When I face difficulties at work, I know my coworkers will try to help me" and "I trust that my coworkers will help me when I need them." In this study, the Cronbach's Alpha (reliability) coefficient for the Trust in Coworkers Scale was found to be 0.814. According to Nunnally and Bernstein (1994), a scale is considered reliable if its Cronbach's Alpha is above 0.70, indicating that the Trust in Coworkers Scale is reliable in this study.

Job Passion Scale:

To measure the job passion of aircraft maintenance technicians, the Job Passion Scale developed by Vallerand et al. (2003) and adapted into Turkish by Güner Kibaroglu et al. was used. The scale is a 5-point Likert type and consists of 12 items and 2 dimensions (1 = Strongly Disagree; 5 = Strongly Agree). The two dimensions of the Job Passion Scale are: Harmonious Job Passion (6 items) and Obsessive Job Passion (6 items). The goodness-of-fit values for the two-factor structure of the Job Passion Scale are $\chi^2/sd = 2.176$, RMSEA = 0.072, CFI = 0.983, TLI = 0.78. In this study, the reliability coefficient for the Harmonious Passion subscale was calculated as 0.786, and for the Obsessive Passion subscale, it was 0.797.

3.3. Research Model and Data Analysis Procedure

In this study, it is hypothesized that the dimensions of perceived overqualification, namely Qualification Dimension, Misfit Dimension, and Simplicity Dimension, will have an effect on the dimensions of job passion, which are Harmonious Job Passion and Obsessive Job Passion. Furthermore, it is proposed that trust in coworker will play a mediating role in the relationship between perceived overqualification and job passion. The research model is illustrated below (Figure 1).

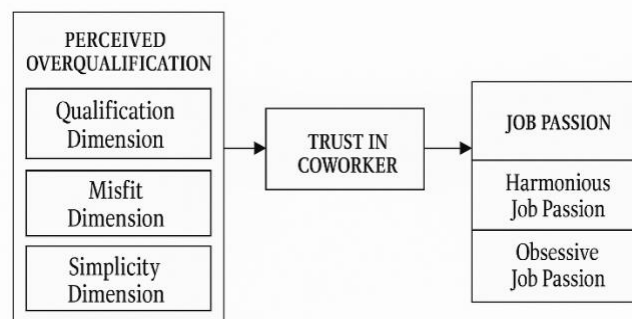


Figure 1. Research Model

In this study, the data consists of aircraft maintenance technicians working in the Turkish civil aviation sector. Before testing the model created in Figure 1, the data related to the normal distribution of the scales are presented in Table 1.

Table 1. Reliability and Validity Values of the Scale

Scales	Sub-dimension	Number of Items	Reliability Coefficient	CR	AVE	Skewness	Kurtosis
Perceived overqualification	Qualification dimension	5		0.890	0.622		
	Misfit dimension	4	0.828	0.893	0.682	-.062	.162
	Simplicity dimension	4		0.722	0.501		
Trust in coworker	Trust in coworker	3	0.814	0.890	0.617	-.912	1.537
Job passion	Harmonious job passion	6		0.829	0.478		
	Obsessive job passion	6	0.813	0.835	0.466	-.057	-.541

In this research, missing data imputation was performed initially. Following the Mahalanobis distance values, skewness and kurtosis values were examined. Based on the data presented in Table 1, it was determined that the skewness and kurtosis coefficients of each scale included in the study were within the range of +1.5 to -1.5, indicating that the data is normally distributed (Kline, 2011; Tabachnick & Fidell, 2019). Furthermore, since the AVE (Average Variance Extracted) values are 0.466 and above, and the CR (Composite Reliability) values are greater than 0.60 (Fornell & Larcker, 1981), it can be stated that convergent validity has been achieved for all the scales used in this study. Finally, the determination of discriminant validity for all variables was confirmed by the fact that the square roots of the average variance extracted are higher than the squared correlation coefficients between the variables (Kline, 2011). Based on this, the demonstration of convergent validity and discriminant validity also implies that construct validity has been ensured.

To test the hypotheses related to the research model that satisfies the normal distribution condition and convergent validity, Pearson correlation, multiple linear regression, and mediation analysis using Process 4.2 macro were conducted using SPSS 25 statistical software.

4. Result

The demographic characteristics of the study, which involved 227 aircraft maintenance technicians, are presented in Table 2.

Table 2. Demographic Characteristics

		f	%
Gender	Female	17	7.5%
	Male	210	92.5%
	25 years and below	16	7.0%
Age	26-33 years	74	32.6%
	34-41 years	102	44.9%
	42 years and above	35	15.4%
	Married	124	54.6%
Marital Status	Single	84	37.0%
	Prefer not to say	19	8.4%
	High School	13	5.7%
Education Level	Associate Degree	71	31.3%
	Bachelor's Degree	99	43.6%
	Postgraduate Degree	44	19.4%
	1-5 years	59	26.0%
Tenure in the Current Organization (Year)	6-10 years	73	32.2%
	11-15 years	50	22.0%
	16 years or more	45	19.8%

When examining Table 2, it is found that 17 of the aircraft maintenance technicians (7.5%) are female, and 210 (92.5%) are male. Regarding the age distribution of the participants, nearly half are in the 34-41 age range. 54.6% are married, 37% are single, and 8.4% did not specify their marital status. It was determined that 63% of the participants have an educational level of either college or graduate/postgraduate studies. Finally, concerning the participants' length of tenure in their current workplaces, 26% have worked for 1-5 years, 32.2% for 6-10 years, 22% for 11-15 years, and 19.8% for 16 years or more.

Table 3. Correlations Between Research Variables

Variables	Ort.	Std.	1	2	3	4	5	6
1. Qualification Dimension	19.96	3.37	(1)					
2. Misfit Dimension	10.76	4.45	0.290**	(1)				
3. Simplicity Dimension	12.41	3.53	0.321**	0.297**	(1)			
4. Trust in Coworker	12.57	1.74	0.159*	0.144*	0.083	(1)		
5. Harmonious Job Passion	23.59	3.47	0.421**	0.241**	-0.043	0.157	(1)	
6. Obsessive Job Passion	17.32	4.69	0.301**	-0.115	0.062	-0.052	0.340**	(1)

* $p < 0.05$, ** $p < 0.01$.

Table 3 presents the correlation analysis results. It was found that there is a positive and significant relationship between the dimension of perceived qualification ($r = 0.421$; $p < 0.01$) and attribution ($r = 0.241$; $p < 0.01$) with harmonious job passion. In contrast, a negative, non-significant relationship was observed between the dimension of simplicity dimension and harmonious job passion ($r = -0.043$; $p > 0.01$). A positive and significant relationship was found between qualification dimension and obsessive job passion ($r = 0.301$; $p < 0.01$). However, a negative, non-significant relationship was detected between attribution and obsessive job passion ($r = -0.115$; $p > 0.01$), and a positive, non-significant relationship was found between simplicity dimension and obsessive job passion ($r = 0.062$; $p > 0.01$). Lastly, a positive, non-significant relationship was found between trust in coworker and harmonious job passion ($r = 0.157$; $p > 0.01$), while a negative, non-significant relationship

was found between trust in coworker and obsessive job passion ($r = -0.052$; $p > 0.01$).

Based on the correlation findings, the regression results aiming to reveal the effect of the dimensions of perceived

Table 4. Regression Analysis Results

Dependent Variable	Independent Variable(s)	Beta	t	p	F	Model (p)	R ²	Adjusted R ²	Durbin-Watson
Model I					23.682	.000**	.242	.231	1.861
Harmonious Job Passion	Intercept	15.844	12.507	.000**					
	Qualification dimension	0.458	7.055	.000**					
	Misfit dimension	0.143	2.928	.004*					
	Simplicity dimension	-0.237	-3.801	.000**					

* $p < 0.05$, ** $p < 0.01$.

As shown in Table 4, Model I, which includes the dimensions of perceived overqualification (qualification, misfit, and simplicity dimensions), is statistically significant ($R^2 = 0.242$; $F_{(3, 222)} = 23.682$; $p < 0.01$). This model explains 24.2% of the total variance in harmonious job passion. Within the model, qualification dimension has a statistically significant and positive effect on harmonious job passion ($\beta =$

overqualification on the dimensions of job passion are presented in Table 4 and Table 5.

0.458; $p < 0.01$), and underestimation also shows a statistically significant and positive effect on harmonious job passion ($\beta = 0.143$; $p < 0.05$). In contrast, simplicity dimension has a statistically significant and negative effect on harmonious job passion ($\beta = -0.237$; $p < 0.01$). Accordingly, while hypotheses H1a and H2a are rejected, hypothesis H3a is supported.

Table 5. Regression Analysis Results

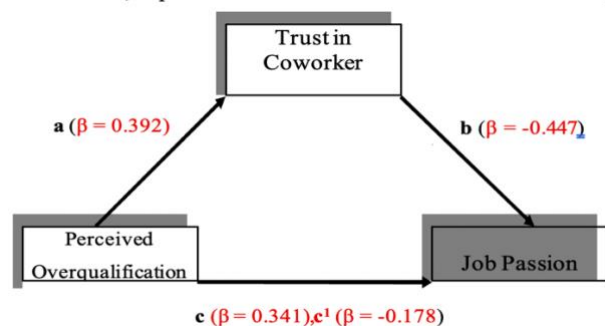
Dependent Variable	Independent Variable(s)	Beta	t	p	F	Model (p)	R ²	Adjusted R ²	Durbin-Watson
Model II					11.599	.000**	.135	.123	1.614
Obsessive Job Passion	Intercept	9.621	5.270	.000**					
	Qualification dimension	0.503	5.369	.000**					
	Misfit dimension	-0.235	-3.337	.001**					
	Simplicity dimension	0.015	.171	.865					

* $p < 0.05$, ** $p < 0.01$.

As shown in Table 5, Model II, which includes the dimensions of perceived overqualification (qualification, misfit, and simplicity dimensions), is statistically significant ($R^2 = 0.135$; $F_{(3, 222)} = 11.599$; $p < 0.01$). This model explains 13.5% of the total variance in obsessive job passion. The results indicate that qualification dimension has a statistically significant and positive effect on obsessive job passion ($\beta = 0.503$; $p < 0.01$), and misfit dimension has a statistically significant and negative effect on obsessive job passion ($\beta = -0.235$; $p < 0.05$). However, the simplicity dimension has a statistically positive but non-significant effect on obsessive job passion ($\beta = 0.015$; $p > 0.01$). Accordingly, while hypotheses H1b and H3b were rejected, hypothesis H2b was supported.

Following the regression analyses, the mediating effects were tested. To determine whether the mediation is partial or full, the assumptions of Baron and Kenny (1986) were considered. According to their method (Baron & Kenny, 1986, p. 1176), three conditions must be met to establish mediation:

(a) the independent variable must significantly affect the mediator, (b) the mediator must significantly affect the dependent variable, and (c) the independent variable must significantly affect the dependent variable. Additionally, the absence of zero within the bootstrap confidence interval and a decrease in the beta coefficient when the variables are included in the same model indicate mediation (Preacher & Hayes, 2008). Furthermore, if the Z-score from the Sobel Test exceeds 1.96 and is statistically significant, the mediating effect can be considered significant (Frazier et al., 2004). In this context, to test the mediating effect, Model 4 of the PROCESS macro version 4.2 was employed (Preacher et al., 2007). The statistical significance of the model and the bootstrapping analyses were conducted using the same software, with a 95% confidence interval and 5,000 bootstrap samples.

Table 6. Mediating Analysis Results

Sobel test: 2,972; $p=0,002$

When Table 6 is examined, it is found that the standardized regression coefficient for path "a" is 0.392 with a significance level of 0.001; for path "b" the coefficient is -0.447 with a significance level of 0.05; and for path "c" the coefficient is 0.341 with a significance level of 0.001. In light of this information, it is evident that all three conditions of Baron and Kenny have been met. However, in order to fully confirm the presence of a mediating effect, it must be checked whether path c1 becomes non-significant or shows a decrease in effect when the independent and mediating variables are included in the model simultaneously. When examining path "c1" ($\beta = -0.178$; $p = 0.001$), it is observed that there is a decrease compared to path "c". Although this indicates the presence of a mediating effect, it is not sufficient on its own; the significance of the mediating effect should be confirmed by evaluating the Sobel test Z-score. Since the Z-score for this model was found to be 2.293, which is greater than 1.96 and statistically significant, it can be concluded that a mediating effect exists. Thus, the H4 hypothesis is supported.

When Table 7, which presents the overall status of the hypotheses, is examined, it is observed that hypotheses H2b, H3a, and H4 are supported, whereas the other hypotheses are rejected.

Table 7. Hypotheses Table

Hypotheses	Accepted/Rejected
H_{1a}: Qualification dimension has a negative effect on employees' harmonious job passion.	Rejected
H_{1b}: Qualification dimension has a negative effect on employees' obsessive job passion.	Rejected
H_{2a}: Misfit dimension has a negative effect on employees' harmonious job passion.	Rejected
H_{2b}: Misfit dimension has a negative effect on employees' obsessive job passion.	Accepted
H_{3a}: Simplicity dimension has a negative effect on employees' harmonious job passion.	Accepted
H_{3b}: Simplicity dimension has a negative effect on employees' obsessive job passion.	Rejected
H₄: Trust in coworker plays a mediating role in the relationship between perceived overqualification and employees' job passion.	Accepted

5. Discussion and Conclusion

This study investigated how different dimensions of perceived overqualification namely, qualification, misfit, and simplicity influence job passion, both harmonious and

obsessive, within the theoretical framework of Optimal Distinctiveness Theory. Furthermore, it examined whether trust in coworkers serves as a mediating mechanism in these relationships. The findings extend existing literature by demonstrating that perceived overqualification does not necessarily lead to negative outcomes, challenging traditional assumptions in the field.

Contrary to the initial hypotheses (H_{1a} and H_{1b}), which posited that perceived overqualification would negatively impact harmonious and obsessive job passion, the findings revealed a positive relationship between perceived overqualification and both types of job passion. This result does not support the assumption proposed in the conceptual framework that overqualification weakens a sense of belonging and thereby diminishes passion for work. However, within the context of Optimal Distinctiveness Theory (ODT), this unexpected outcome highlights another theoretical possibility. When individuals perceive that their capabilities exceed job requirements, they may experience a heightened need for differentiation. This drive to stand out may, paradoxically, fuel greater passion for work, as employees seek to validate their qualifications and distinguish themselves within the organization or group. In such cases, perceived overqualification may simultaneously trigger the need for uniqueness while enhancing one's sense of belonging particularly when the organization acknowledges and values such distinctiveness. Therefore, instead of interpreting overqualification strictly as a barrier to group integration, it may function as a dual motivational force that strengthens job passion in organizational settings where distinctiveness and inclusion are balanced. In addition to ODT, this finding can also be interpreted through the lens of Compensatory Control Theory (CCT). According to CCT, when individuals face uncertainty, threat, or a perceived loss of control, they seek alternative psychological means to restore a sense of order and meaning (Kay et al., 2009). Perceived overqualification may create a sense of status threat or meaninglessness, stemming from the feeling that one's potential is unrecognized. However, some individuals may respond to this threat by becoming more invested in their work seeking to regain control through enhanced engagement, improved performance, or a deeper search for meaning. This compensatory mechanism is likely to be more salient in complex, high-risk, and skill-intensive work environments, such as the one examined in this study aircraft maintenance technicians in the aviation industry. In such contexts, perceived overqualification may not be seen as a misfit or deficiency, but rather as a form of privilege a resource that can be transformed into higher performance. Thus, the findings diverge from previous studies that have suggested overqualification diminishes job passion (Karagöz, 2023; Özel & Yılmaz, 2025) and instead point to alternative psychological processes whereby individuals mobilize internal resources to restore psychological equilibrium. In this light, the potential loss of control or meaning induced by overqualification may be compensated through enhanced job passion, consistent with the assumptions of CCT.

The findings related to the second hypothesis revealed a nuanced relationship between perceived misfit and job passion. Specifically, misfit perception was found to have a positive effect on harmonious passion (H_{2a}), but a negative effect on obsessive passion (H_{2b}). This indicates that the impact of perceived misfit on job passion may vary depending on the type of passion involved. According to ODT, perceived misfit may weaken one's need for belonging, thereby

diminishing emotional bonds with the organization and reducing both harmonious and obsessive job passion. In this study, however, only H_{2b} was supported, partially validating this assumption. The negative link between misfit and obsessive passion suggests that when individuals perceive a poor fit between themselves and their job, they may struggle to emotionally identify with their work in a rigid or compulsive manner. However, the unexpected positive relationship between misfit and harmonious passion suggests an alternative theoretical interpretation. It implies that individuals may develop harmonious passion for work even when they believe the job is not an ideal fit. This voluntary engagement may stem from adaptive psychological mechanisms aimed at preserving personal meaning or purpose. As previously discussed, this pattern is also consistent with CCT, which posits that individuals facing psychological threats such as lack of meaning, structure, or identity fit seek alternative sources of stability (Kay et al., 2009). Perceived misfit may lead individuals to feel that their work does not reflect their identity or allow for authentic self-expression. Yet, they may compensate for this incongruence by investing emotionally in the job through social relationships, a desire to contribute, or alignment with a higher purpose. This kind of voluntary engagement can be viewed as an expression of the individual's desire to "claim space" within the organization and to construct meaning despite perceived misalignment. As such, even a job that is not fully compatible with one's self-concept may be psychologically embraced, resulting in elevated levels of harmonious passion. This finding aligns with previous research emphasizing the positive outcomes of overqualification, such as the study by Erdogan et al. (2011), which showed that certain compensatory factors such as growth opportunities or social support can make a job more attractive to employees. In this respect, the current result underscores the idea that regardless of the objective quality of the job, individuals' pursuit of psychological equilibrium plays a critical role in shaping their passion for work.

In line with the third hypothesis, the findings indicate that perceived simplicity has a negative effect on harmonious passion (H_{3a}), while it has no significant effect on obsessive passion (H_{3b}). The first result suggests that when employees perceive their work as mentally or professionally unchallenging, they are less likely to engage with it in a self-driven and intrinsically motivated manner. From the perspective of ODT, this may reflect a failure to fulfill individuals' need for uniqueness and skill expression. When employees are unable to demonstrate their competencies, the work may be experienced as meaningless or unfulfilling, thereby reducing their internal commitment to it. This interpretation aligns with prior research, such as Gizlier (2021), which found that low-challenge tasks are associated with decreased job engagement. However, the absence of a significant effect of perceived simplicity on obsessive passion (H_{3b}) represents a theoretically unexpected finding and contributes a novel insight to the existing literature. While perceived simplicity may indeed undermine motivation, it does not appear to elicit the rigid, emotionally driven attachment that characterizes obsessive passion. This can be interpreted through the lens of CCT. Although simple tasks may create a cognitive void by threatening an individual's sense of meaning, responsibility, or status, they may fail to trigger compensatory attachment mechanisms. In other words, individuals may not feel compelled to forcefully maintain a connection to work they perceive as unchallenging. This

suggests that when a task lacks complexity, employees may disengage without experiencing the internal pressure typical of obsessive passion. The finding implies that identity-based identification with the job does not occur under conditions of perceived simplicity, and thus obsessive attachment is not activated. In this context, the motivational loss caused by simplicity is reflected in reduced harmonious passion, but it is not compensated through a sense of obligation or inner compulsion associated with obsessive passion. This points to the possibility that in low-complexity roles, employees may struggle to form psychological bonds with their work and may not seek alternative routes to restore control or meaning, thereby resulting in diminished intrinsic engagement without compulsive compensation.

The final finding of this study supports Hypothesis 4, indicating that trust in coworkers mediates the relationship between perceived overqualification and job passion. Notably, when trust was included in the model, the direct positive effect of overqualification on job passion decreased, suggesting a paradoxical mediation effect.

This finding echoes the work of Chiu et al. (2018), who emphasize that trust can exert both constructive and destructive effects depending on contextual factors. This result challenges a core assumption of ODT that trust unequivocally fosters belonging. For overqualified individuals, trust-based relationships with coworkers may amplify awareness of their own distinctiveness, thereby reinforcing feelings of being "different" from the group. As a result, the sense of not belonging may be heightened, leading to a reduction in job passion despite the presence of interpersonal trust. This dynamic can be better understood by incorporating insights from Social Identity Theory (SIT) (Tajfel & Turner, 2001), which posits that individuals derive self-concept, belonging, and self-esteem from their group membership. When individuals perceive themselves as more qualified than their peers, this can disrupt the identification process with the group. While trust in coworkers typically fosters inclusion, it may paradoxically intensify perceptions of "otherness" for those who feel overqualified ultimately weakening social identity and diminishing job passion. Derricks, & Sekaquaptewa (2021) revealed that a climate of trust may provide individuals with positive emotional support; however, social comparisons—especially among individuals who perceive themselves as minorities—can weaken their sense of belonging and negatively affect their engagement and passion for work. Trust, in this view, becomes not just a socio-emotional resource but also a mechanism for reassessing one's position within the group. Thus, the role of trust appears dualistic: in some contexts, it enhances belonging and nurtures job passion; in others, it heightens social comparisons and alienation. For instance, Patrick, & Kumar (2019) found that trust can foster job passion by strengthening social bonds and promoting voluntary commitment, yet the direction of its influence may depend on how individuals perceive their status within the group. Although few existing studies explicitly examine this dual function of trust, the present findings provide a theoretical foundation for future inquiry. Ultimately, the impact of trust on group identity may vary according to context, culture, and individual characteristics. Therefore, further research across diverse samples particularly those focused on group identity strength is necessary to test the generalizability of this finding.

In conclusion, this study demonstrates that the impact of perceived overqualification on job passion should not be

understood in a one-dimensional or inherently negative way. Notably, the findings indicate that perceptions of overqualification and misfit can actually enhance individuals' passion for their work, as they seek to make their qualifications visible and transform their distinctiveness into meaningful contributions. However, a key insight from the study is that trust in coworkers may indirectly attenuate this positive effect. This suggests that social bonds are not universally supportive; in some cases, they may reinforce feelings of difference rather than belonging. These dynamics were observed in a sample of aviation maintenance technicians, professionals working in highly specialized roles requiring technical expertise raising the possibility that the findings may be sector-specific. Accordingly, future studies should explore the generalizability of these results across other occupational contexts. It is also important to note that all variables in this study were based on self-reported perceptions. Future research could benefit from incorporating objective indicators, such as turnover rates or performance evaluations, to triangulate these findings.

From an organizational management perspective, it is critical to foster a work environment in which the potential of overqualified employees is recognized, and their distinct strengths are leveraged, rather than treating them as problematic outliers. In light of issues such as unemployment and financial insecurity, overqualified individuals may actively seek alternative opportunities. Therefore, it is recommended that organizations design enriched roles with clear advancement pathways for such employees.

Additionally, it is essential to monitor whether trust-based interactions within the workplace genuinely enhance the sense of belonging for overqualified individuals—or, paradoxically, highlight their differences and hinder integration.

Ethical approval

The approval of this research was authorized by the Yozgat Bozok University Social and Human Sciences Ethics Committee with the decision numbered 18/38 dated October 23, 2024.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Acaray, A. (2019). Algılanan aşırı nitelikliliğin iş tatmini ve işten ayrılma niyeti üzerine etkisi: Örgüt temelli özsaygının düzenleyici rolü. *Hitit Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 12(2), 447–468.
- Agustiani, T., Mora, L., & Ibad, C. (2024). Increasing employee engagement through workplace happiness: A quality of work life mediation study. *Psikoborneo Jurnal Ilmiah Psikologi*, 12(3), 378–384.
- Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173–1182.
- Brewer, M. B. (1991). The social self: On being the same and different at the same time. *Personality and Social Psychology Bulletin*, 17(5), 475–482.
- Chiu, T.S., Chih, W.H., Ortiz, J., & Wang, C.Y. (2018). The contradiction of trust and uncertainty from the viewpoint of swift guanxi. *Internet Research* 28(3), 716–745.
- Çetinceli, K. (2023). İş arkadaşlarına güven: Bir ölçek uyarlama çalışması. *Uluslararası Akademik Birikim Dergisi*, 6, 225–232.
- Derricks, V., & Sekaquaptewa, D. (2021). They're comparing me to her: Social comparison perceptions reduce belonging and STEM engagement among women with token status. *Psychology of Women Quarterly*, 45(3), 343–360.
- Erdogan, B., & Bauer, T. (2009). Perceived overqualification and its outcomes: The moderating role of empowerment. *Journal of Applied Psychology*, 94(2), 557–565.
- Erdogan, B., Bauer, T. N., Peiró, J. M., & Truxillo, D. M. (2011). Overqualified employees: Making the best of a potentially bad situation for individuals and organizations. *Industrial and Organizational Psychology*, 4(2), 215–232.
- Fine, S., & Cronshaw, S. (1999). *Functional job analysis: A foundation for human resources management*. Lawrence Erlbaum.
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39–50.
- Frazier, P. A., Tix, A. P., & Barron, K. E. (2004). Testing moderator and mediator effects in counseling psychology research. *Journal of Counseling Psychology*, 51(1), 115–134.
- Gizlier, Ö. (2021). Algılanan aşırı nitelikliliğin çalışan sesliliği üzerindeki etkisi. *Beykoz Akademi Dergisi*, 9(1), 57–67.
- Güner Kibaroglu, G., Güner, B., & Basım, H. N. (2023). İşe tutkunluk (job passion) ölçeğinin Türkçeye uyarlanması. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 32(2), 615–629.
- Harari, M. B., Manapragada, A., & Viswesvaran, C. (2017). Who thinks they're a big fish in a small pond and why does it matter? A meta-analysis of perceived overqualification. *Journal of Vocational Behavior*, 102, 28–47.
- Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). The Guilford Press.
- Johnson, G. J., & Johnson, W. R. (1996). Perceived overqualification and psychological well-being. *The Journal of Social Psychology*, 136(4), 435–445.
- Johnson, G. J., & Johnson, W. R. (2000). Perceived overqualification, positive and negative affectivity, and satisfaction with work. *Journal of Social Behavior & Personality*, 15(2), 167–184.
- Johnson, R., Morrow, P. C., & Johnson, G. C. (2002). An evaluation of a perceived overqualification scale across work settings. *The Journal of Psychology*, 136(4), 425–441.
- Karagöz, H. (2023). Algılanan aşırı nitelikliliğin işe tutulma üzerindeki etkisinde örgütsel güvenin aracı rolü: Hizmet sektöründe bir araştırma. *Selçuk Üniversitesi Sosyal Bilimler Meslek Yüksekokulu Dergisi*, 26(2), 303–315.
- Kay, A. C., Whitson, J. A., Gaucher, D., & Galinsky, A. D. (2009). Compensatory control: Achieving order through the mind, our institutions, and the heavens. *Current Directions in Psychological Science*, 18(5), 264–268.
- Kline, R. (2011). *Principles and practice of structural equation modeling* (3rd ed.). Guilford Press.
- Kossyva, D., Theriou, G., Aggelidis, V., & Sarigiannidis, L. (2023). Definitions and antecedents of engagement: A

- systematic literature review. *Management Research Review*, 46(5), 719–738.
- Kulkarni, M., Lengnick-Hall, M. L., & Martinez, P. G. (2015). Overqualification, mismatched qualification, and hiring decisions: Perceptions of employers. *Personnel Review*, 44(4), 529–549.
- Liu, S., & Wang, M. (2012). Perceived overqualification: A review and recommendations for research and practice. In J. R. & P. L. Perrewé (Eds.), *The role of the economic crisis on occupational stress and well being* (Vol. 10, pp. 1–42). Emerald Group Publishing.
- McAllister, D. J. (1995). Affect- and cognition-based trust as foundations for interpersonal cooperation in organizations. *Academy of Management Journal*, 38(1), 24–59.
- Nešić, A., Mitrović Veljković, S., Meško, M., & Bertonecel, T. (2020). Correlation of trust and work engagement: A modern organizational approach. *Amfiteatru Economic*, 22(Special Issue No. 14), 1283–1300.
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.
- Nursanti, T. D., & Lestari, F. (2024). Work engagement among post-millennial generation in Jakarta: Examining work-life balance and work values dynamics. *Jurnal Manajemen Bisnis dan Kewirausahaan*, 8(5), 1220–1234.
- Özel, E. T., & Yılmaz, A. (2025). The mediating role of organization-based self-esteem in the effect of perceived overqualification on work engagement. *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi*, 20(3), 715–741.
- Pangestu, A., Wiradendi-Wolor, C., & Usman, O. (2024). Pengaruh work-life balance and job crafting terhadap work engagement. *EKOMA: Jurnal Ekonomi, Manajemen, Akuntansi*, 3(6), 1327–1342.
- Patrick, H. A., & Kumar, S. R. (2019). Does trust in the workplace influence work engagement? An investigation among information technology employees. *International Journal of Advance and Innovative Research*, 6(1–XXIII), 126–133.
- Preacher, K. J., Hayes, A. F., & Rucker, D. D. (2007). Addressing moderated mediation hypotheses: Theory, methods and prescriptions. *Multivariate Behavioral Research*, 42(1), 185–227.
- Rousseau, D. M., Sitkin, S. B., Burt, R. S., & Camerer, C. F. (1998). Not so different after all: A cross-discipline view of trust. *Academy of Management Review*, 23(3), 393–404.
- Streiner, D. L. (1994). Figuring out factors: The use and misuse of factor analysis. *Canadian Journal of Psychiatry*, 39(3), 135–140.
- Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Pearson.
- Tajfel, H., & Turner, J. (2001). An integrative theory of intergroup conflict. In M. A. Hogg & D. Abrams (Eds.), *Intergroup relations: Essential readings* (pp. 94–109). Psychology Press.
- Tomás, I., González-Romá, V., Valls, V., & Hernández, A. (2023). Perceived overqualification and work engagement: The moderating role of organizational size. *Current Psychology*, 42, 23069–23079.
- Uçar, Z., & Sezgin, O. (2021). Algılanan aşırı vasıflılık: Ölçek geliştirme, güvenilirlik ve geçerlilik çalışması. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (42), 196–208.
- Vallerand, R. J., Blanchard, C. M., Mageau, G. A., Koestner, R., Ratelle, C., Leonard, M., ... Marsolais, J. (2003). Les passions de l'âme: On obsessive and harmonious passion. *Journal of Personality and Social Psychology*, 85(4), 756–767.
- Van Knippenberg, D. (2000). Work motivation and performance: A social identity perspective. *Applied Psychology*, 49(3), 357–371.
- Yu, H., Yang, F., Wang, T., Sun, J., & Hu, W. (2019). How perceived overqualification relates to work alienation and emotional exhaustion: The moderating role of LMX. *Current Psychology*, 40(1), 6067–6075.
- Zhang, Y., Bolino, M. C., & Yin, K. (2022). The interactive effect of perceived overqualification and peer overqualification on peer ostracism and work meaningfulness. *Journal of Business Ethics*, 181(2), 461–479.

Cite this article: Oney, T., Palabiyik, N., Kansoy, S.U. (2025). The Mediating Role of Trust In Coworker In The Effect Of Perceived Overqualification On Job Passion: A Study On Aircraft Maintenance Technicians. *Journal of Aviation*, 9(3), 630-639.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Panopticon Perceptions and Work Engagement Among Airline Employees: The Role of Surveillance in Employee Motivation

Ahmet Selim Süzer¹ 

¹Topkapi University, Faculty of Economics, Administrative and Social Sciences, Aviation Management Assist. Prof., Kazlıçeşme, 34087, Istanbul, Türkiye. (ahmetselimsuzer@topkapi.edu.tr)

Article Info

Received: 28 May 2025
Revised: 25 August 2025
Accepted: 31 August 2025
Published Online: 09 October 2025

Keywords:

Perception of the Panopticon
Work Engagement
Positive and Negative Panopticon
Surveillance
Employee Motivation

Corresponding Author: Ahmet Selim Süzer

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1709289>

Abstract

The purpose of this study is to examine the effects of airline employees' perceptions of workplace surveillance, conceptualized through the Panopticon, on their work engagement. The study employed a quantitative research design with a sample of 305 airline employees working in Istanbul, including cabin crew, flight crew, ground services, technical staff, and administrative personnel. Data were collected using the Panopticon Scale, which measures Positive Panopticon, Negative Panopticon, External Responsibility, and Awareness of Being Watched, and the short form of the Utrecht Work Engagement Scale (UWES-9), which evaluates vigor, dedication, and absorption. The collected data were analyzed through descriptive statistics, correlation analysis, and linear regression to examine the relationships between Panopticon perceptions and work engagement levels. The findings indicate that Positive Panopticon perception significantly enhances overall work engagement and its sub-dimensions, particularly vigor and absorption, by creating a sense of security and motivating employees to perform tasks more effectively. In contrast, Negative Panopticon perception was found to reduce work engagement and vigor, increasing stress and decreasing job satisfaction. Awareness of being watched positively affected employees' vigor but did not have a statistically significant impact on dedication, absorption, or overall engagement. These results suggest that surveillance policies should be carefully designed and communicated in a transparent and supportive manner, as positive perceptions can strengthen motivation and performance, whereas negative perceptions may undermine employee commitment and well-being.

1. Introduction

In recent decades, the role of surveillance in organizations has attracted increasing scholarly attention due to its profound implications for employee behavior and organizational outcomes. With the advancement of digital technologies, monitoring practices have expanded beyond traditional methods and now constitute an integral component of workplace management across diverse industries (Liu, 2017; Sheridan, 2016). While surveillance is often implemented to enhance safety, security, and efficiency, it simultaneously raises questions regarding employee privacy, autonomy, and motivation (Manokha, 2020; Lee, 2017).

Theoretical perspectives such as Jeremy Bentham's Panopticon model, later elaborated by Michel Foucault, provide valuable insights into how perceptions of constant observation shape individuals' conduct and psychological states (Bentham, 2020; Foucault, 2020). Within the organizational context, these frameworks highlight how surveillance mechanisms may not only regulate behavior but also affect employees' sense of trust, well-being, and long-term commitment to their workplace (Brunon-Ernst, 2016; Galivc, 2017).

This issue becomes particularly salient in safety-critical sectors such as the airline industry, where strict monitoring is embedded in daily operations. Airline employees, who are subject to intensive oversight due to the industry's inherent risks, represent an important group for understanding the dual role of surveillance: while it safeguards safety and compliance, it may also influence employees' motivation, engagement, and organizational commitment (Mettler & Naous, 2022; Manokha, 2019).

Against this backdrop, the present study investigates the relationship between airline employees' perceptions of surveillance and their organizational commitment. Specifically, it explores how employees sustain work motivation under strict monitoring conditions and how surveillance practices are reflected in their job performance and engagement. By analyzing these dynamics through empirical data, the study aims to contribute to both theoretical debates and practical strategies that balance organizational control with employee well-being.

1.1. Panopticon Perception and Workplace Surveillance

The concept of the Panopticon, originally introduced by Jeremy Bentham in the late 18th century, represents an architectural model designed to facilitate continuous

observation without the observed being aware of when they are monitored (Bentham, 2020). This design aimed to internalize discipline through the anticipation of surveillance, ensuring individuals regulate their behavior even in the absence of actual monitoring. Michel Foucault (2020) later expanded this concept in his seminal work *Discipline and Punish*, employing the Panopticon as a metaphor for modern disciplinary societies where control is exerted through internalized surveillance. According to Foucault, individuals in such systems behave as if they are constantly being watched, resulting in self-regulation and conformity to organizational norms (Sheridan, 2016).

In contemporary organizational contexts, the Panopticon has evolved beyond a mere architectural model to encompass digital and technological systems that enable pervasive monitoring of employees' actions and performance. Surveillance mechanisms are no longer limited to physical observation but have expanded to digital platforms, including electronic monitoring, performance-tracking software, and camera systems (Ball, 2022; Manokha, 2019). These practices mirror the central principle of the Panopticon: employees' uncertainty regarding when they are observed compels them to maintain compliance and discipline (Fetherston & Waldmann, 2021).

Modern surveillance systems in workplaces are implemented with the intention of improving operational efficiency, ensuring compliance, and enhancing security. Visual surveillance methods such as camera systems, digital surveillance tools that monitor internet use and communication, and performance monitoring systems are among the most common approaches (Liu, 2017; Manokha, 2020). However, while these systems aim to strengthen organizational control, they may also generate psychological costs, including heightened stress and perceived invasions of privacy (Hess, 2021).

Perceptions of workplace surveillance have been conceptualized through the lens of the Panopticon, which reflects both positive and negative dimensions. In this study, Panopticon perception is assessed across four key dimensions (Bryikbeyi, 2019):

- Negative Panopticon: The discomfort and anxiety employees experience due to continuous surveillance and control mechanisms
- Positive Panopticon: The belief that surveillance enhances security, fairness, and organizational order, which can foster motivation.
- External Responsibility: The inclination to comply with organizational norms primarily because of external monitoring pressures rather than intrinsic motivation.
- Awareness of Being Watched: Employees' conscious recognition of surveillance tools and the conditions under which they are monitored.

These dimensions collectively illustrate the dual nature of surveillance: while it can create a structured and secure environment, it may simultaneously trigger psychological strain and diminish employees' autonomy. Such perceptions have significant implications for organizational outcomes, particularly work engagement.

1.2. Work Engagement and Its Subdimensions: Vigor, Dedication, and Absorption

Work engagement is a positive, fulfilling, work-related state of mind characterized by vigor, dedication, and absorption (Schaufeli et al., 2002). It is widely regarded as a crucial determinant of individual and organizational performance because it reflects employees' emotional and cognitive connection to their work (Nguyen et al., 2020).

Unlike transient emotions, engagement represents a persistent state that enhances employees' productivity and organizational commitment.

Vigor denotes high levels of energy and mental resilience during work, accompanied by a willingness to invest effort and persist in the face of challenges (Schaufeli et al., 2006). Employees who exhibit vigor demonstrate enthusiasm and stamina, which enable them to sustain their performance under demanding conditions. Dedication refers to a profound sense of significance, enthusiasm, and pride in one's work. It is associated with strong identification with organizational goals and a perception that work contributes meaningfully to personal and organizational success (Özkalp & Meydan, 2015). Employees high in dedication typically exhibit a strong sense of purpose, resilience, and organizational loyalty.

Absorption reflects a state of deep concentration and immersion in work tasks, often accompanied by difficulty detaching from work (Schaufeli et al., 2002). Absorbed employees experience a sense of flow, where time passes quickly due to full cognitive engagement. This dimension plays a critical role in knowledge-intensive and high-risk sectors, such as aviation, where sustained attention is essential. Collectively, these three dimensions create a holistic picture of engagement as both an energetic and emotional investment in work. High engagement levels are associated with improved job performance, reduced turnover intentions, and enhanced organizational citizenship behaviors (Ilkhanizadeh & Karatepe, 2017). Conversely, diminished engagement can lead to decreased productivity and heightened burnout risk.

1.3. The Interaction Between Surveillance Perceptions and Work Engagement

Surveillance in the workplace has a complex relationship with work engagement, producing both facilitating and inhibiting effects depending on how it is perceived and implemented. When employees view surveillance as supportive, fair, and aimed at enhancing safety and efficiency, it can bolster organizational trust and reinforce engagement (Manokha, 2020). For instance, Positive Panopticon perceptions may encourage employees to adhere to standards, reduce uncertainty, and foster a sense of security, thereby promoting vigor and dedication (Gosnell et al., 2020).

Conversely, Negative Panopticon perceptions—characterized by discomfort, stress, and perceived intrusions into privacy—can erode psychological safety, diminish intrinsic motivation, and reduce engagement (Soliman, 2020). Employees who feel excessively monitored may exhibit surface compliance rather than genuine commitment, undermining their dedication and absorption (Bevno et al., 2021). Similarly, high awareness of being watched, when coupled with negative interpretations, can heighten stress and restrict autonomy, leading to disengagement and burnout (Lee & Ok, 2018).

Empirical studies underscore these dynamics. Liu (2017) found that digital monitoring improved short-term productivity but was associated with long-term declines in morale and job satisfaction. Research by Alafeshat and Tanova (2019) in service industries revealed that perceived over-surveillance correlates with reduced organizational commitment and increased turnover intentions. Hafermalz (2021) further noted that persistent surveillance can foster alienation, particularly in roles requiring autonomy and creativity.

The impact of surveillance on engagement dimensions is nuanced. While structured oversight may enhance vigor by promoting disciplined work habits, it can simultaneously impair absorption if employees perceive surveillance as

punitive rather than supportive (Hu & Ho, 2016). Dedication, which thrives on intrinsic meaning and trust, is particularly vulnerable to the negative psychological implications of excessive monitoring (Kim et al., 2022). These findings highlight the critical role of perception: surveillance framed as a protective and developmental tool can sustain engagement, whereas coercive or opaque implementation can undermine it.

1.4. Aviation Industry Context: Surveillance Practices and Psychological Outcomes

The aviation industry represents a unique context where stringent surveillance is indispensable for ensuring operational safety, regulatory compliance, and passenger security. Employees in this sector, including pilots, cabin crew, and ground staff, operate under continuous observation through physical, digital, and procedural monitoring systems (Manokha, 2020). These systems include in-flight camera surveillance, cockpit voice recorders, and performance monitoring technologies designed to minimize risk and enhance efficiency (Lee & Kim, 2018).

While these mechanisms fulfill critical safety functions, they also shape employees' psychological experiences. Research indicates that constant monitoring can heighten stress levels, reduce perceived autonomy, and exacerbate fatigue, particularly in roles with high cognitive and emotional demands (Hu et al., 2017). Marqueze et al. (2017) observed that persistent surveillance in flight operations contributes to insomnia, reduced concentration, and heightened error susceptibility. Over time, these stressors may erode vigor, limit absorption due to cognitive overload, and weaken dedication through diminished job satisfaction.

Privacy concerns further complicate the psychological landscape. Employees often perceive extensive monitoring as an infringement on personal space, undermining trust and organizational loyalty (De Moya & Pallud, 2020). Liu (2017) emphasized that perceptions of privacy violations can generate anxiety and foster intentions to leave the organization. These effects are particularly pronounced among pilots and cabin crew, whose performance evaluations hinge on data captured by digital surveillance tools (Gosnell et al., 2020).

The dual pressures of safety compliance and surveillance-induced stress necessitate a delicate balance in aviation organizations. While regulatory mandates require rigorous monitoring, excessive control risks alienating employees and diminishing engagement. Studies by Vatankhah et al. (2017) and Alola and Alafeshat (2021) reveal that supportive leadership, transparent communication about surveillance objectives, and psychological support systems can mitigate negative outcomes, sustaining engagement levels. Training programs, career development opportunities, and open dialogue about monitoring practices are critical strategies for reinforcing dedication and preventing burnout (Ilkhanizadeh & Karatepe, 2017; Kim et al., 2022).

All in all, the aviation industry exemplifies the paradox of surveillance: while indispensable for safety and performance, its psychological ramifications can undermine the very engagement it seeks to safeguard. Understanding employees' Panopticon perceptions and their interaction with engagement subdimensions is thus essential for designing balanced surveillance systems that enhance safety without sacrificing well-being.

2. Method

2.1. Research Model

This study aims to investigate the impact of airline employees' perceptions of workplace surveillance,

conceptualized through Panopticon theory, on their level of work engagement. Specifically, it analyzes the effects of four dimensions of Panopticon perception on the three subdimensions of work engagement: vigor, dedication, and absorption. By examining these relationships, the research seeks to reveal how surveillance perceptions influence employees' motivational and engagement levels in a highly regulated and safety-critical industry such as aviation.

In the research, employees' surveillance perceptions are assessed across four main dimensions: "Positive Panopticon," "Negative Panopticon," "External Responsibility," and "Awareness of Being Watched." The effects of these dimensions on levels of work engagement—specifically vigor, dedication, and absorption—are tested. The research model investigates how employees' perceptions of surveillance (independent variables) influence their levels of work engagement and its subdimensions (dependent variables).

2.2. Study Group

The participant group of this study consists of a total of 305 airline employees working in Istanbul. Participants hold various positions within the airline industry, including flight crew, cabin crew, ground services, technical staff, and administrative personnel. The sample includes employees from these diverse roles, providing a suitable structure for examining the relationship between perceptions of surveillance and levels of work engagement in the airline sector. Participants' demographic characteristics and working conditions are analyzed in detail in the relevant sections of the study.

2.3. Data Collection Instrument

In this study, two separate scales were used to measure Panopticon perception and work engagement. The Panopticon Perception Scale, originally developed based on Hazar's (2012) interview questions and literature review and finalized by Bıyıkbeyi (2019), consists of 17 items across four dimensions: Positive Panopticon (8 items), Negative Panopticon (7 items), External Responsibility (2 items), and Awareness of Being Watched (2 items).

Work engagement was measured using the short form of the Utrecht Work Engagement Scale (UWES-9), developed by Schaufeli et al. (2006). The scale consists of 9 items and three dimensions: Vigor (3 items), Dedication (3 items), and Absorption (3 items). The Turkish adaptation of the scale was conducted by Özkalp and Meydan (2015).

2.4. Statistical Analysis of the Data

The data obtained in this study were analyzed using IBM SPSS Statistics for Windows, Version 22.0. Frequency and percentage analyses were employed to identify the descriptive characteristics of the participants, while mean and standard deviation statistics were used to evaluate the scale scores.

To assess whether the research variables were normally distributed, skewness and kurtosis values were examined. According to the literature, values between +1.5 and -1.5 (Tabachnick & Fidell, 2013) or between +2.0 and -2.0 (George & Mallery, 2010) are considered indicative of a normal distribution. In this study, the variables were found to be normally distributed; therefore, parametric methods were applied. The relationships between the dimensions defining employees' scale levels were analyzed using Pearson correlation and linear regression analyses.

3. Findings and Interpretations

This section presents the findings related to the key characteristics of airline employees. Various demographic factors such as participants' age, gender, marital status, job position, and years of professional experience were examined. These findings provide an overview of the general profile of the employees who participated in the study.

Table 1. Distribution of Employees by Descriptive Characteristics

Groups	Frequency (n)	Percentage (%)
Age		
25 and below	65	21.3
26-30	94	30.8
31-35	69	22.6
36-40	28	9.2
41 and above	49	16.1
Gender		
Female	152	49.8
Male	153	50.2
Marital Status		
Single	96	31.5
Married	209	68.5
Position		
Flight Cockpit crew	36	11.8
Cabin crew	120	39.3
Ground Services	78	25.6
Technical Staff	51	16.7
Aviation management and administrative staff	20	6.6
Years of Experience		
1-5 years	66	21.6
6-10 years	83	27.2
More than 10 years	156	51.1

Gender distribution is relatively balanced, with 49.8% of employees identifying as female and 50.2% as male. Regarding marital status, many participants (68.5%) are married, whereas 31.5% are single. When analyzed by job position, the largest group is cabin crew, comprising 39.3% of the sample. This is followed by employees in ground services (25.6%), technical roles (16.7%), cockpit crew (11.8%), and managerial or administrative positions (6.6%).

Professional experience also shows a diverse distribution. More than half of the respondents (51.1%) have 10 or more years of experience, 27.2% have worked for 6–10 years, and 21.6% have between 1–5 years of experience. These figures suggest that the sample largely consists of experienced professionals across various roles within the airline industry. In addition to demographic characteristics, the table also reports the arithmetic means, standard deviations, and minimum–maximum values for employees' Panopticon perceptions and their levels of work engagement.

Table 2 presents the distribution of participants' scores across various scales. Regarding the External Responsibility scores, the mean score of 305 participants was 3.667, with scores ranging from 1 to 5 (standard deviation [SD] = 0.871). The mean score for the Positive Panopticon perception was 3.635, indicating that participants generally held a moderate level of positive Panopticon perception (SD = 0.813). In contrast, the mean score for the Negative Panopticon perception was lower, at 2.473 (SD = 0.944).

Regarding Surveillance Awareness, the participants' mean score was 3.069, with a relatively high standard deviation (SD = 1.216). This indicates that employees have varied experiences and levels of awareness regarding being monitored. The overall mean score for Work Engagement was 2.871. Examining the sub-dimensions of work engagement, the mean scores were as follows: vigor 3.092 (SD = 1.093), dedication 2.964 (SD = 1.207), and absorption 2.557 (SD = 0.988). These results suggest that employees generally exhibit a moderate level of work engagement.

Table 2. Mean Scores of Panopticon Perceptions and Work Engagement

Variable	N	Mean	SD	Min	Max	Kurtosis	Skewness	Cronbach's Alpha
External Responsibility	305	3.667	0.871	1.00	5.00	0.102	-0.627	0.845
Positive Panopticon	305	3.635	0.813	1.00	5.00	0.135	-0.495	0.869
Negative Panopticon	305	2.473	0.944	1.00	5.00	-0.198	0.423	0.874
Awareness of Being Watched	305	3.069	1.216	1.00	5.00	-1.041	-0.083	0.886
Work Engagement	305	2.871	0.929	1.00	5.00	-0.608	-0.121	0.916
Vigor	305	3.092	1.093	1.00	5.00	-0.755	-0.069	0.903
Dedication	305	2.964	1.207	1.00	5.00	-0.856	0.023	0.899
Absorption	305	2.557	0.988	1.00	5.00	-0.571	0.221	0.887

The relationships between employees' Panopticon perceptions and their levels of work engagement were

examined through correlation analysis, and the results are presented below.

Table 3. Correlation Analysis Between Panopticon Perceptions and Work Engagement Scores

	External Responsibility	Positive Panopticon	Negative Panopticon	Surveillance Awareness
Overall Work Engagement	r = 0.036 p = 0.533	r = 0.415** p = 0.000	r = -.234** p = 0.000	r = 0.118* p = 0.039
Vigor	r = 0.066 p = 0.250	r = 0.374** p = 0.000	r = -.262** p = 0.000	r = 0.213** p = 0.000
Dedication	r = 0.057 p = 0.318	r = 0.327** p = 0.000	r = -.227** p = 0.000	r = 0.076 p = 0.187
Absorption	r = -0.042 p = 0.464	r = 0.359** p = 0.000	r = -0.092 p = 0.109	r = 0.005 p = 0.926

*Note: $p < 0.05$; $p < 0.01$; Pearson Correlation Analysis

Table 3 presents the results of the correlation analysis examining the relationships between employees' Panopticon perceptions and their levels of work engagement.

- No significant relationship was found between overall work engagement and external responsibility ($r = 0.036$, $p = 0.533$).
- However, a strong and positive relationship was identified between positive Panopticon perception and overall work engagement ($r = 0.415$, $p < 0.01$).
- A significant negative relationship was found between negative Panopticon perception and overall work engagement ($r = -0.234$, $p < 0.01$).
- Surveillance awareness was positively and significantly correlated with overall work engagement ($r = 0.118$, $p < 0.05$).

Regarding the vigor dimension:

- A positive and significant correlation was found between positive Panopticon perception and vigor ($r = 0.374$, $p < 0.01$).
- A negative correlation was observed between negative Panopticon perception and vigor ($r = -0.262$, $p < 0.01$).
- Additionally, surveillance awareness showed a positive and significant relationship with vigor ($r = 0.213$, $p < 0.01$).

Regarding the dedication dimension:

- A positive relationship was found between positive Panopticon perception and dedication ($r = 0.327$, $p < 0.01$).
- A negative relationship was identified between negative Panopticon perception and dedication ($r = -0.227$, $p < 0.01$).
- No significant relationship was observed between surveillance awareness and dedication ($r = 0.076$, $p = 0.187$).

Regarding the absorption dimension:

- A positive correlation was found between positive Panopticon perception and absorption ($r = 0.359$, $p < 0.01$), whereas no significant relationship was found between negative Panopticon perception and absorption ($r = -0.092$, $p = 0.109$).
- Surveillance awareness was not significantly correlated with absorption ($r = 0.005$, $p = 0.926$).

These results indicate that positive Panopticon perception has a positive effect on work engagement, while negative Panopticon perception exerts a negative impact.

Table 4. The Effect of Panopticon on Work Engagement

Dependent Variable	Independent Variable	β	t	p	F	Model (p)	R ²
Overall Work Engagement	Constant	1.438	3.813	0.000	16.416	0.000	0.169
	External Responsibility	-0.011	-0.201	0.841			
	Positive Panopticon	0.380	6.543	0.000			
	Negative Panopticon	-0.077	-1.327	0.186			
	Surveillance Awareness	0.034	0.630	0.529			
Vigor	Constant	1.442	3.241	0.001	15.784	0.000	0.163
	External Responsibility	0.036	0.684	0.494			
	Positive Panopticon	0.296	5.074	0.000			
	Negative Panopticon	-0.120	-2.080	0.038			
	Surveillance Awareness	0.137	2.549	0.011			
Dedication	Constant	1.705	3.361	0.001	10.151	0.000	0.107
	External Responsibility	0.026	0.464	0.643			
	Positive Panopticon	0.277	4.589	0.000			
	Negative Panopticon	-0.119	-1.983	0.048			
	Surveillance Awareness	0.004	0.064	0.949			
Absorption	Constant	1.167	2.851	0.005	12.730	0.000	0.134
	External Responsibility	-0.102	-1.877	0.062			
	Positive Panopticon	0.409	6.883	0.000			
	Negative Panopticon	0.062	1.052	0.294			
	Surveillance Awareness	-0.061	-1.108	0.269			

3.1. Linear Regression Analysis

This study examined the effects of employees' Panopticon perceptions on overall work engagement and its sub-dimensions. According to the regression analysis, the results are as follows:

The model was found to be significant ($F = 16.416$, $p < 0.001$), with the independent variables, including Panopticon perception, explaining 16.9% of the variance in employees' overall work engagement scores ($R^2 = 0.169$). Positive Panopticon perception was found to have a significant and positive effect on overall work engagement ($\beta = 0.380$, $p < 0.001$). In contrast, external responsibility ($\beta = -0.011$, $p = 0.841$), negative Panopticon ($\beta = -0.077$, $p = 0.186$), and surveillance awareness ($\beta = 0.034$, $p = 0.529$) did not have significant effects on overall work engagement.

Vigor dimension: This model was also found to be significant ($F = 15.784$, $p < 0.001$), with the independent variables explaining 16.3% of the variance in vigor ($R^2 = 0.163$). Positive Panopticon perception had a positive and significant effect on vigor ($\beta = 0.296$, $p < 0.001$). Negative Panopticon perception had a significant and negative effect on vigor ($\beta = -0.120$, $p = 0.038$). Additionally, surveillance awareness showed a positive and significant effect on vigor ($\beta = 0.137$, $p = 0.011$). These findings suggest that a positive Panopticon perception may increase employees' energy at work, while a negative Panopticon perception may decrease this energy.

Commitment dimension: The model was found to be significant ($F = 10.151$, $p < 0.001$), with the independent variables explaining 10.7% of the variance in commitment ($R^2 = 0.107$). Positive Panopticon perception was found to have a positive and significant effect on commitment ($\beta = 0.277$, $p < 0.001$). Negative Panopticon perception had a negative and significant effect on commitment ($\beta = -0.119$, $p = 0.048$). However, surveillance awareness ($\beta = 0.004$, $p = 0.949$) and external responsibility ($\beta = 0.026$, $p = 0.643$) did not show significant effects on commitment.

Absorption dimension: This dimension was also explained by a significant model ($F = 12.730$, $p < 0.001$), with the independent variables accounting for 13.4% of the variance in absorption ($R^2 = 0.134$). Positive Panopticon perception had a significant and positive effect on absorption ($\beta = 0.409$, $p < 0.001$). Conversely, negative Panopticon ($\beta = 0.062$, $p = 0.294$), surveillance awareness ($\beta = -0.061$, $p = 0.269$), and external responsibility ($\beta = -0.102$, $p = 0.062$) did not have significant effects on absorption.

These findings indicate that positive Panopticon perception may enhance employees' work engagement, energy (vigor), and their level of absorption in work. Conversely, negative Panopticon perception may adversely affect employees' commitment and vigor levels.

4. Conclusion and Recommendations

The primary aim of this study was to investigate the effects of airline employees' perceptions of workplace surveillance, conceptualized through the Panopticon model, on their overall work engagement and its sub-dimensions: vigor, dedication, and absorption. Specifically, the study examined how positive and negative Panopticon perceptions, external responsibility, and awareness of being watched influence employees' motivation, energy, and commitment to their work. The findings indicate that different perceptions of surveillance exert differential effects on work engagement, highlighting the

complexity of monitoring practices in safety-critical sectors such as aviation.

Positive Panopticon perception emerged as a significant factor in enhancing employees' overall work engagement. When surveillance mechanisms are perceived as supportive rather than controlling, employees report higher levels of vigor, dedication, and absorption. Such mechanisms create a sense of security, clarify performance expectations, and provide implicit guidance on appropriate workplace behaviors, thereby fostering stronger attachment to work tasks. In sectors such as aviation, where operational safety and compliance are paramount, employees who perceive surveillance positively are more likely to remain motivated, maintain sustained focus on their tasks, and demonstrate consistent performance. Furthermore, positive perceptions contribute not only to enhanced energy levels (vigor) but also to increased absorption, reflecting employees' ability to become fully immersed in their work. This reinforces prior research suggesting that supportive surveillance, when experienced as fair and enabling, can act as a motivator rather than a stressor (Manokha, 2020; Alola & Alafeshat, 2021).

Conversely, negative Panopticon perception was found to adversely affect overall work engagement and particularly vigor. Employees who feel oppressed or constantly scrutinized report lower energy, decreased self-confidence, and heightened stress levels. These experiences can undermine intrinsic motivation and diminish employees' willingness to invest effort in their tasks. In practical terms, negative perceptions of surveillance may lead to disengagement, reduced job satisfaction, and increased turnover intentions, particularly in environments where the consequences of mistakes are significant. These findings align with existing literature indicating that excessive or intrusive monitoring can create psychological strain and erode commitment, emphasizing the need for organizations to balance oversight with autonomy (Kim et al., 2022; Gosnell et al., 2020).

The study also explored the role of awareness of being watched. Interestingly, this dimension had a positive effect on vigor, suggesting that employees who are informed about surveillance tools and monitoring practices may feel safer and more energized while performing their duties. However, awareness alone did not significantly influence dedication, absorption, or overall work engagement. This implies that mere knowledge of surveillance mechanisms does not automatically translate into higher commitment or deeper engagement. Instead, it is the quality and perception of monitoring—whether it is experienced as supportive or controlling—that determines its motivational impact. This distinction is critical for organizational practices, highlighting that transparency must be paired with fairness and supportive leadership to effectively enhance engagement.

External responsibility, another sub-dimension of Panopticon perception, did not demonstrate significant effects on work engagement in this study. This finding suggests that compliance driven solely by external pressures may be insufficient to foster genuine motivation or commitment. Employees may perform tasks adequately under external expectations, but without perceived autonomy or meaningful support, this does not translate into higher engagement.

In conclusion, the results of this study underscore the dual nature of workplace surveillance. Surveillance policies and monitoring practices can be either beneficial or detrimental depending on employees' perceptions and experiences. Positive surveillance, which employees perceive as fair, protective, and enabling, can strengthen work engagement and enhance performance, whereas negative surveillance, experienced as controlling or oppressive, may diminish

motivation and increase the likelihood of disengagement. Organizations operating in high-risk sectors, such as aviation, should carefully design and communicate surveillance practices, ensuring transparency, fairness, and support. Providing employees with training, leadership support, and opportunities to understand the rationale behind monitoring systems can mitigate potential adverse effects, fostering a work environment where surveillance serves as a motivator rather than a source of stress. Future research should continue to explore the psychological mechanisms underlying these perceptions and examine interventions that balance operational control with employee well-being.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Alafeshat, R. and Tanova, C. (2019) 'Servant leadership style and high-performance work system practices: Pathway to a sustainable Jordanian airline industry', *Sustainability*, 11(22), p. 6191.
- Alola, U.V. and Alafeshat, R. (2021) 'The impact of human resource practices on employee engagement in the airline industry', *Journal of Public Affairs*, 21(1), e2135.
- Ball, K. (2022) 'Surveillance in the workplace: Past, present, and future', *Surveillance and Society*.
- Bentham, J. (2020) *The Panopticon Writings*. Verso Books.
- Bevno, M., Hvorecký, J. and Šimúth, J. (2021) 'E-PANOPTICON of face-to-display workers: From the office to the home', *Ad Alta: Journal of Interdisciplinary Research*, 11(1).
- Bıyıkbeyi, T. (2019) Panoptikon algısının çalışanlar üzerindeki etkisi: İşe adanmışlık ve tükenmişlik üzerine bir araştırma. Doktora Tezi, Kahramanmaraş Sütçü İmam Üniversitesi, Sosyal Bilimler Enstitüsü, İşletme Anabilim Dalı, Kahramanmaraş.
- Brunon-Ernst, A. (2016) *Beyond Foucault: New Perspectives on Bentham's Panopticon*. Routledge.
- De Moya, J.F. and Pallud, J. (2020) 'From panopticon to heautopticon: A new form of surveillance introduced by quantified-self practices', *Information Systems Journal*, 30(6), pp. 940–976.
- Fetherston, R. and Waldmann, T. (2021) 'The psychological effect on employees of their increasing surveillance at work', *Irish Ergonomics Society*, 44.
- Foucault, M. (2020) 'Panopticism', in *The Information Society Reader*. Routledge, pp. 302–312.
- Galivc, M., Timan, T. and Koops, B.-J. (2017) 'Bentham, Deleuze and beyond: An overview of surveillance theories from the panopticon to participation', *Philosophy & Technology*, 30, pp. 9–37.
- George, D. and Mallery, M. (2010) *SPSS for Windows Step by Step: A Simple Guide and Reference*, 17.0 update. 10a edn. Boston: Pearson.
- Gosnell, G.K., List, J.A. and Metcalfe, R.D. (2020) 'The impact of management practices on employee productivity: A field experiment with airline captains', *Journal of Political Economy*, 128(4), pp. 1195–1233.
- Hafermalz, E. (2021) 'Out of the panopticon and into exile: Visibility and control in distributed new culture organizations', *Organization Studies*, 42(5), pp. 697–717.
- Hazar, E. (2012) Gözetleme toplumu bağlamında çağdaş sosyal kontrol araçları: Kapalı devre kamera sistemleri ve toplumsal fayda ve maliyetleri Ankara ili örneği. Yüksek Lisans Tezi, Hacettepe Üniversitesi, Savunma Bilimleri Enstitüsü, Ankara.
- Hess, K. (2021) 'To serve and inspect: The tragedy of employee well-being in the age of Foucault's discipline', *Geo. JL & Pub. Pol'y*, 19, p. 763.
- Hu, H.H.S., Hu, H.Y. and King, B. (2017) 'Impacts of misbehaving air passengers on frontline employees: Role stress and emotional labor', *International Journal of Contemporary Hospitality Management*, 29(7), pp. 1793–1813.
- Hu, J.L. and Ho, C.W. (2016) 'Service quality and non-salary mechanism for airline companies in Taiwan', *Journal of Air Transport Management*, 55, pp. 61–66.
- Ilkhanizadeh, S. and Karatepe, O.M. (2017) 'An examination of the consequences of corporate social responsibility in the airline industry: Work engagement, career satisfaction, and voice behavior', *Journal of Air Transport Management*, 59, pp. 8–17.
- Kim, H., Yu, M. and Hyun, S. (2022) 'Strategies to improve work attitude and mental health of problem employees: Focusing on airline cabin crew', *International Journal of Environmental Research and Public Health*, 19(2), p. 768.
- Lee, J.H., Ok, C.M., Lee, S.H. and Lee, C.K. (2018) 'Relationship between emotional labor and customer orientation among airline service employees: Mediating role of depersonalization', *Journal of Travel Research*, 57(3), pp. 324–341.
- Lee, S. and Kim, J.K. (2018) 'Factors contributing to the risk of airline pilot fatigue', *Journal of Air Transport Management*, 67, pp. 197–207.
- Liu, Y. (2017) *Employee Monitoring: Workplace as a Panopticon?* Thesis Commons.
- Manokha, I. (2019) 'New means of workplace surveillance: From the gaze of the supervisor to the digitalization of employees', *Monthly Review*, 70(9), pp. 25–39.
- Manokha, I. (2020) 'The implications of digital employee monitoring and people analytics for power relations in the workplace', *Surveillance & Society*, 18(4), pp. 540–554.
- Marqueze, E.C., Nicola, A.C.B., Diniz, D.H. and Fischer, F.M. (2017) 'Working hours associated with unintentional sleep at work among airline pilots', *Revista de Saúde Pública*, 51, p. 61.
- Mettler, T. and Naous, D. (2022) 'Beyond panoptic surveillance: On the ethical dilemmas of the connected workplace', *ECIS*.
- Nguyen, H.N., Le, Q.H., Tran, Q.B., Tran, T.H.M., Nguyen, T.H.Y. and Nguyen, T.T.Q. (2020) 'The impact of organizational commitment on employee motivation: A study in Vietnamese enterprises', *The Journal of Asian Finance, Economics and Business*, 7(6), pp. 439–447.
- Özkalp, E. and Meydan, B. (2015) 'Schaufeli ve Bakker tarafından geliştirilmiş olan İşe Angaje Olma Ölçeği'nin Türkçe'de güvenilirlik ve geçerlilik analizi', *İş, Güç Endüstri İlişkileri ve İnsan Kaynakları Dergisi*, 17(3), pp. 4–19.
- Schaufeli, W.B. and Bakker, A.B. (2002) 'The measurement of engagement and burnout: A twosample confirmatory factor analytic approach', *Journal of Happiness Studies*, 3(1), pp. 71–92.
- Schaufeli, W.B., Bakker, A.B. and Salanova, M. (2006) 'The

- measurement of work engagement with a short questionnaire: A cross-national study', *Educational and Psychological Measurement*, 66(4), pp. 701–716.
- Shin, L.R. and Hyun, S.S. (2019) 'Impact of managerial influence tactics on job creativity and performance: A focus on Korean airline service employees', *Sustainability*, 11(16), p. 4429.
- Soliman, M.H.A. (2020) 'The Toyota way to effective strategy deployment: How organizations can focus energy on key priorities through Hoshin Kanri to achieve the business goals', *Journal of Operations and Strategic Planning*, 3(2), pp. 132–158.
- Tabachnick, B.G. and Fidell, L.S. (2013) *Using Multivariate Statistics*. 6th edn. Boston: Pearson.
- Vatankhah, S., Javid, E. and Raoofi, A. (2017) 'Perceived organizational support as the mediator of the relationships between high-performance work practices and counter-productive work behavior: Evidence from airline industry', *Journal of Air Transport Management*, 59, pp. 107–115.

Cite this article: Suzer, A.S. (2025). Panopticon Perceptions and Work Engagement Among Airline Employees: The Role of Surveillance in Employee Motivation. *Journal of Aviation*, 9(3), 640-647.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 **Journal of Aviation** <https://javsci.com> - <http://dergipark.gov.tr/jav>

Resistance to Change, Self-Efficacy, and Organizational Agility in Civil Aviation

Seray Toksöz ¹ 

¹Istanbul Esenyurt University, Aviation Management Department, 34000, Esenyurt İstanbul, Türkiye. (seraytoksoz@esenyurt.edu.tr)

Article Info

Received: 09 June 2025

Revised: 18 August 2025

Accepted: 25 August 2025

Published Online: 09 October 2025

Keywords:

Civil Aviation

Resistance to Change

Self-Efficacy

Organizational Agility

Structural Equation Modeling

Corresponding Author: Seray Toksöz

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1716249>

Abstract

In the aviation industry, organizational agility is vital due to the sector's dynamic structure and strict safety requirements. This study investigates the effect of resistance to change on organizational agility, with self-efficacy examined as a mediating variable. The research sample comprises 435 civil aviation employees from various positions (operational staff, management, technical crew, etc.). Data were collected through validated measurement tools, including the "Resistance to Change Scale," "Organizational Agility Scale," and "Self-Efficacy Scale." Statistical analyses were conducted using SPSS 30.0 and AMOS 24.0. Confirmatory factor analyses confirmed the reliability and validity of the scales. Structural equation modeling (SEM) was applied to test the hypothesized relationships. The results revealed that resistance to change has a significant direct and indirect impact on organizational agility. Specifically, self-efficacy partially mediates the relationship between the cognitive, emotional, and behavioral dimensions of resistance to change and organizational agility. Bootstrap analysis confirmed the significance of four out of nine mediation pathways. The findings highlight that enhancing employees' self-efficacy can mitigate the negative effects of resistance to change and improve organizational agility. This has practical implications for HR professionals and aviation leaders aiming to foster agile, resilient organizations in high-risk environments.

1. Introduction

The civil aviation sector is a strategic industry shaped by dynamic factors such as high safety standards, strict regulations, and ever-evolving customer expectations. It requires constant innovation and adaptability to rapidly changing global conditions. In this context, organizational agility has emerged as a critical capability for companies aiming to respond quickly to change and gain a competitive advantage (ICAO, 2023).

Organizational agility is defined as an organization's ability to respond to internal and external environmental changes in a rapid, flexible, and effective manner (Doz & Kosonen, 2010). This capability is not only determined by corporate-level strategies but is also deeply influenced by individual and team-level behavioral factors. Among these, employees' resistance to change and their self-efficacy perceptions play crucial roles in either facilitating or hindering agile practices (Vakola, 2014; Bandura, 1997).

Employees' attitudes toward organizational change are significant in determining how well the change is accepted and internalized across the organization. Resistance to change can stem from employees' desire to maintain the status quo, fear of uncertainty, lack of information, or negative past experiences with organizational change (Oreg, 2006). In high-stress and highly regulated sectors such as civil aviation, disruptions to routines or the introduction of new systems can provoke

anxiety and uncertainty among employees, thereby weakening organizational agility. Research indicates that employees with high resistance to change are less likely to embrace organizational reforms and adapt to new procedures (Erwin & Garman, 2010).

According to Bandura's (1986) Social Cognitive Theory, self-efficacy refers to an individual's belief in their ability to successfully perform a specific task. This belief strongly influences motivation, levels of resistance, and performance. Individuals with high self-efficacy tend to be more solution-oriented, resilient, and open to change. They are also more likely to exhibit agile behavior in the workplace (Luthans & Youssef, 2007). In high-risk sectors like civil aviation, employees' confidence in their own abilities plays a key role in ensuring effective responses in critical situations and contributing positively to organizational goals.

Organizational agility consists of three core elements: sensitivity, speed, and flexibility (Tallon & Pinsonneault, 2011). Sensitivity refers to the ability to detect environmental signals, speed is about responding quickly to these signals, and flexibility involves the ability to apply diverse solutions effectively. For these elements to function optimally, employees must be cognitively, emotionally, and behaviorally prepared for change. Therefore, the level of employees' self-efficacy and their resistance to change directly impact an organization's capacity to act agilely.

In the context of the civil aviation sector, organizational agility not only enhances operational efficiency but also has strategic implications for areas such as flight safety, passenger satisfaction, and compliance with international standards. The sudden crises that emerged during the COVID-19 pandemic, for example, clearly demonstrated the importance of agile organizational structures (IATA, 2022). As such, agility must be supported not only through top-down strategic initiatives but also through employees' individual attitudes and beliefs.

Purpose of the Study

The primary purpose of this study is to examine the relationships between resistance to change, self-efficacy, and organizational agility among employees working in the civil aviation sector. Specifically, this research aims to understand how these psychological and behavioral factors interact with one another and contribute to organizational adaptability and performance. The central research problem of this study lies in determining the extent to which employees' reactions to change and their confidence in their abilities influence the development of an agile organizational structure.

Within this framework, the study seeks to answer the following research questions:

What is the level of resistance to change among employees in the civil aviation sector?

How is self-efficacy related to organizational agility?

In what ways does resistance to change affect organizational agility?

How do these three variables interact and reflect on organizational performance?

This study aims to contribute not only to the theoretical understanding of the subject but also to provide practical, actionable insights for managers, HR professionals, and policy-makers in the aviation industry. It is widely recognized that organizations composed of change-ready, self-confident, and agile employees are more capable of managing crises and achieving sustainable success. Therefore, the findings of this research are expected to offer strategic guidance for enhancing workforce readiness and agility in the aviation sector.

2. Materials and Methods

2.1. Theoretical Background and Research Hypotheses

In this section, the conceptual framework of the study will be addressed. The variables will be explained with a focus on the aviation industry context.

2.1.1. Resistance to Change

The change process is an inevitable reality that individuals and organizations constantly face. However, employees' attitudes towards change are an important factor that directly affects the success of change. Resistance is defined as employees' desire to maintain the current situation and their opposition behaviors stemming from uncertainty or concerns related to change (Oreg, 2006). In sectors that require high risk and security, such as civil aviation, changes in routines and procedures can cause anxiety and uneasiness among employees, which can negatively affect organizational agility (Erwin & Garman, 2010).

The source of resistance can be based on uncertainty, perception of loss of control, lack of information, and past experiences (Vakola, 2014). Therefore, understanding the attitudes of employees who resist change is critical for the effectiveness of change management processes. Resistance can be shaped not only at the individual level, but also by

group dynamics and organizational culture (Ford, Ford & D'Amelio, 2008).

2.1.2. Self-Efficacy

The concept of self-efficacy, introduced by Bandura (1977), is defined as an individual's belief in their ability to accomplish a specific task. Individuals with a high sense of self-efficacy are more resilient in the face of challenges, remain motivated, and adapt to new situations more quickly (Bandura, 1997). The confidence of employees working in the civil aviation sector in their own skills and competencies both increases individual performance and plays a positive role in the adaptation process to change (Luthans & Youssef, 2007). Self-efficacy directly contributes to organizational agility by increasing employees' capacity to cope with stress, solve problems, and exhibit innovative behaviors (Stajkovic & Luthans, 1998). In addition, it is stated that individual beliefs trigger the development of agile behaviors at the group and organizational level (Snyder & Lopez, 2007).

2.1.3. Organizational Agility

Organizational agility is defined as the ability of organizations to quickly adapt to changing internal and external conditions (Doz & Kosonen, 2010). This ability is not only about structural flexibility, but is also closely related to the speed of decision-making processes, employee motivation, information flow and innovation capacity (Tallon & Pinsonneault, 2011). In the civil aviation sector, organizational agility is of vital importance to increase operational efficiency, flight safety and customer satisfaction. High agility enables rapid and effective intervention in crisis situations; thus minimizing the impact of disruptions that may occur in the sector (IATA, 2022). Environmental sensitivity, speed and flexibility are generally accepted as the basic components of organizational agility (Overby, Bharadwaj & Sambamurthy, 2006).

2.1.4. Relationship between Resilience, Self-Efficacy and Organizational Agility

Employee resistance to change is one of the biggest obstacles to organizational agility. High resistance restricts knowledge sharing, prevents innovation, and slows down adaptation processes (Kotter & Schlesinger, 2008). In contrast, employees with high self-efficacy have a more positive approach to change processes and accelerate the adoption of agile practices (Bandura, 1997). Self-efficacy can help reduce resistance by reducing anxiety about change. This interaction plays a critical role in increasing organizational agility (Luthans & Youssef, 2007). In the civil aviation sector, employees' self-confidence, both technically and psychologically, increases their capacity to act agile and enables them to respond more flexibly to crises (Vakola, 2014).

2.1.5. Importance of Conceptual Model in Civil Aviation

The civil aviation sector, as an area where high risks and complex processes are managed, makes the need for organizational agility even more evident. The presence of employees who resist change or have low self-efficacy directly affects not only individual but also operational and institutional performance. Therefore, a good understanding of the psychological and behavioral characteristics of employees is necessary for the effectiveness of management strategies (IATA, 2022; ICAO, 2023). In line with this conceptual

framework, employees' resistance levels, self-efficacy perceptions and the effects of these two variables on organizational agility can be examined in the civil aviation sector and strategic recommendations can be developed for sustainable competition and security.

2.2. Research Method

The purpose of this research is to examine the effect of the resistance levels to change and self-efficacy perceptions of employees in the civil aviation sector on organizational agility. In the research, resistance to change and self-efficacy were determined as independent variables, and organizational agility was determined as the dependent variable. In addition, how self-efficacy perception affects the relationship between resistance to change and organizational agility was examined.

The research model covers the relationships and interactions between these three basic variables.

The variables included in the research model are as follows:

Independent Variables:

Resistance to Change

Self-Efficacy

Dependent Variable:

Organizational Agility

Ethics committee approval for the research was obtained from the Istanbul Esenyurt University Ethics Committee. The meeting date of the committee is 2025 and the decision number is 2025/20-02.

The study group of the research consists of aviation sector personnel working in private and public aviation organizations (such as airline companies, ground handling service providers and airport operators) operating at Istanbul New Airport. The universe of the research consists of approximately 65,000 employees working in the civil aviation sector throughout Turkey. These employees include pilots, cabin crew, air traffic controllers, maintenance technicians, ground handling personnel and operational support units.

The sample of the study consists of a total of 435 aviation employees working in civil aviation organizations in Istanbul, provided that they are 18 years of age or older. The participants were reached through both face-to-face and online surveys using the convenience sampling method between November 2023 and March 2024.

The research model designed within this framework is shown below:

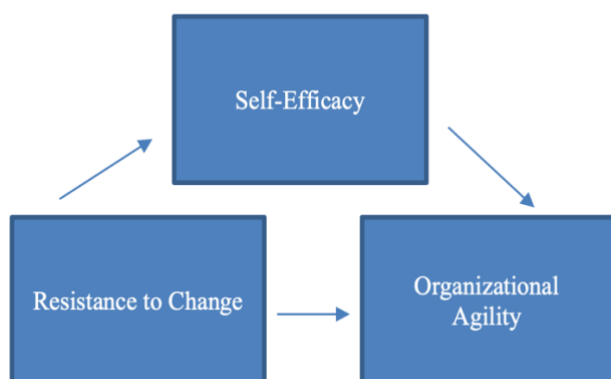


Figure 1. Research Model

Research Hypotheses

- H1: Cognitive response variable has a negative and significant effect on the Start variable. (Supported: $\beta = -0.456$, $p < 0.05$)
- H2: Behavioral response variable has a positive and significant effect on the Fatigue variable. (Supported: $\beta = 0.217$, $p < 0.05$)
- H3: Emotional response variable has a negative and significant effect on the Fatigue variable. (Supported: $\beta = -0.192$, $p < 0.05$)
- H4: Cognitive response variable has a negative and significant effect on the Fatigue variable. Supported: $\beta = -0.320$, $p < 0.05$)
- H5: Emotional response variable has a positive and significant effect on the Start variable. (Supported: $\beta = 0.264$, $p < 0.05$)*
- H6: Behavioral response variable has a negative and significant effect on Initiation variable. (Supported: $\beta = -0.570$, $p < 0.05$)
- H7: Initiation variable has a negative and significant effect on Organizational Agility. (Supported: $\beta = -0.462$, $p < 0.05$)
- H8: Sustainment effort persistence variable has a positive and significant effect on Organizational Agility. (Supported: $\beta = 0.142$, $p < 0.05$)
- H9: Fatigue variable has a positive and significant effect on Organizational Agility. (Supported: $\beta = 0.406$, $p < 0.05$)
- H10: Emotional response variable has a positive and significant effect on Organizational agility. (Supported: $\beta = 0.495$, $p < 0.05$)
- H11: Behavioral response variable has a negative and significant effect on Organizational agility. (Supported: $\beta = -0.495$, $p < 0.05$)
- H12: Behavioral response variable has no significant effect on Maintenance effort persistence variable. (Rejected)
- H13: Emotional response variable has no significant effect on Maintenance effort persistence variable. (Rejected)
- H14: Cognitive response variable has no significant indirect effect on Organizational agility variable via Maintenance effort persistence. (Rejected)

Mediator Hypotheses

- H15: The initiation variable plays a full mediating role in the effect of cognitive response on organizational agility. (Supported: $\beta = 0.202$, $p < 0.05$)
- H16: The fatigue variable plays a full mediating role in the effect of cognitive response on organizational agility. (Supported: $\beta = -0.125$, $p < 0.05$)
- H17: The initiation variable plays a partial mediating role in the effect of emotional response on organizational agility. (Supported: $\beta = -0.101$, $p < 0.05$)
- H18: The initiation variable plays a partial mediating role in the effect of behavioral response on organizational agility. (Supported: $\beta = 0.215$, $p < 0.05$)

2.3. Sample, measures and procedures

Measurement Tools

Personal Information Form:

It was prepared to collect demographic information such as gender, age, education level, job title and working period of the participants.

Resistance to Change Scale:

The "Resistance to Change Scale" developed by Oreg (2003) was used to measure the attitudes of the employees towards the change processes. The scale measures the resistance levels of the individuals towards the change with 5-

point Likert type items (1: Strongly Disagree – 5: Strongly Agree). This scale, which has been adapted into Turkish and whose validity/reliability studies have been conducted before, was verified during the pilot application of the research.

Self-Efficacy Scale:

The “General Self-Efficacy Scale” based on Bandura’s self-efficacy theory and developed by Schwarzer and Jerusalem (1995) was used. This scale, consisting of 10 items, evaluates the belief of the individuals in their own abilities. The scale is designed as a 5-point Likert type.

Organizational Agility Scale: In the study, an adapted version of the “Organizational Agility Scale” developed by Gibson and Tether (2005) was used to measure the capacity of organizations to adapt to change quickly and effectively. The scale consists of 5-point Likert-type items and evaluates agility in three dimensions (strategic, structural and process agility)

2.4. Data Analysis Process

The analyses regarding the demographic data obtained in the study were conducted using descriptive statistical methods; frequency and percentage distributions were calculated.

Cronbach Alpha Reliability Analysis was applied for the internal consistency levels of the perceived organizational support and employee performance scales.

In order to test the validity of the scales and verify the factor structure of the model:

Confirmatory Factor Analysis (CFA)

Structural Regression Analysis (SRA) was performed within the scope of Structural Equation Modeling (SEM).

These analyses were conducted using statistical data analysis programs (SPSS, AMOS, LISREL, etc.). While factor loadings were tested with CFA, the effect of the independent variable, perceived organizational support, on the dependent variable, employee performance, was modeled with YRA.

3. Result and Discussion

In the study, the survey responses of 435 participants were analyzed using SPSS for Windows 30.0 and AMOS 24.0 programs. In the detailed frequency analysis of the sample, demographic characteristics and descriptive information about work life were presented with percentage rates. Confirmatory factor analyses of the Resistance to Change (RDC) Scale, Organizational Agility (ORC) Scale and Self-Efficacy (SEE) scales included in the survey form were conducted and their validity and reliability in the sample were measured by calculating Cronbach's alpha, Composite reliability and Average Variance Explained (AVE) values. Discriminant validity analysis was applied between the variables and it was investigated whether the separation between the variables was sufficient for structural equation modeling. The mediating role of Self-efficacy in the effect of the Resistance to Change variable on the Organizational Agility variable was investigated in the model. Bootstrap (n=5000) method was preferred in the mediation research.

3.1. Descriptive Statistics of Demographic Characteristics

Demographic characteristics of the sample

The responses of the participants regarding their demographic characteristics and work experience in the sample group of 435 people are presented in detail in Table 1.

Table 1. Descriptive Statistics of Aviation Workers

		n	%
Gender	Female	310	71.3%
	Male	125	28.7%
Education	Lise	30	6.9%
	Associate's degree	95	21.8%
	Undergraduate	190	43.7%
	Postgraduate	120	27.6%
Age	<25	15	3.4%
	25-30	120	27.6%
	31-35	110	25.3%
	>35	190	43.7%
Position	Officer	340	78.2%
	Manager	95	21.8%
Seniority at work	1-5 years	90	20.7%
	6-10 years	130	29.9%
	11-15 years	55	12.6%
	>15 years or more	160	36.8%

71.3% of the participants were female and 28.7% were male. 6.9% of the participants had a high school degree, 21.8% had an associate degree, 43.7% had a bachelor's degree, and 27.6% had a postgraduate degree. In the sample, age groups were under 25 years old 3.4%, 25-30 years old 27.6%, 31-35 years old 25.3%, and over 35 years 43.7%. 78.2% of the participants were employed, and 21.8% were in managerial positions. The work experience groups were 1-5 years 20.7%, 6-10 years 29.9%, 11-15 years 12.6%, and more than 15 years 36.8

3.2. Confirmatory Factor Analyses of Scales Included in the Model

In the confirmatory factor analysis, as the sample size increases, especially in samples larger than 200, the Chi-Square (χ^2) value also becomes higher and the statistical significance level of the Chi-Square (χ^2) test becomes low. In the confirmatory factor analysis evaluation of the scales used for the research and the suitability of the generally tested models, the Chi-Square (χ^2) value corrected with the degree of freedom (Chi-Square value/Degree of freedom), other goodness of fit indices and the values in the standardized residual covariance matrix were decided as a result of the examination.

Table 2. Goodness of Fit Indexes and Fit Values Used in Confirmatory Factor Analysis

Indexes Good Fit Acceptable Fit	Indexes Good Fit Acceptable Fit	Indexes Good Fit Acceptable Fit
χ^2 / df	$0 \leq \chi^2/df \leq 2$	$2 < \chi^2/df \leq 3$
GFI	≥ 0.85	0.85-0.89
CFI	≥ 0.97	≥ 0.95
SRMR	≤ 0.05	$.06 \leq SRMR \leq .08$
RMSEA	≤ 0.05	$.06 \leq RMSEA \leq .08$

3.3. Resistance to Change (RC) Scale Confirmatory Factor Analysis

In the literature, the confirmatory factor analysis applied to the scale consisting of 15 items and 3 dimensions, the standard factor loadings are between (.85; .93) values for the Cognitive

Response (CSR) dimension, between (.76; .89) values for the Emotional Response (ESR) dimension and between (.76; .89) values for the Behavioral Response (BRT) dimension. In the model, the items “I believe that the change will benefit the organization” and “I personally believe that I will benefit from the change” from the Cognitive Response (CSR) dimension, the item “I am really excited about the change” from the Emotional Response (ECS) dimension, and the item “I praise others about the change made” from the Behavioral Response (CSR) dimension were eliminated from the analysis due to their low factor loadings ($FY < 0.5$). In the confirmatory factor analysis, since the model index values ($P > 0.05$) were found to be χ^2 (59.673), χ^2/df (1.523), it is understood that the Confirmatory Factor Analysis is significant. Since the fit index values of the model GFI (.901) and CFI (.954), SRMR (.0542), RMSEA (.079) remained within the acceptable fit limits, it was understood that the construct validity was achieved.

3.4. Organizational Agility (ORC) Scale Confirmatory Factor Analysis

In the literature, the standard factor loadings in the confirmatory factor analysis applied to the scale consisting of 8 items and a single dimension are between (.85; .93) values. In the model, the item “Product/service variety suitable for our business can be easily and quickly changed” was eliminated from the analysis because its factor loading was low ($FY < 0.5$). In the confirmatory factor analysis, since the model index values ($P > 0.05$) were found to be χ^2 (13.946), χ^2/df (1.992), it is understood that the Confirmatory Factor Analysis is significant. Since the fit index values of the model are within the good fit limits of GFI (.991) and CFI (.995), SRMR (.048), RMSEA (.023), it is understood that the construct validity is ensured.

3.5. Confirmatory Factor Analysis for Self-Efficacy (SEF) Scale

In the confirmatory factor analysis applied to the scale consisting of 17 items and 3 dimensions in the literature, the

standard factor loadings are between (.85; .93) values for the Initiation (BSL) dimension, between (.76; .89) values for the Resilience (YLM) dimension and between (.76; .89) values for the Stimulation Effort, Persistence (SCI) dimension. In the model, the items “One of my problems is not being able to start a job on time” from the Starting (BSL) dimension, “Failure increases my determination”, “I give up easily”, “I do not always have much confidence in my abilities” from the Not Giving Up (YLM) dimension, “When I have to do something I do not like, I push myself until I finish it” from the Persistence (SCI) dimension were eliminated from the analysis due to their low factor loadings ($FY < 0.5$). Since the model fit values ($P > 0.05$) were found as χ^2 (126.324), χ^2/df (2.477), it is understood that the Confirmatory Factor Analysis is significant. Since the fit index values of the model are within the acceptable fit limits of GFI (.878) and CFI (.934), SRMR (.076), RMSEA (.079), it is seen that the structural validity of the scale is provided for the research sample.

3.6. Convergence and Discriminant Validity applied to the scale sub-dimensions

Composite reliability (CR) values are calculated from the factor loadings calculated from the confirmatory factor analysis of the measurement model. When the composite reliability value is ($CR \geq 0.70$), it can be said that the composite reliability condition is met.

The indicator of convergence validity is the average variance explained (AVE) value. In order to confirm convergence validity, it is sufficient for the average variance explained ($AVE \geq 0.50$). If the entire composite reliability value ($CR \geq 0.70$) is found, it is also sufficient for it to be ($AVE \geq 0.40$). In order to ensure discriminant validity, the square root result ($\sqrt{AVE}$) of the average variance explained (AVE) value must be higher than the correlation values in the same row and column.

Table 3. Convergent and discriminant validity values calculated from standard factor loadings

Dimension	$\bar{x}$	SD	BLT	DYT	DVT	ORC	BSL	YLM	SCI
BLT	2.29	1.07	(.766)						
DYT	2.21	1.00	.683**	(.740)					
DVT	2.25	1.01	.448**	.615**	(.719)				
ORC	3.15	.90	.076	.169**	.132**	(.714)			
BSL	3.88	.94	-.478**	-.423**	-.542**	-.209**	(.740)		
YLM	4.19	.90	-.150**	-.182**	-.002	.291**	.257**	(.733)	
SCI	3.94	.84	-.116*	-.097*	-.027	.308**	.119*	.667**	(.717)
Cronbach's Alpha			.815	.828	.801	.871	.906	.707	.700
Composite reliability (CR)			.809	.829	.805	.892	.905	.719	.704
Announced Average Varyans (AVE)			.587	.549	.517	.510	.548	.538	.515

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

The reliability values of the scales in the study in the sample; Since it was found as (.912) for all items of Resistance to Change (RDC) Scale, (.855) for all items of Organizational Agility (ORC) Scale and (.924) for all items of Self-Efficacy (OSE) Scale, “high reliability degree” was obtained for all scales. In the sub-dimensions, values were obtained as (.906), Indomitability dimension (.707), Sustainment Effort, Persistence dimension (.700), Cognitive Response dimension

(.815), Emotional Response dimension (.828), Behavioral Response dimension (.801). While “high reliability” level was obtained for Indomitability and Maintenance Effort, Persistence dimensions. Since the coefficient calculated for all scales in combined reliability values is ($CR \geq 0.70$), it can be stated that the combined reliability condition is met. The average explained variance values for all variables ($AVE \geq 0.50$), the conditions for convergent validity are also

met. The square root results of the average explained variance (AVE) values calculated for discriminant validity are given in parentheses. Since these values are higher than the correlation value in the same row and column, it is seen that discriminant-discriminant validity is provided.

3.7. Structural equation modeling path analysis applied to observed values of the research model

Models that test the existence of mediator or moderator variables in many ways form the basis of structural equation modeling. In fact, models that test the existence of mediator or moderator variables can be considered as simple structural equation models (Kline 2005). Since the indirect effects in the model are statistically significant and do not meet the normal distribution assumption in most cases, simulation (using at least 2000 resamples for a 95% Confidence Interval (CI)) has been tested instead of the Sobel test in recent years (Preacher and Hayes 2004, 2008).

The normal distribution of the variables in the research model was investigated by calculating the skewness and kurtosis coefficients. It is seen in Table 4 that the skewness and kurtosis coefficients of all variables are in the range (-1.5; +1.5), which is the desired range for normal distribution. Therefore, the maximum likelihood method was used for parameter estimation in the model.

Table 4. Skewness and kurtosis coefficients for variables in the model

	Skewness	Kurtosis
Change Resistance Scale		
Cognitive Response	.384	-.742
Emotional Response	.758	-.068
Behavioral Response	.718	.239
Organizational Agility Scale		
Organizational Agility	-.101	.173
Self-Efficacy Scale		
Initiation	-.963	.555
Persistence	-1.309	1.394
Sustainment Effort, Persistence	-1.064	1.337

In the research model, the mediating effect of the Self-efficacy variable on the effect of the Resistance to Change variable on the Organizational Agility variable was examined. Since the Resistance to Change scale has 3 sub-dimensions and the Self-efficacy scale has 3 sub-dimensions, a total of 9 mediation hypotheses were tested.

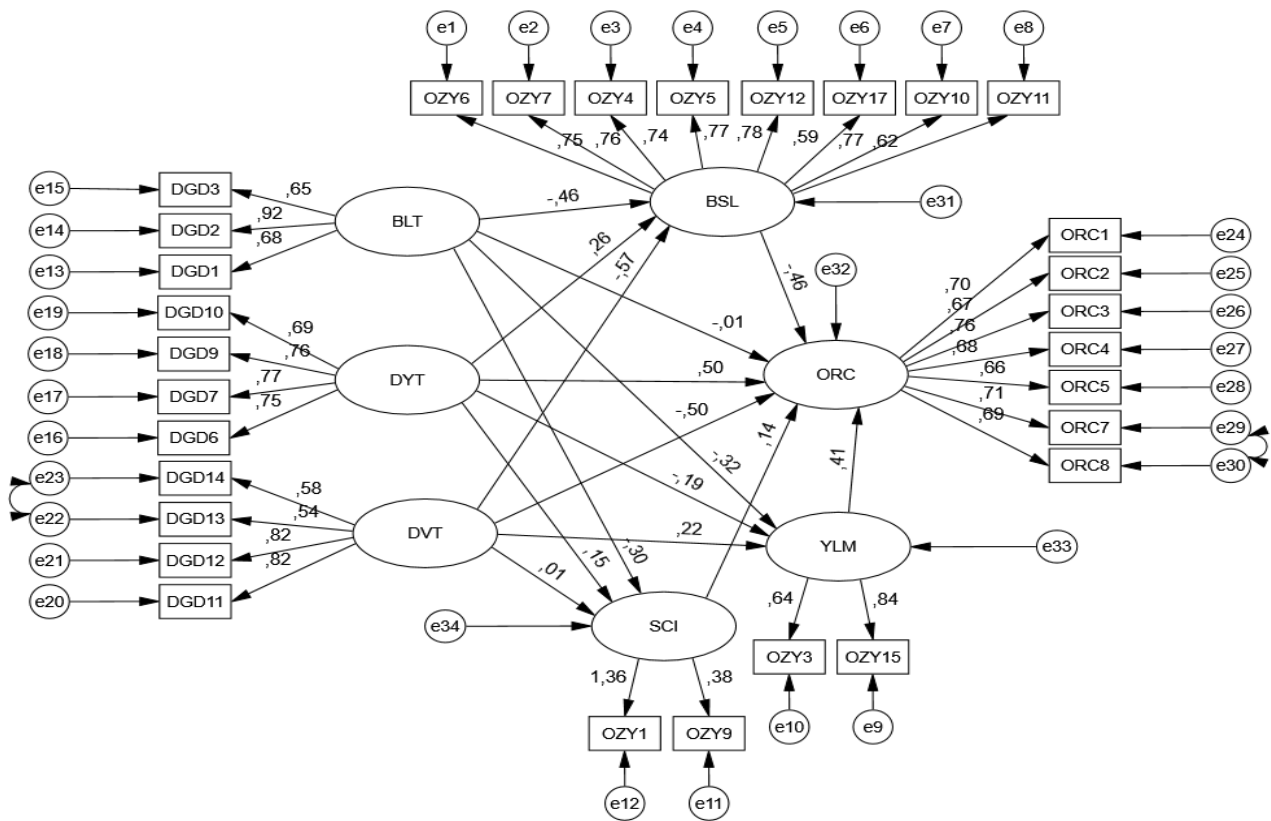


Figure 1. Mediator model path analysis with latent variables (bootstrap n=5000)

In the model where latent variables are used, it is understood that the model is significant since the model test values ($p < 0.05$) are χ^2 (956.975), χ^2/df (2.521). Since the model's fit index values GFI (.906), CFI (.943), SRMR (.0788), RMSEA

(.07910) are within the acceptable fit limits, it is understood that the model is valid. Model regression parameters are given in Table 5, and detailed values related to mediator hypotheses are given in Table 6.

Table 5. Significance test of direct regression coefficients in the model

Exogen Coefficient	Endogen Coefficient	Exogen Coefficient	Endogen Coefficient	Exogen Coefficient	Endogen Coefficient	Z	P	Hypothesis
Std. coefficient	Std. coefficient	Std. coefficient	Std. coefficient	Std. coefficient	Std. coefficient			
BLT	→	BSL	-.523	-.456	-8.227	***		Accept
DVT	→	SCI	.002	.005	.094	.925		Reject
DVT	→	YLM	.198	.217	2.147	.032*		Accept
DYT	→	YLM	-.178	-.192	-1.922	.045*		Accept
BLT	→	YLM	-.344	-.320	-5.040	***		Accept
DYT	→	BSL	.262	.264	3.308	***		Accept
DVT	→	BSL	-.557	-.570	-6.617	***		Accept
BLT	→	SCI	-.138	-.296	-2.642	.008**		Accept
DYT	→	SCI	.059	.147	1.900	.057		Reject
BSL	→	ORC	-.387	-.462	-5.727	***		Accept
SCI	→	ORC	.292	.142	3.883	***		Accept
YLM	→	ORC	.362	.406	5.325	***		Accept
DYT	→	ORC	.411	.495	4.842	***		Accept
BLT	→	ORC	-.013	-.013	-.192	.848		Reject
DVT	→	ORC	-.405	-.495	-4.368	***		Accept

*** $p < 0,001$ ** $p < 0,01$ * $p < 0,05$ BSL: Starting YLM: Persistence SCI: Sustaining effort, persistence ORC: Organizational agility BLT: Cognitive response DYT: Emotional response DVT: Behavioral response

In the path analysis model with observed variables, the effects of direct regression were examined in Table 9. The effect of behavioral response on the persistence variable of maintenance effort, the effect of emotional response on the persistence variable of maintenance effort and the effect of cognitive response variable on organizational agility variables were not found to be significant. All other direct effects were determined to be significant ($p < 0.05$). Accordingly;

- The effect of cognitive response variable on the Initiation variable ($\beta = -.456$; $p < 0.05$) was found to be negative and significant. Accordingly, the increase in the cognitive response variable directly affects the Initiation variable in a decreasing direction
- The effect of behavioral response variable on the Fatigue variable ($\beta = .217$; $p < 0.05$) was found to be positive and significant. Accordingly, the increase in the behavioral response variable directly increases the Fatigue variable
- The effect of emotional response variable on the Fatigue variable ($\beta = -.192$; $p < 0.05$) was found to be negative and significant. Accordingly, an increase in the emotional response variable directly affects the fatigue variable in a decreasing direction
- The effect of the cognitive response variable on the fatigue variable ($\beta = -.320$; $p < 0.05$) was found negative and significant. Accordingly, an increase in the cognitive response variable directly reduces the fatigue variable
- The effect of the emotional response variable on the initiation variable ($\beta = .264$; $p < 0.05$) was found positive and significant. Accordingly, an increase in the emotional response variable directly affects the fatigue variable in an increasing direction
- The effect of the behavioral response variable on the initiation variable ($\beta = -.570$; $p < 0.05$) was found negative

and significant. Accordingly, an increase in the behavioral response variable directly reduces the fatigue variable

- The effect of the initiation variable on the organizational agility variable ($\beta = -.462$; $p < 0.05$) was found negative and significant. Accordingly, the increase in the Cognitive response variable directly affects the Maintenance effort persistence variable in a decreasing direction
- The effect of the Maintenance effort persistence variable on the Organizational agility variable ($\beta = .142$; $p < 0.05$) was found to be positive and significant. Accordingly, the increase in the Maintenance effort persistence variable directly increases the Organizational agility variable
- The effect of the Fatigue variable on the Organizational agility variable ($\beta = .406$; $p < 0.05$) was found to be positive and significant. Accordingly, the increase in the Fatigue variable directly affects the Organizational agility variable in an increasing direction
- The effect of the Emotional response variable on the Organizational agility variable ($\beta = .495$; $p < 0.05$) was found to be positive and significant. Accordingly, the increase in the Emotional response variable directly increases the Organizational agility variable.
- The effect of the Behavioral response variable on the Organizational agility variable ($\beta = -.495$; $p < 0.05$) was found to be negative and significant. Accordingly, the increase in the Behavioral response variable directly affects the Organizational Agility variable in a decreasing direction.

Table 6. Significance test of indirect effects (mediation) in the model

Pattern	Indirect Effect	Lower bound	Upper Bound	p	Hypothesis
BLT→BSL→ORC	.202	.133	.378	.001**	Accept
BLT→SCI→ORC	-.040	-.088	.120	.205	Reject
BLT→YLM→ORC	-.125	-.287	-.030	.006**	Accept
DYT→BSL→ORC	-.101	-.303	-.029	.026*	Accept
DYT→SCI→ORC	.017	-.040	.092	.243	Reject
DYT→YLM→ORC	-.065	-.162	.056	.321	Reject
DVT→BSL→ORC	.215	.131	.434	.001**	Accept
DVT→SCI→ORC	.001	-.072	.067	.914	Reject
DVT→YLM→ORC	.072	-.029	.195	.256	Reject

*** $p < 0,001$ ** $p < 0,01$ * $p < 0,05$ BSL: Initiation YLM: Persistence SCI: Sustainment effort, persistence ORC: Organizational agility BLT: Cognitive response DYT: Emotional response DVT: Behavioral response

In the model, the indirect effect of the Cognitive response variable on the Organizational agility variable via the Start variable, the indirect effect of the Cognitive response variable on the Organizational agility variable via the Fatigue variable, the indirect effect of the Emotional response variable on the Organizational agility variable via the Start variable, and the indirect effect of the Behavioral response variable on the Organizational agility variable via the Start variable were found to be significant. ($p < 0.05$). The bootstrap method ($n=5000$) was used to test the mediation hypotheses in the model. 4 of the 9 mediation hypotheses tested in the model were accepted.

The indirect effect of the Cognitive response variable on the Organizational agility variable via the Start variable ($\beta = .202$; $p < 0.05$) was found to be positive and significant. Accordingly, the Start variable is a full mediator in the effect of the Cognitive response variable on the Organizational agility variable. The indirect effect of the cognitive response variable on the Organizational agility variable via the Initiation variable ($\beta = -.125$; $p < 0.05$) was found to be negative and significant. Accordingly, the Initiation variable is a full mediator in the effect of the Cognitive response variable on the Organizational agility variable.

The indirect effect of the emotional response variable on the Organizational agility variable via the Initiation variable ($\beta = -.101$; $p < 0.05$) was found to be negative and significant. Accordingly, the Initiation variable is a partial mediator in the effect of the Cognitive response variable on the Organizational agility variable.

The indirect effect of the behavioral response variable on the Organizational agility variable via the Initiation variable ($\beta = .215$; $p < 0.05$) was found to be positive and significant. Accordingly, the Initiation variable is a partial mediator in the effect of the Behavioral response variable on the Organizational agility variable.

4. Conclusion

This study examined the effects of resistance to change (cognitive, emotional, and behavioral responses) and self-efficacy on organizational agility among employees in the civil aviation sector. The findings revealed that cognitive and

behavioral resistance generally had a negative influence on proactive behaviors such as initiation, while emotional responses demonstrated a dual effect—positive emotions strengthening agility and negative emotions weakening it. Importantly, self-efficacy was identified as a critical factor that enhanced employees' adaptability and supported agile responses in the face of organizational change.

Sector-specific contribution; considering the scarcity of empirical studies focusing on organizational agility and change dynamics in aviation, this research provides a unique contribution to the literature. The aviation industry, with its highly regulated, technology-driven, and risk-sensitive environment, represents a context where agility is not optional but indispensable. By focusing on civil aviation employees, the study sheds light on how psychological factors such as resistance to change and self-efficacy interact with organizational agility in this critical sector.

Practical implications, the findings suggest that aviation organizations can strengthen agility by:

- Promoting positive emotional readiness for change, for instance through supportive communication and participatory change processes.
- Addressing behavioral resistance early on, since avoidance or disengagement behaviors directly hinder adaptive organizational responses.
- Enhancing self-efficacy through continuous training, simulation-based learning, and empowerment practices, which equip employees to confidently navigate technological and procedural changes.
- Encouraging proactive behaviors (Başlama) as mediators, since these buffer the adverse effects of resistance and transform potential barriers into adaptive responses.

Relation to prior literature: The results are consistent with social cognitive theory (Bandura, 1986) and change management research, which emphasize the roles of beliefs and emotions in shaping change-related behaviors. Similar to findings by Armenakis and Bedeian (1999), emotional readiness emerged as a key determinant of successful

adaptation (Öztrak, 2025). However, unlike some studies in manufacturing and healthcare sectors, where behavioral resistance was found to be less critical, in aviation behavioral opposition had a stronger negative effect on agility, highlighting the sector's unique operational risks.

Limitations and future research: Despite its contributions, this study has certain limitations. First, the dataset was limited to a single airline, which restricts the generalizability of the findings across the broader aviation industry. Future research could incorporate multiple airlines, airports, and different roles within aviation to provide comparative insights. Second, the cross-sectional design captures associations but does not fully explain causal mechanisms; longitudinal studies would provide deeper understanding of how resistance and self-efficacy evolve over time. Finally, integrating organizational-level variables such as leadership style or digital transformation strategies may enrich the model and offer a more holistic view of agility in aviation.

In conclusion, this research emphasizes that in a high-stakes industry like aviation, fostering employees' self-efficacy, addressing resistance to change, and cultivating positive emotional responses are crucial for achieving organizational agility.

Recommendations

Based on the findings of this study, several recommendations can be made for practitioners and researchers in the civil aviation industry. First, organizations should strengthen employees' emotional readiness for change by developing training and communication programs that enhance resilience and reduce negative emotional responses such as fear and uncertainty. In this regard, transparent communication and proactive psychological support are key to fostering a positive emotional climate during organizational transformation. Second, self-efficacy should be promoted through continuous learning opportunities. Structured training programs that not only enhance technical expertise but also build employees' confidence in their ability to cope with change can serve as a psychological shield against resistance. A further recommendation is to identify and address behavioral resistance at an early stage. Since passive withdrawal or avoidance behaviors can undermine agility, managers should employ tools such as 360-degree feedback, behavioral observation, and anonymous surveys to detect resistance patterns and design interventions accordingly. Another finding of this study highlights the mediating role of initiation, which implies that employees should be encouraged to take initiative and ownership in the change process. Involving staff in problem-solving workshops, innovation committees, or collaborative projects may strengthen proactive behaviors and reduce resistance (Öztrak & Güney, 2022).

In addition, the results suggest that technological solutions can play a critical role in supporting agility. The adoption of AI-based scheduling systems, real-time communication platforms, and predictive analytics tools can help organizations reduce workload, increase responsiveness, and enhance employees' sense of control in complex operational environments. Beyond technology, organizations must also cultivate a change-ready culture that embraces continuous improvement and innovation. Leaders should reinforce adaptive values, celebrate change agents, and provide psychological safety to encourage experimentation and

learning from mistakes. From a human resources perspective, policies should be aligned with agility-enhancing practices, such as flexible job roles, cross-training programs, clear feedback systems, and incentives for innovation. Given that ground operations and cargo staff are often the most exposed to operational volatility, targeted interventions in these areas are particularly important.

From a strategic and policy standpoint, the study highlights several broader implications. Leadership approaches that emphasize participation and transformation are especially effective in reducing resistance and fostering organizational trust. Talent management practices should integrate agility-related competencies into recruitment, training, and promotion systems, thereby institutionalizing agility as a core organizational capability. Regulatory and operational policies in aviation should also strike a balance between strict compliance and the flexibility required for rapid adaptation. Furthermore, digital transformation strategies must be implemented in parallel with employee training programs to ensure that new technologies are adopted effectively without increasing resistance. Finally, aviation organizations should consider employee well-being as an integral component of agility by introducing structured resilience and mental health programs to mitigate the emotional strain associated with constant change in high-risk environments.

For future research, several avenues can be suggested. Cross-cultural studies could investigate whether cultural dimensions such as power distance or uncertainty avoidance shape employees' responses to change and perceptions of agility. Longitudinal research designs would also be valuable to examine how resistance—particularly emotional and behavioral dimensions—evolves over time and impacts long-term agility. Furthermore, leadership styles such as transformational and participative leadership could be tested as potential moderators in the relationship between resistance to change and organizational agility. Finally, incorporating digital transformation variables, including digital literacy and AI adoption, may enrich the explanatory framework of agility. Since this study was limited to a single airline, future research should involve multiple airlines, airports, and occupational groups to enhance generalizability and provide a more comprehensive understanding of the dynamics of agility in the aviation sector.

Ethical approval

The ethical approval for this research was granted by the Istanbul Esenyurt University Scientific Research and Publication Ethics Committee with the decision number 2025/02, dated 20.02.2025. The committee confirmed that the research was deemed ethically appropriate.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Prentice-Hall.
- Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. W.H. Freeman.

- Doz, Y., & Kosonen, M. (2010). Embedding Strategic Agility: A Leadership Agenda for Accelerating Business Model Renewal. *Long Range Planning*, 43(2-3), 370-382.
- Erwin, D. G., & Garman, A. N. (2010). Resistance to organizational change: linking research and practice. *Leadership & Organization Development Journal*, 31(1), 39-56.
- ICAO (2023). Annual Report of the Council. International Civil Aviation Organization.
- IATA (2022). Airline Industry Economic Performance Report. International Air Transport Association.
- Luthans, F., & Youssef, C. M. (2007). Emerging positive organizational behavior. *Journal of Management*, 33(3), 321-349.
- Oreg, S. (2006). Personality, context, and resistance to organizational change. *European Journal of Work and Organizational Psychology*, 15(1), 73-101.
- Tallon, P. P., & Pinsonneault, A. (2011). Competing Perspectives on the Link Between Strategic Information Technology Alignment and Organizational Agility: Insights from a Mediation Model. *MIS Quarterly*, 35(2), 463-486.
- Vakola, M. (2014). What's in there for me? Individual readiness to change and the perceived impact of organizational change. *Leadership & Organization Development Journal*, 35(3), 195-209.
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191-215.
- Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. New York: W.H. Freeman.
- Doz, Y., & Kosonen, M. (2010). Embedding Strategic Agility: A Leadership Agenda for Accelerating Business Model Renewal. *Long Range Planning*, 43(2-3), 370-382.
- Erwin, D. G., & Garman, A. N. (2010). Resistance to organizational change: Linking research and practice. *Leadership & Organization Development Journal*, 31(1), 39-56.
- ICAO (2023). Annual Report of the Council. International Civil Aviation Organization.
- IATA (2022). Airline Industry Economic Performance Report. International Air Transport Association.
- Kotter, J. P., & Schlesinger, L. A. (2008). Choosing strategies for change. *Harvard Business Review*, 86(7-8), 130-139.
- Luthans, F., & Youssef, C. M. (2007). Emerging positive organizational behavior. *Journal of Management*, 33(3), 321-349.
- Oreg, S. (2006). Personality, context, and resistance to organizational change. *European Journal of Work and Organizational Psychology*, 15(1), 73-101.
- Overby, E., Bharadwaj, A., & Sambamurthy, V. (2006). Enterprise agility and the enabling role of information technology. *European Journal of Information Systems*, 15(2), 120-131.
- Öztırak, M., & Güney, S. (2022). The mediator role of proactive personality in the effect of psychological empowerment on self-leadership: a study for the aviation industry. *Journal of Aviation*, 6(3), 318-324.
- Öztırak, M. (2025). Revenge in the Sky: The Impact of Organizational Revenge on Organizational Sustainability in the Aviation Sector. *Journal of Aviation*, 9(1), 196-206.
- Öztırak, M. (2025). Employees with the Wind at Their Back: The Effect of Organizational Support on Performance in Aviation. *Journal of Aviation*, 9(2), 408-416.
- Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related proformance: A meta-analysis. *Psychological Bulletin*, 124(2), 240-261.
- Tallon, P. P., & Pinsonneault, A. (2011). Competing perspectives on the link between strategic information technology alignment and organizational agility: Insights from a mediation model. *MIS Quarterly*, 35(2), 463-486.
- Vakola, M. (2014). What's in there for me? Individual readiness to change and the perceived impact of organizational change. *Leadership & Organization Development Journal*, 35(3), 195-209.

Cite this article: Toksoz, S. (2025). Resistance to Change, Self-Efficacy, and Organizational Agility in Civil Aviation. *Journal of Aviation*, 9(3), 648-657.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

The Mediating Role of Occupational Stress in the Impact of Digital Leadership on Open Innovation Capability in the Aviation Sector

Ethem Topçuoğlu¹ , Onur Oktaysoy² , Yaşar Şahin^{3*} 

¹ Giresun University, Academy of Aviation Management, 28000, Merkez, Giresun, Türkiye. (ethem.topcuoglu@giresun.edu.tr)

² Kafkas University, Faculty of Economics and Administrative Sciences, 36000, Merkez, Kars, Türkiye. (onuroktaysoy@kafkas.edu.tr)

^{3*} Trabzon University, Beşikdüzü Vocational School, 61800, Beşikdüzü, Trabzon, Türkiye. (yasarsahin@trabzon.edu.tr)

Article Info

Received: 12 June 2025

Revised: 07 August 2025

Accepted: 25 August 2025

Published Online: 09 October 2025

Keywords:

Digital leadership

Open innovation capability

Occupational stress

Aviation sector

Corresponding Author: *Yaşar Şahin*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1717814>

Abstract

In today's business world, where digitalization has become a strategic necessity, the impact of leadership styles on innovation capacity is becoming increasingly important. In particular, in the aviation industry, a sector characterized by low error tolerance and high information intensity, digital leaders must not only possess the ability to implement technology but also the competence to steer organizational innovation processes and manage employees' stress levels. In this context, the primary objective of this study is to empirically investigate how digital leadership influences open innovation capability and to examine the potential mediating role of occupational stress experienced by employees in this relationship. The study sample, which employs quantitative research methods, consists of 407 participants working in the aviation sector in Türkiye. The data obtained through the survey method were analyzed using structural equation modeling with the Smart-PLS 4.1.1 program. The findings indicate that digital leadership has a direct positive effect on open innovation capability and that occupational stress plays a partial mediating role in this relationship. These findings indicate that digital transformation processes should focus not only on technology but also on human resource strategies. The study presents a unique conceptual framework within the triangle of digital leadership, open innovation, and occupational stress, highlighting the impact of leadership on innovative and psychological outcomes in high-risk sectors such as aviation.

1. Introduction

The influence of digital technologies on the business world has significantly redefined the competitive landscape for organizations. This transformation has had a profound impact not only on technical infrastructure but also on leadership practices, organizational behavior, and innovation capacity. In today's rapidly digitizing world, the qualities required of leaders have changed, bringing the concept of digital leadership to the forefront (Borah et al., 2022). Digital leadership is defined as a multidimensional leadership style that encompasses not only the use of technological tools but also the strategic management of digital transformation processes, the development of agile decision-making skills, and the support of an organizational learning culture (Zeike et al., 2019). Another dimension of this transformation process is open innovation capability.

The open innovation approach, which extends beyond traditional R&D boundaries, aims to enhance the innovation capacity of organizations by systematically incorporating external knowledge sources. The literature frequently emphasizes that digital leadership serves as a strategic catalyst in the development of open innovation, playing a decisive role in many processes ranging from the integration of digital infrastructures to the management of cultural transformation (Sagbas et al., 2023; Turan-Torun et al., 2025). However,

digital transformation and innovation processes are shaped not only by structural factors but also by individual and psychosocial factors. At this point, occupational stress, an inevitable element of organizational life, emerges as a critical variable. Especially in sectors where the pressure for change is intense, the level of stress experienced by employees can directly affect their innovative behavior and level of participation in transformation (Vasanth & Santhi, 2020). Stress can weaken creative and collaborative processes such as open innovation by depleting employees' cognitive resources and causing them to avoid taking risks. In this context, it has been suggested that occupational stress may play a mediating role in the relationship between digital leadership and open innovation capability.

These interactions are even more pronounced in highly regulated, technology-intensive, and stressful work environments such as aviation. Indeed, according to data from the International Civil Aviation Organization (ICAO), digitalization investments in the global aviation sector increased by more than 20% in 2023 (ICAO, 2024). However, the psychological effects of these technological investments on employees and their reflections on innovation processes are still poorly understood. This situation creates an important gap in the literature regarding the understanding of the relationship between digital leadership, occupational stress, and open

innovation capability, necessitating an examination of this relationship at both theoretical and empirical levels.

Based on this, the main objective of this study is to examine the effect of digital leadership on open innovation capability from the perspective of the aviation sector and to analyze the mediating role of occupational stress in this effect. The findings aim not only to contribute to the literature but also to provide practitioners with important insights into how leadership strategies, employee well-being, and organizational innovation capacity can be optimized in digital transformation processes.

2. Conceptual Framework

2.1. Digital Leadership

Digital transformation has become one of the fundamental dynamics of today's business world. However, this ongoing process requires organizations to fundamentally change their management approaches, business models, and leadership approaches. In particular, rapid advances in digital technologies are significantly affecting leaders' decision-making processes, management styles, and ability to adapt to change (Topcuoglu et al., 2023). These developments have brought the concept of digital leadership to the forefront, which differs from traditional leadership approaches. Digital leadership is a type of leadership that goes beyond the mere ability to use technology and involves the effective use of digital tools and methods in line with strategic objectives. While the opportunities provided by digital technologies facilitate the management of complex and dynamic processes, the mere existence of technology is not sufficient for organizational success. For success, leaders must be able to effectively use digital tools and technologies to achieve organizational goals (Zeike et al., 2019). Therefore, digital leadership encompasses the competencies of managing digital transformation processes, making data-driven strategic decisions, keeping up with technological innovations, and creating flexible organizational structures (Oktaysoy et al., 2022).

Various definitions of digital leadership can be found in the literature. Sağbaş and Erdoğan (2022) defines a digital leader as "a leader who anticipates, directs, and effectively uses digital platforms to achieve the organization's goals." Similarly, Borah et al. (2022) characterize digital leadership as a leadership approach that effectively utilizes digital tools in leadership tasks, while Zhu et al. (2022) explains digital leadership as a synthesis of various leadership approaches, including ideas, creativity, vision, curiosity, and wisdom. Considering these definitions, it is evident that digital leadership focuses on the ability to effectively integrate technology into organizational processes (Ly, 2024). Accordingly, digital leaders are considered to be individuals who possess the ability to coordinate employees' activities on digital platforms, manage strategic decision-making processes through digital data and platforms, and produce quick solutions to problems, thereby effectively utilizing digital technologies (Sagbas et al., 2023).

In this context, digital leadership stands out as a multidimensional leadership approach that is not limited to technical competence but also combines organizational vision with digital capabilities. Digital leaders are expected to not only use existing technologies but also position them in a way that increases the organization's capacity for innovation. Indeed, digital leadership plays a critical role in the processes of spreading digital culture within the organization, developing digital literacy, and aligning digital strategies with

corporate goals (Ordu & Nayır, 2021). In this context, the abilities of digital leaders to pioneer change, overcome resistance to digital change, and encourage employees to actively participate in the digital transformation process have become a strategic necessity for contemporary organizational structures (Turan-Torun et al., 2025). Therefore, it should be emphasized that digital leadership is not merely a technology-focused concept but a holistic leadership paradigm that redefines people, strategy, and culture around digitalization.

2.2. Open Innovation Capability

Rapidly changing competitive conditions and increasing external information flow in recent years have caused a significant paradigm shift in companies' innovation strategies. Within the framework of this transformation, the concept of "open innovation capability," one of the key factors determining the applicability of the open innovation approach, has come to the fore. Open innovation capability refers to an organization's capacity to identify and access external knowledge sources and transform this knowledge into innovative outputs (Lazarenko et al., 2019). At the core of this capability lies the view that the limitations of traditional "closed innovation" models must be overcome and that innovation processes must be enriched with knowledge sources beyond organizational boundaries (Bogers et al., 2019). Especially in knowledge-based sectors, the strategic value of external collaborations has increased; firms' innovation performance has become dependent not only on internal resources but also on the quality of interactions established with external resources (Topcuoglu et al., 2023).

Open innovation capability is defined as a multi-layered capacity consisting of a combination of factors such as strategic governance at the organizational level, cultural openness, knowledge management systems, and sustainable relationships with external stakeholders (Tsai et al., 2022). The dynamic capabilities framework stands out as the fundamental theoretical basis for the development of this capacity. This model, based on Teece's proposed steps of "sensing, capturing, and transforming," emphasizes organizations' abilities to recognize opportunities, strategically structure them, and reallocate their resources (Habicht et al., 2012). At the individual level, individuals' knowledge absorption capacity plays a critical role among the determinants of open innovation capability. Employees' prior knowledge, levels of interaction with external networks, and cognitive flexibility are among the key factors influencing access to external knowledge and its functional application (Hadi & Ali, 2025). Additionally, a linear relationship has been observed between employees' attitudes toward open innovation, their self-efficacy beliefs, and the level of internal support within the organization, and this capacity (Cepeda & Arias-Pérez, 2018).

Strong empirical evidence has been obtained indicating that external and internal factors affecting open innovation capabilities must be evaluated together. At the macro level, legal regulations, sectoral collaborations, and the rate of digitalization, and at the micro level, corporate knowledge infrastructure, governance structure, and organizational culture have been identified as determinants (Shi & Zhang, 2018). In particular, it has been found that cultural environments that are open to information sharing increase the speed and effectiveness of innovation processes. The contribution of open innovation capability to innovation performance has also been supported by quantitative data in various studies. It is known that binding, knowledge-absorbing, and creative capacities have direct and meaningful effects on innovation outputs (Cui & Song, 2022). On the other

hand, it has been determined that the effect of desorptive (external knowledge sharing) capacity is limited.

In light of all these findings, it is concluded that open innovation capability plays a central role in the processes of organizations gaining competitive advantage at both the theoretical and practical levels. In this context, organizations need to address their information access strategies not only through technology investments but also through human resources, cultural transformation, and strategic network management in a holistic manner (Han et al., 2020). Open innovation capability should not be viewed solely as a technology management issue; it should be positioned as a transformative capacity that requires strategic awareness, organizational learning, and organizational flexibility.

2.3. Occupational Stress

With the increasing demands of modern working life, rising levels of uncertainty, and accelerating technological change, occupational stress has become an inevitable part of organizational life. Conceptually, occupational stress is defined as a psychological tension that arises when the demands of the work environment exceed an individual's cognitive, emotional, or physical resources (Hart & Cooper, 2002). Within this framework, stress is recognized as a multidimensional phenomenon that exists not only at the individual level but also at the organizational level. Three main models stand out in the theoretical explanation of occupational stress. The first is the cognitive appraisal model developed by Lazarus and Folkman. According to this model, stress arises when an individual perceives environmental demands as threats and believes they cannot cope with these threats (Finkel et al., 2025). The second approach is the job demands-control model (Karasek, 1979), which explains the level of stress through the interaction between the structural demands of the job and the individual's decision-making autonomy. Thirdly, the effort-reward imbalance model (Siegrist, 1996) suggests that stress arises when there is an imbalance between the effort an individual expends on their work and the rewards they receive (Jovanović et al., 2006).

The causes of occupational stress have a multi-layered structure consisting of individual, work-related, and organizational factors. Task ambiguity, excessive workload, role conflicts, time pressure, and lack of organizational support are among the main triggers of stress (Yelkencioglu & Yuksel, 2022). Additionally, structural elements such as toxic leadership behaviors, lack of organizational justice, and exclusion from decision-making processes are also identified as dynamics that increase psychological strain (Kaygin et al., 2023).

The effects of occupational stress on individuals are observed at physiological, cognitive, and behavioral levels. Chronic stress has been found to cause physiological disorders such as hypertension, cardiovascular diseases, and immune system weakness (Chen, 2023). At the psychological level, anxiety, depression, burnout syndrome, and concentration disorders are commonly reported. Behavioral effects include absenteeism, poor performance, withdrawal, and increased alcohol and substance use (Yavan & Pekkaya, 2017). At the organizational level, occupational stress leads to increased employee turnover, absenteeism, and low motivation, negatively affecting both productivity and employee loyalty (Thakre & Barua, 2015). Studies conducted in the service sector, in particular, have indicated that high stress levels directly affect customer satisfaction and service quality. In this context, it is necessary to develop multifaceted intervention strategies at the individual and organizational levels to effectively manage occupational stress. Among individual

interventions, stress management training, mindfulness exercises, physical exercise, and psychological counseling stand out. At the organizational level, it is necessary to clarify job descriptions, adopt a participatory management approach, transform leadership styles, and structure the organizational culture in a supportive manner (Kinnunen-Amoroso & Liira, 2013). Indeed, it has become an inevitable necessity for managers and policymakers to adopt a holistic approach that systematically analyzes the origins of stress and to develop strategies aimed at enhancing both individual awareness and organizational resilience.

3. Interrelationships and Hypotheses

3.1. The Impact of Digital Leadership on Occupational Stress

The relationship between digital leadership and occupational stress is a prominent topic in the field of organizational behavior in today's world, where digital transformation increases psychosocial pressures on employees. Digital leadership is not merely the strategic use of digital technologies, but also the ability to guide employees, provide emotional support, and create a psychologically safe environment as they navigate the changes, uncertainties, and intense demands brought about by digitalization (Bregenzer & Jimenez, 2021). In this context, digital leadership has become a critical factor in regulating employees' stress perceptions. Theoretically, this relationship can be explained within the Job Demands-Control Model. The decision autonomy, access to resources, and meaningful communication environment provided by digital leaders to employees facilitate the perception of environmental demands as opportunities for development rather than threats, thereby reducing stress levels (Ertiö et al., 2024).

Empirical research supports this theoretical foundation. Ramakrishnan et al. (2024) demonstrated in their study conducted in the Malaysian public sector that digital leadership, together with organizational intelligence, reduces employee stress and has an indirect effect on digital service quality. Newton and Bish (2013) found that leaders who provide both near and far vision significantly reduce employees' stress levels. In a study conducted by Tran (2024) at private universities in Vietnam, it was found that relationship-focused leadership approaches balance stress responses arising from workloads and role conflicts. Similarly, a study conducted by Malik et al. (2025) determined that when leadership support was insufficient in digital work environments, employees' stress levels increased, negatively affecting their mental health and job performance. Based on the aforementioned theoretical and empirical framework, the first hypothesis of the study, H₁, was developed.

H₁: *Digital leadership has a significant negative effect on occupational stress.*

3.2. The Effect of Occupational Stress on Open Innovation Capability

Open innovation capability refers to an organization's capacity to generate innovation by interacting with external knowledge sources, and employees' contributions play a critical role in this process. However, organizational efforts to promote innovation also bring about stressors such as increased workload, time pressure, uncertainty, and decision complexity for employees (Yordam Dağıstan et al., 2024). This situation highlights the impact of occupational stress on open innovation capacity, functioning both as a potential barrier and a trigger under certain conditions (Haque &

Yamoah, 2021). Theoretically, this relationship can be explained by the Yerkes-Dodson Law. According to this approach, moderate levels of occupational stress may support creative thinking and innovative behavior by increasing cognitive arousal. In contrast, high levels of stress may weaken individual motivation and cognitive capacity, thereby acting as a barrier to innovation (Luis et al., 2020).

Empirical studies also support these theoretical assumptions. Luis et al. (2020) found an inverse U-shaped relationship between occupational stress and individual innovative behavior, indicating that both low and high stress levels negatively affect innovation, while moderate stress levels increase innovative behavior. Similarly, a study conducted among healthcare workers by Bunce and West (1994) suggested that employees developed innovative solutions as a method of coping with occupational stress, and that these strategies were effective. Haq et al. (2024) found, in their study on immigrants, that occupational stress has a significant impact on innovative entrepreneurship and innovative work behavior, suggesting that gender is a crucial variable in this relationship. Furthermore, Xu et al. (2024) found that challenging stressors positively affect an organization's innovation capacity through individual innovative behavior. Based on the theoretical and empirical framework above, the second hypothesis, H_2 , was developed.

H_2 : Occupational stress has a significant effect on open innovation capability.

3.3. The Impact of Digital Leadership on Open Innovation Capability

In the era of digital transformation, organizations must gain a competitive edge, adapt to technological advancements, and effectively leverage external information sources. In this context, the concepts of digital leadership and open innovation capability are considered two fundamental structures that have emerged as key frameworks in both strategic management and innovation literature. Digital leadership is defined as a type of leadership that views technology not merely as a tool, but rather as an integral part of integrating digital strategies with visionary leadership approaches (Wang et al., 2024). Open innovation capability, on the other hand, refers to an organization's capacity to produce innovative outputs by combining internal and external knowledge resources. There is a strong interaction between these two concepts, particularly in terms of knowledge sharing and innovation capacity. The relationship between these two concepts can be explained theoretically within the framework of the Resource-Based View and the Knowledge-Based View. The technology vision demonstrated by digital leaders, policies that encourage digital competencies, and an organizational climate that supports information sharing directly influence employees' innovative behaviors and facilitate the internalization of information obtained from external sources. In this context, digital leadership is both a prerequisite and a facilitator of open innovation (Nagano, 2020).

Empirical research also supports this theoretical framework. A study conducted by Fatima et al. (2021) demonstrated that the impact of digital leadership on open innovation is achieved through knowledge sharing and innovation capability. In a study conducted in the telecommunications and information technology sectors, it was emphasized that knowledge sharing supports open innovation by increasing internal interactions within organizations, and that digital leaders play a decisive role in the effectiveness of this process. Similarly, Benitez et al. (2022) examined the effects of digital leadership on innovation performance through platform digitalization capability. They

found that digital leadership increases innovation performance by strengthening the digital platform infrastructure. Again, Majumdarr et al. (2024) found that digital transformational leadership has a significant effect on innovation capacity. Based on the theoretical and empirical framework above, the third hypothesis of the study, H_3 , was developed.

H_3 : Digital leadership has a positive and significant effect on open innovation capability.

3.4. The Mediating Role of Occupational Stress in the Impact of Digital Leadership on Open Innovation Capability

Digital leadership is a leadership style that not only strategically guides organizations' digital transformation processes but also encourages employees to think innovatively. This leadership style enhances open innovation capability by promoting information sharing, the effective use of digital technologies, and cultivating an organizational climate that supports innovation (Fatima et al., 2021). However, it is anticipated that this positive effect may be hindered by psychological processes experienced at the employee level. In particular, there is evidence that occupational stress may reduce innovative participation by suppressing employees' creative potential (Ramakrishnan et al., 2024). Within this framework, the fourth hypothesis of the study, H_4 , was formulated based on the assumption that the effect of digital leadership on open innovation capability may vary depending on the level of occupational stress and that stress may play a mediating role in this relationship.

H_4 : Occupational stress plays a mediating role in the effect of digital leadership on open innovation capability.

The research model, which presents the hypotheses developed within the scope of the research, is shown in Figure 1 below.

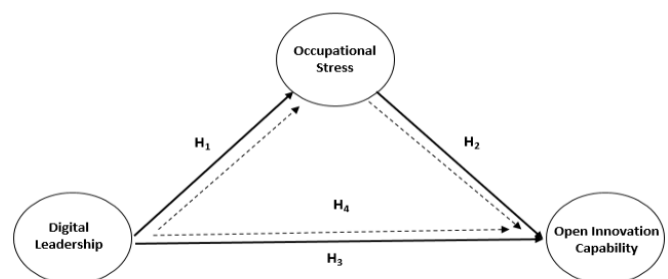


Figure 1. Research Model

4. Method

In this study, a quantitative research design was adopted to test the mediating role of occupational stress in the effect of digital leadership on open innovation capability. The research model includes digital leadership as the independent variable, open innovation capability as the dependent variable, and occupational stress as the mediating variable. The study population consists of employees working in the aviation sector. The sample was determined using convenience sampling, and data were collected from a total of 407 employees. According to the formula developed by Cochran (1977) for determining the sample size, the number of participants is considered sufficient as it exceeds 384. To document the scientific and ethical principles of the study, approval was obtained from the Giresun University Social Sciences Ethics Committee on May 28, 2025, with the

reference number 06/336. The data were collected digitally between June 02, 2025, and June 10, 2025.

To measure digital leadership perception in the study, a scale consisting of a single dimension and six questions, developed by Zeike et al. (2019) and adapted into Turkish by Oktaysoy et al. (2022), was used. The internal consistency coefficient of the scale was determined as Cronbach's alpha, with a value of 0.870, in the study conducted by Oktaysoy et al. (2022), indicating statistical reliability.

To measure the occupational stress levels of employees, the scale developed by Marcatto et al. (2023) was first translated into Turkish by the authors, followed by a meaning verification, and then translated back into English to adapt the Occupational Stress Scale. This scale, which measures individuals' subjective assessments of their stress levels in the workplace, has a single-dimensional structure and consists of 4 statements. In the study conducted by Marcatto et al. (2023), the Cronbach's Alpha value of the scale in question was determined to be 0.820.

To measure open innovation capability, the scale developed by Yao et al. (2020) was first translated into Turkish by the authors, who performed checks, and then translated back into English to adapt the Open Innovation Capability Scale. The adapted scale consists of a single dimension and four statements. In the data collection process, a 5-point

Likert-type scale format was used for all three scales, with 1 = "Strongly Disagree" and 5 = "Strongly Agree."

This study, based on quantitative research methods, analyzed the direct effects between the variables in the research model and the mediating role of occupational stress using Structural Equation Modeling (SEM) with the Smart-PLS 4.1.1 software. Smart-PLS is a frequently preferred analysis tool in social sciences due to its ability to accommodate both predictive and explanatory models, simultaneously evaluate the multiple dependent relationships of latent variables, and work with small samples (Ringle et al., 2014). The structures predicted in the model were tested comprehensively, taking into account both the measurement model and the structural model components. All findings obtained from the tests are presented under the "Results" heading.

5. Results

The study reached 407 participants, and general information about the participants is presented in Table 1 below.

Table 1. Demographic findings regarding participants.

Demographic	Items	n	%
Gender	Female	183	45.00
	Male	224	55.00
Marital Status	Married	219	53.80
	Single	188	46.20
Age	18-20 years old	14	3.50
	21-30 years old	77	18.90
	31-40 years old	243	59.70
	41-50 years old	73	17.90
Educational Status	High school	28	6.90
	Associate degree	109	26.80
	Bachelor's degree	206	50.60
	Postgraduate	64	15.70
Income	50.000-70.000 TL	30	7.40
	70.001-90.000 TL	178	43.70
	90.001-110.000 TL	74	18.20
	110.001-130.000 TL	67	16.50
	130.001 TL and above	58	14.20

When evaluating the demographic profile of aviation sector employees participating in the study, as presented in Table 1, it can be observed that the sample exhibits a balanced and representative distribution across gender, age, education, and income levels. 55% of the participants are male and 45% are female, which is consistent with gender representation in the sector. The age distribution, with the 31–40 age group standing out (59.7%), indicates that the sample consists mainly of experienced and highly productive individuals. Data on educational attainment reveal that a significant portion of the participants (66.3%) have a bachelor's or postgraduate degree, which is consistent with the sector's high knowledge and skill requirements. In terms of income level, the majority of participants belong to the middle and upper income groups (72.4%), providing insight into the economic stability and

employee well-being within the sector. The demographic structure obtained is considered an appropriate sample for effectively testing the variables examined in the study, such as digital leadership, occupational stress, and open innovation.

Reliability and validity analyses were conducted to determine Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) values, testing the structural validity and internal consistency of the scales used in the study. The results are presented in Table 2 below. Additionally, the criterion that each scale item's factor loading should be above 0.50 (Uygungil-Erdogan et al., 2025) was also considered, and these data are presented in Table 2.

Table 2. Validity and reliability analysis.

Items	Factor Loading	Mean	Standard Deviation	Kurtosis	Skewness	VIF
Digital Leadership Scale						
Cronbach's Alpha= 0.873, rho_A=0.881, CR=0.906, AVE=0.618						
DL1	0.646	4.025	0.895	1.394	-1.143	1.407
DL2	0.823	3.622	0.908	-0.616	-0.424	2.266
DL3	0.810	3.838	0.860	0.476	-0.773	2.030
DL4	0.703	3.280	1.045	-1.324	0.030	1.815
DL5	0.840	3.649	0.915	0.150	-0.812	2.579
DL6	0.871	3.572	0.953	-0.298	-0.456	2.780
Occupational Stress Scale						
Cronbach's Alpha= 0.910, rho_A=0.915, CR=0.937, AVE=0.788						
OS1	0.893	3.708	1.068	-0.664	-0.514	3.423
OS2	0.884	3.754	1.110	-0.583	-0.628	3.223
OS3	0.824	3.963	1.004	-0.071	-0.876	1.976
OS4	0.947	3.823	1.065	-0.569	-0.648	5.318
Open Innovation Capability Scale						
Cronbach's Alpha= 0.886, rho_A=0.899, CR=0.921, AVE=0.745						
OIC1	0.808	4.302	0.586	-0.596	-0.184	1.941
OIC2	0.893	4.150	0.661	-0.133	-0.327	2.561
OIC3	0.882	4.170	0.645	-0.659	-0.175	2.537
OIC4	0.868	4.130	0.665	-0.760	-0.153	2.384

As shown in Table 2, the analysis results indicate that the Cronbach's Alpha value for the digital leadership scale is 0.873, the composite reliability (CR) value is 0.906, and the average variance extracted (AVE) value is 0.618. The factor loadings of the items in this scale range from 0.646 to 0.871, with all items exceeding the acceptable threshold of 0.5. The results obtained indicate that the Digital Leadership Scale has a high level of internal consistency and structural validity. Similarly, for the occupational stress scale, Cronbach's Alpha value was found to be 0.910, CR value 0.937, and AVE value 0.788. The factor loadings of the items in the scale range from 0.824 to 0.947, indicating high structural validity. These values suggest that the occupational stress scale exhibits strong internal consistency. Finally, the Cronbach's Alpha value calculated for the open innovation capability scale is 0.886, the composite reliability (CR) value is 0.921, and the average variance extracted (AVE) value is 0.745. The factor loadings of the items in the scale range from 0.808 to 0.893, indicating that the scale has a very high measurement capacity.

In addition to these values, when the VIF values of the scales are examined, it is seen that the VIF value does not exceed 10 for any item. This finding indicates that there is no multicollinearity problem in the model (Hair et al., 2017). Furthermore, the skewness and kurtosis values of the scales were found to be within the range of -1.96 to +1.96 for all items. This indicates that the data are normally distributed (Yazıcıoğlu & Erdoğan, 2014).

The validity, reliability, and standard method bias analyses conducted within the scope of the research demonstrate that the scales used are scientifically adequate as measurement tools. However, it is necessary to examine the discriminant validity separately to assess whether these structures are significantly different from each other (Hair et al., 2017). Discriminant validity is considered a crucial criterion that evaluates the degree to which a construct exhibits a high correlation with its indicators while differing significantly from other constructs (Sarstedt et al., 2022). In this context, the Fornell-Larcker criterion (Fornell & Larcker, 1981) and the Heterotrait-Monotrait ratio (HTMT), considered the most widely used analyses of discriminant validity in the relevant

literature, were employed in this study. The findings of the analysis are presented in Table 3 below.

Table 3. Discriminant validity values.

Fornell-Larcker Criterion and HTMT			
	1	2	3
Digital Leadership	0.786	0.489*	0.330*
Occupational Stress	-0.442	0.888	0.349*
Open Innovation Capability	0.299	-0.317	0.863

*HTMT

Divergence validity analyses were conducted to test whether the conceptual differences between the structures examined in the study were statistically distinct. In this regard, the Fornell-Larcker criterion was first discussed, and the root mean square error (RMSE) values of each construct were found to be higher than their correlation coefficients with the other constructs (Digital Leadership = 0.786, Occupational Stress = 0.888, Open Innovation Capability = 0.863). This finding indicates that each construct represents a unique conceptual structure (Fornell & Larcker, 1981). However, according to the Heterotrait-Monotrait ratio (HTMT) analysis, the HTMT values between digital leadership and occupational stress (0.489), digital leadership and open innovation capability (0.330), and occupational stress and open innovation capability (0.349) are below the generally accepted threshold value of 0.90 (Henseler et al., 2015). These values support the existence of strong conceptual differentiation among the structures used in the study. Therefore, the findings obtained from the analyses reveal that the measurement model has sufficient discrimination validity and that there is no overlap between the structures. In this regard, it can be stated that the model provides an appropriate theoretical basis for structural analysis.

In structural equation modeling, model fit indices are used to assess whether the theoretical structure established aligns with empirical data at a holistic level. In this context, indicators such as SRMR, d_ULS, d_G, χ^2 , and NFI play a critical role in testing whether the model is valid not only in terms of linear relationships but also in terms of structural

integrity. Accordingly, an SRMR value below 0.08 indicates that the model contains a reasonable level of error related to residuals and exhibits good fit. In contrast, an NFI value of 0.90 or higher indicates that the estimated model has high explanatory power compared to the null model. These statistical indicators demonstrate that the model's structure, grounded in theoretical foundations, is also statistically supported (Byrne, 2016).

Table 4. Model fit goodness values.

	Model Fit	
	Saturated Model	Estimated Model
SRMR	0.059	0.059
d_ULS	0.361	0.361
d_G	0.141	0.141
Chi-Square	344.714	344.714
NFI	0.904	0.904

To assess the overall fit of the model, basic fit indices, including SRMR, d_ULS, d_G, χ^2 , and NFI, were considered. According to the data presented in Table 4, the SRMR value was calculated as 0.059 for both the saturated and estimated models, indicating that the model exhibits good fit, as this value is below the 0.08 threshold (Hensler et al., 2014). Similarly, the d_ULS (0.361) and d_G (0.141) values indicate

that the difference between the estimated model and the observed data is minimal. Additionally, the NFI value, which represents the explanatory power of the model, is 0.904, indicating a good model fit ($NFI > 0.90$). When all these indicators are evaluated together, it is concluded that the established structural model is consistent with empirical data and possesses a valid structure in terms of structural equation modeling.

To statistically validate the research model, a bootstrapping method with 5,000 samples was applied using Smart-PLS software. In this method, the sample, initially consisting of 407 participants, was expanded through random resampling, aiming to increase the reliability of the model's parameter estimates. Bootstrapping enables the accurate calculation of standard errors, confidence intervals, and statistical significance levels, particularly for path coefficients, and plays a crucial role in evaluating the robustness of the model's hypothesis structure (Hair et al., 2017). Within the scope of this analysis, the significance levels of the relationships predicted in the model were interpreted based on beta (β) coefficients, p-values, and t-statistics. Thus, both the direction and strength of the structural paths were determined, and the model's general validity was empirically tested.

The structural model diagram created for the research is shown in Figure 2.

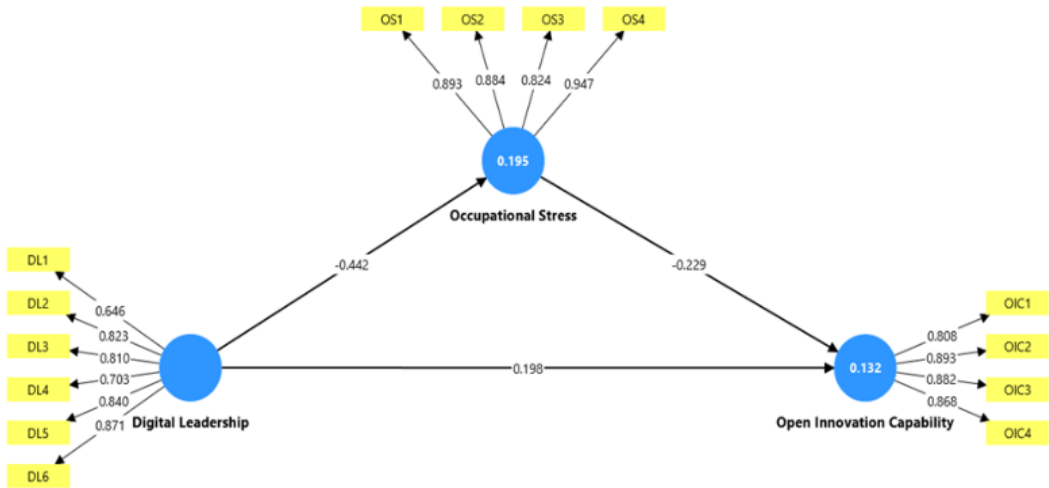


Figure 2. Structural model path diagram.

As a result of the structural model analysis, it was determined that all hypotheses tested within the scope of the research were statistically significant and supported in this direction. The direction and strength of the relationships predicted in the model were evaluated through path coefficients (β), p-values, and t-statistics, demonstrating that each hypothesis is consistent with the empirical data. Detailed findings regarding the hypothesis tests are presented in Table 5 below.

Table 5. Hypothesis test results.

Path	β	Standard Deviation	t-Value	p	Hypothesis	f2-VAF
H ₁	-0.442	0.039	11.193	0.000	Accept	0.242
H ₂	-0.229	0.054	4.264	0.000	Accept	0.049
H ₃	0.198	0.048	4.100	0.000	Accept	0.036
H ₄	0.101	0.027	3.732	0.000	Accept Partial	VAF: %34

When examining the structural model path coefficients presented in Table 5, it is observed that digital leadership has a significant and negative effect on occupational stress ($\beta = -0.442$, $t = 11.193$, $p < 0.001$), which supports the H₁ hypothesis. Similarly, the effect of occupational stress on open innovation capability was also found to be negative and significant ($\beta = -0.229$, $t = 4.264$, $p < 0.001$); this result supports the acceptance of H₂. Furthermore, the direct effect of digital leadership on open innovation capability is statistically significant ($\beta = 0.198$, $t = 4.100$, $p < 0.001$), confirming H₃. However, the research data also revealed that occupational stress plays a mediating role in the effect of digital leadership on open innovation capability. The indirect effect coefficient calculated in the analysis of the mediating effect ($\beta = 0.101$, $t = 3.732$, $p < 0.001$) was found to be statistically significant, supporting the H₄ hypothesis. Additionally, the level of the existing mediating effect was determined through a VAF (Variance Accounted For) calculation (%0-%20 no mediation, %20-%80 partial

mediation, %80-%100 complete mediation). The calculated VAF value was found to be 33.8%, indicating that the mediation effect is at a partial (partial mediation) level (Hair et al., 2017). These findings reveal that digital leadership has a significant impact on open innovation capability, both directly and indirectly through occupational stress.

6. Conclusion and Discussion

This study analyzed the impact of digital leadership on open innovation capability, examined the mediating role of occupational stress in this impact, and evaluated all these relationships within the context of the aviation sector. The aviation sector is an area that creates intense stress on employees due to its complex technological systems, strict regulatory structure, and constant high-performance expectations, and requires a balance between innovation and operational safety. In this context, it is evident that strategic managerial skills such as digital leadership are critical not only for technological transformation but also for the psychological well-being of employees and the sustainability of organizational innovation capacity.

Hypothesis H₁, tested in the study, revealed that digital leadership has a significant and negative effect on occupational stress. This finding suggests that digital leaders can mitigate employee stress levels by fostering open communication, developing technological support skills, and cultivating trust-based relationships. This is particularly important in sectors such as aviation, where stress has a direct impact on decision quality, highlighting the importance of the people-oriented aspect of leadership.

The second hypothesis (H₂) of the study examined the effect of occupational stress on open innovation capability, concluding that stress has a significant negative impact on this capability. This finding indicates that the stress experienced by employees limits their participation in innovation processes, particularly in terms of openness to external information, creative thinking, and collaboration. Open innovation is not only related to technological infrastructure but also psychological trust, cognitive flexibility, and social interaction capacity (Vanni et al., 2024). However, occupational stress can create a barrier that prevents participation in innovative processes by directing the individual's attention toward internal anxieties (Vasanth & Santhi, 2020). This effect is even more pronounced in sectors such as aviation, where stress is experienced as a structural element (Rich, 2016). Psychologically supportive leadership approaches are needed to enable individuals working in environments with low error tolerance and high regulatory pressure to take an active role in innovation processes. In this context, digital leaders' stress-reducing practices are of strategic importance not only for employee well-being but also for the sustainability of organizational innovation.

Within the context of the third hypothesis (H₃) of the study, the effect of digital leadership on open innovation capability was examined, and it was found to be statistically positive and significant. This finding shows that digital leadership is not only a leadership style that directs technological transformation, but also a strategic management tool that supports open innovation. Digital leaders ensure the effective use of information technologies while also creating a culture that facilitates access to external information sources, collaborative learning processes, and multi-actor collaborations (Benitez et al., 2022; Fatima et al., 2021). This relationship is of particular strategic importance in the aviation sector. Structurally, the aviation sector is characterized by high

safety standards, the need for continuous technological innovation, and intense competitive conditions. In this context, aviation companies must develop their innovation capacities not only through internal resources but also through external knowledge networks and collaborations. Digital leadership comes into play precisely at this point, facilitating both the integration of digital infrastructure and the establishment of sustainable, innovative relationships with external stakeholders. Therefore, the positive impact of digital leadership on open innovation capabilities serves as a strategic lever for sustaining innovation in high-tech sectors, such as the aviation industry. The ability of digital leaders to both identify technological opportunities and integrate them into organizational culture plays a key role in the success of external innovation processes.

The fourth and final hypothesis (H₄) of the study tested whether occupational stress plays a mediating role in the relationship between digital leadership and open innovation capability. The findings reveal that occupational stress exhibits a partial mediating effect in this relationship. In other words, digital leadership directly enhances open innovation capability, but this effect is shaped by the level of occupational stress experienced by employees. Digital leaders' use of practices such as open communication, empathetic governance, and digital infrastructure support helps reduce stress, enabling employees to participate more effectively and creatively in innovative processes (Ramakrishnan et al., 2024). This demonstrates that digital leadership is not merely a form of governance but also a psychosocial support mechanism that transforms the employee experience. The high risk, perfectionism, multi-actor, and variable environment inherent in the aviation sector are significant factors that contribute to increased occupational stress. This stress level has the potential to disrupt innovation processes based on collaboration with external knowledge sources, such as open innovation. Therefore, digital leaders must manage this stress load in a balanced manner, not only for the sake of employee health but also to maintain the organization's innovative capacity. In this context, the partial mediating effect revealed by the study suggests that employees' emotional and cognitive loads must be considered for digital leadership practices to be effective. The success of open innovation is closely related not only to technological infrastructure or strategic orientation but also to the psychological resilience of the individuals implementing these processes (Haque & Yamoah, 2021). Especially in fields such as aviation, which require intensive information and attention, the stress-reducing role of leaders has become a decisive factor in the sustainability of innovation.

Overall, this study contributes to the literature by examining the multidimensional relationships between digital leadership, occupational stress, and open innovation capability through a comprehensive model, while also providing valuable insights into the applicability of these concepts in the specific aviation sector context. The results indicate that digital leadership practices should not be limited to technological infrastructure and strategic orientation. Still, they should also be combined with a human-centered approach that prioritizes employee well-being. In particular, the sustainability of innovation in high-risk and high-demand environments is directly related to the stress-regulating role of leadership. In this respect, the study highlights a leadership approach that focuses on the human factor in digital transformation processes.

However, this research also has some limitations. First, the sample consists of 407 employees working in companies operating in the aviation sector in Türkiye, and the fact that the

sample has not been expanded in terms of sector and geography limits the generalizability of the findings. Furthermore, the study adopts an approach based solely on employee perceptions, and the assessments of managerial actors (leaders) are not included in the model. This may lead to a one-sided perspective, particularly in evaluating multidimensional phenomena such as leadership and innovation. Future studies are recommended to include multiple data sources (managers, customers, etc.). Similarly, applying similar models across different sectors (such as health, finance, and education) could enable cross-sectoral comparative analyses. Furthermore, integrating potential regulatory or mediating variables, such as psychological resilience, organizational support, and digital competence, into the model is crucial for filling conceptual gaps in the literature.

Ethical approval

To document the scientific and ethical principles of the study, approval was obtained from the Giresun University Social Sciences Ethics Committee on May 28, 2025, with the reference number 06/336.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

The article was first written in Turkish by the authors and then translated into English. Grammarly Pro was used to check the English translation for language and grammar. Zotero was used to organize the references.

References

- Benitez, J., Arenas, A., Castillo, A., & Esteves, J. (2022). Impact of digital leadership capability on innovation performance: The role of platform digitization capability. *Information & Management*, 59(2), Article 2.
- Bogers, M., Chesbrough, H., Heaton, S., & Teece, D. J. (2019). Strategic Management of Open Innovation: A Dynamic Capabilities Perspective. *California Management Review*, 62(1), 77–94.
- Borah, P. S., Iqbal, S., & Akhtar, S. (2022). Linking social media usage and SME's sustainable performance: The role of digital leadership and innovation capabilities. *Technology in Society*, 68, 101900.
- Bregenzner, A., & Jimenez, P. (2021). Risk Factors and Leadership in a Digitalized Working World and Their Effects on Employees' Stress and Resources: Web-Based Questionnaire Study. *Journal of Medical Internet Research*, 23(3), e24906.
- Bunce, D., & West, M. (1994). Changing work environments: Innovative coping responses to occupational stress. *Work & Stress*, 8(4), 319–331.
- Byrne, B. M. (2016). *Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming* (3rd ed.). Routledge.
- Cepeda, J., & Arias-Pérez, J. (2018). Information technology capabilities and organizational agility: The mediating effects of open innovation capabilities. *Multinational Business Review*, 27(2), 198–216.
- Chen, P. Y. (2023). *Occupational Stress*. Hogrefe Publishing.
- Cochran, W. G. (1977). *Sampling Techniques* (3rd ed.). John Wiley & Sons.
- Cui, F., & Song, J. (2022). Impact of Entrepreneurship on Innovation Performance of Chinese SMEs: Focusing on the Mediating Effect of Enterprise Dynamic Capability and Organizational Innovation Environment. *Sustainability*, 14(19), Article 19.
- Ertiö, T., Eriksson, T., Rowan, W., & McCarthy, S. (2024). The role of digital leaders' emotional intelligence in mitigating employee technostress. *Business Horizons*, 67(4), 399–409.
- Fatima, T., Masood, A., Majeed, M., & Ali, M. U. (2021). Impact Of Digital Leadership On Open Innovation: A Moderating Serial Mediation Model. *Academy of Management Proceedings*, 2021(1), 13398.
- Finkel, A., Fougere, G., & Roux, S. (2025). An Automata-Based Method to Formalize Psychological Theories: The Case Study of Lazarus and Folkman's Stress Theory. 204–215.
<https://www.scitepress.org/Link.aspx?doi=10.5220/0013175400003896>
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39–50.
- Habicht, H., Möslin, K. M., & Reichwald, R. (2012). Open Innovation Maturity. *International Journal of Knowledge-Based Organizations (IJKBO)*, 2(1), 92–111.
- Hadi, N. U., & Ali, I. (2025). Exploring the unknowns of international open innovation and international dynamic capabilities on the speed of innovation and firm international performance: A strategic view. *Journal of Innovation & Knowledge*, 10(2), 100683.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling* (2nd ed.). SAGE Publications.
- Han, S., Lyu, Y., Ji, R., Zhu, Y., Su, J., & Bao, L. (2020). Open innovation, network embeddedness and incremental innovation capability. *Management Decision*, 58(12), 2655–2680.
- Haq, I., Haque, A., Kaur, H., & a Rahim, N. (2024). Occupational Stress affecting Innovative Capabilities and Innovative Work Behavior of Migrant Entrepreneurs. *Polish Journal of Management Studies*, 29, 238–253.
- Haque, A. ul, & Yamoah, F. A. (2021). The Role of Ethical Leadership in Managing Occupational Stress to Promote Innovative Work Behaviour: A Cross-Cultural Management Perspective. *Sustainability*, 13(17), Article 17.
- Hart, P. M., & Cooper, C. L. (2002). Occupational stress: Toward a more integrated framework. In *Handbook of industrial, work and organizational psychology*, Volume 2: Organizational psychology (pp. 93–114). Sage Publications, Inc.
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115–135.
- ICAO. (2024). Digitalization in aviation: Tackling the challenges.
<https://www.icao.int/Meetings/InnovationFair2024/Documents/Presentations/Session-3-Digitalization-in-aviation-tackling-the-challenges.pdf>
- Jovanović, J., Lazaridis, K., & Stefanović, V. (2006). Theoretical approaches to problem of occupational

- stress. *Acta Facultatis Medicae Naissensis*, 23(3), 163–169.
- Karasek, R. A. (1979). Job Demands, Job Decision Latitude, and Mental Strain: Implications for Job Redesign. *Administrative Science Quarterly*, 24(2), 285–308.
- Kaygin, E., Kavak, O., & Topcuoglu, E. (2023). Heavy work investment and its premises. *International Journal of Management Studies*, 30(1), 63–92.
- Kinnunen-Amoroso, M., & Liira, J. (2013). Management of work-related stress by Finnish occupational physicians. *Occupational Medicine*, 63(5), 361–364.
- Lazarenko, Y., Garafonova, O., Marhasova, V., Tkalenko, N., & Grigashkina, S. (2019). Managing Organizational Open Innovation Capability in a Knowledge-Intensive Business Environment. *MATEC Web of Conferences*, 297, 07002.
- Luis, D. J., Ruth, C.-J., & Zhuofan, Z. (2020). Does Stress Lead to Creativity? The Relationship Between Occupational Stress and Individual Innovative Behavior. *Studies in Business and Economics*, 15(1), 21–30.
- Ly, B. (2024). The Interplay of Digital Transformational Leadership, Organizational Agility, and Digital Transformation. *Journal of the Knowledge Economy*, 15(1), 4408–4427.
- Majumdarr, S., Dasgupta, S. A., Hassan, Y., Behl, A., & Pereira, V. (2024). Linking digital transformational leadership, symmetrical internal communication with innovation capability: A moderated mediation model. *Journal of Knowledge Management*, ahead-of-print(ahead-of-print).
- Malik, U. M., Ullah*, D. J., Gul, D. S., Bangash, S. A., Khan, Z. A., & Ikram, M. (2025). Occupational Stress, Mental Health and Employee Performances in Small Medium Enterprises. *Social Science Review Archives*, 3(1), Article 1.
- Marcatto, F., Blas, L. D., & Ferrante, D. (2023). Diagnostic Utility of the Perceived Occupational Stress Scale. *European Journal of Psychological Assessment*.
- Nagano, H. (2020). The growth of knowledge through the resource-based view. *Management Decision*, 58, 98–111.
- Newton, C. J., & Bish, A. (2013). Proximal and Distal Levels of Leader Vision: A Stress Buffering Perspective. *Academy of Management Proceedings*, 2013(1), 11780.
- Oktaysoy, O., Topcuoglu, E., & Kaygin, E. (2022). A Study on Digital Leadership Scale Adaptation. *International Journal of Organizational Leadership*, 11(4), 407–425.
- Ordu, A., & Nayır, F. (2021). Dijital Liderlik Nedir? Bir Tanım Önerisi. *e-Uluslararası Eğitim Araştırmaları Dergisi*, 12(3), 68–81.
- Ramakrishnan, S., Mutum, D. S., Chit, M. M., & Wong, M. S. (2024). Occupational stress as a mediator between organisational intelligence traits and digital government service quality: A triangulation design approach. *Journal of Service Theory and Practice*, 34(6), 787–821.
- Rich, S. (2016). A brief examination of the effects of occupational stress on creativity and innovation. *The Psychologist-Manager Journal*, 19(2), 107–121.
- Ringle, C. M., Silva, D. da, & Bido, D. de S. (2014). Modelagem de Equações Estruturais com Utilização do Smartpls. *ReMark - Revista Brasileira de Marketing*, 13(2), Article 2.
- Sağbaş, M., & Erdoğan, F. A. (2022). Digital Leadership: A Systematic Conceptual Literature Review. *İstanbul Kent Üniversitesi İnsan ve Toplum Bilimleri Dergisi*, 3(1), Article 1.
- Sagbas, M., Oktaysoy, O., Topcuoglu, E., Kaygin, E., & Erdogan, F. A. (2023). The Mediating Role of Innovative Behavior on the Effect of Digital Leadership on Intrapreneurship Intention and Job Performance. *Behavioral Sciences*, 13(10), Article 10.
- Sarstedt, M., Hair, J. F., Pick, M., Liengaard, B. D., Radomir, L., & Ringle, C. M. (2022). Progress in partial least squares structural equation modeling use in marketing research in the last decade. *Psychology & Marketing*, 39(5), 1035–1064.
- Shi, X., & Zhang, Q. (2018). Inbound open innovation and radical innovation capability: The moderating role of organizational inertia. *Journal of Organizational Change Management*, 31(3), 581–597.
- Siegrist, J. (1996). Adverse health effects of high-effort/low-reward conditions. *Journal of Occupational Health Psychology*, 1(1), 27–41.
- Thakre, N., & Barua, P. (2015). Occupational Stress, Job Satisfaction and Job Involvement Amongst Organizational Employees. *Indian Journal of Mental Health (IJMH)*, 3, 79.
- Topcuoglu, E., Kobanoglu, M. S., Kaygin, E., Karafakioglu, E., Erdogan, S. U., Torun, B. T., & Oktaysoy, O. (2023). The improving role of digital leadership in the impact of social loafing on job performance. *International Journal of Organizational Leadership*, 12(1), Article 1.
- Topçuoğlu, E., Oktaysoy, O., Erdoğan, S. U., & Karatepe, S. G. (2023). İşsizlik ve Girişimcilik Kavramlarına Bibliyometrik Bakış. *İşletme Araştırmaları Dergisi*, 15(2), Article 2.
- Tran, Q. H. N. (2024). Investigate the relationship between leadership behaviours, organisational commitment, occupational stress and organisational citizenship behaviours in Vietnamese private business school libraries. *Library Management*, 45(1/2), 101–117.
- Tsai, F.-S., Cabrilo, S., Chou, H.-H., Hu, F., & Tang, A. D. (2022). Open innovation and SME performance: The roles of reverse knowledge sharing and stakeholder relationships. *Journal of Business Research*, 148, 433–443.
- Turan-Torun, B., Oktaysoy, O., Kobanoglu, M. S., Topcuoglu, E., Yenikaya, M. A., Topcuoglu, V., & Uygungil-Erdogan, S. (2025). Identification of heavy work investment antecedents: A research on digital leadership. *Frontiers in Psychology*, 16, 1588412.
- Uygungil-Erdogan, S., Şahin, Y., Sökmen-Alaca, A. İ., Oktaysoy, O., Altıntaş, M., & Topçuoğlu, V. (2025). Assessing the Effect of Artificial Intelligence Anxiety on Turnover Intention: The Mediating Role of Quiet Quitting in Turkish Small and Medium Enterprises. *Behavioral Sciences*, 15(3), Article 3.
- Vanni, K., Syvanen, A., & Viteli, J. (2024). Relationship between Digital Stress and Innovation Capacity. *Human Factors, Business Management and Society*, 135(135).
- Vasanth, S., & Santhi, R. (2020). Relationship between Occupational Stress and Resilience. *Indian Journal of Public Health Research & Development*, 11(3), 615–620.
- Wang, G., Mansor, Z. D., & Leong, Y. C. (2024). Linking digital leadership and employee digital performance in SMEs in China: The chain-mediating role of high-involvement human resource management practice and employee dynamic capability. *Heliyon*, 10(16), e36026.

- Xu, Y., Liao, C., Huang, L., Li, Z., Xiao, H., & Pan, Y. (2024). The positive side of stress: Investigating the impact of challenge stressors on innovative behavior in higher education. *Acta Psychologica*, 246, 104255.
- Yao, J., Crupi, A., Minin, A. D., & Zhang, X. (2020). Knowledge sharing and technological innovation capabilities of Chinese software SMEs. *Journal of Knowledge Management*, 24(3), 607–634.
- Yavan, Ö., & Pekkaya, M. (2017). Mesleki strese etkili ana faktörlerin önem derecelerinin belirlenmesi: Bir üniversitede uygulama. *Uluslararası Yönetim İktisat ve İşletme Dergisi*, 13(13), Article 13.
- Yazıcıoğlu, Y., & Erdoğan, S. (2014). SPSS uygulamalı bilimsel araştırma yöntemleri (4th ed.). Detay Yayıncılık.
- Yelkencioğlu, I., & Yuksel, A. H. (2022). Occupational stress and mindfulness: An empirical study. *Journal of Business Economics and Finance*, 11(2), Article 2.
- Yordam Dağıstan, S., Erol, G., & Düşmezkalender, E. (2024). Mesleki Damgalama, Öznel İyi Oluş ve Mesleki Stres Arasındaki İlişki: Otel Çalışanları Üzerine Araştırma. *Journal of Tourism and Gastronomy Studies*, 12, 2817–2835.
- Zeike, S., Bradbury, K., Lindert, L., & Pfaff, H. (2019). Digital Leadership Skills and Associations with Psychological Well-Being. *International Journal of Environmental Research and Public Health*, 16(14), Article 14.
- Zhu, J., Zhang, B., Xie, M., & Cao, Q. (2022). Digital leadership and employee creativity: The role of employee job crafting and person-organization fit. *Frontiers in Psychology*, 13, 827057.

Cite this article: Topcuoglu, E., Oktaysoy, O., Sahin Y. (2025). The Mediating Role of Occupational Stress in the Impact of Digital Leadership on Open Innovation Capability in the Aviation Sector. *Journal of Aviation*, 9(3), 658-668.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Shift Planning with Artificial Intelligence within the Scope of Strategic Decision-Making Approach in Airport Ground Handling Operations

Mine Değirmencioğlu^{1*}, Armağan Macit²

^{1*}Mehmet Akif Ersoy University, Civil Aviation Transport Management Department, 34469, Bucak, Burdur, Türkiye. (mdegirmencioğlu@mehmetakif.edu.tr)

²Ege University, Civil Aviation Transport Management Department, İzmir, Türkiye. (armagan.macit@ege.edu.tr)

Article Info

Received: 22 June 2025

Revised: 07 August 2025

Accepted: 25 August 2025

Published Online: 10 October 2025

Keywords:

Strategic Decision-Making
Aviation Management
Strategic Management

Corresponding Author: Armağan Macit

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1724765>

Abstract

This study examines the potential contribution of artificial intelligence-based shift planning to strategic decision-making processes in airport ground handling operations. Today, the need for decision-making aligned with multidimensional goals such as resource management, legal compliance, and employee satisfaction alongside operational efficiency, is increasingly evident. In this context, considering the multi-departmental structure of a ground handling company operating at Antalya Airport, traditional shift planning was comparatively analyzed against AI-supported optimization. During the implementation process, not only operational outputs but also the managerial benefits of decision support systems were evaluated. The findings reveal that AI-based planning enhances not only efficiency but also strategic flexibility and predictability. By demonstrating that digital technologies enable a data-driven and agile decision-making approach in human resources planning, this study makes a meaningful contribution to theoretical gaps in literature.

1. Introduction

Airports are not merely locations where flights are executed; they are also high-density and complex operational systems where time, resource, and human management are critically integrated (Wadud, 2013). At the core of this system lie ground handling operations, which contribute to operational continuity across a wide range from aircraft turnaround processes to passenger services. However, the increasing passenger traffic, fluctuating demand structures, and operational uncertainties necessitate a re-evaluation of strategic decision-making processes in ground handling companies (Čileček et al., 2024). In this regard, effective decision-making structures are becoming more important, especially in time-sensitive, multi-variable, and multi-actor processes such as shift planning.

Shift planning is not merely limited to assigning working hours to employees; it is directly linked to strategic outcomes such as service quality, employee satisfaction, workforce balance, and cost efficiency (Yılmaz, 2017; Van den Bergh et al., 2013). Traditional planning methods often rely on fixed templates and past experiences and show limited effectiveness against uncertainty, the need for operational flexibility, and individual preferences (Bergh et al., 2013; Hulst et al., 2017). This situation makes it necessary to support decision-making

processes with more data-driven, dynamic, and predictive methods.

The strategic decision-making process is explained in the literature through two fundamental approaches: synoptic formalism and political incrementalism. The synoptic approach, pioneered by Simon (1960), suggests that decisions should be made rationally based on systematic data analysis aligned with explicit goals, while Dean and Sharfman (1993) view procedural rationality as a key determinant of decision quality. Conversely, the political incrementalist approach argues that decisions are shaped through intuition, experience, power dynamics, and intra-organizational interactions (Lindblom, 1959; Eisenhardt & Zbaracki, 1992). Khatri and Ng (2000) and Hodgkinson et al. (2009) emphasize the decisive role of intuition, particularly under conditions of uncertainty and scarcity of information. Allen et al. (1979) and Child (1972) assert that political behavior creates strategic effects that shape how, by whom, and under what conditions decisions are made.

Recent studies have shown that these two approaches are not mutually exclusive but rather complementary (Elbanna, 2006; Shepherd & Rudd, 2014). Particularly in industries such as aviation, where environmental complexity is high, it is necessary to evaluate both data-driven rational analyses and intuition- and interaction-based dynamics together. This holistic approach enhances not only the quality of decisions

but also their contextual relevance and implementation success (Child et al., 2010).

In this context, artificial intelligence (AI) technologies offer the potential to provide both the analytical capacity of the synoptic approach and the flexibility to integrate with political-incrementalist dynamics in strategic decision-making processes. Through components such as machine learning (ML), deep learning (DL), and natural language processing (NLP), AI performs prediction, optimization, and pattern recognition over large datasets and supports cognitive functions such as learning from past experiences and generating scenarios (Garcia et al., 2021; Jiao et al., 2022; von Krogh, 2018). Particularly in airport ground handling, AI-supported decision-making structures offer not only technical solutions but also human-centered planning capabilities in highly constrained and variable systems such as shift planning (Gong et al., 2019; Pouillet & Parmentier, 2020).

The primary aim of this study is to examine, both theoretically and practically, the AI-supported shift planning approach integrated into strategic decision-making processes within the context of airport ground handling operations. Accordingly, the study presents theoretical approaches and a literature review on strategic decision-making and then evaluates the impact of AI techniques on planning processes through a case study. Thus, the study not only offers a technological model proposal but also presents a comprehensive framework regarding the integration of AI into strategic management decision-making.

2. Conceptual Framework and Literature Review

Although the strategic decision-making process has been extensively studied in managerial literature, there is no consensus on a common definition. Schwenk (1995) characterizes such decisions as rare, unstructured, and critical events in organizational life, while Mintzberg et al. (1976) describes strategic decisions as processes made under uncertainty and lacking formal structure. Quinn (1978) associates strategic decisions with long-term direction and goal formulation, whereas Johnson et al. (2008) argue that such decisions have a lasting impact on the organization due to their high risk and dependency on resources. On the other hand, Eisenhardt and Zbaracki (1992) consider strategic decisions to be those that shape the organization's future and are typically made by top-level executives, while Hickson et al. (1986) suggest that these decisions reflect the values and attitudes of managers at the organizational level. Collectively, these perspectives reveal that strategic decisions are multidimensional processes involving multiple actors, high uncertainty, and long-term implications.

Two main theoretical approaches emerge to explain these decision-making processes: synoptic formalism and political incrementalism. The synoptic-formalism approach conceptualizes the decision-making process through structured phases such as setting clear objectives, collecting systematic data, comparing alternatives, and making logical choices (Simon, 1960; Fredrickson & Mitchell, 1984). This model adds objectivity, consistency, and accountability to the process, and is elaborated with concepts such as procedural rationality (Dean & Sharfman, 1993), comprehensiveness (Atuahene-Gima & Li, 2004), and behavioral integration (Carmeli & Schaubroeck, 2006). Procedural rationality refers to the systematic collection and analysis of information; comprehensiveness involves multi-source and multi-criteria evaluations; and behavioral integration indicates the presence

of trust, communication, and collective reasoning among participants (Hambrick & Mason, 1984; Lubatkin et al., 2005).

However, in situations characterized by information scarcity, time pressure, and environmental complexity, this rational model may fall short. This is where the political incrementalist approach becomes relevant. Lindblom's (1959) model suggests that decisions evolve gradually based on experience and negotiation. Quinn (1980) adapted this model to strategic decision-making by developing the concept of logical incrementalism. Eisenhardt and Zbaracki (1992) demonstrate that decisions emerge not only from data-driven analysis but also from intuition, conflict of interest, and power balances. Intuition is evaluated in various forms such as instinctive feeling (Parikh et al., 1994), recognition (Simon, 1992), and holistic insight (Miller & Ireland, 2005; Elbanna et al., 2013), while political behavior directs the decision process through tactics like information manipulation, timing interference, and selective presentation of alternatives (Child, 1972; Allen et al., 1979; Elbanna, 2006).

A growing consensus in the literature suggests that these two approaches are not mutually exclusive but rather complementary (Shepherd & Rudd, 2014; Elbanna, 2006). Particularly in contexts with high uncertainty and multiple stakeholders, decision-makers develop hybrid structures by utilizing both systematic data analysis and intuitive judgments (Child et al., 2010). This structure is especially functional in areas where operational-level decisions have strategic impacts such as shift planning.

Shift planning is a multidimensional process of strategic importance in terms of workforce management, service quality, and cost control (Van den Bergh et al., 2013). Traditional planning methods are based on fixed templates (e.g., fixed, rotating, or split shift models) and fail to offer sufficient flexibility for variable demands (Hulst et al., 2017; Bergh et al., 2013). While these methods ensure operational stability, they fall short in addressing individual preferences, legal constraints, and real-time changes. Accordingly, there is an increasing need for more flexible, adaptable, and data-driven approaches.

At this point, modern shift planning systems have begun to incorporate not only mathematical methods such as linear and integer programming but also metaheuristic algorithms (e.g., genetic algorithms, particle swarm optimization) (Gong et al., 2019; Sahraeian, 2024). However, the most advanced solutions are provided by artificial intelligence (AI)-based systems. AI is a scientific and technological domain that aims to replicate human-like cognitive processes (learning, decision-making, problem-solving) through machines (McCorduck et al., 1977; Boden, 2014; Russell & Norvig, 2010). Drawing from multiple disciplines, AI enhances organizational decision support systems with high predictive capacity and flexibility (Pirim, 2006; Ünal & Kılınc, 2020).

The core technical components of AI include machine learning (ML), deep learning (DL), and natural language processing (NLP). ML focuses on extracting patterns from historical data and making predictions (von Krogh, 2018), while DL can analyze more complex relationships through multi-layered neural networks (Garcia et al., 2021). NLP processes text and speech data to evaluate user requests, sentiment analysis, or internal communications (Jiao et al., 2022). When used in combination, these technologies create powerful decision support systems, particularly for problems such as shift planning, which involve numerous constraints and variables.

AI applications are also rapidly expanding in the aviation sector. They are employed in flight operations, air traffic management, maintenance planning, and route optimization to reduce costs and improve safety and efficiency (Chung et al., 2020; Maple et al., 2023; Seçkiner et al., 2021). In dynamic, human-resource-dependent environments such as ground handling—where timing is critical—AI solutions are successfully used for staff allocation, shift balancing, resource optimization, and scenario generation (Číleček et al., 2024; Zhang & Cai, 2021). These systems can simultaneously account for numerous factors, such as employee preferences, peak workload hours, and operational constraints, enabling more balanced schedules and improving the balance between satisfaction and productivity (Li & Li, 2020; Gong et al., 2019).

Furthermore, NLP-based systems provide qualitative insights to managers by analyzing employee feedback, satisfaction surveys, and shift requests (Joseph et al., 2016; Jiao et al., 2022). This enhances human-centered planning approaches and allows decisions to be evaluated not only for their accuracy but also for their contextual validity and organizational acceptance (Trunk et al., 2020; Shepherd & Rudd, 2014).

In conclusion, AI-supported shift planning systems offer data-oriented, yet flexible and adaptable decision-making structures that integrate the strengths of both synoptic formalism and political incrementalism. These systems not only improve operational performance but also enhance the quality, speed, and contextual relevance of strategic decisions. Integrating such technologies into complex airport ground handling operations provides organizations with sustainable competitive advantage and strategic agility (Pouillet & Parmentier, 2020; Brondell et al., 2023; Elbanna et al., 2014).

A review of recent studies on strategic decision-making using artificial intelligence in the aviation sector reveals that some studies stand out with their findings and may offer insights into how they relate to shift planning.

Pérez-Campuzano, Morcillo Ortega, Rubio Andrada, and López-Lázaro (2021) investigated the potential impact of AI applications on strategic decision-making in airlines during the COVID-19 period and noted that supervised/unsupervised learning techniques were underutilized in the areas of strategy, finance, and marketing. This approach could contribute to flexible shift planning models in ground handling during crisis periods.

Ziakkas, Plioutsias, and Pechlivanis (2022) examined AI-supported direct voice input technologies in cockpit decision-making processes within the framework of e-MCO (Extended Minimum Crew Operations) and SiPO (Single Pilot Operations) concepts. Improving human-machine interaction could serve as an example for the design of similar systems that would alleviate the decision-making burden on managers in ground handling operations management.

A study by Fondevila-Gascón, Gutiérrez-Aragón, Lopez-Lopez, Curiel-Barrios, and Alabart-Algueró (2025) assessed passengers' perceptions of AI-based airline operations and revealed high support for AI, particularly in air traffic management, maintenance, and sustainability, but caution toward fully autonomous decision-making mechanisms. Maintaining human oversight in AI-based shift planning in ground handling services may be effective in increasing acceptance rates.

Moghadasnian and Karimi's (2025) study examined the relationship between artificial intelligence (AI) integration and

leadership styles in airline operations and found that evolutionary algorithms and reinforcement learning were effective in reducing both cost (7–12%) and fuel consumption (6–10%). These results demonstrate that multi-objective optimization in ground handling shift planning can be implemented in concert with strategic leadership.

Moghadasnian and Rajol (2025) examined the transformative role of AI in airline business management in optimizing operational processes, improving customer experience, and enhancing strategic decision-making. The findings support the potential of AI-based shift planning in ground handling to increase operational efficiency and service quality.

3. Methodology

In this study, a multi-departmental workload optimization model was developed for AI-supported shift planning. The model aims to minimize overtime and increase labor utilization efficiency by distributing the total weekly workload equally among employees. The AI-based planning model, implemented via ChatGPT, assumes a fixed total weekly workload for each department, calculates the ideal average duration per person, and generates comparative analyses against existing shift plans. This allows for comparison of human-generated and AI-generated shift plans in terms of efficiency in meeting operational load.

The primary goal of the AI-supported shift planning model used in this study is to enhance both operational efficiency and employee well-being by balancing the total weekly workload across available staff within legal working time limits. The model aims to meet total labor demands while minimizing the differences in weekly working hours across employees.

The model is formulated as follows:

N: Number of personnel

T: Total weekly workload (in hours)

X_i : Weekly working time of employee i

$\bar{x} = T/N$: Average working time

L: Minimum legal weekly working time

U: Maximum legal weekly working time

$$\min \sum_{i=1}^N (x_i - \bar{x})^2$$

$$\sum_{i=1}^N x_i = T$$

$$L \leq x_i \leq U$$

The model assumes that employees can rotate duties equally, and weekly working hours should not exceed 40 hours, preferably staying within the 33.5–39.5-hour range. All duration calculations were converted into minutes using Python, and based on each employee's weekly total, overall workload, per-person average, and deviation values were calculated. Additionally, by assuming an average cost x per hour, potential overtime-related costs were calculated to assess the model's economic advantage. The artificial intelligence algorithm produces result by operating the relevant mathematical model.

3.1. Implementation and Case Study

The implementation area of the study consists of a ground handling company operating at Antalya Airport. As part of the case study, weekly shift schedules for the Passenger Services, Operations, and Ramp departments were analyzed for weeks 16 through 19. This period corresponds to the spring season, when the company operates at high capacity, and represents different levels of operational intensity. Daily personnel assignment schedules for each department were evaluated based on the total durations reflecting internal shift workload.

Additionally, the monthly flight schedule for the same period was incorporated to establish the necessary operational data infrastructure for shift planning. This flight schedule revealed variations in labor demand on specific days due to increased passenger traffic and flight numbers, allowing the AI model to generate a more equitable and realistic workload distribution. The workload analysis was conducted daily, aggregated weekly, and optimized through AI-driven alternative shift plans with equal distribution. However, the ground handling company's relevant programs do not accommodate immediate operational changes and fail to consider the staff's requests and expectations regarding shift

planning. This constitutes a fundamental limitation of the study. Equal workload distribution was considered to increase staff satisfaction in terms of fairness.

4. Findings

This section presents the output obtained from the implementation of the AI-based shift planning model in the Passenger Services, Operations, and Ramp departments. Weekly workload distributions, per capita averages, and AI-supported optimization results are presented in comparative tables for each department, followed by a general evaluation.

4.1. Passenger Services Department

Weekly shift plans for weeks 16–19 was analyzed. The total weekly working hours ranged between 19,371.5 and 19,941 hours, while the number of personnel varied from 493 to 508. The AI-supported planning model demonstrated that the same workload could be handled with lower average working hours per person.

Table 1. Passenger Services – Real and AI-Powered Shift Times

Week	Actual Total Hours	Number of Personnel	Actual Avg. per Person	AI Total Hours	AI Avg. per Person
16	19.371.5	493	39.28 hours	18.839.5	38.22 hours
17	19.329.5	499	38.73 hours	18.212.5	36.5 hours
18	19.456.5	507	38.37 hours	18.739.5	36.95 hours
19	19.941.0	508	39.25 hours	18.831.0	37.07 hours

Through AI-based planning, the per capita workload was distributed more equally and within legal limits, and a reduction in total workload was achieved. The passenger services department, with the largest number of personnel within the airport's operational flow and multiple workflows simultaneously, is the department with the highest demand for strategic planning and decision-making. Therefore, the findings demonstrate that artificial intelligence can create

effective outcomes for strategic decision-making in passenger services.

4.2. Operations Department

The workload in the Operations department ranged between 5,326.5 and 5,412.5 hours, while the number of personnel varied from 136 to 160 during weeks 16–19. The AI model stabilized this workload between 33.5 and 39.8 hours per person per week, reducing unnecessary overtime.

Table 2. Operations – Real and AI-Powered Shift Times

Week	Actual Total Hours	Number of Personnel	Actual Avg. per Person	AI Total Hours	AI Avg. per Person
16	5.326.5	159	33.5 hours	4.938.0	31.05 hours
17	5.412.5	156	34.7 hours	5.148.0	33.0 hours
18	5.392.5	145	37.2 hours	5.130.5	35.38 hours
19	5.408.5	136	39.8 hours	5.012.5	36.85 hours

The operations department is one of the departments most affected by time pressure, including flight times, aircraft turnaround times, and on block and off block processes. Therefore, the results obtained demonstrate that AI has the potential to provide strategic decision-making for the operations department, enabling efficient operation with enough personnel.

4.3. Ramp Department

The analysis in the Ramp department covers weeks 16–18. The weekly total working hours ranged from 2,360.0 to 2,769.5, and the number of personnel varied between 61 and 74. The AI model balanced these durations more effectively.

Table 3. Ramp – Real and AI-Powered Shift Times

Week	Actual Total Hours	Number of Personnel	Actual Avg. per Person	AI Total Hours	AI Avg. per Person
16	2.347.5	60	39.13 hours	2.100.0	35.00 hours
17	2.769.5	71	39.00 hours	2.556.0	36.00 hours
18	2.769.5	70	39.56 hours	2.520.0	36.00 hours
19	2.836.5	70	40.52 hours	2.555.0	36.5 hours

The ramp department is the department with the highest demand for physical labor. Therefore, minimizing working hours should be a top priority. The findings in this context indicate that artificial intelligence will contribute to strategic decision-making for the ramp department.

Table 4. Cross-Departmental Comparative Evaluation

Department	Week	Actual Total Hours	Number of Personnel	Actual Avg. per Person (h)	AI Total Hours	AI Avg. per Person
Pass. Services	16–19	19.371–19.941	18.212–18.839	38.37–39.28	36.5–38.22	9540 X
Oper.	16–19	5.326–5.412	4.938–5.148	33.5–39.8	31.05–36.85	1880 X
Ramp	16–19	2.347.5–2.836.5	2.100–2.555	39.13–40.52	35.00–36.5	1090 X

Based on the assumed hourly unit cost (X), cost savings were particularly significant in the Passenger Services and Operations departments due to reduced overtime hours.

Using AI in shift planning has been observed to have the most effective effect on passenger services and the least effective in the ramp department. This is likely to be due to factors such as staff density within departments and an imbalance in per-person workload. However, it can be argued that AI can optimize under constraints, and therefore, when using AI in shift planning, the most effective results can be achieved while meeting many constraints.

5. Conclusion and Discussion

This study analyzed four weeks of shift data from three main departments—Passenger Services, Operations, and Ramp of a ground handling company operating at Antalya Airport to reveal the effectiveness and strategic relevance of AI-based shift planning. In response to common issues in airport operations, such as uncertainty, workforce imbalance, and inefficient resource use, AI-supported planning emerges not only as an operational solution but also as a decisive tool in managerial decision-making processes.

The analysis revealed that AI-supported shift planning led to a meaningful reduction in total weekly workload, with average working hours per employee distributed more equitably and within legal limits. A total estimated cost saving of approximately 12,420 X was achieved. Department-specific shift durations were optimized within the 35–38 hour range, maintaining labor balance and minimizing overtime. These findings highlight the significance of prediction-based decision-making in strategic human resources planning.

The results are aligned with findings by Eginli and Nacaklı (2020), who demonstrated the operational benefits of augmented reality in aircraft maintenance training. Similarly, Akduman and Karahan (2021) emphasized the efficiency of digital systems in recruitment processes, while this study illustrates that digital solutions also offer substantial advantages in workforce management and decision support processes. Therefore, AI technologies are not limited to operational applications but also contribute to transforming managerial decision-making mechanisms.

Moghadasnian and Rajol (2025) demonstrated the transformative role of artificial intelligence in airline management by optimizing operational processes, improving customer experience, and enhancing strategic decision-making. Similarly, within airport ground handling companies, artificial intelligence can contribute to managerial strategic decision-making, optimizing operational processes, and minimizing costs.

4.4. Cross-Departmental Comparative Evaluation

When evaluating all three departments collectively, AI-supported shift planning enabled a more balanced per-person workload distribution, eliminated overtime, and enhanced operational efficiency.

Moreover, although human factors such as employee satisfaction, job fulfillment, and burnout—which are difficult to measure through analytics—directly impact the success of operational systems, they should not be overlooked. While Kaya (2023) highlighted concerns regarding AI in his study, the planning model proposed in this research has the potential to alleviate psychological stress by reducing overwork and unbalanced shifts. When compared to the social implications of shift systems highlighted by Uğurlu and Ünlü (2023) and Çelik and Korkmaz (2022), this study also demonstrates that AI-based models can support employee well-being.

In summary, the results of this study show that AI-based planning systems offer not only efficiency gains but also multidimensional outcomes such as strategic foresight, resource optimization, organizational sustainability, and employee satisfaction. In the future, testing this model across different airports, over extended time periods, and under new technological parameters could offer valuable contributions to both operational structures and strategic management approaches.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

Allen, R. W., Madison, D. L., Porter, L. W., Renwick, P. A., & Myers, B. T. (1979). Organizational politics: Tactics and characteristics of its actors. *California Management Review*, 22(1), 77–83.

Atuahene-Gima, K., & Li, H. (2004). Strategic decision comprehensiveness and new product development outcomes in new technology ventures. *Academy of Management Journal*, 47(4), 583–597.

Boden, M. A. (2014). Creativity and artificial intelligence: A contradiction in terms. In *The philosophy of creativity: New essays* (pp. 224–246).

Carmeli, A., & Schaubroeck, J. (2006). Top management team behavioral integration, decision quality, and organizational decline. *The Leadership Quarterly*, 17(5), 441–453.

Child, J. (1972). Organizational structure, environment and performance: The role of strategic choice. *Sociology*, 6(1), 1–22.

Child, J., Elbanna, S., & Rodrigues, S. (2010). The political aspects of strategic decision making. In P. Nutt & D. Wilson (Eds.), *The handbook of decision making* (pp. 105–137). Wiley.

Chung, S. H., Ma, H. L., Hansen, M., & Choi, T. M. (2020). Data science and analytics in aviation. *Transportation*

- Research Part E: Logistics and Transportation Review, 134, 101837.
- Cileçek, J., Teichmann, D., & Szabo, S. (2024). Optimization model of staffing for aircraft ground handling in the case of personnel substitutability. *Journal of Project Management*, 9(3), 255–268.
- Dean, J. W., Jr., & Sharfman, M. P. (1996). Does decision process matter? A study of strategic decision-making effectiveness. *Academy of Management Journal*, 39(2), 368–392.
- Eginli, M. A., & Nacaklı, Y. (2020). Uçak bakım eğitimlerinde artırılmış gerçeklik kullanımının değerlendirilmesi. *Journal of Aviation*, 4(1), 61–78.
- Eisenhardt, K. M., & Zbaracki, M. J. (1992). Strategic decision making. *Strategic Management Journal*, 13, 17–37.
- Elbanna, S. (2006). Strategic decision-making: Process perspectives. *International Journal of Management Reviews*, 8(1), 1–20.
- Elbanna, S., Child, J., & Dayan, M. (2013). A model of antecedents and consequences of intuition in strategic decision making: Evidence from Egypt. *Long Range Planning*, 46(1–2), 149–176.
- Fredrickson, J. W., & Mitchell, T. R. (1984). Strategic decision processes: Comprehensiveness and performance in an industry with an unstable environment. *Academy of Management Journal*, 27(2), 399–423.
- Garcia, A. B., Babiceanu, R. F., & Seker, R. (2021). Artificial intelligence and machine learning approaches for aviation cybersecurity: An overview. In *2021 Integrated Communications Navigation and Surveillance Conference (ICNS)* (pp. 1–8).
- Gong, X., Wang, S., & Jiao, R. (2019). An efficient 2D genetic algorithm for optimal shift planning considering daily-wise shift formats: A case of airport ground staff scheduling. In *2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 1440–1444). IEEE.
- Hambrick, D. C., & Mason, P. A. (1984). Upper echelons: The organization as a reflection of its top managers. *Academy of Management Review*, 9(2), 193–206.
- Hickson, D., Butler, R., Cray, D., Mallory, G., & Wilson, D. (1986). Top decisions: Strategic decision making in organizations. Jossey-Bass.
- Hodgkinson, G. P., Sadler-Smith, E., Burke, L. A., Claxton, G., & Sparrow, P. R. (2009). Intuition in organizations: Implications for strategic management. *Long Range Planning*, 42(3), 277–297.
- Jiao, Y., Dong, J., Han, J., & Sun, H. (2022). Classification and causes identification of Chinese civil aviation incident reports. *Applied Sciences*, 12(21), 10765.
- Johnson, G., Scholes, K., & Whittington, R. (2008). Exploring corporate strategy. Pearson.
- Joseph, S. R., Hlomani, H., Letsholo, K., Kaniwa, F., & Sedimo, K. (2016). Natural language processing: A review. *International Journal of Research in Engineering and Applied Sciences*, 6(3), 207–210.
- Kaya, M. (2023). Havacılık yönetimi öğrencilerinin yapay zekâ kaygısı ve teknoloji kaynaklı işsizlik endişesi [Master's thesis, Eskişehir Teknik Üniversitesi Lisansüstü Eğitim Enstitüsü].
- Khatri, N., & Ng, H. A. (2000). The role of intuition in strategic decision making. *Human Relations*, 53(1), 57–86.
- Li, Z., & Li, S. (2020). A comparison of melody created by artificial intelligence and human based on mathematical model. In *Proceedings of the 7th Conference on Sound and Music Technology (CSMT)* (pp. 121–130).
- Lindblom, C. E. (1959). The science of “muddling through.” *Public Administration Review*, 19(2), 79–88.
- Lubatin, M. H., Lane, P. J., & Schulze, W. S. (2005). A strategic management model of agency relationships in firm governance. In *The Blackwell handbook of strategic management* (pp. 225–254).
- Maple, C., Szpruch, L., Epiphaniou, G., Staykova, K., Singh, S., Penwarden, W., ... & Avramovic, P. (2023). The AI revolution: Opportunities and challenges for the finance sector. arXiv preprint.
- McCorduck, P., Minsky, M., Selfridge, O., & Simon, H. (1977). History of artificial intelligence. *IJCAI Proceedings*, 951–954.
- Miller, C. C., & Ireland, R. D. (2005). Intuition in strategic decision making: Friend or foe in the fast-paced 21st century? *Academy of Management Executive*, 19(1), 19–30.
- Mintzberg, H., Raisinghani, D., & Theoret, A. (1976). The structure of “unstructured” decision processes. *Administrative Science Quarterly*, 246–275.
- Parikh, J., Lank, A., & Neubauer, F. (1994). Intuition: The new frontier of management. Wiley-Blackwell.
- Pirim, H. (2006). Yapay zekâ. *Yaşar Üniversitesi E-Dergisi*, 1(1), 81–93.
- Poulet, J., & Parmentier, A. (2020). Shift planning under delay uncertainty at Air France: A vehicle-scheduling problem with outsourcing. *Transportation Science*, 54(4), 956–972.
- Quinn, J. B. (1978). Strategic change: Logical incrementalism. *Sloan Management Review*, 20, 7–21.
- Russell, S. J., & Norvig, P. (2010). Artificial intelligence: A modern approach (3rd ed.). Pearson.
- Sahraeian, P. (2024). Shift scheduling literature review. SSRN.
- Schwenk, C. R. (1995). Strategic decision making. *Journal of Management*, 21(3), 471–493.
- Seçkiner, S., Atay, M., & Eroğlu, Y. (2021). Robotik süreç otomasyonlarının havacılık sektörü uygulamaları ve geleceği. *Journal of Aviation*, 5(2), 290–297.
- Shepherd, N. G., & Rudd, J. M. (2014). The influence of context on the strategic decision-making process: A review of the literature. *International Journal of Management Reviews*, 16(3), 340–364.
- Simon, H. A. (1960). The new science of management decisions. Harper & Brothers.
- Simon, H. A. (1992). What is an ‘explanation’ of behaviour? *Psychological Science*, 3(3), 150–161.
- Spitz, R. (2020). The future of strategic decision-making. *Journal of Futures Studies*.
- Trunk, A., Birkel, H., & Hartmann, E. (2020). On the current state of combining human and artificial intelligence for strategic organizational decision making. *Business Research*, 13, 875–919.
- Ünal, A., & Kılınç, İ. (2020). Yapay zekâ işletme yönetimi ilişkisi üzerine bir değerlendirme. *Yönetim Bilişim Sistemleri Dergisi*, 6(1), 51–78.
- von Krogh, G. (2018). Artificial intelligence in organizations: New opportunities for phenomenonon-based theorizing. *Academy of Management Discoveries*, 4(4), 404–409.
- Wadud, Z. (2013). Simultaneous modeling of passenger and cargo demand at an airport. *Transportation Research Record*, 2336(1), 63–74.

- Yılmaz, M. K. (2017). Yolcu hizmetlerinde çalışan memnuniyeti: Havacılık işletmelerinde vardiyalı çalışanlar üzerine bir araştırma. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi*, 6(6), 127–137.
- Zhang, H., & Cai, J. (2021). Teaching mathematics through problem posing: Insights from an analysis of teaching cases. *ZDM–Mathematics Education*, 53(4), 961–973.
- MoghadasNian, S., & Karimi, P. (2025). Strategic Leadership in AI-Enhanced Aviation: Balancing Financial and Environmental Goals Through Differentiated Search. In *Proceedings of the 9th International Conference on Management, Accounting, Economics and Banking in the Third Millennium*. Bern, Switzerland. Language: English.
- Moghadasnian, S., & Rajol, M. (2025). Artificial Intelligence in Airline Business Management A Paradigm Shift in the Industry. *Journal of Business Data Science Research*, 4(01), 6-12.
- Pérez-Campuzano, D., Ortega, P. M., Andrada, L. R., & López-Lázaro, A. (2021). Artificial Intelligence potential within airlines: a review on how AI can enhance strategic decision-making in times of COVID-19. *Journal of Airline and Airport Management*, 11(2), 53-72.
- Ziakkas, D., Plioutsias, A., & Pechlivanis, K. (2022, January). Artificial intelligence in aviation decision making process. The transition from extended minimum crew operations to single pilot operations (SiPO). In *13th AHFE International Conference on Artificial Intelligence and Social Computing* (pp. 101-107). AHFE Conference.
- Fondevila-Gascón, J. F., Gutiérrez-Aragón, Ó., Lopez-Lopez, D., Curiel-Barrios, G., & Alabart-Algueró, J. (2025). Passenger perceptions of Artificial Intelligence in airline operations: Implications for air transport management. *Journal of Air Transport Management*, 129, 102874.

Cite this article: Degirmencioglu, M., Macit A. (2025). Shift Planning with Artificial Intelligence within the Scope of Strategic Decision-Making Approach in Airport Ground Handling Operations. *Journal of Aviation*, 9(3), 669-675.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Multidimensional Seat Comfort and Its Influence on Passenger Recommendation Behavior: Insights from Skytrax Reviews

Şahap Akan¹ 

¹Dicle University, School of Civil Aviation, 34469, Sur, Diyarbakır, Türkiye. (sahap.akan@dicle.edu.tr)

Article Info

Received: 30 August 2025
Revised: 22 September 2025
Accepted: 24 September 2025
Published Online: 10 October 2025

Keywords:

Airline industry
Skytrax
Seat comfort
Recommendation
Consumer Behavior

Corresponding Author: Şahap Akan

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1773181>

Abstract

This study examines how the multidimensional structure of seat comfort influences passengers' recommendations. To this end, 1,062 passenger reviews from Skytrax of the world's top 20 airlines from August 2008 and April 2025 were analysed using logistic regression. Five seat comfort variables were included: seat legroom, seat recline, seat width, aisle space, and TV screen viewing. The results indicate that all of these variables influence recommendation behavior, though to different degrees. Seat recline and aisle space were the strongest determinants, followed by seat width, viewing the TV screen, and seat legroom. This study contributes to the literature by moving beyond a generic satisfaction perspective and treating seat comfort as a multidimensional driver of passenger behavior. These findings are expected to have theoretical and practical implications, informing scholars' understanding of customer responses and guiding airline managers in improving service and seating strategies.

1. Introduction

“When a journey ends, what passengers often remember is not the destination itself but the physical feeling left in their bodies after sitting for hours. Comfort should not be understood only as the absence of discomfort, since in many cases both comfort and discomfort are experienced at the same time.” In travel conducted within restricted and narrow spaces, psychological perception becomes just as important as physical ease (Kremser et al., 2012). In this respect, seat comfort has turned into a decisive factor shaping passengers' overall satisfaction, airline preferences, and their willingness to recommend. Within the aircraft cabin, the perception of comfort is most strongly influenced by the seating experience (Wang et al., 2021). As a core point of the passenger experience, its importance increases depending on the duration and type of the flight. Even minor changes—whether on long-haul flights or short flights with tighter seating—can make a significant difference and reshape passengers' perceptions. Therefore, understanding the multidimensional structure of seat comfort is not only about improving service but also a strategic tool for strengthening customer loyalty and long-term commitment (Akash & Binoosh, 2022).

The literature emphasizes the significance of seat comfort as an important component of service delivery and a key factor in shaping the overall flight experience. Atalık et al. (2019), in their evaluation of in-flight service quality, identified seat comfort as the most critical element affecting value for money.

Similarly, Sebjan et al. (2017) reached comparable conclusions, further emphasizing that seat width is the most significant factor influencing perceived seat comfort. Li et al. (2024), using machine learning techniques, demonstrated that seat comfort ranks among the most influential determinants of service quality, noting that improving seat comfort from “very bad” to “very good” could increase passenger satisfaction by 29 percent. Ban and Kim (2019), through their analysis of passenger reviews, found that seat comfort was the most decisive factor influencing recommendation behavior. While these findings underline the importance of seat comfort for service quality and customer satisfaction, they generally approach it as a broad and holistic concept. Only a limited number of studies have examined specific subcomponents of seat comfort in detail. Most existing research has not explored aspects such as seat legroom, aisle space, or viewing screen conditions within a wider perspective. Moreover, studies that simultaneously address both the physical dimensions of seat comfort and passenger behavioral outcomes remain scarce. Therefore, there is a need for research that holistically examines the multidimensional structure of seat comfort. The present study seeks to systematically examine how each element within this multidimensional construct of seat comfort affects passengers' recommendation behavior.

This research makes several contributions to the literature. First, it stands out as one of the earliest studies to examine the impact of seat comfort—evaluated under the “seat” category in Skytrax—on passengers' recommendation behavior.

Second, the concept of seat comfort has not been treated merely as a general satisfaction factor; its direct influence on recommendation behavior has also been assessed. Additionally, the study disentangles its core components and provides a structural evaluation, an approach that is valuable for revealing causal relationships concerning the subdimensions of seat comfort in the existing literature. Third, the research integrates sectoral data into academic modeling. In this respect, it represents one of the notable studies in which real-time customer experiences are systematically organized and analyzed, thereby offering meaningful insights for both theory and practice.

2. Literature Review

2.1. Seat comfort

The physical environment plays a more critical role in the airline industry than in other service industries. Although various types of services are provided to passengers during a flight, these services alone often fail to ensure satisfaction. One of the main reasons behind this is that the physical conditions of the aircraft do not meet expectations, which in turn leads to dissatisfaction (Ban et al., 2019). For this reason, the seats—being the point of greatest contact and the most influential factor in shaping the flight experience—must be maintained at a high level of comfort. Consequently, seat comfort has emerged as a distinct area of research in the literature.

Previous studies have approached seat comfort from two main perspectives: physical design features and perceptual assessments (Wang et al., 2021). Studies focusing on physical design features have highlighted measurable ergonomic parameters such as legroom, seat width, and backrest shape (Phothong & Worasuwanarak, 2021). Other studies, such as Miller et al. (2019), have modeled seat comfort primarily through physical design factors like seat width and pitch, limiting their assessment to seat fit while neglecting perceptual or behavioral outcomes. Similarly, Zhao et al. (2019) investigated seat pitch using physical pressure measurements, focusing exclusively on physical variables. Kokorikou et al. (2016), in their study on ergonomic comfort and sustainable seat design, also concentrated solely on seat-related design elements. By contrast, studies with a perceptual focus emphasize subjective passenger experience and psychological aspects. For instance, Kremser et al. (2012) evaluated seat comfort from a perceptual perspective but considered only seat pitch as a physical variable. Liu et al. (2019) examined how passengers' adopted sitting postures influenced comfort perception, shedding light on behavioral variations rather than seat design itself. Anjani et al. (2020) assessed different seat pitch levels by combining both physical and psychological variables. Vanacore et al. (2019) adopted a multidimensional approach that integrated measurable physical factors with passenger perceptions, though their study did not account for broader cabin comfort factors or behavioral outcomes, thus remaining limited to the seat itself. The present study, however, moves beyond treating seat comfort as a single variable. It conceptualizes it as a multidimensional construct and systematically analyzes how its physical components influence recommendation behavior. In doing so, it provides a holistic assessment that integrates both physical design and customer behavior perspectives into a single model. Furthermore, the study classifies the subcomponents of seat comfort structurally and contributes to the literature by presenting a multidimensional framework based on secondary data.

2.1. Hypotheses

Seat legroom is one of the most important factors influencing passenger comfort, particularly in the economy class. It is defined as the actual knee space derived from the concept of seat pitch but varying depending on the seat structure (Phothong & Worasuwanarak, 2021). As a key component of passenger comfort, seat legroom has been recognized in the literature for its impact on consumer behavior. Lee and Luengo-Prado (2004) demonstrated that increasing legroom in two U.S. airlines significantly influenced passenger preferences. Business class passengers, in particular, were observed to assign a high value when provided with additional legroom. Panda et al. (2025) analyzed factors affecting passenger satisfaction by comparing different models, including logistic regression, and found that legroom had a significant effect on satisfaction across all models. Phothong and Worasuwanarak (2021) further noted that even minor differences in legroom can substantially affect passenger comfort on long-haul flights. Therefore, legroom is expected to influence both the flight experience and passengers' likelihood of recommending the airline.

H1. Seat legroom has a positive and significant effect on passengers' recommendation behavior.

Seat recline emerges as one of the key components of passenger comfort, particularly influencing perceptions of relaxation and sleep quality during long flights (Eversdijk et al., 2024). Findings in the literature support this view. McGill and Fenwick (2009) argued that lumbar support and seat recline allow the spine to return to a natural position, which directly enhances comfort perception. The physiological dimension of comfort, therefore, is likely to improve satisfaction and indirectly influence recommendation behavior. Caballero-Bruno (2022), in an experiment on sleeping quality across different seat positions in autonomous vehicles, found that a flat position provided higher sleep quality compared to a reclined one. Similarly, Roach et al. (2018) showed that different backrest angles had a significant effect on sleep duration and quality during a daytime, highlighting not only the physiological but also the psychological contribution of recline to perceived restfulness. This suggests that seat recline may enhance comfort and, in turn, trigger recommendation behavior.

H2. Seat recline has a positive and significant effect on passengers' recommendation behavior.

Seat width refers to the distance between armrests, a dimension that directly shapes comfort perception. Variations in seat width affect not only perceived comfort but also physical well-being, as narrower seats create additional body pressure that may result in passenger discomfort and tension (Miller et al., 2019). For this reason, it is a factor that must be carefully addressed in seat design. Anjani et al. (2021), in their study measuring the influence of different seat widths on comfort, reported that even a one-inch increase in width significantly enhanced perceived comfort and lowered discomfort scores. Similarly, Mendoza (2018) emphasized that minor increases in seat width positively affect comfort and the overall flight experience. Vredenburg et al. (2015) further noted that one of the most common conflicts among passengers arises when seatmates encroach upon personal space, which heightens discomfort and irritation. Therefore, seat width is a critical factor for both comfort and satisfaction.

H3. Seat width has a positive and significant effect on passengers' recommendation behavior.

Aisle space is another important component of passenger comfort, often regarded as an indicator of personal space (Lacic et al., 2016). Several studies have noted its direct and indirect influence on seat comfort. Fuchte (2014) argued that congestion in aisles, particularly during luggage storage, limits perceptions of personal space and negatively affects comfort. Ban et al. (2019), analyzing passenger reviews from Skytrax, identified aisle space as a significant determinant of comfort, which also influences satisfaction and recommendation behavior. Findings from Lacic et al. (2016) support this conclusion, underlining its relevance for the passenger experience.

H4. Aisle space has a positive and significant effect on passengers' recommendation behavior.

The concept of the seat should be considered not only in terms of its physical characteristics but also with respect to surrounding elements. One such factor is the presence of the in-flight TV screen, a feature that significantly contributes to both comfort and overall service quality (Park et al., 2020). In the literature, TV screens and similar in-flight entertainment elements are often examined not merely as ergonomic aspects but as multidimensional components of comfort that affect the time passengers spend seated. Most prior studies have assessed TV experience under the broader category of entertainment, focusing on its role in comfort. Atalik et al. (2019) noted that entertainment is an essential determinant of passenger satisfaction. Similarly, Liu et al. (2019) emphasized the importance of ergonomics, suggesting that TV screens should be placed closer and allow for adjustable personal lighting, thereby improving the comfort associated with the viewing experience. Enhancing this experience can thus strengthen seat comfort and positively affect passenger perceptions.

H5. Viewing TV screen has a positive and significant effect on passengers' recommendation behavior.

Based on these hypotheses, the research model has been developed (Figure 1).

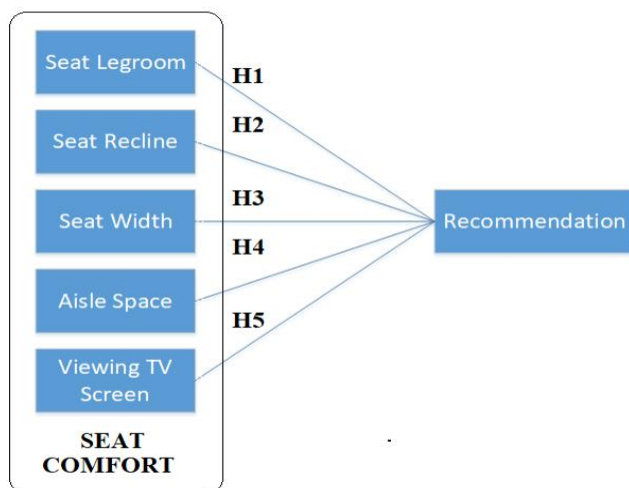


Figure 1. Research Model

3. Methodology

3.1. Data and Data Process

Since airlines do not publish passenger reviews directly on their websites, several independent, web-based platforms offer this service. These platforms allow passengers to evaluate every stage of the air transport service they receive. One of the most widely used is Skytrax (Skytrax, 2024; Song et al., 2020). Skytrax is an international rating organization that aims to

improve service quality for airlines and airports worldwide through surveys and customer reviews. In addition to enabling passengers to share their evaluations, Skytrax grants various awards to the aviation companies that provide these services (Alanazi et al., 2024). For researchers, Skytrax passenger reviews also represent a valuable source of data. As secondary data, they provide meaningful insights for studies conducted from different perspectives (Bakır et al., 2022). This study included secondary data obtained from Skytrax in the analysis.

A total of 1,352 passenger reviews were collected for the study. However, 290 reviews were excluded due to being incomplete, leaving 1,062 valid evaluations for analysis. Due to the insufficient number of observations in other classes, only economy and premium economy classes were included in the analysis. Reviews posted between August 2008 and April 2025 were included, and the dataset was retrieved on April 12, 2025. Data collection was carried out using the "Web Scraper" program. The airlines included in the study correspond to the top 20 carriers listed in "The World's Top 100 Airlines" in 2024. These are: Qatar Airways, Singapore Airlines, Emirates, ANA All Nippon Airways, Cathay Pacific Airways, Japan Airlines, Turkish Airlines, EVA Air, Air France, Swiss International Air Lines, Korean Air, Hainan Airlines, British Airways, Fiji Airways, Iberia, Vistara, Virgin Atlantic, Lufthansa, Etihad Airways, and Saudi Arabian Airlines.

3.2. Data analysis

In this study, data on seat comfort obtained from the Skytrax platform was analyzed to examine passengers' recommendation behavior. Since the dependent variable is binary, a logistic regression analysis was performed. Logistic regression is a statistical model that explains the relationship between a categorical dependent variable (e.g., the presence or absence of a condition) and one or more independent variables that may be continuous or categorical. Logistic regression is also referred to in the literature as a logistic model or logit model (Nick & Campbell, 2007). This method estimates the probability of an outcome based on the independent variables (Domínguez-Almendros et al., 2011). Logistic regression is modeled according to the following equation (Kleinbaum, 1994):

$$P(X) = \frac{1}{1 + e^{-(\alpha + \sum \beta_i X_i)}} \quad (1)$$

In this equation:

P(X): represents the probability that a passenger will recommend the airline (1 = recommendation, 0 = no recommendation).

α : denotes the constant term of the model.

β_i : indicates the coefficient of each independent variable.

X_i : represents the independent variables related to seat comfort (seat legroom, seat recline, seat width, aisle space, viewing TV screen).

Through this equation, the probability of a passenger recommending the airline was modeled based on their evaluations of seat comfort. Before proceeding with the analysis, several prerequisites were addressed to ensure the robustness of the model. First, descriptive statistics were generated for the variables, and a correlation matrix was constructed to determine the direction and strength of the relationships among them. To assess potential multicollinearity among the independent variables, variance inflation factor (VIF) and tolerance values were calculated and examined. In addition, the omnibus likelihood ratio test was conducted to evaluate the overall validity and significance of

the model. Model explanatory power was further assessed through R^2 statistics, which revealed the extent to which the dependent variable was explained (McFadden, Cox & Snell, Nagelkerke, and Tjur). The coefficients and significance levels of the predictors were then reported. Furthermore, a classification table and a receiver operating characteristic (ROC) curve were generated to evaluate the classification performance of the model. All analyses were carried out using Jamovi software (version 2.4.28), an open-source statistical package known for its user-friendly interface that facilitates the execution of statistical procedures.

4. Results

The results of the logistic regression analysis conducted to examine the effects of the independent variables on passengers' recommendation behavior are presented below. During the analysis process, descriptive statistics were first reported, VIF values were calculated, and a correlation matrix was generated. The purpose of this matrix was to check for multicollinearity, observe the direction and strength of the

relationships among the variables, and better understand the structure of the data (Hair et al., 2019). As shown in Table 1, the correlation between aisle space and seat legroom was found to be 0.735, while the remaining correlation coefficients ranged from 0.534 to this value. Since all correlation coefficients were below the 0.8 threshold, there was no indication of multicollinearity (Schreiber-Gregory, 2018). In addition, VIF values ranged between 1.04 and 1.23, which is well below the cut-off point of 3.3, further confirming the absence of multicollinearity (Kock, 2017). Similarly, tolerance values varied between 0.815 and 0.964, all above the threshold of 0.2, again suggesting no multicollinearity risk (Senaviratna & A. Cooray, 2019). Table 1 also reports descriptive statistics for passenger satisfaction levels with respect to seat comfort factors, measured on a five-point scale. Among these, the highest mean was observed for viewing TV screen at 3.151 (std. dev = 1.418), followed by aisle space at 2.832 (std. dev = 1.348), seat legroom at 2.788 (std. dev = 1.471), seat recline at 2.763 (std. dev = 1.318), and seat width at 2.712 (std. dev = 1.383).

Table 1. Descriptive statistics and correlation matrix

	Mean	Std. Dev.	VIF	Tolerance	1	2	3	4	5
Seat Legroom	2.788	1.471	1.230	0.815	-				
Seat Recline	2.763	1.318	1.120	0.889	0.700*	-			
Seat Width	2.712	1.383	1.200	0.834	0.719*	0.693*	-		
Aisle Space	2.832	1.348	1.220	0.818	0.735*	0.642*	0.732*	-	
Viewing TV Screen	3.151	1.418	1.040	0.964	0.534*	0.562*	0.540*	0.568*	-

Note: $p < 0.001$ *

In addition, the omnibus likelihood ratio test was conducted to examine whether the independent variables made a significant contribution to the model. This test evaluates the combined effect of all variables on recommendation behavior (Cheng et al., 2010). As shown in Table 2, the results indicate that all predictors played a significant role in improving the model's predictive accuracy ($p < 0.001$). Among them, seat recline made the strongest contribution, with the highest chi-square value ($\chi^2 = 50.6$). This was followed by aisle space ($\chi^2 = 42.8$), seat width ($\chi^2 = 22.7$), viewing TV screen ($\chi^2 = 19.1$), and seat legroom ($\chi^2 = 12.5$), respectively.

Table 2. Likelihood ratio tests for individual predictors

Predictor	χ^2	df	p
Seat Legroom	12.469	1	<.001
Seat Recline	50.593	1	<.001
Seat Width	22.709	1	<.001
Aisle Space	42.735	1	<.001
Viewing TV Screen	19.056	1	<.001

In logistic regression analysis, the overall validity and explanatory power of the model are reported in the model

summary. Table 3 presents the results related to the model summary. A low deviance value (591) indicates that the model fits the data well (Lei & Bae, 2013). The explanatory strength of the model was assessed through several pseudo R^2 measures. The values were found as follows: McFadden's $R^2 = 0.589$, Cox & Snell $R^2 = 0.549$, Nagelkerke $R^2 = 0.741$, and Tjur $R^2 = 0.651$. The McFadden's R^2 value of 0.589 exceeds the recommended range for a good fit (0.2–0.4), suggesting a very strong explanatory power (McFadden, 1974). In addition, the Cox & Snell R^2 value of 0.549 indicates that the independent variables explain 54.9% of the variance in the dependent variable (Engel et al., 2016). The Nagelkerke R^2 value of 0.741 also reflects the explanatory strength and accuracy of the model (Ardiansyah & Nurjanah, 2022; Lincoln et al., 2022). Likewise, the Tjur R^2 value of 0.651 shows that the model achieves a 65.1% discrimination performance in predicting the two categories of the dependent variable (Tjur, 2009). Finally, the model significantly outperformed the null model ($\chi^2 (5) = 846$, $p < .001$), with a deviance reduction from approximately 1,437 to 591. These findings confirm that the model explains a substantial portion of the variance in the dependent variable.

Table 3. Model summary

Model	Deviance	R^2_{McF}	R^2_{CS}	R^2_N	R^2_T	Overall Model Test		
						χ^2	df	p
Full Model	591	0.589	0.549	0.741	0.651	846	5	<.001

Note: R^2_{McF} = McFadden's R^2 , R^2_{CS} = Cox & Snell R^2 , R^2_N = Nagelkerke R^2 , R^2_T = Tjur R^2

Table 4 shows the coefficients and related statistical findings for the variables that affect recommendation behavior. For each independent variable, the estimates, confidence intervals, standard errors, z-values, and p-values are reported. The estimated coefficients explain the log-odds difference between a recommendation of 1 and a recommendation of 0 (Hosmer, 2000). As shown in Table 4, the p-values of all predictors were below .001, indicating that

each variable significantly influences recommendation behavior. The estimated coefficients were 0.347 for seat legroom, 0.773 for seat recline, 0.522 for seat width, 0.753 for aisle space, and 0.380 for viewing the TV screen. Accordingly, the highest log-odds coefficients were observed for seat recline and aisle space.

Table 4. Model coefficient- recommendation

Predictor	Estimate	95% Confidence Interval		SE	Z	p
		Lower	Upper			
Intercept	-8.633	-9.659	-7.606	0.524	-16.48	< .001
Seat Legroom	0.347	0.155	0.540	0.098	3.53	< .001
Seat Recline	0.773	0.550	0.996	0.114	6.79	< .001
Seat Width	0.522	0.305	0.739	0.111	4.71	< .001
Aisle Space	0.753	0.519	0.987	0.119	6.31	< .001
Viewing TV Screen	0.380	0.207	0.553	0.088	4.30	< .001

Note. Estimates represent the log odds of "Recommendation = 1" vs. "Not Recommendation = 0"

Table 5 shows how well the logistic regression model distinguished between recommendation and non-recommendation behavior. For the "No Recommendation" group, the model correctly classified 573 out of 627 cases, for an accuracy rate of 91.4%. In the Recommendation group, the

model correctly predicted 371 out of 435 cases, for an accuracy rate of 85.3%. Overall, the accuracy rate was 88.9%. These results suggest that the model performs well in classifying passenger recommendation behavior.

Table 5. Classification table

	Predicted		Percentage Correct
	No Recommendation	Recommendation	
No Recommendation	573	54	91.4
Recommendation	64	371	85.3
Accuracy			88.9
AUC			0.95

In Figure 2, the discriminative power of the model was evaluated using the ROC curve (Roumeliotis et al., 2024). The AUC was found to be 0.95. This value reflects the model's ability to distinguish between recommendation and non-recommendation behavior. The closer the value is to 1, the stronger the model's discriminatory power. According to Hosmer et al. (2000), an AUC greater than 0.90 indicates that the model demonstrates an excellent level of classification performance.

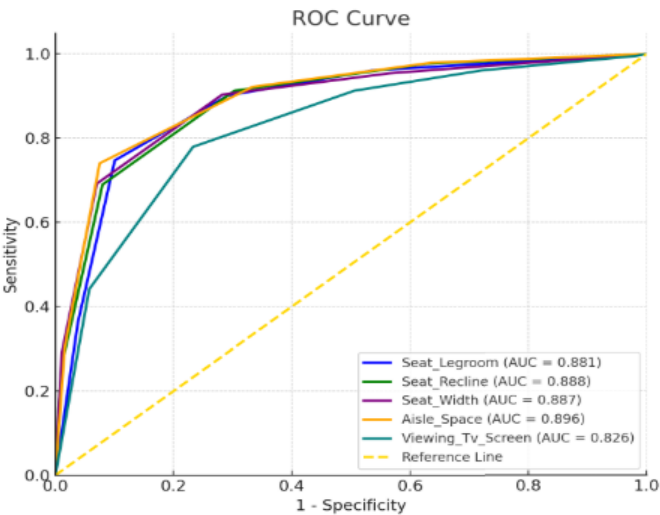


Figure 2. ROC curve

5. Conclusion

Seat comfort, as an essential part of the passenger experience, goes beyond its physical attributes and represents a multidimensional construct that shapes customer behavior. This study provides a new perspective in the literature by systematically examining the effects of the main components of passenger comfort on recommendation behavior. Several important theoretical contributions emerge. First, seat recline was identified as the strongest predictor of recommendation behavior ($\beta = 0.773$, $p < 0.001$; $\chi^2 = 50.6$). This finding highlights that seat recline is not merely a posture adjustment but a factor central to the passenger experience, enhancing restfulness and comfort during the flight. While the existing literature emphasizes the physiological benefits of seat recline (Eversdijk et al., 2024; McGill & Fenwick, 2009), this study statistically confirms its influence on recommendation behavior, demonstrating how physical comfort dimensions can directly shape customer actions. Second, aisle space was also found to have a significant effect on recommendation behavior ($\beta = 0.753$, $p < 0.001$; $\chi^2 = 42.8$). Prior studies have linked aisle space to satisfaction (Ban et al., 2019), with passenger comments noting that crowded aisles diminish perceptions of personal space and lower satisfaction (Fuchte, 2014). This research extends those insights by showing that aisle space also shapes recommendation behavior, establishing it as an independent predictor. Third, seat width was shown to have a

positive and significant effect on recommendation behavior ($\beta = 0.522$, $p < 0.001$; $\chi^2 = 22.7$). While earlier research highlighted its role in passenger satisfaction, the present study reveals that seat width, by combining physical comfort with psychological factors such as perceived personal space, also influences post-flight behavioral outcomes such as recommendation (Anjani et al., 2021; Mendoza, 2018). Thus, seat width impacts not only an immediate sense of comfort, but also brand perception and recommendation after the flight. Fourth, the viewing TV screen variable significantly affected recommendation behavior ($\beta = 0.380$, $p < 0.001$; $\chi^2 = 19.1$). As a central feature of the modern airline experience, in-flight entertainment systems allow passengers to use their time more effectively while reducing stress and anxiety during flights. Theoretically, this finding underscores the importance of technological and experiential innovations not only for short-term satisfaction but also for building sustainable satisfaction and a positive brand image. This highlights the strategic role of technology-based components in shaping customer experience. Finally, seat legroom was also found to have a significant effect on recommendation behavior ($\beta = 0.347$, $p < 0.001$; $\chi^2 = 12.5$). Although prior studies have emphasized the critical role of legroom in seat comfort (Lee & Luengo-Prado, 2004; Panda et al., 2025; Phothong & Worasuwannarak, 2021), this study shows its limited effect on recommendation behavior. This result theoretically indicates that the influence of comfort elements on customers is multidimensional, with each factor carrying different weight. It also suggests that different combinations of these factors may influence passengers' recommendation behavior.

The study also provides valuable managerial implications for airline managers and practitioners. First, the findings reveal that ergonomic elements of seat comfort, such as seat recline and aisle space, play an important role in shaping recommendation behavior. Accordingly, one key managerial implication is that seat layout optimization should not be limited to increasing seating capacity alone, but should also involve the development of supportive policies. This issue becomes particularly relevant for long-haul flights, where passengers' expectations regarding seat comfort are even higher (Kuprikov et al., 2021). Airlines should therefore design dynamic seating policies that vary depending on flight duration and route. For instance, on routes with lower load factors or high service expectations, corridor width and seat recline could be optimized to provide passengers with a more spacious and comfortable seating environment. Implementing such flexible practices has the potential to positively influence recommendation and choice behavior, thereby providing airlines with a competitive advantage in the long run.

Psychological and perceptual factors also play a significant role in shaping passengers' comfort experiences. Therefore, rather than depending solely on traditional technical standards, airline managers should revise comfort criteria in seat design and layout by considering passenger feedback (Ahmadpour et al., 2022; Lacic et al., 2016). Feedback gathered from various channels, including social media, could serve as a practical guide in this regard. This approach would enable airlines to establish a minimum comfort threshold that considers the needs of various passenger groups, such as business travelers, and update it periodically through a dynamic standardization process. When feedback indicates that comfort levels fall below this threshold, managers should proactively respond and promptly make adjustments.

This study has several limitations. First, it relies on secondary data and only covers the top 20 airlines in 2024, focusing on economy and premium economy classes. Future studies could expand the scope by including additional

airlines, other cabin classes, and various business models. This could reveal differences between airline types and service strategies. Second, the analysis focused on only five variables related to seat comfort. Including factors such as seat privacy, storage space, and sleep comfort would likely improve the model. Third, the study used logistic regression. While this method is suitable, it cannot fully capture nonlinear relationships or interaction effects. Alternative approaches, including machine learning, could provide richer insights. Finally, the sample reflects passengers traveling with the top 20 airlines. Therefore, the results cannot be generalized to all regions or customer groups. Future studies should examine a wider set of airlines and consider cultural and demographic variations among passengers.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

References

- Ahmadpour, N., Robert, J.-M., & Lindgaard, G. (2022). Impact of the seat on aircraft passenger comfort experience in the cabin interior. In *Advances in Ergonomics In Design, Usability & Special Populations: Part II* (Vol. 19).
- Akash, V. M., & Binoosh, S. A. (2022). Loyal and disloyal customer satisfaction in aviation industry. *Proceedings of the 2nd Indian International Conference on Industrial Engineering and Operations Management*, 829–838.
- Alanazi, M. S. M., Li, J., & Jenkins, K. W. (2024). Evaluating airport service quality based on the statistical and predictive analysis of Skytrax passenger reviews. *Applied Sciences (Switzerland)*, 14(20), 1–17.
- Anjani, S., Li, W., Ruiter, I. A., & Vink, P. (2020). The effect of aircraft seat pitch on comfort. *Applied Ergonomics*, 88(June), 103132.
- Anjani, S., Song, Y., Hou, T., Ruiter, I. A., & Vink, P. (2021). The effect of 17-inch-wide and 18-inch-wide airplane passenger seats on comfort. *International Journal of Industrial Ergonomics*, 82(January), 103097.
- Ardiansyah, T., & Nurjanah. (2022). Entrepreneurial student motivation analysis through online media at universities in Jakarta: Binary logistic regression approach. *Proceedings - 2022 2nd International Conference on Information Technology and Education, ICIT and E 2022*, 257–261.
- Atalık, Özlem, Bakır, M., & Akan, Ş. (2019). The role of in-flight service quality on value for money in business class: A logit model on the airline industry. *Administrative Sciences*, 9(1), 1–15.
- Bakır, M., Akan, Ş., Özdemir, E., Nguyen, P. H., Tsai, J. F., & Pham, H. A. (2022). How to achieve passenger satisfaction in the airport? Findings from regression analysis and necessary condition analysis approaches through online airport reviews. *Sustainability (Switzerland)*, 14(4), 1–20.
- Ban, H. J., Joung, H.-W., & Kim, H.-S. (2019). The text mining approach to understand seat comfort experience of airline passengers through online review. *Culinary Science & Hospitality Research*, 25(9), 38–46.
- Ban, H. J., & Kim, H. S. (2019). Understanding customer experience and satisfaction through airline passengers' online review. *Sustainability (Switzerland)*, 11(15), 1–

- 17.
- Caballero-Bruno, I., Wohllebe, T., Töpfer, D., & Hernández-Castellano, P. M. (2022). The effect of seating recline on sleep quality, comfort and pressure distribution in moving autonomous vehicles. *Applied Ergonomics*, 105(January), 103844.
- Cheng, P. E., Liou, M., & Aston, J. A. D. (2010). Likelihood ratio tests with three-way tables. *Journal of the American Statistical Association*, 105(490), 740–749.
- Domínguez-Almendros, S., Benítez-Parejo, N., & Gonzalez-Ramirez, A. R. (2011). Logistic regression models. *Allergologia et Immunopathologia*, 39(5), 295–305.
- Engel, M. S., Pfaffenbach, C., & Fels, J. (2016). Analysis of socio-cultural differences and psychoacoustic parameters in sound perception in a public park and its surroundings. *Proceedings of the INTER-NOISE 2016 - 45th International Congress and Exposition on Noise Control Engineering: Towards a Quieter Future*, 1991–1998.
- Eversdijk, S. M., de Vos, F. J. C., van Zee, A. A. T., Houtepen, N. C. A., van Haaff, M. I., Iserief, M. A. C., & Vink, P. (2024). Does a reclined backrest with less legroom meet the same comfort as a fixed backrest with 80 mm more leg room? *Work*, 1–9.
- Fuchte, J. C. (2014). Enhancement of aircraft cabin design guidelines with special consideration of aircraft turnaround and short range operations. In *DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. - Forschungsberichte (Issue 17)*.
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning.
- Hosmer, D. W. (2000). *Applied logistic regression*. Wiley&Sons, Inc.
- Kleinbaum, D. G. (1994). *Introduction to logistic regression*. In *Logistic Regression*.
- Kock, N. (2017). Common method bias: A full collinearity assessment method for PLS-SEM. In H. Latan & R. Noonan (Eds.), *Partial least squares path modeling* (pp. 215–257). Springer.
- Kokorikou, A., Vink, P., De Pauw, I. C., & Braca, A. (2016). Exploring the design of a lightweight, sustainable and comfortable aircraft seat. *Work*, 54(4), 941–954.
- Kremser, F., Guenzkofer, F., Sedlmeier, C., Sabbah, O., & Bengler, K. (2012). Aircraft seating comfort: The influence of seat pitch on passengers' well-being. *Work*, 41(SUPPL.1), 4936–4942.
- Kuprikov, M. Y., Orekhov, A. A., Shulga, Y. D., & Min, Y. N. (2021). Influence of passenger comfort requirements on the interior layout of long-haul aircraft. *Civil Engineering and Architecture*, 9(3), 820–827.
- Lacic, E., Kowald, D., & Lex, E. (2016). High enough? Explaining and predicting traveler satisfaction using airline reviews. *HT 2016 - Proceedings of the 27th ACM Conference on Hypertext and Social Media*, May, 249–254.
- Lee, D., & Luengo-Prado, M. J. (2004). Are passengers willing to pay more for additional legroom? *Journal of Air Transport Management*, 10(6), 377–383.
- Lei, T., & Bae, K. T. (2013). Deviance statistics in model fit and selection in ROC studies. *Medical Imaging 2013: Image Perception, Observer Performance, and Technology Assessment*, 8673, 86731A1-8.
- Li, Q., Jing, R., & Xihua Zhu. (2024). Determinants of travel satisfaction for commercial airlines: A data mining approach. *Engineering Applications of Artificial Intelligence*, 133(PF), 108597.
- Lincoln, T. M., Schlier, B., Strakeljahn, F., Gaudiano, B. A., So, S. H., Kingston, J., Morris, E. M. J., & Ellett, L. (2022). Taking a machine learning approach to optimize prediction of vaccine hesitancy in high income countries. *Scientific Reports*, 12(1), 1–12.
- Liu, J., Yu, S., & Chu, J. (2019). The passengers' comfort improvement by sitting activity and posture analysis in civil aircraft cabin. *Mathematical Problems in Engineering*, 2019, 1–10.
- McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior (pp. 105–142).
- McGill, S. M., & Fenwick, C. M. J. (2009). Using a pneumatic support to correct sitting posture for prolonged periods: A study using airline seats. *Ergonomics*, 52(9), 1162–1168.
- Mendoza, R. L. (2018). Health risk, price efficiency, and airline seat size regulation. *International Journal of Healthcare Management*, 11(2), 122–132.
- Miller, E. L., Lapp, S. M., & Parkinson, M. B. (2019). The effects of seat width, load factor, and passenger demographics on airline passenger accommodation. *Ergonomics*, 62(2), 330–341.
- Nick, T. G., & Campbell, K. M. (2007). *Logistic regression*. In *Topics in Biostatistics*.
- Panda, A., Perannagari, K. T., & Govindaluri, S. M. (2025). Identifying key predictors of airline passenger satisfaction: A comparative model evaluation study. *2025 IEEE International Conference on Interdisciplinary Approaches in Technology and Management for Social Innovation, IATMSI 2025*, 3, 1–6.
- Park, S., Lee, J., & Nicolau, J. L. (2020). Understanding the dynamics of the quality of airline service attributes: Satisfiers and dissatisfiers. *Tourism Management*, 81(January), 1–8.
- Phothong, K., & Worasuwanarak, B. (2021). Aircraft seat: The study of airline seat pitching and comfortable. *E3S Web of Conferences*, 244, 1–5.
- Roach, G. D., Matthews, R., Naweed, A., Kontou, T. G., & Sargent, C. (2018). Flat-out napping: The quantity and quality of sleep obtained in a seat during the daytime increase as the angle of recline of the seat increases. *Chronobiology International*, 35(6), 872–883.
- Roumeliotis, S., Schurgers, J., Tsalikakis, D. G., D'Arrigo, G., Gori, M., Pitino, A., Leonardis, D., Tripepi, G., & Liakopoulos, V. (2024). ROC curve analysis: a useful statistic multi-tool in the research of nephrology. *International Urology and Nephrology*, 56(8), 2651–2658.
- Schreiber-Gregory, D. N. (2018). Ridge regression and multicollinearity: An in-depth review. *Model Assisted Statistics and Applications*, 13(4), 359–365.
- Sebjan, U., Tominc, P., & Sirec, K. (2017). Multiple conceptual modelling of perceived quality of in-flight airline services. *Promet-Traffic&Transportation*, 29(3), 311–319.
- Senaviratna, N. A. M. R., & A. Cooray, T. M. J. (2019). Diagnosing multicollinearity of logistic regression model. *Asian Journal of Probability and Statistics*, 5(2), 1–9.
- Song, C., Guo, J., & Zhuang, J. (2020). Analyzing passengers' emotions following flight delays- a 2011–2019 case

- study on SKYTRAX comments. *Journal of Air Transport Management*, 89(February), 101903.
- Tjur, T. (2009). Coefficients of determination in logistic regression models - A new proposal: The coefficient of discrimination. *American Statistician*, 63(4), 366–372.
- Vanacore, A., Lanzotti, A., Percuoco, C., Capasso, A., & Vitolo, B. (2019). Design and analysis of comparative experiments to assess the (dis-)comfort of aircraft seating. *Applied Ergonomics*, 76(December 2017), 155–163.
- Vredenburg, A. N., Zackowitz, I. B., & Vredenburg, A. G. (2015). Air rage: What factors influence airline passenger anger? *Proceedings of the Human Factors and Ergonomics Society*, 2015-Janua, 400–404.
- Wang, J., Zhi, J. Y., Du, Y., Xiang, Z. R., Feng, S., & Chen, J. P. (2021). A method identifying key optimisation points for aircraft seat comfort. *Ergonomics*, 64(3), 287–304.
- Zhao, C., Yu, S. huai, Miller, C., Ghulam, M., Li, W. hua, & Wang, L. (2019). Predicting aircraft seat comfort using an artificial neural network. *Human Factors and Ergonomics In Manufacturing*, 29(2), 154–162.

Cite this article: Akan, S. (2025). Multidimensional Seat Comfort and Its Influence on Passenger Recommendation Behavior: Insights from Skytrax Reviews. *Journal of Aviation*, 9(3), 676-683.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Bibliometric Analysis of Sustainable Aviation Fuels Using Biblioshiny

Vurgun Topçuoğlu^{1*}, Mevlüt Üzülmaz²

^{1*}Istanbul Nisantasi University, Aviation Management Department, Istanbul, Türkiye. (vurgun.topcuoglu@nisantasi.edu.tr)

²Erciyes University, Aviation Management Department, Kayseri, Türkiye. (mevlutuzulmez@erciyes.edu.tr)

Article Info

Received: 24 June 2025

Revised: 21 July 2025

Accepted: 07 August 2025

Published Online: 10 October 2025

Keywords:

Aviation

Sustainable Aviation Fuels

Bibliometric Analysis

Corresponding Author: *Vurgun Topçuoğlu*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1726687>

Abstract

With the liberalization of the air transport sector and the positive impact of globalization, aviation activities are experiencing rapid growth. The growth in the aviation sector is not limited to passenger transportation, but also extends to air cargo transportation. While the sector offers numerous opportunities for economic development, it also brings various negative impacts, including high levels of carbon emissions and noise pollution. To reduce carbon emissions, businesses and authorized institutions have developed various projects, and the use of sustainable aviation fuels (SAF) is crucial in these initiatives. Although numerous studies are available in the literature, it is evident that insufficient studies are compiling the current status and future potential of sustainable aviation fuels. In this study, 480 scientific studies from the Web of Science database were examined, and 403 relevant scientific publications were systematically analyzed using a bibliometric analysis method in the Biblioshiny program. The analysis, data collection, and analysis processes, along with the findings obtained, are presented through visualizations. The fact that the words “emission” and “energy” are used 46 times each, and the word “airplane” is used 40 times, in the studies demonstrates the multidimensionality of the subject. According to the analysis, it is believed that SAF production has not yet reached the desired level, but is expected to become more effective in the future.

1. Introduction

With the end of the Cold War period and the more effective use of military technologies in the field of civil aviation, the aviation sector has gained significant momentum (Töret & Söğüt, 2022). With the impact of the moderate environment created by globalization worldwide, the development in the aviation field has continued at an accelerated pace. In 2019, airline passenger traffic worldwide increased by 4.1% (Dube et al., 2021). However, with the COVID-19 pandemic in 2020, these increases started to decline dramatically. In the second quarter of 2020, international passenger traffic dropped by approximately 95% (Sun et al., 2020). In the post-pandemic period, signs of slow recovery were seen. In 2021, air traffic worldwide increased by 13% compared to the previous year (Dube et al., 2021). Following this period of fluctuation and recovery, the aviation sector has undergone significant transformation. Especially with the investments made by developing countries in airport infrastructure, the demand for air transportation in these countries, along with the development of technological opportunities, is driving significant progress in the aviation sector (Erdem, 2023). The progress in the aviation sector not only creates employment but also has positive effects on other sectors that contribute to the country's economy. Airport investments have significantly expanded the country's trade and tourism potential by

increasing air traffic (Aksoy & Dursun, 2018). While the aviation sector makes a significant contribution to global economic growth, it also generates high carbon emissions. Air transportation is a fossil fuel-intensive sector. Commercial aviation relies on liquid fuels derived from crude oil. The perfect combustion of 1 kg of kerosene produces 3.16 kg of CO₂ (ICAO, 2017). According to the International Energy Agency, the aviation sector is responsible for about 2.5% of global carbon dioxide (CO₂) emissions (Hannes Gauch, 2025). Today, this rate is constantly on an upward trend, driven by increasing air traffic and expanding air transportation. Sustainable aviation fuels play a crucial role in achieving net-zero emissions targets, with a 65% share (IATA, 2021). Sustainable aviation fuels are expected to produce fewer emissions than conventional fuels, improve air quality, be stable, be produced from a variety of sources, and improve flight operations (Heyne et al., 2021).

The technological processes and methods used in the production of sustainable aviation fuels are continually being developed and diversified, supported by various teams, companies, and even countries (Nigam & Singh, 2011). Since the conditions under which aviation activities take place are challenging and variable, several factors are considered when selecting a sustainable aviation fuel, including sensitivity to temperature changes, combustion rate, adaptability to the existing system, the amount of energy released, and the

compounds formed as a result of combustion. Before an aviation fuel is put into commercial use, it must pass many tests and receive approval from authorized organizations. The approval of these tests is carried out by the American Society for Testing and Materials (ASTM) (Yaşar & Onat, 2025). Sustainable aviation fuels, which are approved and blended into fuels at specific ratios, are used in commercial flights (Yılmaz & Atmanlı, 2016). Hydrogenated esters and fatty acids (HEFA technology) are the most widely accepted products in this field. In the HEFA production technique, molecules containing long carbon chains, such as vegetable oils, used cooking oils, and animal fats, are processed using hydrogen to produce products with jet fuel properties (Ng et al., 2021). The most significant disadvantage of this method is the high energy requirement. The amount of energy required increases the cost significantly. The increasing use of renewable energy sources has the potential to reduce these costs (Zubaidi, 2024). The cost of SAF is projected to drop to around USD 1,000 per ton in the 2030s (Nyoh, 2021). As an alternative to this approach, Power to Liquid (PtL) technology comes to the fore. This technology represents an innovative approach that produces synthetic fuel from atmospheric carbon dioxide and water, utilizing renewable energy sources (Ridjan et al., 2016). It is promising for zero-emission fuel production, especially in environments with high potential for solar and wind energy. Due to the high economic investment requirements, PtL technology has not been as well accepted in the sector as HEFA (Schmidt et al., 2018).

The barriers to sustainable fuel production are not only production-related, but also include economic, environmental, and technological barriers. From an economic perspective, the cost of sustainable aviation fuel production is 2 to 4 times higher than that of conventional jet fuel. In 2022, the cost of SAFs ranged from \$ 1,500 to \$ 2,500 per ton (Souza et al., 2024). However, with technological advances, R&D studies, optimizations in production processes, and support, the production cost of pure fuels is expected to reach a level comparable to that of conventional jet fuels by 2035. To achieve this goal, several steps should be taken in conjunction, including increasing production capacity, diversifying raw material sources, strengthening the supply chain, and obtaining support from the authorities. High costs are incurred for the establishment and operation of the facilities necessary for producing Sustainable Aviation Fuels (SAFs). In this respect, especially the costs related to licensing, construction, and the labor force are significant (Bielski, 2015).

The aviation sector is taking important steps towards the use of sustainable aviation fuels. Large aviation companies enter into long-term supply agreements with sustainable fuel producers, supporting technology transfer, incentives, and R&D collaborations to increase the use of these fuels (Yaşar & Onat, 2025). However, the support of countries, along with businesses, is greatly needed. For the effective use of SAFs, international cooperation and the support of leaders who have a significant influence on country governance are crucial. It is assessed that many financial and political obstacles can be overcome through tax incentives, mandatory blending rates, and support for installation and deployment (Abbas et al., 2024).

Table 1. Companies producing pure fuels

Producer	Production location	Anticipated supply start	Technology
BP	Europe; China	since 2021	HEFA
Neste	Finland; Singapore	since 2021	HEFA
Phillips 66	Humber, UK	since 2022	HEFA
Repsol	Cartagena, Spain	since 2022	HEFA
Moeve (formerly Cepsa)	Huelva, Spain	since 2023	HEFA
EcoCeres	Shanghai; China	since 2024	HEFA
ST1	Göteborg, Sweden	since 2024	HEFA
LanzaJet	Georgia, USA	2025	Alcohol-to-jet
Twelve	Washington, USA	2025	Power-to-Liquid

Source: International Airlines Group (*Sustainable Aviation Fuel*, 2024)

The environmental and socio-economic impacts of sustainable aviation fuels become more visible as their use increases. The use of these fuels can reduce carbon emissions by up to 80% and contribute positively to the circular economy and the environment through the utilization of agricultural and organic waste (Wang & Rijal, 2024). Diversification of raw materials to be used for the production of sustainable aviation fuels also supports agricultural producers and rural development (Bielski, 2015). Considering technological developments, environmental regulations, and sectoral targets, sustainable aviation fuels are expected to be one of the strategically important issues for the aviation sector in the coming period. As SAF production increases, the aviation sector is expected to make a significant contribution to achieving zero carbon emission targets and combating climate change.

2. Literature Review

Nygren et al. (2009) found that the aviation industry should focus on alternative fuel initiatives to prevent a shortage of jet fuel in the coming years, resulting from a 3% growth in air traffic and a 3% annual growth in fuel demand. It was also noted that new fuel sources should be both sustainable and cost-effective (Nygren et al., 2009).

In 2009, Barros and Peypoch used a two-stage Data Envelopment Analysis method to examine the operational performance of airlines that are members of the Association of European Airlines (AEA). It was demonstrated that there are significant differences in the efficiency of airlines in Europe, with most operating at high technical efficiency. In the second stage, regression analysis revealed that population size, low-cost airline status, and network alliance membership have a positive impact on airline efficiency (Barros & Peypoch, 2009). In their 2014 study, Chai et al. examined the growth in Chinese aviation fuel demand. They found through regression analysis that a 1% increase in passenger occupancy results in a 0.8% increase in fuel demand. In comparison, a 1% increase in GDP per capita yields a 0.4% increase in fuel demand. Aviation fuel demand in China is projected to increase very rapidly (Chai et al., 2014).

Yılmaz and Atmanlı (2016) stated that the aviation sector has grown in tandem with the global economy and globalization, and as a result, fuel costs have become increasingly important. Furthermore, the use of petroleum-based fuels has led to an increase in pollutant emissions into

the atmosphere. The study examined the necessity of using biofuels in the aviation sector, as well as the properties and environmental impacts of alternative fuel types.

In their 2016 study, Kousoulidou and Lonza presented a forecast for the future growth of the aviation sector in Europe, as well as the widespread use of biofuels. Based on 2010 predictions, changes in traffic volume, fuel consumption, and CO₂ emissions were forecasted through three different scenarios until 2030. European and national policies, innovations, and the latest technological developments are discussed, and the role of biofuels in aviation to reduce environmental impact is evaluated (Kousoulidou & Lonza, 2016). To calculate the environmental impacts of new aircraft technologies and alternative fuels in the aviation sector, Moolchandani et al. utilized a simulation called FLEET (Fleet Level Environmental Assessment Tool), in accordance with the NASA program, to estimate future CO₂ emissions. As a result of the study, it was concluded that there is an improvement in CO₂ emissions; however, this alone is not sufficient (Moolchandani et al., 2017).

The study, prepared by Salih Aygün, Murat Sağbaş, and Fahri Alp Erdoğan, analyzes the development process and current status of sustainability research in the aviation sector by examining 123 academic articles published in the Web of Science database between 2001 and 2023. At the end of the study, it was determined that the USA contributed the most, with 29 publications, and Türkiye ranked second, with 19 publications. As a result of the research, the words “energy, aircraft, emissions, life cycle” were found to be the most used words in the research (Aygün et al., 2023).

Ozan Öztürk and Hülya Göktepe published a study in 2024 that examines alternative energy sources for the aviation sector. In the study, six different primary alternative energy sources were discussed, including synthetic carnosene (bio-jet fuels and PtL fuels, liquid hydrogen, liquid natural gas, ammonia, alcohol-based fuels and electrical systems, and the natural gas source came to the fore as it is the most suitable for the existing structure and provides up to 80% CO₂ emission reduction. The research also suggests that other studies are not yet mature and that various energy sources should be used in combination instead of a single energy source (Öztürk & Göktepe, 2024).

3. Methods

Although the first studies on sustainable aviation fuels date back to the production of biodiesel, the issue has gained importance in recent years. In the database search, the keywords “sustainability” and “aviation fuel” were searched, and 480 works were found. Among these works, those irrelevant to the field of aviation were excluded, and 403 works were selected for use in the program. Works published between 2005 and 2025 were used.

In this study, a bibliometric analysis method was employed. Bibliometric analysis is a method used to systematically identify and analyze scientific studies published in a specific field and within a specific period, employing statistical, mathematical, and scientific methods (Broadus, 1987). Bibliometric analysis offers the opportunity to examine the current structure and dynamics of the research field from a macro-level perspective (Tomaž Čater, 2015). Bibliometric analysis is a widely accepted and commonly used form of analysis in many scientific disciplines (Abad-Segura et al., 2020).

Thanks to bibliometric analysis, influential authors, journals, and words related to the subject, as well as countries where the subject is studied more extensively, can be quantitatively analyzed. Additionally, it can reveal the connections between research and visual tools (Broadus, 1987). Bibliometric analysis methods are among the most frequently used methods in the field of aviation, as well as in many other scientific fields. In the field of aviation, bibliometric analysis methods are employed to track trends, identify collaborations, and provide a comprehensive overview of the studies as a whole. For example, there are many written works such as bibliometric measurement of risk management in aviation, bibliometric analysis of scientific publications on armed uncrewed aerial vehicles, bibliometric analysis of published works on sustainable fuel, bibliometric analysis on sustainability trends in aviation (Aydın, 2024; Kavak et al., 2022; Xu et al., 2025; Yaşar Dinçer et al., 2024).

The bibliometric analysis method can be visualized on a computer through programs such as R Studio, Citespace, and VOSviewer, and the links between journals, works, and authors can be presented more clearly with the help of visual maps (Guleria & Kaur, 2021). In this study, the Biblioshiny annex was created using version 4.4.1 of the RStudio program. The fact that the R Studio program is free of charge, easy to use, and can provide graphics in various formats makes it a preferred choice. Future trend and regression forecasts using R analysis are one of the most successful and widely used methods (Daswito et al., 2023).

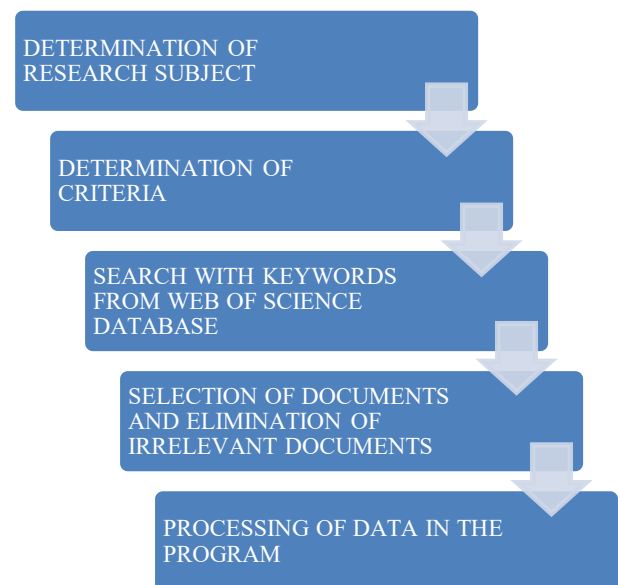


Figure 1. Steps of bibliometric analysis

The bibliometric analysis process consists of six basic stages (Figure 1). This process starts with the identification of the research topic and ends with the interpretation of the analysis results. Each stage builds upon the previous one and proceeds systematically.

4. Result and Discussion

4.1. Distribution of articles by year

While the number of articles published between 2005 and 2014 was less than 10 annually, this figure increased rapidly after 2014. According to the Web of Science database, 42 articles were published in 2021, 43 articles in 2022, 69 articles

in 2023, and 89 articles in 2024. This increasing trend aligns with the 15% annual increase rate determined in the general aviation sustainability study conducted by Aygün et al. (2023). However, the 29% increase in SAF shows a faster growth trend than general sustainability studies. The quantitative increase in the number of scientific publications included in the printed literature over the following years demonstrates that SAF-related research is recognized as an emerging scientific trend within the academic community. In 2008, SAF fuels began to be tested, and SAFs were approved for use in commercial aircraft in 2011, which increased interest in this topic (Dodd, 2023).

In 2011, ASTM D7566 (Standard for Aviation Turbine Fuel Containing Synthetic Hydrocarbons) was revised to allow commercial airlines to blend up to 50% biofuel with conventional jet fuel. The ASTM D4054 evaluation process is used for the approval of new Safety Assessment Factors (SAFs). There are two traditional and two fast-track options to obtain ASTM D7566 approval. The traditional route is tested for 2-3 years, and up to 50% of the material can be used. The fast track is completed in 1-2 years and can be used up to a maximum of 10% (Hunt, 2023). With the impact of global warming, environmental awareness, and climate change, this issue is being studied by an increasing number of researchers (Abrantes et al., 2021; Sacchi et al., 2023; Watson et al., 2024). In addition, governments and aviation companies offer significant incentives for achieving the net-zero project in the aviation sector (Birpınar & Dinçbaş, 2022). The EU runs the Fit for 55 program to support sustainable aviation fuels, while in the US, the Inflation Act provides support of USD 1.25-1.75 per gallon of SAF. In Türkiye, the Microalgae-based Sustainable Biojet Fuel Project is being carried out in cooperation with Tübitak, Turkish Airlines, and Boğaziçi University. EasyJet, Air France-KLM, SAS, and Airbus are involved in and support initiatives such as Project Skypower. The expansion in the financial volume of the industry related to SAF production, the increase in resources allocated to research and development activities, the acceleration of technological innovations, competitive market dynamics and the steady growth trend of the sector encourage scientific interest in this field and contribute to the advancement of academic research (Özbay et al., 2024).

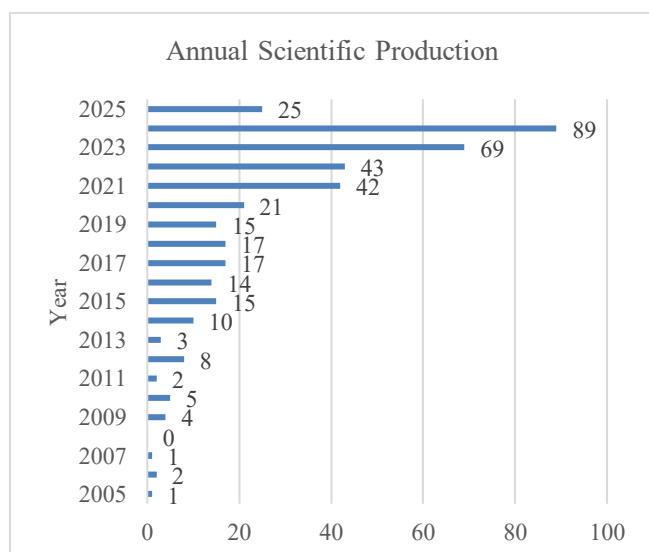


Figure 2. Number of articles by years

An analysis of the distribution of articles by year (Figure 2) shows that the number of studies on the subject has been steadily increasing. The impact of financial investments on academic research is an important factor. The fact that the global SAF market is expected to grow over time will contribute to strengthening industry-university collaborations and increasing the number of applied research projects (Pulidindi & Ahuja, 2024).

4.2. Distribution of academic publications by document type

The distribution of academic publications by type in the study, conducted using the Web of Science database, is shown in Table 2. Upon examination of the table, the vast majority of studies, at 70.72%, consist of research articles, followed by 12.90% of review articles and 12.90% of proceedings and other documents.

Table 2. Distribution of academic publications by document types

Document Type	Frequency	%
Research Articles	285	70,72
Review Articles	52	12,90
Proceedings Documents	52	12,90
Book Chapters	3	0,74
Early Access	5	1,24
Editorial Materials	6	1,49

The main reason for the predominance of research articles in Web of Science is that the database indexes high-quality peer-reviewed journals with high priority. Since research articles are published through a detailed peer-review process, they more easily meet Web of Science's quality standards (Bornmann & Daniel, 2008). Other types of documents have lower rates because review articles are less frequently written and are usually prepared by inviting abstracts, not all conference proceedings are indexed, and book chapters are not the primary focus of Web of Science. Editorial material is usually short and limited in content (Mongeon & Paul-Hus, 2016).

Therefore, the distribution of 70.72% of research articles, 12.90% of reviews and proceedings, and 12.90% of other documents in the table aligns with the structure and academic nature of the Web of Science.

4.3. Most cited authors and works (Citation of authors)

The number of citations for a scientific article increases as the article attracts attention and is recognized as a scientific work. Citation counts have a positive impact on the authors' recognition and reputation (Weihs & Etzioni, 2017). Citation counts are one of the key criteria used in ranking academic search engines. Authors with a high number of citations are ranked first and foremost in search results. In this way, they have the opportunity to receive more citations. This phenomenon is scientifically referred to as the Matthew Effect (Bol et al., 2018). When examining the top 3 most cited works, Sims et al. (Sims et al., 2010) attracted attention in academia with their work titled "Overview of 2nd Generation Biodiesel Technology" and received the most citations on this subject. In the study, instead of producing biodiesel from agricultural products, the authors discussed the production of ethanol-based biodiesel from secondary products such as bark. Since the use of agricultural products for fuel is not considered very appropriate by society, they tried to both reduce costs and use

an unused material as a raw material. The desired result could not be achieved due to technological inadequacy and process difficulty. The second most cited work is Yusuf Chisti's (Chisti, 2013) "Barriers to the Commercial Use of Fuels Derived from Algae." The third most cited work is the 2014 study by Hari et al. on the direction, opportunities, and barriers to aviation biofuels from renewable resources, which examined alternative biofuel feedstocks, production techniques, and emerging biofuels, and evaluated the opportunities and challenges in the development of alternative fuels (Hari et al., 2015).

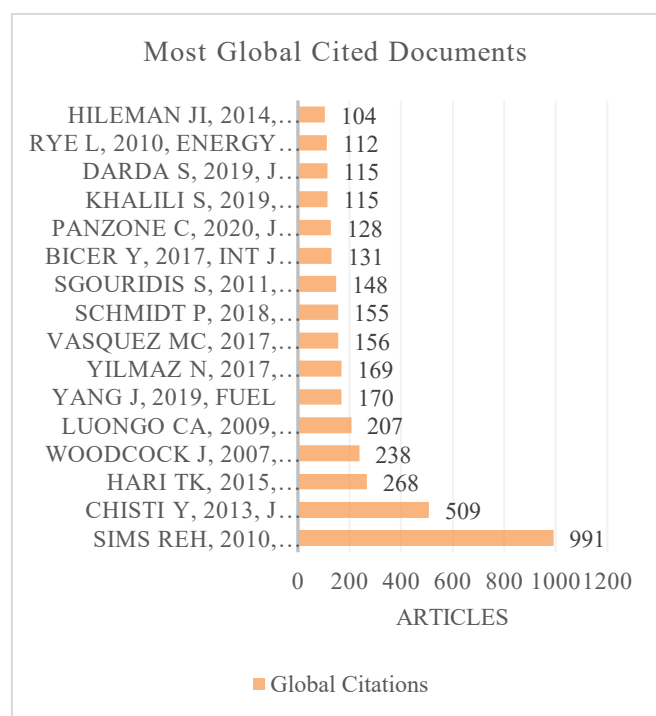


Figure 3. Most cited authors and works

Figure 3 shows the works and authors with 100 or more citations globally. Since studies with 100 or more citations account for only 1.8% of all publications worldwide, the works that exceed this threshold are among the most influential in the scientific literature, demonstrating the academic importance of the topics. It demonstrates that these studies are widely accepted within the scientific community and that SAF research is grounded in a strong theoretical foundation. A common feature of highly cited papers is that they address the SAF field in an integrated manner across different dimensions (technical, economic, environmental, and policy) and provide concrete examples of practical applications. This is evident when the three most cited papers are analyzed.

The so-called H-index, also known as the Hirsch index, is an indicator that reveals the impact and productivity of scientific journals and researchers. It was first proposed by Jorge E. Hirsch in 2005 to reveal the scientific impact of articles (Gasparyan et al., 2018). The h-index of a researcher is determined if that researcher's article is cited at least h times in h number of times. Local H-index values (Figure 4) of the authors examined within the scope of the research are presented.

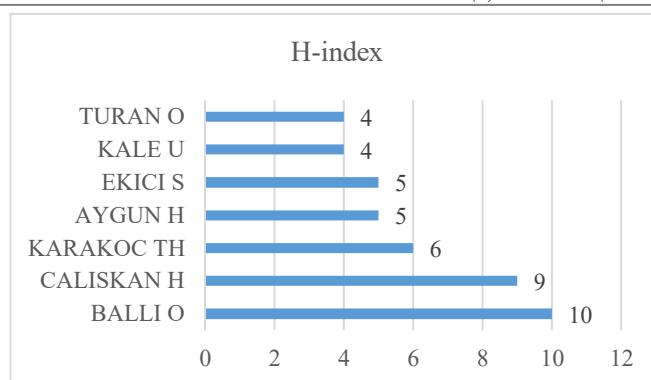


Figure 4. Local H-index and impact factor

According to the results of bibliometric analysis in the field of sustainable aviation fuels, the authors with the highest h-index have made significant scientific contributions in the field. The institution with the highest number of publications is considered the local h-index in this study. This is an indicator not only in terms of the number of articles of these researchers, but also in terms of the impact of their work in the scientific world.

A high h-index indicates the author's academic productivity and reputation in their field. Especially in an interdisciplinary field such as sustainable aviation fuels, researchers with a high h-index are usually people who synthesize knowledge from different disciplines and produce innovative solutions. Moreover, studies published in high-impact-factor journals influence global research trends in sustainable aviation fuels. In particular, SAF studies published in prestigious journals in the fields of energy, environmental engineering, and aerospace technologies are of great academic and industrial interest.

4.5. The institutions that publish the most on the subject

Identifying the institutions that publish the most articles in various fields helps pinpoint some of the most nationally and internationally influential institutions, providing valuable data on the scientific productivity of these institutions. Developed and developing countries offer incentives to universities, industrial organizations, research centers, and other institutions to produce high-quality, qualified information, thereby advancing progress in various disciplinary fields (Çizmecioğlu et al., 2023). Universities play an active role in knowledge production and dissemination. Universities have the responsibility of disseminating accurate information to society and producing optimal solutions to current situations (Gürpınar & Aydoğmuş, 2022). Universities play a significant role in shaping society by educating current and future managers (Godemann et al., 2015). The study by Arısoy et al. highlights the responsibilities of universities to train qualified individuals and conduct research for the benefit of society (Arısoy et al., 2024). Figure 5 illustrates the institutions with the highest number of publications on the subject, along with the corresponding publication count. Eskişehir Technical University, the institution with the highest number of publications, was separated from Anadolu University in 2018 and established as a research university. Eskişehir Technical University ranks high in quantitative publication production. Behind this success lies the presence of academic staff with expertise in their fields (Tolga Baklacioğlu, Tahir Hikmet Karakoç, Önder Altuntaş, etc.) and the strategic approach of

the institution towards research and development activities with biodiesel and aircraft engines.

When the data from the Council of Higher Education Thesis Center are examined, it is revealed that the institution exhibits a periodic upward trend in the number of doctoral theses (65 in 2022, 70 in 2023, and 87 in 2024) (UTM | Statistics, 2025). This indicates that the university's graduate education activities are continually evolving. In light of the information presented on the institution's electronic web page, the cooperation mechanisms established by the university with industrial stakeholders draw attention (Eskisehir.edu.tr, 2022).

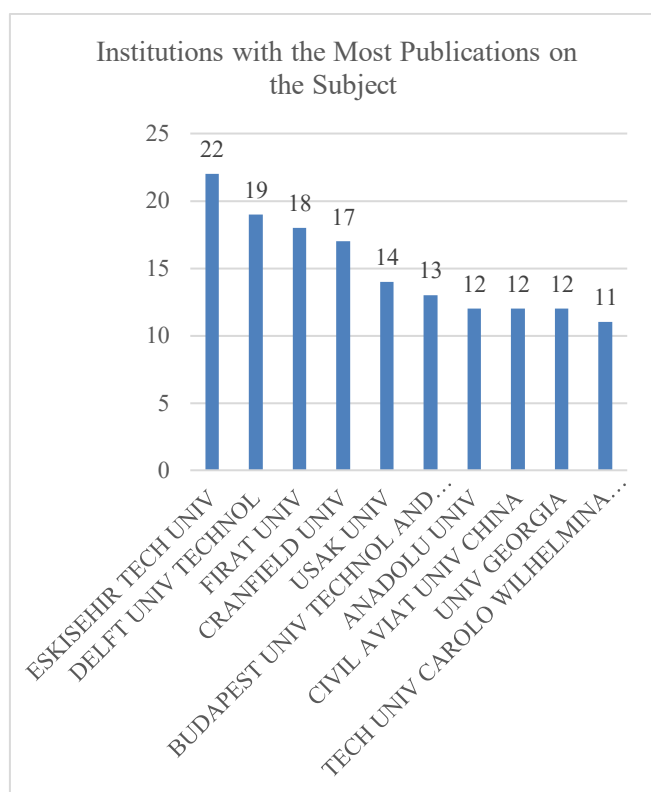


Figure 5. Institutions with the most publications on the subject and the number of publications

Within the framework of this cooperation, it is ensured that academic knowledge is integrated with sectoral practices, aiming to enhance the competencies of graduates.

Table 3. Distribution of the most active countries in academic publications

Country	Frequency	Country	Frequency
USA	240	ITALY	57
UK	125	AUSTRALIA	48
TÜRKİYE	124	NETHERLANDS	38
CHINA	112	INDIA	36
BRAZIL	91	FRANCE	28

The United States allocates a significant portion of its resources to military expenditures and research and development (R&D). The US allocates approximately half of its defense budget to personnel costs and the other half to procurement, research and development, and testing activities. The US Department of Defense and universities in the US attach great importance and support R&D activities (O'Hanlon, 2024). In particular, factors such as the cooperation

between research universities and industry, as well as legal sanctions on patents and intellectual property rights, make it attractive for researchers. Researchers are also supported because the US aims to establish a competitive advantage over countries that can rival it, such as China and Russia (Mowery, 2012).

Country Scientific Production

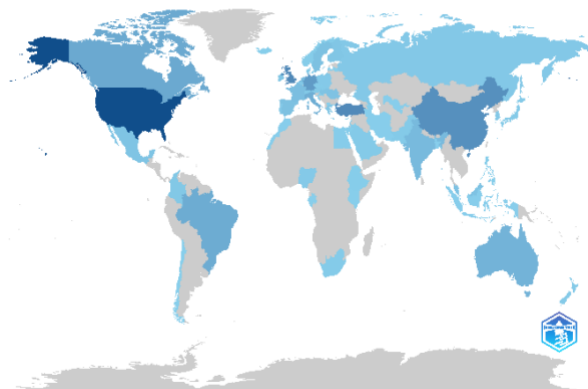


Figure 6. Map of Countries by Scientific Publications

4.6. Co-authorship relationship by country

Although it shows the amount of cross-country collaboration, the proportions may vary by subject. SCP (shown in green - single country participant) indicates work written in a single country, while the indicators in red show how much of the work is international (Figure 7). When examining the United States, Türkiye, the United Kingdom, and Germany, which are among the countries with the highest number of studies, it is evident that the majority of studies are conducted within these countries. In the aforementioned countries, the aviation industry has a distinct advantage, as it hosts the leading organizations in the sector on a global scale. Delta Air Lines, United Airlines, Southwest Airlines, Lufthansa Group, Turkish Airlines, UPS Cargo, and FedEx Express, on the cargo side, cooperate with universities, especially in personnel training. This strategic cooperation paves the way for a significant increase in aviation-oriented academic publications in these countries and privileges staff training opportunities. The primary reason for the tendency of authors of scientific studies to originate from a single country rather than a multinational structure is that research grants are typically allocated within national and regional borders, rather than being international in scope. According to Rand Corporation reports, organizations such as the US Department of Defense, the French National Research Agency (ANR), and the National Natural Science Foundation of China (NSFC) allocate a large portion of their basic research budgets to organizations in their own countries, while the budget allocated to foreign organizations is at most 3% of the total, which is insufficient (Hottes et al., 2023). This situation leads to the shaping of scientific production within geographical limitations.

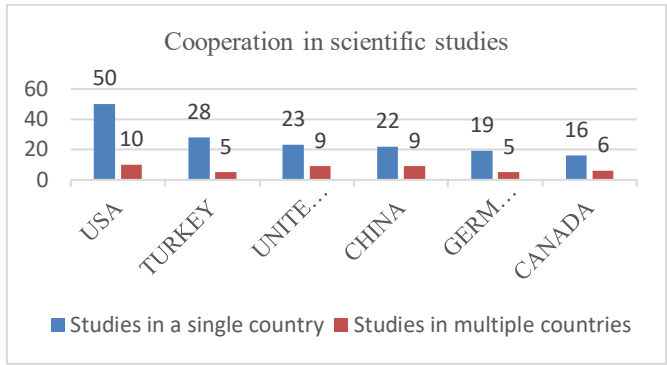


Figure 7. Co-authorship relationship by country

The global dissemination of scientific research is one of the most important academic goals of our time. To achieve this goal, national governments and private sector organizations must significantly increase their financial support for research and development activities. The inadequacy of existing funding models restricts scientific research, particularly in developing countries. In addition to strengthening financial support mechanisms, it is crucial to restructure research in a direction that promotes open access. This approach enables research results to reach a wider audience and facilitates the sharing and development of scientific knowledge. Establishing multinational participation models that bring together experts from different disciplines to collaborate on joint projects can enhance the quality of research and increase the number of outputs. To change the current situation, international academic networks should be strengthened, international projects should be expanded, and sectoral cooperation and open-access policies should be supported.

4.7. Keyword analysis (Word cloud)

The word cloud is a visual graphic in which words are sized according to the number of occurrences in the relevant articles, with the most frequently occurring word displayed in the central area in the largest size. In this study, the words "emission," "energy," "performance," and "aircraft" were mentioned 46, 44, 42, and 40 times, respectively (Figure 8). Through keyword analysis, a particular topic can be scanned

in the database over various periods to reveal the area in which the topic has evolved, experienced congestion, and created research opportunities for researchers (Zubaidi, 2024).



Figure 8. Word cloud

When the word cloud in this study is analyzed, it can be observed that researchers focus most on reducing environmental impact and improving energy efficiency, with the words "emission," "energy," and "performance" being repeated the most. The prominence of terms such as life cycle, biodiesel, biofuels, biomass, and hydrogen, along with technoeconomic analysis, addresses the research on next-generation fuels. In addition, the high frequency of the words aircraft, optimization, design, and aviation indicates that there are alternative searches. Additionally, thanks to this method, studies on a topic can be examined at a national level, creating an opportunity for researchers to initiate similar research in their regions.

4.8. Other related terms

A CoWordNet graph is provided to illustrate the common words used in conjunction with each other in the studies. Sustainable aviation fuel studies are represented by three different colors in the link map, indicating that they are distributed across three distinct areas. The visual obtained as a result of the analysis (Figure 9) indicates that the subject is multifaceted, as evidenced by its occurrence in three different regions.

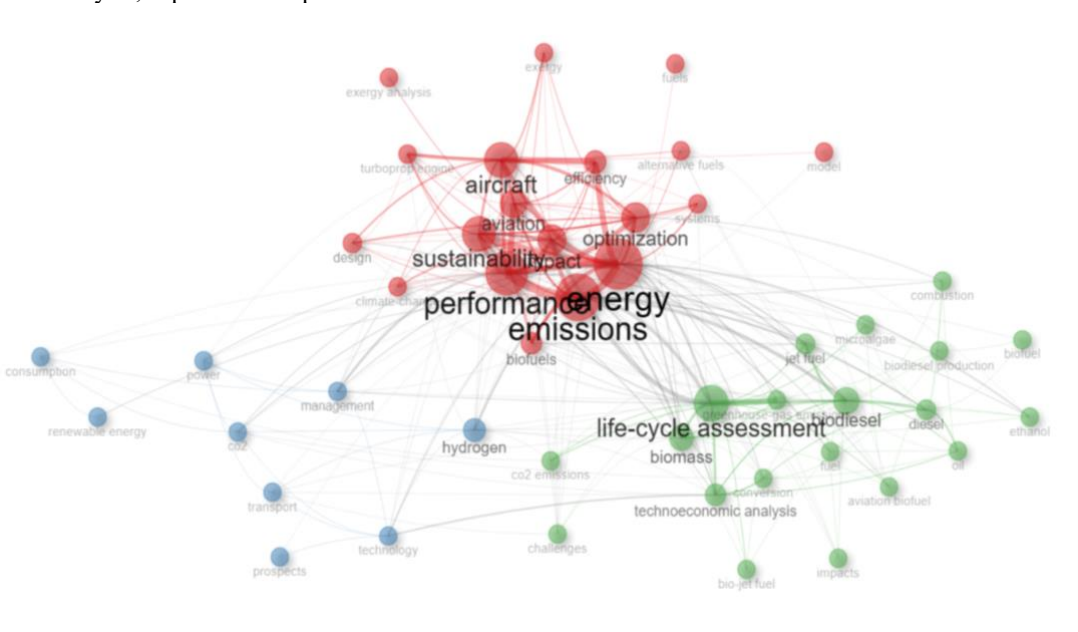


Figure 9. CoWordNet (connected words)

Three different thematic regions were identified in the CoWordNet visual graph. The first region, coded in green, comprises word groups that focus on emissions, the carbon life cycle, and biodiesel. Szyk and Lenort's (2024) study, titled "Sustainable Aviation Fuels as the Path to Carbon Neutrality in Air Transport," is an example in this thematic area. The second region, colored in red, shows terminological clusters related to aircraft, energy, and performance evaluations. Liu and Yang's (2024) "Analyzing Engine Performance and Combustor Performance to Assess Sustainable Aviation Fuel Blends" can be included in this category. The third region, marked in blue, contains conceptual groupings in the fields of the aviation industry, hydrogen technologies, and systems. The study by Yelugoti and Wang (2023) is representative of this last category (Liu & Yang, 2024; Szyk & Lenort, 2024; Yelugoti & Wang, 2023).

The three thematic areas identified in our CoWordNet analysis (emissions-biodiesel, aircraft-energy-performance, aviation-hydrogen) confirm the six main categories of alternative energy sources identified by Öztürk and Göktepe (2024). In particular, the fact that hydrogen technologies are a distinct cluster indicates that this technology is becoming increasingly important in the SAF literature.

5. Conclusion

The aviation sector is a strategic industry of great importance for the global economy and international connectivity. Various reasons prevent the aviation sector from reaching its targeted point. The primary problems are economic fluctuations, environmental concerns, passenger expectations, lack of adequate technological infrastructure, incomplete adaptation of sustainable fuels to existing systems, adaptation of renewable energy sources to the aviation sector, and the extended return on investment in the sector, fossil-based jet fuel prices being cheaper than sustainable fuels, etc. These factors make the transition to sustainable aviation fuels difficult. Secondary problems are inadequate aviation infrastructure and capacity constraints. Failure to expand airport capacity in parallel with the increase in air traffic, problems with slot allocations, issues in airspace management, and employee strikes reduce the profitability of companies (Doganis, 2019). Environmental sustainability is another major challenge facing the industry. The contribution of aviation activities to carbon emissions and environmental impacts, including noise pollution, is widely criticized by society. Regulatory differences between countries can significantly impact international operations and limit market access. Increasing carbon taxes also affect the economic performance of the sector.

The multidimensional nature of the problems faced by the sector hinders its growth and prevents it from achieving the desired results. A holistic approach should be taken to solve these problems, and the ties between stakeholders should be strengthened. The Net Zero Emission program, the largest project in the sector, should receive the necessary support. The most significant breakthrough will be the replacement of fossil fuels with aviation fuels, which are the largest expense item for the sector within the scope of sustainability. As a result of increasing technological developments and the integration of various alternative raw material resources in sustainable fuel production, the aviation sector will gradually achieve the Net Zero Emission target with aviation engine systems with higher efficiency coefficients and minimized emission emissions, advanced energy storage systems and the widespread use of renewable energy systems in airport infrastructures.

This research aims to review scientific studies on sustainable aviation fuels systematically and to provide a methodological framework for future research. The number of publications in this field is expected to increase exponentially if industry and government support continue to be provided. In this study, only articles from the Web of Science were analyzed, and studies from other databases constitute a limitation of this study. Other researchers working on this subject can focus on hydrogen fuel, engine technologies, or, similar to this study, articles in other databases.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abad-Segura, E., González-Zamar, M.-D., Infante-Moro, J. C., & Ruipérez García, G. (2020). Sustainable Management of Digital Transformation in Higher Education: Global Research Trends. *Sustainability*, 12(5), Article 5.
- Abbas, I., Shaar, A., & El Osta, R. (2024). The pathway for achieving sustainable aviation fuel production in the Middle East and North Africa region. *Environmental Progress & Sustainable Energy*, 43 (3), e14395.
- Abrantes, I., Ferreira, A. F., Silva, A., & Costa, M. (2021). Sustainable aviation fuels and imminent technologies-CO2 emissions evolution towards 2050. *Journal of Cleaner Production*, 313, 127937.
- Aksoy, C., & Dursun, Ö. O. (2018). Türkiye'de sivil havacılık sektörünün gelişimine genel bir bakış. *Elektronik Sosyal Bilimler Dergisi*, 17 (67), 1060-1076.
- Arısoy, E., Özer, N., & Şad, S. N. (2024). Lisansüstü eğitimde danışman-öğrenci ilişkileri ölçeğinin türkçe formunun psikometrik özelliklerinin incelenmesi. *Kalem Uluslararası Eğitim ve İnsan Bilimleri Dergisi*, 14 (1), 155-182.
- Aydın, N. (2024). Silahlı insansız hava araçlarına ilişkin bilimsel yayınların bibliyometrik analizi. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, 80, 309-331.
- Aygün, S., Sağbaş, M., & Erdoğan, F. A. (2023). Bibliometric analysis of sustainability in civil aviation. *Journal of Aviation*, 7(3), 448-456.
- Barros, C. P., & Peypoch, N. (2009). An evaluation of European airlines' operational performance. *International Journal of Production Economics*, 122(2), 525-533.
- Bielski, S. (2015). The agricultural production of biomass for energy purposes in Poland. *The Journal "Agriculture and Forestry"*, 61(1), 153-160.
- Birpınar, M. E., & Dinçbaş, T. (2022). National technology initiative in line with the net-zero emission target. In M. F. Kacır (Ed.), *National Technology Initiative: Social Reflections and Türkiye's Future* (pp.427-442). Türkiye Bilimler Akademisi Yayınları.
- Bol, T., de Vaan, M., & van de Rijt, A. (2018). The Matthew effect in science funding. *Proceedings of the National Academy of Sciences*, 115(19), 4887-4890.
- Bornmann, L., & Daniel, H. (2008). What do citation counts measure? A review of studies on citing behavior. *Journal of Documentation*, 64(1), 45-80.
- Broadus, R. N. (1987). Toward a definition of "bibliometrics". *Scientometrics*, 12(5), 373-379.

- Chai, J., Zhang, Z.-Y., Wang, S.-Y., Lai, K. K., & Liu, J. (2014). Aviation fuel demand development in China. *Energy Economics*, 46, 224-235.
- Chisti, Y. (2013). Constraints to commercialization of algal fuels. *Journal of Biotechnology*, 167 (3), 201-214.
- Çizmecioğlu, S., Boz, E., & Çalık, A. (2023). Vakıf üniversitelerinin akademik performans analizi için yeni bir bütünlük ÇKKV çerçevesi. *International Journal of Engineering Research and Development*, 15(1), 24-39.
- Daswito, R., Besral, B., & Ilmaskal, R. (2023). Analysis using R Software: A big opportunity for epidemiology and public health data analysis. *Journal of Health Sciences and Epidemiology*, 1(1), 1-5.
- Dodd, H. (2023). Sustainable aviation fuel. <https://atag.org/industry-topics/sustainable-aviation-fuel> (Access to May, 05, 2025)
- Doganis, R. (2019). *Flying Off Course: Airline Economics and Marketing*. Routledge.
- Dube, K., Nhamo, G., & Chikodzi, D. (2021). COVID-19 pandemic and prospects for recovery of the global aviation industry. *Journal of Air Transport Management*, 92, 102022.
- Erdem, U. (2023). Türkiye Hava Ulaşım Ağı'nın (THUA) değişiminin modellenmesi: Dinamik mekânsal- karmaşık ağ yaklaşımı. *Ege Coğrafya Dergisi*, 32(1), 173-193.
- Eskişehir Teknik Üniversitesi (2025). <https://eskisehir.edu.tr/tr/Haber/Detay/eskisehir-teknik-universitesi-ile-mytechnic-arasında-is-birligi-gelisiyor> (Access to May, 05, 2025)
- Gasparyan, A. Y., Yessirkepov, M., Duisenova, A., Trukhachev, V. I., Kostyukova, E. I., & Kitas, G. D. (2018). Researcher and author impact metrics: Variety, value, and context. *Journal of Korean Medical Science*, 33(18), 1-16.
- Godemann, J., Moon, J., Bebbington, J., & Herzig, C. (2015). Higher education and sustainable development exploring possibilities for organisational change. *Accounting, Auditing & Accountability Journal*, 27 (2), 218-233.
- Guleria, D., & Kaur, G. (2021). Bibliometric analysis of ecopreneurship using VOSviewer and RStudio Bibliometrix, 1989–2019. *Library Hi Tech*, 39(4), 1001-1024.
- Gürpınar, E., & Aydoğmuş, Ö. H. (2022). Kamu mali olarak bilginin sınırları: Örtük bilgiye stratejik bir yaklaşım. *Yaşar Üniversitesi E-Dergisi*, 17(65), 173-188.
- Hannes Gauch, T. L. (2025). Aviation. IEA. <https://www.iea.org/energy-system/transport/aviation> (Access to May, 05, 2025)
- Hari, T. K., Yaakob, Z., & Binitha, N. N. (2015). Aviation biofuel from renewable resources: Routes, opportunities and challenges. *Renewable & Sustainable Energy Reviews*, 42, 1234-1244.
- Heyne, J., Rauch, B., Clercq, P. L., & Colket, M. (2021). Sustainable aviation fuel prescreening tools and procedures. *Fuel*, 290, 1-8.
- Hottes, A. K., Blumenthal, M. S., Mondschein, J., Sargent, M., & Wesson, C. (2023). International basic research collaboration at the U.S. Department of Defense: An overview. https://www.rand.org/pubs/research_reports/RRA1579-1.html (Access to May, 05, 2025)
- Hunt, K. (2023). Fueling the Future of Aviation | ASTM. <https://www.astm.org/news/fueling-future-aviation-ja23> (Access to May, 05, 2025)
- IATA. (2021). Our Commitment to Fly Net Zero by 2050. <https://www.iata.org/en/programs/sustainability/flynetzero/> (Access to May, 05, 2025)
- ICAO. (2017). Methodology ICAO Carbon Calculator_v10-2017. https://www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v10-2017.pdf (Access to May, 05, 2025)
- Kavak, O., Topçuoğlu, E., & Kaygın, E. (2022). Sivil havacılıkta risk yönetimine bibliyometrik bakış. *Sakarya Üniversitesi İşletme Enstitüsü Dergisi*, 4(2), 77-86.
- Kousoulidou, M., & Lonza, L. (2016). Biofuels in aviation: Fuel demand and CO2 emissions evolution in Europe toward 2030. *Transportation Research Part D: Transport and Environment*, 46, 166-181.
- Liu, Z., & Yang, X. (2024). Analyzing Engine Performance and Combustor Performance to Assess Sustainable Aviation Fuel Blends. *Aerospace*, 11 (12).
- Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics*, 106 (1), 213-228.
- Moolchandani, K., Govindaraju, P., Roy, S., Crossley, W. A., & DeLaurentis, D. A. (2017). Assessing Effects of Aircraft and Fuel Technology Advancement on Select Aviation Environmental Impacts. *Journal of Aircraft*, 54(3), 857-869.
- Mowery, D. C. (2012). Defense-related R&D as a model for “Grand Challenges” technology policies. *Research Policy*, 41(10), 1703-1715.
- Ng, K. S., Farooq, D., & Yang, A. (2021). Global biorenewable development strategies for sustainable aviation fuel production. *Renewable and Sustainable Energy Reviews*, 150, 111502.
- Nigam, P. S., & Singh, A. (2011). Production of liquid biofuels from renewable resources. *Progress in Energy and Combustion Science*, 37(1), 52-68.
- Nygren, E., Aleklett, K., & Höök, M. (2009). Aviation fuel and future oil production scenarios. *Energy Policy*, 37(10), 4003-4010.
- Nyoh, I. B. (2021). Communicating climate change and energy in rural Africa: A case analysis to explain how participatory communication can support transition to renewables and adoption of solar technologies in rural Africa. *Public Sciences & Policies*, 7(2), 183-200.
- O'Hanlon, M. E. (2024). U.S. Defense Spending in Historical and International Context | Econofact. <https://econofact.org/u-s-defense-spending-in-historical-and-international-context> (Access to May, 05, 2025)
- Özbay, G., Tüysüz, V., & Semint, S. (2024). Havacılık alanında ön lisans ve lisans düzeyinde eğitim veren üniversiteler üzerine bir araştırma. *Havacılık ve Uzak Çalışmaları Dergisi*, 4(1), 22-47.
- Öztürk, O., & Göktepe, H. (2024). Modern Havacılık Sektöründe Alternatif Enerji Kaynakları: Sürdürülebilirlik Hedeflerine Doğru Adımlar. *Journal of Aerospace Science and Management*, 2(1), 21-42.
- Pulidindi, K., & Ahuja, K. (2024). Sustainable Aviation Fuel Market Size, Share & Outlook – 2034. *Global Market Insights Inc.* <https://www.gminsights.com/industry-analysis/sustainable-aviation-fuel-market> (Access to May, 05, 2025)
- Ridjan, I., Mathiesen, B. V., & Connolly, D. (2016). Terminology used for renewable liquid and gaseous fuels

- based on the conversion of electricity: A review. *Journal of Cleaner Production*, 112, 3709-3720.
- Sacchi, R., Becattini, V., Gabrielli, P., Cox, B., Dimaichner, A., Bauer, C., & Mazzotti, M. (2023). How to make climate-neutral aviation fly. *Nature Communications*, 14(1), 3989.
- Schmidt, P., Batteiger, V., Roth, A., Weindorf, W., & Raksha, T. (2018). Power-to-Liquids as Renewable Fuel Option for Aviation: A Review. *Chemie Ingenieur Technik*, 90(1-2), 127-140.
- Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101 (6) 1570-1580.
- Souza, R. C. U., González-Quinonez, L. A., Reyna-Tenorio, L. J., Salgado-Ortiz, P. J., & Chere-Quinonez, B. F. (2024). Renewable energy development and employment in Ecuador's rural sector: An economic impact analysis. *International Journal of Energy Economics and Policy*, 14(1), Article 1.
- Sun, X., Wandelt, S., & Zhang, A. (2020). How did COVID-19 impact air transportation? A first peek through the lens of complex networks. *Journal of Air Transport Management*, 89, 101928.
- Sustainable Aviation Fuel. (2024). <https://www.iairgroup.com/sustainability/sustainable-aviation-fuel/> (Access to May, 05, 2025)
- Szyc, R., & Lenort, R. (2024). Sustainable Aviation Fuels as the Path to Carbon Neutrality in Air Transport. *Rocznik Ochrona Środowiska*. 26, 707-715.
- Tomaž Čater, I. Ž. (2015). *Bibliometric Methods in Management and Organization*. ResearchGate.
- Töret, A. B., & Söğüt, Z. (2022). Çobanlık ve hayvancılıkta insansız hava aracı kullanımı ile dijital dönüşüm: Eskişehir örneği. *Kültür Araştırmaları Dergisi*, 15, 300-320.
- Ulusal Tez Merkezi (2025). <https://tez.yok.gov.tr/UlusalTezMerkezi/IstatistikiBilgiler> (Access to May, 05, 2025)
- Wang, F., & Rijal, D. (2024). Sustainable Aviation Fuels for Clean Skies: Exploring the Potential and Perspectives of Strained Hydrocarbons. *Energy & Fuels*, 38(6), 4904-4920.
- Watson, M. J., Machado, P. G., da Silva, A. V., Saltar, Y., Ribeiro, C. O., Nascimento, C. A. O., & Dowling, A. W. (2024). Sustainable aviation fuel technologies, costs, emissions, policies, and markets: A critical review. *Journal of Cleaner Production*, 449, 141472.
- Weih, L., & Etzioni, O. (2017). Learning to Predict Citation-Based Impact Measures. 2017 ACM/IEEE Joint Conference on Digital Libraries (JCDL), 1-10.
- Xu, Y., Zhang, Y., Deng, X., Lee, S.-Y., Wang, K., & Li, L. (2025). Bibliometric analysis and literature review on sustainable aviation fuel (SAF): Economic and management perspective. *Transport Policy*, 162, 296-312.
- Yaşar Dinçer, F. C., Yirmibeşoğlu, G., Bilişli, Y., Arık, E., & Akgün, H. (2024). Trends and emerging research directions of sustainable aviation: A bibliometric analysis. *Heliyon*, 10(11), e32306.
- Yaşar, G., & Onat, B. (2025). Sürdürülebilir havacılık yakıtları üretimi ve çevresel etkileri. *Journal of Anatolian Environmental and Animal Sciences*, 10(2), 182-190.
- Yelugoti, S. R., & Wang, W.-C. (2023). The combustion performance of sustainable aviation fuel with hydrogen addition. *International Journal of Hydrogen Energy* 48 (15), 6130-6145.
- Yılmaz, N., & Atmanlı, A. (2016). Havacılıkta alternatif yakıt kullanilmasinin incelenmesi. *Sürdürülebilir Havacılık Araştırmaları Dergisi*, 1(1), 3-10.
- Zubaidi, M. I. (2024). Impact of Identity Politics on Security and Stability in Medan. *Jurnal Indonesia Sosial Teknologi*, 5(4), 1539-1546.

Cite this article: Topcuoglu, V., Uzulmez, M. (2025). Bibliometric Analysis of Sustainable Aviation Fuels Using Biblioshiny. *Journal of Aviation*, 9(3), 684-693.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Flying Towards Equality: The Role of Female Employees in Enhancing Airline Performance

Mehmet Şahin Durak¹ 

¹Kırklareli University, Aviation Management Department, Kırklareli, Türkiye. (msdurakk@gmail.com)

Article Info

Received: 20 June 2025
Revised: 07 August 2025
Accepted: 22 September 2025
Published Online: 10 October 2025

Keywords:

Airline Industry
Gender Diversity
Panel Data Analysis
Profitability

Corresponding Author: Mehmet Şahin Durak

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1729023>

Abstract

This study empirically investigates the impact of the proportion of female employees on firm performance in the airline industry. Panel data analysis was conducted using data from 25 globally operating airline companies for the period from 2019 to 2023. The primary objective of the study is to measure the effect of the proportion of female employees (EMPFEM) on the profitability of airline companies. In this context, EMPFEM is identified as the main independent variable, while profitability performance is evaluated through three key dependent variables: return on assets (ROA), return on equity (ROE), and return on sales (ROS). The analysis results reveal that EMPFEM has a positive and statistically significant effect on ROA and ROS, while no significant relationship was found with ROE. These findings suggest that gender diversity can be a strategic factor enhancing performance of the airline companies. The study is evaluated within the frameworks of the resource-based view and corporate social responsibility perspectives, highlighting that diversity policies may contribute to financial performance. The results indicate that increasing female employment is important not only from a gender equality standpoint but also in terms of sustainable profitability and competitive advantage in the airline industry.

1. Introduction

Global air transport demand is expected to more than double over the next two decades. The International Air Transport Association's (IATA) projection report demonstrates that the number of passengers will increase at an average annual growth rate of 3.7% during this period (IATA, 2024). This growth will naturally lead to a significant increase in employment demand within the sector. Moreover, according to predictions by the International Civil Aviation Organization (ICAO), over the coming years, there will be a need for more than 350,000 new pilots and over 480,000 maintenance technicians (ICAO, 2025). This growth trend facing the sector is increasing the need for multidisciplinary and highly skilled human resources not only for technical positions but also in areas such as ground services, digitalization, sustainability, customer experience, and management. This rapid growth and increasing employment needs make the resolution of diversity and gender equality issues, already on the agenda in the aviation sector, even more urgent (Ferla & Graham, 2019; Lutte & Morrison, 2022; McCarthy et al., 2015).

Women's participation in the workforce has increased significantly worldwide in the 20th century. However, the representation of women in both leadership and operational roles in the aviation sector remains low. This situation forms the basis for criticism of the lack of diversity and gender equality in the sector (Corazza, 2024). International data

reveals that the proportion of women in flight crews and maintenance personnel remains in single digits. For example, according to ICAO, as of 2021, only 4.7% of commercial pilots worldwide were women. Additionally, 3.1% of maintenance engineers and 21.1% of air traffic controllers are women (IATA, 2024).

The inadequate representation of women in the aviation sector negatively affects both the sectoral growth potential and the financial and operational performance of airline companies. The low participation of women, especially in technical staff and senior management, causes the synergy provided by innovative perspectives and diversity to be missed (Ferla & Graham, 2019). Therefore, global initiatives aimed at increasing and supporting diversity in the sector need to be expanded. Initiatives such as the "25by2025" campaign launched by IATA play an important role by supporting the goal of increasing the proportion of women in the sector (IATA, 2023). The effective implementation of such policies will directly contribute to the sustainable growth and competitiveness of the aviation sector.

This study focuses on an important research area, given that the impact of the proportion of female employees in the airline industry on business performance has not yet been fully understood. In this context, the aim of the study is to empirically demonstrate the effect of the proportion of female employees on the profitability of airline companies. As a method, a comprehensive panel data analysis will be conducted on a panel data set consisting of annual data of 25

global airlines between 2019 and 2023. Thus, the effect of gender balance on performance indicators will be examined using statistical models that simultaneously evaluate both time and airline company differences.

In this context, the research question that the study seeks to answer is as follows:

RQ: Does the share of female employees of airline companies have a significant impact on the airlines' profitability?

To address this research question, the study employs a panel data analysis covering 25 international airlines over the 2019–2023 period. The female employee ratio is taken as the main explanatory variable, while profitability is measured through three indicators: return on assets (ROA), return on equity (ROE), and return on sales (ROS). By integrating both cross-sectional and time-series dimensions, the research design allows for a robust examination of the relationship between gender diversity and airline profitability.

This study contributes to the literature and the industry in multiple ways. First, it jointly models key profitability indicators within a single panel-data framework, offering a holistic view of firm performance. Second, it introduces a harmonized, cross-national dataset and comparative analysis across 25 international airlines, enabling policy-relevant inference beyond single-carrier or single-country studies. In practice, this study demonstrates the critical role that the female workforce can play in addressing the hundreds of thousands of qualified personnel shortages that ICAO will face in the coming years, supported by numerical data. It also supports IATA's diversity goals, such as "25by2025," with concrete business justifications. In addition, it guides airline managers to better understand the impact of the female employee ratio on business performance and provides regulatory institutions with insights on how incentive policies focused on gender balance can be shaped based on efficiency. Thus, the study adds original empirical findings to academic discussions and offers an action plan that is directly applicable to the industry.

In the following sections, first, the literature on the relationship between gender balance and business performance will be examined in detail. Then, the research design (data set, performance indicators and panel data methods) will be explained in detail. This will be followed by the presentation and discussion of empirical findings in light of the dynamics of the global airline industry. The final section will summarize the main results, discuss theoretical and managerial implications, and provide suggestions for future research.

2. Literature Review

This section examines the existing academic literature addressing the relationship between gender diversity and business performance in the airline industry. The literature generally consists of studies that explore the relationship between the proportion of female employees in businesses and their financial and operational performance. A significant portion of these studies indicate that increasing gender diversity in businesses has positive effects on financial results.

2.1. Female Employment in the Airline Industry

The aviation industry has historically been a male-dominated industry, and the percentage of female employees has remained at very low levels for many years. Particularly in operational and leadership roles such as pilots, technicians and

senior managers, female representation has been extremely limited. As of 2021, only 4.7% of commercial airline pilots worldwide are women. In addition, 3.1% of aircraft maintenance technicians and 21.1% of air traffic controllers are women. A similar picture is observed regionally; for example, while the female pilot ratio in the US remains around 5%, it is around 4–5% in the UK. In contrast, India has managed to increase the female pilot ratio in civil aviation to 12–14%, reaching the highest share in the world in this field. While women constitute the majority in cabin crew positions, the representation of women in technical positions such as pilots and maintenance engineers is still in single-digit percentages. Although there have been partial improvements in recent years (e.g., the proportion of female pilots in the USA increased from 5.6% to 8.2% between 2018 and 2023), the growth in female employment in the sector has been very slow (IATA, 2024).

The picture is similar when looking at the representation of women in managerial and leadership positions in the aviation sector. Approximately one-fifth of senior management positions in global airline companies are held by women. For example, as of 2021, the proportion of women in senior management positions in airline companies was 23% in North America, 18% in Europe, and 15% in Asia-Pacific (Statista, 2021; Suau-Sanchez et al., 2025). When IATA's 25by2025 initiative was launched, only three CEOs were women among its more than 290 member airlines, and it was estimated that only 19% of senior roles were held by women. These figures demonstrate the gender gap in aviation and the urgent need for action to reduce inequality in a meaningful timeframe (IATA, 2024). When looking at overall employment rates, it is seen that the share of women in the total workforce of airline companies can be relatively high in some regions. For example, women constitute 42% of employees in the aviation sector across the European Union. This general ratio does not mean that the imbalances in roles mentioned above have been eliminated. While women are more concentrated in areas such as ground services, customer services, or cabin crew in the sector, the majority of men continue to be in piloting, maintenance-technical, flight operations, and senior management positions (Corazza, 2024). Despite various efforts to change this situation, the aviation sector still faces a significant gender imbalance (Costa et al., 2020; Durbin et al., 2016; Ferla & Graham, 2019; McCarthy et al., 2015). The importance of efforts to increase women's employment in the sector in terms of both equality and corporate performance is increasingly understood (Sengur, 2025).

2.2. The Relationship Between Female Employment and Business Performance

There are numerous studies in the academic literature examining the relationship between the proportion of female employees in businesses and financial and operational performance. A significant portion of these studies reveal that increasing gender diversity in businesses has positive and significant effects on financial results. For example, Post and Byron's (2015) meta-analysis of 140 empirical studies reveal that financial indicators increase significantly as the proportion of women on boards of directors rises. The study is based on a broad literature review examining the relationship between female representation on boards and the financial performance of businesses. The results from these 140 studies were statistically combined to examine whether they varied according to the legal, regulatory, and socio-cultural contexts of businesses. The findings suggest that female representation

on boards of directors is positively related to financial returns and that this relationship is stronger in countries with stronger shareholder protection. Similarly, Conyon and He (2017) using quantile regression method examined the relationship between corporate performance and board gender diversity. Based on annual data from more than 3000 US companies between 2007 and 2014, this study confirms that the presence of women on the board of directors has a positive effect on corporate performance and that this effect varies across different segments of the performance distribution. Quantile regression results revealed that female directors have a greater positive effect in high-performing companies compared to low-performing companies. The study emphasized that the effect of board gender diversity is not homogeneous as assumed in previous studies. Moreover, Reguera-Alvarado et al. (2017), which focuses on Spain, examined the relationship between board gender diversity and the economic performance of businesses. The study is based on a sample of 125 non-financial companies listed on the Madrid Stock Exchange between 2005 and 2009. The findings highlight that the mandatory quota regulation implemented in Spain increased the number of female directors by approximately 98% and that the increase in the rate of female directors positively affected the economic performance of businesses. In addition, it was stated that regulatory interventions that ensure gender balance can be not only an ethical requirement but also a value-creating governance mechanism.

In a global study, Noland et al. (2016) analyzed a dataset of 21,980 companies from 91 countries and showed that the presence of women in senior management is positively correlated with firm profitability. This study revealed that the presence of women in senior management is correlated with increases in firms' financial performance (e.g., return on assets). It is emphasized that this positive correlation could stem from productivity gains resulting from reducing workplace discrimination or from the diversity of skills that women managers bring to the company.

The academic literature examining the relationship between the rate of female employees in businesses and financial and operational performance goes beyond the representation of women in management positions and addresses the effects of spreading gender diversity throughout businesses. In addition to the findings on the positive effects of diversity in management ranks, there are studies indicating that the overall rate of female employees can also contribute to business performance. For example, Laskar et al. (2024) investigated the impact of gender diversity at both board and workforce levels on business performance in the Indian context. The study is based on annual data of 200 companies listed on the Bombay Stock Exchange for the period 2012-2019. The panel data analysis conducted by the authors on 200 companies indicates that gender diversity at both board and workforce levels statistically significantly improves business performance.

In the context of Japan, Kodama's (2016) study analyzed the correlation between the female workforce ratio and business performance. He argued that existing studies indicate a positive correlation between the level of female employment and business performance. However, he also emphasized that this does not mean a direct causality between the increasing female workforce and high corporate performance. Therefore, he argued that in order to increase performance, businesses should not only increase female employment but also implement structural transformations such as flexible working hours, work-life balance initiatives and inclusive corporate

culture. Some studies in the literature have also reached conclusions that the relationship between the female workforce ratio and financial performance may not be positive. For example, in their study of 159 businesses in France, Ferrary and Deo (2019) found that profit margins peaked in businesses where the female ratio reached 40–60% in middle managers and general staff, but performance relatively declined when the female ratio was lower or higher than this band. This finding reveal that the level of gender diversity should be in perfect balance and that the best performance can be achieved with this balance. Therefore, the goal for businesses should not only be to increase the number of female employees, but also to ensure a balanced gender distribution.

Similarly, sector-based studies on public enterprises provide important insights into the relationship between female representation and performance. For example, Moreno-Enguix et al. (2025) analyzed Spanish state-owned enterprises using panel data for the 2014–2021 period and found that the presence of female board members positively impacted financial performance. However, this effect became apparent when female representation exceeded a certain threshold, consistent with Rosabeth Moss Kanter's classic "critical mass" theory. The study concluded that a certain number of female board members (e.g., three or more) had a significant positive impact on profitability, but that female presence in companies with a single female board member did not produce a statistically significant difference.

2.3. Gender Diversity Studies in the Airline Sector

Studies examining the relationship between female employment and business performance in the airline sector are limited in number compared to the general management literature. However, significant research has been conducted in this area in recent years. Suau-Sanchez et al. (2025) investigated the impact of gender diversity at the board and executive levels on productivity using data from 45 global airline companies for the period 2019-2022. For this purpose, they analyzed a dataset of airlines from different continents. They used a Network Data Envelopment Analysis (DEA) to evaluate the performance of airlines regarding gender diversity in board and executive roles. The analysis results highlight that airline with greater gender diversity in their boards and executive teams in the pre- and post-COVID-19 periods exhibited higher productivity.

Lu et al. (2025) demonstrates that the proportion of women on boards of directors plays an important role in their research covering 40 international airline companies. The research examined the moderating role of board gender diversity in the relationship between environmental and business performance in the airline industry. The findings revealed that the positive relationship between environmental performance and profitability was stronger and more significant in businesses with high female representation. In addition, a biplot analysis was conducted to determine the advantages and disadvantages of airlines according to their efficiency. The findings obtained from the analysis of 40 airlines indicate that environmental performance has a more significant effect on profitability than operational efficiency. In addition, it was understood that relational capital does not always improve the relationship between environmental and business performance. It was concluded that it moderates the relationship between environmental performance and profitability/efficiency in businesses with high board gender diversity. Corazza (2024) investigated the benefits of increasing female representation in the aviation sector for airline companies. Scenarios adapted from various industries were applied to aviation and subjected

to multiple analyses. The study examined the gender pay gap, assessed the existing gender imbalance, and explored how addressing these issues could contribute to the sustainability and operational success of the sector. The results indicate that increased female participation in air transport operations leads to improvements in both financial performance and operational efficiency. Moreover, Abdi and Mohammadi (2025) examined the impact of board diversity on environmental, social and governance (ESG) performance of airline companies. The study is based on data from 34 international airline companies. The findings revealed various correlations between different variables. First, it was demonstrated that increasing the number of female directors can positively affect ESG performance. Second, it was found that the environmental performance of airlines can be improved with the presence of a special corporate social responsibility (CSR) committee. The study also examined the differences between traditional and low-cost airlines, emphasizing the role of strategic ownership in board effectiveness. These findings indicate the importance of board diversity and strategic ownership in the airline industry.

The studies summarized above reveal that female representation in both general businesses and the airline industry generally has positive and significant effects on financial, operational and ESG indicators. However, it is seen that the majority of the existing literature focuses on a single performance dimension and limited geographical samples or cross-sectional designs. In particular, studies examining the female employee ratio and business profitability indicators within a panel data framework and over multiple years are extremely limited. Therefore, studies that examine this relationship holistically through a longitudinal panel data

analysis covering global airline companies indicate an important gap in the literature. This study aims to fill this gap and empirically evaluate the impact of female employment on airline performance by simultaneously addressing differences across time and indicators.

3. Data and Methodology

In this study, the female employee ratio and financial data of 25 airlines operating on a global scale for the period 2019–2023 were examined through panel data analysis. The data were obtained from Refinitiv Eikon. The female employee ratio was taken from the annual reports of the airlines. In order to measure the effect of the female employee ratio on profitability in the study, the return on assets (ROA), return on equity (ROE) and return on sales (ROS) variables related to the profitability of the airlines were used as dependent variables. These variables are the most commonly used variables in the literature to measure profitability. The female employment ratio was used as the independent variable by determining the female employee ratio in the total number of employees for each airline. Asset turnover ratio, tangibility ratio, cash ratio, long-term debt ratio, market leverage ratio and asset per employee were used as control variables in the study. The financial data used in the study can be obtained from the Refinitiv Eikon database. The female employee ratio was obtained by examining the annual reports of the airlines by the researchers. Table 1 shows the details of the dependent, explanatory and control variables used in the study.

Table 1. Summary of variables and measurement

Variable	Formula / Definition		Explanation
Dependent Variable	ROA	Net Income / Total Assets	Indicates how efficiently a company uses its assets to generate profit.
	ROE	Net Income / Stockholders' Equity	Shows the return generated on shareholders' investments.
	ROS	Operating Profit / Revenue	Measures profitability in terms of sales efficiency.
Independent Variable	EMPFEM	Female Employees / Total Employees	Represents the share of female employees in the workforce, the main explanatory variable of the study.
	TATO	Net Sales / Total Assets	Reflects how effectively a company uses its assets to generate sales.
	TANGTC	Tangible Assets / Total Assets	Indicates the proportion of physical assets, showing the capital intensity of the firm.
Control Variable	CASH	Cash and Equivalents / Total Assets	A measure of liquidity, showing the firm's ability to cover obligations with available cash.
	LTDTA	Long-Term Debt / Total Assets	Indicates leverage by showing how much of the firm's assets are financed by long-term debt.
	MVOI	Market Value of Equity / Total Debt	Reflects the relationship between market capitalization and debt, showing financial stability and investor confidence.
	TAEMP	Total Assets / Number of Employees	Captures capital intensity per employee, reflecting workforce productivity and asset utilization.

In the study, three research models were created where return on assets (ROA), return on equity (ROE), and return on sales (ROS) are the dependent variables. The research models in this study are as follows.

$$\begin{aligned} ROA_{it} = & \beta_0 + \beta_1 EMPFEM_{it} + \beta_2 TATO_{it} \\ & + \beta_3 TANGTC_{it} + \beta_4 CASH_{it} \\ & + \beta_5 LTDTA_{it} + \beta_6 MVOI_{it} \\ & + \beta_7 TAEMP_{it} + \varepsilon_{it} \end{aligned} \quad (1.1)$$

$$\begin{aligned} ROE_{it} = & \beta_0 + \beta_1 EMPFEM_{it} + \beta_2 TATO_{it} \\ & + \beta_3 TANGTC_{it} + \beta_4 CASH_{it} \\ & + \beta_5 LTDTA_{it} + \beta_6 MVOI_{it} \\ & + \beta_7 TAEMP_{it} + \varepsilon_{it} \end{aligned} \quad (1.2)$$

$$\begin{aligned} ROS_{it} = & \beta_0 + \beta_1 EMPFEM_{it} + \beta_2 TATO_{it} \\ & + \beta_3 TANGTC_{it} + \beta_4 CASH_{it} \\ & + \beta_5 LTDTA_{it} + \beta_6 MVOI_{it} \\ & + \beta_7 TAEMP_{it} + \varepsilon_{it} \end{aligned} \quad (1.3)$$

Panel data analysis is widely used to estimate economic and financial relationships by employing models constructed with cross-sectional data observed over time (Yerdelen Tatoğlu, 2012). Panel data combines the advantages of both time series and cross-sectional analyses. As a result, panel data analysis

yields a larger number of observations than either time series or cross-sectional data alone, enabling more robust and reliable statistical inferences. A panel data equation can be defined as follows:

$$Y_{it} = \beta_{it} + \beta_{it}X_{it} + \varepsilon_{it} \quad (1.4)$$

where; Y_{it} denotes the dependent variable, β_{it} , the constant term, X_{it} , the independent variables, and ε_{it} , the errors terms.

4. Empirical Findings

In this study, three models were created to determine the effect of the female employee ratio on profitability. Return on assets (ROA), return on equity (ROE) and return on sales (ROS) variables related to the profitability of airlines were used as dependent variables. The descriptive statistics of the study are presented in the table below.

Table 2 presents descriptive statistics for the variables used in the study. The ROA (Return on Assets) value of the airlines varies between a minimum of -0.335 and a maximum of 0.136. ROE (Return on Equity) is observed as a minimum of -0.941 and a maximum of 3.712. The ROS (Return on Sales) variable varies between -0.822 and 0.234, and its standard deviation is higher than ROA and ROE. This indicates that fluctuations in sales profitability occur due to external shocks, especially changes in passenger demand due to Covid-19.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
ROA	125	-0.0245	0.0855	-0.3346	0.1357
ROE	125	-0.0138	0.3763	-0.9414	3.7120
ROS	125	-0.1114	0.2614	-0.8223	0.2335
EMPFEM	125	44.570	7.7124	30.000	63.300
TANGTC	125	1.0484	0.9102	-8.4867	2.0497
CASH	125	0.6648	0.1639	0.0770	0.9173
TATO	125	0.5119	0.2393	0.1015	1.4051
LTDTA	125	0.3786	0.1317	0.0653	0.6871
MVOI	124	-0.0003	0.0294	-0.2633	0.1210
TAEMP	125	668.42	292.39	305.39	2146.8

The EMPFEM variable, which confirm the proportion of female employees, is between a minimum of 30% and a maximum of 63.3%, and the average is approximately 44.57%. The standard deviation observed in this variable is 7.71, indicating that there are differences in the employee structure. The TANGTC variable, which indicates the ratio of tangible fixed assets to total assets, has a minimum of -8.49 and a maximum of 2.05, and this wide range indicates that there are significant differences in asset structures in some companies. The average of the CASH (Cash and Equivalents / Total Assets) variable used as a liquidity indicator is 0.66, ranging from a minimum of 0.077 to a maximum of 0.92. The average of the TATO (Net Sales / Total Assets) variable, which measures asset efficiency, is 0.51, and its minimum and maximum values are 0.10 and 1.41, respectively. This ratio reflects the differences in the efficiency of companies in sales production. The LTDTA variable, which is the ratio of long-term debt to assets, indicates a moderate debt structure with an average of 0.38, ranging from a minimum of 0.07 to a

maximum of 0.69. The minimum value of the MVOI (Market Value / Total Debt) variable is -0.26, and its maximum value is 0.12. Finally, the TAEMP variable, which indicates the amount of assets per employee, varies widely between 305.4 and 2146.8, with an average of approximately 668.4, indicating significant differences among companies in terms of workforce and asset structure.

Table 3. Correlation among the variables

	EMPFEM	TANGTC	CASH	TATO	LTDTA	MVOI	TAEMP
EMPFEM	1						
TANGTC	-0.0599	1					
CASH	0.1365	0.0043	1				
TATO	0.0901	0.1274	-0.1272	1			
LTDTA	-0.1112	-0.0777	-0.0361	-0.3881	1		
MVOI	-0.0141	0.0251	-0.1073	0.2057	-0.0727	1	
TAEMP	0.1247	-0.0556	0.3232	-0.3865	0.0965	-0.1894	1

Table 3 shows the correlation matrix between variables. The high correlation coefficients between independent variables may indicate a multicollinearity problem. The existence of high correlation may cause the regression model to become unstable and the predictive power to be weakened. The correlation coefficients among the independent variables used in this study are low and there is no multicollinearity problem. Moreover, high multicollinearity can often bias the standard errors of the estimated coefficients. Therefore, the variance inflation factor (VIF) was applied. Supplementary Table 1

shows that the VIF does not exceed 10. It confirms that there is no significant multicollinearity problem among the variables. Therefore, it proves the reliability of the panel regression analysis. In the study, unit root analysis was performed, and the non-stationary series were made stationary by taking the first difference. Moreover, the Hausman test was applied to determine the model, and it was confirmed that the fixed effects model was appropriate¹.

Table 4. Summary of panel regression analysis

Variable	ROA Coef. (SE)	ROA p-val	ROE Coef. (SE)	ROE p-val	ROS Coef. (SE)	ROS p-val
EMPFEM	0.00507 (0.00219)	0.0290	0.00277 (0.00582)	0.6380	0.02358 (0.00609)	0.0010
TANGTC	0.01607 (0.00196)	0.0000	-0.39912 (0.00520)	0.0000	-0.00879 (0.00350)	0.0190
CASH	-0.00344 (0.04591)	0.9410	-0.26519 (0.12827)	0.0500	-0.28237 (0.13914)	0.0540
TATO	0.31774 (0.03771)	0.0000	0.53789 (0.08892)	0.0000	1.11215 (0.10264)	0.0000
LTDTA	-0.03864 (0.06386)	0.5510	-0.33028 (0.15049)	0.0380	0.32215 (0.19738)	0.1160
MVOI	0.04860 (0.10828)	0.6580	-0.01299 (0.16889)	0.9390	-0.14812 (0.28322)	0.6060
TAEMP	0.00015 (0.00003)	0.0000	0.00014 (0.00008)	0.0930	0.00046 (0.00010)	0.0000
Constant	-0.51062 (0.11156)	0.0000	0.21803 (0.29055)	0.4600	-1.96620 (0.30072)	0.0000

Table 4 present the panel regression analysis results. In these models, return on assets (ROA), return on equity (ROE) and return on sales (ROS) variables are used as dependent variables. Coef. expresses the estimated effect of the independent variable on the dependent. SE (Standard Error) in parentheses is the standard error of this coefficient and confirm the uncertainty in the estimation of the coefficient. p-val is the p-value indicating whether the coefficient is statistically significant or not. Panel regression analysis results reveal that some variables have significant effects on the financial performance indicators of the firms. The female employee ratio (EMPFEM) has a positive and significant effect on ROA and ROS, indicating that gender diversity can contribute to business performance. This is extremely valuable for airlines because the increase in the female employee ratio can positively contribute to financial performance by strengthening elements such as service quality, operational efficiency and corporate reputation of airlines. Asset turnover (TATO) has statistically positive and significant effects on all performance measures, ROA, ROE and ROS. Therefore, it reveal that how efficiently airlines use their most important resources, aircraft, is a determinant of profitability. While the tangible fixed asset ratio (TANGTC) has a positive effect on ROA, it has a negative and significant effect on ROE and ROS. High fixed asset density may negatively affect profitability

indicators depending on the level of efficient use of resources. The negative effect of long-term debt (LTDTA) on ROE indicates that debt can reduce equity return. Moreover, the amount of assets per employee (TAEMP) has a significant and positive effect on ROA and ROS. Therefore, the findings support the positive relationship between employee productivity and profitability.

5. Discussion

This study examined the impact of the female employee ratio on business profitability in the global airline industry and revealed significant findings. The analysis results indicate that the female employee ratio has a positive and statistically significant effect on return on assets (ROA) and return on sales (ROS). However, no significant relationship was found on return on equity (ROE). These findings prove that in a service-intensive and operational efficiency-critical industry such as aviation, the composition of human resources is a strategic factor that influences financial performance.

In our study, the finding of a positive and significant relationship between the female employee ratio and business profitability (ROA and ROS) is consistent with the results of many studies in the literature. For example, Post and Byron (2015) found a positive relationship between female executive

¹ The Hausman test results indicate that the fixed effects model is appropriate in the first model (ROA as the dependent variable, $\chi^2 = 31.197$, $p = 0.0001$) and the third model (ROS as the dependent

variable, $\chi^2 = 35.804$, $p = 0.0000$), while the random effects model is more suitable in the second model (ROE as the dependent variable, $\chi^2 = 13.729$, $p = 0.0562$).

representation and accounting-based financial returns. Ferrary and Déo (2023) also reported similar results, emphasizing that gender diversity in middle and lower-level management is a strategic resource that increases corporate performance. In addition, it is seen in the literature that gender diversity exhibits complex relationships with different performance measures. In the study of Laskar et al. (2024), while female diversity positively affects market value-based performance, negative findings were found in accounting-based profitability. This situation confirms that the results may vary depending on the differences in the sample and performance indicators. Suau-Sánchez et al. (2025) also revealed that the number of female executives at the senior level in the airline industry increases operational efficiency, for example, 25% representation can provide a 1.9% improvement in capacity efficiency and a 3.2% improvement in operational indicators. Our findings generally confirm a positive relationship between female employment and profitability; however, the lack of a significant relationship with ROE suggests a weak link in this measure, similar to Post and Byron's market return. On the other hand, our divergence from Laskar's negative relationship with accounting profitability may be explained by differences in industry and country context. Overall, our findings support the positive diversity–performance relationship in the literature by validating that a female workforce can support profitability in the airline industry.

Our research results are consistent with the “resource-based view” perspective, where gender diversity can be seen as a strategic resource that increases firm performance. According to the resource-based view, an organization's human resources provide inimitable, valuable competencies (Clardy, 2008; Wright et al., 1994); in this context, the new knowledge, experience, and values that women bring create a competitive advantage. Post and Byron (2015) also stated that using different knowledge and experiences of each member can improve performance. These findings are parallel to Ferrary and Déo's argument that a balanced gender composition at the middle and staff level provides a corporate competitive advantage. When considered from a CSR (Corporate Social Responsibility) perspective, increasing the employment of women is a practice that meets the social expectations of businesses and their sensitivity towards stakeholders (Kaur, 2013; Vilke et al., 2014). For example, Chang et al. (2024) indicates that the characteristics of female managers such as compassion and empathy support the creation of policies that consider the well-being of stakeholders and lead to a stronger CSR performance. In this respect, it is possible for companies to increase both financial success and achieve social responsibility goals while ensuring gender diversity. Finally, it is suggested that mixed teams can make more creative decisions and better understand different customer needs (Ferrary & Déo, 2023; Hoogendoorn et al., 2011). In our data, the increase in the proportion of women has a positive contribution to profitability after a threshold value (which could be the 35–45% band in this study). In summary, in the light of current theoretical approaches, as the proportion of women employees increases, the rare and valuable resources of the companies increase, which leads to positive results in both performance and social responsibility dimensions.

Beyond RBV and CSR, our findings also align with gender theories that warn against seeing the “female ratio” as sufficient for inclusion. Tokenism theory shows that when women are few in number, they face visibility, stereotyping, and isolation. This limits both their effectiveness and the organization's gains. It also emphasizes not only “how many” women are employed, but also “where” they work and “what

authority” they hold. (Kanter, 1977). Social role theory suggests that social expectations push women into “communal” roles and away from leadership or technical positions. Thus, performance outcomes depend more on role fit, seniority, authority, and task importance than on the number of women employed (Eagly et al., 2002; Eagly et al., 2012). In this light, future research should not only examine the overall female-employment share but also analyze distributions by function (e.g., flight operations, maintenance), hierarchy (supervisory, executive), and qualifications. This may explain why our models show significant effects on ROA and ROS but not on ROE.

Our study also has several limitations. First, the sample is limited to 25 international airlines, which, although representing a significant portion of the industry, limits the generalizability of the results. Second, our analysis focuses on the overall proportion of female employees but does not distinguish between organizational levels or departments. It is possible that the performance impact of gender diversity is more pronounced at certain levels (e.g., in leadership or technical roles) than at others. Finally, the study period (2019–2023) includes the period when the COVID-19 pandemic severely affected the industry. Although we controlled for time effects, the crisis may have introduced unique dynamics that do not represent normal operations. Future research could build on these findings in various ways. Extending the analysis to a longer time period (before and after the pandemic) or to other industries would reveal whether the positive impact of female employment holds true under different conditions.

6. Conclusion

The purpose of this study is to empirically examine the effect of the female employee ratio on profitability in the airline industry. To this end, data from 25 airlines covering the period 2019–2023 were analyzed. Return on assets (ROA), return on equity (ROE), and return on sales (ROS) were employed as dependent variables to measure airline profitability. These variables were chosen because they are the most commonly used indicators in the profitability literature and help capture various aspects of airline profitability. The female employee ratio served as the independent variable. Asset turnover ratio, tangibility ratio, cash ratio, long-term debt ratio, market leverage ratio, and asset per employee were included as control variables. A panel data analysis method was applied. This study contributes to the literature both in terms of the period examined and the models developed.

The findings of this study demonstrate that the female employee ratio exerts a significant and positive influence on key profitability indicators, namely Return on Assets (ROA) and Return on Sales (ROS). The statistically significant impact of female workforce representation (EMPFEM) on both ROA and ROS suggests that gender diversity constitutes a critical factor in enhancing financial performance within the airline industry. This result is particularly salient for airline companies, where variables such as service quality, operational efficiency, and corporate image are closely linked to organizational performance. Female employees contribute substantially across various operational domains—including customer relations, in-flight services, ground operations, and managerial roles—thereby enhancing passenger satisfaction and elevating the overall service quality. Moreover, a workforce characterized by gender diversity fosters a more inclusive and innovative organizational culture, benefiting from varied perspectives and problem-solving approaches. This, in turn, not only improves internal dynamics but also

positively shapes stakeholder perceptions and reinforces brand equity. From a strategic standpoint, increasing the proportion of female employees can yield a dual benefit: it enhances internal performance while simultaneously bolstering external reputation. Gender equality policies, when embedded within broader corporate social responsibility frameworks, may further serve as a source of competitive advantage by strengthening investor and consumer confidence. In this context, promoting female employment in the airline sector emerges not merely as a social imperative but as a strategic determinant of long-term profitability and sustainable financial performance.

This study, which investigates the impact of the female employee ratio on airline profitability, has several limitations. First, although the financial data of the 25 airlines with the highest passenger volumes globally were analyzed, this sample may not fully represent the entire airline industry. The study included only those airlines for which complete financial and female employee ratio data were available, based on an extensive database and financial report review. Second, the analysis covered the period from 2019 to 2023. While this timeframe is critically important for understanding the current landscape, different results may emerge with an alternative analysis period. Nonetheless, the findings provide significant insights into the present situation. Future research should involve a more in-depth analysis of the female employee ratio. In particular, identifying how profitability varies based on the positions held by female employees could offer valuable contributions to the literature. Therefore, it is recommended that future studies conduct similar empirical analyses by classifying female employees according to their representation in senior, middle, and lower-level management positions.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abdi, Y., & Mohammadi, M. (2025). Moderating Role of Strategic Ownership on Board Composition and ESG (Environmental, Social, and Governance) Performance in Global Airlines: Insights From Full-Service and Low-Cost Carriers. *Strategic Change*, 34(2), 277-303.
- Chang, Y., Wu, K.-T., Lin, S.-H., & Lin, C.-J. (2024). Board gender diversity and corporate social responsibility. *International Journal of Corporate Social Responsibility*, 9(7). <https://doi.org/10.1186/s40991-024-00095-x>
- Clardy, A. (2008). Human resource development and the resource-based model of core competencies: Methods for diagnosis and assessment. *Human Resource Development Review*, 7(4), 387-407.
- Canyon, M. J., & He, L. (2017). Firm performance and boardroom gender diversity: A quantile regression approach. *Journal of Business Research*, 79, 198-211.
- Corazza, M. V. (2024). Flying high: Revealing the sustainability potential of women in aviation. *Sustainability*, 16(16), 7229.
- Costa, Q., Soares, J., & Costa, A. (2020, December 5). Gender equality potential in aviation. *Aviation in the XXI-ST Century* 2020 <https://conference.nau.edu.ua/index.php/Congress/Congress2020/paper/viewFile/7592/6287>
- Durbin, S., Lopes, A., Neugebauer, J., & Warren, S. (2016, Jun 6). Mentoring for equality: Women activists creating change in the UK aviation and aerospace industry. *Acting for Women and Equalities in Organizations? Gender, Work and Organization Conference*. <https://uwe-repository.worktribe.com/output/911058>
- Eagly, A. H., & Karau, S. J. (2002). Role congruity theory of prejudice toward female leaders. *Psychological review*, 109(3), 573.
- Eagly, A. H., Woo, W., & Diekmann, A. B. (2012). Social role theory of sex differences and similarities: A current appraisal. In *The developmental social psychology of gender* (pp. 123-174). Psychology Press.
- Ferla, M., & Graham, A. (2019). Women slowly taking off: An investigation into female underrepresentation in commercial aviation. *Research in Transportation Business & Management*, 31, 100378.
- Ferrary, M., & Deo, S. (2019). Gender diversity and firm performance: What organizational layer matter? *Academy of Management Proceedings*, 2019(1), 12923.
- Ferrary, M., & Déo, S. (2023). Gender diversity and firm performance: When diversity at middle management and staff levels matter. *The International Journal of Human Resource Management*, 34(14), 2797-2831.
- Hoogendoorn, S., Oosterbeek, H., & van Praag, M. (2011). The impact of gender diversity on the performance of business teams: Evidence from a field experiment. *SSRN Electronic Journal*.
- IATA. (2023). Diversity, Equity & Inclusion in Aviation. International Air Transport Association. <https://www.iata.org/contentassets/93253b033dea48e38aabc9f639d7b486/25by2025-best-practice-guide-2023.pdf>
- IATA. (2024). Gender in aviation: Celebrating progress while looking to the future. International Air Transport Association. <https://www.iata.org/contentassets/cd7f1170cbf447c7824f63e8d138e5d0/gender-in-aviation-final.pdf>
- ICAO. (2025). Training Report, Vol. 7, No. 3: Attracting, Educating and Retaining the Next Generation of Aviation Professionals. Montreal: ICAO. https://www.icao.int/sites/default/files/2025-02/icao_training_report_vol7_No3.pdf
- Kaur, P. (2013). Corporate Social Responsibility and gender in workplace. *International Journal of Humanities and Social Science Invention*, 2(11), 36-40.
- Kanter, R. M. (1977). Some effects of proportions on group life: Skewed sex ratios and responses to token women. *American journal of Sociology*, 82(5), 965-990.
- Kodama Naomi. (2016, August 26). Positive correlation between the ratio of female employees and the company's business performance. *Research Institute of Economy, Trade and Industry*. <https://www.rieti.go.jp/en/papers/contribution/yasashii21/05.html>
- Laskar, N., Sahu, J. P., & Choudhury, K. S. (2024). Impact of gender diversity on firm performance: empirical evidence from India. *Managerial Finance*, 50(3), 614-633.
- Lu, W.-M., Wang, H.-F., & Nguyen, T. H. Y. (2025). The moderating effect of relational capital and board gender diversity on the relationship between environmental performance and firm performance in the airline

- industry. *Business Strategy and the Environment*, 34(6), 6925–6947.
- Lutte, R. K., & Morrison, S. M. (2022). “You’ll Never Really Be One of Us”: Women’s Underrepresentation in the Aviation Workforce. *Journal of Aviation/Aerospace Education & Research*, 31(2).
- McCarthy, F., Budd, L., & Ison, S. (2015). Gender on the flightdeck: Experiences of women commercial airline pilots in the UK. *Journal of Air Transport Management*, 47, 32–38.
- Moreno-Enguix, M. d. R., Gras-Gil, E., & Lloret, N. N. E. (2025). Critical mass of women on boards and firm performance: Insights from Spanish state-owned enterprises. *Journal of the Knowledge Economy*. Advance online publication.
- Noland, M., Moran, T., & Kotschwar, B. R. (2016). Is gender diversity profitable? Evidence from a global survey. Peterson Institute for International Economics Working Paper, (16-3).
- Post, C., & Byron, K. (2015). Women on boards and firm financial performance: A meta-analysis. *Academy of management Journal*, 58(5), 1546-1571.
- Reguera-Alvarado, N., de Fuentes, P., & Laffarga, J. (2017). Does board gender diversity influence financial performance? Evidence from Spain. *Journal of Business Ethics*, 141(2), 337–350.
- Sengur, F. K. (2025). Female leadership in aviation. In *Research Handbook on Air Transport Leadership and Governance* (pp. 138–158). Edward Elgar Publishing.
- Statista. (2021). Gender distribution among senior roles in the airline industry in 2021, by region. <https://www.statista.com/statistics/741182/airline-industry-senior-roles-by-gender-and-region/>
- Suau-Sanchez, P., Voltes-Dorta, A., & Lamolla, L. (2025). Board and executive gender diversity as a driver of airline efficiency: A network-DEA analysis. *Journal of Air Transport Management*, 124, 102745.
- Vilkė, R., Raišienė, A. G., & Simanavičienė, Ž. (2014). Gender and Corporate social responsibility: ‘big wins’ for business and society? *Procedia - Social and Behavioral Sciences*, 156, 198–202.
- Yerdelen Tatoglu, F. (2012). İleri panel veri analizi stata uygulamalı. Beta Yayınları.
- Wright, P. M., McMahan, G. C., & McWilliams, A. (1994). Human resources and sustained competitive advantage: a resource-based perspective. *The International Journal of Human Resource Management*, 5(2), 301–326.

Cite this article: Durak, M.S. (2025). Flying Towards Equality: The Role of Female Employees in Enhancing Airline Performance. *Journal of Aviation*, 9(3), 694-702.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

An Analysis of Commercial Aircraft Accidents Using the Human Factors Analysis and Classification System (HFACS): The Case of The United States

Münevver Aysel Kaya^{1*}, F. Didem Göçmen²

^{1*} University of Turkish Aeronautical Association (UTAA), Aviation Management, 06790, Ankara, Türkiye. (aycelkaya@outlook.com)

² University of Turkish Aeronautical Association (UTAA), Civil Air Transportation Management Department, 06790, Ankara, Türkiye. (dgoemen@thk.edu.tr)

Article Info

Received: 30 June 2025

Revised: 07 August 2025

Accepted: 25 August 2025

Published Online: 16 October 2025

Keywords:

Aviation Safety

Human Factors

HFACS

Aircraft Accidents

NTSB Reports

Corresponding Author: F. Didem Göçmen

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1729542>

Abstract

A significant portion of aviation accidents is attributed to human factors, highlighting the need for comprehensive and systematic analyses in this field. This study examines 57 scheduled commercial aircraft accidents that occurred in the United States between 2020 and 2024 using the Human Factors Analysis and Classification System (HFACS) framework, with the aim of evaluating the contributing human factors in a multi-layered manner. The research demonstrates that human errors are not solely the result of individual performance deficiencies but also stem from systemic, managerial, and organizational shortcomings. The study utilizes official accident reports from the United States National Transportation Safety Board (NTSB), analysed through content and descriptive analysis techniques. Only accidents involving turbofan-powered fixed-wing aircraft engaged in scheduled passenger transportation were included. NTSB reports are considered highly reliable primary sources due to their comprehensive analysis of technical, operational, and human factors related to aviation incidents. Based on 207 coding conducted according to the HFACS model, human errors were analysed across four levels: unsafe acts, preconditions for unsafe acts, supervisory factors, and organizational influences. The analysis revealed that the most frequently observed human errors were related to decision-making and perception, primarily resulting from cognitive limitations, information deficiencies, and inadequate situational awareness. Environmental factors such as turbulence and technological shortcomings were also identified as direct threats to operational safety. Furthermore, operational planning errors, the neglect of safety priorities, dysfunctional procedures, and insufficient resource management were highlighted as indirect contributors stemming from managerial and organizational deficiencies. The findings emphasize the necessity of developing accident prevention strategies not only at the individual level but also across organizational and systemic levels.

This study is derived from a Master's thesis completed at the School of Graduate Studies, University of Turkish Aeronautical Association.

1. Introduction

Since the late 1950s, the air transportation sector has taken significant steps to reduce accident rates. As a result of these efforts, traveling by commercial passenger aircraft has become a safer mode of transportation than driving in large cities (Wiegmann & Shappell, 2001). In achieving this level of safety, studies aimed at understanding human factors have been as decisive as technological advancements. It is widely accepted that approximately 80% of all accidents in modern civil and military aviation are caused by human factors (de Hoyos, 2023).

In the last twenty years, many aviation organizations have encouraged personnel working in safety and risk management to develop programs aimed at reducing the effects of human factors. Despite advancements in aircraft technology and increased system reliability, human errors continue to be one of the most significant safety risks. Although the contribution of human errors to accidents is well known, current analyses

and preventive measures are often insufficient; while accident reports provide detailed accounts of the timing and manner of events, they rarely examine the underlying causes in depth. In many cases, the lack of concrete evidence leads to the assumption of pilot error, which in turn causes deeper structural reasons to be overlooked. However, scientific analyses aimed at revealing how and why accidents occur are crucial for preventing the recurrence of similar incidents (ICAO Circular, 1993).

According to the International Civil Aviation Organization (ICAO), the most effective step in preventing accidents is the comprehensive analysis of past accidents (ICAO, 2010). In recent years, safety is no longer seen as limited to individual errors; organizational structures, managerial processes, and environmental conditions are also considered among the causes of accidents (Xiong, Beckmann & Tan, 2018). Understanding the root causes of human errors in aviation is important not only for evaluating past events but also for shaping future safety policies.

This study aims to reveal the structural patterns behind incidents by systematically examining accident reports through multi-level, pre-defined thematic frameworks. For this purpose, the study employs one of the most widely used models in the literature, the Human Factors Analysis and Classification System (HFACS). Inspired by James Reason's Swiss Cheese Model, the HFACS model was developed by Wiegmann and Shappell to classify human errors into four basic levels: unsafe acts, preconditions for unsafe acts, supervisory factors, and organizational influences (Wiegmann & Shappell, 2001). Originally developed for the U.S. Navy, HFACS has gradually become widely used by many military institutions. Today, having been applied in more than 1,000 military aviation accidents, the model has improved the quality of data collection on human errors and strengthened the effectiveness of research strategies. Civil aviation organizations such as the FAA and NASA have also demonstrated the applicability of HFACS in civil aviation. Today, the model is used not only in the military but also in civil aviation and other sectors for safety analyses (Wiegmann & Shappell, 2001). HFACS provides an effective framework for systematically classifying and analyzing the underlying causes of human errors (Dönmez & Uslu, 2018).

The study focuses on identifying the most common types of unsafe acts encountered in the examined accidents and the environmental or technological conditions under which these behaviors occur. Additionally, based on the statements found in the reports, the analysis explores how deficiencies in managerial planning and elements of organizational structure are reflected in the accidents. The HFACS model enables the classification of human errors at different levels, and in this context, the findings obtained are expected to contribute to evaluations aimed at improving aviation safety.

2. Conceptual Framework

2.1. The Concept of Human Factors

Human factors is a multidimensional field of study that examines an individual's physiological, psychological, and cognitive capacities within the context of their interaction with the system. Particularly, understanding the internal and external variables that affect human performance plays a significant role in ensuring safety in high-risk sectors (Tamer, 2021). This concept not only addresses human behavior in terms of individual competencies but also includes the environmental, managerial, and organizational factors that lead to these behaviors (Demirhan, 2024).

Humans are inherently beings with limitations. These limitations manifest in areas such as attention, perception, decision-making, and reaction time, increasing the likelihood of errors, especially among individuals operating in complex systems. Indeed, the literature emphasizes that human errors are the most common cause of aircraft accidents and that the human factor is involved, either directly or indirectly, in approximately 80% of such incidents (Baber, 2007). However, this rate is seen more as an indicator of deficiencies in the design and operation of the system the individual is part of, rather than a reflection of the individual's incompetence.

The aviation sector is one of the most prominent fields for the systematic examination of human factors. Elements such as time pressure, information load, the necessity of decision-making, and environmental conditions in the working environment of flight personnel increase the likelihood of errors. As emphasized by Tamer (2021), determining and

reducing the error tendencies of individuals involved in aviation activities is one of the fundamental components of the sector's safety approach.

The evaluation of human factors cannot be reduced merely to the analysis of individual competencies or errors; it also requires a holistic consideration of systemic elements such as organizational structure, management philosophy, task distribution, and workload planning. To accurately analyze the underlying causes of aircraft accidents, it is necessary to consider not only the individual's role within the system but also institutional deficiencies outside the organizational structure. This elevates the consideration of human factors beyond individual responsibility, requiring it to be addressed within a multi-actor and multi-layered systems approach (Kızıltepe, 2021).

Initially, the discipline of human factors in aviation developed with a focus on individuals' physical limitations and ergonomic needs. Early research concentrated on topics such as cockpit workload, attention processes, and human-machine interaction. Over time, the field began to be addressed from a broader perspective, incorporating not only individual performance but also environmental conditions, organizational structures, and managerial decision-making processes. Human factors have arguably found their greatest recognition in the field of aviation, becoming an integral part of the research, development, testing, and evaluation cycle (Deaton & Morrison, 2010). These developments have highlighted the need for a more systematic examination of the causes of human errors, leading to an increased focus on theoretical models.

2.2. Analysis of Aircraft Accidents Through Systematic Models and the HFACS Model

The analysis of aircraft accidents is an important approach used to enhance aviation safety and to develop strategies for accident prevention. Theoretical models developed in this context delve into the root causes of accidents by considering a wide range of variables such as human factors, technical problems, and environmental influences, thus contributing to safer flight operations. The evolution of safety management in aviation consists of four stages: the Technical Era, the Human Factors Era, the Organizational Era, and the Total System Era (ICAO, 2018). Theoretical models such as Heinrich's "Domino Theory," Hollnagel's "FRAM," Svenson's "AEB," Reason's "Swiss Cheese Model," Leveson's "STAMP," SHELL, and the 5M model are among the key tools designed to improve aviation safety (SIA, 2012). CASA recommends the continuous updating of these models to ensure sustainable safety, and Maurino (2017) defines safety management as an evolutionary discipline.

The Domino Theory posits that accidents occur through a sequential chain of cause-and-effect, suggesting that breaking any link in this chain can prevent accidents (Heinrich, 1931; Griffin, Young & Stanton, 2015). Reason's Swiss Cheese Model states that accidents occur when weaknesses in a system's defense barriers align (Reason, 1990, 1997). This model facilitates the analysis of not only human errors but also organizational and systemic deficiencies. The SHELL model highlights the risks arising from mismatches in the interactions between humans and software, hardware, environment, and other individuals (ICAO, 2014; CASA, 2014c). The 5M model aims to analyze accident causes multidimensionally by focusing on human, machine, media, mission, and management factors (Rodrigues & Cusick, 2012; Stolzer &

Goglia, 2015). The STAMP model argues that accidents result more from deficiencies in system control processes than from component failures (Leveson, 2003). The FRAM model presents a dynamic approach by analyzing performance variability and function interactions in systems to understand unexpected outcomes in complex systems (Hollnagel, 2012; Patriarca et al., 2020). All these models contribute to the development of a safety management culture in aviation.

The Human Factors Analysis and Classification System (HFACS) offers a taxonomy that classifies human errors across four hierarchical levels: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences (Shappell & Wiegmann, 2000). Developed based on Reason’s model of latent and active failures, HFACS has been effectively used in the analysis of thousands of accident records, particularly by the U.S. Navy and other military forces (Wiegmann & Shappell, 2003). HFACS comprises 19 causal categories analyzed at four levels:

- 1. Unsafe Acts (Decision Errors, Skill-Based Errors, Perceptual Errors, Violations)
- 2. Preconditions (Mental State, Physiological State, Mental/Physical Limitations, CRM Deficiency, Personal Readiness, Physical Environment, Technological Environment)
- 3. Unsafe Supervision (Inadequate Supervision, Inappropriate Operational Planning, Failure to Correct Known Problem, Supervisory Violations)
- 4. Organizational Influences (Resource Management, Organizational Climate, Organizational Processes)

Under unsafe acts, errors (including skill-based, decision, and perceptual errors) and violations (routine and exceptional) are categorized, while preconditions encompass factors such as the individual’s mental and physiological states, CRM deficiency, lack of personal readiness, and physical environment (Wiegmann & Shappell, 2001). The third level, unsafe supervision, includes deficiencies such as inadequate oversight, flawed operational planning, and failure to correct known issues (Wiegmann & Shappell, 2001; NTSB, 1982). Organizational influences reveal how weaknesses in resource

management, organizational climate, and processes shape individual behaviors (Tamer, 2021; Demirhan, 2024).

This system enables the identification of systemic deficiencies underlying accidents. Additionally, by analyzing past events, recurring human errors and systemic failures can be identified. This allows organizations to focus on weak areas, make data-driven improvements, and reduce accident rates (Wiegmann & Shappell, 2001). HFACS provides a structure for examining and analyzing historical accident and safety data. By separating human contribution in terms of performance, the analyst can identify the root factors associated with an unsafe act. The HFACS framework also serves as a useful tool for guiding future field investigations and for the development of more robust accident databases, ultimately enhancing the quality and accessibility of human factor-related accident data. Common trends within an organization can be uncovered by comparing the psychological origins of unsafe acts or the latent conditions that make them possible. Identifying these patterns supports the determination and prioritization of areas that require intervention.

Through the use of HFACS, an organization can identify where hazards have occurred in the past and implement procedures to prevent the consequences of these hazards. This contributes to improved human performance and the reduction of accidents and injuries. The HFACS framework has been successfully applied to analyze accidents in military, commercial, and general aviation sectors (Shappell & Wiegmann, 2001). The HFACS model provides a comprehensive framework for the systematic analysis of human factors in aircraft accidents. By contributing to the development of data-driven strategies for accident prevention in both military and civil aviation, it helps strengthen the culture of safety (Shappell & Wiegmann, 1999, 2001, 2003).

Table 1 presents various studies based on the HFACS model, including their methodologies and key findings. These studies employed different data collection and analysis methods to understand the role of human factors in aircraft accidents and to propose solutions based on these factors.

Table 1. Summary of HFACS-Based Aircraft Accident Studies

Author(s)	Year	Research Focus	Methodology	Key Findings
Liu et al.	2025	LLM-based reasoning in HFACS-guided accident investigations	HFACS-Guided LLM (GPT-4o) Reasoning	HFACS-CoT methods improved LLM accuracy in detecting human errors and precursors; in some cases outperformed experts.
Meng & Lu	2022	HFACS and Bayesian Network integration for CFIT analysis	Hybrid HFACS–Bayesian Network	The hybrid model effectively analyzed human factors in CFIT accidents, showing enhanced explanatory capacity.
Kılıç & Gümüř	2020	Night flight accident analysis (2015–2020)	HFACS Analysis	Environmental conditions were dominant; skill-based and decision errors also significant.
Kılıç & Gündođdu	2020	Air cargo accidents (2010–2020)	HFACS Analysis	Skill and decision errors were prominent; organizational and environmental shortcomings contributed to accidents.
Kılıç	2019	General aviation and training accidents (2018)	HFACS Analysis	Skill-based errors accounted for 80% of unsafe acts; 58.57% of them were linked to physical environmental preconditions.
Dönmez & Uslu	2018	Organizational-Operational links in 21st-century aviation events	HFACS, Data & Statistical Analysis	Organizational and managerial faults directly impacted cockpit crew's unsafe behaviors.
Yeřilbař & Cotter	2014	HFACS structure for manned vs. unmanned aircraft	Structural Comparison via HFACS	Identified operational and structural differences in human factor classifications between UAVs and manned aircraft.

Author(s)	Year	Research Focus	Methodology	Key Findings
Bilbro	2013	Inter-rater reliability of HFACS and HFACS-M in the U.S. DoD	Comparative Reliability Analysis	Found both HFACS versions reliable with nuanced differences in application.
Ergai	2013	Internal and inter-observer reliability of HFACS	Reliability Assessment	Demonstrated the consistency of HFACS classifications across observers and sessions.
Li, Harris & Yu	2008	HFACS application to Chinese civil aviation (1999–2006)	HFACS & Data Analysis	Organizational lapses correlated with unsafe acts; highlighted management's impact on operator behavior.
Li, Harris & Yu	2007	41 Chinese civil aviation accidents (1999–2006)	HFACS Analysis	Found most accidents resulted from decision and skill-based errors; supervisory and systemic issues were also evident.
ATSB	2007	HFACS applied to general, commercial, and agricultural flights in Australia	HFACS, Comparative Country Study	Highlighted national differences in human factor patterns between Australia and the U.S.
Shappell et al.	2006	Commercial aviation accidents (1990–2002)	HFACS & Data Analysis	Unsafe acts, especially skill and decision errors, were found to be leading contributors in commercial aviation accidents.
Wiegmann et al.	2005	14,436 general aviation accidents (1990–2000) from NTSB database	HFACS Large-Scale Analysis	Skill-based, decision, and perceptual errors were the most frequent human error types contributing to accidents.
Wiegmann & Shappell	2001	HFACS analysis of commercial accidents (1990–1996)	HFACS & Data Analysis	Demonstrated how human error shaped commercial aviation accidents, forming the basis of HFACS development.

The studies included in the table are significant works that comprehensively examine human factors in aircraft accidents. A majority of these studies employed the HFACS model to understand the impact of human errors on accidents and to develop applicable solutions to prevent such errors. In addition, studies conducted in different years analyzed various aviation accidents from a human factors perspective, thereby contributing to the development of a safety culture in the industry. Particularly, elements such as cockpit communication, decision-making processes, managerial errors, and organizational deficiencies are prominently featured in the findings of these studies. These studies reveal that human factors are among the primary causes of accidents and emphasize the necessity of considering human factors in ensuring aviation safety. The findings obtained from the studies will be useful in improving safety practices in the sector, enhancing training programs, and formulating policies for safer flight operations.

Several national and international studies that do not rely on the HFACS model have also examined commercial aviation accidents from a human factors perspective. Kharoufah et al. (2018) analyzed more than 200 commercial air transport accidents and incidents between 2000 and 2016, identifying lack of situational awareness and non-adherence to procedures as prominent human factors. The study also found that charter operations had a higher proportion of accidents related to human factors compared to other types of operations. Von Thaden et al. (2006) conducted a case-based analysis of commercial aircraft accidents between 1990 and 2000, revealing the role of organizational factors in events attributed to pilot error. Their findings indicated that inadequate procedures and directives were the most common organizational problems, suggesting that interventions targeting organizational-level improvements could be effective across the system. Studies conducted in Türkiye also highlight the importance of human factors. Terzioğlu (2007) examined pilots' awareness of Crew Resource Management (CRM), emphasizing that, in addition to technical competence, communication, teamwork, and decision-making skills are critical in preventing accidents. Işıldak et al. (2021) analyzed

the statistical distribution of civil aviation accidents in Türkiye between 1909 and 2020, identifying notable trends in certain time periods, flight routes, and aircraft types. These findings demonstrate that human factors should be addressed not only at the operational level but also within organizational structures and at the sectoral level, and they show that, alongside HFACS-based research, alternative methodological approaches hold a significant place in the aviation safety literature.

3. Methodology

3.1. Research Design

This study was conducted within the scope of qualitative research methods aiming to systematically analyze human errors, which are considered one of the main causes of aviation accidents. Qualitative research designs are flexible, exploratory, and interpretative approaches used to gain a deep understanding of complex social phenomena within a specific context. The analytical strategies employed in the study include descriptive analysis and content analysis techniques. Descriptive analysis is an approach based on summarizing and interpreting the data obtained in line with predetermined themes. The main objective of descriptive analysis is to present the findings in a meaningful and interpretable manner to the reader (Özdemir, 2010: 336; Karataş, 2015: 73). Content analysis, on the other hand, is a method that enables the systematic and objective examination of written, verbal, or visual materials (Tavşancıl & Aslan, 2001). Within the scope of the study, the layers of the HFACS model were structured based on the cases presented in NTSB reports, and each level was analyzed through case-specific examples. In this way, the interrelations among human factors contributing to accidents were addressed in detail within a cause-effect framework.

3.2. Data Source and Sampling

The primary data source of the research consists of aircraft accident reports published by the National Transportation Safety Board (NTSB), which is responsible for conducting official investigations into aviation accidents in the United

States. NTSB reports are considered highly reliable primary sources for scientific research, as they contain comprehensive analyses of the technical, operational, and human factors related to accident events. The data analyzed within the scope of the research is limited to finalized reports of accidents that occurred between 2020 and 2024, involving only turbofan-powered fixed-wing passenger aircraft, and classified under 14 CFR Part 121 scheduled passenger transport operations. The study focuses exclusively on accidents that took place within the borders of the United States. The data collection process was carried out systematically through the NTSB's digital data archive. As a result of filtering, 57 finalized accident reports were obtained in digital format. These reports were coded in detail based on the HFACS model and analyzed using a dual-coder approach by two researchers. During the coding process, each event was structured according to the four fundamental levels of HFACS (unsafe acts, preconditions for unsafe acts, unsafe supervision, organizational influences). The data were transformed into thematic codes and compiled into an Excel-based analysis table. The distribution of the codes across HFACS layers enabled both numerical frequency analysis and qualitative contextual interpretation.

In data analysis, descriptive analysis and content analysis techniques were used together. In descriptive analysis, each

report was classified according to HFACS themes, and comparative patterns were identified. In content analysis, the codes were grouped according to HFACS levels and thematic clusters were created. The main themes identified included violations, perceptual errors, planning deficiencies, physical environment, and inappropriate operational planning. These themes were matched with HFACS levels and interpreted through a multi-layered error chain approach.

4. Findings

The data on aviation accidents were analyzed according to the four levels of the HFACS model. Codings for each level were evaluated under separate headings, and the human factors leading to accidents were examined across different categories. When the overall distribution of the codes is considered, the highest proportion was found at the level of preconditions for unsafe acts, with 61.8%. This was followed by unsafe acts (16.9%), unsafe supervision (13.0%), and organizational influences (8.2%). This distribution indicates that a large part of the accidents stemmed from factors such as environmental, team-related, or technological conditions that set the stage for individual errors. The key findings at each level are explained below with relevant examples.

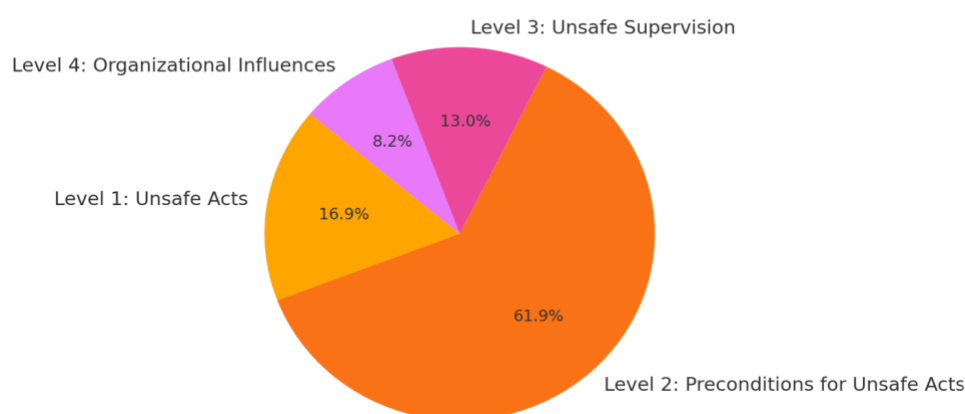


Figure 1. Overall Coding Distribution by HFACS Levels

4.1. Unsafe Acts (HFACS Level 1)

Within the scope of the 57 aviation accidents analyzed in this study, a total of 35 distinct codes were identified under the first level of the HFACS model, titled Unsafe Acts. This level encompasses individual behavioral errors that have a direct impact on the occurrence of accidents, including critical human factors such as decision errors, skill-based deficiencies, perceptual issues, and procedural violations. The coding results related to unsafe acts are presented in Table 2.

Table 2 – Coding Results Related to Unsafe Acts

Category	Frequency (n)	Percentage (%)
Decision Error	12	34.3%
Perceptual Error	11	31.4%
Violations	7	20.0%
Skill-Based Error	5	14.3%
Total	35	100%

4.1.1. Decision Errors (n=12, 34.3%)

The most frequently encountered type of unsafe act was decision errors. These errors occur when pilots make incorrect or incomplete assessments during operational decision-making moments. Examples classified under this category include approaching the wrong runway, continuing flight despite disregarding meteorological assessments, or failing to avoid turbulent areas. The frequent occurrence of decision errors may indicate underdeveloped situational awareness and risk assessment capabilities.

4.1.2. Perceptual Errors (n=11, 31.4%)

The second most common behavioral error was perceptual errors. This category includes errors that arise when the flight crew misperceives or misinterprets the external environment (e.g., weather conditions, other aircraft, runway conditions) or aircraft systems. Frequent causes include misinterpretation of cockpit instruments, visual illusions, distraction, or lack of sensory input. These findings suggest that factors such as

sensory overload, information saturation, or visual-auditory discrepancies are influential during flight operations.

4.1.3. Violations (n=7, 20.0%)

Ranked third, violations refer to instances where personnel intentionally or unintentionally fail to comply with existing rules, procedures, or standard operating practices. In this study, violations were not classified as routine or exceptional within the HFACS analysis; rather, both types were evaluated together. Examples include landing without clearance from air traffic control, cabin crew movement during turbulence warnings, or non-standard approach profiles. These behaviors are often driven by factors such as time pressure, overconfidence, or organizational tolerance embedded in safety culture.

4.1.4. Skill-Based Errors (n=5, 14.3%)

The least observed category was skill-based errors, which refer to situations where an individual's knowledge or skills are insufficient to meet task requirements. Such errors often involved novice or inexperienced personnel struggling with complex tasks, mishandling aircraft systems, or failing to respond appropriately to unexpected situations. These findings highlight the importance of robust training systems, on-the-job observation processes, and assignment policies.

4.1.5. Overall Assessment

The findings at this level indicate that a significant portion of the accidents stemmed from individual errors, most of which were related to cognitive processes such as decision-making and perception. Furthermore, the presence of structured behavioral patterns such as violations in noteworthy proportions suggests that individual errors may not only result from personal shortcomings but also reflect organizational attitudes and norms. These findings underscore the need to address both individual-level interventions (e.g., training, awareness enhancement) and institutional-level factors that influence behavioral patterns in order to improve aviation safety.

4.2. Preconditions for Unsafe Acts (HFACS Level 2)

A total of 128 codes derived from the 57 aviation accidents analyzed in the study were categorized under the second level of the HFACS model: *Preconditions for Unsafe Acts*. This level includes environmental, physiological, psychological, and team-related conditions that create a foundation for the emergence of unsafe acts. The coding results are presented below:

Table 3 – Results Related to Preconditions for Unsafe Acts

Subcategory	Frequency (n)	Percentage (%)
Physical Factors	53	41.4%
Technological Environment	22	17.2%
Cognitive/Physical Limitations	20	15.6%
Inadequate Personal Preparation	16	12.5%
Lack of Crew Resource Management (CRM)	12	9.4%
Mental State	4	3.1%
Physiological State	1	0.8%
Total	128	100%

4.2.1. Physical Factors (n=53, 41.4%)

This subcategory emerged as the most frequently coded factor among the analyzed accidents. Physical factors refer to external conditions related to the flight environment, with turbulence being the predominant element identified in the majority of cases. Turbulence has been shown to cause significant loss of control, injuries, and secondary operational errors for both cockpit and cabin crew. This finding underscores that flight safety depends not only on human performance but also on the adequacy of preventive measures against environmental conditions.

4.2.2. Technological Environment (n=22, 17.2%)

This category involves deficiencies related to equipment, systems, and sensors used during flight. The most frequently encountered issue was the inability of weather radars to detect or fully display cloud structures associated with turbulence. Since radars often detect only precipitation-bearing clouds, dry but hazardous convective turbulence zones may go unnoticed, thus limiting the flight crew's capacity to make preventive decisions. The findings reveal that perceptual limitations of technological systems hinder effective management of environmental risks such as sudden turbulence.

4.2.3. Cognitive/Physical Limitations (n=20, 15.6%)

This subcategory refers to cognitive and physiological capacity boundaries that constrain human performance. In many of the analyzed cases, cabin crew members standing during severe turbulence were physically unable to protect themselves, emerging as a central theme under this subcategory. Such events are not due to knowledge deficiencies or procedural errors but arise from the overwhelming effects of environmental conditions on human biomechanical and reflexive capabilities. For instance, when turbulence begins without warning, standing cabin crew members may not have the physical ability to brace or secure themselves. This limitation lies beyond individual control and should be evaluated from a systemic perspective in terms of human endurance and protectability. These findings highlight the critical role of timing, turbulence forecasting, and adequate alert systems in protecting human performance boundaries. Therefore, these cases reaffirm the principle widely cited in human factors literature: the system must adapt to human physical limitations.

4.2.4. Inadequate Personal Preparation (n=16, 12.5%)

This category refers to insufficient individual preparedness of crew members before or during flight. Common issues included a lack of operational briefings, outdated procedural knowledge, and poor anticipation of flight conditions. For example, in several cases, cabin crew were not adequately informed about potential turbulence and continued their tasks without taking precautions, resulting in safety risks. These examples suggest that individual errors can stem not only from momentary lapses but also from insufficient preparation processes.

4.2.5. Lack of Crew Resource Management (CRM) (n=12, 9.4%)

Deficiencies in CRM include weak information exchange between cockpit and cabin crews, unclear task allocation, and communication failures during decision-making processes. In many coded cases, coordination breakdowns occurred during

rapidly evolving situations such as turbulence, which hindered timely safety decisions.

4.2.6. Mental State (n=4, 3.1%)

This category includes psychological factors such as stress, anxiety, or distraction that negatively influence cognitive processes. Although it represents a low frequency, the impact of such mental states on decision-making was clearly observed in certain cases involving turbulence or weather-related emergencies.

4.2.7. Physiological State (n=1, 0.8%)

This rarely observed category involves cases where the physical health status of crew members adversely affected their performance. In one case, a cabin crew member experienced a sudden physical ailment during flight, posing a risk to both personal and passenger safety.

4.2.8. General Evaluation

Findings at the level of preconditions for unsafe acts indicate that a significant portion of accidents stemmed not from individual errors but from environmental and systemic risk factors. The frequent coding of environmental factors such as turbulence, along with the limitations of radar systems in detecting such hazards, highlight external conditions as key contributors to human error. These results suggest the necessity of improving not only crew training and individual competencies but also environmental awareness, technological systems, and predictability in operational planning.

4.3. Unsafe Supervision (HFACS Level 3)

This level refers to failures to systematically prevent or appropriately guide unsafe acts and preconditions. The 27 coded entries in this study reveal the role of supervisory and managerial deficiencies in the development of accidents. The findings related to each subcategory are detailed below:

Table 4. Results Related to Unsafe Supervision (HFACS Level 3)

Category	Frequency (n)	Percentage (%)
Inappropriate Operational Planning	17	63.0%
Failure to Correct a Known Problem	6	22.2%
Inadequate Supervision	4	14.8%
Supervisory Violations	0	0.0%
Total	27	100%

4.3.1. Inappropriate Operational Planning (n=17, 63.0%)

This category includes deficiencies arising from unrealistic or insufficiently risk-aware operational planning conducted prior to or during flight. In most coded incidents, factors such as the failure to consider turbulent weather conditions in flight planning, lack of alternative landing scenarios, and scheduling of duty hours in a way that triggers operational fatigue were prominent. These findings indicate that airline management must conduct multi-layered assessments in operational planning that incorporate not only technical parameters but also human performance capacity and environmental variables.

4.3.2. Failure to Correct a Known Problem (n=6, 22.2%)

This category refers to instances where previously observed or reported operational risks were not systematically addressed. In the analyzed accidents, this included disregarding previously reported turbulence warnings on the same route, unaddressed maintenance requests for technical faults, and persistent deficiencies in crew training. These findings suggest that internal feedback mechanisms within the organization are limited in functionality and that the concept of a learning organization has not been sufficiently institutionalized.

4.3.3. Inadequate Supervision (n=4, 14.8%)

Inadequate supervision refers to managerial shortcomings in crew assignment, performance monitoring, training continuity, and the enforcement of procedural compliance. Coded cases revealed examples such as assigning crew members to flights without verifying their qualifications, irregular training cycles, and approving flights despite hazardous weather conditions. These findings emphasize that management must assume active responsibility not only in planning but also in the implementation and oversight phases of operations.

4.3.4. Supervisory Violations (n=0, 0.0%)

In the examined sample, there were no explicit findings indicating that managerial personnel deliberately violated existing regulations. However, this does not imply that such violations never occur; rather, it suggests that the 57 accidents analyzed did not provide sufficient open data to support such cases.

4.3.5. Overall Assessment

Findings under the third HFACS level—Unsafe Supervision—demonstrate that accidents may originate not only from operational failures but also from weaknesses in organizational decision-making structures. Strategic errors in operational planning, in particular, were found to expose flight crews to hazardous conditions and elevate the likelihood of individual errors. These results highlight that aviation safety must be addressed not only at the individual level but also in terms of institutional oversight and strategic governance.

4.4. Organizational Influences (HFACS Level 4)

The fourth level of the HFACS model, Organizational Influences, aims to analyze the systemic and structural factors underlying individual errors. A total of 17 codes at this level reveal the indirect yet significant impact of organizational structures and institutional policies on aviation accidents.

Table 5. Results Related to Organizational Influences (HFACS Level 4)

Category	Frequency (n)	Percentage (%)
Organizational Processes	11	64.7%
Resource Management	5	29.4%
Organizational Climate	1	5.9%
Total	17	100%

4.4.1. Organizational Processes (n=11, 64.7%)

This subcategory refers directly to the inadequacy or dysfunctionality of internal procedures, policies, and operational standards within the organization. Coded cases

revealed issues such as poorly defined standard operating procedures, lack of systematic protocols for crisis situations, and discrepancies between procedures and real-world operational practices.

These findings highlight that organizations are not only responsible for generating procedures but also for ensuring their applicability and effectiveness in practice. One recurring theme under this subcategory was the lack of coordination between cockpit and cabin procedures during unexpected events such as turbulence.

4.4.2. Resource Management (n=5, 29.4%)

Resource management involves evaluating how effectively and sufficiently an organization utilizes its personnel, equipment, time, and financial resources. In the coded events, factors such as insufficient crew scheduling, equipment shortages, and rigid duty assignments due to operational pressure were particularly prominent. These results show that flight safety is not solely a function of individual competence but is also directly influenced by the structural support provided by the organization.

4.4.3. Organizational Climate (n=1, 5.9%)

This category includes intangible yet structural elements such as organizational culture, leadership style, prioritization of safety, and communication norms. In the single coded case, a management approach focused more on timeliness and performance metrics than on safety considerations was observed to negatively influence decision-making processes. Although rarely identified directly, the long-term role of organizational climate in shaping a safety culture should not be underestimated.

4.4.4. Overall Assessment

The findings at HFACS Level 4—Organizational Influences—demonstrate that aviation accidents may originate not only from individual or supervisory failures but also from structural deficiencies within the organization itself. The effectiveness of organizational processes, particularly the applicability of established procedures in real-world scenarios, contributes indirectly but significantly to accident causation. These results emphasize that strategic management areas such as process design, resource planning, and safety prioritization are fundamental determinants of flight safety in airline operations. Errors at this level generally point to systemic dysfunctions that go beyond the scope of individual decisions.

4.5. Evaluation of Accident Factors within the HFACS Framework

The analyses revealed that in the majority of the 57 examined accidents, multiple causal factors were simultaneously influential. For instance, in several cases, cockpit-related human errors co-occurred with adverse environmental conditions—especially turbulence. The findings identified a diverse range of contributing factors, including 44 environmental, 10 cockpit-related, 8 technological, and 3 each from cabin crew, air traffic control (ATC), operations, ground services, and management, as well as 2 related to maintenance. Among environmental factors, turbulence emerged as the most frequently recurring issue, underscoring the critical role of external conditions in maintaining flight safety.

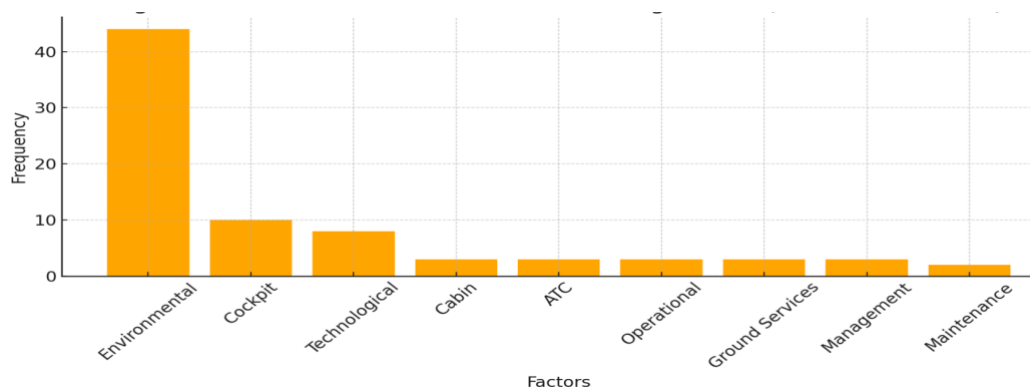


Figure 2. Frequency Distribution of Identified Accident Factors in 57 Aircraft Accidents

The findings reveal that aviation accidents cannot be reduced to a single human error or system failure; rather, multiple factors across various HFACS levels interact simultaneously. This condition of multi-causality underscores the importance of the HFACS model's multilayered structure and necessitates the adoption of a holistic and integrated safety management approach in accident prevention.

4.6. Distribution of Accidents by Flight Phase and Its Relationship with Environmental Factors

The analysis of the 57 investigated accidents showed a marked concentration during the descent phase, which accounted for 27 accidents—by far the most common. This was followed by the cruise phase with 14 accidents and the climb phase with 4. In contrast, significantly fewer accidents occurred during ground phases of flight, such as taxiing, parking, or pushback, which are generally considered less complex in terms of operational demands.

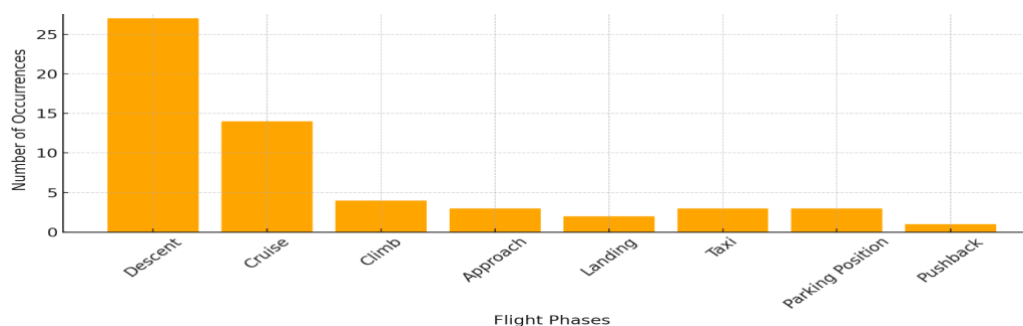


Figure 3. Distribution of Accidents by Flight Phase

5. Discussion

In this study, analyses based on the four levels of the HFACS model have clearly revealed that aviation accidents do not solely stem from individual errors but arise from complex, multi-layered, system-oriented causes. The findings indicate that individual behaviors often represent the final link in the accident chain, while environmental, managerial, and organizational factors play a decisive role in the development of such events. The findings related to each level of the HFACS model are discussed in detail below in light of the relevant literature.

5.1. Unsafe Acts Level

The data obtained indicate that the most common factors at the unsafe acts level are decision-making and perception errors. Decision errors such as failure to avoid turbulent areas and misaligned approaches are associated with a lack of situational awareness. In terms of perception errors, cognitive mistakes such as distraction and misinterpretation of cockpit indicators stand out. These results are largely consistent with Endsley's (1995) model of situational awareness. Similarly, Demirhan (2024) found decision errors in 60% and perception errors in 45% of the accidents examined in their study. These ratios are parallel to those found in the current study. Dönmez (2018), in an HFACS-based analysis, emphasized the impact of cognitive load and information flow on pilot decision-making processes, stating that perceptual and judgment errors are among the primary causes of accidents. Tamer (2021), in their analysis of the Tenerife air disaster, also highlighted the role of decision-making errors, communication breakdowns, and time pressure on pilot behavior. This finding aligns with the emphasis on stress and divided attention observed in the present study.

5.2. Preconditions for Unsafe Acts Level

According to the findings, the preconditions level had the highest coding density, and the impact of environmental factors was clearly observed. Environmental pressures such as turbulence, radar limitations, and cockpit conditions were identified as primary precursors of individual errors. In particular, injuries to cabin crew during turbulence suggest that the system has failed to develop adequate preventive measures. These findings are consistent with the deficiencies in defense layers as indicated in Reason's Swiss Cheese Model. Dönmez (2018) similarly emphasized that unpredictable conditions like clear-air turbulence could lead to incorrect pilot decisions. Furthermore, the inability of radars to detect clear-air turbulence—only identifying precipitation-based masses—demonstrates the negative impact of technological limitations on decision-making processes. In Demirhan's (2024) study, environmental factors were found to be directly influential in 40% of accidents. This rate is consistent with the current

findings, indicating that external conditions in the flight environment play a critical role in accident causation.

5.3. Unsafe Supervision Level

Findings at this level show that strategic deficiencies in the planning stages of flight operations have created conditions conducive to accidents. Factors such as ignoring turbulence reports, lack of alternative scenarios, and unresolved known issues reveal significant managerial shortcomings. These findings appear to conflict with the "proactive safety management" principles emphasized in ICAO's (2021) Safety Management Manual. Dönmez (2018) statistically demonstrated that managerial deficiencies could directly cause individual errors and that management-originated violations are associated with unsafe behaviors. Similarly, Demirhan (2024) reported that managerial factors played a role in approximately 30% of the accidents. These results highlight the inadequacy of management in shaping a safety culture and monitoring safety processes systematically, suggesting that accidents are not merely operational but strategic problems.

5.4. Organizational Influences Level

The most significant problems identified at the organizational level were the impracticality of procedures and inadequacies in resource management. Safety procedures must not only exist but also be understood and practically applicable by personnel. Furthermore, deficiencies in time, equipment, and personnel planning were found to be contributing factors to individual errors. Tamer (2021), in the analysis of the Tenerife accident, noted that communication and authority issues at the organizational level had a direct impact on the accident. This finding supports the current study's identification of weaknesses in organizational climate and procedural processes. Dönmez (2018) also stated that organizational deficiencies are directly linked to "planned inappropriate operations." The findings at this level demonstrate that aviation safety is contingent not only upon individual skills but also on the operational efficiency of institutional structures.

5.5. General Evaluation

The examined reports show that approximately 61.8% of the causal factors were concentrated at the preconditions level, namely, in environmental and system-based contributors. Among the physical environmental factors, turbulence played a prominent role. Turbulence, characterized by sudden and unexpected air movements, can negatively affect pilots' attention and decision-making processes, reducing situational awareness and increasing the risk of errors. It may also lead to communication and coordination issues within Crew Resource Management (CRM). Therefore, environmental factors such as turbulence not only impact individual performance directly

but also indirectly weaken intra-crew interaction, posing critical risks to aviation safety. Consequently, beyond enhancing individual competencies, system approaches that consider the interaction between human, machine, and organization form the cornerstone of aviation safety.

In this context, studies utilizing the HFACS model provide effective results in the systematic analysis of accidents. For example, Avcı and Ercan (2022) found that CRM problems were decisive in 41.4% of the 59 Turkish civil aviation accidents between 2003 and 2017. Their study confirms that intra-crew communication and coordination deficiencies can lead to serious vulnerabilities in aviation safety. Similarly, in their analysis of 30 commercial night flight accidents between 2015 and 2020, Kılıç and Gümüş (2020) found physical environment to be a factor in 63.33% of cases, skill-based errors in 33.33%, decision errors in 26.66%, and technological environment in 13.3%. These findings emphasize the impact of environmental conditions and human abilities on nighttime flights.

In another study by Kılıç and Gündoğdu (2020) analyzing 15 air cargo plane accidents between 2010 and 2020, skill-based errors were found in 53.3%, inadequate supervision in 46.66%, technological factors in 40%, decision errors in 33.3%, physical environment in 33.3%, and organizational processes in 33.3% of accidents. These results demonstrate the decisive roles of individual skills as well as managerial and technological factors. Furthermore, Dönmez (2018) found, in a study of 324 aircraft accidents in the U.S. from 2000 to 2016, that skill-based errors were present in 90%, personal factors in 79%, decision errors in 62%, environmental factors in 52%, and organizational processes in 35% of the cases. These figures clearly demonstrate the multifaceted nature of human factors in aviation safety.

The fact that perception errors were effective in 39% of accidents points to the need to improve personnel's situational awareness skills, while the 29.2% impact of environmental factors highlights the role of weather and external elements in accident formation. Risks related to human factors, such as fatigue, are important considerations for aviation safety. In conclusion, improving crew dynamics, perception capabilities, environmental conditions, and management processes emerges as a key area for accident prevention.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Avcı, F., & Ercan, S. (2022). Türk Sivil Havacılık Kazalarının HFACS Modeliyle Değerlendirilmesi (2003–2017). *Havacılık Emniyeti ve İnsan Faktörleri Dergisi*, 7(1), 58–75.
- Baber, E. (2007). İnsan faktörü analizi ve sınıflandırma sistemi (HFACS) ve kara havacılık kazalarına uygulanabilirliği (Yüksek Lisans Tezi). Gazi Üniversitesi, Fen Bilimleri Enstitüsü.
- Bilbro, J. (2013). An inter-rater comparison of DOD human factors analysis and classification system (HFACS) and human factors analysis and classification system maritime (HFACS-M) (Doctoral dissertation, Monterey, California: Naval Postgraduate School).
- CASA. (2014c). SMS 6 – SMS for aviation – A practical guide: Safety policy and objectives (2nd ed.). CASA. <https://www.casa.gov.au/sites/default/files/2021-06/safety-management-systems-book-6-human-factors.pdf>
- de Hoyos, J. U. (2019). Human Factor in Military Aviation Accidents: A Resume of 31 USAF accidents extracted from Accident Investigation Board public reports https://openlibrary.org/books/OL33881833M/Human_Factor_in_Military_Aviation_Accidents
- Deaton, J. E., & Morrison, J. G. (2010). Aviation research and development: A framework for the effective practice of human factors, or “What your mentor never told you about a career in human factors...”. In J. A. Wise, V. D. Hopkin & D. J. Garland (Eds.), *Handbook of Aviation Human Factors* (2nd ed.,). Boca Raton, FL: CRC Press.
- Demirhan, Y. (2024). Ticari uçak kazalarının HFACS modeli ile incelenmesi ve EYS açısından değerlendirilmesi (Yüksek Lisans Tezi). Türk Hava Kurumu Üniversitesi, Sosyal Bilimler Enstitüsü.
- Dönmez, K. (2018). 21. yüzyıl havacılık olaylarında operasyon organizasyon ilişkisi: İnsan faktörleri analiz ve sınıflandırma sistemi uygulaması (Yüksek Lisans Tezi). Anadolu Üniversitesi, Fen Bilimleri Enstitüsü.
- Dönmez, K., & Uslu, S. (2018). İnsan faktörleri analiz ve sınıflandırma sistemi'nin (HFACS) literatürde yaygın kullanımının değerlendirilmesi. *Journal of Aviation*, 2(2), 156–176.
- Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37(1), 32–64.
- Ergai, A. (2013). Assessment of the Human Factors Analysis and Classification System (HFACS): Intrarater and inter-rater reliability, Clemson University.
- Griffin, T., Young, M., & Stanton, N. (2015). Human factors models for aviation accident analysis and prevention. Ashgate Publishing Limited.
- Heinrich, H. (1931). *Industrial accident prevention: A scientific approach*. McGraw Hill.
- Hollnagel, E. (2012). FRAM: The functional resonance analysis method: Modelling complex socio-technical systems. Ashgate.
- ICAO. (1993). Investigation of human factors in accidents and incidents (Human Factors Digest No. 7; Circular 240-AN/144). Montreal, Canada: International Civil Aviation Organization.
- ICAO. (2010). Manual of Aircraft Accident and Incident Investigation (Doc 9756). Montreal, Canada: International Civil Aviation Organization.
- ICAO. (2014). Human factors training manual (3rd ed., Doc 9683). Montreal, Canada: ICAO.
- ICAO. (2018). Safety management manual (SMM) (4th ed., Doc 9859). Montreal, Canada: ICAO.
- Işıldak, B., Keleş, M. K., & Özdağoğlu, A. (2021). Sivil havacılıkta uçak kazalarının analizi: Türkiye örneği. 14. Uluslararası Güncel Araştırmalarla Sosyal Bilimler Kongresi Tam Metin Kitabı (ss. 1430-1444)
- Karataş, Z. (2015). Sosyal bilimlerde araştırma yöntemleri. *Manevi Temelli Sosyal Hizmet Araştırmaları Dergisi*, 1(1), 63–64, 72–73.
- Kılıç, B., & Gümüş, E. (2020). Application of HFACS to the nighttime aviation accidents and incidents. *Journal of Aviation*, 4(2), 10-16.
- Kılıç, B., & Gundogdu, S. (2020). Human factors in air cargo operations: An analysis using HFACS. *Journal of Aviation Research*, 2(2), 101-114.

- Kızıltepe, N. (2021). Analysis of human factors in aircraft accidents: The case of the USA (Master's thesis). İbn Haldun University, İstanbul.
- Kharoufah, H., Murray, J., Baxter, G., & Wild, G. (2018). A review of human factors causations in commercial air transport accidents and incidents: From 2000–2016. *Progress in Aerospace Sciences*, 99, 1-13. :
- Leveson, N. G. (2003). A new accident model for engineering safer systems. *Safety Science*. Elsevier.
- Li, W.-C., Harris, D., & Yu, C.-S. (2008). Routes to failure: Analysis of 41 civil aviation accidents from the Republic of China using the Human Factors Analysis and Classification System. *Accident Analysis & Prevention*, 40(2), 426–434.
- Liu, Q., Li, F., Ng, K. K., Han, J., & Feng, S. (2025). Accident investigation via LLMs reasoning: HFACS-guided Chain-of-Thoughts enhance general aviation safety. *Expert Systems with Applications*, 269, 126422.
- Maurino, D. (2017). Why SMS: An introduction and overview of safety management systems. ITF Discussion Paper 2017.16. <https://www.itf-oecd.org/sites/default/files/whysms.pdf>
- Meng, B., & Lu, N. (2022). A Hybrid Model Integrating HFACS and BN for Analyzing Human Factors in CFIT Accidents. *Aerospace*, 9(11), 711.
- Özdemir, M. (2010). Nitel veri analizi: Sosyal bilimlerde yöntem bilim sorunsalı üzerine bir çalışma. *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi*, 11(1), 327–336.
- Patriarca, R., Di Gravio, G., Woltjer, R., Costantino, F., Praetorius, G., Ferreira, P., & Hollnagel, E. (2020). Framing the FRAM: A literature review on the Functional Resonance Analysis Method. *Safety Science*, 129, 104827.
- Reason, J. (1997). Managing the risks of organizational accidents. Ashgate.
- Reason, J. T. (1990). Human error. Cambridge University Press.
- Safety Institute of Australia. (2012). Models of causation: Safety. Safety Institute of Australia Ltd.
- Tamer, Ş. (2021). Havacılıkta insan faktörünün uçak kazalarına etkisinin incelenmesi: Tenerife uçak kazası örneği (Yüksek lisans tezi, İstanbul Gelişim Üniversitesi, Lisansüstü Eğitim Enstitüsü,
- Terzioğlu, M. (2007). Uçak kazalarının nedeni olarak insan hatalarını azaltmada ekip kaynak yönetimi (Master's thesis, Dokuz Eylül Üniversitesi (Turkey):
- Shappell, S. A., & Wiegmann, D. A. (1997a). A human error approach to accident investigation: The taxonomy of unsafe operations. *International Journal of Aviation Psychology*, 7, 269–291.
- Shappell, S. A., & Wiegmann, D. A. (1997b). Why would an experienced aviator fly a perfectly good aircraft into the ground? In *Proceedings of the Ninth International Symposium on Aviation Psychology* (pp. 26–32). The Ohio State University.
- Shappell, S. A., & Wiegmann, D. A. (2000). The Human Factors Analysis and Classification System--HFACS. , (). Retrieved from <https://commons.erau.edu/publication/737>
- Shappell, S. A., & Wiegmann, D. A. (2001). Applying the human factors analysis and classification system (HFACS) to the analysis of commercial aviation accident data. In *Proceedings of the 11th International Symposium on Aviation Psychology* (pp. 679–684). Columbus, OH: The Ohio State University.
- Shappell, S., & Wiegmann, D. (2009). A methodology for assessing safety programs targeting human error in aviation. *International Journal of Aviation Psychology*, 19, 252–269.
- Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A., & Wiegmann, D. A. (2007). Human error and commercial aviation accidents: An analysis using the human factors analysis and classification system. *Human Factors*, 49(2), 227–242.
- Shappell, S., Wiegmann, D., Fraser, J., Gregory, G., Kinsey, P., & Squier, H. (1999b). Beyond mishap rates: A human factors analysis of U.S. Navy/Marine Corps TACAIR and rotary wing mishaps using HFACS. *Aviation, Space, and Environmental Medicine*, 70, 416–417.
- SIA. (2012). Safety Institute of Australia. Models of causation: Safety. In *The core body of knowledge for generalist OHS professionals*. Tullamarine, VIC, Australia.
- Stolzer, A. J., & Goglia, J. J. (2016). Safety management systems in aviation (2nd ed.). Ashgate.
- Tavşancıl, E., & Aslan, E. (2001). İçerik analizi ve uygulama örnekleri. İstanbul: Epsilon Yayıncılık.
- Von Thaden, T. L., Wiegmann, D. A., & Shappell, S. A. (2006). Organizational Factors in Commercial Aviation Accidents. *The International Journal of Aviation Psychology*, 16(3), 239–261.
- Wiegmann, D. A., & Shappell, S. A. (2001). A human error analysis of commercial aviation accidents using the Human Factors Analysis and Classification System (HFACS). *International Journal of Aviation Psychology*, 11(4), 357–370.
- Wiegmann, D. A., & Shappell, S. A. (2003). A human error approach to aviation accident analysis: The human factors analysis and classification system. Ashgate.
- Wiegmann, D. A., Faaborg, T., Boquet, A., & Detwiler, C. (2005). Human error and general aviation accidents: A comprehensive, fine-grained analysis using HFACS. FAA Civil Aerospace Medical Institute Report.
- Xiong, C., Beckmann, V., & Tan, R. (2018). Effects of infrastructure on land use and land cover change (LUCC): the case of Hangzhou International Airport, China. *Sustainability*, 10(6), 2013.
- Yeşilbaş, V., & Cotter, T. S. (2014). Structural analysis of HFACS in unmanned and manned air vehicles. In *Proceedings of the International Annual Conference of the American Society for Engineering Management (ASEM)* (pp. 1–10). American Society for Engineering Management. <https://www.researchgate.net/publication/336851769>

Cite this article: Kaya, M.A., Gocmen, F.D. (2025). An Analysis of Commercial Aircraft Accidents Using The Human Factors Analysis and Classification System (HFACS): The Case of The United States. *Journal of Aviation*, 9(3), 703-713.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Financial Sustainability of European Air Navigation Service Providers and the Impact of the COVID-19 Pandemic

Orkun Bayram¹ 

¹Balikesir University, International Trade and Logistics Department, 10145, Altieylül, Balıkesir, Türkiye. (orkun.bayram@balikesir.edu.tr)

Article Info

Received: 08 July 2025
Revised: 07 August 2025
Accepted: 23 August 2025
Published Online: 16 October 2025

Keywords:

Air Navigation Service Providers
Financial Sustainability
COVID-19 Shock
Panel Data Analysis
Crisis Management

Corresponding Author: *Orkun Bayram*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1731086>

Abstract

This study examines the financial resilience of European Air Navigation Service Providers (ANSPs) before and after the COVID-19 shock. Using a balanced panel dataset covering 2017–2023 for over 30 ANSPs, we employ fixed-effects estimators to quantify changes in key financial metrics—revenue, operating costs, capital expenditures, and free cash flow—once air traffic volumes collapsed. Our findings reveal a pronounced downturn in profitability and liquidity in 2020, followed by uneven recovery trajectories across providers. We also identify factors—such as pre-pandemic leverage and cost structure—that moderated the depth of the shock. These insights contribute to crisis-management literature in aviation finance and offer policy implications for bolstering sectoral sustainability against future disruptions.

1. Introduction

The smooth operation of modern air transport critically depends on Air Navigation Service Providers (ANSPs), which coordinate enroute and terminal air traffic across national boundaries. As monopolistic, capital-intensive entities, ANSPs recover costs through user charges calibrated to forecast traffic volumes. Under stable demand, this framework balances infrastructure investment with operational expenses; however, it inherently exposes providers to volume fluctuations and external shocks.

The COVID-19 pandemic represented an unprecedented demand shock: between March and May 2020, European air traffic plunged by 72.8 % compared to the previous year (Total of Total Network Manager Area (All flights) over March 1st to May 31st compared between 2020 and 2019), eliminating a large share of enroute charges (EUROCONTROL, 2025). Unlike airlines, which could ground fleets or renegotiate leases, ANSPs maintained continuous service obligations—yet their revenue base evaporated, with documented steep cash-flow contractions for individual providers such as Nav Canada and European Air Navigation Service Providers (Carey, 2020; EUROCONTROL, 2021), but a comprehensive, cross-provider analysis of financial resilience during this period remains lacking. In particular, the roles of pre-pandemic leverage, fixed-cost structure, and national policy

support in moderating the depth and duration of the crisis have not been systematically quantified.

This paper fills that gap by employing a balanced panel dataset of over 30 European ANSPs spanning 2017–2023. Using fixed-effects estimators and robustness checks (including random-effects and system GMM specifications), we assess how key financial indicators—revenue, operating costs, capital expenditures, and free cash flow—responded to the COVID-19 shock and subsequent recovery efforts. Our contributions are threefold: (1) we provide the first large-scale, panel-level evidence on ANSP financial sustainability under stress; (2) we identify structural factors (e.g., leverage ratios, cost composition) that enhanced or undermined resilience; and (3) we derive policy implications for reinforcing ANSP stability against future disruptions. These insights will inform regulators, policymakers, and service providers seeking to bolster the sector's crisis-management capabilities.

2. Literature Review

Financial sustainability stems from the capability to absorb, adapt to, and recover from economic shocks (Broto and Lamas, 2020; Chen and Sun, 2024). Adaptability is a key element to reach sustainability, and the level of an organization's or an ecosystem's adaptability may even lead to benefit from the shocks, or it may stay unaffected, recover from, or reconfigure itself after the shock (Gallopín, 2006;

Salignac et al., 2019). Which of these consequences would prevail depends on the internal and external resources available to organizations, and moderating impacts of an organization's resources needs to be included in assessments of financial sustainability.

Ensuring sustainability and resilience of the aviation industry against systemic disruptions is critical not only for the industry itself, but due to the cascading potential impacts on other industries such as transportation, storage, postal service, and wholesale and retail trade. While some systemic disruptions were short-lived such as the Blue Screen of Death (BSOD) crisis (albeit very disruptive), long-term disruptions such as Covid-19 pandemic led to stark financial struggles for all parts of the aviation industry (Venkata, 2025; Zhou and Zhang, 2024). Due to these consequences, analysis of financial resilience of the aviation industry is of paramount importance in management and policy frameworks to withstand different types of disasters, which is associated with achieving resilience (Rose, 2004; Handmer et al., 1996).

In the recent past, the aviation sector has experienced economic downturns due to pandemics, wars, terrorist attacks, and financial crises (Bilotkach et al., 2015; Caprian, Lom and Caprian, 2023; Ölçen and Alnıpak, 2023; Tuncal, 2025). Before Covid-19 pandemic, disasters and crises such as Gulf War, Asian Financial Crisis, 9/11 attacks, and severe acute respiratory syndrome (SARS) epidemic had caused significant decreases in the demand for air travel. Furthermore, there were significant shifts in consumer attitude, moving away from business and first-class seats (Mason, 2005). All these changes resulted in the revenues for airlines dropping, and therefore a decrease in the revenues of organizations on whom the airlines rely on to provide their services.

Following the Second World War, the states established Air Navigation Service Providers (ANSPs) to exercise authority over and regulate airspace above their sovereign territory. While airlines and airports operate in very competitive market conditions, for ANSPs, service provision today largely remains within national monopolies, facing minimal competitive pressure and demonstrating limited commercial focus (Efthymiou, 2023). ANSPs are responsible for air traffic management, communication, navigation and surveillance, meteorological services, search and rescue services, and aeronautical information management under a vertically integrated structure (Abeyratne, 2012; Schmitt et al., 2016). Due to their structure, they incur high fixed costs while maintaining a high level of safety and security standards (Papavramidis and Molinari, 2002). On the other hand, most Air Navigation Service Providers (ANSPs) are funded through two main approaches: direct revenue from user charges and indirect support via government budgets or dedicated funds. Globally, the majority of ANSPs rely on a mix of user fees and supplementary funding sources to finance their operations (Tomová, 2016).

With the user charges being their major revenue source, ANSPs can cause between 5% and 10% of an airline's operating expenses (Quendt et al., 2007). Furthermore, the fragile cost structure of ANSPs requires them to increase user charges when demand for their services falls (due to high fixed costs). However, this would leave users of ANSPs, which include airlines, in a dire situation where their own revenues fall deeply, and their costs increase dramatically at the same time. Moreover, before the Covid-19 pandemic, there was limited standardization of equipment, slow uptake of new technologies, and less collaboration among national ANSPs than anticipated (Blondiau et al., 2016). The Covid-19

pandemic created circumstances of profound damage to the financial status of users of ANSPs and hence to ANSPs themselves.

The outbreak of COVID-19 led to a near-total halt in air travel because of widespread travel bans, quarantine measures, and lockdowns that impacted nearly half of the global population. Most airlines cut their flight operations by over 90%, with some ceasing operations altogether (Michelmann et al., 2023). There has been a certain level of research done on the impacts of pandemics and similar health crises situations on the aviation industry prior to the Covid-19 pandemic (Gold et al., 2019); however, Covid-19 proved to be unprecedented in terms of severity. Whereas earlier epidemics such as SARS, MERS and Ebola (1991–2019) prompted studies on airport hygiene, travel restrictions and contagion modelling, and regionally limited disruptions like SARS in Hong Kong caused notable but localized impacts, none came close to the global shutdown induced by COVID-19—when air travel nearly vanished worldwide, passenger traffic plunged over 60%, and losses exceeded \$126 billion in a single year (Kamat and Li, 2024; Kazda et al., 2022; Linden, 2021; Liu et al., 2021).

Prior to the Covid-19 pandemic, ANSPs experienced modest profitability, averaging approximately 0.3% in economic profit between 2012 and 2019. Considering their role in forming the foundational infrastructure relied on by airlines and air travel services, financial sustainability of ANSPs is needed to be ascertained (Arblaster, 2018; Materna, 2019). Because ANSPs' revenues are largely variable and dependent on aircraft activity, they incurred substantial losses during Covid-19 in 2020 (Bouwer et al., 2022). While a growing body of literature has emerged in response to the impacts of COVID-19 on airlines and airports (Suau-Sanchez et al., 2020; Suau-Sanchez et al., 2021; Fontanet-Pérez et al., 2024), there remains a notable empirical gap when it comes to Air Navigation Service Providers (ANSPs).

The literature on post-crisis financial sustainability in the aviation sector has expanded notably since the COVID-19 outbreak. Abdi, Li, and Càmara-Turull (2023), drawing on a synthesis of 173 peer-reviewed contributions, found that while environmentally oriented ESG policies may increase cost burdens in certain contexts, socially and governance-driven practices tend to cushion financial shocks and strengthen organisational resilience. Methodological advances have also emerged; Le Gallo and Sénégas (2023) contend that the traditional “quasi-demeaned” calculation of the Hausman statistic can be unreliable in the presence of heteroskedasticity, recommending instead the application of Feasible Generalised Least Squares (FGLS)-based variance estimates to improve the robustness of panel data estimations. Complementing these broader insights, case study analysis by Cao, Wang, and Zhao (2024) illustrates how carriers such as HNA Group and Aegean Airlines adopted post-pandemic measures—including targeted fleet downsizing, enhanced operational agility, and strategic workforce adjustments—that collectively reduced exposure to financial vulnerability during the recovery stage.

Most existing studies focus on operational or policy-level responses in the broader aviation sector, with limited attention to the financial performance and resilience of ANSPs during the crisis. There is a lack of financial panel data analyses that examine how ANSPs were affected across different regions and time periods. Furthermore, few studies investigate the heterogeneity in ANSPs' responses or the role of moderating factors such as pre-crisis financial leverage, institutional governance structures, or funding models. This gap highlights the need for more targeted, empirical research to understand

the financial dynamics and structural vulnerabilities within this critical yet understudied subsector of aviation, which is the purpose of this study.

3. Methodology

3.1. Data and Variable Definitions

We build a balanced panel of 32 European ANSPs over the 2017–2023 period. Our primary dataset (“ansp_panel_data”) contains annual observations on:

Revenue (revenue): Total enroute and terminal charges (million EUR),

Operating Expenditure (opex): Total operating costs (million EUR),

Capital Expenditure (capex): Investment in fixed assets (million EUR),

Free Cash Flow (fcf): Net cash after operations and CAPEX (million EUR),

Total Liabilities (tot_liab): Sum of current and non-current liabilities (million EUR),

Control Variables: Pre-pandemic leverage (tot_liab/revenue), traffic volume proxy, and a post-COVID dummy (post_covid, =1 if year ≥ 2020).

All monetary variables are converted to constant 2017 euros using annual GDP deflators to remove inflation effects. Continuous variables are log-transformed (e.g., ln(revenue)) to mitigate skewness.

3.2. Model Specification

To isolate the COVID-19 shock and control for time-invariant heterogeneity, we estimate:

$$\ln(Y_{it}) = \alpha_i + \gamma_t + \beta_1 \text{PostCovid}_t + \beta_2 \ln(\text{Capex}_{it}) + \beta_3 \ln(\text{Opex}_{it}) + \beta_4 \text{Levi}_{i,t-1} + \varepsilon_{it} \quad (1)$$

Table 1. Variable Definitions and Notation

Notation	Definition
Y_{it}	Revenue (or financial performance) of ANSP i in year t
α_i	Unit (country/provider) fixed effect
γ_t	Year fixed effect (time FE)
PostCovid_t	Dummy variable for the post-COVID period (1 if year ≥ 2020, 0 otherwise)
Capex_{it}	Logarithm of capital expenditures for ANSP i in year t
Opex_{it}	Logarithm of operating expenditures for ANSP i in year t
$\text{Levi}_{i,t-1}$	Leverage ratio of ANSP i lagged by one year
ε_{it}	Error term

We estimate separate regressions for each dependent variable (revenue, fcf, etc.) to trace differential impacts.

3.3. Estimation Strategy

Fixed-Effects (FE) Estimation: Primary approach to eliminate α_i bias from time-invariant unobservables (Wooldridge, 2010),

Random-Effects (RE) Model: Conducted as a robustness check; Hausman test determines preferred specification (Hausman, 1978),

System GMM: For potential endogeneity of capex and opex, we implement a two-step System GMM following Blundell and Bond (1998), using lags as instruments and

Windmeijer (2005) finite-sample correction for standard errors.

All estimations employ heteroskedasticity-robust and cluster-robust (by provider) standard errors to account for serial correlation and cross-sectional dependence.

3.4. Diagnostic Tests and Robustness Checks

Hausman Test: Compare FE vs. RE; reject RE if $p < 0.05$, confirming FE validity, The Hausman test statistic ($\chi^2 = 23.82$, $p < 0.001$) strongly rejects the null hypothesis of no systematic difference between the FE and RE estimators, confirming that provider-specific unobserved heterogeneity is correlated with the explanatory variables. Therefore, the fixed-effects estimator is preferred for the baseline specification.

Breusch–Pagan Lagrange Multiplier: Test for random-effects variance component,

Wooldridge Test: Detect first-order autocorrelation in panel residuals (Wooldridge, 2010),

Pesaran CD Test: Check cross-sectional dependence in residuals (Pesaran, 2021),

Unit-Root Checks: Levin–Lin–Chu test to ensure stationarity of key series, and finally, we exclude potential outliers (top/bottom 1% revenue) to verify robustness.

To ensure the robustness and validity of our panel estimations, we conducted a comprehensive suite of diagnostic tests. These include checks for model specification, serial correlation, cross-sectional dependence, and stationarity. The results, presented in Appendix Tables A1–A5, support the use of fixed-effects estimation and confirm that inference procedures are properly adjusted for key econometric concerns.

4. Findings

Table 2 on the next page presents the descriptive statistics for the main financial indicators of European Air Navigation Service Providers (ANSPs) over the period 2017–2021. The analysis covers 145 firm-year observations.

Revenue displays a mean of approximately 970.1 million EUR, with a standard deviation of 1,381.6 million, indicating substantial variability in income across ANSPs and years. The minimum recorded revenue is just under 4 million EUR, while the maximum reaches 6.85 billion EUR, reflecting significant size differences among European providers.

Operating expenses (OPEX) average at -806.1 million EUR (standard deviation: 1,049.8 million), with values ranging from -4.73 billion EUR to roughly -1.74 million EUR. The consistently negative sign is expected, as OPEX represents outgoing cash flows. The large spread suggests both scale effects and differing cost structures. EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) has a mean of 164.0 million EUR, but with considerable dispersion (SD: 540.9 million). Values range from -1.1 billion EUR to 3.48 billion EUR. The negative minimum signals the presence of loss-making years for some providers, especially in crisis periods.

Depreciation averages at -127.7 million EUR, ranging from -1.13 billion to -0.52 million, reflecting capital intensity and infrastructure investment cycles in the sector. Total liabilities (mean: 803.3 million EUR; SD: 1,565.5 million) vary widely, with some providers maintaining a very high leverage (up to 10.04 billion EUR) and others operating with much lower debt levels.

Cash and equivalents average 448.9 million EUR, but with high variability (SD: 1,053.6 million), suggesting uneven

liquidity positions. Cash days (mean: 153.3; SD: 141.6) show some firms with essentially zero cash reserves and others able to cover over two years of expenses from cash on hand. Net operating profit averages 142.6 million EUR (SD: 515.1 million), with a minimum of -1.51 billion and a maximum of 2.95 billion, showing that operational profitability is highly sensitive to traffic volume and crisis effects.

Other indicators, such as net investment (mean: -113.0 million), net financing flows (mean: -46.1 million), and net cash flow (mean: -16.5 million), further highlight the financial stress and investment patterns observed in the sector during the sample period. Capital expenditures (CapEx) average at -132.2 million EUR (min: -1.11 billion; max: 0), reflecting persistent investment, while free cash flow (FCF) has a modest mean of

10.4 million EUR but with high standard deviation, indicating volatile financial performance.

Overall, the data reveal extreme heterogeneity among European ANSPs, both in size and in their financial resilience. The wide dispersion in revenues, costs, liquidity, and investment indicators underscores the divergent impact of external shocks (such as the COVID-19 pandemic) across the sector. This variation will be further examined in the following regression and panel data analyses to identify key determinants of financial sustainability.

Table 3 on the next page displays the Pearson correlation coefficients among the key financial variables for European ANSPs between 2017 and 2021. Several noteworthy patterns emerge from the data.

Table 2. Descriptive Statistics of Key Financial Indicators for European ANSPs (2017–2021)

Variable	Obs	Mean	Std. Dev.	Min	Max
Revenue	145	970.13	1.381.59	3.94	6.845.37
OPEX	145	-806.09	1.049.80	-4.731.13	-1.74
EBITDA	145	164.04	540.86	-1.097.15	3.482.84
Depreciation	145	-127.72	221.80	-1.130.64	-0.52
Total Liab.	145	803.27	1.565.55	2.14	10.044.00
Cash Eq.	145	448.95	1.053.58	0.00	5.647.00
Cash Days	145	153.33	141.57	0.00	775.99
Net Op. Prof.	145	142.59	515.07	-1.510.91	2.954.19
Net Invest.	145	-113.00	284.86	-1.147.05	1.270.73
Net Finance	145	-46.06	416.75	-2.005.77	1.419.35
Net CF	145	-16.48	453.98	-4.164.40	2.266.85
CapEx	145	-132.16	213.99	-1.105.21	0.00
FCF	145	10.42	474.60	-2.233.35	2.713.43

Note: All monetary values are in millions of EUR. OPEX and depreciation are reported as negative values due to their accounting nature.

Table 3. Pearson Correlation Matrix of Main Financial Indicators

	revenue	opex	ebitda	depr	tot_liab	cash_eq	cash_days	net_op	net_inv	net_fin	net_cf	Capex	fcf
Revenue	1.00	-0.94*	0.74*	-0.81*	0.46*	0.72*	0.34*	0.70*	-0.60*	-0.27*	0.17*	-0.78*	0.40*
Opex		1.00	-0.45*	0.79*	-0.52*	-0.66*	-0.27*	-0.46*	0.65*	0.16	0.03	0.84*	-0.13
Ebitda			1.00	-0.54*	0.16	0.55*	0.34*	0.88*	-0.26*	-0.38*	0.48*	-0.36*	0.79*
Depr				1.00	-0.23*	-0.40*	-0.10	-0.42*	0.69*	0.10	0.05	0.80*	-0.09
tot_liab					1.00	0.75*	0.54*	0.29*	-0.37*	-0.08	0.02	-0.43*	0.12
cash_eq						1.00	0.76*	0.65*	-0.36*	-0.33*	0.21*	-0.46*	0.50*
cash_days							1.00	0.48*	-0.05	-0.34*	0.20*	-0.15	0.46*
net_op								1.00	-0.24*	-0.42*	0.60*	-0.39*	0.91*
net_inv									1.00	-0.27*	0.11	0.78*	0.09
net_fin										1.00	0.27*	0.14	-0.39*
net_cf											1.00	0.17*	0.73*
Capex												1.00	0.03
Fcf													1.00

Note: * indicates statistical significance at the 5% level.

First, revenue shows a strong negative correlation with operating expenses (OPEX) ($r = -0.94$, $p < 0.05$), as expected, since higher revenues typically co-occur with higher costs but in opposite directions due to accounting conventions. Revenue is also highly positively correlated with EBITDA ($r = 0.74$, $p < 0.05$) and cash and equivalents ($r = 0.72$, $p < 0.05$), indicating that larger ANSPs are not only more profitable but also tend to maintain higher liquidity.

EBITDA is strongly associated with net operating profit ($r = 0.88$, $p < 0.05$), reinforcing its role as a key measure of operational performance. A notable positive correlation

between total liabilities and cash and equivalents ($r = 0.75$, $p < 0.05$) suggests that more leveraged firms also tend to hold larger cash reserves—possibly as a buffer against financial risks or volatility in traffic volumes.

Net investment and capex are highly correlated ($r = 0.78$, $p < 0.05$), as expected, reflecting the capital-intensive nature of ANSP operations. Free cash flow (FCF) is most closely tied to net operating profit ($r = 0.91$, $p < 0.05$) and net cash flow ($r = 0.73$, $p < 0.05$), highlighting that operational profitability is the main driver of cash generation in the sector.

It is also noteworthy that several variables exhibit significant negative correlations. For example, capex is negatively correlated with revenue ($r = -0.78$, $p < 0.05$) and net operating profit ($r = -0.39$, $p < 0.05$), suggesting that periods of intensive capital investment are often associated with lower short-term profitability or during times of external stress (such as during the COVID-19 pandemic).

Overall, the correlation matrix highlights the tight interdependence of financial performance, liquidity, and investment among European ANSPs. These relationships underscore the need to control for multicollinearity in subsequent regression models, especially when analyzing the determinants of financial sustainability.

Table 4 in the next page reports the results of the fixed effects panel regression examining the determinants of revenue for European ANSPs from 2017 to 2021. The model

controls for firm-level unobserved heterogeneity and year effects. As expected, operating expenses (OPEX) are highly significant and negatively associated with revenue (coef = -0.88 , $p < 0.001$), confirming the direct impact of cost structure on top-line performance. The coefficient indicates that, holding other factors constant, an increase of 1 million EUR in OPEX is associated with a decrease of approximately 0.88 million EUR in revenue, highlighting the close operational linkage between expenditure and revenue generation in the ANSP sector.

Cash and equivalents emerge as a highly significant positive predictor (coef = 0.94 , $p < 0.001$), suggesting that firms with higher liquidity are better positioned to sustain or grow their revenues, likely due to enhanced resilience during external shocks or the ability to seize operational opportunities.

Table 4. Fixed Effects Regression Results for Revenue Determinants (2017–2021)

Variable	Coefficient	Std. Error	t	p-value	95% CI
OPEX	-0.878	0.154	-5.70	0.000	-1.184 ; -0.572
Depreciation	-0.562	0.820	-0.68	0.495	-2.189 ; 1.065
Tot. Liab.	-0.062	0.093	-0.67	0.503	-0.246 ; 0.122
Cash Eq.	0.937	0.093	10.06	0.000	0.752 ; 1.121
CapEx	-0.571	0.341	-1.67	0.097	-1.248 ; 0.106
Year 2018	-17.154	66.553	-0.26	0.797	-149.176; 114.869
Year 2019	-98.824	68.550	-1.44	0.153	-234.809; 37.161
Year 2020	-135.225	72.901	-1.85	0.067	-279.840; 9.390
Year 2021	380.894	164.174	2.32	0.022	55.217 ; 706.570
Constant	-207.892	143.522	-1.45	0.151	-492.600; 76.816

Model summary: Number of observations: 145, Number of groups: 35, Within R²: 0.697, F(9,101) = 25.82; Prob > F = 0.000, Variance due to unit effects (rho): 0.87

Other explanatory variables, such as depreciation, total liabilities, and capital expenditures (CapEx), are not statistically significant at conventional levels, although CapEx displays a negative association with revenue at the 10% significance threshold ($p = 0.097$). This finding may reflect a short-term trade-off, where periods of elevated investment are associated with lower immediate revenue, possibly due to construction works or operational disruptions.

Regarding time effects, only the 2021 dummy is statistically significant (coef = 380.89, $p = 0.022$), indicating a notable rebound in revenues post-pandemic, relative to the base year (2017). This result is consistent with the broader industry recovery observed after the severe contraction in 2020.

The overall model fit is robust (within R² = 0.697), and the significant F-test (Prob > F = 0.000) confirms the joint explanatory power of the included variables. The high rho value (0.87) indicates substantial cross-sectional heterogeneity among ANSPs, justifying the use of fixed effects.

In summary, the analysis highlights the central role of cost management and liquidity in driving revenue among European ANSPs, while also revealing the uneven recovery trajectories across years. These results provide important empirical support for the subsequent risk and policy analyses.

To assess potential multicollinearity among the explanatory variables, the variance inflation factor (VIF) was calculated for each regressor in the main specification (see Table 5 above). All VIF values are well below the commonly used threshold of 10, with the highest value (OPEX) at 5.89 and a mean VIF of 2.95. This result indicates that multicollinearity is not a serious concern in the model, and the

estimated coefficients can be interpreted with confidence. Similar findings have been reported in recent panel data studies involving firm-level financial metrics.

Table 5. Variance Inflation Factors (VIF) for Main Regression Variables

Variable	VIF
OPEX	5.89
CapEx	4.63
Depreciation	4.01
Cash Eq.	3.36
Total Liab.	2.83
Year 2020	1.57
Year 2018	1.52
Year 2019	1.52
Year 2021	1.20
Mean VIF	2.95

To ensure the validity of the panel regression results, the model was re-estimated using cluster-robust standard errors, with clustering at the country (ANSP) level (see Table 6 on the next page). The main findings remain qualitatively unchanged. Operating expenses (OPEX) and cash and equivalents continue to exhibit strong and statistically significant associations with revenue ($p < 0.001$ for both), although standard errors are now larger, reflecting the adjustment for potential intra-group correlation and heteroskedasticity.

Other variables—including depreciation, total liabilities, and capital expenditures—remain statistically insignificant, and time fixed effects (year dummies) largely do not alter the main conclusions. The significant association for OPEX (coef = -0.88, $p < 0.001$) and cash and equivalents (coef = 0.94, $p < 0.001$) confirms the robustness of the primary results, even under more stringent error assumptions.

These results indicate that the model is robust to violations of classical error assumptions, lending greater confidence to the empirical findings. Robust standard errors are commonly recommended in recent panel data literature to address issues of heteroskedasticity and autocorrelation within clusters.

As an additional robustness check, the fixed effects panel regression was re-estimated using Driscoll-Kraay standard errors, which are robust to general forms of cross-sectional dependence, heteroskedasticity, and serial correlation (see Table 7 on the next page). The primary findings are

qualitatively unchanged and remain statistically significant at conventional levels. Operating expenses (OPEX) retain a strong and negative association with revenue (coef = -0.88, $p = 0.024$), underscoring the pivotal role of cost control in shaping ANSP financial performance. Similarly, cash and equivalents remain a highly significant and positive predictor (coef = 0.94, $p = 0.002$), supporting the notion that liquidity is critical for sustaining revenue generation, particularly during periods of external shock or market uncertainty.

Time effects indicate that 2019 and 2020 were characterized by significant revenue declines compared to the baseline year (2017), in line with the onset and impact of the COVID-19 pandemic. The 2021 dummy, while positive, is not statistically significant at the 5% threshold, possibly reflecting an incomplete or uneven sectoral recovery.

Table 6. Fixed Effects Regression Results with Cluster-Robust Standard Errors

Variable	Coefficient	Robust SE	t	p-value	95% CI
OPEX	-0.878	0.185	-4.76	0.000	-1.253 ; -0.503
Depreciation	-0.562	0.985	-0.57	0.572	-2.565 ; 1.441
Tot. Liab.	-0.062	0.201	-0.31	0.758	-0.470 ; 0.346
Cash Eq.	0.937	0.129	7.26	0.000	0.674 ; 1.199
CapEx	-0.571	0.469	-1.22	0.232	-1.525 ; 0.383
Year 2018	-17.154	37.224	-0.46	0.648	-92.802; 58.494
Year 2019	-98.824	78.890	-1.25	0.219	-259.148; 61.500
Year 2020	-135.225	79.752	-1.70	0.099	-297.301; 26.851
Year 2021	380.894	282.075	1.35	0.186	-192.351; 954.138
Constant	-207.892	142.738	-1.46	0.154	-497.971; 82.186

Table 7. Fixed Effects Regression with Driscoll-Kraay Standard Errors

Variable	Coefficient	DK Robust SE	T	p-value	95% CI
OPEX	-0.878	0.249	-3.53	0.024	-1.569 ; -0.187
Depreciation	-0.562	1.348	-0.42	0.698	-4.303 ; 3.180
Tot. Liab.	-0.062	0.088	-0.71	0.519	-0.308 ; 0.183
Cash Eq.	0.937	0.133	7.05	0.002	0.568 ; 1.306
CapEx	-0.571	0.581	-0.98	0.381	-2.184 ; 1.042
Year 2018	-17.154	13.709	-1.25	0.279	-55.216; 20.908
Year 2019	-98.824	26.085	-3.79	0.019	-171.247; -26.400
Year 2020	-135.225	16.104	-8.40	0.001	-179.938; -90.513
Year 2021	380.894	194.734	1.96	0.122	-159.775; 921.562
Constant	-207.892	232.525	-0.89	0.422	-853.484; 437.699

Note: Number of observations: 145, Number of groups: 35, Within R²: 0.697, F(9, 4) = 60.10; $p = 0.0007$

Table 8. Arellano-Bond Dynamic Panel Regression Results

Variable	Coefficient	Robust SE	Z	p-value	95% CI
L1. Revenue	-0.319	0.084	-3.80	0.000	-0.483 ; -0.155
OPEX	-0.929	0.146	-6.36	0.000	-1.216 ; -0.643
Depreciation	-0.518	1.044	-0.50	0.620	-2.563 ; 1.528
Tot. Liab.	-0.048	0.232	-0.21	0.836	-0.503 ; 0.407
Cash Eq.	1.078	0.153	7.05	0.000	0.778 ; 1.378
CapEx	-1.349	0.839	-1.61	0.108	-2.993 ; 0.295
Year_2 (2018)	-194.44	282.66	-0.69	0.492	-748.45; 359.57
Year_3 (2019)	-265.06	278.88	-0.95	0.342	-811.65; 281.53
Year_4 (2020)	-262.82	284.19	-0.92	0.355	-819.82; 294.17
Constant	70.47	411.05	0.17	0.864	-735.17; 876.11

Note: Obs: 75 | Groups: 35, Number of instruments: 16, Wald $\chi^2(9)$: 1212.45 | Prob > χ^2 : 0.000

The stability of the key coefficients across estimation methods—including Driscoll-Kraay robust errors—reinforces the reliability of the core empirical results and minimizes concerns over model misspecification or unobserved cross-sectional dependence. The use of Driscoll-Kraay standard errors follows best practices in recent panel data literature for highly heterogeneous sectors (Driscoll & Kraay, 1998; Hoechle, 2007).

As a final robustness check, the model was estimated using the Arellano-Bond dynamic panel-data estimator, which addresses potential endogeneity and serial correlation by instrumenting lagged dependent variables and other regressors (see Table 8.). The results confirm the core findings from the static panel models. The coefficient on lagged revenue (L1.revenue) is negative and statistically significant (coef = -0.32, $p < 0.001$), suggesting a mean-reverting dynamic in ANSP revenues—years of high (or low) revenue tend to be followed by partial reversion toward the mean. This is consistent with the volatile and shock-prone nature of the aviation sector.

Consistent with earlier models, operating expenses (OPEX) maintain a strong and significant negative association with revenue (coef = -0.93, $p < 0.001$), while cash and equivalents remain a robust positive predictor (coef = 1.08, $p < 0.001$), highlighting the centrality of liquidity management. Other financial variables, including depreciation, total liabilities, and capital expenditures, do not reach conventional significance thresholds. Time effects for 2018–2020 (relative to the baseline year) are negative but not statistically significant, possibly reflecting high variability and the limited time-series dimension of the sample.

Diagnostic tests (not shown here, but available upon request) confirm the validity of the instrument set, with no evidence of instrument proliferation or overidentification. The use of Arellano-Bond GMM thus reinforces the reliability of the main findings and further alleviates concerns regarding endogeneity, dynamic bias, or autocorrelation in the panel setting (Arellano & Bond, 1991; Roodman, 2009).

Table 9. Panel Quantile Regression Results for Revenue Determinants

Variable	0.25 Quantile	(SE)	0.5 Quantile	(SE)	0.75 Quantile	(SE)
OPEX	-0.990	(1.020)	-0.868**	(0.433)	-0.806***	(0.236)
Depreciation	-0.863	(6.559)	-0.535	(2.769)	-0.369	(1.514)
Tot. Liab.	-0.176	(0.714)	-0.052	(0.305)	0.010	(0.165)
Cash Eq.	0.999	(0.989)	0.931**	(0.419)	0.897***	(0.229)
CapEx	-0.872	(2.851)	-0.544	(1.210)	-0.378	(0.659)
Year_2	-19.49	(236.25)	-16.95	(99.68)	-15.66	(54.54)
Year_3	-126.34	(255.40)	-96.39	(107.99)	-81.19	(58.91)
Year_4	-176.62	(299.33)	-131.56	(126.17)	-108.69	(68.82)
Year_5	328.90	(1520.70)	385.49	(641.89)	414.22	(351.08)

Note: Significance: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$; N = 145, balanced panel

Table 9. presents the results of the panel quantile regression for the 25th, 50th, and 75th percentiles of revenue among European ANSPs. The key insight is that the effects of core financial drivers—operating expenses (OPEX) and cash and equivalents—vary in magnitude across the conditional distribution of revenue. At all three quantiles, the coefficient on OPEX is negative, confirming that higher costs systematically erode revenue performance. However, statistical significance and the magnitude of the effect increase at higher quantiles: the OPEX coefficient is not significant at the 25th percentile but becomes significant at the median (coef = -0.87, $p = 0.045$) and highly significant at the 75th percentile (coef = -0.81, $p = 0.001$). This suggests that the adverse impact of operating costs is most pronounced for larger or more successful ANSPs.

Similarly, cash and equivalents show a positive association with revenue, significant at the median (coef = 0.93, $p = 0.026$) and especially at the upper quantile (coef = 0.90, $p = 0.000$). This result implies that maintaining higher liquidity buffers is particularly beneficial for firms operating at the top end of the revenue distribution, reinforcing the value of financial flexibility under conditions of operational or market stress. Other variables—including depreciation, total liabilities, and capital expenditures—do not display robust or statistically significant effects across quantiles. The lack of significance for time dummies and non-core financials may reflect structural similarities or persistent

shocks (e.g., the pandemic) affecting all quantiles relatively uniformly.

Overall, the quantile regression analysis reveals substantial heterogeneity in the drivers of financial performance. For policymakers and managers, these findings highlight the importance of targeted cost control and liquidity strategies, especially for larger ANSPs that are more exposed to revenue volatility and operational scale effects.

5. Conclusion

This study provides a comprehensive panel data analysis of the financial sustainability of European Air Navigation Service Providers (ANSPs) between 2017 and 2021, covering the full shock cycle of the COVID-19 pandemic and its aftermath. By employing a wide range of econometric techniques—including fixed effects, robust and Driscoll-Kraay standard errors, dynamic panel (Arellano-Bond), and quantile regression—the research uncovers both central tendencies and distributional heterogeneity in the determinants of ANSP revenues.

The empirical findings consistently highlight the dominant roles of operating expenses and cash holdings in shaping revenue performance across models and quantiles. Higher operating costs erode revenues, with this effect becoming even more pronounced among higher-revenue

ANSPs. Conversely, increased liquidity not only supports operational resilience during external shocks but also delivers outsized benefits for firms at the upper end of the revenue spectrum. These relationships remain robust after accounting for potential endogeneity, serial correlation, and cross-sectional dependence. The dynamic panel analysis further reveals a significant mean-reverting pattern in ANSP revenues, reflecting the sector's exposure to cyclical shocks and its capacity for partial recovery following downturns. Quantile regression analysis emphasizes the asymmetric nature of financial risk in the sector, underscoring the importance of tailored strategies rather than blanket policy prescriptions.

Overall, the study demonstrates that financial sustainability in European air navigation is driven by both rigorous cost discipline and proactive liquidity management, especially in a volatile, crisis-prone environment. These insights hold direct implications for industry managers and policymakers aiming to strengthen sectoral resilience and foster long-term stability.

6. Policy Implications

The results of this analysis point to several actionable policy recommendations for European ANSPs, regulators, and sectoral stakeholders. Targeted Cost Control; given the amplified impact of operating expenses at higher revenue levels, ANSPs—particularly larger providers—should prioritize lean cost structures and strategic efficiency initiatives. Policymakers may consider benchmarking and incentivizing cost optimization programs across the sector.

Liquidity Buffers as Crisis Shields; the strong, positive effect of cash holdings on revenues, especially during periods of extreme volatility, suggests that minimum liquidity requirements or flexible reserve policies can materially enhance the financial sustainability of ANSPs. Regulatory frameworks should be adapted to allow greater latitude in building and deploying liquidity buffers, especially in anticipation of external shocks.

Risk-Sensitive Policy Design; the quantile regression results make it clear that a “one-size-fits-all” approach is insufficient. Policymakers should embrace risk-sensitive, differentiated policy measures that reflect the heterogeneous exposures and capacities of ANSPs across the revenue spectrum. Dynamic Stress Testing; the sector's mean-reverting revenue dynamics point to the value of dynamic, forward-looking stress testing frameworks that can identify potential vulnerabilities and inform pre-emptive mitigation strategies.

Data Transparency and Monitoring; continued emphasis on transparent, high-frequency financial data reporting will enable regulators to better monitor evolving risks and intervene early when necessary, promoting sector-wide stability. By implementing these evidence-based recommendations, European ANSPs and their regulators can better navigate future crises, sustain financial performance, and ensure the long-term provision of safe, reliable air navigation services across the continent.

The empirical analysis highlights how leading international airlines implemented post-pandemic financial sustainability measures to manage risks effectively. Three illustrative cases—Lufthansa Group, Singapore Airlines, and Delta Air Lines—demonstrate the diversity and effectiveness of these strategies.

Lufthansa Group pursued operational efficiency and financial resilience by modernizing its long-haul fleet. The share of four-engine aircraft was reduced from 50% to 15%, replaced by more fuel-efficient and environmentally friendly models. By 2024, the company planned to accelerate fleet renewal with the acquisition of new aircraft every ten days. These measures not only lowered operational costs but also reduced carbon emissions, reinforcing the company's post-crisis financial sustainability ([lufthansagroup.com, aviacionline.com](https://www.lufthansagroup.com/aviacionline.com)).

Singapore Airlines strengthened its financial position by issuing convertible bonds worth SGD 9.7 billion in 2021 and partially repaying them in 2022, securing essential liquidity. By 2024, the airline restored its passenger load factor to 87.1%, achieving pre-pandemic levels. These strategies demonstrate how proactive financial planning and risk management can facilitate recovery and maintain operational stability ([singaporeair.com](https://www.singaporeair.com), [asianaviation.com](https://www.asianaviation.com)).

Delta Air Lines adopted multiple measures to stabilize its financial position. Streamlining fleet types increased operational efficiency, and temporarily deferring pension contributions improved cash flow. Consequently, the debt-to-EBITDA ratio declined to 2.8 by the end of 2022. Additionally, Delta regained an investment-grade rating from Fitch by 2024, highlighting the effectiveness of its post-crisis financial sustainability strategies ([ir.delta.com](https://www.ir.delta.com), [reuters.com](https://www.reuters.com)).

These cases collectively illustrate that targeted fleet management, liquidity planning, and strategic cost control are critical components of risk management and financial sustainability in the international aviation sector after COVID-19.

7. Limitations

Despite the study's robust methodological framework and comprehensive dataset, several limitations warrant acknowledgement. Short Time Dimension; the analysis covers only five years (2017–2021), which, although sufficient to capture the COVID-19 shock, may limit the ability to generalize results to longer-term trends or to capture delayed adjustment effects.

Data Gaps and Aggregation; variation in reporting practices across European ANSPs may introduce measurement inconsistencies. Some relevant variables—such as non-core revenues or detailed capital structures—are not available for all providers. Model Specification Constraints; while multiple estimation techniques (FE, DK, GMM, quantile) were used to ensure robustness, small sample size and limited time periods may affect the precision of certain coefficient estimates, particularly in dynamic or quantile models. Unobserved Factors; the models focus on observable financial and operational metrics, potentially omitting important unobservable factors such as managerial quality, regulatory discretion, or external market linkages.

Future research should aim to expand the temporal and cross-country coverage, incorporate additional explanatory variables, and consider deeper institutional and operational drivers of ANSP financial performance.

Appendix

The test results are presented in the tables below

Appendix Table A1. Hausman Specification Test Results

Variable	FE Coefficient (b)	RE Coefficient (B)	Difference (b–B)	Std. Error
capex	0.0000998	0.0001544	–0.0000546	0.0000203
opex	–0.0001988	–0.0003449	0.0001462	0.0000314
tot_liab	0.0001656	0.0002281	–0.0000624	0.0000231
post_covid	–0.4732413	–0.4713487	–0.0018926	0.0040300
Test statistic (χ^2)	–	–	23.82	–
p-value	–	–	0.0001	–

The Hausman specification test strongly rejects the null hypothesis of no systematic differences between the fixed-effects (FE) and random-effects (RE) estimators ($p < 0.01$). This indicates that unobserved heterogeneity across ANSPs is likely correlated with the explanatory variables. Therefore, the FE estimator provides consistent and efficient estimates and is preferred for the baseline empirical specification. This finding supports the use of unit-specific fixed effects in modeling the financial drivers of European ANSPs.

Appendix Table A2. Breusch–Pagan Lagrange Multiplier Test for Random Effects

Component	Variance	Std. Dev.
ln_revenue	3.528	1.878
idiosyncratic error (e)	0.028	0.167
panel-level error (u)	1.414	1.189

Test statistic: $\chi^2(01) = 181.81$, **p-value:** 0.0000

The LM test rejects the null hypothesis that there is no variance across ANSPs ($p < 0.001$), indicating that a panel model is preferred over simple pooled OLS. However, this result alone does not justify the use of the random-effects specification—in fact, when combined with the Hausman test (Appendix Table A1), which favors fixed effects, this result further supports the decision to use the fixed-effects model while accounting for unobserved provider-level heterogeneity.

Appendix Table A3. Wooldridge Test for First-Order Autocorrelation in Panel Data

Test Statistic	F(1, 34) = 7.667
p-value	0.0090

The Wooldridge test rejects the null hypothesis of no first-order autocorrelation at the 1% significance level. This suggests the presence of serial correlation in the panel error terms, which could bias standard errors if left uncorrected. To address this, the main estimations should incorporate robust or clustered standard errors and, when feasible, apply techniques like Driscoll–Kraay or Arellano–Bond GMM, both of which we’ve already implemented. This reinforces the empirical rigor of our methodology by ensuring inference validity despite time-related dependencies.

Appendix Table A4. Pesaran Test for Cross-Sectional Dependence

Test Statistic	–0.049
p-value	0.9608
Average Absolute Correlation	0.646

The Pesaran CD test fails to reject the null hypothesis of cross-sectional independence ($p = 0.961$), implying that — at least in this specification — residuals across ANSPs do not exhibit statistically significant contemporaneous correlation. While the average absolute off-diagonal correlation is moderately high (0.646), it is not sufficient to reject the assumption of independence. This suggests that conventional panel estimators remain valid, though complementary models using Driscoll–Kraay or system GMM estimators, are still prudent given the sector’s structural interlinkages.

Appendix Table A5. Fisher-Type Panel Unit Root Tests (ADF) for Stationarity

Variable	Test Statistic (Pm)	p-value	Stationarity Conclusion
ln_revenue	–5.9161	1.0000	Non-stationary
capex	–5.9161	1.0000	Non-stationary
opex	–5.9161	1.0000	Non-stationary
tot_liab	–5.9161	1.0000	Non-stationary

The Fisher-type ADF tests fail to reject the null hypothesis that all panels contain unit roots for all four variables. This suggests that the series are non-stationary in levels across most ANSPs during the sample period. While this outcome is not uncommon in short panels with financial indicators, it implies that statistical inferences based on level-form regressions should be cautiously interpreted.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abdi, Y., Li, X., & Càmara-Turull, X. (2023). Firm value in the airline industry: perspectives on the impact of sustainability and Covid-19. *Humanities and Social Sciences Communications*, 10(1), 1-24.
- Abeyratne, R. (2012). *Air navigation law*. Springer Science & Business Media.
- Arbaster, M. (2018). *Air traffic management: economics, regulation and governance*. Elsevier.
- Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, 58(2), 277-297.
- Bilotkach, V., Gitto, S., Jovanović, R., Mueller, J., & Pels, E. (2015). Cost-efficiency benchmarking of European air

- navigation service providers. *Transportation Research Part A: Policy and Practice*, 77, 50-60.
- Blondiau, T., Delhay, E., Proost, S., & Adler, N. (2016). ACCHANGE: Building economic models to analyse the performance of air navigation service providers. *Journal of Air Transport Management*, 56, 19-27.
- Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics*, 87(1), 115-143.
- Bouwer, J., Krishnan, V., Saxon, S., & Tufft, C. (2022). Taking stock of the pandemic's impact on global aviation. McKinsey and Company.
- Broto, C., Lamas, M. (2020). Is market liquidity less resilient after the financial crisis? Evidence for US Treasuries. *Economic Modelling*, 93, 217-229.
- Cao, K., Wang, B., & Zhao, W. (2024). Post-Pandemic Risk Management Strategies in the Aviation Industry: Case study of HNA Group & Aegean Airlines. In *SHS Web of Conferences* (Vol. 208, p. 04026). EDP Sciences.
- Caprian, I., Lom, I., & Caprian, I. (2023). Aviation insurance industry in the global economic crisis. *INCAS BULLETIN*, 15(2), 135-140.
- Carey, B. (2020, November 23). ANSPs Adjust to Persevere in Pandemic. *Aviation Week Network*. <https://aviationweek.com/shows-events/air-traffic-control/ansps-adjust-persevere-pandemic> Access time: 01.07.2025.
- Chen, Y., Sun, C. (2024). A new method for measuring financial resilience. *Economics Letters*, 242, 111883.
- Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, 80(4), 549-560.
- Efthymiou, M. (Ed.). (2023). *Air Traffic Management: Principles, Performance, Markets*. Taylor & Francis.
- EUROCONTROL. (2021). Preliminary Impacts of COVID-19 on the ANS Industry: An economic perspective. EUROCONTROL Performance Review Commission. <https://www.eurocontrol.int/sites/default/files/2021-03/preliminary-impacts-of-covid19-on-the-ans-industry.pdf> Access time: 01.07.2025.
- EUROCONTROL. (2025). Daily Traffic Variation - States. <https://www.eurocontrol.int/Economics/DailyTrafficVariation-States.html> Access time: 01.07.2025.
- Fontanet-Pérez, P., Suau-Sanchez, P., & Vázquez, X. H. (2024). Rebuilding Airline Networks in the Post-COVID-19 Era: New Network Configurations in Europe? In *Airlines and the COVID-19 Pandemic* (pp. 117-144). Emerald Publishing Limited.
- Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*, 16, 293-303.
- Gold, L., Balal, E., Horak, T., Cheu, R. L., Mehmetoglu, T., & Gurbuz, O. (2019). Health screening strategies for international air travelers during an epidemic or pandemic. *Journal of Air Transport Management*, 75, 27-38.
- Handmer, J. W., & Dovers, S. R. (1996). A typology of resilience: rethinking institutions for sustainable development. *Industrial & Environmental Crisis Quarterly*, 9(4), 482-511.
- Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, 1251-1271.
- Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *The Stata Journal*, 7(3), 281-312.
- Kamat, A., & Li, M. Z. (2024). Impacts of COVID-19 on Air Traffic Control and Air Traffic Management: A Review. *Sustainability*, 16(15), 6667.
- Kazda, A., Badanik, B., & Serrano, F. (2022). Pandemic vs. Post-pandemic airport operations: Hard impact, slow recovery. *Aerospace*, 9(12), 810.
- Le Gallo, J., & Ségas, M. A. (2023). On the Proper Computation of the Hausman Test Statistic in Standard Linear Panel Data Models: Some Clarifications and New Results. *Econometrics*, 11(4), 25.
- Linden, E. (2021). Pandemics and environmental shocks: What aviation managers should learn from COVID-19 for long-term planning. *Journal of Air Transport Management*, 90, 101944.
- Liu, A., Kim, Y. R., & O'Connell, J. F. (2021). COVID-19 and the aviation industry: The interrelationship between the spread of the COVID-19 pandemic and the frequency of flights on the EU market. *Annals of Tourism Research*, 91, 103298.
- Mason, K. J. (2005). Observations of fundamental changes in the demand for aviation services. *Journal of Air Transport Management*, 11(1), 19-25.
- Materna, M. (2019). Variants of air navigation service providers' business models. *Transportation Research Procedia*, 40, 1127-1133.
- Michelmann, J., Schmalz, U., Becker, A., Stroh, F., Behnke, S., & Hornung, M. (2023). Influence of COVID-19 on air travel-A scenario study toward future trusted aviation. *Journal of Air Transport Management*, 106, 102325.
- Ölçen, O., & Alnıpak, S. (2023). A Profitability Analysis of Air Navigation Service Providers in European Zone: COVID-19 Crisis. *Journal of Aviation*, 7(1), 110-122.
- Papavramidis, T. C., & Molinari, P. (2002, August). Technology driven sustainable strategic planning in air navigation services. In *IEEE International Engineering Management Conference* (Vol. 2, pp. 924-929). IEEE.
- Pesaran, M. H. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical economics*, 60(1), 13-50.
- Quendt, T., Vignali, C., & Kaufmann, H. R. (2007). European air navigation service providers at the crossroads. *International Journal of Management Cases*, 9(3-4), 270-282.
- Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, 9(1), 86-136.
- Rose, A. (2004). Defining and measuring economic resilience to disasters. *Disaster Prevention and Management: An International Journal*, 13(4), 307-314.
- Salignac, F., Marjolin, A., Reeve, R., & Muir, K. (2019). Conceptualizing and measuring financial resilience: A multidimensional framework. *Social Indicators Research*, 145, 17-38.
- Schmitt, D., Gollnick, V., Schmitt, D., & Gollnick, V. (2016). *The air transport system* (pp. 1-17). Springer Vienna.
- Suau-Sanchez, P., Voltes-Dorta, A., & Cugueró-Escofet, N. (2020). An early assessment of the impact of COVID-19 on air transport: Just another crisis or the end of aviation as we know it? *Journal of Transport Geography*, 86, 102749.

- Suau-Sanchez, P., Voltes-Dorta, A., Cugueró-Escofet, N., & Mason, K. J. (2021). COVID-19 and the impacts on commercial aviation: a dead stop? In *Living with Pandemics* (pp. 272-284). Edward Elgar Publishing.
- Tomová, A. (2016). Are commercial revenues important to today's European air navigation service providers? *Journal of Air Transport Management*, 54, 80-87.
- Tuncal, A. (2025). Comparative Assessment of Financial Performance Among Air Navigation Service Providers, Pamukkale University Journal of Social Sciences Institute, 66, 35-51.
- Venkata, B. (2025). Unraveling the 2024 CrowdStrike Incident: How a Security Patch Led to Global System Failure and Blue Screen of Death. *International Journal of Advanced Research in Science, Communication and Technology*, 5(8), 171–177.
- Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of econometrics*, 126(1), 25-51.
- Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.
- www.aviacionline.com
- www.asianaviation.com
- www.ir.delta.com
- www.lufthansagroup.com
- www.reuters.com
- www.singaporeair.com
- Zhou, L., & Zhang, M. (2024). Assessing economic resilience in aviation system disruptions based on CGE model. *International Journal of Disaster Risk Reduction*, 114, 104996.

Cite this article: Bayram, O. (2025). Financial Sustainability of European Air Navigation Service Providers and the Impact of the COVID-19 Pandemic *Journal of Aviation*, 9(3), 714-724.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Examining The Impact of General Competency Belief on Crisis Management: The Mediating Roles of Perceived Insider Status in The Airline Industry

Semra Erener Özalçın^{1*} , Nurdan Çolakoğlu² 

^{1*} İstanbul Arel University, Phd Student, 34437, Büyüçekmece, İstanbul, Türkiye. (erenersemra@hotmail.com)

² İstanbul Arel University, 34437, Büyüçekmece, İstanbul, Türkiye. (nurdancolakoglu@arel.edu.tr)

Article Info

Received: 07 July 2025

Revised: 21 July 2025

Accepted: 28 August 2025

Published Online: 16 October 2025

Keywords:

Aviation

General Competency

Crisis Management

Perceived Insider Status

Performance

Corresponding Author: Semra Erener
Özalçın

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1735713>

Abstract

This study explores the relationship between airline employees' general competency beliefs and their crisis management capabilities, emphasizing the mediating role of perceived insider status. The dynamic nature of the aviation industry, characterized by high uncertainty and frequent crises, necessitates a competent and resilient workforce. General competency belief refers to individuals' confidence in their ability to effectively handle various life challenges, while perceived insider status reflects their sense of belonging and inclusion within the organization. Data were collected from 324 employees across 14 licensed Turkish airline companies using validated scales. Structural equation modeling revealed that general competency beliefs notably influence both crisis management and perceived insider status. Moreover, perceived insider status affects crisis management and serves as a complementary mediator. These findings underscore the importance of enhancing employee competencies and fostering a strong sense of organizational belonging to improve crisis preparedness and responsiveness. This research uniquely integrates three key concepts—competency belief, insider status, and crisis management—into a comprehensive model within the aviation sector. The study contributes to the literature by filling a gap in empirical research and offering practical insights for human resources and crisis preparedness strategies in high-risk service industries.

This article is derived from the unpublished doctoral dissertation entitled "Examining the Impact of General Competency Belief on Crisis Management: The Mediating Roles of Organizational Learning and Perceived Insider Status in the Airline Industry," completed as part of the PhD program at İstanbul Arel University.

1. Introduction

General competency belief represents an individual's overall confidence in their ability to develop behaviors and achieve outcomes in response to situations encountered throughout life. This belief also encompasses the motivation to cope effectively with challenges originating from the environment that may lead to stress (Çelikkaleli & Çapri, 2008).

The concept of competence was first introduced into academic literature by Philip Selznick in 1957 and was identified as a critical factor in organizational success. However, it remained relatively overlooked until David McClelland's Influential 1973 article "Testing for Competence Rather Than Intelligence," which positioned competence as a more valid predictor of workplace performance than intelligence (Bayraktar, 2002).

The aviation industry frequently faces crises that arise unexpectedly and cannot be anticipated before they occur. These crises require rapid, high-stakes responses and often disrupt organizational goals, values, and operational order.

Given this dynamic environment, airlines must employ a highly skilled and competent workforce.

Airline service is a complex set of processes consisting of pre- and post-flight operations, in-flight comfort, flight frequency, and connection convenience components provided to passengers during their journey through advanced technology products. Due to the high probability of encountering crises given the nature of the industry, it is essential for employees to possess the competencies required by their roles, and it is important for their belief in their capabilities to develop positively.

The main objective of this research is to determine the effect of airline employees' beliefs about their general competencies on crisis management activities. Based on the idea that employee belongingness is one of the measures that can be taken regarding the causes of company-related crises, this investigation will examine the mediating role of employees' perceived insider status on the effect of employees' general competency beliefs on crisis management.

Previous studies have examined self-efficacy, perceived insider status, and crisis management separately; however, research integrating these constructs into a unified model

within the airline industry context remains scarce. Addressing this gap, the present study makes a contribution to the literature by comprehensively elucidating how general competency belief impacts crisis management effectiveness through the mediating role of perceived insider status.

Accordingly, this research offers a novel perspective by combining general competency belief and perceived insider status to explain crisis management efficacy, particularly within the dynamic and crisis-prone airline sector.

2. Conceptual Framework

2.1 General Competency Belief: Concept and Definition

General competency belief represents an individual's overarching confidence in their capacity to succeed across various areas of life. The total competency belief formed as a result of self-efficacy experiences, which is the belief that individuals can perform a certain job, constitutes individuals' general competency beliefs. The level of general confidence is affected by both past experiences and environmental factors (Bandura, 1997).

Key determinants of competency beliefs include prior accomplishments, encouragement derived from observing others' successes, emotional well-being, and physical health. Together, these elements shape how individuals perceive their ability to perform certain tasks and cope with various situations, forming "general competency beliefs" that express and reflect how competent they feel across a wide array of life domains. General competency beliefs, which express people's confidence in their ability to cope with various stressful or challenging situations, reflect the generalization in their minds about various functional areas (Luszczynska, Scholz, & Schwarzer, 2005).

Competency beliefs are comprised of multiple interrelated psychological processes: cognitive processes, which influence self-enhancing or self-disempowering thought patterns; motivational processes, which influence how well individuals motivate themselves and their perseverance; emotional processes, which regulate their sensitivity to stress and resilience; and decision-making processes, which guide choices in complex or high-stakes situations (Bandura & Locke, 2003).

These components collectively influence how individuals interpret their capabilities and regulate their behaviors, shaping their motivation and performance in various fields (Bandura & Locke, 2003).

Professional knowledge and skills that individuals acquire during their education form the basis of professional effectiveness. Beyond formal education, factors such as skill development during different career phases, salary, job status, promotions, job satisfaction, career satisfaction, perceived career success, and intrinsic motivation all contribute to strengthening and sustaining this belief system (Trivellas, Kakkos, Blanas, & Santouridis, 2015).

Competency beliefs are a key driver in building and developing a productive, resilient, flexible, and motivated workforce. Employees with higher competency beliefs tend to perform at superior levels because they feel more capable and motivated to cope with challenges and complete tasks effectively. Such beliefs not only enhance individual outcomes but also contribute significantly to overall organizational performance through employees who are more likely to set ambitious goals and persist in achieving them (Jiang & Chen, 2013).

Employees with strong beliefs in their ability to perform tasks effectively are highly motivated to participate in organizational processes and remain committed and enthusiastic in their roles even under difficult and uncertain conditions.

2.2 Crisis and Crisis Management

2.2.1 Crisis Concept

A crisis can be characterized as a problem that is encountered and not easy to solve, an event going through a complicated phase, things going badly, and a sudden encounter with danger. Changes, uncertainties, and difficulties that occur in planned events that do not proceed as expected can also be characterized as crises (Hutchins, Annulis, & Gaud, 2008).

At the organizational level, a crisis is a situation that occurs unexpectedly at times and in ways that organizations do not anticipate, threatening their existence by disrupting their existing systems. Organizational crises are states of tension in which the organization's existing mechanisms become inadequate and require an immediate response. Unlike ordinary operational challenges or market fluctuations, crises create profound disturbances that demand extraordinary managerial action (Tutar, 2021).

Crises that confront organizations with the necessity to respond urgently and act quickly when they do not expect it also negatively affect the normal functioning of the organization. Organizational crises typically unfold through a sequence of stages: the pre-crisis development period, the crisis and crisis intervention period, and the post-crisis and resolution phase (Tüz, 2016).

2.2.2 Crisis Management

The fundamental objective of crisis management is to ensure preparedness against crises. Crisis management does not aim to completely eliminate crises but rather to manage them effectively and develop the ability of society or organizations to cope with such events (Bakan, 2018).

Although the crisis management process is a continuum that starts from the period before the crisis begins and continues until post-crisis learning and improvement practices, its main purpose is to plan and prepare well for the pre-crisis period, develop and manage early warning systems to end crises without damage. In this way, crises are not only perceived as periods containing negative effects for the organization but can also be seen as harboring opportunities within them.

Today, organizations need strategic planning to mitigate potential crisis conditions because they continuously face unique changes and uncertainties in the competitive world. The main purpose of crisis management efforts is to enable organizations to respond to crises in a timely and effective manner and to plan preparations that will allow them to recover quickly by minimizing production and service interruptions that the organization may experience.

The crisis management process requires the ability to conduct emergency operations quickly, efficiently, and effectively during a crisis. The main goal is to minimize the impact of crises on the organization, accelerate the recovery process, and ensure business continuity. To this end, it is a holistic approach that includes being prepared for crises, timely intervention when crises occur, and post-crisis recovery. This process, which aims to protect the continuous welfare of organizations, consists of the basic stages of Crisis Signal Detection, Preparation and Prevention, Crisis Response

and Containment, Recovery and Normalization, and Learning and Evaluation (Pheng, Ho, & Ann, 1999).

2.3 Perceived Insider Status

In today's fast-paced and competitive business environment where the transformation speed of information has increased, the importance of qualified and highly motivated human resources is gradually increasing. This situation makes determining and increasing employees' feelings of belonging to the organizations they work for and their commitment to the organization—in other words, their feeling of being part of the organization—increasingly important in terms of organizational competitiveness and sustainability.

While various researchers have examined the relationship between employees and their organizations using insider/outsider distinctions, the first quantitative study that directly evaluates employees' perceptions of feeling part of their organizations was conducted by Stamper and Masterson. The researchers developed and published the "Perceived Insider Status" scale consisting of 6 items and a single dimension (Stamper & Masterson, 2002).

Stamper and Masterson aimed to determine how employees position themselves in their member organizations and how this positioning reflects both on increasing overall organizational performance and on employees' participation in voluntary work behaviors. Employees who think they are accepted by the organization and feel themselves as part of the organization will have the perception of being an "insider," while employees who feel alienated or excluded from the organization will have the perception of being an "outsider."

The concept, which is an indicator of the employee's sense of belonging to the organization, is a cognitive and psychological evaluation of the person's acceptance by the organization and other members of the organization. Perceived insider status is also an important factor that expresses how employees perceive their roles and status within an organization. The concept, which reflects individuals' sense of inclusion and acceptance in the organization they belong to, focuses on employees' perceptions of their participation and insider status within the institution. Various human resources practices such as training opportunities, promotions, and benefit packages offered by the organization to employees, along with organizational support provided to employees, positively contribute to the level of perceived insider status (Lapalme, 2009).

Employees who feel that their contributions are recognized and appreciated will experience greater job satisfaction arising from this feeling, and a strong bond will form between them and their organizations. Strong feelings of appreciation, motivation, and commitment will also positively reflect on individual performance. High morale and motivation will not only increase employee commitment to the organization but will also lead to the formation and spread of positive employee attitudes. A positive organizational perspective will create a foundation for a less stressful and more positive organizational climate (Armstrong-Stassen & Schlosser, 2011).

2.4 Relationships Between Variables

Team members with high competency beliefs in the organization can act with high motivation in taking safety measures and following crisis instructions thanks to their confidence in their ability to take necessary actions in crisis situations. They can evaluate different options under stress and

pressure and make better decisions, feeling less fear and anxiety (Frisby, Sellnow, Lane, Veil, & Sellnow).

Individuals with high competency beliefs also have strong perceptions of being insiders because they feel safer and more capable in their roles during their working lives and are perceived by other organizational members as competent and reliable. Similarly, an individual with high insider status can exert more effort to gain more resources and support, and the success opportunities obtained in this way can increase their competencies (McClelland, 2005).

Organizations should strive to increase the competencies of their employees to strengthen their sense of organizational belonging and making them feel that they produce more value for their organizations. Increasing employees' confidence in their own competencies will raise their motivation, organizational commitment, and job satisfaction, and this situation will positively affect not only individual performance but also the total performance results achieved by the organization (McClelland, 2005).

As also emphasized in the study by Tunç and Topçuoğlu (2025) in the aviation sector, employees with a high sense of general self-efficacy contribute considerably to organizational performance during crises by demonstrating creative thinking, adapting to environmental initiatives, and taking responsibility; this impact becomes more evident under conditions that require rapid decision-making and operational flexibility (Tunç & Topçuoğlu, 2025).

Precautionary measures taken prior to a crisis—such as ensuring passenger and crew safety, complying with regulatory requirements for uninterrupted flight operations, performing comprehensive aircraft maintenance (including in-flight air and water systems), adhering to rigorous cleaning and disinfection protocols, and maintaining effective communication through the timely and accurate dissemination of information to passengers and stakeholders—constitute critical components of crisis management that contribute to business continuity and operational efficiency in the airline industry (Abdallah, Elhoss, & Chahine, 2025).

However, despite such measures, the industry remains vulnerable to internal and external shocks that may lead to permanent closures. Between 2010 and 2023, financial distress emerged as the leading cause of airline cessations, followed by crises such as the COVID-19 pandemic, wars and conflicts, mergers and restructuring processes, and regulatory non-compliance. These factors demonstrate the complex and unpredictable risks that necessitate not only preventive actions but also adaptive and resilient crisis management strategies (Sun, Zheng, Wang, & Wandelt, 2025).

Employees' perceived insider status plays a critical role in mitigating both intentional and unintentional insider threats within the aviation industry. When employees feel that they are trusted, valued, and genuinely part of the organization, their commitment to adhering to security protocols, maintaining operational integrity, and proactively identifying potential risks meaningfully increases. Fostering a positive perceived insider status among employees also directly supports the cultivation of a robust aviation security culture. When employees feel integrated and valued, they are more likely to embrace security protocols and actively participate in safeguarding critical assets. Thus, the interplay between perceived insider status and security culture forms a critical defense mechanism in maintaining operational safety and business continuity in the airline industry (Palmer, 2025).

3. Scope and Limitations of The Study

This research was conducted based on data obtained from a total of 14 airline companies operating in Türkiye and licensed by the Turkish Directorate General of Civil Aviation. The survey form was applied to industry employees using the judgmental sampling method, one of the non-probability sampling methods, regardless of whether they had managerial roles. The results of the research were analyzed and interpreted through structural equation modeling using SPSS and AMOS statistical analysis programs, and the validity of the established hypotheses was tested.

3.1 Data Collection Method and Pilot Study

The survey form prepared in line with the research scales consists of a total of 56 questions, including 8 personal information questions and 48 research questions in 4 sections. The data used in the research were obtained based on the answers given to the survey form by a total of 324 airline employees in different duties and positions.

Following the Exploratory Factor Analysis (EFA) and reliability tests, Confirmatory Factor Analysis (CFA) was performed for all measurement scales. The model fit indices obtained from the CFA indicated that the scales achieved good or acceptable levels of model fit, thus supporting their construct validity (Meydan & Şeşen, 2011). Subsequently, convergent and discriminant validity analyses were conducted. For this purpose, the Average Variance Extracted (AVE) was calculated to assess convergent validity, while Composite Reliability (CR) was computed to determine construct reliability and internal consistency. The results demonstrated that the research model is reliable, internally consistent, and meets the required thresholds for both convergent and discriminant validity.

3.2 Research Variables and Measurement Scales

3.2.1 General Competency Belief Scale

The first scale used in the study, which constitutes the independent variable of the research, is the "General Competency Belief Scale" developed by Jerusalem and Schwarzer (1992). The Turkish versions validity and reliability studies of the scale were conducted by Çelikkaleli and Çapri in 2008 (Cronbach's Alpha value 0.89). The scale is 4-point Likert type and consists of a single dimension with 10 items (Çelikkaleli & Çapri, 2008).

3.2.2 Crisis Management Scale

The second scale containing the dependent variable of the research is the "Crisis Management Scale" developed by Çalışkan. The scale consists of 23 items and contains no negative items. The scale is 5-point Likert type. The scale has three sub-dimensions: the first dimension is "pre-crisis activities" consisting of nine items with a Cronbach's Alpha value of 0.89, the second dimension is "activities during crisis" consisting of 10 items with a Cronbach's Alpha value of 0.92, and the third dimension is "post-crisis activities" consisting of four items with a Cronbach's Alpha value of 0.93 (Çalışkan, 2020).

3.2.3 Perceived Insider Status Scale

The final scale included in the research is the "Perceived Insider Status Scale" developed by Stamper and Masterson (2002), consisting of 6 statements and a single dimension, with Cronbach's alpha values varying between 0.79-0.93 (0.88 for

the entire scale) in subsequent studies (Stamper & Masterson, 2002).

The scale, adapted to Turkish by Mirap in 2008, has a Cronbach's Alpha value of 0.79 (Ofıazer Mirap, 2008). The 5-point Likert type scale was subsequently used by different researchers in various studies, and when the scale's Cronbach's Alpha value was recalculated in related studies, it was found to be in the range of 0.80-0.86 (Akkoyun, 2024).

3.3 Research Model and Hypotheses

The independent variable of the research is general competency belief, and the dependent variable is crisis management. The perceived insider status variable is the other variable whose mediating role in the effect of the independent variable on the dependent variable is to be determined in the research. As shown in the research model given in Figure 1, there are a total of three variables in the study.

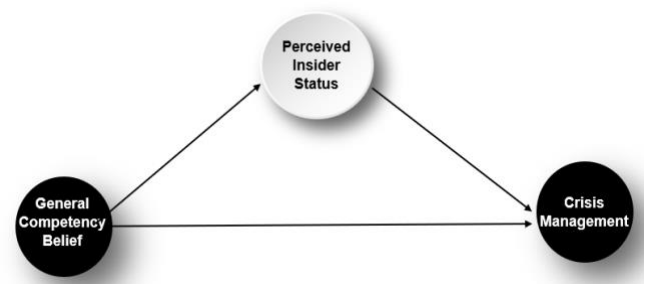


Figure 1. Research Model

Considering the technological infrastructure that airline companies must possess, the employee qualifications needed to establish and operate this structure, and the international competitive environment they operate in, the research hypotheses were determined as follows, based on the thought that airline employees' general competency beliefs have an effect on crisis management skills, and employee perceived insider status play a role in this effect:

H1: Employees' general competency beliefs significantly affect the crisis management process.

H2: Employees' general competency beliefs affect their perceived insider status.

H3: Employees' perceived insider status affects the crisis management process.

H4: Perceived insider status has a mediating effect on the impact of employees' general competency beliefs on the crisis management process.

3.4 Research Findings

3.4.1 Frequency Analysis

Among the airline employees who answered the survey questions within the scope of the research, 41% are female and 59% are male. The highest response rate was from personnel working in departments related to commercial operations (14.8%) and departments responsible for ground and flight operations (13.9%).

The current educational status of participants reveals that the employment of educated personnel should be high within the scope of the international characteristics and technical knowledge needs of the aviation industry. Only 16% of research participants are associate degree and high school

graduates, while the rate of bachelor's degree graduate employees is 64.5%, and the rate of master's and doctoral graduate employees is 19.2% in total.

74% of research participants have more than 5 years of experience in the same industry but in different airlines, and 34.9% have more than 15 years of total aviation experience. Their company and industry experience suggests that they have sufficient organizational culture in the airlines they work for and have experience with crisis management due to the crises they have encountered during their working lives.

3.4.2 Exploratory Factor Analysis and Reliability Analysis

Since the number of participants from whom the data used in the research were obtained (324) is larger than both the number of variables (56) and 5 times the number of variables (280), the suitability condition for factor analysis has been met for all four scales in the research (Yaşlıoğlu, 2017).

As stated in the literature, during exploratory factor analysis, structures in new studies can be tested based on the number of factors in scales previously used in different studies (Costello & Osborne, 2005). The suitability of research scales for the aviation industry was tested using the options for determining and fixing the number of factors in the SPSS program.

3.4.2.1 Exploratory Factor Analysis: General Competency Belief Scale

According to the factor analysis results conducted within the scope of the research, the Kaiser-Meyer-Olkin (KMO) value was 0.899, and Bartlett's test results were Chi-square = 1655.98, $df = 45$, $p = 0.000$. During the scale's reliability analysis, the 3rd question was removed from the scale and the analysis was repeated. In the final state, the scale, which became a total of nine questions, had a Cronbach's Alpha value of 0.898, Kaiser-Meyer-Olkin (KMO) value of 0.891, Bartlett's test results of Chi-square = 1545.81, $df = 36$, $p = 0.000$, and total variance of 55.581.

3.4.2.2 Exploratory Factor Analysis: Crisis Management Scale

According to the factor analysis results conducted within the scope of the study, the Kaiser-Meyer-Olkin (KMO) value was 0.971, and Bartlett's test results were Chi-square = 7537.35, $df = 253$, $p = 0.000$.

During factor analysis, it was observed that questions 1, 3, and 4, which were in the first sub-factor in the original scale, were in the second sub-factor, and questions 1, 2, 3, and 5, which were in the second factor, were in the first factor. At the same time, questions 5, 9, and 10 in the second sub-factor were determined to tend to appear under multiple factors and were removed from the analysis, and the factor analysis was renewed. With the renewed factor analysis, it was determined that question 3 in the second sub-factor also tended to be under multiple factors, and the question was removed from the analysis, and factor analysis was applied to the scale for the third time.

Due to the natural structure of airlines, both the establishment of strict rules and regulations by aviation authorities to encounter and overcome crises at any moment, and the necessity of creating and implementing procedures for airline companies' operational processes are known by employees, and activities are carried out intertwined with crises in the aviation industry. It is thought that the answers to the questions in the pre-crisis and post-crisis activities sub-

factors of the scale lead to a different structure in the sub-factors of the scale for these reasons.

According to the final factor analysis results conducted within the scope of the study, the scale consisting of a total of 3 factors and 19 questions had a Kaiser-Meyer-Olkin (KMO) value of 0.964, and Bartlett's test results were Chi-square = 5869.60, $df = 171$, $p = 0.000$. The total variance of the scale was calculated as 75.201. During the reliability analysis conducted according to the new structure of the scale, no item that needed to be removed from the scale was identified, and the Cronbach's Alpha values of the factors were determined as 0.946, 0.937, and 0.907, respectively.

3.4.2.3 Exploratory Factor Analysis: Perceived Insider Status Scale

According to the factor analysis results conducted within the scope of the research, the Kaiser-Meyer-Olkin (KMO) value was 0.799, Bartlett's test results were Chi-square = 1488.73, $df = 15$, $p = 0.000$, and the total variance of the scale was calculated as 63.492.

During the scale's reliability analysis, the 4th question was removed from the scale because its Cronbach's Alpha value was larger than the scale's Cronbach's Alpha value, and the analysis was repeated. In the final state, the scale, which became a total of five questions, had a Cronbach's Alpha value of 0.885, Kaiser-Meyer-Olkin (KMO) value of 0.760, Bartlett's test results of Chi-square = 1340.18, $df = 10$, $p = 0.000$, and total variance of 69.248.

3.5 Structural Equation Modeling

3.5.1 Measurement Model Evaluation

Before evaluating the measurement model, confirmatory factor analysis of the research scales was performed, and the construct validity of the mediated and unmediated models created within the scope of the research and the accuracy of the established hypotheses were tested.

3.5.2 Confirmatory Factor Analysis: General Competency Belief Scale

The graphical representation resulting from confirmatory factor analysis and AMOS 23.0 program's modification suggestions is given in Figure 2. During the analysis, no question that needed to be removed from the scale for any reason was identified, and good fit values were achieved with only one modification (Gürbüz, 2021).

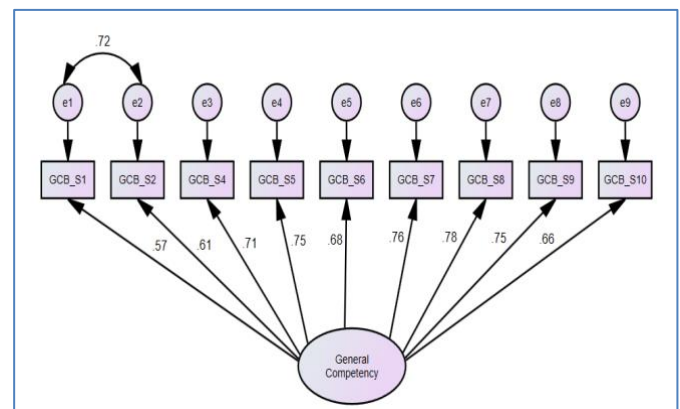


Figure 2. General Competency Belief Scale CFA Chart

3.5.3 Confirmatory Factor Analysis: Crisis Management Scale

For the "Crisis Management Scale," which became a scale consisting of a total of 19 questions after exploratory factor analysis, three modifications were made during confirmatory factor analysis, taking into account the AMOS program's modification suggestions. As a result of the modifications, better good/acceptable goodness of fit values were obtained (Meydan & Şeşen, 2011). The final confirmatory factor analysis graphical representation resulting from AMOS 23.0 program's modification suggestions is given in Figure 3.

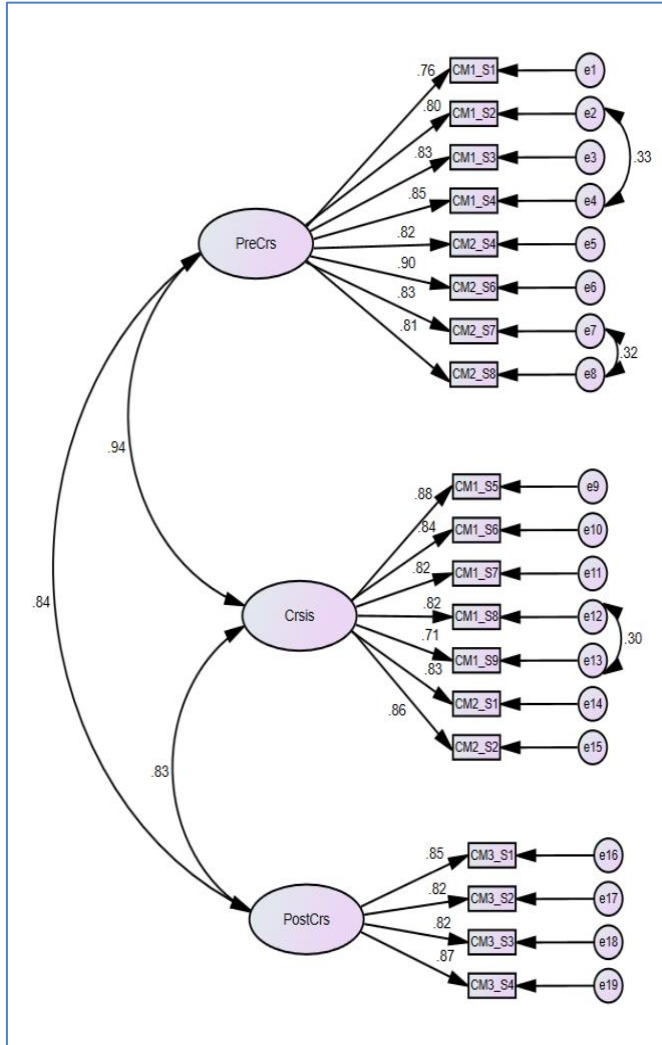


Figure 3. Crisis Management Scale CFA Chart

3.5.3 Confirmatory Factor Analysis: Perceived Insider Status Scale

During confirmatory factor analysis, good/acceptable fit values were achieved with only one modification (Gürbüz, 2021). The graphical representation resulting from AMOS 23.0 program's modification suggestions is given in Figure 4.

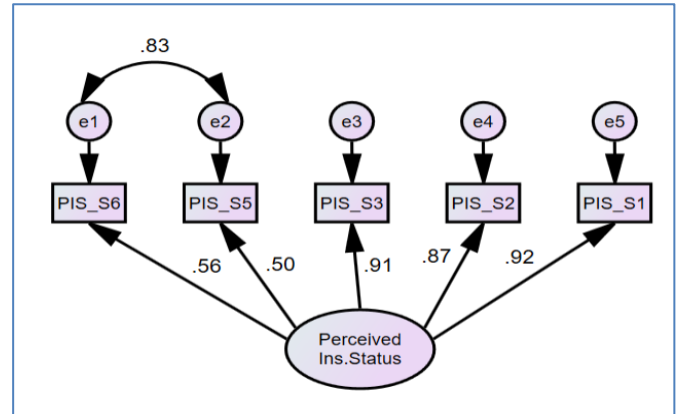


Figure 4. Perceived Insider Status Scale CFA Chart

3.6 Measurement Model Analysis Results

The values obtained as a result of confirmatory factor analysis for the scales of variables used in the research are given in Table 1. As can be understood from the values in the table, all goodness of fit values of the scales used in the research met good fit/acceptable fit criteria (Meydan & Şeşen, 2011). Fit values that ensure model validity have been achieved for all research scales.

Table 1. Confirmatory Factor Analysis Model Fit

	CMIN/DF	RMSEA	CFI	GFI	AVE	CR
General Competency Belief	2.201	0.061	0.98	0.961	0.50	0.90
Crisis Management	2.848	0.076	0.954	0.886	0.69	0.98
Perveived Insider Status	1.917	0.053	0.997	0.991	0.60	0.88

In addition to determining and evaluating the appropriateness of goodness of fit values during Confirmatory Factor Analysis, convergent and discriminant validity analyses were also performed to evaluate the validity of measurement models of research variables.

All conditions required for the existence of convergent validity in a measurement model—AVE > 0.5, CR > 0.7, and CR > AVE—were satisfied (Hair, Black, Babin, & Anderson, 2014).

The fact that AVE (average variance extracted) values, which express the average explained variance and measure convergent validity, and CR (composite reliability) values, which are construct reliability and internal consistency criteria, conform to the determined standards shows that the construct is both reliable and valid (Fornell & Larcker, 1981).

The measurement model analysis results using Fornell-Larcker criteria for determining discriminant validity are presented in Table 3.

Table 3 Fornell-Larcker Criterion Analysis for Checking Discriminant Validity

	1	2	3
General Competency Belief	0.71		
Crisi Management	.266**	0.83	
Perveived Insider Status	.210**	.540**	0.77

**. Correlation is significant at the 0.01 level (2-tailed).

3.7 Structural Model Analysis and Hypothesis Testing Results

Using AMOS 23.0 program, mediated and unmediated research models were tested according to Baron and Kenny (Baron & Kenny, 1986). Two separate models were created in the research, and the research hypotheses were formed and

analyses and hypothesis tests were completed within the scope of two separate models.

The first model directly examines "The Effect of General Competency Belief on Crisis Management" and is a model without a mediating variable, with its graphical representation shown in Figure 5.

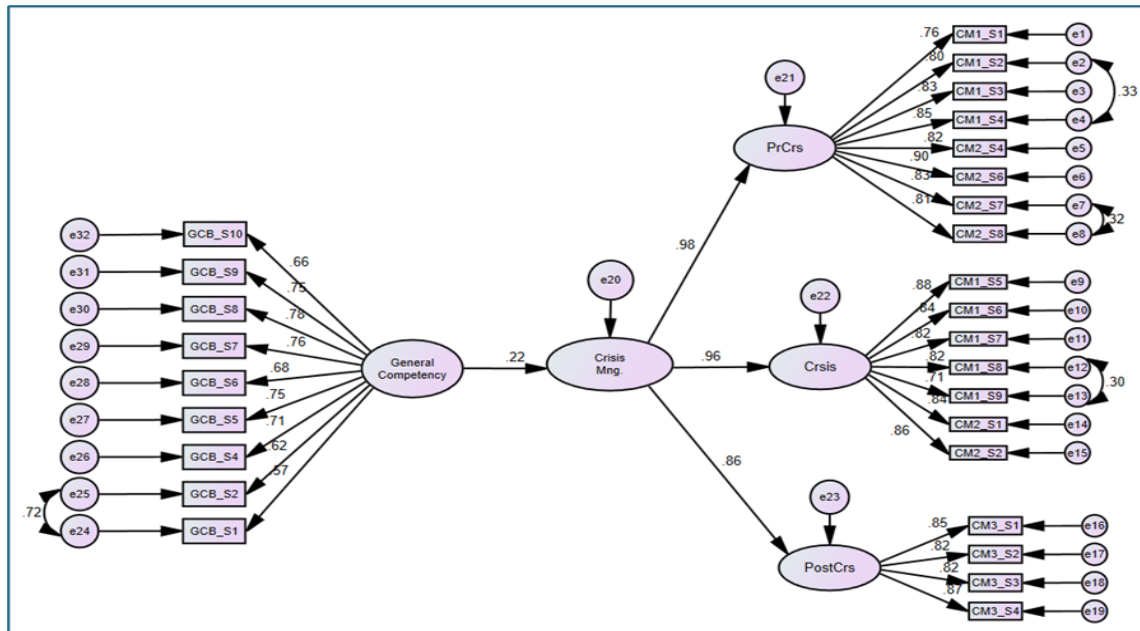


Figure 5. Model 1- Direct Effect Model (Without Mediator)

The other model is the model where "Perceived Insider Status" is included as a mediating variable, with its graphical representation shown in Figure 6.

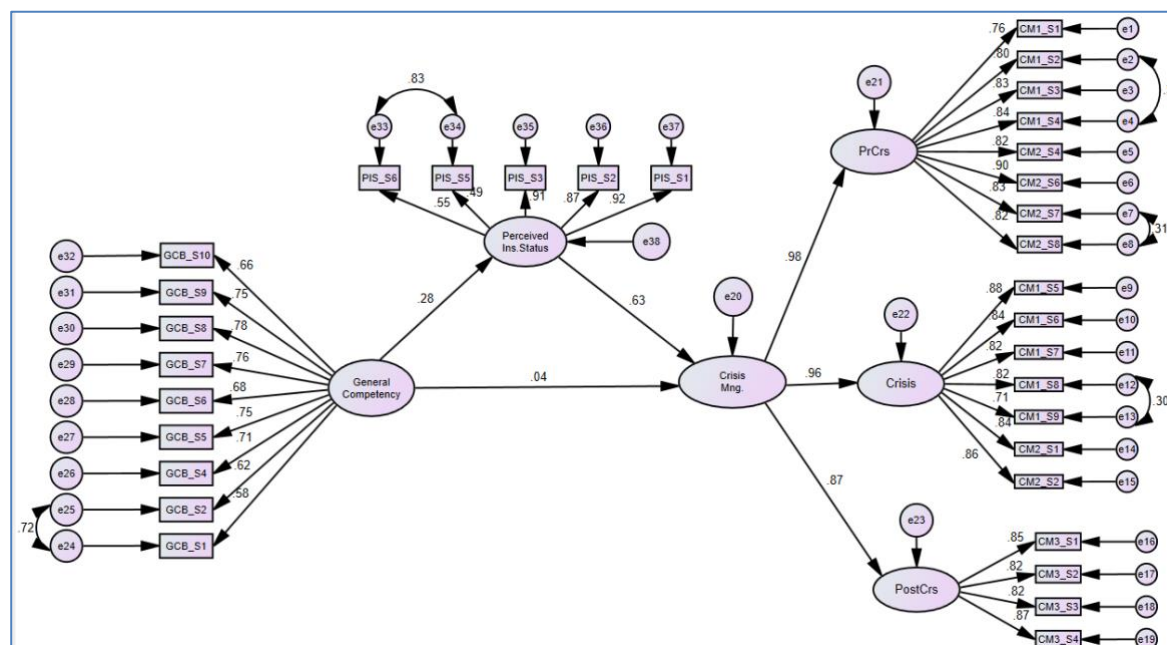


Figure 6. Model 2- Mediated Model Including Perceived Insider Status

The hypotheses of the study were tested using Structural Equation Modeling with the Bootstrap method, and the results are presented in Table 4.

Table 4. Hypotheses Test Results

	Model 1	Model 2
General Competency Belief→ Crisis Management	0.22 (p<0,001)	0.04 (p=0,388)
General Competency Belief→ Perceived Insider Status		0.28 (p<0,001)
Perceived Insider Status→ Crisis Management		0.63 (p<0,001)
	CMIN/df=2.20	CMIN/df=2.069
	CFI=0.945	CFI=0.943
Model Fit	GFI=0.861	GFI=0.844
	IFI=0.945	IFI=0.943
	RMSEA=0.061	RMSEA=0.058

Model 1 tested Hypothesis H1 and obtained a standardized path coefficient of 0.22, indicating a positive and statistically valuable effect. Therefore, **H1** is supported.

According to Model 2, the following results were obtained:

- General competency belief had a significant positive effect on perceived insider status ($\beta = 0.28$), thereby supporting **H2**.
- Perceived insider status had a strong and significant positive effect on crisis management ($\beta = 0.63$), supporting **H3**.
- When perceived insider status was included, the direct effect of general competency belief on crisis management decreased to $\beta = 0.04$, indicating a reduction in the direct effect and confirming **H4**.

These findings demonstrate that perceived insider status functions as a *complementary mediator* between general competency beliefs and crisis management. That is, it does not completely eliminate the direct effect but explains an important portion of it in the same direction (Zhao, Lynch, & Chen, 2010).

4. Conclusion and Discussion

4.1 Summary of Key Findings

The compliance obligation with international standards at every stage of the aviation industry, the continuously updated knowledge needs arising from the high technologies of aircraft, which are one of the main elements of transportation activities, necessitate the employment of educated and competent personnel.

From the data obtained within the scope of the research, it is understood that the airline employees participating in the research have high company and industry experience, carry high beliefs about their experience and competencies, have mastered the culture of the organizations they are members of, and have experience in crisis management through the crises they have encountered during their working lives.

With 85.2% "more accurate" and "completely accurate" answers given to all questions, the scale that research participants gave the highest rate of positive answers to was the "General Competency Belief Scale," which represents the independent variable of the research study. This situation

shows that airline employees have a high level of self-confidence regarding their competencies.

In all questions directed to them about crisis management, the options "agree" and "strongly agree" were approved at over 50%. The statement "Having a crisis plan reduces the uncertainty experienced during a crisis" was answered "agree" and "strongly agree" at a total rate of 82.14%. The answers received are indicators that airline employees are familiar with crisis plans and the concept of crisis management, are prepared for crisis situations, and have high awareness about coping with crises.

In the "Perceived Insider Status Scale," the rate of participants choosing "agree" and "strongly agree" options in all questions was 72.63%.

As a result of all analyses, it was determined that the research model is a model with *reliability/internal consistency, good fit values, and convergent and discriminant validity*. Testing of eight hypotheses established within the scope of mediated and unmediated research models according to Baron and Kenny was carried out, and all hypotheses were confirmed (Hair, Black, Babin, & Anderson, 2014).

4.2 Theoretical Contributions and Recommendations

The aviation industry is, by its nature, a field where the probability of experiencing different crises at any moment is high. Unlike smaller accidents that may cause less negative consequences in other industries, the possible consequences of potential accidents in the aviation field are vital. Therefore, both crisis scenarios and crisis management plans must be carefully prepared and implemented in response to both the possibility of recurrence of past events and potential situations that have not yet occurred but are likely to develop.

In addition to major crises such as accidents, terrorism, unexpected natural events, and pandemics, situations such as flight cancellations, diverting flights to other airports for various reasons, overbooking beyond capacity, work slowdowns, and strikes that airlines may encounter during their operations are also crises that airlines face that, while not vital, need to be managed correctly.

Pre-crisis planning and emergency measures in crises experienced by airlines are vital for overcoming crises with minimal damage. Being prepared for crises that may particularly attack basic brand values and taking timely action by acting quickly to make informative and accurate explanations to the public is important. Effective communication and leadership using the right communication channels for different stakeholders will considerably affect customers' brand perception during and after the crisis (Grundy & Moxon, 2013).

When employees feel like insiders in their organizations, they behave more willingly in terms of innovative behavior, proposing creative ideas and solutions thanks to their strong sense of belonging. The feeling of being valued and adequate encourages them to actively participate in innovative activities while also making them feel deeper commitment to the organization and engage in cooperation and knowledge sharing with their colleagues. As in all organizations with employees who have a high sense of insider perception, this situation also increases general performance and customer satisfaction in airlines (Lee & Hyun, 2016).

The research makes an original contribution to the literature by addressing three important concepts-general competency belief, perceived insider status, and crisis

management-together. In the four-stage literature review conducted, it was found that these variables appeared in separate studies, but no study examining them together in a holistic framework, especially in the context of the aviation industry, was found. Detailed investigations conducted across related national and international academic databases have revealed this gap.

The fact that the research is based on data obtained from 324 employees working in different cities and positions from 14 airlines licensed by the Directorate General of Civil Aviation in Türkiye provides important originality to the study by ensuring that it reflects Turkish civil aviation in general. The research will contribute to a holistic management approach in the aviation industry by bringing together three different variables that have not been considered together before.

The strategies applied by airlines to cope with this major crisis during the COVID-19 period, which had significant effects worldwide and deeply shook the aviation industry, became an important experience for airline employees in terms of rapid adaptation. It is thought that being an industry that encounters crises much more frequently compared to other fields in general, the readiness and adaptation ability developed through airline employees' previous crisis experiences was effective in the answers received from research participants and shaped their reactions.

Considering that the aviation industry is a field where employee competencies and sense of belonging are extremely vital, it would be beneficial for researchers to repeat this study in the future across foreign airlines with representatives in Türkiye and other subsidiaries of the aviation industry in general.

Ethical approval

Yes, Istanbul Arel University Ethics Committee approval dated 12/06/2025 and numbered 25/15.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abdallah, F., Elhoss , W., & Chahine, J. (2025). The importance of crisis management in the aviation industry: A case study on Kuwait . *Edelweiss Applied Science and Technology*, 9(4), 2459-2470.
- Akkoyun, E. (2024). The effect of vocational high school teachers' perceived administrator support, career satisfaction and internalization status on continuance commitment (Master's thesis). Istanbul Aydın University.
- Armstrong-Stassen, M., & Schlosser, F. (2011). Perceived organizational membership and the retention of older workers. *Journal of Organizational Behavior*, 32(2), 319–344.
- Bakan, P. (2018). Contemporary management approaches – Principles, concepts and approaches (Vol. 6). İstanbul: Beta Basım A.Ş.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.
- Bandura, A., & Locke, E. A. (2003). Negative self-efficacy and goal effects revisited. *Journal of Applied Psychology*, 88(1), 87–99.
- Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173–1182.
- Bayraktar, O. (2002). The use of competencies in human resources management and a case study in the banking sector (Doctoral dissertation). İstanbul University, Social Sciences Institute.
- Çalışkan, D. D. (2020). Crisis management: A scale development study. *Turkish Journal of Social Sciences Research*, 5(2), 106–120.
- Çelikkaleli, Ö., & Çapri, B. (2008). Validity and reliability study of the Turkish form of the General Competence Belief Scale. *Çukurova University Journal of Institute of Social Sciences*, 17(3), 93–104.
- Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation*, 10(7), 1–9.
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39–50.
- Frisby, B. N., Sellnow, D. D., Lane, D. R., Veil, S. R., & Sellnow, T. L. (n.d.). Instruction in crisis situations: Targeting learning preferences and self-efficacy. *Risk Management*, 15(4), 250–271.
- Gürbüz, S. (2021). *Structural equation modeling with AMOS (Vol. 2)*. Ankara: Seçkin Publishing.
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate data analysis (7th ed.)*. Harlow: Pearson Education.
- Hutchins, H. M., Annulis, H. M., & Gaud, W. S. (2008). Crisis planning: Survey results from Hurricane Katrina and implications for performance improvement professionals. *Performance Improvement Quarterly*, 20(3–4), 27–51.
- Jiang, T.-H., & Chen, S.-L. (2013). The discussion of machinery manufacturing industry employees' self-efficacy, organizational learning and job performance: The example of Taichung Industrial Park. In *2013 IEEE International Conference on Industrial Engineering and Engineering Management* (pp. 786–791). Bangkok, Thailand.
- Lapalme, M.-È., Simard, G., & Tremblay, M. (2009). Bringing the outside in: Can “external” workers experience insider status? *Journal of Organizational Behavior*, 30(7), 919–940.
- Lee, K.-H., & Hyun, S. S. (2016). An extended model of employees' service innovation behavior in the airline industry. *International Journal of Contemporary Hospitality Management*, 28(8), 1622–1648.
- Luszczynska, A., Scholz, U., & Schwarzer, R. (2005). The General Self-Efficacy Scale: Multicultural validation studies. *The Journal of Psychology*, 139(5), 439–457.
- McClelland, D. C. (2005). Achievement motivation theory. In J. B. Miner (Ed.), *Organizational behavior 1: Essential theories of motivation and leadership* (pp. 46–59). New York: M. E. Sharpe.
- Meydan, C. H., & Şeşen, H. (2011). *Structural equation modeling: AMOS applications*. Ankara: Detay Yayıncılık.

- Grundy & Moxon, (2013). The effectiveness of airline crisis management on brand protection: A case study of British Airways. *Journal of Air Transport Management*, 28, 55–61.
- Oflazer Mirap, S. (2008). A research in private healthcare organizations to measure the effects of perceived belonging status on task performance, contextual performance and total performance. In *Proceedings of the 16th National Management and Organization Congress* (pp. 142–148). Afyonkarahisar.
- Palmer, V. (2025). Systematic literature review on insider threat: Is the Australian aviation industry complacent or just not understanding insider threat? *Journal of the Air Transport Research Society*, 4, 1-11.
- Pheng, L. S., Ho, D. K. H., & Ann, Y. C. (1999). Crisis management: Survey of property development firms. *Property Management*, 17(3), 231–251.
- Stamper, C. L., & Masterson, S. S. (2002). Insider or outsider? How employee perceptions of insider status affect their work behavior. *Journal of Organizational Behavior*, 23(8), 875–894.
- Sun, X., Zheng, C., Wang, K., & Wandelt, S. (2025). The art of airline cessation: A comprehensive analysis based on airline ceases reported between the years 2010 and 2023. *Journal of Air Transport Management*, 1-12.
- Trivellas, P., Kakkos, N., Blanas, N., & Santouridis, I. (2015). The impact of career satisfaction on job performance in accounting firms: The mediating effect of general competencies. *Procedia Economics and Finance*, 33, 468–476.
- Tunç, A., & Topçuoğlu, E. (2025). Mediating role of sustainable development goals in the effect of green transformational leadership on employee performance in the aviation industry. *Journal of Aviation*, 9(2), 331–337.
- Tutar, H. (2021). *Management in crisis and stress environment* (Vol. 5). Ankara: Hayat Yayınları.
- Tüz, M. V. (2016). *Business management in crisis period*. İstanbul: Ekin Basım Yayın.
- Yaşlıoğlu, M. M. (2017). Factor analysis and validity in social sciences: Using exploratory and confirmatory factor analyses. *İstanbul University Journal of Business Administration Faculty*, 46(Special Issue), 74–85.
- Zhao, X., Lynch, J. G., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *Journal of Consumer Research*, 37(2), 197–206.

Cite this article: Erener Ozalcin, S., Colakoglu, N. (2025). Examining The Impact of General Competency Belief on Crisis Management: The Mediating Roles of Perceived Insider Status in The Airline Industry *Journal of Aviation*, 9(3), 725-734.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Financial Repercussions of the Pandemic Shock in OECD Countries: An Analysis of the Airline and Healthcare Industries

Çağatay Mirgen^{1*}, Yunus Emre Kahraman²

^{1*}National Defence University, Department of Business Administration, 10185, Altıeylül, Balıkesir, Türkiye (cagatay.mirgen2@msu.edu.tr)

²Osmaniye Korkut Ata University, Health Services Vocational School, Department of Pharmacy Services, Osmaniye, Türkiye. (yunusemrekahraman@osmaniye.edu.tr)

Article Info

Received: 08 July 2025
Revised: 22 July 2025
Accepted: 07 August 2025
Published Online: 16 October 2025

Keywords:

Airline industry
Healthcare industry
Financial performance
Panel data analysis
Covid-19

Corresponding Author: Çağatay Mirgen

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1737091>

Abstract

This study aims to analyze the financial impact of the COVID-19 pandemic on the airline and healthcare industries in OECD countries from a comparative perspective. The pandemic has created a crisis that has reshaped economic and sectoral dynamics globally. In this context, the study analyzes the key indicators affecting the financial performance of publicly traded companies operating in the airline and healthcare industries. In the analysis, stock prices are used as the dependent variable, while independent variables include earnings before interest, taxes, depreciation, and amortization (EBITDA) margin, liquidity ratio, free cash flow, total revenue, asset turnover, return on assets (ROA), and return on equity (ROE). According to the results of the analysis conducted using the panel data analysis method, the liquidity ratio and total revenue exhibit a positive and statistically significant impact on stock prices in the airline industry. In the healthcare industry, the EBITDA margin and total revenue also demonstrate statistically significant and positive effects on stock prices. In both industries, asset turnover shows a statistically significant negative relationship with stock prices. The remaining variables do not exhibit statistically significant effects.

1. Introduction

Throughout history, epidemics have caused enormous losses to humanity and caused various crises. The plague epidemic, known as the “Black Death”, which took place between 1347 and 1351, caused approximately 75-100 million people to lose their lives. Similarly, the hemorrhagic fever in Mexico between 1545-1548, the cholera epidemic between 1899-1923, the AIDS virus, which was first identified in Cameroon in 1908, SARS, ebola, and swine flu, which were effective in Asia and Canada in 2002-2003, have been among the epidemics in human history (Zeren and Hızarcı, 2020; Gürsoy et al., 2020). On the other hand, the COVID-19 pandemic has triggered a multifaceted global crisis, causing significant disruptions not only in the field of health but also across economic, social, and psychological domains (Temir, 2020). Unforeseeable pandemics such as COVID-19 tend to generate severe crises, particularly in economic and financial sectors (Yücel & Durak, 2021). COVID-19 disrupted global supply chains, reduced employment rates, and slowed down economic growth (Cavlak, 2020).

The economic and financial impacts of the pandemic have shown significant differences between sectors. While some sectors have been deeply negatively affected by this process, it has been observed that some sectors have achieved positive results under pandemic conditions (Yetiz, 2021). In particular, the airline and healthcare industries stand out as two critical sectors that have experienced the direct effects of the

pandemic. Although the airline industry is an important contributor to global economic growth, it faces problems such as demand contraction, idle capacity, and low productivity during periods of economic slowdown (Dağlı, 2021). The COVID-19 pandemic, combined with factors such as declining demand in the airline industry, travel restrictions, and operational limitations, has led to severe financial difficulties within the sector (Hopancı et al., 2021; Kalkın, 2021). On the other hand, the healthcare industry exhibited a different dynamic during the pandemic. Increased demand and accelerated adaptation processes paved the way for new business opportunities and improved financial performance in the healthcare industry. The pandemic has created significant opportunities for businesses that offer innovative solutions and flexibility, especially in the healthcare industry (Sakarya et al., 2014; Tükenmez et al., 2017). The financial resilience and crisis management capacities of these sectors during the pandemic played an important role in economic recovery processes. In this context, the study aims to investigate the factors affecting stock prices for companies in the airline and healthcare industries in OECD countries.

Previous research on the COVID-19 pandemic provides important findings, especially in terms of economic and financial impacts. For example, Yücel and Durak (2021) examined the effects of the recession in economic activities on financial performance during the pandemic period, while Dağlı (2021) detailed the financial challenges in the airline industries. Sakarya et al. (2014) discuss financial opportunities and innovative solutions in the healthcare industry, while

Keleş and Özulucan (2020) analyze the financial indicators of the airline industry and reveal performance differences between sectors.

The primary aim of this study is to comparatively analyze the financial performance of the airline and healthcare industries in OECD countries, including the COVID-19 pandemic period. OECD countries, as developed economies, have experienced the financial effects of the pandemic with different dynamics, and in this context, they offer an ideal data set for comprehensive and comparative analysis. The airline and healthcare industries were chosen as two important sectors that felt the direct effects of the pandemic in different ways. While the airline industry has been under great economic pressure due to travel restrictions and a decline in passenger demand, the healthcare industry has had opportunities to improve its financial performance thanks to increased demand and operational flexibility. In this context, this study aims to make a unique contribution to the literature by conducting a comparative analysis of the financial performance of the airline and healthcare industries over a time period that includes the pandemic. In this study, the effects of key financial indicators such as ROA (return on assets), ROE (return on equity), EBITDA (earnings before interest, taxes, depreciation, and amortization) margin, liquidity ratio, free cash flow, total revenue, and asset turnover on stock prices are analyzed.

2. Literature Review

Pandemic shocks have had profound and long-term effects on the global economy, significantly affecting the financial performance of businesses. In OECD countries, the determinants and impacts of financial performance have emerged as a prominent area of research, particularly in sectors such as aviation and healthcare, which have exhibited varying responses to the conditions of the pandemic.

In the literature, studies on the factors affecting the financial performance of businesses have explored the effects of elements such as profitability, liquidity, sustainability, risk management, and operational efficiency, using various methods and variables. The airline industry faced decreased demand, travel restrictions, and operational constraints due to the pandemic, while the healthcare industry, on the other hand, found opportunities to improve its financial performance through increased demand and new business opportunities. In this context, Table 1 presents a summary of the literature review of the studies examined.

The literature review given above summarizes the methods and findings of various studies on financial performance, capital structure, and sustainability. It is noteworthy that the dependent and independent variables and methods used in the studies are quite diverse. For example, in addition to statistical methods such as regression analysis, multi-criteria decision-making methods such as CHAID decision trees and TOPSIS are also used. The findings range from the relationship between underpricing and long-term stock returns to the negative impact of free float on Tobin's Q. Moreover, sectoral differences appear to play an important role in performance assessments. It has been determined that factors such as sustainability, liquidity ratios, and resource dependence have significant effects on financial performance. This literature review provides a comprehensive framework of factors affecting financial performance.

This study analyzes the financial performance of the airline and healthcare industries in OECD countries. However, many

studies in the literature have evaluated financial performance using different variables and focal points. It has been observed that the relationships between companies' management structures and operational processes are highlighted. Bayrakdaroglu (2010) and Çelik (2014) examined the links between governance practices and financial performance, while Tükenmez et al. (2017) analyzed the effects of public disclosure and transparency scores on corporate profitability. Okan et al. (2014) analyzed the effects of board size and international diversification on financial performance and revealed the positive effects of these variables. Topaloğlu and Ege (2018) evaluate the limited effects of board structure on financial indicators using panel regression analysis.

The effects of corporate social responsibility practices on financial performance have also been frequently discussed in the literature. Kamatra and Kartikaningdyah (2015) emphasized the effect of ROA and ROE in their study. Sakarya et al. (2014) and Agrawal et al. (2020) addressed the effects of corporate social responsibility practices on financial performance. Oware and Mallikarjunappa (2020) revealed that social responsibility activities do not always have a direct impact on profitability indicators.

In a study conducted by Shuid and Noor (2012), it is stated that there is a negative relationship between financing SMEs with debt and financial performance, but tax incentives have a positive effect. However, they found that there is no significant relationship between working capital management and financial performance. Salur and Demirci (2018) examined the changes in the financial performance of medium sized enterprises during the public offering process.

In addition to these studies, there are also studies focusing on the effects of pandemics on global economies. For example, Ağazade and Karakaya (2019) evaluate the bidirectional relationship between financial development and economic growth for OECD countries, while Öndeş and Özkan (2021) reveal the effects of COVID-19 on financial performance in the IT sector.

Although previous studies in the literature have examined factors such as governance structures, corporate social responsibility practices, and financing strategies, this study does not focus on these variables. To broaden the scope of future research, it is recommended to investigate the potential impacts of such variables on financial performance. Therefore, the exclusion of these variables is considered a limitation of this study. Nevertheless, we believe that the findings contribute to the existing literature by highlighting sector-specific vulnerabilities and offering insights into investor behavior. Furthermore, this study distinguishes itself from previous research by focusing on companies operating in the airline and healthcare industries within OECD countries, thereby enabling a comparative analysis between the two sectors.

Recent studies highlight the impact of environmental, social, and governance (ESG) factors on value creation, consumer perception, and sustainability in the airline and tourism industries. Sim and Kim (2024) found that consumer-driven ESG perception significantly influences brand image and behavioral intentions. Yildiz et al. (2024) demonstrated that ESG practices contribute to long-term firm value in the airline industry, although their short-term effects may be limited. Lin et al. (2024), on the other hand, discussed how ESG measurement criteria could be improved to better address the needs of local sectors within the context of a developing country. Katı (2025) found Pegasus outperformed Turkish Airlines financially post-COVID.

Table 1. Literature review

Researcher	Variables	Method	Results
Irfani (2014)	Underpricing, long-term stock returns	Multiple regression analysis	Financial performance ratios have no effect on underpricing and long-term stock returns; underpricing has no long-term return.
Topaloğlu and Nur (2016)	Dependent: return on assets, return on equity; independent: cash conversion period	Multiple linear regression	A positive relationship was found between cash conversion period and return on assets.
Karkacier and Yazgan (2017)	Leverage ratio	Gray Relational Analysis (GRA)	Leverage ratio plays a critical role in the financial performance of tourism firms.
Soytaş et al. (2017)	Sustainability; financial performance	Data analysis	Sustainability has a positive impact on financial performance.
Kesbiç and Taşdemir (2019)	Free float; financial performance outcomes	Correlation analysis	There is a negative relationship between free float and Tobin's Q.
Aigbedo (2021)	Return on assets (ROA), revenue growth (RG), environmental performance (EP)	Regression analysis	Revenue growth affects environmental performance; the effect is stronger for larger firms. The environmental performance of the industry is more explanatory than the impact of financial performance.
Büyükarıkan (2020)	Dependent return on equity; 20 ratio analysis	CHAID decision tree	The two most significant ratios influencing a firm's financial performance are financial profitability and capital structure.
Hashem et al. (2020)	Stock prices, total assets, return on equity, return on assets, price-earnings ratio, price-book ratio, dividend per share, debt ratio	Multiple regression analysis	Share prices are positively correlated with total assets, price-to-book ratio, and dividends per share, and negatively correlated with debt ratio.
Keleş and Özulucan (2020)	Liquidity ratios, financial structure ratios, operating ratios, profitability ratios.	Ratio method	Pegasus outperformed Turkish Airlines financially and held a stronger investment position.
Yılmaz and Kandemir (2021)	Dependent: financial performance; Independent: level of resource dependence, influence and control strategies	Survey and regression analysis	It is found that the level of resource dependence and strategies positively affect financial performance.
Özbek and Ghouchi (2021)	Current ratio, quick ratio, cash ratio, financial leverage ratio, asset turnover, receivables turnover, fixed asset turnover, return on equity, return on assets, operating profit margin, gross profit margin, net profit margin.	WASPAS, EDAS; Entropy method for weighting	Ryanair showed the highest performance and Lufthansa the lowest performance. The study reveals that effective performance evaluation is possible with financial ratios.
Doruk (2022)	Financial ratios; before and after COVID-19	Welch T test	Food firms show no overall performance difference, but short-term performance varies.
Suryaningsih and Suseno (2022)	Independence ratios, efficiency ratios, productivity ratios, local income	Panel data analysis	Fiscal performance indicators have a positive impact on the economic growth of special autonomy regions.
Kurt and Kablan (2022)	Financial indicators of airline companies in BIST Transportation Index (XULAS); DHMI financial data.	TOPSIS, MABAC	COVID-19 was found to have a negative impact on airline transportation and DHMI financial performance.
Ağırkaya and Keleş (2022)	Airline passenger transportation financial data obtained from the Central Bank of the Republic of Turkey sector balance sheets.	Ratio analysis	It was observed that the pandemic led to a financial contraction in the sector, but the sector maintained its strategic importance.
Asker (2023)	Financial indicators of low-cost airlines.	CRITIC, ARAS	Small-scale airlines performed best in different periods, while large-scale airlines showed no significant change.
Şenol (2023)	Financial indicators of Borsa Istanbul healthcare industries companies.	TOPSIS	Post-pandemic, healthcare outperformed other sectors; ANGEN led in performance.
Şenol et al. (2023)	Financial indicators of Borsa Istanbul pharmaceutical companies.	TOPSIS	The pharmaceutical companies gained positive financial momentum during the pandemic period, with ECILC and DEVA showing the best performance in 2020, and SEYKM and RTALB in 2022.
Sim and Kim (2024)	Perceived ESG, brand image, consumer behavior	PLS-SEM	Governance dimension of ESG significantly influences brand image, attachment, and consumer behavioral intentions.
Lin et al. (2024)	ESG indicators in tourism and hospitality	Semantic network analysis and interviews	ESG criteria in developing countries require adaptation; governance and resources are key.
Yildiz et al. (2024)	ESG scores, firm value, operational efficiency, risk management	Panel data analysis	ESG enhances firm value via efficiency and risk control; governance is key, but short-term gains may be limited.
Katı (2025)	17 financial ratios	Ratio analysis	COVID-19 impacted both firms; Pegasus showed stronger financial performance than Turkish Airlines post-pandemic.

3. Data Set and Methodology

The Organization for Economic Cooperation and Development (OECD) plays a critical role in international economic cooperation and development. Most of its 38 member countries account for a significant part of the world economy and lead the development of effective policies in various areas, such as international trade, investment, education, and environmental policy. The main objective of the OECD is to promote economic growth among its member countries, raise living standards, and contribute to the sustainable development of the global economy. In this context, the OECD is not only a platform that sets standards for its members but also acts as a mediator to develop common solutions to global problems. For example, during the pandemic, the coordination achieved among OECD countries played a critical role in the development of economic recovery and public health strategies. The collaboration and exchange of experiences between countries have enabled a more effective fight against the global crisis. In addition, the organization provides guidance to policymakers in member countries by offering leadership on critical contemporary issues such as energy security, digitalization, and environmental sustainability.

The SARS-CoV-2 virus that causes COVID-19 was first detected in December 2019 in the city of Wuhan in China's Hubei province (WHO, 2023). On 30 January 2020, the World Health Organization declared an international public health emergency due to the global COVID-19 pandemic (Mahase, 2020: 1). The World Health Organization announced on May 5, 2023, that COVID-19 was no longer a global health emergency. However, it was emphasized that it continues to be a global health threat (WHO, 2023). The pandemic period attracted attention as a process that had significant impacts on global economies. Within the scope of this study, a dataset including quarterly periods from the fourth quarter of 2019 to the third quarter of 2024, including the pandemic period, has been prepared. The selection of this period was made to better analyze the economic and sectoral impacts created by the COVID-19 pandemic globally. The sectors included in the study are the airline and healthcare industries, which are considered to be most affected by the pandemic (Yücel and Durak, 2021; Dağlı, 2021; Sakarya et al., 2014; Keleş and Özulucan, 2020).

The airline industry is highlighted as a sector that has incurred substantial economic losses due to travel restrictions and reduced passenger demand during the pandemic. This study examines publicly traded companies within this sector, including Air Canada, Deutsche Lufthansa AG, Turkish Airlines AO, and Ryanair Holdings PLC, all of which operate in OECD countries. The key focus of the study is to analyze the factors influencing stock prices within the sector during the pandemic period. Similarly, the healthcare industry, which has been directly impacted by the pandemic, also played a significant role in addressing the crisis. Companies operating in this sector and included in the study include Johnson and Johnson, AstraZeneca PLC, EİS Eczacıbaşı İlaç Sanayi, and Takeda Pharmaceutical Co. Ltd. Healthcare companies have played critical roles during the pandemic, such as developing vaccines and maintaining healthcare services.

In the study, full access to representatives of all sectors in OECD countries could not be obtained. The main reason is that some countries have no publicly traded companies in the sectors. Nevertheless, the selected companies are globally

recognized and represent the characteristic features of the relevant sectors. Analyzing the performance of the airline and healthcare industries during the pandemic period aims to shed light on the resilience capacity and recovery processes of the sectors in times of crisis. In this context, the effects of the pandemic on these sectors will be evaluated by analyzing the financial data and performance indicators of the selected companies in detail. Through the analysis of these effects, the study aims to reveal the impact of the pandemic on financial and sectoral dynamics. The selected sectors and companies belonging to these sectors are shown in the table below.

Table 2. Companies selected for sectors

Sector	Companies	Country
Airline Industry	Air Canada	Canada
	Air France KLM SA	France
	Delta Air Lines Inc	USA
	Deutsche Lufthansa AG	Germany
	El Al Israel Airlines Ltd	Israel
	Finnair Oyj	Finland
	Japan Airlines Co Ltd	Japan
	Korean Air Lines Co Ltd	South Korea
	LATAM Airlines Group SA	Chile
	Ryanair Holdings PLC	Ireland
	Turkish Airlines AO	Turkey
Healthcare Industry	Bausch Health Companies Inc	Canada
	ICON PLC	Ireland
	AstraZeneca PLC	England
	Bayer AG	Germany
	Celltrion Inc	South Korea
	Celon Pharma SA	Poland
	EİS Eczacıbaşı İlaç, Sınai ve Finansal Yatırımlar	Turkey
	Sanayi ve Ticaret AŞ	
	Genomma Lab Internacional SAB de CV	Mexico
	Getinge AB	Sweden
	Johnson and Johnson	USA
	Krka dd Novo Mesto	Slovenia
	Orion Oyj	Finland
	Photocure ASA	Norway
	Richter Gedeon Vegyeszeti Gyar Nyrt	Hungary
	Takeda Pharmaceutical Co Ltd	Japan
	Teva Pharmaceutical Industries Ltd	Israel

Although the study aimed to select companies from all OECD countries, the absence of publicly listed companies in some of these countries constitutes a limitation of the research. Therefore, all accessible publicly listed companies were considered, resulting in the inclusion of 11 companies from the airline sector and 16 companies from the healthcare sector in the analysis. Deutsche Lufthansa AG, the German airline company, is the owner or partner of many airline companies in many countries. For example, Swiss Airlines (Switzerland), Austrian Airlines (Austria), Brussels Airlines (Belgium), and Air Dolomiti (Italy) are all part of

the Lufthansa Group. Therefore, it can be said that Deutsche Lufthansa AG also represents the airlines of these countries.

Table 3 below includes the main variables frequently used in financial analysis and performance evaluation studies and their explanations. In the literature review, it is seen that the relevant variables are frequently used in different studies (Büyükanıkan, 2020; Keleş and Özulucan, 2020; Hashem et al., 2020; Aigbedo, 2021; Topaloğlu and Nur, 2016). Price close, refers to the natural logarithm of the closing stock prices of companies. EBITDA margin is a ratio that measures a company's operational profitability and is an important indicator in assessing financial sustainability. The quick ratio shows the company's capacity to pay its short-term liabilities, while free cash flow is the amount of free cash generated from operations and is used to assess growth opportunities. Total revenue represents the company's total sales revenue and provides information on the volume of operations, while asset turnover measures the efficiency and utilization of assets. ROA and ROE represent return on assets and return on equity, respectively, and reveal how effectively the company utilizes its assets and equity. These variables are important in evaluating financial performance on a company-specific basis as well as on a sector or market basis. Therefore, the study includes the relevant variables.

Table 3. Variables and explanations

Variable	Variable Summary Description
Price Close	Natural logarithm of the stock closing price
EBITDA Margin	EBITDA/Sales
Quick Ratio	(Current Assets - Inventories) / Short Term Liabilities
Free Cash Flow	Cash Flows from Operating Activities + Capital Expenditures (Billion \$)
Total Revenue	Total Sales Revenue (Billion \$)
Asset Turnover	Net Sales / Assets
ROA	Return on Assets
ROE	Return on Equity

Panel data consists of N number of units and T number of observations corresponding to each unit (Yerdelen Tatoğlu, 2018b). Since the data set of aviation and healthcare industry companies selected from OECD countries is also panel data, panel data analysis was used in the study. The panel data model constructed for both models is as follows.

$$\begin{aligned}
 Price\ Close_{it} = & \alpha_{it} + \beta_1 EBITDA\ Margin_{it} \\
 & + \beta_2 Quick\ Ratio_{it} \\
 & + \beta_3 Free\ Cash\ Flow_{it} \\
 & + \beta_4 Total\ Revenue_{it} \\
 & + \beta_5 Asset\ Turnover_{it} + \beta_6 ROA_{it} \\
 & + \beta_7 ROE_{it} + u_{it}
 \end{aligned} \quad (1)$$

Where “ α ” is the constant term, “ β ” is the coefficient of the explanatory variable, “ u ” is the random error term, “ i ” stands for unit, and “ t ” stands for time. Price close is the dependent variable, and the other variables are the independent variables.

Table 4 below summarizes the basic descriptive statistics of the dependent and independent variables used in the models. In this context, the number of observations, mean value, standard deviation, minimum, and maximum values of the variables are presented. This information gives a general idea about the distribution of the analyzed variables. For Model 1, there are 220 observations in total. Model 2 includes a total of 320 observations. The price close's mean is 63.494,

and the standard deviation is 72.882. This shows that the close price data in Model 2 has a wider distribution compared to Model 1.

The correlation matrix contains the correlation coefficients that explain the relationship between the variables selected in the two models. Model 1 shows weak and generally negative correlations between the price close variable and other variables. Model 2 shows that profitability ratios have a stronger relationship with the closing share price (Table 5).

The results in Table 6 show the results of the Pesaran (2004) CD test and the probability values (p-values) of the panel unit root test results used to determine which test group should be preferred in unit root tests. When the p-values of the Pesaran CD test are below 0.05, second-generation panel unit root tests should be preferred, and when they are above 0.05, first-generation panel unitroot tests should be preferred (Yerdelen Tatoğlu, 2018a). In the airline industry, p-values for all variables are less than 0.05. These results indicate that it would be appropriate to apply second-generation panel unit root tests. A different situation emerges in the healthcare industry. Since the p-values for EBITDA margin ($p=0.289$) and free cash flow ($p=0.491$) variables are above 0.05, it would be appropriate to use first-generation panel unit root tests for these variables. However, since the p-values for the other variables are below 0.05, second-generation tests should be preferred for these variables.

In addition to the Pesaran CD Test results, Levin, Lin and Chu (LLC) panel unit root test results are also presented on the basis of sectors and variables. The LLC test is one of the unit root tests that assess whether the series in the panel data set are stationary. The null hypothesis H_0 is “the units contain unit root,” and the alternative hypothesis is “the units are stationary” (Yerdelen Tatoğlu, 2018a). The p-values of the test below 0.05 indicate that the series are stationary and do not contain a unit root. In this context, the airline industry evaluation found all variable p-values to be below 0.05. This result indicates that all variables in the airline sector are stationary. In the healthcare industry, the p-values of all variables are also below 0.05. This indicates that all variables in the healthcare industry are stationary. In conclusion, the results of the Levin, Lin, and Chu unit root test reveal that there is stationarity in the variables of the two sectors.

The Table 7 shows the tests performed to select the regression estimation method. The F test is a test used to choose between fixed effects and classical. In this case, the F test is used to assess whether the model is more appropriate with fixed effects or a classical model (Yerdelen Tatoğlu, 2018b). According to the results in the table, when the airline and healthcare industries data are analyzed for the F test (SE), the results obtained for the Unit Effect (Prob>F) are 0.0000. This indicates that the fixed effects are significant in both sectors, and therefore fixed effects are more appropriate than the classical model. Therefore, the results of the F test support that fixed effects are a better choice than the classical model for both sectors and that the regression model will make more accurate predictions with fixed effects.

The LR Test (RE) aims to choose between random effects and classical regression models (Yerdelen Tatoğlu, 2018b). The LR test results for the airline and healthcare industries show that the probability value for the unit effect (Prob>F) is less than 0.05, which indicates that the unit effects for the two sectors are significant and the model is appropriate with random effects.

Table 4. Descriptive statistics of variables

Sector	Variable	Observation	Mean	Std. Deviation.	Min	Max
Airline Industry Model 1	Price Close	220	14.077	11.945	0.007	58.024
	EBITDA Margin	220	0.008	0.378	-2.031	0.609
	Quick Ratio	220	0.794	0.345	0.081	1.879
	Free Cash Flow	220	-0.077	0.922	-5.407	3.414
	Total Revenue	220	3.695	3.599	0.039	16.658
	Asset Turnover	220	0.134	0.064	0.009	0.298
	ROA	220	-0.005	0.035	-0.199	0.189
	ROE	220	-0.155	5.828	-54.778	60.059
Healthcare Industry Model 2	Price Close	320	63.494	72.882	0.527	335.95
	EBITDA Margin	320	0.258	0.126	-0.184	0.582
	Quick Ratio	320	1.648	1.135	0.552	9.435
	Free Cash Flow	320	0.19	1.267	-13.214	4.755
	Total Revenue	320	3.835	5.926	0.005	24.02
	Asset Turnover	320	0.125	0.059	0.029	0.488
	ROA	320	0.013	0.026	-0.085	0.18
	ROE	320	0.023	0.226	-1.427	3.081

Table 5. Correlation matrix

Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model 1 Airline Industry	(1) Price Close	1.000							
	(2) EBITDA Margin	-0.074	1.000						
	(3) Quick Ratio	0.460	-0.110	1.000					
	(4) Free Cash Flow	-0.062	0.526	0.021	1.000				
	(5) Total Revenue	0.306	0.287	-0.188	0.164	1.000			
	(6) Asset Turnover	-0.078	0.648	-0.068	0.395	0.542	1.000		
	(7) ROA	0.063	0.535	0.107	0.740	0.324	0.617	1.000	
	(8) ROE	-0.172	0.012	-0.106	0.221	0.015	0.098	0.362	1.000
Model 2 Healthcare Industry	(1) Price Close	1.000							
	(2) EBITDA Margin	0.443	1.000						
	(3) Quick Ratio	-0.194	-0.400	1.000					
	(4) Free Cash Flow	0.135	0.129	-0.064	1.000				
	(5) Total Revenue	0.416	0.351	-0.423	0.343	1.000			
	(6) Asset Turnover	0.109	0.019	0.226	0.019	-0.205	1.000		
	(7) ROA	0.131	0.317	0.133	0.309	-0.078	0.536	1.000	
	(8) ROE	0.040	0.064	0.007	0.119	0.005	0.092	0.169	1.000

Table 6. Peseran CD test and unit root test results

Variable	Model 1 Airline Industry		Model 2 Healthcare Industry	
	CD Test	LLC	CD Test	LLC
Price Close	8.73 (0.000)	-2.696 (0.0035)	5.83 (0.000)	-1.699 (0.0446)
EBITDA Margin	14.68 (0.000)	-6.479 (0.0000)	-1.06 (0.289)	-9.8268 (0.0000)
Quick Ratio	3.38 (0.001)	-0.782 (0.0000)	6.39 (0.000)	-4.057 (0.0000)
Free Cash Flow	13.84 (0.000)	-5.988 (0.0000)	0.69 (0.491)	-11.4461 (0.0000)
Total Revenue	29.8 (0.000)	-1.677 (0.0468)	10.32 (0.000)	-7.627 (0.0000)
Asset Turnover	29.74 (0.000)	-4.167 (0.0000)	0.51 (0.613)	-4.5539 (0.0000)
ROA	20.52 (0.000)	-7.687 (0.0000)	1.36 (0.172)	-10.6281 (0.0000)
ROE	4.76 (0.000)	-11.420 (0.0000)	2.61 (0.009)	-11.8370 (0.0000)

Table 7. Tests for the selection of regression estimation method

Tests	Results	Model 1 Airline Industry	Model 2 Healthcare Industry
F Test (SE)	Unit Effect (Prob>F)	152.55 (0.000)	447.52 (0.000)
	Time Effect (Prob>Chibar2)	0.64 (0.872)	0.15 (1.000)
LR Test (RE)	Unit Effect (Prob>F)	400.66 (0.000)	893.90 (0.000)
	Time Effect (Prob>Chibar2)	0.00 (1.000)	0.00 (1.000)
Hausman Test	(Prob>Chi2)	5.41 (0.611)	0.37 (0.999)
Heteroscedasticity (Leneve, Brown and Forsythe's Tests)	W0	5.196 (0.000)	6.229 (0.000)
	W50	3.827 (0.000)	5.069 (0.000)
	W10	4.801 (0.000)	5.883 (0.000)
Autocorrelation (Durbin-Watson Test)	Durbin-Watson	0.497	0.486
	Baltagi-Wu LBI	0.795	0.609
Correlation Between Units (Breusch-Pagan Lagrange Multiplier Test)	(Pr)	212.019 (0.000)	375.294 (0.000)

Based on the results of the F-test and the Likelihood Ratio (LR) test, it was determined that the classical model should not be continued. Therefore, the Hausman (1978) test was employed. Hausman test is a test used to evaluate the difference between fixed effects and random effects models (Yerdelen Tatoğlu, 2018b). When the p-value of the Hausman test exceeds 0.05, it indicates a preference for the random effects model. According to the Hausman test results, the p-value for the airline sector is 0.6105 and 0.9998 for the healthcare industry. Since all of the p-values in the results are greater than 0.05, the random effects model should be used in both models.

Autocorrelation is considered in regression analysis to determine whether the error terms are correlated with each other. For this purpose, people frequently use the Durbin-Watson test. If the results of the test are less than 2, this indicates the presence of autocorrelation (Yerdelen Tatoğlu, 2018b). The results indicate that autocorrelation exists in all sectors. Another important issue is to test whether there is heteroscedasticity. When the assumption of a normal distribution fails, Levene (1960) proposed a robust heteroskedasticity test. Brown and Forsythe (1974) proposed

alternative local estimators based on the trimmed mean instead of the mean in Levene's test statistic, which also provides a robust structure against outlier observations (Tatoğlu, 2018b). In this context, Leneve, Brown, and Forsythe's tests are used for variance. Finally, the test results for the presence of inter-unit correlation (Breusch-Pagan Lagrange Multiplier Test) indicate a Pr value of 0.0000 across all sectors. This suggests a strong correlation between the units. These findings highlight the need for improving the regression model and taking additional steps to address autocorrelation.

In the context of regression analysis, it is essential to address key econometric issues such as heteroscedasticity, autocorrelation, and cross-sectional dependence. Diagnostic tests were conducted to detect the presence of these problems. Since the test results indicated the existence of all three issues, the most appropriate estimation method was selected accordingly. Therefore, the final results were obtained using the Driscoll-Kraay (1998) robust standard error estimator, which is well-suited to account for heteroscedasticity, autocorrelation, and interdependence across cross-sectional units.

Table 8. Results of estimation

Models	Dependent Variable	Price Close	Coefficient	Standard Error	t	P>t
Model 1 Airline Industry	Independent Variables	EBITDA Margin	0.102	0.109	0.940	0.360
		Quick Ratio	0.456	0.171	2.670	0.015
		Free Cash Flow	-0.037	0.084	-0.440	0.666
		Total Revenue	0.128	0.031	4.180	0.001
		Asset Turnover	-5.725	1.236	-4.630	0.000
		ROA	1.567	2.577	0.610	0.550
		ROE	-0.018	0.011	-1.640	0.118
		cons	1.752	0.806	2.170	0.043
	Summary Statistics	Prob > F = 0.000				
		R ² = 0.386				
		Observation = 220				
Model 2 Healthcare Industry	Independent Variables	EBITDA Margin	0.896	0.307	2.920	0.009
		Quick Ratio	-0.037	0.035	-1.050	0.309
		Free Cash Flow	-0.021	0.014	-1.490	0.153
		Total Revenue	0.033	0.016	2.110	0.049
		Asset Turnover	-2.639	0.374	-7.060	0.000
		ROA	0.548	1.286	0.430	0.675
		ROE	0.038	0.171	0.220	0.829
		cons	3.234	1.030	3.140	0.005
	Summary Statistics	Prob > F = 0.000				
		R ² = 0.131				
		Observation = 320				

Table 8 presents the estimation results, showing the effects of two different regression models on stock prices. The natural logarithm of the stock closing price is used as the dependent variable, while the selected independent variables are incorporated into the analysis. For each model, statistical indicators such as coefficients, standard errors, t-values, and p-values are reported.

In Model 1, the coefficient for the EBITDA margin variable is 0.102 with a p-value of 0.360, which is not statistically significant. However, the coefficient for asset turnover is -5.725, and the p-value is 0.000, indicating that the variable has a strong impact on stock prices and that the effect is statistically significant. In addition, the liquidity ratio and total revenue variables also show a statistically significant relationship (p-values 0.015 and 0.001), while the

free cash flow, ROA, and ROE variables are not significant. The R² value of the model is 0.3857, which shows the explanatory power of the model.

In Model 2, variables such as EBITDA margin, total revenue, and asset turnover again show a significant effect. In particular, the coefficient for asset turnover is -2.639, and the p-value is 0.000, indicating that this variable has a strong effect. However, the coefficients for liquidity ratio, free cash flow, ROA, and ROE are not significant (p-value > 0.05). The R² value of the model is 0.1307, which indicates that the model explains only 13.07% of the dependent variable. This is lower than Model 1, but still considered acceptable for the variables considered, given the many exogenous factors affecting stock prices.

Overall, the variables influencing stock prices differ between the two models. Notably, asset turnover exhibits a significant effect on stock prices. Given the relatively low R^2 value in Model 2, the exclusion of several potential determinants of stock prices, and the inherent limitations of the model, the results are deemed acceptable within the context of the study.

4. Conclusion

This study aims to analyze the financial impact of the COVID-19 pandemic on the airline and healthcare industry in OECD countries. Using panel data analysis, the research comprehensively examines the financial indicators that influence stock prices in both sectors. According to the findings, asset turnover emerges as one of the most significant variables affecting stock prices in the airline sector. In addition, liquidity ratio and total revenue also exhibit statistically significant effects on the sector. In the healthcare sector, EBITDA margin, total revenue, and asset turnover are found to have a statistically significant impact on stock prices. Conversely, variables such as ROA, ROE, and free cash flow do not show significant effects in either sector.

In both sectors, asset turnover has a significant and negative impact on stock prices. However, in the healthcare industry, EBITDA margin and total revenue have a positive impact on stock prices. In the healthcare industry, an increase in EBITDA margin and total revenue indicates a company's operational profitability and growth potential. High EBITDA margin indicates that the company controls its costs effectively. In addition, revenue growth will strengthen the company's cash flow and increase sustainable profitability prospects. In the airline sector, liquidity ratio and total revenue have positive effects. Therefore, a high liquidity ratio and an increase in total revenue can be considered as important indicators that may positively affect stock prices in airline companies. While a high liquidity ratio may indicate the capacity of companies to meet their short-term debts and their financial flexibility, the increase in total revenue can be interpreted as an indicator of operational success and growth potential. Liquidity strength enhances a company's resilience during times of crisis and lowers financing costs. Similar to healthcare companies, revenue growth is likely to support the company's cash flow and strengthen sustainable profitability expectations. Investor perception may positively influence these factors, potentially leading to an increase in share prices.

Portfolio management is the allocation of funds held by investors among available securities in a way that ensures minimum risk and maximum profitability. According to the traditional portfolio approach, it is assumed that investors can reduce the risk factor only by increasing the number of securities in the portfolio without considering the relationship between their returns. However, in modern portfolio theory, it has been argued that risk cannot be reduced only by diversifying the portfolio and that the direction and degree of the relationship between the securities in the portfolio are also important in terms of risk reduction. Markowitz (1952) posited that diversification mitigates risk and the expected return is contingent on risk. This approach is also valid for sectoral diversification. For example, diversification between the healthcare and airline industries may allow for effective risk mitigation. High EBITDA margins and increased revenues in the healthcare industry increase operational profitability and resilience to economic fluctuations, while high liquidity in the

airline sector strengthens companies' financial flexibility and growth potential. A portfolio that combines these two sectors would allow investors to minimize their risks in both sectors and increase their potential returns. Thus, sectoral diversification can reduce risk and provide a more robust portfolio structure.

In the literature, liquidity ratio, income level, and asset utilization efficiency are emphasized as important factors affecting financial performance in the airline sector. In Keleş and Özulucan (2020) studies, the positive effect of the ratio method on investor confidence and the operational efficiency level of the companies is stated to be a factor affecting stock performance. This is consistent with the positive effects of liquidity ratios and total revenue variables. In addition, Kurt and Kablan (2022) emphasized that financial statement data for the COVID-19 period showed a negative change compared to the previous period. In this study, the negative effect of the asset turnover variable supports this finding. The positive effects of EBITDA margin and total revenue variables in the healthcare industry are consistent with the findings of Şenol (2023). Şenol (2023) revealed that post-pandemic healthcare companies have a more positive impact on financial performance than other companies. In terms of the findings obtained for EBITDA margin, it is seen that the performance of companies in the healthcare industry is better.

Among the limitations of this study are the exclusion of all sector representatives within OECD countries from the dataset and the restriction of the independent variables analyzed solely to financial performance indicators. Future research may contribute to the literature by expanding these analyses through the use of broader datasets (e.g., weekly or monthly data) and models that incorporate non-financial factors influencing stock prices.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Ağazade, S., and Karakaya, A. (2019). Finansal gelişme ve ekonomik büyüme: OECD ülkeleri örneğinde panel nedensellik analizi. *Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty*, 6(2), 471-484.
- Ağırkaya, M. B., and Keleş, D. (2022). Havayolu yolcu taşımacılığı sektörünün finansal performans göstergelerinin makroekonomik analizi: oran analizi yöntemi ile COVID-19 süreci ve öncesine ilişkin bir karşılaştırma. *Mali Çözüm*, 32(171), 151-170. <https://archive.ismmmo.org.tr/docs/malicozum/171mali-cozum/8.pdf>
- Agrawal, O. P., Bansal, P., and Kathpal, S. (2020). Effect of financial performance on corporate social responsibility and stock price: a study of BSE listed companies. *International Journal on Emerging Technologies*, 11(1), 286-291.
- Aigbedo, H. (2021). An empirical analysis of the effect of financial performance on environmental performance of companies in global supply chains. *Journal of Cleaner Production*, 278 (121741), 1-17.
- Asker, V. (2023). Kovid-19 salgınında düşük maliyetli havayolu işletmelerinin finansal performansı.

- Karamanoğlu Mehmetbey Üniversitesi Sosyal ve Ekonomik Araştırmalar Dergisi, 25(44), 87-102. <https://dergipark.org.tr/tr/download/article-file/2639700>
- Bayraktaroğlu, A. (2010). Mülkiyet yapısı ve finansal performans: İMKB örneği. *Ekonomi Bilimleri Dergisi*, 2(2), 11-20. <https://dergipark.org.tr/tr/download/article-file/56648>
- Brown, M. B., and Forsythe, A. B. (1974). The small sample behavior of some statistics which test the equality of several means. *Technometrics*, 16, 129-132.
- Büyükarıkan, U. (2020). Finansal performansa etki eden finansal değişkenlerin chaid karar ağacıyla belirlenmesi: tekstil sektörü örneği. *Aydın İktisat Fakültesi Dergisi*, 5(1), 1-10. <https://dergipark.org.tr/tr/download/article-file/1182053>
- Cavlak, H. (2020). COVID-19 Pandemisinin finansal raporlama üzerindeki olası etkileri: BIST 100 endeksi'ndeki işletmelerin ara dönem finansal raporlarının incelenmesi. *Gaziantep Üniversitesi Sosyal Bilimler Dergisi*, 19(COVID-19 Special Issue), 143-168.
- Çelik, V. (2014). Örgütsel öğrenme kapasitesi ve yeniliğin, finansal performansa etkisi. *Balıkesir Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 17(31), 193-212.
- Dağlı, D. (2021). Havayolu işletmelerinin COVID-19 öncesi ve COVID-19 sürecindeki finansal performanslarının topsis yöntemi ile değerlendirilmesi. *İşletme Araştırmaları Dergisi*, 13 (3), 2242-2255.
- Doruk T. Ö. (2022). COVID-19'un finansal performansa etkisi: gıda sektörü firmaları için karşılaştırmalı bir değerlendirme. *Muhasebe ve Denetime Bakış Dergisi*, 66, 67-82
- Driscoll, J. C., and Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics*, 80(4), 549-560. <https://www.jstor.org/stable/2646837>
- Enekwe, C. I., Agu, C. I., and Nnagbogu, E. K. (2014). The effect of financial leverage on financial performance: evidence of quoted pharmaceutical companies in Nigeria. *IOSR Journal of Economics and Finance (IOSR-JEF)*, 5(3), 17-25. <https://www.iosrjournals.org/iosr-jef/papers/vol5-issue3/C0521725.pdf>
- Gençtürk, M., Senal, S., and Aksoy, E. (2022). COVID-19 pandemi sürecinde Katılım 30 endeksi ile hükümet kısıtlama politikaları arasındaki ilişki analizi. *Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty*, 9(2), 1127-1151.
- Gürsoy, S., Tunçel, M. B., and Sayar, B. (2020). Koronavirüsün (COVID-19) finansal göstergeler üzerine etkileri. *Ekonomi Maliye İşletme Dergisi*, 3(1), 20-32.
- Hashem, A., Ayoub, F., Zurqan, S., Awamleh, I., and Aljamaeen, M. (2020). Journal of critical reviews journal of critical reviews corporate financial performance effect on stock prices: empirical evidence from a small market: a study in Amman stock exchange over the period 2006 -2017. *Journal of Critical Reviews*, 7(12), 4233-4240.
- Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of The Econometric Society*, 46(6), 1251-1271.
- Hopancı, B., Akdeniz, H., and Şahin, Ö. (2021). COVID19 pandemisinin havacılık sektörü üzerine etkileri. *Mühendis ve Makina*, 62(704), 446-467.
- Irfani, A. (2014). A study of financial performance and stock return in ipo underpricing phenomenon on the Indonesia stock exchange (IDX). *Indonesian Capital Market Review*, 4(2), 101-116. 10.21002/icmr.v4i2.3618.
- Kalkın, G. (2021). COVID-19 ve havacılık sektörünün geleceği: havacılık yönetimi kapsamında bir değerlendirme. *Journal of Aviation*, 5(1), 53-63.
- Kamatra, N., and Kartikaningdyah, E. (2015). Effect corporate social responsibility on financial performance. *International Journal of Economics and Financial Issues*, 5(1), 157-164. <https://dergipark.org.tr/en/download/article-file/363162>
- Karkacier, O., and Yazgan, A. E. (2017). Turizm sektöründe gri ilişkisel analiz GIA yöntemiyle finansal performans değerlemesi. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 37, 154-162. <https://dergipark.org.tr/tr/download/article-file/1724922>
- Katı, M. (2025). Financial Performance Analysis of BIST Airline Companies through Ratio Analysis: Evidence from the Covid-19 Pandemic Process. *Journal of Aviation*, 9(1), 100-108.
- Keleş, D., and Özuluçan, A. (2020). Havacılık işletmelerinde rasyo yöntemi ile finansal performans ölçümü: borsa istanbul (BIST)'da işlem gören iki havayolu işletmesi üzerine bir araştırma. *İşletme Bilimi Dergisi*, 8(3), 503-534.
- Kesbiç, C. Y., and Mıynat Taşdemir, B. (2019). Halka açıklık oranının finansal performans üzerindeki etkisi. *Journal of Management and Economics*, 26(2), 689-703.
- Kurt, G., Kablan, A. (2022). Covid-19'un, BIST ulaştırma endeksinde faaliyet gösteren havayolu işletmelerinin finansal performansı üzerindeki etkilerinin, çok kriterli karar verme yöntemleri ile analizi, *İşletme Akademisi Dergisi*, 3(1), 16-33.
- Levene, H. (1960). Contributions to probability and statistic: Essay in honor of harold hoteling. In: Olkin, I., Ed., *Contributions to Probability and Statistics*. Stanford University Press, 278-292.
- Levin, A., Lin, C., F., and Chu C., S., J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, 108, 1-24.
- Lin, M. S., Zhang, H., Luo, Y., & Li, Y. (2024). Environmental, social, and governance (ESG) measurement in the tourism and hospitality industry: views from a developing country. *Journal of Travel & Tourism Marketing*, 41(1), 154-168.
- Mahase, E. (2020). China coronavirus: who declares international emergency as death toll exceeds 200. *BMJ: British Medical Journal (Online)*, 368, 408-408.
- Maiga, A.S., Nilsson, A. and Jacobs, F. A., (2014). Assessing the interaction effect of cost control systems and information technology integration on manufacturing plant financial performance. *The British Accounting Review*, 46(1), 77-90.
- Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, 7(1), 77-91.
- Nasution, H. F., Sadalia I., and Fachrudin K. A. (2019). Analysis of financial performance effect on dividend payout ratio members of holding mining industry with capital expenditure as moderating variable. *International Journal of Research and Review*, 6(11), 450-460. https://www.ijrrjournal.com/IJRR_Vol.6_Issue.11_Nov_2019/IJRR0057.pdf
- Okan, T., Sarı, S., and İlhan Nas, T. (2014). Yönetim kurulu yapısı ile finansal performans arasındaki ilişkide uluslararası çeşitlenmenin aracılık etkisi. *İstanbul*

- Üniversitesi İşletme Fakültesi İşletme İktisadi Enstitüsü Yönetim Dergisi, 25(77), 39-78. <https://dergipark.org.tr/en/download/article-file/98093>
- Öndeş T., and Özkan T. (2021). Bütünleşik CRITIC-EDAS yaklaşımıyla COVID-19 pandemisinin bilişim sektörü üzerindeki finansal performans etkisi. Gümüşhane Üniversitesi Sosyal Bilimler Enstitüsü Elektronik Dergisi, 12(2), 506-522. <https://dergipark.org.tr/tr/download/article-file/1572486>
- Oware, K.M., and Mallikarjunappa, T. (2020). Does employee volunteerism contribute to financial performance? effect of third-party assurance and financial performance of listed firms in emerging economies. Social Responsibility Journal, 17, 469-488.
- Özbek, A., and Ghouchi, M. (2021). Finansal oranları kullanarak havayolu şirketlerinin performans değerlendirmesi. International Journal of Engineering Research and Development, 13(2), 583-599.
- Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. Institute of Labor Economics, 1240, 1-39.
- Sakarya, Ş., Yıldırım A., and Aytekin, S. 2014). Kurumsal Sosyal sorumluluk açıklamalarının finansal performans üzerine etkisi: BIST-30'da bir uygulama. AKÜ İİBF Dergisi, 1(1), pp. 1-15. <https://dergipark.org.tr/tr/download/article-file/18825>
- Salur, M. N., Demirci, M. N., and Kesen, B. (2018). KOBİ'lerde halka açılmanın finansal performansa etkisi: BIST gelişen işletmeler piyasasında bir uygulama. İşletme Araştırmaları Dergisi, 10(1), 82-102. <https://isarder.org/index.php/isarder/article/view/511>
- Şenol, A. (2023). COVID-19 salgını sürecinde Borsa İstanbul'da işlem gören sağlık işletmelerinin finansal göstergeler ile TOPSIS yöntemiyle değerlendirilmesi. Elektronik Sosyal Bilimler Dergisi, 22(88), 1445-1459.
- Şenol, A., Sancak, S., and Akkuş, H. (2023). COVID-19 pandemi sürecinin sağlık işletmelerine sektörel etkilerinin finansal analizi: Türkiye ilaç sektörü örneği. Pamukkale Üniversitesi İşletme Araştırmaları Dergisi, 10(3), 717-734. <https://doi.org/10.47097/piar.1323263>
- Shuid, S. H., and Noor, R. M. (2012). Effectiveness of financial incentives on SMEs' financial performance in Malaysia, 2012 IEEE Colloquium on Humanities. Science and Engineering Research (CHUSER 2012), December 3-4, Kota Kinabalu, Sabah, Malaysia, (657-661). <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6504394>
- Sim, M., & Kim, H. (2024). Measurement validation of a consumer-driven environmental, social, and governance (ESG) index for the airline industry. Journal of Sustainable Tourism, 33(3), 474-499.
- Soytaş, M. A., Denizel, M., Durak Uşar, D., and Ersoy, İ. (2017). Sürdürülebilirlik yatırımlarının finansal performansa etkisi: Türkiye örneği. Yönetim ve Ekonomi Araştırmaları Dergisi, 15(2), 140-162.
- Suryaningsih, S., and Suseno, D. (2022). Financial performance effect on economic growth in special autonomy province. Economics Development Analysis Journal, 11(4), 485-497.
- Temir, C. (2020). COVID-19'un sermaye piyasaları üzerine etkisi. İstanbul Ticaret Üniversitesi Girişimcilik Dergisi, 4(7), 50-66. <https://dergipark.org.tr/en/download/article-file/1232385>
- Topaloğlu, E. E., and Ege, İ. (2018). Borsa İstanbul'da işlem gören bankaların yönetim kurulu yapısının finansal performansa etkisi: panel veri analizi. Sosyal ve Beşeri Bilimler Araştırmaları Dergisi, 19(41), 9-34. <https://dergipark.org.tr/tr/download/article-file/491627>
- Topaloğlu, E. E., and Nur, T. (2016). Nakit dönüşüm süresinin finansal performansa etkisi: kurumsal yönetim endeksinde bir uygulama. Akademik Bakış Uluslararası Hakemli Sosyal Bilimler Dergisi, 53, 304-317. <https://dergipark.org.tr/tr/download/article-file/383162>
- Tükenmez, N. M., Gençyürek, A. G., and Karakelleoğlu, M. İ. (2017). Kurumsal yönetim derecelendirme notlarının şirketlerin finansal performansı üzerindeki etkisi. Ege Stratejik Araştırmalar Dergisi, 8(1), 1-18. <https://dergipark.org.tr/tr/download/article-file/270026>
- WHO. (2023). Statement on the fifteenth meeting of the IHR(2005) Emergency Committee on the COVID-19 pandemic. World Health Organization. [https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-coronavirus-disease-\(covid-19\)-pandemic](https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic)
- Yerdelen Tatoğlu, F. Y. (2018a). Panel zaman serileri analizi: stata uygulamalı. Beta Basım Yayım Dağıtım, 2. Baskı. İstanbul.
- Yerdelen Tatoğlu, F. Y. (2018b). Panel veri ekonometrisi: stata uygulamalı. Beta Basım Yayım Dağıtım, 4. Baskı. İstanbul.
- Yetiz, F. (2021). COVID-19 pandemi sürecinin türk bankacılık sektörü çalışanlarına ve müşterilerine etkileri: SWOT analizi. Avrupa Bilim ve Teknoloji Dergisi, 22, 109-117.
- Yildiz, F., Dayi, F., Yucel, M., & Cilesiz, A. (2024). The Impact of ESG Criteria on Firm Value: A Strategic Analysis of the Airline Industry. Sustainability, 16(19), 8300.
- Yılmaz, A. İ., and Karademir, M. (2021). Kaynak bağımlılığını yönetme stratejilerinin finansal performansa etkisi. İşletme Ekonomi ve Yönetim Araştırmaları Dergisi, 4(1), 122-133.
- Yücel, S., and Durak, İ. (2021). COVID-19'un BIST imalat sektörü firmalarına olan finansal etkilerinin finansal oranlar ve istatistiksel tekniklerle incelenmesi. The Journal of Accounting and Finance, 90, 101-126.
- Zeren, F., and Hızarcı, A. E. (2020). The impact of COVID-19 coronavirus on stock markets: evidence from selected countries. Muhasebe ve Finans İncelemeleri Dergisi, 3(1), 78- 84.

Cite this article: Mirgen, C., Kahraman, Y.E. (2025). Financial Repercussions of the Pandemic Shock in OECD Countries: An Analysis of the Airline and Healthcare Industries. Journal of Aviation, 9(3), 735-744.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Investigating the Relationships Between Oil Prices and Airline Stock Values

Eşref Kuloğlu¹ 

¹Bayburt University, Business Administration Department, 69000, Bayburt, Türkiye. (esrefkuloğlu@bayburt.edu.tr)

Article Info

Received: 18 July 2025
Revised: 25 August 2025
Accepted: 12 September 2025
Published Online: 16 October 2025

Keywords:

Aviation
Brent Crude Oil
Causality
Toda Yamamoto
Borsa İstanbul

Corresponding Author: *Eşref Kuloğlu*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1746107>

Abstract

The primary objective of this research is to reveal the causal relationship between the stock values of Turkish Airlines and Pegasus Airlines, both listed on the Borsa İstanbul, and the price of Brent crude oil. Turkish Airlines, a pioneer in this regard, was launched on the stock exchange on December 20, 1990. Pegasus Airlines, Turkey's second-largest aviation company, began trading on the stock exchange on April 26, 2013. In this research, the monthly stock prices of the two airlines between May 1, 2013, and January 31, 2025, as well as Brent crude oil prices during the same period, were used as data. Toda Yamamoto's causality analysis was used. To establish the econometric model used in the study, the stationarity of the time series must first be examined. The unit root tests show that the stock and Brent crude oil values are stationary at level one. Accordingly, the analysis was conducted by adding one to the obtained lag length to calculate the length for the Toda-Yamamoto analysis. The analysis found a unidirectional causality between Brent crude oil prices and the two companies' stocks. The study demonstrates the relationship between two aviation sector companies traded on Borsa İstanbul and the oil variable, a significant expense item, and a key macroeconomic variable. In this regard, due to the limited number of studies conducted on this topic in the literature, this study is expected to fill a significant gap.

This study is an improved and updated version of the abstract presented at the 6th International Aviation Management Conference organized by the University of Turkish Aeronautical Association on 19-20 December 2023.

1. Introduction

The aviation sector accounts for a significant share of national economies in many developed countries. Developments in the aviation sector, which is crucial for the logistics and transportation sectors, are constantly monitored. Developments in the aviation sector are also vital to reducing transportation costs and increasing speed. In this sense, it is essential for companies to control their costs and for national economies, as well as for macroeconomic variables such as inflation. Furthermore, the aviation sector's share of passenger transportation, particularly in private aviation, is increasing daily. With the enactment of the Civil Aviation Law in 1983, significant developments have occurred in the private sector, leading to the entry of many large and small aviation companies into the sector. In addition to Turkish Airlines, the largest in the industry, many other passenger transportation companies operate. The two major airlines listed on the Borsa İstanbul are Turkish Airlines and Pegasus Airlines.

These two companies, which are essential for Turkey and the global aviation sector, are important to Borsa İstanbul. With their significant increases in value, particularly over the last decade, these companies represent a substantial portion of the Borsa İstanbul's total value. On the other hand, Turkish Airlines was named Turkey's most valuable company with a brand value of \$2,266 billion, according to a 2025 study by the

international brand valuation organization Brand Finance (<https://brandirectory.com/reports/turkiye/2025>).

Historically, oil price volatility has significantly impacted economic activity. Numerous studies have investigated the relationship between oil price volatility and other economic variables. The relevant literature demonstrates that oil prices affect stock prices in at least two ways. First, oil is a key input in producing many goods and services, so it affects future cash flows. High oil prices cause high costs, thereby reducing future cash flows and, consequently, stock prices. Second, oil price affects the discount rate used in stock valuation. Central banks raise interest rates to control the inflationary impact of high oil prices, which, in turn, negatively impact stock values due to high discount rates (Shaeri et al., 2016:712).

This study investigates the relationship between oil prices, one of the most critical inputs for airlines since the early 1980s, and the stock returns of these companies. Investigating this relationship, it is evident that empirical studies in the literature on this topic have been conducted using various econometric models. While studies are often sector-based, relatively few studies use firm data. Furthermore, numerous studies explore the relationship between oil prices and sub-sectors. This study examines the causal relationship between oil prices, a key expense item for aviation companies, and the stock prices of two publicly traded aviation companies in Turkey. In this context, the causal relationship with oil prices is investigated

using the monthly stock prices of Turkish Airlines and Pegasus Airlines, Turkey's largest publicly traded airlines, between 2013 and 2025. The relationship between oil prices and stock returns in the relatively less studied aviation sector will be examined in this respect. In this respect, it is planned to contribute to the existing literature by examining the relationship between a commodity that affects all sectors, such as oil prices, and stock returns in the aviation sector, which is relatively less studied.

The air transportation sector has become increasingly preferred over other modes of transportation due to its rapid delivery over long distances, thus providing time and space advantages. Its relationship with many sectors, such as logistics and tourism, also drives investors to invest in this sector. Companies operating in the air transportation sector must consider numerous economic conditions to maximize their share value (Samson, 2021:3).

Civil aviation is significantly affected by economic developments. There is also a relationship between the aviation sector and global economic growth. Global crises mean underutilization of capacity in the aviation sector. Aviation companies may be forced to sell seats and transport cargo at low prices to fill capacity. If other external factors contribute to economic crises, more profound and longer-lasting crises can occur in the aviation sector. During these crises, people's use of aircraft for business and leisure decreases (Gökırmak, 2014:2). Figure 1 illustrates the various ways oil prices can affect airline stock prices.

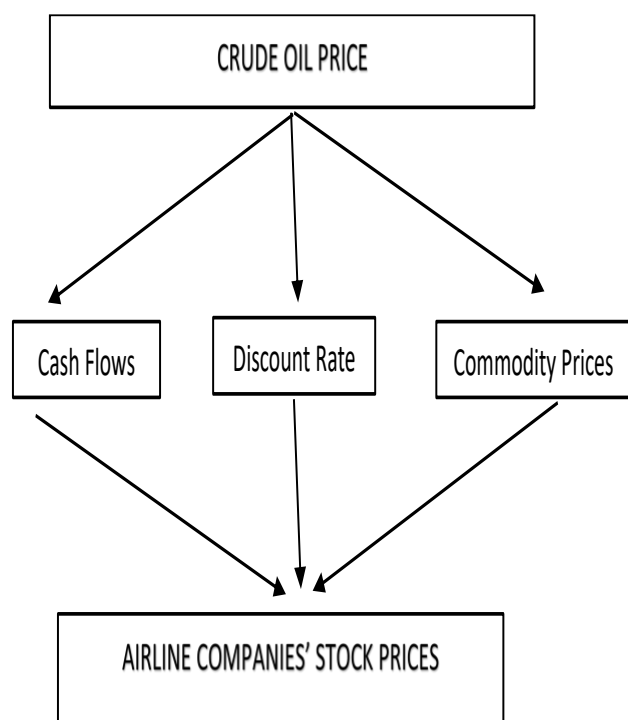


Figure 1. The Effect of Crude Oil Prices on Airline Company Stock Values.

Source: Kathiravan, et al.:2019:8).

As shown in Figure 1, rising oil prices will affect the cash price of stocks because they increase costs. Conversely, changes in oil prices will affect inflation rates. Higher inflation will increase capital costs, thus decreasing the airline's stock price. Similarly, changes in oil prices will affect airlines' commodity prices and the value of commodity trading firms.

2. Literature Review

The origins of the relationship between oil prices and airline stock values date back to the 1980s. Early studies include Hamilton (1983) and Mork (1989) examining the relationship between the US economy and stock markets. Chen et al. (1986) examined the relationship between oil prices and airline stock value returns and examined oil prices and US stock returns during 1958-1984, but found no significant relationship. A comprehensive study of the relationship between oil prices and stock returns was conducted by Jones & Kaul (1996). Relevant regulations were examined in the US, Canadian, UK, and Japanese stock markets, and the negative impact of oil shocks on these markets was observed. Similarly, Huang et al. (1996) found no significant relationship between oil prices and their consequences.

In the 2000s, one of the fundamental studies examining oil and gas sector returns and oil prices in Canadian stock markets was conducted by Sadorsky (2001). The findings demonstrated that oil prices have a significant impact on company returns. Following the 2008 global economic crisis, studies on oil prices and stock returns increased due to market volatility. In this context, a survey by Nandha and Faff (2008) examined the relationship between stock returns and oil prices for various companies worldwide during the 1983-2005. The study found that oil prices negatively affected stock returns in all sectors except mining and oil.

A study by Killian (2008) revealed that energy price shocks negatively affected these stocks. Another study by Miller and Ratti (2009), revealed that oil prices negatively affected stock prices. In this context, a study by Park and Ratti (2008) examined stock returns and oil price shocks in the United States and 13 European countries from 1986 to 2005. Accordingly, Norway, an oil-exporting country, is positively affected by oil shocks. Similarly, a study by Gogineni (2010), which explores the relationship between oil-intensive industries and oil prices, finds that firms operating in oil-intensive sectors are more sensitive to oil prices.

Oil price fluctuations occasionally have a more pronounced impact on industries. In this context, a study by Moya-Martinez et al. (2014) examined the Spanish stock market's exposure to oil price fluctuations from 1993 to 2010. The study found that the link between stocks and oil prices was low in the 1990s and high in the 2000s.

Other studies on this subject are summarized in the table below.

Table 1. Literature

Author(s)	Data set and Method	Conclusion
Papapetrou (2001)	Oil and stock prices in Greece in 1989-1999..	Oil prices reduce stock returns.
Dayanandan and Donker (2011)	Gas and oil companies in the United States between 1990 and 2008. Panel data analysis was used in the study, which included 200 companies.	The results showed that oil prices positively and significantly affect company returns.
Eyüboğlu and Eyüboğlu (2016)	Oil prices and stock prices of Delta Airlines, Lufthansa, Air France, and Turkish Airlines companies for January 2009-November 2014, using monthly data.	The findings indicated a long-run relationship between firms prices and oil.
Shaeri et al. (2016)	Financial and non-financial sectors and oil prices between 1983 and 2015.	According to the results obtained, airline companies were found to be the sector most negatively affected by the increases in oil prices compared to other industries.
Yashodha et al. (2016)	Financial risks, including interest rate, exchange rate, and fuel price risks, and the stock prices of CATHAY Airlines and China Airlines between 1996 and 2011 was investigated.	Oil has negative impact on firms value.
Kristjanpoller & Concha (2016)	Oil and the stock returns of companies in the aviation sector.	A strong correlation was found among the 56 aviation companies included in the study.
Hsu (2017)	The study examined the impact of oil price shocks on the values of airline companies.	According to the study results, oil prices negatively affect airline companies' stock values.
Horobet, Belascu & Păun (2022)	They examined the relationship between oil prices and the returns of the largest airline companies between 2007 and 2020.	The study's results indicate that oil prices negatively affect airline stock returns in the long run. The study also shows that airline stock returns are affected by exchange rates and oil prices.
Asadi et al. (2023)	The study investigated the relationship between oil prices and stock returns of eight airline companies between 2007 and 2021.	According to the study results, while there is a strong negative correlation between the relevant variables in the short term, the relationship weakens in the long term.
Gelirli & Kısacık (2024)	They examined the relationship between oil price fluctuations and airline profitability of Turkish Airlines from 2001 to 2022.	According to the study results, the firm's profitability affected by oil fluctuations in the short and medium term.
Ullah, Biao, Sarvar & Wu (2025)	The relationship between the aviation sectors and oil prices in the U.S. and China between 2014 and 2023 is examined.	The study found that US airlines are highly sensitive to oil prices in the short term. China, on the other hand, exhibits more heterogeneous movements.
Cai, Zhang, & Zhang (2025)	The study examines the effects of different shocks in oil prices (such as supply, economic activity, oil consumption demand, inventory shocks) on stock returns and volatility of airline companies.	The study's results indicate that volatility in stock returns is primarily driven by oil shocks driven by economic activity. Airline stock volatility, on the other hand, is more broadly affected by different types of oil shocks.

3. Data and Methods

This study investigates the relationship between the stock values of two airlines listed on the Borsa Istanbul in Turkey, oil prices, and data obtained from investing.com. Because Pegasus Airlines, one of the two airlines, went public on April 26, 2013, the data used in the study was collected monthly as of May 1, 2013. The data used in the study are included in the analysis by considering the exchange rate during the relevant period. The raw data used in the study are transformed by taking natural logarithms and are seasonally adjusted. Oil prices are used as the independent variable, and airline stock prices are the dependent variable.

This study used monthly stock prices of two airlines between May 1, 2013, and January 31, 2025, as well as Brent crude oil prices for the same period. Toda Yamamoto's causality analysis is used.

The stationarity of the relevant variables was investigated in the study, and according to unit root tests, all series were stationary at their first differences. Causal relationships are

then examined using Toda-Yamamoto causality analysis for the relevant data.

Descriptive statistics for the data used in the study are in the table below.

Table 2. Descriptive statistics

	Brent Crude Oil	Turkish Airlines	Pegasus Airlines
Mean	4.22	1.12	0.72
Median	4.27	1.09	0.638
Maximum	4.81	2.31	1.95
Minimum	3.13	0.08	-0.33
Standard Deviation	0.32	0.57	0.62
Skewness	-0.52	0.52	0.40
Kurtosis	3.29	2.35	2.23
Jarque-Bera	4.22	1.12	0.72

For the Toda-Yamamoto causality test, unit root tests should be performed to determine the maximum stationarity (d_{max}).

3.1. Unit Root Tests

The variables between which a relationship is sought must be stationary to conduct time series analysis. If an explanatory variable in the series has a stochastic trend, the series can appear misleadingly related, even if they are independent. This situation is called spurious regression (Stock and Watson, 2011:563).

In this study, before beginning the analysis, unit root tests were conducted among the variables to determine the stationarity of the series. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, commonly used in the literature, were applied for this analysis.

After examining the time series graphs of the variables, unit root tests were performed to perform cointegration analysis between the variables. Unit root tests are performed to determine the level of stationarity of the series. The data obtained from the test results determines which analysis should be applied. The unit root test hypotheses were established as follows:

H_0 : The series is non-stationary.

H_1 : The series is stationary.

Table 3. ADF Test

Variables	Level			First Difference		
	None	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept
Brent Crude Oil	-0.28 (0.5830)	-2.47 (0.1232)	-2.55 (0.3038)	-9.92 (0.0000) *	-9.89 (0.0000) *	-9.87 (0.0000) *
THYAO	0.01 (0.6847)	-0.88 (0.7919)	-1.44 (0.8423)	-13.30 (0.0000)	-13.28 (0.0000) *	-13.42 (0.0000) *
PGSUS	-0.27 (0.5868)	-1.01 (0.7474)	-1.70 (0.7449)	-12.02 (0.0000) *	-12.00 (0.0000) *	-12.08 (0.0000) *

*%5 significance level

Table 4. Phillips-Perron Test

Variables	Level			First Difference		
	None	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept
Brent Crude Oil	-0.28 (0.5830)	-2.22 (0.1977)	-2.28 (0.4380)	-9.78* (0.0000)	-9.74* (0.0000)	-9.72* (0.0000)
THYAO	0.00 (0.6816)	-0.92 (0.7763)	-1.45 (0.8389)	-13.21 (0.0000)	-13.18 (0.0000)	-13.32 (0.0000)
Pegasus	-0.25 (0.5928)	-1.00 (0.7508)	-1.69 (0.7499) *	-12.02 (0.0000)	-12.00 (0.0000)	-12.07 (0.0000)

*%5 significance level

According to the unit root test results, the data of Brent oil and two airline companies are stationary at the first difference.

3.2. Determine Optimal Lag Length Selection

In this study, ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) unit root tests were conducted to determine

the stationarity of the series. The results of the unit root tests were obtained using the EViews 12 program. Based on the unit root test analyses, the series were assumed to be stationary at degree 1. After determining the lag length of each series, 1 lag was added to the lag length to be used for each aviation company.

Table 5. Lag Length Selection

Table 3: Lag Length Selection

THYAO					
Lag	LR	FPE	AIC	SC	HQ
0	NA	0.026135	2.031268	2.074732	2.048930
1	652.7550	0.000183	-2.929774	-2.799382*	-2.876788
2	10.42449	0.000179	-2.951065	-2.733745	-2.862754
3	17.85286	0.000165*	-3.032604*	-2.728357	-2.908969*
4	0.568268	0.000175	-2.977036	-2.585861	-2.818078
5	1.329232	0.000184	-2.927781	-2.449678	-2.733498
6	1.470467	0.000193	-2.879885	-2.314854	-2.650278
7	3.303782	0.000199	-2.847732	-2.195774	-2.582802
8	0.87128*	0.000177	-2.967507	-2.228621	-2.667252
PEGASUS					
Lag	LR	FPE	AIC	SC	HQ
0	NA	0.028741	2.126320	2.169784	2.143982
1	613.7906	0.000272	-2.534996	-2.404605*	-2.482010
2	11.63695	0.000264	-2.565760	-2.348440	-2.477449
3	17.10597*	0.000244*	-2.641371*	-2.337124	-2.517736*
4	0.838395	0.000258	-2.587982	-2.196807	-2.429023
5	0.958164	0.000272	-2.535685	-2.057582	-2.341402
6	0.636630	0.000287	-2.480840	-1.915809	-2.251233
7	3.198067	0.000297	-2.447792	-1.795833	-2.182861
8	7.237248	0.000297	-2.450032	-1.711145	-2.149776

In the first step of the Toda Yamamoto approach, the lag length and maximum degree of integration (d_{max}) of the variables are calculated. In the next step, a VAR ($k + d_{max}$) model is created by adding a lag equal to d_{max} to the standard VAR (k) model with added lags. Accordingly, the lag lengths used in the analysis were set to 4 for Turkish Airlines and 4 for Pegasus, and the VAR model was established.

3.3. Toda Yamamoto Causality Test

One of the fundamental studies that revealed the causal relationship between variables was conducted by Granger (1969). The Granger causality test has been criticized for its lack of power in small samples and its exposure to pre-test deviations, and many approaches have been developed to overcome these problems (Tari et al., 2019:444). One of the approaches developed in this regard is the causality analysis conducted by Toda-Yamamoto (1995), which has been frequently used in studies in recent years.

One of the advantages of the Toda-Yamamoto (1995, pp. 225-250) causality test is that the series do not need to be stationary or cointegrated at the same level. An advantage of this test is that it prevents data loss when the series are made stationary by differencing, as in the Granger causality test. This has led to the frequent use of this analysis in determining causality. The previously calculated actual lag length (k) and the variables' largest integration degree (d_{max}) are used for the

Toda-Yamamoto causality test. Accordingly, the VAR($k + d_{max}$) model is obtained by adding a lag equal to the largest integration coefficient to the standard VAR(k) model with added lags. The equation for the relevant model is as follows:

$$Y_t = \mu + A_{11}Y_{t-1} + \dots + A_{1k}Y_{t-k} + \sum_{l=k+1}^{k+d_{max}} A_{il}Y_{t-l} + u_t$$

$t=1,2, \dots, T$

After estimating this equation, the hypotheses used for causality testing are as follows:

$$H_0: A_{il} = 0$$

$$H_1: A_{il} \neq 0$$

The Wald test statistic is used when testing this equation. If the Wald test statistic is significant, the main hypothesis, which states no Granger causality between the variables used in the model, will be rejected (Tari et al., 2019:446). The results obtained according to the VAR model created with four lags calculated for each company in the study are shown in the table below.

Table 6. Toda Yamamoto Causality Analysis Test Results

Firms	Aspect of Causality	χ^2 Test Statistics	Probability Value	Decision
THYAO	Stock Price=> Brent	2.416372	0.6597	No causal relationship between Price to Brent
THYAO	Brent=>Stock Price	15.56020	0.0037	A causal relationship between Brent to Price
PEGASUS	Stock Price=> Brent	2.243102	0.69.11	No causal relationship between Price to Brent
PEGASUS	Brent=>Stock Price	17.19482	0.0018	A causal relationship between Brent to Price

According to the results in the table, a one-way causality between Brent Oil prices and the relevant airline companies was identified.

4. Conclusion

As a result of financial liberalization and globalization, companies in financial markets are known to utilize numerous sources to raise funds. The most fundamental of these, stock issuance, is also used in the aviation sector.

In the economics and finance literature, economic and finance theorists argue that there is a close relationship between oil prices and oil shocks, macroeconomics, economic activity, and stock returns. Accordingly, numerous studies have been conducted on the thesis that oil price shocks negatively affect most sectors. Accordingly, oil price shocks have a negative impact on real output, which in turn negatively impacts firm profits and, consequently, stock values.

This study examines the relationship between two aviation sector companies traded on the Borsa Istanbul and the oil variable, a significant expense item, and a key macroeconomic variable. Causality tests were conducted to demonstrate this relationship. Instead of the frequently used Granger causality model, the Toda-Yamamoto approach, which tolerates the shortcomings of this model, was used. After considering the basic logic of the Toda-Yamamoto approach, the study

analyzed monthly data from two airline companies traded on the BIST (Istanbul Stock Exchange) between 2013 and 2025.

The study results revealed a unidirectional causality between the oil variable, one of the aviation sector's most significant expense items, and the companies' stock values. In this regard, the study draws on Nandha and Faff (2008), who noted that oil prices are a crucial expense item for many sectors. Oil price fluctuations are particularly significant for the aviation sector. Therefore, examining the impact of Brent crude oil prices, a considerable expense and a key macroeconomic variable for the industry, on stock prices is considered highly significant.

The causal relationship between oil prices and airline stocks identified in this study using the Toda-Yamamoto method is consistent with similar findings in the existing literature. For example, Sadorsky (2001) demonstrates that fluctuations in energy prices have a significant impact on stock returns, while Kilian (2008) and Park and Ratti (2008) emphasize that oil price shocks are reflected in sectoral stock returns through different channels. Furthermore, more recent studies focusing on Turkish and global markets (Ullah, Cai, & Wang, 2025; Asadi, 2023; Gelirli & Kısacık, 2024) reveal significant relationships between oil prices and airline stocks in both the short and long term. Therefore, the findings of this study are consistent with the literature and confirm that oil prices are a critical variable in shaping the financial performance of airlines.

In this context, it is thought that this study will fill an important gap since company-based studies are less in the literature. Future studies could be further diversified by increasing the number of variables and employing different types of analyses.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Asadi, M., Pham, S. D., Nguyen, T. T., Do, H. X., & Brooks, R. (2023). The nexus between oil and airline stock returns: Does time frequency matter?. *Energy Economics*, 117, 106444.
- Cai, Y., Zhang, Y., & Zhang, A. (2025). Oil price shocks and airlines stock return and volatility—A GFEVD analysis. *Economics of Transportation*, 41, 100396.
- Chen, N. F., Roll, R., & Ross, S. A. (1986). Economic forces and the stock market. *Journal of Business*, 383-403.
- Dayanandan, A., & Donker, H. (2011). Oil prices and accounting profits of oil and gas companies. *International Review of Financial Analysis*, 20(5), 252-257.
- Eyüboğlu, K., & Eyüboğlu, S. (2016). Brent petrol fiyatının havayolu şirketlerinin hisse senedi fiyatlarına etkisi. *Çukurova Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 20(1), 39-53.
- Gelirli, N., & Kısacık, S. (2024). Oil price fluctuations and airline profitability: The case of Turkish Airlines. *Business & Management Studies: An International Journal*, 12(2), 253-267.
- Gogineni, S. (2010). Oil and the stock market: An industry level analysis. *Financial Review*, 45(4), 995-1010.
- Gökırmak, H. (2014). Türk Hava Yolları'nın havacılık sektöründeki konumu. *Siyaset, Ekonomi ve Yönetim Araştırmaları Dergisi*, 2(4), 1-29.
- Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: Journal of the Econometric Society*, 424-438.
- Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy*, 91(2), 228-248.
- Horobet, A., Belascu, L., & Păun, C. (2022). Oil price volatility and airlines' stock returns: Evidence from panel ARDL and PMG estimations. *Journal of Risk and Financial Management*, 15(9), 400.
- Hsu, C. (2017). How fuel price shocks affect airline stock returns: An empirical study of major US carriers. *The International Journal of Business and Finance Research*, 11(2), 51-59.
- <https://brandirectory.com/reports/turkiye/2025>, Access Date: 07.07.2025.
- Huang, R. D., Masulis, R. W., & Stoll, H. R. (1996). Energy shocks and financial markets. *Journal of Futures Markets*, 16(1), 1-27.
- Jones, C. M., & Kaul, G. (1996). Oil and the stock markets. *The Journal of Finance*, 51(2), 463-491.
- Kathiravan, Chinnadurai/Selvam, Murugesan et. al. (2019). Relationship between crude oil price changes and airlines stock price : the case of Indian aviation industry. *International Journal of Energy Economics and Policy*, 9 (5), S. 7 - 13.
- Kilian, L. (2008). The economic effects of energy price shocks. *Journal Of Economic Literature*, 46(4), 871-909.
- Kristjanpoller, W. D., & Concha, D. (2016). Impact of fuel price fluctuations on airline stock returns. *Applied Energy*, 178, 496-504.
- Miller, J. I., & Ratti, R. A. (2009). Crude oil and stock markets: Stability, instability, and bubbles. *Energy Economics*, 31(4), 559-568.
- Mork, K. A. (1989). Oil and the macroeconomy when prices go up and down: An extension of Hamilton's results. *Journal of Political Economy*, 97(3), 740-744.
- Moya-Martínez, P., Ferrer-Lapeña, R., & Escribano-Sotos, F. (2014). Oil price risk in the Spanish stock market: An industry perspective. *Economic Modelling*, 37, 280-290.
- Nandha, M., & Faff, R. (2008). Does oil move equity prices? A global view. *Energy economics*, 30(3), 986-997.
- Papapetrou, E. (2001). Oil price shocks, stock market, economic activity and employment in Greece. *Energy economics*, 23(5), 511-532.
- Park, J., & Ratti, R. A. (2008). Oil price shocks and stock markets in the US and 13 European countries. *Energy economics*, 30(5), 2587-2608.
- Sadorsky, P. (2001). Risk factors in stock returns of Canadian oil and gas companies. *Energy economics*, 23(1), 17-28.
- Samson, Ş. (2021). Havayolu işletmelerinde operasyonel bazı değişkenler ile hisse senedi fiyatları arasındaki ilişki: Türk Hava Yolları örneği, İstanbul Gelişim University Master Thesis, İstanbul.
- Shaeri, K., Adaoglu, C., & Katircioglu, S. T. (2016). Oil price risk exposure: A comparison of financial and non-financial subsectors. *Energy*, 109, 712-723.
- Stock, J. H., Watson, M. W., (2011). Ekonometriye giriş, Trans. B. Saraçoğlu, Efil Yayınevi.
- Tarı, R., Koç, S., & Abasız, T. (2019). Ekonometri, 14. Baskı, Kocaali: Umutepe Yayınları.
- Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal Of Econometrics*, 66(1-2), 225-250.
- Ullah, A., Biao, H., Sarwar, S., & Wu, Z. (2025). Transmission of oil price risk to airline stock returns: Evidence from China and the United States. *Research in Transportation Economics*, 110.
- Yashodha, Y., Hamid, B. A., & Habibullah, M. S. (2016). Financial risk exposures of the airlines industry: Evidence from Cathay Pacific Airways and China Airlines. *International Journal of Business and Society*, 17(2).

Cite this article: Kuloglu, E. (2025). Investigating the Relationships Between Oil Prices and Airline Stock Values. *Journal of Aviation*, 9(3), 745-750.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Examination of Human Factors in Civilian Unmanned Aerial Vehicles Accidents with PEAR Model: United Kingdom Sample

Ramazan Çoban¹ 

¹Malatya Turgut Ozal University, School of Civil Aviation, Aviation Management Department, 44900, Yeşilyurt, Malatya, Türkiye. (ramazan.coban@ozal.edu.tr)

Article Info

Received: 26 July 2025

Revised: 23 August 2025

Accepted: 15 September 2025

Published Online: 16 October 2025

Keywords:

Unmanned aerial vehicles

UAV accidents

Human factors

PEAR model in aviation

Drone accidents

Corresponding Author: Ramazan Çoban

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1751655>

Abstract

This research primarily aims to examine the human factors that cause accidents involving civilian UAVs using a qualitative research method within the framework of the PEAR model. Examining the consequences of UAV accidents constitutes a secondary aim of this research. The research was conducted using a phenomenological design, a qualitative research design. The research sample was determined using purposive sampling and the saturation point method. The study sample consisted of 85 UAV accidents that occurred in different locations and while performing different tasks in the United Kingdom between 2015 and 2025. Accident reports were examined using document review to collect data. The obtained data were subjected to content analysis using a descriptive approach within the framework of the PEAR model. Five themes emerged from the content analysis. These themes are: People-related factors, Environment-related factors, Action-related factors, Resource-related factors, and Consequences of UAV Accidents. Research findings indicate that resource-related factors (mostly technical issues) account for 39% of UAV accidents, environmental factors (mostly physical environment) for 26%, action-related factors for 22%, and human-related factors for 13%. Both actions and human-related factors are directly related to the behaviours, skills decisions, and attitudes of UAV pilots and flight crew. In this context, it can be concluded that the sum of these two factors (35%) accounts for human factors in UAV accidents. While UAVs have mostly sustained material damage as a result of these accidents, in some cases, a small number of people in the vicinity were slightly injured, and vehicles were partially damaged.

1. Introduction

Unmanned aerial vehicles (UAVs) or the drone sector, has become a rapidly developing and popular sector within the global aviation industry. While the terms UAV and drone are used interchangeably in the literature, this study prefers to use the term UAV to refer to unmanned aerial vehicles. A UAV is defined as an aircraft capable of flying without a pilot. UAVs can be flown remotely by a pilot or automatically (Watts et al., 2012). While primarily used for military purposes, their intended uses have expanded throughout history, and today they have become useful tools used in many civilian operations, such as reconnaissance, research, scientific data collection, and surveillance. It is expected that the areas of use for UAVs will gradually diversify, and as technology advances, their use in more sectors will continue (Murray et al., 2025). In recent years, UAVs, which have become accessible and usable to everyone, are largely viewed from a technological perspective worldwide. In this context, developments are largely focused on the technological infrastructure. Thanks to technological investments in UAVs, their costs are decreasing and their capabilities are increasing (Gupta et al., 2021; Macit et al., 2025).

Due to the widespread use of UAVs and their status as aircraft, the concept of safety in UAVs has become a crucial factor to consider. In this context, various safety factors and limitations are currently taken into account during the design,

production, and operational use of UAVs (Howard et al., 2018). However, in most countries worldwide, including the United States of America (USA), regulations regarding the use and operations of UAVs are still in their early stages and in their development. As the use of UAVs becomes more widespread, international aviation authorities and governments are attempting to manage this process by enacting new regulations (Hobbs and Lyall, 2016; Watts et al., 2012). On the one hand, legal regulations regarding the classification, use of airspace, and safe operation of UAVs are constantly being updated. On the other hand, the widespread use of UAVs in many areas, deficiencies in legal regulations, and the failure to fully implement necessary safety measures lead to an increase in UAV accidents. While there were 50 UAV accidents reported to the USA aviation authority FAA in February 2014, this number increased to over 200 in 2016 (Özyörük, 2020).

While human factors are the most dominant factor among the causes of accidents and incidents occurring during flights with modern and conventional manned aircraft, current research examining UAV accidents indicates that mechanical and equipment problems are the most dominant factor in UAV accidents. However, since UAV technologies have emerged and are developing in recent years, it is not surprising that technical problems often contribute to UAV accidents (Wild et al., 2016). While the concept of a UAV requires little or no integration between human and technical systems, all UAVs

require humans for both control and maintenance. Because the pilots, payload operators, and other UAV crew members, such as observers, are located in a land-based area far from the UAV itself, the methods and precautions used in UAV missions can differ significantly from those of manned aircraft. Furthermore, the environmental conditions under which UAV missions are conducted, the type of missions, and the structure of the mission crew may have unique differences (Spravak et al., 2005). For these reasons, unmanned aviation operations involve a unique set of human factors compared to traditional manned aviation operations (Hobbs and Lyall, 2016).

In recent years, with the widespread use of UAVs in many sectors, more research has been conducted on the flight problems experienced by UAVs. However, most of this research has focused on the technical aspects of UAVs. Very little of this research has addressed human factors in UAV operations (Wang et al., 2023). While technical malfunctions or problems are currently considered the primary factors in UAV accidents, it is thought that, as with manned aircraft, human factors will increasingly contribute to accidents as UAV technologies advance (Murray et al., 2025). The rapid advances in technology and the widespread use of UAVs worldwide require greater attention to human factors concerns in the design, operation, and pilot training of UAVs (Mouloua et al., 2003).

This research, conducted based on a literature review, focuses on human factors, which contribute to accidents involving rapidly technologically developing UAVs worldwide, but on which limited research has been conducted. This focus is driven by the assumption that technological advancements will make UAVs more powerful and user-friendly in terms of structure and operation in the coming years, but that human factors will become increasingly prominent in UAV accidents. In this context, the primary objective of this research is to examine the human factors that contribute to accidents in civilian UAVs within the framework of the PEAR model. The PEAR model, one of the aviation accident investigation models, is an acronym formed by combining the initials of the human factors that contribute to accidents in the aviation sector (People: The person doing the job; Environment: The environment in which the job is performed; Actions: The actions and behaviors performed; Resources: The resources required to perform the job). It provides a simple and fundamental framework for identifying human factors in accident investigations (Johnson and Maddox, 2007: 39). Examining the consequences of UAV accidents constitutes a secondary objective of this research.

2. Literature Review

2.1. Unmanned aerial vehicles

UAVs are now considered one of the most significant technological achievements of the modern age. Simply put, a UAV can be defined as an aircraft capable of remote control and automatic flight without a pilot. Another definition is that a UAV is an aircraft without a pilot or passengers, carrying only equipment appropriate for its mission and capable of performing its mission either remotely or automatically (Kahveci and Can, 2017). From a broader perspective, a UAV is defined as an aircraft operated as a component of an unmanned aerial vehicle system, capable of sustained flight via aerodynamic forces, and capable of being flown or hovered without a pilot, either remotely controlled by the UAV pilot or autonomously planned by the UAV pilot (SHT-IHA, 2020).

UAVs are fixed- or rotary-wing aircraft composed of integrated systems that can be remotely controlled or fly autonomously. Systems consisting of a ground control station, ground data terminal, and other hardware that enable UAVs to

perform their missions are called UAV systems. UAV systems include the UAV itself and its sensor payloads (Yakar et al., 2023). Depending on the aircraft and the mission, UAVs can be flown by a single pilot or, in some cases, a crew. This crew may also include an observer to ensure safety or an operator to operate the payloads. Large UAVs are controlled by fixed or mobile ground control stations. Small UAVs are typically controlled by easily portable remote controls, laptops, or ground control stations consisting of small components (Watts et al., 2012). A general distinction is made between small UAVs, which are usually in the pilot's direct line of sight and fly close to the ground, and larger UAVs, which can fly outside line of sight and at higher altitudes (FAA, 2015). While piston and electric engines are used in civilian UAVs, electric engines are more commonly used today. As the number of engines increases, the UAV's payload capacity also increases. However, the flight endurance decreases with increasing flight load. Electric UAVs consist of different structural features and components depending on their mission. The fuselage, propellers, engines, battery, flight controllers, power distribution boards, electronic speed controller (ESC), receiver, and camera are the basic structural components of electric UAVs (Yakar et al., 2023).

The emergence and technical development of remotely piloted aircraft can be traced back to the end of the 18th century. UAVs were primarily used for military purposes. While military-grade unmanned balloons were used for reconnaissance in the USA in 1793 during the Civil War, in 1849, the Austrians used nearly 200 pilotless balloons loaded with time-fuse bombs to launch an airstrike on Venice, Italy. More technologically advanced UAVs, other than balloons, in the form of aircraft have been used for military purposes since the beginning of the 20th century. The first unmanned aircraft, the Ruston Proctor, was designed at the end of World War I (1916) (Kahveci and Can, 2017). Research on military UAVs continued during and after World War II. UAVs were used in USA military operations in Vietnam, Afghanistan, and Iraq, and continue to be used today (Keane and Carr, 2013: 559). As UAV control technologies have improved and their costs have decreased, their use has expanded to many non-military operations (Mygal, 2022).

Commercial civilian UAV use has emerged since the early 2000s. Miniaturization of electrical components, advances in computer technology, and advances in lightweight and durable materials have made civilian fixed and rotary wing UAVs economical and popular (Giones and Brem, 2017). In recent years, many civilian UAVs have emerged, varying in size, structure, durability, and purpose. Equipped with advanced and extensive sensors, UAVs have become beneficial tools for many sectors thanks to their intelligent adaptation and versatility. Unlike the expensive manned vehicles used in the aviation sector, civilian UAVs are inexpensive and portable. Furthermore, by eliminating the need for a pilot, UAVs often significantly reduce operating costs (Albihn, 2022). Today, civilian UAVs are used in many areas, including natural disasters, search and rescue, agricultural spraying, agricultural monitoring, aerial photography, mapping, environmental and wildlife monitoring, urban construction, archaeology, forest fire monitoring, police operations, and public safety. Due to this rapid development in UAV technologies, the global UAV market, both military and civilian, reached \$9.3 billion in 2019. This market is projected to reach \$45.8 billion by 2025 (Akyürek and Eraslan, 2024: 158).

With the advancement of technology, different types of UAVs have begun to be produced worldwide to meet needs. Therefore, the need to eliminate the differences among UAV types and classify them based on practical requirements has arisen. UAVs can generally be classified according to their

technical specifications and intended use. When classifying them according to their technical specifications, technical features such as wing structure, weight, power source or engine type, and whether they are automatic or remotely controlled are taken into account. Based on their intended use, UAVs can be divided into military and civilian. Military UAVs are generally used for reconnaissance, surveillance, and attack, while civilian UAVs are used for hobby, scientific research, and commercial missions (Kahveci and Can, 2017). In addition, ICAO (2011) legal regulations divide UAVs into two main classes: automatic and remotely controlled. The most commonly used method for classifying UAVs is by weight. In Turkey, UAVs are divided into four groups based on their weights: UAV0 (500g (included) - 4kg), UAV1 (4kg (included) - 25kg), UAV2 (25kg (included) - 150kg), and UAV3 (150kg (included) and more) (Genç and Erciyes, 2020). When looking at the UAV classifications of other countries worldwide, it is seen that while there are slight differences in the weight classifications in the legal regulations regarding UAVs in the USA, Canada, European Union, United Kingdom (UK), China, India, Malaysia, Japan, and Russia, these regulations are largely similar. Countries such as Canada, Malaysia, and UK accept the upper class of UAV1 as 20 kilograms (Hassanalian and Abdelkefi, 2017).

Although the UAV sector is a promising and developing sector today, UAV pilots still face certain challenges and limitations (Grindley et al., 2024). The first of these challenges is the mobility characteristics of UAVs. The minimum turning radius, which generally depends on the payload size, weight, and energy efficiency, determines the mobility of UAVs. A UAV carrying a larger payload generally requires a larger turning radius when planning its route (Sundar and Rathinam, 2013; Avellar et al., 2015). Secondly, the payload capacity of a UAV is directly proportional to its size and energy capacity. Therefore, the payload size, which is closely related to operating costs, imposes a limitation on UAV missions (Dorling et al., 2016). Thirdly, with the exception of some solar-powered models, the amount of energy most UAVs can carry and the type of missions they will perform limit their flight range (Tokekar et al., 2016). Finally, UAVs must maintain constant communication with ground control stations and process and transmit received and transmitted information. However, obstacles such as power constraints, line-of-sight issues, magnetic field interference, and rainy weather can cause connection and signal loss issues in UAVs (Otto et al., 2018).

2.2. Human factors in unmanned aerial vehicles

Accidents, which occur regularly throughout industrial and commercial activities worldwide, result in the death or injury of many people, or businesses suffer significant financial losses. Although numerous measures, such as technological advancements, new management models, and legal regulations prioritizing occupational safety, have reduced the direct and indirect consequences of occupational accidents, accidents remain a source of concern for many sectors today (Çoban, 2022). When examining the causes of accidents, it can be said that accidents result from the interaction of technological, environmental, organizational, and human factors (Reason, 2008; Sharit, 2012). In the aviation sector, where safety and security are paramount, as in all business sectors, technological factors that cause aircraft accidents refer to the technical malfunction or failure of a component in a system or equipment. Environmental factors include conditions such as weather, noise, lighting, and other factors that negatively affect the performance of employees, vehicles, and equipment (Ergai, 2013). Inadequate communication, poor safety culture, unclear and inadequate procedures, deficiencies in training and

standards, organizational processes and management style are among the organizational factors that cause or contribute to accidents (Heimann, 1993).

A significant factor contributing to accidents is the human factor. The concept of human factors refers to the failure of a planned mental or physical activity to achieve its intended outcome, and to a situation where these failures are not attributed to chance but are related to human errors (Reason, 1990). The concept of human factors attempts to reveal how people interact with equipment, the physical environment, organizational rules, and other people in the workplace. In the aviation industry, the concept of human factors is directly related to employee performance and seeks to optimize human performance through the systematic application of certain scientific methods. Understanding the human factors, or human errors, that cause accidents in the aviation industry is one of the significant challenges facing the industry. Examining and understanding the concept of human factors in the aviation industry can shed light on how a professional and motivated aviation employee can make fatal errors (ICAO Doc 9806, 2002). Today, while the number of accidents caused by technological factors has decreased significantly, the number of accidents caused by human factors has increased significantly and constitutes more than 80% of total accidents (Piwek, 2018).

While most accidents involving civilian UAVs, whose use is likely to increase rapidly in the coming years, are caused by technological factors, the importance of human factors in these accidents is increasing. Some studies indicate that human factors are second only to technological factors in UAV accidents (MacPherson, 2018; Murray et al., 2025). Although UAVs are classified as unmanned, one of the most significant challenges facing this rapidly developing sector relates to human factors. As UAVs enter civilian airspace, failure to consider human factors will not only lead to loss of life but also lead to accidents that will damage public confidence in UAV operations (Hobbs and Shively, 2014).

Compared to traditional manned aircraft, the unique conditions of UAV missions differentiate the human factors that may arise during these missions. With the emergence of UAVs, considered the technology of the future and actively serving humans even today, ergonomics and human-machine interaction have undergone changes. Rapid advances in digitalization and automation have enabled the technological advancement of UAVs, while simultaneously creating new requirements for the cognitive, psychological, and physiological abilities of modern humans. These requirements can lead to new human factors challenges that must be addressed in the interactions between UAVs, which are advanced digital and technological systems, and humans (Mygal, 2022). In traditional manned aircraft, pilots can receive rich sensory cues about the aircraft's situation, such as visual, auditory, proprioceptive, and olfactory. However, the lack of these sensory cues for a UAV pilot reduces their situational awareness of the UAV (Williams, 2008). While video images offer a partial solution to obtaining these sensory cues, they require broadband bandwidth. However, this bandwidth may be impractical in some situations (Hobbs and Shively, 2014).

Workload, connection problems, and emergency flight termination are important human factors issues in UAV missions. Especially in automated UAV missions, prolonged pilot workload exposure can lead to complacency and a loss of situational awareness. In such cases, the pilot must be prepared for the possibility of a rapid increase in workload. Furthermore, UAV manufacturers should consider solutions that ensure pilot engagement during extended automated flights (Cummings et al., 2013). The potential for connection

loss can lead to human error in UAV missions. The pilot must strive to maintain connection with the UAV while flying the UAV. No connection between the UAV and the pilot is completely reliable. The pilot must be knowledgeable about managing connection drops, delays, or poor connections. While connection delays are less of a problem when the UAV is in automated flight, they are more of a problem during manual flight. Connection problems can also negatively impact communication between the UAV pilot and air traffic controllers (Hobbs and Shively, 2014). Another important human factor issue during UAV missions is the safe termination of flight in emergency situations. In emergency situations, the UAV pilot may be required to destroy the UAV by landing, controlled crash, or other means. In such cases, even if no life is lost on the UAV, the pilot is still responsible for ensuring the safety of life and property on the ground. The pilot must also consider the risk of inadvertent activation of the flight termination system during normal flight (Hobbs, 2010).

The complexity of UAV missions can require multiple team members to work simultaneously. This can present many new challenges for flight safety and mission effectiveness. Missions involving multiple UAVs can present significant challenges, particularly in terms of workload, situational awareness, cooperation, and coordination. Furthermore, operational issues such as establishing a timetable that ensures the efficient operation of the mission team, properly managing handover processes, and adhering to procedures and checklists become more critical in complex UAV missions (Özyörük, 2020: 76). A review of the literature reveals that, although limited, studies examining the impact of human factors on UAV missions exist, and that these studies demonstrate that human factors are a significant factor in UAV accidents.

A study by Asim et al. (2010) examining 56 accidents involving USA military UAVs found that 32% of accidents were caused by human factors. Murray et al. (2025) examined 290 UAV accidents that occurred between 2008 and 2019. The findings indicated that skill errors, depth perception, and environmental issues were the most significant human factors contributing to UAV accidents. Perception problems, in particular, were found to negatively impact UAV pilot performance more than other aviation industry employees. In another study conducted by Bell and Cooke (2003) to examine the relationship between workload and performance in a three-person UAV crew, they found significant decreases in both team performance and individual crew member performance and cognitive abilities during high-workload tasks.

Reliance on automation, a lack of sensory signals, the psychological and emotional perception of ground control stations that resembles an office environment rather than an aircraft cabin, assignments that are incompatible with human physiology, fatigue, and the risks associated with emergency flight termination are important human factors that can lead UAV pilots to make errors (Mygal, 2022). Furthermore, the inadequate training level of UAV pilots is a significant human factor contributing to UAV accidents. Human-machine interaction is common during high-tech UAV missions. In these interactions, pilots who are unlicensed, fail to use intelligent interfaces, misinterpret warning alerts, or delay reacting in emergency situations can lead to serious accidents. Therefore, it is crucial for UAV pilots to receive interdisciplinary training (Rigolot, 2020). Lack of knowledge is a significant human factor that hinders pilots' ability to select the appropriate UAV for the mission, correctly use the airspace, and assess weather conditions, limiting UAV

missions (Fontaine et al., 2016). Ergonomic factors are also important human factors affecting the performance of UAV pilots and mission crews. Ergonomic factors such as user interfaces, screen designs and angles, seating position, thermal comfort, and noise, particularly at ground control stations where large UAVs are controlled, affect UAV crew performance (Akyürek and Eraslan, 2024).

2.3. PEAR model

Today, the majority of accidents and incidents involving manned aircraft and various aviation personnel are caused by human factors. Therefore, various accident investigation models, such as SHELL, Swiss Cheese, the Human Factors Analysis and Classification System (HFACS), and PEAR, have been developed to analyze the causes of accidents and incidents in the aviation sector (Dönmez and Uslu, 2018). The PEAR model, one of the aviation accident investigation models, was proposed by Johnson and Maddox (2007) to examine the human factors that cause accidents and incidents in the aircraft maintenance sector. Each letter of the word PEAR, which is easy to remember and recall, represents a different human factor (Çoban, 2022). While the PEAR model was developed to examine human factors in the aircraft maintenance sector, its understandable, simple, and practical structure makes it suitable for analyzing human factors that can be seen in all aviation personnel. Therefore, each dimension of the model is explained to encompass all aviation personnel.

The letter **P** in the model refers to the *people* working in aviation operations. People are the most important dimension of the model. Aviation tasks are performed by people. Not every individual performing aviation tasks has the same characteristics, and each individual may have certain limitations that affect their performance. The physical, physiological, psychological, and psychosocial aspects that employees exhibit while performing their duties are considered within the human dimension. Furthermore, both physical and mental fatigue, a critical element for human performance and capacity, are within the scope of the human dimension of the PEAR model (Yang and Fan 2016; FAA, 2018). The *environment*, symbolized by the letter **E** in the model, addresses the physical and organizational conditions in which aviation activities take place and that directly or indirectly affect employee performance. The physical environment relates to conditions such as heat, light, noise, and workplace design in the work environment; the organizational environment relates to working conditions such as management style, communication, organizational culture, perceived workplace atmosphere, norms, and interdependence (Johnson and Maddox, 2007).

Actions, symbolized by the letter **A** in the model, encompass the practices and behaviors required for employees to perform their jobs safely and effectively. Actions are the final implementation phase of aviation activities and directly impact aviation safety. Actions must be performed accurately, timely, and safely by aviation employees according to technical documents, instructions, or checklists. Finally, *resources*, symbolized by the letter **R** in the model, refer to the resources necessary for performing activities and are associated with employees, the environment, and actions. While resources such as tools, equipment, manuals, and computers are tangible, resources such as the number and qualifications of personnel, time, and communication skills required for the job are less tangible (Johnson and Maddox, 2007). Each dimension comprising the PEAR model and its sub-factors are presented in Table 1.

Table 1. Dimensions of the PEAR Model

P-People			
Physical Factors	Physiological Factors	Psychological Factors	Psychosocial Factors
Physical size	Nutritional factors	Workload	Interpersonal conflicts
Gender	Health	Experience	Financial hardships
Age	Lifestyle	Knowledge	Personal loss
Strength	Fatigue	Training	
Sensory limitations	Chemical dependency	Attitude	
		Mental/emotional state	
E-Environment			
Physical Environment		Organizational Environment	
Weather		Personnel	
Location of activities		Corporate culture	
Shift		Morale	
Workspace		Supervision	
Safety		Company size	
Sound level		Profitability	
Lightning		Crew structure	
		Labor-management relations	
		Pressures	
A-Actions			
	Steps required to perform and complete a task		
	The number of people involved to complete a task		
	Sequence of activities		
Requirements			
	Communication, Attitude, Certification, Information control, Knowledge, Skill, Inspection		
R-Resources			
Manuals		Computer software systems	
Tools		Test equipment	
Work stands and lifts		Fixtures	
Other people		Task lightning	
Materials		Ground handling equipment	
Quality systems		Training	
Procedures and work cards		Paperwork and associated signoffs	

Sources: (Johnson and Maddox, 2007; Zimmermann and Mendonca, 2021)

3. Method

This research primarily aims to examine the human factors that contribute to accidents involving civilian UAVs using a qualitative research method within the framework of the PEAR model. Examining the consequences of UAV accidents constitutes a secondary aim of this research. Phenomenological research, a qualitative research design, was used to guide the research. Phenomenological studies can make significant contributions to both literature and practice by providing examples, explanations, and experiences that will provide results that will help us better understand a phenomenon (Yıldırım and Şimşek, 2018). Additionally, in a phenomenological study, answers are generally sought to two questions: “*What are the perceptions or experiences related to this phenomenon?*” and “*What are the environments and conditions in which experiences related to this phenomenon occur?*” (Sıgı, 2021). In this context, in order to examine the phenomenon of human factors causing civilian UAV accidents, which is a new and current issue for the civil aviation sector, within the framework of technological, environmental, organizational, human error or other factors and to identify the different consequences that this phenomenon may have in terms of aviation safety and UAV missions, an attempt was made to find answers to the research questions presented in Table 2 by adopting the phenomenological design.

Table 2. Research questions

Questions	
1	What are people-related factors that contribute to UAV accidents?
2	What are environmental factors that contribute to UAV accidents?
3	What are the mission-related people actions that contribute to UAV accidents?
4	What are the resources-related factors that contribute to UAV accidents?
5	What are the consequences of UAV accidents?

3.1. Data collection method and sample

The document review method was used for data collection in this research. In qualitative research, when direct observation and interviews are impossible, important written and visual materials relevant to the research problem can be used as sources of information. Document review offers advantages in terms of saving the researcher time and money, allowing for a longer study period, allowing for the desired sample size, and providing high-quality documentation (Yıldırım and Şimşek, 2018). In this context, to access UAV accident reports suitable for the research purpose and to determine the research sample, institutional databases related to aircraft accidents from international (ICAO, EASA) and national aviation authorities (FAA, Transport Canada, CAA), commercial aviation organizations (IATA, NTSB), and aviation websites (Skybrary) were first examined. After extensive investigation, civil UAV accident reports suitable for research purposes were found on a website (<https://www.gov.uk/aaib->

reports?aircraft_category%5B%5D=unmanned-aircraft-systems&page=2).

Data for the study was collected by reviewing official accident reports prepared and published by the *Air Accidents Investigation Branch (AAIB)*, a division of the UK Government, available on this website. The AAIB investigates civil aircraft accidents and serious incidents within the UK, its overseas territories, and crown dependencies. These brief official accident reports, often several pages long, provide a wealth of data, including the technical specifications of the UAV that caused the accident, the time and environmental conditions when the accident occurred, the UAV pilot's basic competencies (flight hours, training, age, etc.), the accident process and photographs, the manufacturer's and legal authorities' assessment, the consequences of the accident, the necessary safety measures, and the source of the accident data. Unlike other aircraft accident reports, the fact that accident reports are not as long and lack detailed information may pose limitations in terms of data source. However, because the reports are prepared by an official authority and provide basic data appropriate to the research purpose, the data source is considered valid and reliable in terms of quantity and quality. Since the research data is based on accident reports on a publicly available corporate website, no ethics committee permission was obtained for the research.

The UAV accidents were selected using a purposive sampling method. Purposive sampling allows the researcher to select participants or study areas (documents, visual materials, etc.) that best provide an understanding of the research problem (Creswell, 2017). The sample size was determined using the saturation point method, one of the methods used to determine sample size in qualitative research. According to the saturation point method, data collection should be stopped when themes in qualitative research reach saturation and no new perspectives emerge from the collection of new data (Creswell, 2017). In this context, 85 civilian UAV accidents that occurred in the United Kingdom between 2015 and 2025, excluding military operations, in various missions and geographic regions (aerial, commercial, training, police operations, etc.), were included in the sample. The sample size was considered adequate for the research purpose.

3.2. Data analysis method

The data obtained in the study were analyzed using content analysis, a method frequently used in qualitative research. The primary purpose of content analysis is to summarize and interpret the data collected for the purpose of the research using an inductive and descriptive approach, to uncover unnoticed codes, categories, and themes through in-depth processing, and to organize and interpret these in a way that the reader can understand (Yıldırım and Şimşek, 2018). To address the primary objective of the study, which was to examine the human factors that contribute to UAV accidents, a mixed approach encompassing both deductive and inductive approaches was employed for content analysis. Deductive reasoning is reasoning from the general to the specific, while inductive reasoning is reasoning from the specific to the general, or from the part to the whole (Sarılı and Özsoy Somuncuoğlu, 2024). First, a general framework was established using the PEAR model within the deductive approach, guiding the content analysis. The dimensions

constituting the PEAR model (People, Environment, Actions, and Resources) were identified as four main themes. Codes were then generated from specific pieces of data that supported these themes, formed a meaningful whole within themselves, and contributed to UAV accidents. Before creating the codes, the researcher read the dataset several times and took notes. During the coding process, the researcher consulted with UAV, aviation, and qualitative research experts. The resulting codes were then used an inductive approach to generate categories and subthemes. The codes, categories, and subthemes resulting from the content analysis were grouped under relevant themes. The other aim of the study, the consequences of UAV accidents, was examined under a separate theme using an inductive approach. In each theme analysis, statistical information regarding accidents related to that theme is presented first, followed by a thematic analysis, followed by the researcher's comments on that theme and sample accident findings. The discussion and conclusion section discusses the results of the research, and offers recommendations for both UAV pilots and the aviation industry.

3.3. Validity and reliability

This qualitative study employed the following approaches to ensure validity and reliability: The research method, data source, process, and results were clearly and thoroughly described, allowing for further evaluation by another researcher. The research sample was selected using a purposive sampling method. Depth-oriented data was collected through extended interaction with UAV accident reports, the data source for the study, and the raw data was retained for further review. The codes, categories, and subthemes that emerged from the raw data were presented descriptively, without any interpretation. The opinions of experts in aviation management and qualitative research were sought regarding the research topic and process, and adjustments were made based on their feedback (Creswell, 2017; Yıldırım and Şimşek, 2018). Furthermore, a triangulation technique was used to enhance the reliability of the data and enrich the data source. In this context, data obtained from accident reports were comparatively evaluated based on the opinions of UAV training experts and civilian UAV pilot license holders. Both thematic and quantitative analyses and graphs were used in the data analysis to perform method triangulation (Sıgı, 2021).

4. Findings and Analysis

The four themes (People-related factors, Environment-related factors, Actions-related factors, Resources-related factors) that emerged from the content analysis conducted using the PEAR model to examine the human factors that cause UAV accidents, and the fifth theme, which reveals the consequences of UAV accidents, are presented below, respectively.

4.1. Theme 1: People

Before examining people-related factors as a cause of UAV accidents, descriptive statistics obtained from accident reports regarding UAV pilots, the most important people contributing to these accidents, are presented in Table 3.

Table 3. Age groups and flight times of UAV pilots

Flight Times (Hour)	Pilot Age									Total
	15-20	21-24	25-29	30-34	35-39	40-44	45-49	50-54	55+	
Less than 10			2	1	3	1	3			10
11-20		1		3	2	4	1	3		14
21-40			1	5	2		3	1	4	16
41-60				1	1		1			3
61-80				2	1	1				4
81-120		1			1	1	2	1	1	7
121-150							1		1	2
151-200			1	1				1		3
201-400	1		1	1	1			1	1	6
401-1000				1	1		1	1		4
1001-2000				2	3			1		6
2000+								1	1	2
Total	1	2	5	17	15	7	12	10	8	77
%	1%	3%	7%	22%	19%	9%	16%	13%	10%	100%

Note: 77 UAV pilots with known age and flight hours were evaluated.

An examination of Table 3 reveals that UAV pilots fall into different age groups and have varying flight hours. When examining the pilots' ages, the majority are between 30 and 50, with slightly fewer pilots over 55 and under 30. The fact that the majority of pilots are not elderly can be considered an advantage against potential adverse physical and physiological factors that may arise during flight. When examining flight hours, 13% of pilots have less than 10 hours of flight experience, and more than half (52%) have less than 40 hours. Furthermore, approximately 10% of pilots have more than 1,000 hours of flight experience. In general, pilots can be considered to have limited flight experience. Human factors contributing to UAV accidents are presented in the Table 4.

Table 4. People-related factors

Categories	Codes	Frequency	%
Psychological	Lack of Situational Awareness	10	91%
	Lack of Training and Experience	9	
	Time Pressure	2	
Physiological	Fatigue	2	9%
	Total	23	100%

When Table 4 is examined, it is seen that psychological and physiological factors cause UAV pilots to make mistakes, but physical and psychosocial factors do not.

Psychological factors

Lack of situational awareness has been found to be the most common psychological factor causing pilots to make mistakes. A lack of situational awareness can be defined as the inability to consider or foresee all the consequences of an action (Dupont, 1997). The second major psychological factor contributing to UAV accidents has been found to stem from the lack of training and experience of pilots and other UAV crew members. This lack of training is typically due to a lack of refresher training after basic UAV training or insufficient flight experience. Data analysis revealed that two accidents were caused by individuals operating UAVs without any training or experience and operating unlicensed UAVs. Although a low contributing factor, time pressure is one of the psychological factors contributing to UAV accidents. Data

regarding accidents caused by lack of situational awareness, lack of training, unlicensed flight, and time pressure are as follows, respectively.

"During an autonomous flight to inspect a construction site, the UAV struck a crane and was damaged. The cause of this accident was the pilot's failure to notice the addition of a new crane to the construction site, which had previously been flown." (3DR Solo, 43 years, 112 flight hours, Kemsley Mill, 2017)

"The UAV was being flown over a quarry in a rural area to support a police search operation. The pilot, noticing fog during the flight, attempted to command the UAV back to its takeoff point but was unsuccessful. The UAV, which lost control, was recovered undamaged at another location the next day. The accident investigation revealed that the pilot had not received refresher training after completing basic flight training, resulting in a lack of training." (Parrot Anafi USA, 49 years, 3 flight hours, Oxfordshire, 2020).

"The UAV was being flown by a student at a university for research purposes. This was the UAV's first flight, and the student had neither a license nor UAV training. After three minutes of flight, the student, trying to increase the UAV's altitude, gave the wrong command, causing the UAV to crash into a wall. At the time of the accident, the student did not know which mode the UAV was operating in." (DJI Mavic 2 Pro, 28 years, 0 flight hour, Liverpool, 2023)

"During a film shoot where a large group of actors were performing in close proximity to UAV, the pilot was forced to move quickly to film consecutive action scenes. Therefore, the pilot's time pressure was considered a significant cause of the UAV accident. In this accident, one of the actors was struck by the UAV's propellers." (DJI Inspire 2, 53 years 6000 flight hours, Mid Glamorgan, 2020)

Physiological factors

Fatigue has been found to be the only physiological factor contributing to UAV pilot errors. In two accidents, physiological fatigue, resulting from the workload experienced by the pilots, was identified as a significant contributing factor. Data regarding one accident in which fatigue was a key factor is as follows:

"During a commercial test operation, the UAV crashed shortly after takeoff because the pilot inadvertently turned off the radio control transmitter before the automatic flight control system was activated. Because the UAV pilot and his crew had been flying for long hours over the past few days,

fatigue was considered a significant cause of this accident.” (Believer UAS, Unknown, Unknown, Hampshire, 2020).

4.2. Theme 2: Environment

Because the vast majority of UAVs examined in this study are structurally quite small and lightweight compared to other aircraft, they are likely to be affected by environmental conditions during flight. Therefore, before examining the environmental factors that cause accidents, presenting descriptive statistics about the environmental conditions in which accidents occur can help understand their causes. Descriptive statistics for environmental conditions are presented in Tables 5 and 6.

An examination of Table 5 reveals that 82% of accidents occurred during the midday and morning hours, when daylight and visibility are better. 18% of accidents occurred at night and in the evening, when visibility is limited. A comparison by month reveals that, while there is no striking difference, accident rates are slightly higher in February, April, June, July, and August.

Table 5. Distribution of UAV accidents by month and time of day

Mounths	Time of Day				Total
	Morning	Noon	Evening	Night	
January	2	3		1	4
February	2	5		1	8
March	1	4	1	1	7
April	2	6		2	10
May	1	3			4
June	2	4	1	1	8
July	3	5		1	9
August	2	3	1	2	8
September		6	1		7
October	2	5			7
November		4		1	5
December		5		1	6
Total	17	53	4	11	85
%	82%		18%		100%

Table 6. Classification of UAV missions

	Mission Type						Total
	Emergency Service Mission	Non-Commercial Aerial Work	Commercial Aerial Work	Private Flight	Training and Test Flight	Fault Test Flight	
Police Operation	6						6
Construction Site Inspection		5	1				6
TV and Movie Shooting		2					2
Sports Events		1	1				2
Industrial Zone Monitoring	1						1
Fire Watch	2						2
Search and Rescue	1	3	1	1			6
Demonstration Flight			2	2			4
Research Mission		1	1	1			3
Tourist Area Photography			2				2
Aerial Photography		1					1
Residential Area Monitoring		2					2
Coastline Scanning		1					1
Ship Inspection		1	1				2
Maritime Surveillance Mission			2				2
Forest and Nature Surveillance			2				2
Railway Line Monitoring			1				1
Other	9	4	7	5	8	6	39
Total	19	22	21	9	8	6	85
%	22%	26%	25%	11%	9%	7%	100%

Note: The content of the UAV missions in the other group is not specified in the accident reports.

An examination of Table 6 reveals that 73% of UAV missions consist of emergency services and commercial and non-commercial aerial work; 27% are for training, private operations, and testing purposes. In this context, it can be said that environmental conditions vary depending on the UAV mission. For example, physical environmental conditions are more variable in police operations, search and rescue, and maritime and ship missions; missions such as film shoots, demonstration flights, and sporting events require more

people; and missions such as construction, nature, and forest surveillance involve more congested and intense physical conditions.

Table 7. Environment-related factors

Subtheme	Categories	Codes	Frequency	%
Physical Environment	Weather Conditions	Windy weather	9	35%
		Rainy weather	7	
	Visibility	Night conditions	7	24%
		Cloudy and foggy weather	3	
		Visibility limitation due to sun	1	
	Structure of the Physical Environment	Complex and busy work environment	7	28%
		Variability of environmental conditions	2	
		Magnetic field interference	2	
		Signal jamming devices	1	
		Presence of wildlife (Seagull attack)	1	
Social Environment		Children's interest in UAVs	2	9%
		Crowded people	2	
Organizational Environment		Commercial/operational pressure	2	4%
Total			46	100%

Environment-related factors affecting UAV accidents are examined under three different sub-themes: physical, social and organizational environment, as seen in Table 7.

Physical environment

The physical environmental conditions that contribute to UAV accidents have been examined under three categories: weather conditions, visibility, and the structure of the physical environment. An examination of weather-related factors revealed that windy and rainy weather are two significant environmental factors that significantly affect UAVs flight performance. In addition to wind, precipitation patterns such as rain and snow have been found to be the root cause of some accidents, while contributing factors in others. Windy weather conditions can cause problems such as drift, loss of control, and weak signal signals in UAVs with their relatively small structures. Rainy weather can cause failures, particularly of electronic UAV components such as engines and ESCs. Data regarding two accidents caused by windy and rainy weather are as follows:

"A UAV flying over a residential area at night was exposed to winds exceeding the manufacturer's specified limits. Consequently, the UAV experienced signal loss and failed to comply with the pilot's 'return home' command. It was unable to maintain its position, drifted due to the wind, and crashed into a tree." (Aeryon Skyranger R60, 33 years, Unknown, London, 2018).

"A small UAV was flying to test a water leakage fault in its camera after a flight the previous day. Visibility was good, wind speed was 16 mph, but the weather was lightly raining. After flying for five minutes at an altitude of 390 ft, the UAV fell vertically to the ground and disintegrated. The manufacturer's inspection determined that the failure was most likely due to water ingress into the number 2 engine ESC." (DJI Matrice 210, 39 years, 38 flight hours, Somerset, 2018).

An examination of factors related to visibility revealed that nighttime conditions with limited visibility, cloudy and foggy weather, and sun-related factors all contributed to accidents by limiting the performance of UAV pilots and other crew members. Data regarding an accident caused by cloudy weather is as follows:

"A remotely controlled glider flying in uncontrolled airspace collided with a small aircraft at an altitude of 630 ft and sustained serious damage. During the accident investigation, the pilot stated that he did not realize how high or large the model glider was flying, and that the gray cloud cover made it difficult to see the glider." (Valenta Ray X, S037996, 59 years, 3000 flight hours, Worcestershire, 2015).

When factors related to the physical environment are examined, it is seen that the complex, congested, and variable nature of the physical environment limits both UAV flight routes and pilot performance, leading to accidents. UAV missions become particularly difficult in environments with tall buildings, construction sites with high-rise equipment (cranes), high-traffic equipment, and ship and sea missions, as well as environments with variable weather conditions (waves, shaky ground, etc.). Furthermore, magnetic field interference, particularly from high-voltage wires or other sources, signal jamming devices used for various purposes, and the presence of wild animals have been observed as other environmental factors contributing to UAV accidents. Data from three accidents related to the physical environment is as follows:

"During a photography mission over a construction site, the UAV became unstable. The pilot attempted to land the UAV immediately using remote control, keeping it away from obstacles created by tall buildings. However, the UAV became uncontrollable and crashed into a concrete structure, sustaining severe damage. The accident report identified weak signal and compass errors as the primary cause of the accident, but the surrounding high-rise and dense construction was considered a significant environmental factor contributing to the accident." (DJI Inspire 2, 39 years, 1000+ flight hours, London, 2020)

"Shortly after takeoff during an aerial inspection of a bridge over a railway line, the UAV, operating in GPS mode, began to drift away from the pilot and descend rapidly and uncontrollably. The UAV struck vegetation next to the railway, crashed, and sustained damage. The accident investigation determined that the magnetic field generated by high-voltage wires in the vicinity affected the UAV's compass, causing the accident." (Aerialtronics Altura Zenith ATX8, 39 years, 466 flight hours, Gloucestershire, 2019)

"The UAV was being operated commercially for a roof survey of a high-rise building in a residential area. While the pilot was manually flying the UAV, a seagull attacked the 6.14 kg UAV, causing it to crash onto the roof." (DJI Matrice M200, 62 years, 95 flight hours, Galloway, 2020).

Social environment

The social environment factors contributing to UAV accidents have been assessed as the environment created by the people in the area where UAV missions are conducted. The number of people in the social environment, their behaviors, mobility, and their interactions with UAVs have been shown to directly and indirectly contribute to accidents. The risk of accidents has been observed to increase particularly in social environments with large crowds, such as film shoots, demonstration flights, and sporting events. Data from two accidents related to a child's interest in UAVs and the mobility of actors during a film shoot are as follows:

"One of the children attempted to catch a UAV flying at low altitude near a group of children over a park. When the child's hands touched the engine rotors, the UAV lost its balance and quickly lost altitude. As a result of this incident, the children sustained minor injuries." (DJI Air 2S, 45 years, 15 flight hours, Nottinghamshire, 2022).

"During a movie shoot, a large group of actors riding horses were moving in a specific direction. A UAV was flying

close to the actors to film. One of the actors suddenly and unexpectedly changed direction and struck one of the UAV's propellers, sustaining a minor neck injury." (DJI Air 2S, 53 years, 6000 flight hours, Mid Glamorgan, 2020).

Organizational environment

Compared to the core operations of the aviation industry (flight, air traffic, aircraft maintenance, and ground handling), which are conducted within an organizational environment, UAV missions are conducted in an open area rather than within an organizational setting, and are generally conducted by a single pilot or, in some cases, a crew. Therefore, organizational factors such as corporate culture, inter-crew relationships, and organizational size can be difficult to discern in UAV missions. In this context, it has been observed that the operational pressure experienced by the UAV crew due to commercial concerns or profitability is the only indirect factor contributing to UAV accidents. Data from an accident where commercial concerns contributed are as follows:

"A low battery warning occurred at an altitude of 50 meters on a commercially operated UAV used to record boat races. As the UAV returned to its starting point, its battery level dropped significantly, causing damage by striking a boat in the river. While the low battery was the primary cause of this accident, there were also contributing factors. During the intensive filming, the pilot's desire to film more due to commercial concerns and fatigue distracted him, and he neglected to check the battery charge levels before the flight." (Alta X, 53 years, 831 flight hours, Oxfordshire, 2022)

4.3. Theme 3: Actions

Actions that lead to UAV accidents include actions that must be executed correctly, in a specific order and at a specific time, by the pilot to ensure safe and secure flight during UAV missions. The actions that lead to UAV accidents presented in the Table 8 are examined under two categories within the PEAR model: pre-flight actions and in-flight actions.

Table 8. Actions-related factors

Categories	Codes	Frequency	%
Pre-flight Actions	Lack of pre-flight inspection and maintenance	13	70%
	Inadequate risk assessment	6	
	Incorrect flight program	3	
	Failure to observe maximum takeoff weight	2	
	Inadequate pre-flight briefing	1	
In-flight Actions	Incorrect decision and command making	5	30%
	Late reaction	2	
	Failure to comply with flight procedures	2	
	Pilot disregards observer's warning	1	
	Lack of communication between pilot, camera operator, and observer	1	
Total		36	100%

Pre-flight actions

As with all aircraft, for a safe and secure flight mission, certain actions and checks must be performed before a flight to verify the UAV's airworthiness. These actions primarily include structural inspections of the UAV's airframe and components, as well as checking maintenance records. Furthermore, preparing a flight program appropriate to the environment in which the mission will be conducted,

conducting a risk assessment, and conducting an internal briefing of the UAV crew before the flight are critical actions for flight safety. Analyzing the findings in Table 8 reveals that inadequate or incorrect pre-flight checks and maintenance by UAV pilots is the most common cause of accidents. Failure to fully assess the risks inherent in the physical or social environment in which the flight mission is conducted, and therefore creating an incorrect flight program, are two other significant factors contributing to accidents. Failure to observe the UAV's maximum takeoff weight before the flight and inadequate briefings regarding the mission are among other actions that contribute to accidents. Data from two accidents, in which inadequate pre-flight inspections and failure to observe maximum takeoff weight contributed, are as follows:

"The UAV was conducting a fire surveillance mission in a brushy area. The pilot followed a standard pre-flight checklist to ensure the UAV was ready for flight. Two successful missions were conducted, and the battery was replaced before each flight. Four minutes after the third mission, the UAV suddenly began to pitch and fall due to a broken propeller. The accident investigation revealed that the UAV crew failed to detect the damaged propellers due to inadequate inspections before starting the third mission." (DJI Inspire 2, 33 years, 76 flight hours, Surrey, 2019).

"A small UAV equipped with optical and thermal cameras was operating in a congested area during a police operation. After reaching an altitude of 260 ft, the UAV remained stationary for approximately 10 minutes. The UAV then began to rotate, and an "engine overload" message appeared on the screen. The UAV then descended rapidly, crashed in an open area, and disintegrated. The accident investigation concluded that the weight of the thermal cameras placed additional load on the engine." (DJI Matrice 210, 43 years, 100 flight hours, Norfolk, 2019).

In-flight actions

Actions in this category encompass the erroneous actions taken by the UAV pilot, but also by other crew members, after the UAV's mission has begun. Incorrect decisions and commands made by UAV pilots during flight have been found to be a significant contributing factor to accidents. Pilots often lacked the opportunity to correct these erroneous decisions and commands, making accidents inevitable. Furthermore, late reactions to changing environmental conditions and instantaneous error messages from the UAV, acting outside of flight procedures, and the UAV pilot's lack of communication with other flight crew members have been identified as erroneous actions that contributed to accidents. Data from two accidents caused by erroneous commands and delayed reactions are as follows:

"During a search and rescue mission to find a missing person, the UAV pilot saw a message on the control screen he didn't recognize. He didn't realize the message was a warning and attempted to delete it. While attempting to delete the message, the pilot issued an erroneous command, activating the emergency cut-off function. This erroneous command caused the UAV's engines to stall and it to plummet from 70 feet into the lake." (Aeryon Sky Ranger R60, 33 years, 6 flight hours, West Sussex, 2020).

"The UAV pilot was tasked with searching for a missing person in the drainage system. After setup and pre-flight checks, the UAV began flying over the search area. The UAV's collision avoidance system activated as it approached the water, and it moved away from the water channel. To prevent the UAV from contacting some tree branches above the drainage system, the pilot delayed changing his flight path and didn't correct the route in time. This late reaction by the pilot

caused the UAV to crash into the water.” (DJI Matrice 100, 53 years, 15 flight hours, Hull, 2019).

4.4. Theme 4: Resources

Within the PEAR model, resource-related factors presented in Table 9 contributing to UAV accidents were examined

under two headings: technical issues and inadequate human and procedural resources. Findings revealed that the vast majority of factors contributing to accidents were technical issues, while factors related to lack of human and procedural resources were limited.

Table 9. Resources-related factors

Subtheme	Categories	Codes	Frequency	%
Technical Problems	Battery	Low battery level	6	97%
		Battery not fully inserted/locked into the fuselage	6	
		Incorrect battery charge status and software	5	
		Battery and power circuit connection problems	2	
		Abnormal battery discharge	2	
	Engine	Engine malfunctions	6	
		Motor support arms not locking	3	
		Crack at engine connection points	1	
		Fuel pump malfunction	1	
	Propeller	Propeller damage or breakage	6	
		Propeller failure due to material fatigue	3	
	Signal and Compass	Signal loss due to weather or unknown causes	6	
		Compass failure due to magnetic field and signal interference	3	
	ESC	ESC failures due to overload, long-term use, and thermal	5	
		ESC failure due to water leakage and moisture	2	
	Software	Autoflight software errors	3	
		Other software errors	1	
	Parachute	Improper installation of parachute system to fuselage	1	
		Improper maintenance of parachute system	1	
		Parachute deployment due to sudden power loss	1	
	Other	Antenna failure	1	
		Non-standard and unsafe structural and software design	1	
		Inadequate obstacle avoidance system	1	
Lack of human and procedural resources		Lack of emergency procedures	1	3%
		Lack of observer	1	
Total			69	100%

Technical problems

While the fuselage and components of UAVs consist of different mechanical and electronic components, they also require different software to perform flight missions. Technical factors such as fuselage structure, engine type and number, payload capacity, and equipment vary depending on the scope of the mission. Before examining the technical problems that lead to accidents in this context, descriptive statistics regarding the fuselage and engine type of UAVs are presented in Table 10.

An examination of Table 10 reveals that the majority of UAVs involved in accidents were rotary-wing (84%) and electric-powered (88%). Other engine options are less common with fixed-wing and helicopter UAVs. Rotary-wing UAVs are more commonly used than other UAV types due to their use of electric engines, lack of a runway for takeoff, vertical takeoff, ease of maintenance, and affordability. The classification of UAVs using electric engines is presented in Table 11.

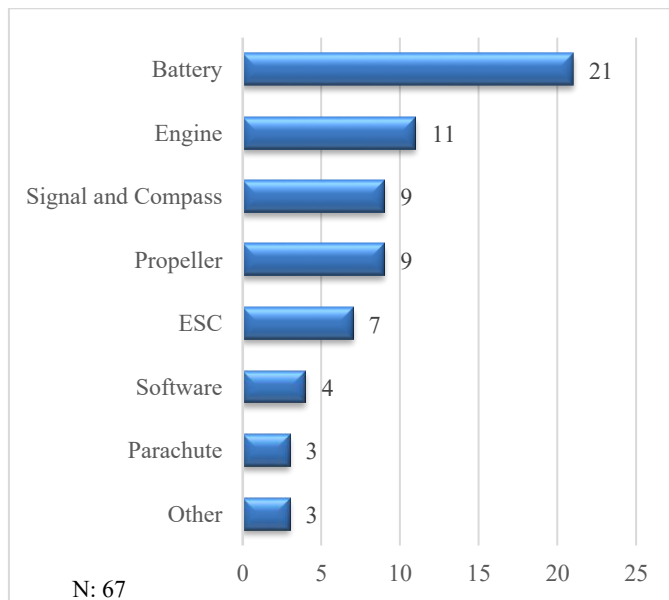
Table 10. UAV’s fuselage structure and engine type

Engine Type	Fuselage Structure			Total	%
	Rotary Wing	Fixed Wing	Helicopter		
Electric Engine	71	3	1	75	88%
Pistone Engine		7		7	
Turbine Engine		1		1	
Wankel Engine			1	1	12%
Non-Engine (Glider)			1	1	
Total	71	11	3	85	100%
%	84%	14%	2%	100%	

Table 11. Classification of UAVs using electric engines

Number of Electric Engines	Fuselage Structure			Total	%
	Rotary Wing	Fixed Wing	Helicopter		
1		2	1	3	4%
2	1	1		2	3%
4	62			62	83%
5	1			1	1%
6	3			3	4%
8	4			4	5%
Total	71	3	1	75	100%
%	95%	4%	1%	100%	

An examination of Table 11 reveals that the majority (95%) of UAVs using electric engines are rotary-wing, and most of these UAVs (83%) have four engines. A classification of technical problems by UAV component is presented in Figure 1.

**Figure 1.** Classification of technical problems

Battery

According to Figure 1, the majority of the 67 technical issues (31%) that caused electric UAV accidents are related to battery problems or malfunctions. Because batteries are the energy source for electric UAV engines, charging problems such as undercharge or incorrect charging, software errors, and abnormal discharge are among the most common technical problems encountered in UAV accidents. Furthermore, other technical problems that contribute to accidents include battery displacement from the UAV body due to lack of pre-flight inspection or weather and mission conditions during flight, battery failure to lock into the body, and battery connection failures to the power units. Data from an accident caused by a battery problem is as follows:

“During a demonstration flight, despite the battery being fully charged, the UAV’s electric engines stalled due to a loss of power, and it plummeted to the ground from a height of 50 meters. The UAV was destroyed in the resulting fire. Following the accident investigation, the UAV manufacturer determined that the power loss was due to the battery not being properly locked into the UAV body.” (Evolve Dynamics Sky Mantis, 27 years, 7 flight hours, Somerset, 2019)

Engine

Engine-related problems are the second most common technical cause of UAV accidents after battery problems (16%). In electric UAVs, failures in electronic components such as batteries or ESCs, and sometimes unknown causes, trigger engine failures. Furthermore, engine-related technical problems that contribute to UAV accidents include the failure or cracking of the arms connecting the engines to the fuselage, and failure of mechanical components in piston engines. Data from an accident caused by engine failure is as follows:

“The UAV was being operated by police on a training mission. Weather conditions were normal before takeoff, and the pilot performed pre-flight checks and took the UAV to an altitude of 300 ft. During the flight, rain began to drizzle. Approximately five minutes later, while repositioning, the UAV suddenly began to spin and crashed to the ground. The accident investigation determined that engine number 3 had failed.” (DJI Matrice 210, 26 years, 57 flight hours, Leicester, 2018).

Propellers

Propellers are essential aerodynamic components necessary for UAV flight. Propeller damage and failures, resulting from various causes such as maintenance errors, material fatigue, and structural cracks, have been observed to lead to accidents. Data from an accident caused by propeller damage is as follows:

“While the UAV was performing a demonstration flight at an altitude of 200 feet, an abnormal noise was heard. The pilot then lost control, and the UAV turned and began to descend rapidly. The UAV sustained serious damage when it hit the ground. The accident investigation determined that the bolt securing the propeller had failed due to material fatigue, causing the propeller to become dislodged.” (Avy Aera 1.5, 34 years, 1784 flight hours, Isle of Arran, 2021)

Signal and compass

Signal loss and compass errors during UAV missions due to unusual weather conditions, unknown causes, and magnetic field interference are among the major technical problems that contribute to accidents. The majority of signal losses are due to unknown causes. However, windy, rainy, and overcast weather conditions, magnetic field interference from high-voltage wires, and signal jamming devices have been shown to cause both signal loss and compass errors. Data from an accident caused by compass failure is as follows:

“The UAV was flying in automatic flight mode to inspect a construction site. During this time, the UAV experienced a compass error, and the pilot attempted to manually control the UAV and return it to its starting point. However, the UAV did not respond to the pilot’s command and, due to the wind, crashed into the roof of a house. The accident investigation determined that the UAV’s compass was in error due to signal interference.” (DJI M600 Pro, 31 years, 44 flight hours, Tyne and Wear, 2019).

ESC

The ESC is the electronic component that controls the electric current required for motor operation in electric UAVs. UAVs operating above maximum takeoff weight and for extended periods, as well as water leaks during rainy weather, have been identified as the primary causes of ESC failure. ESC failures can cause accidents on their own, but they can also trigger motor failures indirectly. Data from an accident caused by an ESC failure is as follows:

“A UAV operating on an emergency mission crashed vertically into the roof of a building at a height of 50 meters

while hovering above it, despite its batteries having sufficient charge. The accident investigation determined that the cause of the loss of lift and control of the UAV was a failure of the number 4 motor ESC." (DJI Matrice 210, 38 years, 6 flight hours, West Midlands, 2018).

Software

UAVs consist of various mechanical and electronic components and also utilize software with various functions for safe flight. Pilots can remotely control UAVs thanks to this software. Findings indicate that auto flight software issues, in particular, are contributing factors to accidents. Data from an accident caused by an auto flight software error is as follows:

"The UAV was flying for testing after the malfunction was fixed. After a certain amount of flight time, when the pilot switched the UAV to auto flight mode, the auto flight software over-throttled the UAV and was slow to correct the issue, resulting in the UAV crashing and sustaining severe damage." (UAS Malloy Aeronautics T005, 33 years, 77 flight hours, Berkshire, 2024).

Parachute

Parachute systems used to rescue UAVs in emergencies have been observed to contribute to accidents by deploying due to reasons such as faulty installation, excessive vibration during flight, or sudden loss of power. Data from an accident caused by a parachute system is as follows:

"The UAV was flying on its fifth mission of the day for commercial aerial research. Flying in automatic flight mode at an altitude of 100 meters, the UAV's parachute system deployed, and the UAV descended under its parachute and landed on the roof of a house. The accident investigation determined that the parachute system was most likely incorrectly installed on the UAV's fuselage, causing excessive vibration and triggering the parachute system to deploy." (DJI Matrice 200 V1, 39 years, 86 flight hours, Montrose-Angus, 2018).

Other

Other technical problems, such as antenna failure, non-standard and unsafe designs, and inadequate obstacle avoidance systems, have been found to contribute to UAV accidents. Data from an accident caused by an inadequate obstacle avoidance system is as follows:

"The UAV, operating at night in dry, clear weather, was flying within the pilot's line of sight. Shortly after the pilot initiated a right turn, the UAV crashed into a tree. The accident investigation revealed that the UAV's obstacle avoidance system could only detect objects approaching in front of it and could not detect obstacles on the other sides." (DJI Matrice M210 V2, 49 years, 9 flight hours, Ludlow, 2020).

Lack of human and procedural resources

Compared to technical issues, lack of human and procedural resources was found to contribute to accidents only slightly and indirectly. In one accident, a lack of emergency procedures contributed to the accidents, while in another, a lack of observers contributed. Data from an accident where the absence of observers contributed is as follows:

"The pilot was conducting a UAV mission without an observer to inspect a construction site. Shortly after takeoff, the pilot's attention was drawn to two messages on the control screen. One message indicated that the UAV had lost heading reference due to magnetic field interference, and the other indicated that its battery charge was low. Although the pilot manually commanded the UAV to return to its starting point,

the UAV did not comply due to the weak signal and drifted in a congested area, landing on a tree. While the causes of the accident were attributed to technical problems, the pilot noted that it would have been beneficial to have an observer present during the operation to prevent losing visual contact when distracted by messages on the control screen." (DJI Phantom 4 Pro, 58 years, 40 flight hours, Warwickshire, 2021)

4.5. Theme 5: Consequences of UAV accidents

Of the 85 UAV accidents examined as part of the research, it was observed that most caused material damage to the UAV fuselage and its components; furthermore, a limited number of accidents caused damage to people and vehicles in the vicinity. The consequences of the accidents on the UAV fuselage and its components are presented in Figure 2

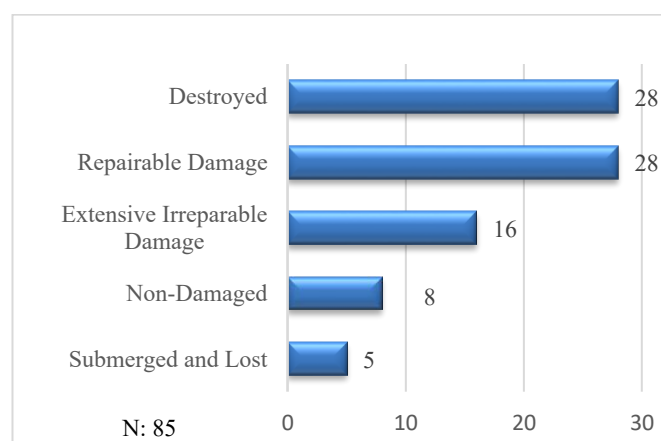


Figure 2. Consequences of accidents

An examination of Figure 2 reveals that a small number of accidents (9%) resulted in no damage, while the majority resulted in destruction, severe damage, or repairable damage. However, in more than half of the accidents (52%), UAVs were either completely destroyed or severely damaged, rendering them unusable. Some UAVs flying over sea or water were damaged or lost due to accidental submersion. Statistics of damaged parts in UAV accidents resulting in repairable damage are presented in Figure 3.

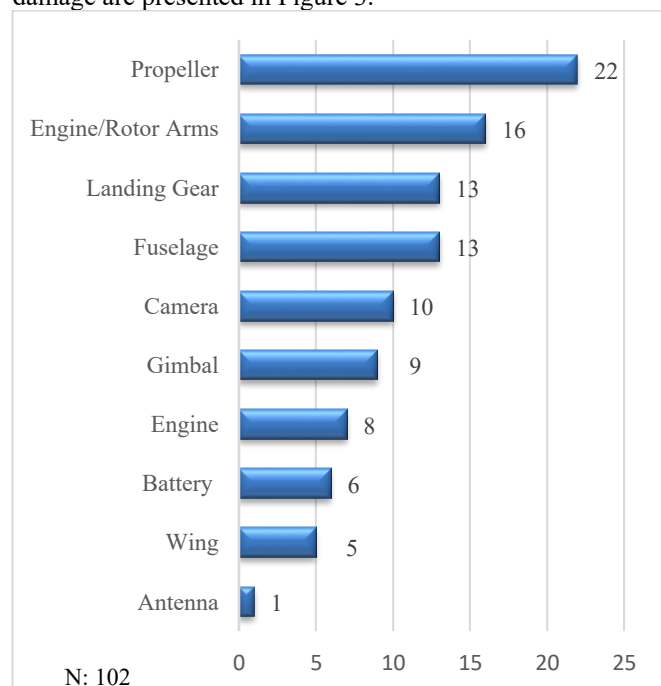


Figure 3. Statistics of damaged parts in UAV Accidents

An examination of Figure 3 reveals that the propellers, followed by the arms connecting the engines to the fuselage, sustained more damage than other components. The high-speed rotation of the propellers, coupled with their kinetic energy and the fact that the engine arms are located on the outer perimeter of the fuselage, may be the reasons for their greater damage in accidents. Overall, damage to the fuselage and landing gear was equal, while camera and gimbal damage was similar. Engine, battery, wing, and antenna failures were found to be relatively minor compared to other component damage.

5. Discussion and Conclusion

Rapid technological advancements have made UAVs widely used tools in both military and civilian environments. UAVs are used in many commercial and non-commercial missions in civilian areas, such as search and rescue, aerial photography, surveillance, reconnaissance, agricultural spraying, and police operations. While the widespread use of UAVs for various purposes provides numerous benefits for humans, it is also observed that accidents are occurring due to the increasing number of UAV flights. Although UAVs are structurally much smaller than traditional aircraft used in civil aviation, UAV accidents can cause harm to people as well as property damage. Today's UAV accidents are generally caused by technical problems. However, with the advancement of UAV technologies, human factors have become an important cause of UAV accidents and require further research. In this qualitative study, conducted in light of a literature review, the main objective of the research was to examine the human factors that contributed to 85 UAV accidents that occurred in the United Kingdom over the last decade using content analysis within the framework of the PEAR model. As a secondary objective of the research, the consequences of UAV accidents were also examined from various perspectives. Five distinct themes emerged from the content analysis. These themes are as follows: People-related factors, Environment-related factors, Actions-related factors, Resources-related factors and Consequences of UAV Accidents.

An examination of people-related factors (Frequency: 23) contributing to UAV accidents revealed that psychological and physiological factors influence the performance of UAV pilots and contribute to the occurrence of accidents. Compared to physiological factors (9%), psychological factors (91%) were found to be significantly more common causes of accidents. Lack of situational awareness and lack of training emerged as two significant psychological factors. According to Dupont (1997), who proposed the Dirty Dozen model to examine human factors in the aviation industry, particularly in aircraft maintenance tasks, repetitive, routine tasks can eventually lead to problems such as complacency, lack of attention, and a lack of awareness of environmental conditions in experienced aviation personnel. Furthermore, the constantly changing and complex environmental conditions in which UAV missions are conducted can reduce the awareness of pilots and UAV crews. Insufficient flight experience, lack of refresher training, and lack of training in unlicensed flight are among the contributing factors to UAV accidents. Time pressure, although minor, has emerged as a psychological factor contributing to UAV accidents. Time pressure, which increases psychological stress in individuals, occurs when the time required to complete a task is limited. Individuals under time pressure exhibit psychological tendencies such as forgetting important data, misjudging information, filtering

information, and making intuitive decisions (Çoban and Aydoğdu, 2020). Fatigue, the only physiological factor contributing to UAV accidents, stems from the UAV crew's intense, repetitive tasks. Fatigue is a natural response of the human body to prolonged physical and mental stress and energy depletion. Fatigue negatively impacts an individual's decision-making, cognitive abilities, reaction time, coordination, alertness, and attention skills (EASA, 2015).

An examination of environment-related factors (Frequency: 46) contributing to UAV accidents revealed that UAV missions are conducted under different environmental conditions and timeframes depending on their purpose (emergency services, commercial, training, etc.). Environmental factors contributing to accidents were examined under three subthemes: physical, social, and organizational environments. It was determined that the physical environment (87%) was more influential in the occurrence of accidents compared to the social (9%) and organizational environments (4%). Windy and rainy weather, visibility conditions, and the complexity and variability of the physical environment are important physical environmental factors that negatively affect the performance of UAV pilots and contribute to accidents. The fact that one accident resulted from a seagull strike is a particularly striking finding. This finding demonstrates that wildlife and birds pose a significant environmental risk to UAVs, just as they do to conventional aircraft. According to Çoban and Bahar (2018), bird strikes constitute the vast majority (97%) of wildlife-related collisions in the civil aviation sector. Because UAVs are structurally smaller, they can sustain greater damage in bird-related collisions. The actions and behavior of people in the vicinity of UAVs have been a direct or indirect cause of UAV accidents. Children, in particular, may view UAVs as playthings, which can increase their interest in them and lead to unsafe behavior and accidents. Pilots' desire for more footage or business during UAV missions, driven by commercial concerns, has been considered a factor related to the organizational environment that contributes to accidents.

An examination of actions-related factors (Frequency: 36) that led to UAV accidents revealed that the accidents were caused by actions that were not performed or were incompletely performed by UAV pilots and other crew members according to procedures and instructions, but should have been performed according to the mission. Pre-flight erroneous actions (70%) were found to be more common than in-flight actions (30%). Inadequate pre-flight inspections and maintenance were the most common negative actions. Furthermore, inadequate risk assessment, incorrect flight program execution, failure to observe maximum takeoff weight, and inadequate briefings within the crew regarding the mission were the pre-flight actions that contributed to accidents. Incorrect decisions or commands, delayed reactions, failure to comply with flight procedures, and miscommunication between the pilot and flight crew were among the factors that contributed to these accidents during flight. According to Doğan (2009), pressure to achieve specific organizational goals due to commercial concerns, communication conflicts among employees, and overconfidence and arrogance among employees can all lead to a departure from organizational rules and procedures. Furthermore, complacency, resulting from the confidence and satisfaction UAV pilots feel from repeatedly performing similar tasks, can reduce pilots' attention and awareness of hazards (Dekker, 2003; Dupont, 1997), leading to incorrect or inadequate actions.

An examination of the resources-related factors (Frequency: 69) contributing to UAV accidents reveals that

technical resource problems (97%) are significantly more prevalent in UAV accidents than lack of human and procedural resources (3%). Since the majority of UAVs involved in accidents are rotorcraft and electric-powered UAVs, most technical problems are related to these types of UAVs. Battery problems or malfunctions (31%) are the leading technical problems contributing to UAV accidents. Battery problems are followed by engine, propeller, signal and compass, ESC, software, parachute, and other technical issues. Some technical problems have been found to be interconnected. Battery and ESC failures have been found to cause failures in other systems, such as engines and parachutes, in some cases. Lack of emergency procedures and a lack of observers are two factors related to limited human and procedural resources that contribute to UAV accidents.

As a result of the content analysis based on the PEAR model, the factors causing UAV accidents are presented in Figure 4 to create a general framework.

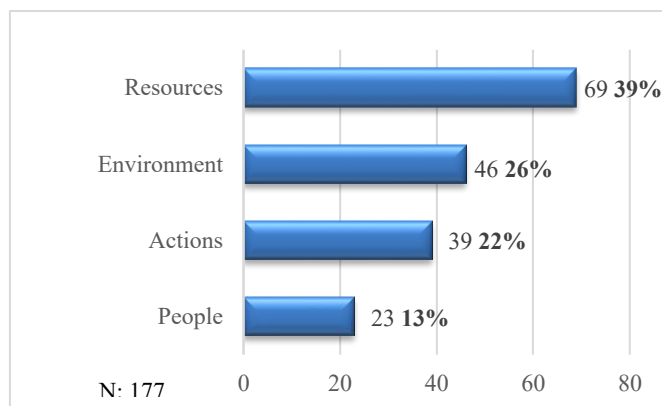


Figure 4. The factors causing UAV accidents

When Figure 4 is examined, a general assessment of the content analysis results of the factors contributing to UAV accidents within the framework of the PEAR model reveals that resources-related factors (39%) are the primary cause of accidents. Technical problems constitute the vast majority of resource-related factors (97%). Environment-related factors (26%) are the second most common cause of accidents. The majority of environmental problems (87%) are factors related to the physical environment. Action-related factors (22%) and human-related factors (13%) are identified as the third and fourth leading causes of accidents. **Both action-related and human-related factors are directly related to the behaviors, skills, decisions, and attitudes of UAV pilots and flight crews. In this context, it can be concluded that a total of these two factors (35%) contributes to UAV accidents as human factors.** Furthermore, factors related to lack of human and procedural resources within the resource dimension, as well as social and organizational factors within the environmental dimension, can also be included under human factors. In this case, the human factor rate in accidents can range from 35% to 40%.

An examination of the relationships between the primary factors contributing to accidents reveals a close relationship between the technological infrastructure of UAVs and environmental conditions. Rainy, windy, overcast, complex, and variable environmental conditions can cause technical problems in UAVs, leading to accidents. Rainy weather, in particular, damages UAVs' electrical components such as ESCs, motors, and batteries; windy weather can cause small UAVs to drift and lose connectivity. Environmental conditions can also cause UAV pilots to make inaccurate assessments of aspects such as visibility, weather forecasting, and risk

analysis. Similarly, a relationship can be argued between UAV technologies and human performance. In some accidents, pilots' inability to follow UAVs' advanced technological infrastructure and warning messages may be a clear example of this relationship. A general assessment of the factors contributing to UAV accidents reveals that technical problems and physical environmental conditions are two significant factors in UAV accidents, while the human factor is increasingly contributing to these accidents.

When the consequences of UAV accidents were examined as part of the second objective of the study, it was found that the majority of accidents (91%) resulted in extensive or repairable material damage, while a minority (9%) resulted in no damage. The most severely damaged components were the propeller, engine arms, landing gear, and fuselage. In addition to material damage, a small number of people were injured in the vicinity of UAV missions, and vehicles and buildings sustained minor damage.

A general review of the research findings reveals findings consistent with recent studies on human factors in UAV accidents (Asim et al., 2010; Özyörük, 2020; Murray et al., 2025). It is believed that these findings will contribute to the literature on human factors in UAV accidents and shed light on future research in this area. The research findings offer some recommendations for UAV pilots, UAV manufacturers, and aviation regulatory authorities. First and foremost, because technical issues remain the dominant factors in UAV accidents, UAV manufacturers should develop designs that specifically consider environmental conditions and human-machine interaction. To classify UAVs of different categories and purposes and address gaps in UAV regulatory regulations, aviation authorities and governments should work in coordination to reach a common ground. Human factors training should be provided in addition to technical training in organizations providing UAV pilot training. Finally, considering that approximately one-third of UAV accidents are caused by human factors, and that this rate is increasing, UAV pilots and other flight crews must adhere to procedures both before and during a mission and be prepared for all potential emergencies. Otherwise, fatal accidents can occur.

Despite the research's contributions to the literature and practitioners, it also has some limitations. These include: The research sample covers only a limited number of accidents in the United Kingdom. Reports of UAV accidents occurring in other countries were not available, and military UAV accidents were excluded. Due to time, space, and financial constraints, interviews with UAV pilots and flight crews were not conducted within the scope of the research. The data source relies solely on the analysis of accident reports, resulting in limited data. In this context, the findings of the research can be generalized by considering the limited number of civilian UAV accidents that occurred in the United Kingdom. To overcome these limitations and reach more general conclusions, accident reports from both military and civilian UAVs from different countries could be examined in conjunction with face-to-face interviews with UAV pilots and flight crews.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Akyürek, İ., and Eraslan, E. (2024). İnsansız hava araçlarında insan hatasının etkilerinin sistematik analizi ve

- sınıflandırılması-İHA tasarımı ve ergonomi. Researcher, 4(2), 157-165.
- Albihn, J. (2022). Human factors in aerial drone operations. Master Thesis, Lund University School of Aviation Faculty of Engineering.
- Asim, M., Ehsan, N., and Rafique, K. (2010). Probable causal factors in UAV accidents based on human factor analysis and classification system. 27th International Congress of The Aeronautical Sciences.
- Avellar, G.S., Pereira, G.A. Pimenta, L.C., and Iscold, P. (2015). Multi-UAV routing for area coverage and remote sensing with minimum time. Sensors, 15(11), 27783-27803.
- Bell, B.G., and Cooke, N.J. (2003). Cognitive ability correlates of performance on a team task. Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting, pp.1087-1091, Denver, CO: Human Factors and Ergonomics Society.
- Çoban R., and Bahar İ. (2018). Havacılık sektöründe yabancı hayatı yönetim üzerine Hamid Karzai Uluslararası Havalimanında (Kabil-Afganistan) bir araştırma. Journal of Aviation, 2(2), 87-104.
- Çoban, R. (2022). Askeri hava aracı kazalarında insan faktörü kavramı üzerine nitel bir araştırma. In: Harmanşah, C. and Hava, H.T., Eds., Havacılık teknolojileri ve uygulamaları kitabı, İzmir, Ege Üniversitesi Yayınları, 39-91.
- Çoban, R., and Aydoğdu, T. (2020). Havacılık sektöründe zaman baskısının teknostrese etkisi: Uçak bakım teknisyenleri üzerine bir araştırma. İşletme Araştırmaları Dergisi, 12(3), 2442-2460.
- Creswell, J.W. (2017). Araştırma deseni nitel, nicel ve karma yöntem yaklaşımları [Research design qualitative, quantitative, and mixed methods approaches]. (Demir, S. B. Çev.) 3. Baskı, Ankara, Eğitilen Kitap Yayın Organizasyon.
- Cummings, M.L., Mastracchio, C., Thornburg, K.M., and Mkrchyan, A. (2013). Boredom and distraction in multiple unmanned vehicle supervisory control. Interacting with Computers, 25(1), 34-47.
- Dekker, S.W.A. (2003). Human factors in aviation - A natural history. Technical Report 2003-02.
- Doğan, N. (2009). İş etiği ve işletmelerde etik çöküş. Sosyal Ekonomik Araştırmalar Dergisi, 16, 179-200.
- Dönmez, K., and Suat, U. (2018). The relationship between flight operations and organizations in aircraft accidents; The application of the human factor analysis and classification system. Anadolu University Journal of Science and Technology A-Applied Sciences and Engineering, 19(2), 316-333.
- Dorling, K., Heinrichs, J., Messier, G.G., and Magierowski, S. (2016). Vehicle routing problems for drone delivery. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 47(1), 70-85.
- Dupont, G. (1997). The dirty dozen errors in aviation maintenance. In meeting proceedings of 11th Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection: Human Error in Aviation Maintenance (pp. 45-49). Washington, D.C.: Federal Aviation Administration/Office of Aviation Medicine.
- EASA, (2015). Module 9, for level B-1 and B-2 certification, human factors. Aviation Maintenance Technician Certification Series.
- Ergai, A. (2013). Assessment of the human factors analysis and classification system (HFACS): Intra-rater and inter-rater reliability. Doctoral Dissertation, Clemson University, South Carolina.
- FAA, (2015). Operation and certification of small unmanned aircraft systems: Notice of proposed rulemaking (Docket No. FAA-2015-0150; Notice No. 15-01). Washington, DC: Author.
- FAA, (2018). Federal Aviation Administration. Aviation maintenance technician handbook-general.
- Fontaine, O., Martinetti, A., and Michaelides-Mateou, S. (2016). Remote pilot aircraft system (RPAS): Just culture, human factors, and learned lessons. Chemical Engineering Transactions, 53, 205-210.
- Genç, Y.M., and Erciyes, E. (2020). İnsansız hava araçları (İHA) tehditleri ve güvenlik yönetimi. Türkiye İnsansız Hava Araçları Dergisi, 2(2), 36-42.
- Giones, F., and Brem, A. (2017). From toys to tools: The co-evolution of technological and entrepreneurial developments in the drone industry. Business Horizons, 60(6), 875-884.
- Grindley, B., Parnell, K.J. Cherett, T., Scanlan, J., and Plant, K.L. (2024). Understanding the human factors challenge of handover between levels of automation for uncrewed air systems: A systematic literature review. Transportation Planning and Technology, 1-27.
- Gupta, A., Afrin, T., Scully, E., and Yodo. N. (2021). Advances of UAVs toward future transportation: The state-of-the-art, challenges, and opportunities. Future Transportation, 1(2), 326-350.
- Hassanalian M., and Abdelkefi, A. (2017). Classifications, applications, and design challenges of drones: A review. Progress in Aerospace Sciences, 91, 99-131.
- Heimann, C.F.L. (1993). Understanding the challenger disaster: organizational structure and the design of reliable systems. American Political Science Review, 87(2), 421-435.
- Hobbs, A. (2010). Unmanned aircraft systems. In: Salas E. and Maurino, D. Eds., Human factors in aviation, 2nd edition, San Diego, Elsevier, 505-531.
- Hobbs, A., and Lyall, B. (2016). Human factors guidelines for unmanned aircraft systems. Ergonomics in Design, 24, 23-28.
- Hobbs, A., and Shively, R.J. (2014). Human factor challenges of remotely piloted aircraft. Report Number: ARC-E-DAA-TN17388, European Association for Aviation Psychology (EAAP), Valletta, Malta.
- Howard, J., Murashov, V., and Branche, C.M. (2018). Unmanned aerial vehicles in construction and worker safety. American Journal of Industrial Medicine, 61(1), 3-10.
- ICAO Doc 9806, (2002). Human factors guidelines for safety audits manual. First Edition.
- ICAO, (2011). Unmanned Aircraft Systems (UAS), Cir. 328, AN/190.
- Johnson, W.B., and Maddox, M.E. (2007). A model to explain human factors in aviation maintenance. Avionics News, April, 38-41.
- Kahveci, M., and Can, N. (2017). İnsansız hava araçları: Tarihçesi, tanımı, dünyada ve Türkiye'deki yasal durumu. Selçuk Üniversitesi Mühendislik Bilim ve Teknoloji Dergisi, 5(4), 511-535.

- Keane, J.F. and Carr, S.S. (2013). A brief history of early unmanned aircraft. Johns Hopkins APL Technical Digest, 32(3), 558-571.
- Macit, A., Özden, M.A., Yavaş, V., and Yeşilay, R.B. (2025). İnsansız hava aracı pilotlarının dijitalleşme ile emniyet bilincinin artırılması: Mobil uygulama örneği. Journal of Aviation Research, 7(1), 18-33.
- MacPherson, E. (2018). Is the world ready for drones? Air Space Law, 43, 149-178.
- Mouloua, M., Gilson, R., and Hancock, P. (2003). Human-Centered Design of. Ergonomics in Design, Winter, 6-11.
- Murray, J., Richardson, S., Joiner, K., and Wild, G. (2025). Identifying human factor causes of remotely piloted aircraft system safety occurrences in Australia. Aerospace, 12, 206-221.
- Mygal, G. (2022). The problem of human factors in unmanned systems. Scientific Journal of Polonia University, 52(3), 237-245.
- Otto, A., Agatz, N., Campbell, J., Golden, B., and Pesch, E. (2018). Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: A survey. Networks, 72(4), 411-458.
- Özyörük, H.E. (2020). İnsansız hava araçlarında (İHA) insan faktörlerinin etkisine dair literatürün sistematik olarak analizi ve sınıflandırılması. Journal of Aviation, 4(2), 71-81.
- Piwek, G.D. (2018). Human factor in flight safety. Hadmérnök XIII. Évfolyam 4. Szám.
- Reason, J. (1990). Human error. New York, Cambridge University Press.
- Reason, J. (2008). The human contribution: Unsafe acts, accidents and heroic recoveries. Ashgate Publishing.
- Rigolot, C. (2020). Transdisciplinarity as a discipline and a way of being: Complementarities and creative tensions. Humanities and Social Sciences Communications, 7(100), 1-5.
- Sarı, G., and Özsoy Somuncuoğlu, S. (2024). Aristoteles'in tündengelim ve tümevarım anlayışı hakkında genel bir değerlendirme. Fikiryat Sosyal Bilimler Araştırmaları Dergisi, 4(2), 153-162.
- Sharit, J. (2012). Human error and human reliability analysis. In: Salvendy, G. Eds., Handbook of human factors and ergonomics, New Jersey, John Wiley & Sons, Inc., Hoboken, 734-800.
- SHT-İHA (2020). Sivil Havacılık Genel Müdürlüğü İnsansız Hava Aracı Sistemleri Talimatı.
- Sığı, Ü. (2021). Nitel araştırma yöntemleri. 2. Baskı, İstanbul, Beta Basım Yayım.
- Spravak, J.J., Moisio, D.A., and Payton, M.G. (2005). Unmanned air vehicles: A new age in human factors evaluations. Technical Paper, AFFTC-PA-05069.
- Sundar, K., and S. Rathinam, (2013). Algorithms for routing an unmanned aerial vehicle in the presence of refueling depots. IEEE Transactions on Automation Science and Engineering, 11(1), 287-294.
- Tokekar, P., Hook, J.V., Mulla, D., and Isler, V. (2016). Sensor planning for a symbiotic UAV and UGV system for precision agriculture. IEEE Transactions on Robotics 32(6), 1498-1511.
- Wang, W., Guo, X., Liu, Y., Tang, A., and Yang, Q. (2023). Factors affecting unmanned aerial vehicles' unsafe behaviors and influence mechanism based on social network theory. Transportation Research Record, 2677(5) 1030-1045.
- Watts, A.C., Ambrosia, V.G. and Hinkley, E.A. (2012). Unmanned aircraft systems in remote sensing and scientific research: Classification and considerations of use. Remote Sensing, 4(6), 1671-1692.
- Wild, G., Murray, J. and Baxter, G. (2016). Exploring civil drone accidents and incidents to help prevent potential air disasters. Aerospace, 3(3), 1-11.
- Williams, K.W. (2008). Documentation of sensory information in the operation of unmanned aircraft systems. (Report No. DOT/FAA/AM-08/23). Washington, DC: Federal Aviation Administration.
- Yakar, M., Ulvi, A., and Fidan, Ş. (2023). İnsansız hava aracı teknolojisi ve operatörlüğü eğitim kitabı, 1. Baskı. Konya, Atlas Akademi Yayınları.
- Yang, K., and Fan, Y. (2016). "Peart" human factors model for aviation maintenance. 2nd International Conference on Education Technology, Management and Humanities Science (ETMHS 2016).
- Yıldırım, A., and Şimşek, H. (2018). Sosyal bilimlerde nitel araştırma yöntemleri. 11. Baskı, Ankara, Seçkin Yayıncılık.
- Zimmermann, N., and Mendonca, F.A.C. (2021). The impact of human factors and maintenance documentation on aviation safety: An analysis of 15 years of accident data through the PEAR framework. Collegiate Aviation Review International, 39(2), 1-25.

Cite this article: Coban, R. (2025). Examination of Human Factors in Civilian Unmanned Aerial Vehicles Accidents with PEAR Model: United Kingdom Sample. Journal of Aviation, 9(3), 751-767.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

From Check-in to Take-off: How Digitalization Reshapes Airport Service Quality

Sinem Büyüksaatçı-Kiriş¹ , Binnur Akıf^{2*} 

¹Istanbul University-Cerrahpasa, Industrial Engineering Department, 34320, Istanbul, Türkiye. (s.buyuksaatcikiris@iuc.edu.tr)

^{2*}Istanbul Gelisim University, Industrial Engineering Department, Istanbul, Türkiye. (bgurul@gelisim.edu.tr)

Article Info

Received: 29 July 2025

Revised: 25 August 2025

Accepted: 12 September 2025

Published Online: 17 October 2025

Keywords:

Digitalization

Digital technologies

Service quality

Airline industry

Airport management

Corresponding Author: Binnur Akıf

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1752519>

Abstract

As air travel becomes increasingly complex and passenger expectations rise, airport authorities are turning to digital technologies—such as artificial intelligence, IoT, biometric systems, and mobile applications—to streamline operations and enhance customer experiences. Depending on these improvements, this study explores the transformative impact of digitalization on service quality at airports, focusing on how technological advancements influence operational efficiency and passenger satisfaction across pre-flight, in-flight, and post-flight stages. Drawing on a qualitative research design, semi-structured interviews were conducted with twelve professionals from Istanbul Airport and Sabiha Gökçen Airport, representing diverse operational roles.

The thematic analysis of the interview data revealed six key dimensions through which digitalization contributes to service improvement: the adoption of smart systems and self-services, personalization of customer experience, training and personnel development, infrastructure enhancement, environmentally sustainable practices, and continuous feedback mechanisms. While digitalization was widely recognized as a catalyst for faster transactions, improved safety, and higher customer satisfaction, concerns such as system failures, data privacy, technological inequality, and diminished human interaction were also highlighted.

By presenting a stage-based assessment of digitalization, which are pre-flight, in-flight, and post-flight, this study offers a comprehensive framework for understanding its dual role as both an enabler and a challenge in modern airport service management. The findings contribute to the growing literature on digital transformation in aviation and provide practical insights for airport administrators seeking to align technology integration with service excellence and long-term sustainability.

1. Introduction

Airports are among the world's busiest and most complex transportation hubs and a crucial component of modern transportation networks. They are constantly evolving in response to increasing passenger numbers and increasing demand, which in turn necessitates operational efficiency. Airport managements are leveraging digitalization not only to increase operational efficiency but also to improve the quality of service they offer to passengers (Dias, 2024; He, 2024; Chiang, 2025). The implementation of digital technologies at airports is crucial for streamlining operational processes, making information flow transparent, and personalizing the passenger experience. Innovative solutions such as biometric authentication, autonomous vehicles, and digital ticketing systems, in particular, significantly improve passenger satisfaction by reducing long queues and transaction delays at airports (Zaharia, & Pietreanu, 2018; Bakir et al, 2024). A recent study conducted at airports in Serbia reveals that AI-based services (e.g., facial recognition, automated baggage drop-off, chatbot assistants) significantly improve the

passenger experience (Ćurčić et al., 2024). In this context, digitalization offers great potential to streamline airport processes, reduce costs, and increase passenger satisfaction.

Digitalization is driving significant changes in various areas of the airport industry, offering significant opportunities, particularly in improving the customer experience and enhancing passenger satisfaction. This process is further strengthened by the integration of numerous digital tools, such as artificial intelligence (AI), the internet of things (IoT), biometric technologies, and mobile applications (Bouyakoub et al., 2017; Poulaki et al., 2021). In recent years, digitalization has revolutionized airport management and operational processes. According to Airport Council International (ACI), digitalization has become a key factor in improving the passenger experience at airports (ACI, 2023). One of the study dated 2021 also showed that digital technologies are among the most important tools used to improve service quality, making passengers' airport experiences faster, more efficient, and more comfortable (Remencová & Sedláčková, 2021). Studies compiled by Hassan and Rahman (2023) indicate that contactless technologies, biometrics, and chatbot systems

increase passenger safety and comfort, and this has been identified as a key strategy for airports in the post-COVID-19 recovery process. Apart from these, it is suggested that AI-supported “AI concierge” applications can increase customer satisfaction by providing continuous and personalized service to passengers throughout the customer journey (Liu et al., 2024). Digital transformation has been shown to make the experience smoother, not only from a technical perspective but also from a psychological perspective, by eliminating “customer pain points” (Holz, 2024). Furthermore, digitalization has not only increased the efficiency of operational processes but also transformed airports' marketing strategies. Airports are offering more services to their customers and creating revenue models through digital platforms. As emphasized by Gündüz (2023), the integration of AI in the airline and accommodation sectors provides a competitive advantage by increasing customer satisfaction.

The integration of digitalization practices with sustainability in the aviation sector is also a crucial factor. The need for a digitalization strategy aligned with sustainability goals has been emphasized in recent years (Prieto Remón, 2021; Kwilinski et al., 2023; Yavas & Ozkan-Ozen, 2023). The widespread use of IoT, big data, and connected systems in smart airports accelerates the transition to paperless processes, reducing waste and pollutants while making passenger flow more efficient (Gürsel et al., 2023). While many digitalized information services increase passenger satisfaction through engaging/exciting features, maintaining some human-based touchpoints also creates a necessary balance for sustainable passenger loyalty (Choi et al., 2024). On the operational sustainability front, IATA's Trajectory Sharing Platform (TSP) initiative aims to reduce unnecessary fuel consumption through better sharing of flight profiles and alignment with air traffic management; indeed, deviations from optimal routes during landing procedures can significantly increase additional fuel consumption. Similarly, the e-Freight program aims to eliminate over 7,800 tons of paper annually through the digitalization of air cargo documentation, thus reducing environmental impact. While often not the initial goal, such digital transformation initiatives pave the way for lasting improvements in environmental performance through knowledge creation and organizational learning (Ordieres-Meré et al., 2020). As seen in the wake of COVID-19, “unconventional” digital solutions can accelerate sustainable development by triggering new business models; they support eco-sustainability principles such as reuse, zero carbon footprint, and reduced energy consumption (Polishchu et al., 2022). However, the environmental impacts of digitalization are not always one-sided; to mitigate potential negative impacts, the transformation must be closely monitored through change management and stakeholder alignment must be ensured.

The most serious crisis in the aviation industry's history occurred with the COVID-19 pandemic. This period brought about a period of declining profitability for airlines and a significant challenge in attracting new customers. As the aviation industry began to recover in mid-2022, airlines seeking to increase passenger numbers and market share tended to adopt more data-driven approaches and advanced analytical tools, while digitalization emerged as a key theme linked to customer satisfaction in the aviation sector (Kurnaz, & Žilinskienė, 2022; Bakır et al., 2025). With the COVID-19 pandemic, reduced contact and hygiene expectations have become key factors determining customer satisfaction in air

travel, and digital solutions such as self-service kiosks, e-baggage tags, biometrics, RFID baggage tracking, cleaning robots, UV/antimicrobial cabin cleaning, and AI-enabled services have become prominent (Chiang, 2025). A study conducted in the Chinese market with 365 participants showed that six digital services, including e-baggage tags, cleaning robots, UV/antimicrobial cleaning, app-controlled in-flight entertainment, and e-library, significantly increased passenger satisfaction, with the e-baggage tag having the strongest impact. In contrast, services such as AI customer service, COVID-19 digital documentation, and facial recognition were met with more caution, flagging them as areas for improvement in terms of trust and usability (Shiwakoti et al., 2022). The example of Dalaman Airport in Turkey also confirmed the positive correlation between digital solutions integrated with health measures and passenger satisfaction, suggesting that management re-align their technology investments with a passenger-centric approach (Kaplan et al., 2024). The systematic use of digital tools at marketing and touchpoints (pre-arrival, boarding, arrival) has also been identified as a strategic lever that increases customer satisfaction through indicators such as waiting time and churn rate (Moses et al., 2023). The pandemic accelerated the transition from Airport 2.0 to 4.0 in the airport maturity model, creating a significant advantage in terms of security and service quality through contactless transactions with full self-service and smart airport ecosystems (Kováčiková et al., 2022).

Despite the advantages offered by digitalization, it also presents some challenges. In particular, the significant costs of installing and maintaining digital infrastructures, cyber security issues, the inconveniences due to poorly designed digital systems and inequalities in access to technology are among the significant obstacles faced by airport managements (Zaharia & Pietreanu, 2018; Pandey et al., 2024; Xiong et al., 2025).

This study is outlined as follows: First, the conceptual foundations of service quality are introduced with a particular emphasis on how service quality is defined and operationalized within airport context. Then, the role of digitalization at the airports across the three critical stages, that are pre-flight, in-flight, and post-flight, are presented in detail. The Material and Method section outlines the research design and data collection process. In the Results and Discussion section, findings from in-depth interviews with airport professionals are analyzed under key thematic categories. Finally, the study concludes with a discussion of the findings, offers managerial and theoretical implications and suggests directions for future research.

2. Conceptual Foundations

2.1. Service Quality and Its Importance at Airports

Modernity along with technological advancements will create a very fierce competition environment in gaining and retaining customers. Service quality has become a necessity for companies and institutions to survive and continue to gain the trust of consumers and society. Traditionally, service quality has been defined as the difference between customer expectations and the perceived quality of services received (Ramadhan et al., 2020). In previous studies, Kotler (2009) defined the service quality dimension as a reflection of the difference between the reality of the service (perceived service) and the service users expect to receive (Suryadana,

2017). Similar definitions have been frequently used in many studies in the literature (Jonkisz et al., 2021; Nguyen et al., 2021; Ahmet et al., 2023; Nguyen et al., 2024; Khan et al., 2025). This difference is seen as a mismatch between perceived service and expected service.

The most popular and powerful tool used in the literature to examine service quality is undoubtedly the SERVQUAL model developed by Parasuraman et al (1985, 1988). The model has five main dimensions: Tangibles, Reliability, Responsiveness, Assurance, and Empathy. Tangibles include the physical environment in which the service is delivered, the facilities, equipment, employee appearance, and the quality of the materials used. Reliability is the state of providing service accurately, consistently, and as promised. Responsiveness relates to employees' willingness to assist customers and their ability to provide prompt service. Assurance is the ability of employees to make customers feel safe through their knowledge, competence, and courtesy. Empathy is the state of giving customers individual attention, understanding their needs, and providing personalized service.

The SERVQUAL model, which was later used in various air transportation studies (Chou et al, 2011; Kenan & Yıldırım, 2012; Basfirinci & Mitra, 2015; Büyüközkan et al., 2020; Aiswarya Babu et al., 2025), was adapted by Bari et al. (2001) to the specific needs of the airline industry and created a scale called AIRQUAL to assess service quality in the airline industry. This scale consists of five dimensions: airline tangibles, terminal tangibles, personnel service, empathy, and airline image.

The first dimension of the basic AIRQUAL model is airline tangibles, which deals with tangible aspects of the aircraft, such as the quality of cabin interiors, in-flight food and beverages, cleanliness of restrooms, seating comfort, and air conditioning. The second dimension, known as terminal tangibles, deals with the physical components of the airport terminal, like the comfort of the waiting area, the availability of stores, the cleanliness of the restrooms, and parking spaces. The third dimension assesses the airline's employee service, including how quickly and willingly employees assist customers. It takes into account the work ethic, customer service, education, experience, attitudes, and knowledge of the employees. The fourth dimension assesses empathy and focuses on the airline's capacity to offer passengers individualized attention and care through seamless services. Last but not least, the fifth dimension looks at the airline's image and reputation, including things like frequent flyer programs, the quality of service, value for money in terms of airfares offered, and the airline's reputation overall. (Usman et al., 2022; Zhang et al., 2023).

Modifications have also been made to the dimensions of the AIRQUAL model to make it suitable for various research purposes. Ekiz et al. (2006) expanded the AIRQUAL scale by adding the dimensions of perceived service quality and customer satisfaction. Jameel (2025) pointed out that security and safety are the most important elements in the aviation industry and added security and safety as the sixth dimension to the AURQUAL model to measure customer satisfaction in Iraqi Airways.

Airports that offer high-quality service make passengers' travel experiences more positive and increase overall satisfaction. Additionally, effective services are also beneficial for airport businesses. More efficient processes mean fewer errors and greater passenger satisfaction. Consequently, airport businesses can gain a stronger competitive advantage by embracing a customer-oriented approach. The importance

of service quality at airports is outlined under some headings below.

- **Passenger Satisfaction:** A good service experience encourages passengers to return to the same airport. A successful airport not only ensures on-time flights but also ensures passengers have a comfortable and safe experience throughout their travels. According to a research study conducted on this subject, a direct correlation has been determined between service quality and passenger satisfaction at airports (An & Noh, 2009; Agarwal & Gowda, 2021). This also leads to positive comments on social media and digital platforms.
- **Operational Efficiency of Businesses:** Fast processing times and therefore efficient processes reduce airport businesses' costs and optimize resource utilization. Minimizing delays, reducing the time spent on check-in, and performing baggage procedures effectively are factors that increase operational efficiency. This helps reduce overall total costs for both the airport and the airline businesses. For example, through digital systems, the need for personnel is reduced, thus saving on operating costs (Kovynyov & Mikut, 2019). A study by Remencová and Sedláčková (2021) reveals that modernizing digital technologies, particularly at regional airports, reduces operating expenses by reducing personnel costs by up to 80%. In this context, the use of automated systems such as check-in kiosks both speeds up passenger processing and supports the financial sustainability of airports in the long term.
- **Economic Sustainability:** The quality of service offered to passengers at airports and the increased passenger satisfaction with the quality have a significant contribution to long-term sustainability of businesses. By increasing passenger satisfaction, airports can attract more passengers and generate more revenue. Furthermore, providing high-quality services enhances airport image and attracts more investors. For example, Singapore Changi Airport is known all over the world for its high service quality and passenger experience. As a result, this success of the airport has supported its economic sustainability (Sezgin & Demiral, 2019; Sullivan, 2023)

2.2. Key Factors Affecting Service Quality at Airports

Based on the studies in the literature, it is possible to group the main factors affecting service quality at airports under the following headings.

- **Service Speed and Efficiency:** One of the primary factors affecting airport service quality is how fast and efficient the service is. Passengers expect fast and seamless service at every stage, from check-in and security checks to ticket inquiries and baggage claim. Providing fast service, especially at check-in points, fast security checkpoints, passport procedures and baggage delivery or tracking processes, ensures that passengers using the airport have a less stressful and more seamless flight experiences (Angtony et al, 2023). Research has shown that increasing service quality and speed at airports increases overall operational efficiency and enables the service of a greater number of passengers in shorter periods of time (Doganis, 2010; Bulut, 2022; Garg & Sharma, A, 2024; Qian, 2025). In addition, it improves economic performance at airports with its high service speed. It means taking advantage of more technological innovations to provide faster service (Poulaki et al., 2021). Investing in personnel training is also one of the factors that increase the efficiency of airports (Usman et al., 2022).

- *Passenger Comfort*: This factor is the other most important factor affecting service quality at airports. A comfortable experience offered to passengers increases their satisfaction and allows for greater preference. Among the facilities offered to passengers at airports, amenities such as seating areas, food and beverage areas, cleanliness and hygiene (air quality), children's playgrounds and conference areas are factors that directly affect passenger comfort. Especially when it comes to long waiting times, comfortable spaces will be very helpful to passengers in this regard (Fodness & Murray, 2007; Bogicevic et al., 2013). Some of the studies on this topic has revealed a direct correlation between passenger satisfaction and loyalty with airports and their comfort. As passenger comfort levels increase, so does their likelihood of choosing the same airport (Rahim, 2016; Boonchunone et al., 2021; Syam et al., 2022)
- *Security Measures*: Security at airports is one of the cornerstones of operational efficiency, as well as protecting the health and safety of passengers and airport employees. The effectiveness of security systems used at airports not only ensures passenger safety but also strengthens the reputation of the airport. The smooth and rapid execution of existing procedures such as security screenings, express baggage checks and passenger transitions are among the factors that increase passenger satisfaction. Effective implementation of security measures ensures that passengers feel safe and also helps prevent possible violations of security measures (Barus et al., 2024; Pik, 2024). Additionally, passenger perception of the security measures may affect overall satisfaction. Research on this topic suggests that airports that improve passenger experience without compromising security are more likely to be preferred (Al-Saad et al., 2019)
- *Customer Service*: An effective customer service system is needed to provide passengers with information, guidance and problem solving. The professionalism, courtesy and helpfulness of staff at airports is an important part of service quality. The professional and helpful attitude of the staff, especially those working in customer service, ensures that passengers' problems are resolved quickly (Chen and Chang, 2013). With the impact of digitalization, mobile applications and online customer service platforms increase the effectiveness of customer service by providing instant feedback solutions to passengers (Sharma, 2024)
- *Technological innovations*: Innovations are factor that transforms service quality at airports. The technological infrastructure at airports can speed up passenger transactions and provide them with instant information and easy access. Mobile applications, QR codes, digital tickets and vending machines are some of the services offered by the technological infrastructure at airports. Effective use of technological infrastructures increases security and processing time, while also increasing airport efficiency by reducing staff workload (Sharma & Bhatnagar, 2023)

2.3. The Role of Digitalization at the Airport

Digitalization not only increases operational efficiency at airports but also positively transforms the passenger experience. New technologies provide speed and accuracy in processes such as ticketing, security screening, biometric authentication and passenger flow monitoring, thereby increasing customer satisfaction. For example, automatic baggage tagging and self-check-in kiosks have accelerated passenger flow and reduced staffing needs at airports. Additionally, IoT technologies provide greater accuracy and speed in baggage tracking and security processes, increasing

overall efficiency (Karakuş et al., 2018). Also digital solutions enable more efficient use of resources and reduce operational costs (Zaharia, & Pietreanu, 2018; Jayasuriya & Rajapaksha, 2020; Poulaki et al., 2021; Dias, 2024)

Digitalization at airports has the potential to significantly improve the passenger experience. Technological innovations are changing passenger expectations of airport processes, increasing operational efficiency, and making travel faster and more convenient. Passenger experience is one of the most important benefits of digitalization at airports. Mobile apps and digital displays provide passengers with real-time flight information and directions at airports, reducing stress levels. Additionally, digital assistants and AI powered systems allow passengers to receive more personalized services (Chiang, 2025).

Below are the applications through which digitalization is integrated into the system during the pre-flight, during-flight and post-flight stages.

2.3.1. Pre-Flight Digitalization

Pre-flight digitalization impacts the passenger experience from the very beginning. Mobile apps, web check-in, digital tickets, facial recognition technologies, and AI-powered customer service reduce passenger waiting times and make airport operations more efficient. Some examples of pre-flight digitalization applications are given below.

- *Web Check-in and Mobile Applications*: Passengers' ability to check in online significantly reduces pre-flight waiting times. Furthermore, mobile applications allow passengers to instantly access information such as flight status, gate number, and weather conditions (Klein, 2020).
- *Mobile Boarding Passes*: Passengers can obtain their boarding passes from their mobile phones before their flight, thus avoiding long queues and reducing waiting time (Mäkelä, 2024). Additionally, paper boarding passes are no longer necessary. This practice also has a significant environmental impact. Considering that millions of flights are made annually, significant paper waste is inevitable (Vongtharawat et al., 2019). Thanks to these mobile cards, this has been prevented.
- *Facial Recognition Technology*: This technology allows for faster identification and security checks for passengers. Facial recognition technology also minimizes long security lines and improves passenger satisfaction. In addition, this technology plays a crucial role in security. Integrated with biometric photos, this technology minimizes security vulnerabilities (Bisoi et al., 2020).
- *Baggage Tracking and Tagging*: Passengers can tag their luggage before their flight and track its status in real-time via digital platforms. This feature aims to prevent potential loss, theft, or confusion, while also prioritizing passenger satisfaction (Valarmathy et al., 2023; Mäkelä, 2024)

2.3.2. During-Flight (In-Flight) Digitalization

During-flight digitalization not only improves the passenger airport experience but also increases operational efficiency. Digital technologies also offer faster and more reliable solutions for flight sequencing, planning, and management. Some examples of digital applications during flight are given below.

- *NextGen (Next Generation Air Transportation System)*: This technology, developed by the Federal Aviation Administration (FAA), is a prime example of digitalization in flight sequencing. NextGen uses data analytics and automation to optimize flight routes and modernize air traffic control systems. This system has increased

operational efficiency by reducing traditional manual processes (FAA, 2025).

- *Artificial Intelligence and Big Data Analytics:* The Skywise platform, developed by Airbus, allows airlines to optimize flight sequences by analyzing flight data. The platform enables airlines to make more informed operational decisions, reducing waiting times and enabling more efficient use of resources (Airbus, 2017). In addition, with the use of artificial intelligence, greater predictability is brought to the operational processes of flights. It is said that airlines aim to minimize delays and reduce operational costs by analyzing flight data (Sahota, 2024). This offers a significant advantage not only for airlines but also for passengers.

2.3.3. Post-Flight Digitalization

The digitalization of post-flight processes in the aviation industry plays a significant role in improving service quality. This digital transformation improves passenger travel experiences and increases the operational efficiency of airlines and airport businesses. A few examples of post-flight digital applications are given below.

- *Digital Twin:* The use of digital twin technology in post-flight services is effective in increasing passenger satisfaction. By creating virtual copies of physical systems, digital twins increase efficiency in airport operations and enable the delivery of personalized passenger services. This allows for instant and personalized cabin service by monitoring passenger status (Oliveira, 2020).
- *Data Mining - Data Analysis and Artificial Intelligence Based Decision Making:* Artificial intelligence and big data analytics applications increase operational efficiency and improve service quality in post-flight processes. These technologies enable more effective decisions to be made by performing real-time data analysis in areas such as flight operations, fleet management, maintenance and inventory management (UTED, 2023).
- *Digital Feedback Systems:* Providing instant feedback on passengers' post-flight experiences allows airport managements to quickly improve their services. AI-powered chatbots and assistants are digital assistants that passengers can get instant answers to when they have any problems, questions or suggestions at the airport. This therefore means significant cost savings and shorter waiting times for passengers seeking information assistance (Auer et al, 2024). These chatbots can provide passengers with access to detailed information about flight times and provide information and guidance when asked (Alla et al., 2023)

3. Material and Method

This study seeks to answer the following research questions: (1) To what extent does digitalization affect airport service quality? (2) What are the perceptions and experiences of airport employees regarding digital systems? (3) What advantages and disadvantages does digitalization offer in pre-flight, in-flight and post-flight processes? These research questions are closely related to the SERVQUAL (Parasuraman et al., 1985; 1988) and AIRQUAL (Bari et al., 2001) models frequently used in the literature. In this regard, this study adopts a qualitative research approach to comprehensively understand the target phenomenon by focusing on participants' experiences, perspectives, and the contextual dynamics surrounding them. Qualitative methodology was

selected due to its capacity to explore complex organizational phenomena through the lived experiences and perspectives of individuals. Qualitative approaches are particularly well-suited to exploring complex, intuitively situated issues and generating detailed, in-depth insights, rather than quantitative results (Creswell & Poth, 2018; Merriam & Tisdell, 2016).

In this context, the study is expected to make three contributions to the literature. First, it addresses a current gap by examining service quality from a digitalization perspective, particularly in the context of the transformation that has accelerated after COVID-19. Second, it makes a unique contribution by analyzing the experiences of airport employees through a qualitative research design. The topic was largely studied from the passenger perspective in existing literature. Third, the six themes highlighted by the participants (smart systems and self-service, personalization, training and staff development, infrastructure, sustainability, and feedback) are compared with findings in the literature, thereby providing new insights into service quality theory.

3.1. Sample and Sampling Strategy

The research was conducted at Istanbul Airport, one of the largest international air transport hubs in Europe, and Sabiha Gökçen Airport. A total of 12 participants were selected through purposive sampling, based on their direct involvement in digitally supported service processes and operations. Purposive sampling is a technique commonly utilized in qualitative research to identify information-rich cases aligned with the research purpose (Patton, 2015). Participants were chosen based on their direct involvement with and experience, that is, the sample included personnel from various functional areas. These are passenger/customer services, frontline service, customer experience, airport management, information technology, security, and operations control.

To ensure diversity of perspectives, the sample included individuals from various roles and organizational levels. These are frontline staff, middle managers, digital systems supervisors, operational staff, supervisors, passenger service representatives, and IT personnel, each offering a distinct viewpoint on the digitalization of service processes. Inclusion criteria is required participants to have at least three years of experience in their current role and be actively engaged in service-related operations affected by digital systems.

Information about the participants in the study is given in Table 1.

3.2. Data Collection

In this study, semi-structured interviews were used as the primary data collection tool, which offer both consistency and adaptability to explore emerging ideas throughout the conversation. Data were collected through semi-structured, in-depth interviews. This method is well-suited to uncovering participants' individual interpretations and reflections while maintaining consistency across cases (Bryman, 2016). The interview guide was developed following a comprehensive review of relevant literature on airport digitalization and service quality and was pilot-tested with two staff members not included in the final sample.

Interviews were conducted between March and April 2025, in either face-to-face setting within the airport premises or via secure video conferencing platforms (Zoom), depending on participants' availability and operational constraints. Each interview lasted approximately 45 to 60 minutes, and all

sessions were audio-recorded with informed consent. The recordings were then transcribed with verbatim for analysis.

Table 1. Information about sample participants

Participant Code	Airport	Gender	Age	Position/Role	Experience (year)
Participant-1	Istanbul Airport	Male	43	Middle manager	3
Participant-2	Istanbul Airport	Female	38	Operational staff	12
Participant-3	Istanbul Airport	Female	25	Frontline staff	7
Participant-4	Istanbul Airport	Male	28	Frontline staff	4
Participant-5	Istanbul Airport	Male	33	Supervisor	9
Participant-6	Istanbul Airport	Male	24	Frontline staff	11
Participant-7	Sabiha Gökçen Airport	Female	47	Middle manager	12
Participant-8	Sabiha Gökçen Airport	Female	29	Frontline staff	15
Participant-9	Sabiha Gökçen Airport	Male	28	Digital systems supervisor	7
Participant-10	Sabiha Gökçen Airport	Male	35	IT personnel	16
Participant-11	Sabiha Gökçen Airport	Male	41	Middle manager	8
Participant-12	Sabiha Gökçen Airport	Male	32	Passenger service representative	10

3.3. Data Analysis and Trustworthiness

Interview transcripts were analyzed using thematic analysis following the six-phase approach outlined by Braun and Clarke (2006): (1) familiarization with the data, (2) generation of initial codes, (3) theme identification, (4) theme review, (5) definition and naming of themes, and (6) writing of the report. To manage and code the data systematically, NVivo 14 software was used.

To enhance the credibility and trustworthiness of the study, several validation strategies were adopted:

- Member checking was conducted by sharing summary findings with selected participants for verification.
- Triangulation was ensured through the inclusion of diverse job roles and hierarchical levels.
- Thick description was applied to contextualize the findings and support transferability (Lincoln and Guba, 1985).

4. Results

Digitalization has led to radical changes in the aviation industry, making airport operations more efficient, safe, and passenger-friendly. This digital transformation is particularly evident in three main stages: pre-flight, in-flight, and post-flight. Each stage is shaped by the contributions of digital technologies to enhancing the passenger experience and increasing operational efficiency. This study examines the role, impact, advantages, and disadvantages of digitalization at each stage. Based on the interviews conducted under this heading, suggestions and practices on how to increase service quality at airports by deepening digitalization were discussed.

Participants supported the fact that digitalization significantly improves service quality; as highlighted in the quotes below. Digitalization shortens transaction times and increases satisfaction by providing fast, instant information through online processes.

Participant-4: *"The ability for passengers to track their luggage or view instantly updated flight information via their mobile devices is an important digital service."*

Participant-7: *"Digitalization services offered through information standards, information screens and mobile applications at airports provide passengers with instant information and comfort."*

Participant-12: *"Passengers leaving the airport via digital systems, that is self-service technology such as automatic check-out, without having to go through the ticket*

office at the exit, shortens processing times and ensures faster passenger flow."

The evidence for improving service quality, derived from each participant's statements, was descriptively presented and grouped under specific headings/themes. This also facilitated a reconciliation between the participant findings and the literature. The headings/themes highlighted by the participants, aligning with the literature, are summarized below.

Smart Systems and Self Services (AI-Based Online Applications)

"Self-check-in and kiosk systems, biometric authentication, fast-track systems, and smart guidance systems, all utilized through digitalization, are crucial for such improvements, as are the questions of how they can be made more efficient. All of these digitalization strategies contribute to time savings and passenger satisfaction." (Participant-3)

Personalization of Customer Experience

"With personalized communication and feedback, passengers' locations at airports, their actions, and upcoming steps can be instantly notified, and such instant, accurate information also provides time savings (i.e., advantage)." (Participant-1)

Education and Personnel Investments

"It's crucial for airport employees to be proficient in digital systems and use them effectively. Their ability to adapt to technology directly impacts service quality." (Participant-6)

"Training for customer relations staff to improve their empathic communication, crisis management and problem-solving skills will directly impact passenger satisfaction." (Participant-2)

"Providing multilingual service is crucial, especially when considering international flights and passengers. Staff fluent in different languages increases passenger numbers and ensures a comfortable flight experience for international passengers. Language training and cultural awareness provided by staff will be beneficial in this regard." (Participant-5)

Infrastructure Improvements

"Passengers waiting at airports can be provided with comfortable seating, children's play areas, and entertainment venues. Additionally, free internet access and charging stations can provide passengers with a better experience. Another infrastructure improvement is efforts to minimize waiting times, especially at high-passenger airports. This time can be significantly shortened by using smart systems and biometric technologies." (Participant-10)

Sustainability and Environmentally Friendly Practices

“Airports are adopting energy-efficient systems (such as solar power, LED lighting, etc.) and zero-waste policies. Such practices are crucial for sustainability and can create significant value for environmentally conscious passengers.” (Participant-8)

“The use of green spaces can create natural living spaces and provide a comfortable and convenient airport experience.” (Participant-11)

Feedback and Continuous Improvement

“Passengers’ ability to easily share their pre-flight, in-flight, and post-flight experiences through digital programs is crucial for a feedback system. Airport management can analyze this feedback and implement initiatives to improve service quality. Airport management can also improve the passenger experience by responding promptly to questions, rather than comments, from passengers.” (Participant-9)

Finally, based on in-depth interviews with participants, the advantages and disadvantages of digitalization for improving service quality at airports pre-flight, in-flight, and post-flight are summarized as presented in Table 2.

Table 2. Advantages and disadvantages of digitalization to improve pre-flight, in-flight and post-flight service quality

	Advantages	Disadvantages
PRE-FLIGHT	Fast transaction processes	The technological infrastructure must be strong
	Less stressful passenger experience	The digitalization can be challenging for passengers who cannot use digital tools
	Increased productivity in the airport workforce	Security concerns (data privacy and personal information)
	Personalized services via digital platforms (e.g., notifications for flight changes)	Technological addiction
	Environmental awareness	System crashes and blockages (which may occur due to use by too many people at the same time)
IN-FLIGHT	Dynamic seat selection, baggage tracking, etc. opportunities increase satisfaction	System malfunctions may disrupt the check-in or other process
	Increasing comfort with in-flight entertainment systems and Wi-Fi	Failure of digital content may negatively affect satisfaction
	In-cabin requests can be submitted via digital display or mobile application	Passengers unfamiliar with technology may have difficulty using it
POST-	Providing flight information linked to instant notifications and receiving notifications via mobile	Security of in-flight digital systems carries the risk of cyberattacks
	Saving time with digital customs declaration and passport transfers	An error in automated systems can cause long delays

Facilitating feedback with mobile surveys and digital complaint systems	Reduced human contact can weaken customer relationships
Lost baggage tracking and notifications via digital platforms	Not every airport has the same digital infrastructure, there is a standardization problem

5. Conclusion and Discussion

This study examines the importance and impact of digitalization on service quality. The role of digitalization at airport is specifically examined in three stages: pre-flight, in-flight, and post-flight. The impact of digitalization is considered at each stages, and exemplary digitalization practices are presented based on interviews. The technologies used in these processes contribute to efficiency in the sector by providing faster, more secure and personalized services, particularly in terms of time. Additionally, improvements that can be made at airports through digitalization, as expressed in the interviews, are also included in this study. The common goal of most of these recommendations is to provide fast service and improve passenger satisfaction. While the improvements are generally passenger-focused, they also include initiatives targeting airport personnel and management.

In this study, a strong harmony was determined when the recent literature was compared with the six themes (self-service, personalization, training, infrastructure, sustainability, feedback) underlined by the participants. The emphasis of the participants to self-service solutions (self-check-in, self-luggage delivery, mobile boarding card, etc.) is compatible with the positive effects of the waiting time, processing time and perceived sense of control of the contactless flows accelerated by the COVID-19 period. Current studies show that self-service increases satisfaction, especially when it is designed to “end-to-end (from pre-reservation to uninterrupted digital flow), and kiosk/door solutions supported by biometry and RFID reduce the line ratio and tail length by reducing the quality of service (Shiwakoti et al., 2022; Chiang, 2025).

On the personalization theme, the findings in our study align with passengers' expectations of “convenience and instant information”. Recent studies show that AI-based services, such as customized offers and multilingual chat assistants, increase satisfaction when aligned with personal preferences (Poulaki et al., 2021; Chiang, 2025).

Participants’ need for “competent adaptation to digital systems” in terms of training and staff development aligns with the evidence presented by Drljača et al. (2020) that Industry 4.0 is redesigning “human resource planning and optimization” in airport operations. This points to the need for technical training and workflow-based reskilling. Additionally, training is a key change management tool for reducing passenger resistance and increasing acceptance in environments with reduced human contact. The literature recommends comprehensive employee training and the allocation of staff to support passenger self-service to reduce resistance to AI (Pence, 2024; Chiang, 2025).

The issues cited by participants regarding the infrastructure theme are consistent with Kováčiková et al.'s (2022) finding that COVID-19 has accelerated the airport maturity model toward “Smart Airport/Airport 4.0” and proliferated contactless solutions that improve process efficiency and security. Furthermore, Chiang (2025) demonstrated that AI applications (smart check-in, RFID baggage, multilingual

chatbots, etc.) increase competitiveness by addressing not only speed and comfort but also infrastructure constraints.

Creating environmental value, as expressed in the sustainability theme, is supported by the statements of Mızrak and Akkartal (2023), who argue that various smart airport applications such as self-service kiosks, self-boarding, digital processing of brochures, and process automation are environmentally friendly approaches through resource efficiency and operational effectiveness.

Finally, for “feedback and continuous improvement”, Shiwakoti et al. (2022) conducted large-scale passenger surveys and open-ended suggestion collection practices during the pandemic, revealing which digital touchpoints (e.g., online boarding, in-flight connectivity/IFE) leveraged satisfaction. This study demonstrated that competitive recovery accelerated when airlines systematically identified passenger needs and incorporated them into service design as feedback.

As a result, providing high service quality at airports not only ensures a more comfortable and stress-free flight experience for passengers but also strengthens the long-term competitiveness and reputation of airport businesses. The continuous development of technological innovations is increasing in parallel with digitalization. In this context, the adoption of consistent flight schedules tailored to passenger demands and expectations is an essential requirement for the long-term development of the sector.

Beyond these findings, this study provides valuable theoretical and managerial implications. Theoretically, it contributes to the growing body of literature on digital service transformation in the aviation industry by offering a stage-based and user-centered framework. It also emphasizes the interplay between technology adoption and service quality, bridging the domains of service science and airport management. From a managerial perspective, the results offer practical insights for airport authorities, technology providers, and policy-makers. These include the need to invest in digital literacy and training programs for airport staff, the importance of user-friendly and inclusive design in digital interfaces, and the necessity to ensure interoperability and standardization across airports.

Furthermore, the study highlights the importance of balancing digital efficiency with human-centered service delivery. While automation and digital systems improve operational speed and accuracy, the human touch which especially in customer service, crisis resolution, and accessibility, is still highly valued by many passengers. Therefore, future strategies should adopt a hybrid model that blends technological advancement with empathetic and culturally responsive service approaches.

Despite the speed, efficiency, and satisfaction improvements offered by digitalization, some limitations that have become more apparent, especially in the post-COVID-19 era, must also be carefully managed. First, increased reliance on technology increases operational fragility: system outages, software errors, or supply chain-related hardware failures can lead to sudden drops in service quality during peak hours (Kovrigin & Vasiliev, 2020). Secondly, in the size of inclusiveness and accessibility, the difficulty in contactless and self-service processes faced by advanced age passengers with low digital literacy may damage the equality of service. In a survey conducted in Olivieri (2025), 74% of the elderly passengers stated the digital tools such as websites and self-service check-in kiosks as main barriers they face. Thirdly, solutions based on the processing of personal data such as biometry and location/preference data raise cyber security and privacy risks. Findings such as data violation, identity theft and out-of-the-ger data use can have a negative impact on

passenger confidence as mentioned by Gupta et al. (2024). In addition to these, “decrease in human touch” can weaken customer relations that require empathy, persuasion and flexibility especially in moments of crisis. In the qualitative study carried out by Pence (2024) on Finnair Ground Services, it was revealed that passengers experienced disappointment and dissatisfaction due to lack of human interaction when they were forced to self-service. Therefore, it shows that digital processes should be completed with the intervention of ‘guiding’ and traditional representative when necessary. As a matter of fact, in the delayed/damaged baggage reports, the application was withdrawn in 2023, which was the only option of self-service, and the face-to-face service was allowed at the destination service point. This revision confirms the indispensability of the role of empathy-based, flexible solutions of empathy of the field, especially in the interruption and crisis conditions.

For future research, quantitative methods could be employed to measure the direct impact of specific digital innovations on passenger satisfaction, loyalty, and behavioral intention. Longitudinal studies could also be conducted to examine how digital transformation initiatives evolve over time and how they influence different categories of travelers (e.g., frequent vs. occasional flyers, digital natives vs. older adults). Moreover, comparative case studies between digitally advanced and less developed airports could offer deeper insights into best practices and contextual barriers to digital integration.

Appendix

The following semi-structured interview questions were designed to explore participants’ experiences with digital service systems and their perceptions of service quality at Istanbul Airport and Sabiha Gökçen Airport. The questions allowed for probing and follow-up to gain deeper insights.

1. Can you describe your role and daily responsibilities at the airport?
2. In what ways has digital technology changed the way you deliver services to passengers?
3. How do passengers typically respond to digital service systems (e.g., self-check-in, mobile apps, biometric gates)?
4. What advantages do you think digitalization has brought to your work environment and service quality?
5. Have you encountered any challenges or difficulties associated with the use of digital systems? If so, what are they?
6. Do you believe the digital systems improve operational efficiency? Why or why not?
7. What kind of training or support is provided to employees to adapt to new digital tools?
8. Are there specific situations where traditional (non-digital) service methods are still preferred or necessary?
9. What improvements would you suggest increasing the effectiveness of digital systems in your unit?
10. Do you have any additional thoughts on the impact of digitalization on passenger satisfaction and service quality?

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- ACI. (2023). Airport Digital Transformation Report. Airport Council International.
- Agarwal, I., & Gowda, K. R. (2021). The effect of airline service quality on customer satisfaction and loyalty in India. *Materials Today: Proceedings*, 37, 1341-1348.
- Ahmed, S., Al Asheq, A., Ahmed, E., Chowdhury, U. Y., Sufi, T., & Mostofa, M. G. (2023). The intricate relationships of consumers' loyalty and their perceptions of service quality, price and satisfaction in restaurant service. *The TQM Journal*, 35(2), 519-539.
- Airbus (2017). Airbus launches Skywise – Aviation's open data platform. Retrieved from: <https://www.airbus.com/en/newsroom/press-releases/2017-06-airbus-launches-skywise-aviations-open-data-platform>.
- Aiswarya Babu, N., Suresh, V. G., & Sharieff, M. H. (2025). Expectation v/s Perception—A Servqual Analysis of Airline Service Quality. In *Applied Research for Growth, Innovation and Sustainable Impact* (pp. 231-237). Taylor & Francis Group.
- Alla, H., Balouki, Y., & Moumoun, L. (2023, January). The use of chatbots as supportive agents in air transportation systems. In *The International Conference on Intelligent System and Smart Technologies* (pp. 239-250). Cham: Springer International Publishing.
- Al-Saad, S., Ababneh, A., & Alazaizah, M. (2019). The influence of airport security procedures on the intention to re-travel. *European Journal of Tourism Research*, 23, 127-141.
- An, M., & Noh, Y. (2009). Airline customer satisfaction and loyalty: impact of in-flight service quality. *Service Business*, 3(3), 293-307.
- Angtony, D., Rifai, A. I., & Indrastuti, I. (2023). The Satisfaction Analysis of Airport Services. *IJEED (International Journal of Entrepreneurship and Business Development)*, 6(2), 318-326.
- Auer, I., Schlögl, S., & Glowka, G. (2024). Chatbots in airport customer service—exploring use cases and technology acceptance. *Future Internet*, 16(5), 175:1-19.
- Bakir, A., Basal, M., Süzen, E., Sahin, Z., & Çora, H. (2024). The Impact of Innovative Customer Service Practices on Organizational Performance in Airline Companies: A Qualitative Analysis. *Journal Of Organizational Behavior Research*, 9(2), 179-193.
- Bakır, M., Akan, Ş., Özdemir, E., & Han, H. (2025). Mapping the intellectual and thematic evolution of airline service quality research: a bibliometric analysis (1981–2024). *Journal of Travel & Tourism Marketing*, 42(6), 785-813.
- Bari, S., Bavik, A., Ekiz, H. E., Hussain, K., & Toner, S. (2001). AIRQUAL: A multiple-item scale for measuring service quality, customer satisfaction, and repurchase intention. *HOS-414 Graduation Project/Thesis*, Eastern Mediterranean University, School of Tourism and Hospitality Management, Gazimagusa, 1-104.
- Barus, G. A., Widiyanto, P., Arini, D. U., & Subagio, M. (2024). Evaluation of Service Quality: Aviation Security, Customer Value and Airport Accessibility (Library Research). *Greenation International Journal of Tourism and Management*, 2(1), 42-52.
- Basfirinci, C., & Mitra, A. (2015). A cross cultural investigation of airlines service quality through integration of Servqual and the Kano model. *Journal of Air Transport Management*, 42, 239-248.
- Bisoi, S., Roy, M., & Samal, A. (2020). Impact of artificial intelligence in the hospitality industry. *International Journal of Advanced Science and Technology*, 29(5), 4265-4276.
- Bogicevic, V., Yang, W., Bilgihan, A., & Bujisic, M. (2013). Airport service quality drivers of passenger satisfaction. *Tourism Review*, 68(4), 3-18.
- Boonchunone, S., Nami, M., Pongthavornvich, J., & Suwunnamek, O. (2021). Impact of airport service quality, image, and perceived value on loyalty of passengers in Suvarnabhumi airport service of Thailand. *Acta Logistica*, 8(3), 237-257.
- Bouyakoub, S., Belkhir, A., Bouyakoub, F. M. H., & Guebli, W. (2017, July). Smart airport: An IoT-based airport management system. In *Proceedings of the International Conference on Future Networks and Distributed Systems* (pp. 1-7).
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.
- Bryman, A. (2016). *Social Research Methods* (5th ed.). Oxford University Press.
- Bulut, C. (2022). Airport service quality: a reconceptualization and a practical application on the non-aeronautical services. *Aviation*, 24(4), 182-196.
- Büyüközkan, G., Havle, C. A., Feyzioğlu, O., & Göçer, F. (2020). A combined group decision making based IFCM and SERVQUAL approach for strategic analysis of airline service quality. *Journal of Intelligent & Fuzzy Systems*, 38(1), 859-872.
- Chen, C. F., & Chang, Y. H. (2013). The impact of service quality, customer satisfaction and loyalty on airline service. *Journal of Air Transport Management*, 33, 59-66.
- Chiang, C. H. (2025). AI in airport operations: enhancing competitiveness and satisfaction. *Enterprise Information Systems*, 19(3-4), 271-290.
- Choi, S., Moon, C., Lee, K., Su, X., Hwang, J., & Kim, I. (2024). Exploring Smart Airports' Information Service Technology for Sustainability: Integration of the Delphi and Kano Approaches. *Sustainability*, 16(20), 8958:1-17.
- Chou, C. C., Liu, L. J., Huang, S. F., Yih, J. M., & Han, T. C. (2011). An evaluation of airline service quality using the fuzzy weighted SERVQUAL method. *Applied Soft Computing*, 11(2), 2117-2128.
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (4th ed.). SAGE.
- Ćurčić, N., Grubor, A., & Jevtić, B. (2024). Implementing artificial intelligence in travel services, customer satisfaction GAP study at Serbian airports. *Ekonomika*, 70(3), 1-9.
- Dias, C. A. S. (2024). Smart Airports: Analysing Digital Transformation and Technological Advancements in Aviation. Master Thesis, University of Beira Interior, Aeronautical Engineering, 1-159.
- Doganis, R. (2010). *The airline business in the twenty-first century*. Routledge.
- Drljača, M., Štimac, I., Bračić, M., & Petar, S. (2020). The role and influence of industry 4.0. in airport operations in the context of COVID-19. *Sustainability*, 12(24), 10614:1-18.

- Ekiz, H.E., Hussain, K., & Bavik, A. (2006). Perceptions of service quality in North Cyprus national airline, tourism and hospitality industry 2006-new trends in tourism and hospitality management. In: 18th Biennial International Conference. Faculty of Tourism and Hospitality Management, Opatija, 778–790.
- FAA - Federal Aviation Administration (2025). Next Generation Air Transportation System (NextGen).
- Fodness, D., & Murray, B. (2007). Passengers' expectations of airport service quality. *Journal of Services Marketing*, 21(7), 492-506.
- Garg, C. P., & Sharma, A. (2024). Time to evaluate service quality indicators for delivering service excellence at airports: Case of India. *Quality Management Journal*, 31(4), 253-270.
- Gupta, S., Joshi, D., Jagtap, S., Trollman, H., Haddad, Y., Atescan Yuksek, Y., ... & Narkhede, B. (2024). From failure to success: a framework for successful deployment of Industry 4.0 principles in the aerospace industry. *International Journal of Industrial Engineering and Operations Management*, 6(4), 277-298.
- Gündüz, C. (2023). Customised holiday experiences through artificial intelligence: Case studies from the aviation and hospitality sectors. *Journal of Aviation*, 7(3), 337-345.
- Gürsel, S., Demir, R., & Rodoplu, H. (2023). The effect of digitalisation on sustainability and smart airport. *International Journal of Sustainable Aviation*, 9(1), 26-40.
- Hassan, A., & Rahman, N. A. A. (2023). *Technology Application in Aviation, Tourism and Hospitality*. Springer.
- He, Y. (2024). Best practices for the airport digitalization. Bachelor Thesis, Haaga-Helia University of Applied Sciences, Business Administration, 1-67.
- Holz, H. F., Becker, M., Blut, M., & Paluch, S. (2024). Eliminating customer experience pain points in complex customer journeys through smart service solutions. *Psychology & Marketing*, 41(3), 592-609.
- Jameel, A. S. (2025). Service quality and customer satisfaction through AIRQUAL dimensions: An empirical investigation on Iraqi airways. *International Journal of Management Studies*, 32(1), 1-18.
- Jayasuriya, N. A., & Rajapaksha, A. (2020). Smart airport: A review on future of the airport operation. *Global Journal of Management and Business Research: A Administration and Management*, 20(3), 25-34.
- Jonkisz, A., Karniej, P., & Krasowska, D. (2021). SERVQUAL method as an “old new” tool for improving the quality of medical services: A literature review. *International journal of environmental research and public health*, 18(20), 10758:1-10.
- Kaplan, Ş., Yener, E. S., Yılmaz, Z., & Öztürk, O. (2024). Evaluation of digital solutions for passenger attitudes towards health measures at Dalaman airport during COVID-19 period. *International Journal of Aeronautics and Astronautics*, 5(1), 1-9.
- Karakuş, G., Karşıgil, E., & Polat, L. (2018, August). The role of IoT on production of services: A Research on aviation industry. In *The International Symposium for Production Research* (pp. 503-511). Cham: Springer International Publishing.
- Kenan, A., & Yıldırım, S. (2012). The measurement of service quality with servqual for different domestic airline firms in Turkey. *Serbian Journal of Management*, 7(2), 219-230.
- Khan, F., Yusoff, R. M., & Kakar, P. (2025). Impact of service quality and customer satisfaction on tourism industry. *Journal of Advanced Research in Social and Behavioural Sciences*, 39(1), 1-11.
- Klein, M. (2020). Digital transformation scenarios of businesses - A conceptual model proposal. *Electronic Journal of Social Sciences*, 19(74), 997-1019.
- Kováčiková, K., Remencová, T., Sedláčková, A. N., & Novák, A. (2022). The impact of Covid-19 on the digital transformation of the airports. *Transportation Research Procedia*, 64, 84-89.
- Kovrigin, E. A., & Vasiliev, V. A. (2020, September). Barriers in the integration of modern digital technologies in the system of quality management of enterprises of the aerospace industry. In *2020 International Conference Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS)* (pp. 331-335). IEEE.
- Kovynyov, I., & Mikut, R. (2019). Digital technologies in airport ground operations. *NETNOMICS: economic research and electronic networking*, 20(1), 1-30.
- Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023). Environmental sustainability within attaining sustainable development goals: The role of digitalization and the transport sector. *Sustainability*, 15(14), 11282:1-14..
- Kurnaz, S., & Žilinskienė, D. (2022). The Effects of the COVID-19 Pandemic and the Future of Aviation. In *Digitalization and the Impacts of COVID-19 on the Aviation Industry* (pp. 53-72). IGI Global.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. SAGE.
- Liu, S. Q., Vakeel, K. A., Smith, N. A., Alavipour, R. S., Wei, C., & Wirtz, J. (2024). AI concierge in the customer journey: what is it and how can it add value to the customer?. *Journal of Service Management*, 35(6), 136-158.
- Mäkelä, M. (2024). Artificial intelligence to benefit the passenger experience at the airport. Master Thesis, Haaga-Helia University of Applied Sciences, Aviation and Tourism Business, 1-50.
- Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative Research: A Guide to Design and Implementation* (4th ed.). Jossey-Bass.
- Mızrak, F., & Akkartal, G. R. (2023). Strategic management of digital transformation processes in the aviation industry: Case of Istanbul Airport. In *Cases on Enhancing Business Sustainability Through Knowledge Management Systems* (pp. 154-177). IGI Global.
- Moses, A. A., Nair, S., & Karim, A. M. (2023). The Effect of Digital Applications on Customer Satisfaction in Malaysian Passenger Airline Industry: Post-Pandemic Era. *International Journal of Academic Reserach in Economics and Management Sciences*, 12(4), 130-144.
- Nguyen, N. X., Tran, K., & Nguyen, T. A. (2021). Impact of service quality on in-patients' satisfaction, perceived value, and customer loyalty: A mixed-methods study from a developing country. *Patient preference and adherence*, 15, 2523-2538.
- Nguyen, H. V., Vu, T. D., Saleem, M., & Yaseen, A. (2024). The influence of service quality on student satisfaction and student loyalty in Vietnam: the moderating role of

- the university image. *Journal of Trade Science*, 12(1), 37-59.
- Oliveira, P. P. (2020). Digital twin development for airport management. *Journal of Airport Management*, 14(3), 246-259.
- Olivieri, A. (2025). How airlines can improve senior passengers' air travel experience. Master Thesis, Haaga-Helia University of Applied Sciences, Sustainable Aviation Business, 1-59.
- Ordieres-Meré, J., Prieto Remon, T., & Rubio, J. (2020). Digitalization: An opportunity for contributing to sustainability from knowledge creation. *Sustainability*, 12(4), 1460:1-21.
- Pandey, R., Rishi, M., & Dwivedi, P. (2024). Identifying Barriers To Airport Digitalization--Using Analytical Hierarchy Process. *Library of Progress-Library Science, Information Technology & Computer*, 44(4), 1484-1492.
- Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1985). A conceptual model of service quality and its implications for future research. *Journal of marketing*, 49(4), 41-50.
- Parasuraman, A. B. L. L., Zeithaml, V. A., & Berry, L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. 1988, 64(1), 12-40.
- Patton, M. Q. (2015). *Qualitative Research & Evaluation Methods: Integrating theory and practice* (4th ed.). SAGE.
- Pence Jr, G. (2024). Digitalization of Customer Service: Flying High or Grounded-Case Study on Finnair Ground Customer Service at Helsinki-Vantaa Airport. Master Thesis, Aalto University, Management & International Business, 1-78.
- Pik, E. (2024). Airport security: the impact of AI on safety, efficiency, and the passenger experience. *Journal of Transportation Security*, 17(1), 9:1-13.
- Polishchuk, O., Kulinich, T., Martynovych, N., & Popova, Y. (2022). Digitalization and sustainable development: the new covid-19 challenge requires non-standard solutions. *Problemy Ekorozwoju*, 17(2), 69-79.
- Poulaki, I., Paraschi, E. P., Marinakos, K., Avramopoulos, A., & Makrygianni, S. (2021). Digital technologies and innovation in airport services: a benefit model approach. *Journal of Air Transport Studies*, 12(2), 41-63.
- Prieto Remón, T. (2021). Impact of international organizations digitalization programs on air transport sustainability: The IATA case. Doctoral Thesis, Madrid Polytechnic University, Industrial Organization Engineering, 1-489.
- Qian, Y. (2025). Improving the quality of passenger service at Chongqing Jiangbei Airport. Haaga-Helia University of Applied Sciences. Bachelor of Business Administration, 1-58.
- Rahim, A. G. (2016). Perceived service quality and customer loyalty: The mediating effect of passenger satisfaction in the Nigerian Airline Industry. *International Journal of Management and Economics*, 52, 94-117.
- Remencová, T., & Sedláčková, A. N. (2021). Modernization of digital technologies at regional airports and its potential impact on the cost reduction. *Transportation Research Procedia*, 55, 18-25.
- Ramadhan, M. R., Lesmini, L., & Harahap, V. N. (2020). Document Digitization and Quality of Service Effect to Customer's Satisfaction in Soekarno Hatta International Airport. *Advances in Transportation and Logistics Research*, 3, 321-328.
- Sahota, N. (2024). Navigating the skies with AI: How airlines are transforming air travel. *Forbes*. Retrieved from: <https://www.forbes.com/sites/neilsahota/2024/03/29/navigating-the-skies-with-ai-how-airlines-are-transforming-air-travel/>
- Sezgin, E., & Demiral, G. N. (2019, April). Airports as shopfronts of tourism destinations: awarded brand Singapore Changi versus surviving Istanbul Ataturk. In *Eurasian Business Perspectives: Proceedings of the 22nd Eurasia Business and Economics Society Conference* (pp. 355-369). Cham: Springer International Publishing.
- Sharma, K. (2024). Assessing Passenger Satisfaction with Smart Airport Technologies: An Empirical Study. *International Journal for Multidisciplinary Research*, 6(2), 1-18.
- Sharma, P., & Bhatnagar, N. (2023). Passenger authentication and ticket verification at airport using QR code scanner. *SKIT Research Journal*, 13(2), 10-13.
- Shiwakoti, N., Hu, Q., Pang, M.K., Cheung, T.M., Xu, Z., & Jiang, H. (2022). Passengers' Perceptions and Satisfaction with Digital Technology Adopted by Airlines during COVID-19 Pandemic. *Future Transportation*, 2(4), 988-1009.
- Suryadana, L. (2017). Service quality, customer value and patient satisfaction on public hospital in Bandung district, Indonesia. *International Review of Management and Marketing*, 7(2), 187-192.
- Sullivan, M. (2023). Changi Airport Group's challenges in managing the growth of Singapore's award-winning airport. In *Singapore Inc.: A Century of Business Success in Global Markets* (pp. 264-266). Routledge.
- Syam, M. F. V. D., Maemunah, S., & Sodikin, A. (2022). The Effect Of Customer Experience, Service Quality, Facilities, Customer Satisfaction And Loyalty On International Airport. *Advances in Transportation and Logistics Research*, 5, 615-626.
- Usman, A., Azis, Y., Harsanto, B., & Azis, A. M. (2022). Airport service quality dimension and measurement: a systematic literature review and future research agenda. *International Journal of Quality & Reliability Management*, 39(10), 2302-2322.
- UTED – Uçak Teknisyenleri Derneği (2023). Sivil Havacılıkta Dijital Dönüşüm ve Veri Analizi. *UTED Haberler*. Retrieved from: <https://www.uted.org/sivil-havacilikta-dijital-donusum-ve-veri-analizi>
- Valarmathy, S., Radhika, K., Bashkaran, K., Selvarasu, S., & Srinivasan, C. (2023, November). Intelligent Baggage Management in Airports: A Cognitive IoT Approach for Real-Time Tracking, Optimization, and Passenger Engagement. In *2023 7th International Conference on Electronics, Communication and Aerospace Technology (ICECA)* (pp. 1876-1880). IEEE.
- Vongtharawat, M., Jeambua, K., & Pooripakdee, S. (2019). Willingness to use and pro-environmental attitudes for airlines' environment friendly services: the perspective of Thai passengers. *International Journal of Humanities, Arts and Social Sciences*, 5(4), 145-156.
- Xiong, S. H., Deng, Y. J., Zhang, H., & Chen, Z. S. (2025). Charting the path forward: a comprehensive barrier and solution analysis for digital transformation of small and medium-sized airports. *Enterprise Information Systems*, 19(5-6), 764-804.
- Yavas, V., Ozkan-Ozen, Y.D. (2023). Integration of Sustainability and Digitalization in Air Logistics:

- Current Trends and Future Agenda. In: Karakoc, T.H., Atipan, S., Dalkiran, A., Ercan, A.H., Kongsamutr, N., Sripawadkul, V. (eds) Research Developments in Sustainable Aviation. ISSASARES 2021. Sustainable Aviation (pp. 109-116). Springer, Cham.
- Zaharia, S. E., & Pietreanu, C. V. (2018). Challenges in airport digital transformation. Transportation research procedia, 35, 90-99.
- Zhang, Y., Lee, S. Y., & Gu, Y. (2023). A review of air transport service quality studies: current status and future research agenda. Journal of the Air Transport Research Society, 1(1), 9-21.

Cite this article: Buyuksaatci Kiris. S., Akif, B. (2025). From Check-in to Take-off: How Digitalization Reshapes Airport Service Quality. Journal of Aviation, 9(3), 768-779.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

A Tool for Fleet and/or Aircraft Assignment in Demand Optimization in Airline Operations

Ali Akbaba¹ 

¹Topkapı University, Aviation Management, Prof. Muammer Aksoy Cad. No: 10 Kazlıçeşme / Zeytinburnu/İstanbul, Türkiye (ali.akbaba75@gmail.com)

Article Info

Received: 23 June 2025

Revised: 15 September 2025

Accepted: 22 September 2025

Published Online: 17 October 2025

Keywords:

Fleet and/or Aircraft assignment

Demand optimization

AOCC

Tool

Airline operations

Corresponding Author: Ali Akbaba

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1724980>

Abstract

Airlines operate in a highly competitive environment and strive to maximize their revenue by optimizing resource utilization to gain a competitive advantage. In this context, optimizing aircraft allocation for flights is of critical importance for revenue maximization. In airline operations, fleet and aircraft assignments are based on demand forecasts at the beginning of the tariff, so when passenger and/or cargo demand differs from the forecast for a particular flight, the assigned aircraft resource needs to be re-evaluated accordingly. The aim of this study is to create a tool that provides operations managers with a preliminary assessment of demand optimization so that aircraft can be allocated in response to demand changes, taking into account aircraft performance, features, costs and revenues. The data for the variables in the study were obtained through a literature review. The averages of these data were calculated and used for study. It was assumed that only for airport suitability, Type 5 was not suitable for ADA and KCM airports, and Type 4 was not suitable for KCM airport. It can be reported that a TOOL has been created using the Microsoft Excel program, which enables the evaluation of passenger and cargo demands based on maximizing profit and minimizing losses.

1. Introduction

Fleet management in airlines involves three dimensions: strategic, tactical, and operational. The strategic dimension entails determining the aircraft types that can have an appropriate fleet structure and incorporating these aircraft types into the fleet. The tactical and operational dimensions, on the other hand, involve optimizing the management of the airline's aircraft resources. Many factors influence the appropriate fleet and aircraft assignment at the tactical and operational levels. Studies related to problems encompassing these factors in fleet and aircraft assignment can generally be grouped as follows: maintenance assignment problems for aircraft in fleet planning (Saltman and Stem, 2022; Sanches et al., 2020); studies on fleet assignment, aircraft routing, and crew planning problems (Ahmed et al., 2022; Fuentes et al., 2021; Fuentes et al., 2021; Unal et al., 2021); studies on turnaround optimization in aircraft and crew planning problems (Evler et al., 2022; Glomb et al., 2023); studies on aircraft recovery in airline operation management for disruption resolution (Lee et al., 2022; WU, 2023; Hu et al., 2021); studies on demand optimization in fleet and tail assignment (Birolini et al., 2021; Hernandez et al., 2020; Khanmirza et al., 2020; Kiarashrad et al., 2021).

When airline companies perform fleet planning during a tariff period, they first determine the destinations they will fly to. They then decide which aircraft fleet they will operate on these selected destinations. Demand forecasts on a flight basis and range data are of critical importance in making these

decisions. Demand optimization in fleet and/or aircraft tail assignment is crucial for revenue maximization in airline management. Therefore, demand optimization in fleet and aircraft assignment has found a research area in the literature, aiming to achieve optimization in fleet and/or aircraft assignment by reducing uncertainties in demand forecasting (Birolini et al., 2021; Hernandez et al., 2020; Khanmirza et al., 2020; Kiarashrad et al., 2021). The purpose of this study can be defined as creating a tool that enables aircraft assignment based on the evaluation of aircraft performance and characteristics, as well as costs and revenues, to optimize profit/loss based on evolving demand in operations management.

The data for the variables in the study were obtained through a literature review. The averages of these data were calculated and used for study. It was assumed that only for airport suitability, Type 5 was not suitable for ADA and KCM airports, and Type 4 was not suitable for KCM airport. Firstly, the effects of the identified independent variables on each other and their effects on the dependent variable of maximum profit/minimum loss were defined. Then, these definitions were transformed into formulas in Microsoft Excel to create a tool. Using the developed tool, three case studies were conducted to assess revenue maximization in fleet and aircraft assignment, and general controls were performed. The study concludes that the tool can be used in fleet and/or aircraft allocation to preliminary assess aircraft resource optimization

decisions based on profit/loss. it can be stated that the created tool can be used in fleet and/or aircraft assignment for evaluating aircraft resource optimization based on profit/loss. Furthermore, the tool can provide data to the user regarding the need for transitions between passenger classes, the percentage of passenger and cargo demand that can be accommodated, and the suitability of the aircraft type for operating flights to the relevant destinations. This data can contribute to the decision-making process.

2. LITERATURE REVIEW

The airline industry is of critical importance both in terms of its direct impact on the economy and its indirect impact on other sectors, making it crucial for both national and international trade (Birolini et al., 2021). According to data from the International Civil Aviation Organization (ICAO), the airline industry is projected to grow by over 100 percent by 2040. The International Air Transport Association (IATA), on the other hand, predicts an average annual growth rate of 3.7 percent in the airline industry until 2035 (Koech et al., 2023). Globalization has led to growth in the airline industry while increasing competition. Therefore, both increasing aircraft resources and efficiently utilizing existing fleets are critical for airlines to gain a competitive advantage (Lee et al., 2022).

Hence, fleet planning is one of the most important strategic issues for airlines, affecting them financially and operationally. Fleet planning has three dimensions: strategic, tactical, and operational (Birolini et al., 2021). The strategic dimension involves determining the aircraft types that can have an appropriate fleet structure to benefit from this growth and including these identified aircraft types in the fleet. Strategic fleet planning should balance cost optimization and market opportunities. Additionally, the decision of whether fleet expansion will be through acquisition or leasing is also part of strategic decision-making (Constantijn et al., 2020; Narcizo et al., 2020; Oliveira et al., 2022).

The tactical dimension of fleet planning involves fleet planning that is suitable for flights after schedule planning, followed by aircraft assignment. The tariff planning process of airline operations is generally as follows (Castro and Oliveira, 2011):

- Long term
 - Publish flight timetable
- Short term
 - Fleet assignment for flights
 - Crew pairing for flights
 - Crew rostering for flights
 - Tail assignment for flights
 - Roster maintenance for aircrafts
- Operation period (AOCC period)
 - Disruption management

When airlines engage in fleet planning during a scheduling period, they first determine the destinations they will fly to. They then decide which aircraft fleet will operate the chosen flights. In making these decisions, demand forecasts and range data play a crucial role. Matching seat capacity with demand forecasts and ensuring compatibility between flight ranges, airport facilities, and aircraft characteristics are critical for fleet assignment in schedule planning (Mohri et al., 2022). Additionally, the network structure in the airline's schedule is important for fleet planning; considerations should be given to transit passenger capacity and the suitability of flight timings (Wu et al., 2022). After fleet assignment, the decision of which aircraft from the relevant fleet will be assigned to a specific flight is made. Since there may be variations in aircraft

characteristics within the same aircraft type, optimizing resource utilization plays a key role in this stage (Birolini et al., 2021). Long-term and short-term fleet planning has received significant attention in the literature, and various techniques have been developed in this regard (Izaak et al., 2023). Following the department responsible for determining the schedule, which may have different names in different airlines, the authority for aircraft assignment shifts to the AOCC (Airline Operations Control Center) to make decisions based on operational developments shortly before the operation. From this point onwards, the aircraft assignment process enters the operational dimension. The duration of this process may vary for each airline.

The operational dimension of aircraft assignment involves the aircraft assignments made by the AOCC (Airline Operations Control Center) based on operational developments. The advantages of AOCC's optimization of aircraft resources for solving the problems arising from differences in demand forecasting during the scheduling period can be reported as one of the reasons for airline companies to resort to the AOCC organization (Geursen et al., 2023). The main task of the AOCC is to reduce the airline's costs and increase revenue by making optimal decisions in irregular operation or disruption management (Su et al., 2021; Süzer, 2024). In general, it can be reported that the AOCC makes one of the following decisions in disruption management (Kohla et al., 2007):

Flight rescheduling to a later time,

Cancellation of the flight,

Changing the aircraft that will perform the flight,

Combining two or more flights

Planning an additional landing point in a flight sector

Execution of the speed of the aircraft in the fastest way within the performance limits.

These decisions aim to effectively manage disruptions, minimize operational impacts, and ensure efficient resource utilization in the airline's operations.

In these decisions, there are generally three dimensions that contribute to the disruption: passenger dimension, aircraft resource dimension, and flight crew dimension (Ogunsina and DeLaurentis, 2022). The aircraft assignment controller within the AOCC organization is responsible for managing the aircraft resource in the resolution of disruptions (Castro and Oliveira, 2011; Machado et al., 2015). Making the optimal decision in the resolution of the aircraft resource dimension is one of the contributions that the AOCC can provide in disruption management (Ogunsina et al., 2021). The aircraft assignment unit strives to integrate the resolution of disruptions by considering the input from other units within the AOCC, such as the crew planning unit, and selecting the optimal aircraft type from the airline's available fleet. Each aircraft has different characteristics and performance specifications, passenger capacity, and passenger configurations (such as business class or economy class capacity). Therefore, the AOCC takes these factors into account to manage disruptions or irregular operations (Wu et al., 2017).

The AOCC not only contributes to disruption management but also enhances revenue maximization by making optimal aircraft assignments when differences are expected in demand forecasts. The appropriate allocation of aircraft resources based on demand developments is particularly critical for positively impacting the airline's revenue. Demand forecasts

made at the beginning of the scheduling period may not align perfectly for every flight in terms of both passenger and cargo. Additionally, airlines have the option to oversell seats beyond the aircraft's capacity due to potential no-show passengers. This oversell rate typically ranges from 5% to 15% of the aircraft's seat capacity (Britinnaca, N.D). Furthermore, a cargo transportation request may arise as the operation day approaches. Due to these reasons, making optimal aircraft assignments as the operation date approaches can contribute to increased revenue for the airline through the AOCC organization. In medium- and large-sized airlines, Making the optimization decision is one of the most critical processes for AOCC managers (Süzer, 2025) and AOCCs encounter such situations numerous times daily. In all of these cases, the final decision requires consulting AOCC departments such as crew planning, maintenance planning, sales, and dispatch, which wastes both time and labour. A tool that allows the AOCC manager and/or aircraft assignment controller to perform a preliminary assessment can contribute to practice. This study was conducted to enable the AOCC manager and aircraft assignment operator to perform a preliminary assessment for aircraft optimization when there are differences in demand forecasts.

3. Methodology

3.1. Purpose of the Research

The airline industry operates in a highly competitive environment. Therefore, airlines strive to gain a competitive advantage by optimizing resource utilization to maximize their revenues. In this context, ensuring optimization in the assignment of aircraft resources to flights holds critical importance for revenue maximization. When airlines create their schedules, they allocate aircraft based on demand forecasts resulting from market research for each flight (Gunter and Zekan, 2021). The uncertainty in demand forecasting decreases as the operation day approaches. If the actual number of passengers and/or cargo for a flight differs from the forecasted demand in the schedule, the assigned aircraft resource needs to be reevaluated accordingly. In all of these cases, the final decision requires consulting AOCC departments such as crew planning, maintenance planning, sales, and dispatch, which wastes both time and labour force. The aim of this study is to create a tool that provides operations managers with a preliminary assessment of demand optimization so that aircraft can be allocated in response to demand changes, taking into account aircraft performance, features, costs and revenues. Thus, TOOL can enable faster decision-making with lower labor costs in the aircraft allocation process in response to demand changes, taking into account aircraft performance, characteristics, costs, and revenues. In parallel, the problem of this study is as follows:

- Can a TOOL be created that allows preliminary assessment by entering aircraft performance and characteristics, costs, and revenues in the Excel program?

3.2. Assumptions of the Study

The study assumes that the aircraft assignments are taking place in a virtual airline which has five aircraft subtypes. The names of the aircraft subtypes were not written in the study. They were called Type 1, 2, 3, 4, and 5 (ICAO, N.D). Additionally, it is assumed that this virtual airline operates flights to 10 destinations.

The developed tool in the study is based on achieving maximum profit/minimum loss in flight operations. Other factors' effects have been disregarded in the analysis.

3.3. Method of the Study

The study was conducted for a virtual airline that operates flights with 5 aircraft subtypes and serves 10 destinations. The aircraft types for the airline are as follows:

- Type 1: Narrow-body
- Type 2: Narrow-body
- Type 3: Narrow-body
- Type 4: Narrow-body
- Type 5: Wide-body

Note: If an aircraft has one aisle, it is called narrow-body, and if it has two or more aisles, it is called wide-body (Simpleflying, 2022).

For the study, 1 base airport and 10 flight destinations have been selected. The airports the airline flies to will be denoted with their 3-letter IATA codes (IATA, N.D). The IATA codes for the selected airports for the study are as follows:

- IST:** Istanbul Airport
- ADA:** Adana Airport
- LHR:** London Heatrow Airport
- MUC:** Munich Airport
- KCM:** Kahramanmaras Airport
- AMS:** Amsterdam Schiphol Airport
- FCO:** Roma Fiumicino Airport
- MAD:** Madrid Adolfo Suarez Airport
- ALG:** Algiers Houari Boumediene Airport
- CDG:** Paris Charles-De-Gaulle Airport
- VIE:** Vienna Schwechat Airport

In this study, an Excel program was used to create a tool for optimizing profit/loss by evaluating the performance and characteristics of aircraft subtypes along with the cost and revenue data associated with each flight. The tool determines the most optimized aircraft type in terms of profit/loss and also allows users to compare the manually entered aircraft type with the currently assigned aircraft type. it can be stated that the created tool can be used in fleet and/or aircraft assignment for evaluating aircraft resource optimization based on profit/loss. Furthermore, the tool can provide data to the user regarding the need for transitions between passenger classes, the percentage of passenger and cargo demand that can be accommodated, and the suitability of the aircraft type for operating flights to the relevant destinations. This data can contribute to the decision-making process.

The selection of variables used in creating this tool was based on the average data obtained from relevant literature. The reasons for selecting these variables, their interrelationships, and their impacts on profit/loss optimization can be summarized as follows (Glomb vd., 2023; Sherali vd.,2006; Unal vd., 2021; İTÜ, 2014; Jeppesen, N.D):

1. Aircraft-airport compatibility: Airlines determine whether they can operate a flight to a specific airport by checking certain criteria based on the aircraft's performance and characteristics, as well as the facilities, services, and physical features of the airport (Boing, N.D; ICAO, 2023). The suitability of an aircraft for a specific airport is determined by comparing the aircraft's capabilities with the airport's requirements.

In the aircraft-airport compatibility analysis conducted by the tool, two types of results are generated: "best option" and "manual selection." During the creation of the tool, checks

were performed in the airline's system to see if the relevant aircraft types are compatible for the flight destinations. If an aircraft type is found to be incompatible for a specific airport, as shown in Table 1 for IST-ADA and ADA-IST flights with TYPE 5 aircraft, values of "0" are entered for the max payload and fixed operation cost to prevent the transportation of passengers and cargo. This ensures that the tool does not generate revenue and cost data for such scenarios and does not mark the related subtype as the "best option."

Additionally, when the user performs a manual selection between two aircraft subtypes, if an aircraft-airport

compatibility issue arises for one of the subtypes, the tool provides the result "not authorized" as a manual evaluation outcome. The scenarios where the tool does not generate revenue and cost and shows "not authorized" as the result of manual selection are shown in Table 19.

In summary, the tool takes into consideration the aircraft-airport compatibility criteria to determine the best option for each flight and provides "not authorized" when manual selection is not feasible due to aircraft-airport incompatibility.

Table 1. Aircraft-Airport Incompatibility Example for TYPE 5 IST-ADA-IST (payload and cost set to "0")

	DEP	ARR	MAX Payload (kg)	SeatBuss	SeatEcon	FixedOpCost
TYPE5	IST	ADA	0	18	232	0
TYPE	ADA	IST	0	18	232	0

The abbreviations used in Table 1 are as follows:

DEP: Departure aerodrome

ARR: Arrival aerodrome

Max. Payload: Maximum payload

AveragePaxW.: Average pax weight

SB (SeatBuss.): Business seat number

SE (SeatEcon.): Economy Seat Number

FixedOpCost: Fixed operation cost

(\$): Dollar

(kg): Kilogram

2. Aircraft Range: The range data for each aircraft type based on its performance with a specific weight has been determined by the aircraft manufacturer (Aygün and Turan, 2023; Point Hacks, 2025). When assigning aircraft to flights, the payload value, which represents the weight each aircraft can carry based on its range for the specific flight route, is of critical importance. Therefore, in this study, the maximum payload that each aircraft type can carry to the respective flight destinations is derived from flight plan system (IVAO, N.D; AIRNAVIGATIONPRO, N.D; PPS FLIGHT PLANNING, N.D).

Payload refers to the total commercial load carried by an aircraft, including passenger weight and cargo weight (Melis et al., 2019; Airways, 2023; FAA, 2023). The maximum payload value restricts the number of passengers and the

amount of cargo that can be transported, making it an essential variable during the creation of the tool.

The formula for calculating the maximum payload is as follows:

Max payload $\geq$ (number of passengers x average passenger weight) + cargo weight.

When the data in Table 2 is substituted into the formula for maximum payload based on the maximum number of passengers (126) for TYPE 1 on the IST-MUC flight route, the following calculations are obtained:

Max payload $\geq$ (number of passengers x average passenger weight) + cargo weight

$$15000 \geq (126 \times 98) + \text{cargo weight (kg)}$$

$$15000 \geq 12348 + \text{cargo weight (kg)}$$

In this case, the maximum payload at the maximum number of passengers is calculated to be 12,348 kg, and the amount of cargo that can be carried is 2,652 kg. Thus, this formula allows for limitations to be imposed on the passenger and cargo demand up to a certain value.

Table 2. Example of Max. (Maximum) Payload Data for TYPE 1 IST-MUC-IST

	DEP	ARR	MAX Payload (kg)	AveragePaxW(kg)	SeatBuss (num.)	SeatEcon (num.)
TYPE 1	IST	MUC	15000	98	12	114
TYPE 1	MUC	IST	15000	93	12	114

Note: The value of 15000 kg represents the maximum payload that TYPE 1 aircraft can carry on the IST-MUC-IST flight route.

3. Aircraft passenger configuration: It refers to the total number of seats offered to passengers, which varies depending on the aircraft subtype (Grimme et al., 2021; Airways, 2023). This number can even vary within the same subtype in certain cases, depending on factors such as seat spacing, whether all seats are designed for economy class or both economy and business class, and whether the aircraft is a narrow-body or wide-body type. The sectors in TOOL were studied for both economy and business class, based on aircraft manufacturers and ticket sales websites. Only KCM Airport has all-economy

seat capacity (Boing, N.D; Airbus, N.D; SeatGuru, N.D). This choice was made because only economy tickets are sold at KCM Airport (Ucuzabilet, N.D; Obilet, N.D; Turkish Airlines, N.D). In Table 3, for example, for the MUC flight route, the aircraft passenger seat capacity is entered separately for both business class and economy class. In this case, TYPE 2 has a capacity of 16 business class and 135 economy class passengers on the MUC flight route. The data is entered into the Excel table accordingly. This data is of critical importance for the TOOL, especially due to the limitation of the number of tickets to be sold. This data is used in the TOOL for calculating payload, revenue, and costs. The payload formula was provided under the aircraft range heading. The revenue and cost formulas will be given under the headings of flight costs and flight revenues.

Table 3. Example of Aircraft Passenger Configuration Data for TYPE 2 on IST-MUC-IST and IST-KCM-IST Flight Routes

	DEP	ARR	MAX Payload	AveragePaxW	SeatBuss	SeatEcon
TYPE 2	IST	MUC	17800	98	16	135
TYPE 2	MUC	IST	17800	93	16	135
TYPE 2	IST	KCM	17800	87	0	151
TYPE 2	KCM	IST	17800	87	0	151

4. Passenger Count and Average Passenger Weights:

Airlines determine passenger weights based on either average values set by international organizations or their own statistics (EASA, 2022). In this study, passenger weights have been estimated differently for domestic and international flights based on the averages determined by these international organizations (EASA, (2022)). The passenger count and average passenger weight, along with the cargo weight, contribute to the total payload carried by the aircraft. Since there is a maximum payload constraint for each flight, the sum of the total passenger weight and cargo weight must not exceed the maximum payload limit.

Table 4 includes the passenger count and weights for the IST-MUC and MUC-IST flight legs. For example, for the IST-MUC flight leg, the average passenger weight is 98 kg. The TOOL calculates the payload by multiplying the passenger count by this weight and then adding the cargo weight.

However, as stated under the "Max Payload" header, the resulting payload should not exceed the maximum payload limit.

In addition, the passenger count is also important for determining the revenue and costs for each flight. Therefore, in the creation of the TOOL, the passenger count and average passenger weights are used as variables. For example, in Table 4, the data provides that the cost per passenger for business class on the IST-MUC route is \$29 and for economy class is \$20. The average ticket price for one year on the IST-MUC flight leg is determined as \$480 for business class and \$157 for economy class. The passenger count is multiplied by these data to calculate passenger revenues and costs, making it a critical variable in determining profitability.

Table 4. Passenger Count and Weight Data Example for TYPE 1 IST-MUC-IST

	D	A	APW (kg)	SB (num)	SE (num)	FC (\$)	BPC (\$)	EPC (\$)	B Pax (\$)	E Pax (\$)
TYPE 1	IST	MUC	98	16	135	9892.43	29	20	480	157
TYPE 1	MUC	IST	93	16	135	9169.71	37	25	470	141

The terms and abbreviations used in Table 4, which were not mentioned before, are as follows:

D: Departure aerodrome

A: Arrival aerodrome

APW.: Average pax weight

SB.: Business seat number

SE.: Economy Seat Number

FC: Fixed operation cost

(\$): Dollar

(kg): Kilogram

BPC (BussPaxCost): Average business class per pax cost

EPC (EconPaxCost): Average economy class per pax cost.

B. Pax: Average Business class ticket price.

E. Pax: Average Economy class ticket price.

5. Cargo Quantity: Cargo is the second component that contributes to the flight's payload, along with the weight of

passengers. Depending on the passenger count and the aircraft's payload capacity, cargo can be transported in passenger aircraft to meet demand. Therefore, the cargo weight (kg) needs to be added to the payload, and this combined value should not exceed the maximum payload limit. For instance, in Table 5, for TYPE 2 on the IST-FCO flight, the total payload, including the cargo weight, should not exceed 17,800 kg. Hence, the cargo weight, similar to the passenger count, significantly affects the payload that can be carried on the aircraft, making it a critical variable in aircraft assignment.

Secondly, the cargo quantity (kg) also affects the cost and revenue. In the TOOL, average cost and revenue per kilogram of cargo were entered as data from literature (MNG Kargo, 2022; Kargomkolay, N.D; Fast Express, N.D). as shown in Table 5. For example, in Table 5, for TYPE 2 on the IST-FCO flight segment, the cost per kilogram is \$0.6 (the obtained cost value will be added to FixedOpCost), and the revenue per kilogram is \$1.85, obtained from literature (MNG Kargo, 2022; Kargomkolay, N.D; Fast Express, N.D). The revenue and cost formulas will be given under the headings of flight costs and flight revenues.

Table 5. Example of Data Entry for TYPE 2 IST-FCO Cargo Quantity Variable's Impact

	DEP	ARR	MAX Payload (kg)	FixedOpCost (\$)	CargoCost (\$ per kg)	Cargo (\$ per kg)
TYPE 2	IST	FCO	17800	8643.08	0.6	1.85
TYPE 2	FCO	IST	17800	8777.04	0.8	2.30

The terms and abbreviations used in Table 5, which were not mentioned before, are as follows:

CargoCost (\$ per kg): Cargo cost in dollars per kilogram.

Cargo (\$ per kg): Cargo revenue in dollars per kilogram.

6. Flight Costs: Airline costs are divided into fixed and variable costs (Gudmundsson et al., 2020; FAA, N.D). The fixed costs are evenly distributed per flight as block hours, regardless of the aircraft subtype. Since the study is based on cost differences, the impact of fixed costs on cost differences is not considered and thus not used in the TOOL. In other words, the study is focused on the variation in variable costs, and the term "flight cost" in the study refers to the total variable costs. To explain in formula, if the fixed costs for a flight in the schedule are represented by X, and Type 1's variable costs for this flight are represented by V1, and Type 2's variable costs for the same flight are represented by V2, then the impact of fixed costs on the cost difference can be expressed as follows:

$$\text{Cost Difference: } (X + V1) - (X + V2) = V1 - V2$$

As seen in the formula above, there is no impact of fixed costs on the cost difference. Airlines that allocate fixed costs to flights differently can modify this part of the formula in the TOOL.

The fixed portion of variable costs, which does not change per passenger or cargo (kg) on a flight, is referred to as "operation fixed costs," and the changing portion is referred to as "operation variable costs" (FAA, N.D; ICAO, N.D). For each selected destination in the study, the average fixed operating costs were first determined from the literature, based on the passenger and cargo volume per flight. The average operating variable costs were then determined from the variable costs per passenger and per cargo (kg) (PLANEAI, N.D; Aircraft Cost Calculator, N.D; Eurocontrol, N.D; AirInsight Group, 2019). When the number of passengers or cargo is entered into the TOOL, this number is multiplied by the operating variable costs, and the TOOL determines the total operating variable costs and adds them to the operating fixed costs. This provides the total cost of the flight (fixed costs per flight are not included).

For example, in the TYPE 2 IST-MUC flight, according to Table 6, when the values are 10 business passengers, 100 economy passengers, and 1000 kg of cargo, the operation costs are calculated in the TOOL using the following formula:

$$\text{Cost} = \text{FixedOpCost} + (\text{Business pax number} \times \text{BussPaxCost}) + (\text{Economy pax number} \times \text{EconPaxCost}) + (\text{Cargo quantity (kg)} \times \text{Cost Per Cargo})$$

$$\text{Cost} = 9892.43 + (10 \times 29) + (100 \times 20) + (1000 \times 0.6) = \$12,782.$$

Table 6. TYPE 2 IST-MUC-IST Flight Cost Data Entry Example

	DEP	ARR	FixedOpCost (\$)	BussPax Cost (\$)	EconPaxCost (\$)	CargoCost (\$ per kg)
TYPE 2	IST	MUC	9892.43	29	20	0.6
TYPE 2	MUC	IST	9169.71	37	25	0.9

7. Flight Revenues: Airlines have set ticket and cargo prices for each flight destination. These two revenue items can be considered as direct revenue categories for flights, and the data for the TOOL was obtained from the airline as follows:

- For passenger revenues in the study, average ticket prices for business class and economy class for the relevant flights were obtained from ticket websites (Ucuzabilet, N.D; Obilet, N.D; Turkish Airlines, N.D).

- For cargo revenues, average cargo prices per kilogram were obtained the relevant websites (MNG Kargo, 2022; Kargomkolay, N.D; Fast Express, N.D).

After obtaining these data, the following formula is applied by the TOOL to calculate the revenue:

$$\text{Revenue} = (\text{Number of Business Class Passengers} \times \text{Business Class Ticket Price}) + (\text{Number of Economy Class Passengers} \times \text{Economy Class Ticket Price}) + (\text{Cargo Quantity} \times \text{Cargo Price Per Kilogram})$$

For example, according to Table 7, the revenue for TYPE 3 IST-FCO with 10 business class passengers, 100 economy class passengers, and 1000 kg of cargo is calculated as follows:

$$\text{Revenue} = (10 \times 480) + (100 \times 165) + (1000 \times 1.85) = 23150\$$$

Here, it can be stated that the factors that differentiate revenue for each aircraft type are the passenger seating capacity and cargo carrying capacity.

Table 7. TYPE 3 IST-FCO-IST Passenger Revenue Data Entry Example

	DEP	ARR	AveragePaxW	SeatBuss	SeatEcon	B Pax
TYPE 3	IST	FCO	95	16	153	480
TYPE 3	FCO	IST	96	16	153	472

The TOOL has been developed in an Excel program by converting the data related to the variables into separate tables for each flight route and 5 aircraft subtypes, similar to the sample data tables in Tables 1, 2, 3, 4, 5, 6, and 7. The TOOL has been developed in the Excel program by writing formulas based on the relationships between the seven variables mentioned above, as well as the dependent variable of maximum profit/minimum loss. The TOOL utilizes the revenue-cost difference for optimizing the profit.

At the end of the study, the Excel formulas that constitute the TOOL are presented in Figure 1 through Tables 8, 9, 10, and 11.

3.3. Data Collection

Data for the variables in this study were obtained through a literature review. These data were averaged. Only in terms of aircraft-airport suitability was it hypothetically assumed that Type 5 was unsuitable for ADA and KCM airports, and Type 4 was unsuitable for KCM airport. These data were then converted into tables for each destination based on aircraft type

in Excel. Finally, the relationships between the variables in these tables and the dependent variable of maximum profit/minimum loss were formulated in Excel.

4. Finding

In this section, first, the usage of the TOOL and the meanings of the terms used have been explained. In the second part, three case studies has been conducted to evaluate the most compatibility aircraft assignment based on profit/loss analysis.

4.1 Usage of the TOOL:

In the study, the Excel program-based TOOL consists of three tables, as shown in Tables 12, 13, and 14. Below, the usage of the TOOL and/or the expressions used in the TOOL have been explained according to Tables 12, 13, 14.

1. Table 12: In the study, passenger and cargo demand, flight route, and aircraft subtype are manually entered into Table 12. The processed data from these inputs is transferred by the TOOL to Table 13 and Table 14 for aircraft assignment. Table 12 consists of the following columns:

SECT: It The flight route is entered here. The first column is manually filled with the first leg of the flight, and the second column is filled by the TOOL with the second leg of the flight. In Table 12, the IST-MUC flight was entered manually, and the MUC-IST flight was transferred by the TOOL.

Passenger Number Business: Business class passenger demand is entered in this section. In Table 12, there are 22 business class passengers for the first leg and 13 business class passengers for the second leg, entered into the TOOL.

Passenger Number Economy: Economy class passenger demand for both the first and second legs of the flight is entered in this section. In Table 12, there are 143 economy class passengers for the first leg and 133 economy class passengers for the second leg, entered into the TOOL.

Cargo Quantity (kg): Cargo quantity is manually entered for both the first and second legs of the flight in this column. In Table 12, there were 5000 kg of cargo for the first leg and 1000 kg of cargo for the second leg entered into the TOOL.

SubType: The aircraft subtype is entered into this column. The subtype entered for the first leg is automatically assigned by the TOOL to the second leg. In Table 12, TYPE 2 was entered for both the first and second legs.

Manual Subtype Selection: This section allows the user to compare the existing aircraft subtype with other available aircraft subtypes, apart from the best option aircraft subtype. The user manually enters the subtype they want to compare with the existing aircraft type in this section.

2. Table 13; In Table 13, the TOOL transfers data to two columns: one related to the comparison between the existing aircraft subtype and the Best Option aircraft subtype, and the other related to the comparison between the existing aircraft subtype and the manually selected aircraft subtype. The cost, revenue, and profit difference data resulting from the processing of the information entered in Table 12 are transferred by the TOOL to these two columns as follows:

Best Option: Based on the data entered in Table 12, the TOOL evaluates and transfers the following three data to this column for the best option aircraft type based on maximum profit/minimum loss:

Total Cost Difference (\$): It provides the cost difference between the existing aircraft subtype and the best option aircraft subtype for the respective flight route, considering the passenger and cargo figures. According to Table 13, this value is \$3695.70 in favor of the existing aircraft subtype (the current

aircraft subtype costs less than the best option aircraft type). The best-option aircraft subtype is reported by the TOOL in Table 14 (based on the entered passenger and cargo figures, TYPE 3 is given as the best option in Table 14).

Total Income Difference (\$): It provides the income difference between the existing aircraft subtype and the best-option aircraft subtype for the respective flight, considering the entered passenger figures and cargo quantity. According to Table 13, this value is \$5579.80 in favor of the best-option aircraft subtype.

Total Profit Difference (\$): It provides the profit/loss difference between the existing aircraft subtype and the best option aircraft subtype based on the respective passenger and cargo figures. According to Table 13, this profit difference is \$1884.1 in favor of the best option aircraft subtype. This section in the TOOL informs about the advantages that can be gained if the best option aircraft subtype is assigned.

Manuel: In the "Manual" column of Table 13, a comparison is made between the manually selected aircraft subtype from Table 12, based on passenger and cargo demand for the respective flight route, and the existing aircraft subtype in terms of Total Cost Difference (\$), Total Income Difference (\$), and Total Profit Difference (\$).

3. Table 14: Table 14 consists of three sections. The first section starts from the "Selection" column and ends at the "Profit" column, comprising 11 columns. The second section is the "Able to Transport" section, indicating how much of the passenger and cargo demand can be accommodated by the respective aircraft subtype on the flight routes, and it consists of 6 columns. The third section is the "Unable to Transport" section, showing how much of the passenger and cargo demand cannot be accommodated by the respective aircraft subtype on the flight routes, and it consists of 3 columns.

Section 1: In this section, the previously unexplained columns are as follows:

Selection: In this column, the first row represents the current aircraft subtype (Current), the second row represents the best-option aircraft subtype based on the processing of data from Table 12 (Best Choice), and the third row represents the manually selected aircraft subtype. The relevant data for each aircraft subtype based on the processing of passenger and cargo data entered in Table 12 is assigned the rows by TOOL.

Subtype: In this column, the subtype for the current and manual selection rows is transferred by TOOL, representing the aircraft type selected by the user. For the Best Choice row, the Subtype column is filled by TOOL with the aircraft subtype that is determined as the best option based on maximum profit/minimum loss after processing the data from Table 12.

Business Pax Capacity / Economy Pax Capacity: In these two columns, the business and economy passenger seat capacities for the respective aircraft subtypes are assigned by TOOL.

Cost / Income / Profit: In these three columns, TOOL transfers the total cost (variable), income, and profit data generated for the specific flight route and aircraft subtype combination.

Section 2: In this section, the portion of the requested passenger count and cargo quantity that can be transported is assigned by TOOL (Able to Transport section). It consists of the following columns:

Bussiness Pax/ Economy Pax: In these two columns, the portion of business class and economy class passenger demand that can be accommodated with the relevant aircraft subtype is assigned by TOOL.

Upgrade Economy to Business/ Downgrade Business to Economy: In the first column, when there is excess demand in economy class, TOOL indicates how much of it can be upgraded to the business class for the respective aircraft subtype. In the second column, when there is excess demand in business class, TOOL indicates how much of it can be downgraded to economy class for the respective aircraft subtype.

Total Pax: TOOL assigns in this column the total passenger demand that can be accommodated in both classes for the respective aircraft subtype.

Cargo: TOOL indicates in this column how much of the requested cargo quantity in kg can be transported with the respective aircraft subtype.

Section 3: In this section, the portion of the passenger and cargo demand that cannot be transported is assigned by TOOL (Unable to Transport). It consists of the following columns:

Business Pax/ Economy Pax: TOOL indicates in these sections how much of the business class and economy class passenger demand cannot be accommodated with the respective aircraft subtype.

Cargo: TOOL assigns in this section how much of the requested cargo quantity in kg cannot be transported with the respective aircraft subtype.

4.2 Case Studies

In this section, three case studies have been conducted: in the first case study, demand has been higher than expected, in the second case study, demand has been lower than expected, and in the third case study, there has been aircraft-airport incompatibility.

Case 1: For the IST-MUC-IST flight route with the current aircraft type as TYPE 2, the following demand is available:

IST-MUC:

Business: 22 pax / Economy: 143 pax / Cargo: 5000 kg

MUC-IST:

Business: 13 pax/ Economy: 133 pax/ Cargo: 1000 kg

When the above passenger and cargo demand was entered into Table 12, TOOL assigned TYPE 3 as the best option based on maximum profit/minimum loss in Table 14. It was assumed that the user manually selected TYPE 4 as an additional option from Table 12 to view the data for TYPE 4, and the data for TYPE 4 was also assigned by TOOL in the Manual Selection row in Table 14. The data transferred by TOOL was shown in Table 14. The result of the data can be reported based on profit/loss as follows:

Based on the data shown in Table 13, it can be observed that even though operating the flight with the best-option aircraft type, TYPE 3, incurs \$3695.7 more cost, it generates \$5578.8 more revenue, resulting in an advantage of \$1884.1 in terms of profit. Additionally, TYPE 3 can accommodate all passenger demands, but 6 business passengers in TYPE 3 are unable to be transported in business class and will be downgraded to economy class, as informed by TOOL.

On the other hand, TOOL indicates that 14 passengers (6 business and 8 economy) cannot be transported in TYPE 2 assignment. Furthermore, with TYPE 2, approximately 1998 kg of the 5000 kg cargo demand for the IST-MUC route cannot be transported, while with the best option TYPE 3, approximately 170 kg of the 5000 kg cargo demand cannot be transported. This highlights the critical importance of

considering the nature of the cargo when evaluating demand for aircraft assignment.

In conclusion, the data reveals that selecting the best option, TYPE 3, offers a significant advantage in terms of profit and passenger accommodation compared to the current aircraft subtype, TYPE 2. It also highlights the importance of considering both passenger and cargo demands when making aircraft assignments.

According to the data in Table 13, even though TYPE 4 generated \$5894.3 more revenue than TYPE 2 based on maximum profit/minimum loss, it incurred \$6773.61 more cost, resulting in a lesser profit of -\$879. Therefore, on the basis of profit/loss, TYPE 4 was not advantageous compared to the current aircraft subtype, TYPE 2, as reported by TOOL. Despite fulfilling all demand, as indicated in the "Unable to Transport" section of Table 14, the higher cost of operating with TYPE 4 resulted in a lower profit.

In this case study, TOOL has recommended assigning TYPE 3 to the flight, as it is the best option based on profit/loss. If there is no availability of aircraft in this subtype, TOOL has informed that operating the flight with TYPE 2 among the compared subtypes would be more advantageous based on profit/loss.

Case 2: For the flight route IST-ALG-IST with the current aircraft subtype TYPE 4, the expected demand is lower than the forecasted demand, as shown below:

IST-ALG:

Business: 8 pax/ Economy: 118 pax/ Cargo: 1000 kg

ALG-IST:

Business: 5 pax / Economy: 125 pax / Cargo: 500 kg

The passenger and cargo demand above was entered in Table 15. Then, TOOL transferred the data to Tables 16 and 17 on the basis of profit/loss. As a result of the data transmitted by the TOOL, the aircraft assignment evaluation on the basis of profit/ loss can be reported as follows:

Best Option: Based on the current passenger numbers and cargo quantity, TOOL has identified TYPE 1 as the best option on a maximum profit/minimum loss basis. Although TYPE 1 generated \$2772 less revenue compared to TYPE 4, it reduced the overall cost of the flight by \$9977.23. Therefore, it provides an advantage of \$7205.23 on a maximum profit/minimum loss basis.

If TYPE 1 was assigned for the flight, it would require upgrading 4 business passengers on the IST-ALG leg and 7 business passengers on the ALG-IST leg to Economy class. Additionally, TOOL indicated that TYPE 1 would not be able to transport 1000 kg of cargo on the IST-ALG leg and 4 economy passengers on the ALG-IST leg. As a result, it was assumed that the user manually inputted TYPE 2 to evaluate the outcomes.

Manual: Based on the current passenger numbers and cargo quantity, TOOL indicated that TYPE 2 provided an advantage in terms of profit difference by reducing the overall cost of the flight by \$2129.72, even though it did not offer a revenue advantage compared to TYPE 4. Additionally, it can transport all passengers and cargo.

According to the data provided by TOOL, if the AOCC manager can solve the issue of 4 passengers and 1000 kg of cargo not being transported, assigning TYPE 1 for the flight would be advantageous. However, if this issue cannot be resolved, manually selecting TYPE 2 would still be more advantageous than TYPE 4 on a maximum profit/minimum loss.

Case 3: Case 3 includes the incorporation of aircraft-airport compatibility into the TOOL application. Therefore, only two tables of TOOL are provided below. As seen in Table 18, the user manually entered TYPE 5 aircraft subtype for IST-ADA and ADA-IST flights to compare with TYPE 1, except for the Best Option aircraft subtype, based on the entered passenger and cargo values. Since TYPE 5 is not suitable for flights to ADA airport, in Table 19, under the Manual column and in the Total Profit row, the expression "Not Authorized" is transferred by TOOL. This statement indicates that the respective aircraft type cannot be assigned to the flight due to aircraft-airport compatibility. In this way, TOOL prevents the evaluation of an aircraft type that cannot be assigned to a flight by the user based on maximum profit/minimum loss criteria.

The above three case studies demonstrate that the TOOL, created with the identified variables, can be useful in providing preliminary AOCC assessments when there is a discrepancy in demand forecasting for a particular flight and if aircraft resources are available. The TOOL provides not only cost, revenue, and profit difference data but also shows the portion of the demand that can be accommodated, as well as the amount of downgrade from business class to economy class and the amount of upgrade from economy class to business class based on the demand.

5. Discussion and Further Studies

The aim of this study is to develop an application that will contribute to the optimization process in the assignment of aircraft resources in response to changes in demand. Studies in the literature related to fleet planning and/or aircraft tail assignment can generally be classified into two categories; tactical or operational dimension. These studies can be grouped as follows: Aircraft maintenance assignment problems in fleet planning (Saltman and Stem, 2022; Sanches et al., 2020); Studies on fleet assignment, aircraft routing, and crew planning problems (Ahmed et al., 2022; Fuentes et al., 2021; Unal et al., 2021); studies on turnaround optimization in aircraft and crew planning problems (Evler et al., 2022; Glomb et al., 2023); studies on aircraft recovery in airline operations management for disruption management (Hu et al., 2021; Lee et al., 2022; Wu, 2023); studies on demand optimization in fleet and aircraft tail Assignment (Birolini et al., 2021; Haider et al., 2024; Hernandez et al., 2020; Khanmirza et al., 2020; Kiarashrad et al., 2021; Rashedi et al., 2025; Xu et al., 2025). The aim of this study is to create a tool that provides operations managers with a preliminary assessment of demand optimization so that aircraft can be allocated in response to demand changes, taking into account aircraft performance, features, costs and revenues.

In airlines, optimization plays a critical role due to the intense competition in the industry. One of the areas of optimization is fleet and/or aircraft tail assignment based on demand. Therefore, demand-driven aircraft assignment optimization has been studied in the literature. Birolini et al. conducted research on flight planning and fleet assignment optimization, presenting a novel mixed-integer nonlinear flight scheduling and fleet assignment model where air travel demand generation and allocation are simultaneously and consistently endogenized (Birolini et al., 2021). Serrano-Hernandez et al. addressed uncertainty issues in airline fleet planning and fleet assignment concerning demand and economic parameters, proposing a strategic multistage tactical two-stage stochastic optimization model for the airline fleet management problem that considers stochasticity in various parameters, such as demand, operational costs, and fares, and decides on fleet compositions and assignments (the Airline Fleet Planning and the Fleet Assignment Problem) (Hernandez

et al., 2020). Khanmirza et al. worked on integrated program design and fleet assignment problems based on passenger demand, developing a master-slave genetic algorithm capable of producing an integrated solution for flight program design, fleet assignment, and fare pricing in response to changes in passenger demand (Khanmirza et al., 2020). Kiarashrad et al. studied the impact of ticket prices as an input in fleet assignment and flight planning problems, presenting an integrated fleet assignment, flight planning, and ticket pricing model for a competitive market.

In this study, a TOOL has been created to make aircraft assignments based on the evaluation of seven variables. The inclusion of crew planning, maintenance, and other operational constraints into this TOOL would further advance this research. The study has developed a tool that evaluates the current aircraft subtype assigned to a flight and compares it with other subtypes on the same flight to produce revenue and cost results. Similarity with other studies can be described as seeking a solution to the revenue and cost losses caused by demand uncertainty in aircraft resource optimization. The study's distinction is that it provides decision data by conducting an initial assessment for aircraft optimization under constantly changing conditions using a practical and different method to solve this problem.

6. Conclusion

Resource management is critical for airlines operating in highly competitive environments. Aircraft allocation for flights is initially based on demand forecasts at the start of the schedule; however, as the flight date approaches, discrepancies may arise between actual and forecasted demand, necessitating a reassessment of aircraft resource optimization. In this study, Microsoft Excel was used to create a TOOL to pre-evaluate these demand differences based on maximum profit/minimum loss criteria. Additionally, the developed TOOL provides data on whether there is a need to switch between passenger classes, the ratio of passenger and cargo demand that can be met, and the suitability of the aircraft type for flying on the relevant flight route. In other words, it provides valuable information for optimizing aircraft resource allocation based on profit and loss considerations.

The study not only offers the airline the best option based solely on demand forecasting but also provides the opportunity to manually evaluate all aircraft subtypes in the fleet. Thus, when it is not possible to assign the most suitable option, the TOOL allows for a comparison between the available subtypes and the sub-types that are suitable in terms of assignment suitability.

The TOOL in this study can also be used in demand optimization assessments in aviation training.

Finally, as a result of this study, the independent variables that significantly affect the dependent variable of maximum profit/minimum loss have been identified in general.

7. Limitations of The Study and Future Studies

This study has considered factors such as aircraft passenger and cargo capacity (max payload), aircraft passenger seat capacity, and aircraft-airport suitability in providing data related to aircraft resource optimization based on profit/loss. However, factors outside of these considerations, such as crew availability and maintenance have not been included in the study.

The data in the study were determined on average as a result of a literature review. It is important to note that other airlines may have different data or more updated information regarding aircraft resource optimization.

TOOL is designed to optimize the time and effort spent by the AOCC manager in making the initial decision on which aircraft to consider in the event of demand fluctuations. Units within the AOCC that include technical, crew planning, dispatch, sales reservation, and handling processes should evaluate and approve the specified optimization for the final decision, thereby preventing errors.

The issue of resolving demand uncertainty in aircraft optimization can be further advanced through predictive applications such as machine learning algorithms or deep learning.

Ethical approval

Approval for this research was authorized by İstanbul Topkapı University Ethics Committee under decision number 2025/15 and dated 14.04.2025.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Ahmed, B. M. et al., (2022). A matheuristic for the robust integrated airline fleet assignment, aircraft routing, and crew pairing problem. *Computers & Operations Research*, 137, 105551.
- Airbus, (N.D). The Unrivalled Efficiency Leader, <https://aircraft.airbus.com/en/aircraft/a320-family/a321neo>
- Aircraft Cost Calculator, (N.D). Turkish Airlines, <https://www.aircraftcostcalculator.com/>,
- AirInsight Group, (2019). Flight Ops Cost, <https://airinsight.com/flight-ops-costs-comparison/>
- AIRNAVIGATIONPRO, (N.D). Air Navigation, <https://play.google.com/store/apps/details?id=com.xample.airnavigation&hl=tr>.
- Airways, (2023). Airways Top 10 Largest Passenger Aircraft, <https://www.airwaysmag.com/legacy-posts/top-10-largest-passenger-aircraft#:~:text=All%20of%20the%20Jumbo%20variant%20has%20around%20605%20seats>
- Aygun, H. and Turan, O., (2023). Analysis of cruise conditions on energy, exergy and NOx emission parameters of a turbofan engine for middle-range aircraft, *Energy*, 267, 126468,
- Birolini S. et al., (2021). Integrated flight scheduling and fleet assignment with improved supply-demand interactions, *Transportation Research Part B: Methodological*, 149, 162-180.
- Britannica . (N.D). Why Do Airlines Overbook Seats on Flights?, <https://www.britannica.com/story/why-do-airlines-overbook-seats-on-flights>
- Boeing, (N.D). Airport Operations, <https://www.boeing.com/commercial/airports/faq>
- Boeing, (N.D). Comercial, <https://www.boeing.com/commercial>.
- Castro A. J. M. and Oliveira E., (2011). A New Concept for Disruption Management in Airline Operations Control, *Proceedings of the Institution of Mechanical Engineers Part G Journal of Aerospace Engineering*, 225 (3),
- Constantijn A.A. et al., (2020). Portfolio-based airline fleet planning under stochastic demand, *Omega*, 97, 102101.
- David Torres Sanchez, David T. Et al., (2020). An optimisation framework for airline fleet maintenance scheduling with tail assignment considerations, *Transportation Research Part B: Methodological*, 133, 142-164.
- EASA, (2022). EASA review of standard passenger weights in 2022 shows no significant change, <https://www.easa.europa.eu/en/newsroom-and-events/news/easa-review-standard-passenger-weights-2022-shows-no-significant-change>
- Eurocontrol, (N.D). Operating Costs, https://ansperformance.eu/economics/cba/standard-inputs/latest/chapters/aircraft_operating_costs.html
- Evler, Jan et al., (2022). Integration of turnaround and aircraft recovery to mitigate delay propagation in airline networks, *Computers & Operations Research*, 138,105602. <https://doi.org/10.1016/j.cor.2021.105602>.
- FAA, (2023). Weight and Balance, https://www.faa.gov/sites/faa.gov/files/2023-09/Weight_Balance_Handbook.pdf
- FAA, (N.D). Aircraft Operating Costs, https://www.faa.gov/sites/faa.gov/files/regulations_policies/policy_guidance/benefit_cost/econ-value-section-4-op-costs.pdf
- Fast Express, (N.D). Fiyat Hesapla, <https://www.fast-express.com/tr/kampanya/>
- Fuentes, M. et al., (2022). The Tail Assignment Problem: A Case Study at Vueling Airlines, *Transportation Research Procedia*, 52, 445-452.
- Fuentes, M. et al., (2021). A Novel Approach to the Tail Assignment Problem in Airline Planning, *Transportation Research Procedia*, 58, 53-60.
- Geursen I. L. et al., (2023). Fleet planning under demand and fuel price uncertainty using actor-critic reinforcement learning, *Journal of Air Transport Management*, 109, 102397.
- Glomb, Lukas et al., (2023). Optimizing integrated aircraft assignment and turnaround handling, *European Journal of Operational Research*, 310(3), 1051-1071.
- Grimme, W., et al., (2021). The role of very large passenger aircraft in global air transport – a review and outlook to the year 2050, *Transportation Research Procedia*, 59, 76-84.
- Gudmundsson, S. V. et al., (2020). Cost structure effects of horizontal airline mergers and acquisitions, *Transport Policy*, 99, 136-144.
- Haider I. et al., (2024). Subnetwork prediction approach for aircraft schedule recovery, *Engineering Applications of Artificial Intelligence*, 133, 108472.
- Hu, Yuzhen et al., (2021). Integrated recovery of aircraft and passengers with passengers' willingness under various itinerary disruption situations, *Computers & Industrial Engineering*, 161, 107664.
- IATA, (N.D). Airline and Airport Code Search, <https://www.iata.org/en/publications/directories/code-search/>
- ICAO, (N.D). Airline Operating Costs and Productivity, <https://www.icao.int/technical-cooperation-programme-administrative-and-operational-services-cost-aosc-budget>.
- ICAO, (N.D). DOC 8643 - Aircraft Type Designators, <https://www.icao.int/doc-8643-aircraft-type-designators>
- ICAO, (2023). Aircraft and Airport Compatibility, https://www.icao.int/MID/Documents/2022/Airport%20Master%20Seminar/AMP%204%20-%20Aircraft%20and%20Airport%20Compatibility_updated.pdf. IATA, (N.D). Airline and Airport Code Search, <https://www.iata.org/en/publications/directories/code-search/>

- IVAO, (N.D). Flight Plan System, <https://wiki.ivao.aero/tr/home/devops/websites/flightplansystem>,
- Izaak L. et al., (2023). Fleet planning under demand and fuel price uncertainty using actor-critic reinforcement learning, *Journal of Air Transport Management*, 109, 102397.
- İTÜ, (2014). Fleet Assignment, <http://aviation.itu.edu.tr/%5Cimg%5Caviation%5Cdatafiles/Lecture%20Notes/Network%20Fleet%20Schedule%20Strategic%20Planning/Assignments/A3%20-%20Fleet%20Assignment.pdf>
- Jeppesen, (N.D). Comercial Aviation, https://ww1.jeppesen.com/documents/aviation/commercial/crtr0502_final.pdf.
- Kargomkolay, (N.D). Cargo Fiyat Karşılaştır, <https://www.kargomkolay.com/ucak-kargo/>
- Khanmirza, Esmael et al., (2020). A heuristic approach for optimal integrated airline schedule design and fleet assignment with demand recapture, *Applied Soft Computing*, 96, 106681.
- Kiarashrad, M. et al., (2021). A mixed-integer nonlinear optimization model for integrated flight scheduling, fleet assignment, and ticket pricing in competitive market, *Journal of Revenue Pricing Management*, 20, 596–607.
- Koech, A.K., Buyle, S., and Macário, R., (2023). Airline brand awareness and perceived quality effect on the attitudes towards frequent-flyer programs and airline brand choice - Moderating effect of frequent-flyer programs, *Journal of Air Transport Management*, 107, 102342,
- Kohl et al., (2007). Airline disruption management—Perspectives, experiences and Outlook, *Journal of Air Transport Management*, 13 (1), 149-162
- Lee J. et al., (2022). A reinforcement learning approach for multi-fleet aircraft recovery under airline disruption, *Applied Soft Computing*, 129, 109556.
- Machado N. et al., (2015). Studying the Impact of the Organizational Structure on Airline Operations Control, *Advances in Artificial Transportation Systems and Simulation*, Santiago, USA, 103-124
- Melis, Damien J. et al., (2019). The effects of changing passenger weight on aircraft flight performance, *Journal of Transport & Health*, 13, 41-62,
- MNG Kargo, (2022). Eylül Yurtdışı Fiyat Listesi, https://www.dhlecommerce.com.tr/assets/img/yurtdisi_fiyat_listesi_eylul_2022.pdf.
- Mohri S. S. et al., (2022). An integrated global airline hub network design with fleet planning, *Computers & Industrial Engineering*, 164, 107883.
- Narcizo R. R. et al., (2020). An empirical model of airline fleet standardization in Brazil: Assessing the dynamic impacts of mergers with an events study, *Transport Policy*, 97, 149-160.
- Obilet, (N.D). Uçak Bileti, <https://www.obilet.com/ucak-bileti>
- Ogunsina K. and DeLaurentis D., (2022). Enabling integration and interaction for decentralized artificial intelligence in airline disruption management, *Engineering Applications of Artificial Intelligence*, 109, 104600.
- Ogunsina K. et al., (2021). Exploratory data analysis for airline disruption management, *Machine Learning with Applications*, 6, 100102.
- Oliveira A. V. M. et al., (2022). An empirical model of fleet modernization: On the relationship between market concentration and innovation adoption by airlines, *Research in Transportation Business & Management*, 43,100704.
- PLANEAI, (N.D). Operating Costs, <https://www.eplaneai.com/blog>
- Point Hacks, (2025). What is considered a short-haul, medium-haul and long-haul flight?, <https://www.pointhacks.com.au/differences-short-medium-long-haul-flights/>
- PPS FLIGHT PLANNING, (N.D). Free Demo, <https://ppsflightplanning.com/get-your-free-demo/>
- Rashedi, N. et. Al., (2025). A machine learning approach for solution space reduction in aircraft disruption recovery, *European Journal of Operational Research*, 323 (1), 297-308.
- Saltzman, Robert M. and Helman I. Stern, Helman I., (2022). The multi-day aircraft maintenance routing problem, *Journal of Air Transport Management*, 102, 102224.
- SeatGuru, (N.D). Airlines, https://www.seatguru.com/airlines/Turkish_Airlines/information.php
- Serrano-Hernandez, Adrian et al., (2020). A Strategic Multistage Tactical Two-Stage Stochastic Optimization Model for the Airline Fleet Management Problem., *Transportation Research Procedia*, 47, 473-480.
- Simpleflying, (2022). Widebody Vs Narrowbody: How Do the Aircraft Types Compare In Terms of A Flight Attendant's Work?, <https://simpleflying.com/widebody-vs-narrowbody-flight-attendant-work-comparison/>
- Su, Y. (2021). Airline Disruption Management: A Review of Models and Solution Methods, *Engineering*, 7(4), 435-447.
- Süzer, A. S. (2024). Havayolu Operasyonlarında Yolcu Hizmetleri Kaynaklı Gecikmelerin Öngörülmesinde Mali Ve Operasyonel Optimizasyon. *International Anatolia Academic Online Journal Social Sciences Journal*, 10(1), 118-131.
- Süzer, A. S. (2025). Havacılık İşletmelerinde Yöneticilerin Akılcı ve Sezgisel Karar Verme Yeteneği ile Duygusal Zekâları Arasındaki İlişkinin Araştırması. *Journal of Transportation and Logistics*, 10(1), 167-179.
- Turkish Airlines, (N.D). Uçak Bileti Rezervasyon, <https://www.turkishairlines.com/tr-tr/ucak-bileti/rezervasyon>,
- Ucuzabilet, (N.D). Ucuz Bilet, <https://www.ucuzabilet.com/>
- Ulrich Gunter and Bozana Zekan, (2021). Forecasting Air Passenger Numbers with a GVAR model, *Annals of Tourism Research*, 89, 103252.
- Unal, Yusuf Z., et al., (2021). A new approach to fleet assignment and aircraft routing problems, *Transportation Research Procedia*, 59, 67-75.
- Xu, Y. et al., (2025). Machine learning assisted dynamic copy generation approach for integrated aircraft and passenger recovery problem, *Transportation Research Part C: Emerging Technologies*, 178,
- Wu J. et al., (2022). Integrated aviation model and metaheuristic algorithm for hub-and-spoke network design and airline fleet planning, *Transportation Research Part E: Logistics and Transportation Review*, 164,
- Wu Z. et al., (2017). "Solving Multiple Fleet Airline Disruption Problems Using a Distributed-Computation Approach to Integer Programming," in *IEEE Access*, 5, 19116-19131

Wu, Zhengtian (2023). Chapter 5 - Solving multiple fleet airline disruption problems using a distributed-computation approach, Editor(s): Zhengtian Wu, In Emerging Methodologies and Applications in Modelling, Identification and Control, Integer Optimization and its Computation in Emergency Management, Academic Press, Hong Kong, 85-117.

Cite this article: Akbaba, A. (2025). A Tool for Fleet and/or Aircraft Assignment in Demand Optimization in Airline Operations. Journal of Aviation, 9(3), 780-796.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Table 8. The Section in the Tool That is Entered Pax, Cargo, Destination and Current Subtype Data Manually

SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType
IST-ADA	22	143	8000	TYPE 2
=RIGHT(B3;3)&"-" &LEFT(B3;3)	10	80	1000	=F3
MANUEL Subtype Selection			TYPE 1	

Table 9. Excel Formulas of the Section of TOOL Where Cost, Income and Profit Difference is Transferred

	Best Option	Manuel
Total Cost Difference \$	=SUM(I10:I11)-SUM(I8:I9)	=IFERROR(SUM(K13:K14)-SUM(K8:K9);"Not Authorized")
Total Income Difference \$	=SUM(J10:J11)-SUM(J8:J9)	=IF(L2="Not Authorized";L2;SUM(L13:L14)-SUM(L8:L9))
Total Profit Difference \$	=SUM(K10:K11)-SUM(K8:K9)	=IFERROR(SUM(K13:K14)-SUM(K8:K9);"Not Authorized")

Table 10. Formulas in First Part of Section Where Current Aircraft Type, Best Option and Manual Selection Aircraft Type Data are Transferred by TOOL

Selections	SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType	Bussines Pax Capacity	Economy Pax Capacity	Cost \$	Income \$	Profit \$
Current	=B\$3	=C\$3	=D\$3	=E\$3	=F\$3	=VLOOKUP(F8;Tables!\$D:\$J;6;0)	=VLOOKUP(F8;Tables!\$D:\$J;7;0)	=VLOOKUP(F8&"- "&B8;Tables!\$B:\$AO;27;0)	=VLOOKUP(F8&"- "&B8;Tables!\$B:\$AO;28;0)	=J8-I8
	=B\$4	=C\$4	=D\$4	=E\$4	=F\$4	=VLOOKUP(F9;Tables!\$D:\$J;6;0)	=VLOOKUP(F9;Tables!\$D:\$J;7;0)	=VLOOKUP(F9&"- "&B9;Tables!\$B:\$AO;39;0)	=VLOOKUP(F9&"- "&B9;Tables!\$B:\$AO;40;0)	=J9-I9
Best Choice	=B\$3	=C\$3	=D\$3	=E\$3	=VLOOKUP(1;Tables!\$AQ\$2:\$AR\$6;2;0)	=VLOOKUP(F10;Tables!\$D:\$J;6;0)	=VLOOKUP(F10;Tables!\$D:\$J;7;0)	=VLOOKUP(F10&"- "&B10;Tables!\$B:\$AO;27;0)	=VLOOKUP(F10&"- "&B10;Tables!\$B:\$AO;28;0)	=J10-I10
	=B\$4	=C\$4	=D\$4	=E\$4	=VLOOKUP(1;Tables!\$AQ\$2:\$AR\$6;2;0)	=VLOOKUP(F11;Tables!\$D:\$J;6;0)	=VLOOKUP(F11;Tables!\$D:\$J;7;0)	=VLOOKUP(F11&"- "&B11;Tables!\$B:\$AO;39;0)	=VLOOKUP(F11&"- "&B11;Tables!\$B:\$AO;40;0)	=J11-I11
Manuel Selection	=B\$3	=C\$3	=D\$3	=E\$3	=E\$5	=VLOOKUP(F13;Tables!\$D:\$J;6;0)	=VLOOKUP(F13;Tables!\$D:\$J;7;0)	=VLOOKUP(F13&"- "&B13;Tables!\$B:\$AO;27;0)	=VLOOKUP(F13&"- "&B13;Tables!\$B:\$AO;28;0)	=J13-I13

Table 11. Formulas the Second and Third Part of the Section Where the Current Aircraft Type, Best Option and Manual Selection Aircraft Type Data are Transferred by TOOL**Note:** Excel Formulas for the Aircraft Assignment TOOL (It consists of four tables)

ABLE TO TRANSPORT						UNABLE TO TRANSPORT		
Bussines Pax	Economy Pax	Upgrade Economy to Bussines	Downgrade Bussines to Economy	Total Pax	Cargo	Bussines Pax	Economy Pax	Cargo
=VLOOKUP(\$F8&"- "&\$B8;Tables!\$B:\$AO;21;0)	=VLOOKUP(\$F8&"- "&\$B8;Tables!\$B:\$AO;22;0)	=VLOOKUP(\$F8&"- "&\$B8;Tables!\$B:\$AO;23;0)	=VLOOKUP(\$F8&"- "&\$B8;Tables!\$B:\$AO;24;0)	=SUM(L8:O8)	=VLOOKUP(\$F8&"- "&\$B8;Tables!\$B:\$AO;26;0)	=C8-(O8+L8)	=D8-(N8+M8)	=E8-Q8
=VLOOKUP(\$F9&"- "&\$B9;Tables!\$B:\$AO;33;0)	=VLOOKUP(\$F9&"- "&\$B9;Tables!\$B:\$AO;34;0)	=VLOOKUP(\$F9&"- "&\$B9;Tables!\$B:\$AO;35;0)	=VLOOKUP(\$F9&"- "&\$B9;Tables!\$B:\$AO;36;0)	=SUM(L9:O9)	=VLOOKUP(\$F9&"- "&\$B9;Tables!\$B:\$AO;38;0)	=C9-(O9+L9)	=D9-(N9+M9)	=E9-Q9
=VLOOKUP(\$F10&"- "&\$B10;Tables!\$B:\$AO;21;0)	=VLOOKUP(\$F10&"- "&\$B10;Tables!\$B:\$AO;22;0)	=VLOOKUP(\$F10&"- "&\$B10;Tables!\$B:\$AO;23;0)	=VLOOKUP(\$F10&"- "&\$B10;Tables!\$B:\$AO;24;0)	=SUM(L10:O10)	=VLOOKUP(\$F10&"- "&\$B10;Tables!\$B:\$AO;26;0)	=C10-(O10+L10)	=D10-(N10+M10)	=E10-Q10
=VLOOKUP(\$F11&"- "&\$B11;Tables!\$B:\$AO;33;0)	=VLOOKUP(\$F11&"- "&\$B11;Tables!\$B:\$AO;34;0)	=VLOOKUP(\$F11&"- "&\$B11;Tables!\$B:\$AO;35;0)	=VLOOKUP(\$F11&"- "&\$B11;Tables!\$B:\$AO;36;0)	=SUM(L11:O11)	=VLOOKUP(\$F11&"- "&\$B11;Tables!\$B:\$AO;38;0)	=C11-(O11+L11)	=D11-(N11+M11)	=E11-Q11
=VLOOKUP(\$F13&"- "&\$B13;Tables!\$B:\$AO;21;0)	=VLOOKUP(\$F13&"- "&\$B13;Tables!\$B:\$AO;22;0)	=VLOOKUP(\$F13&"- "&\$B13;Tables!\$B:\$AO;23;0)	=VLOOKUP(\$F13&"- "&\$B13;Tables!\$B:\$AO;24;0)	=SUM(L13:O13)	=VLOOKUP(\$F13&"- "&\$B13;Tables!\$B:\$AO;26;0)	=C13-(O13+L13)	=D13-(N13+M13)	=E13-Q13
=VLOOKUP(\$F14&"- "&\$B14;Tables!\$B:\$AO;33;0)	=VLOOKUP(\$F14&"- "&\$B14;Tables!\$B:\$AO;34;0)	=VLOOKUP(\$F14&"- "&\$B14;Tables!\$B:\$AO;35;0)	=VLOOKUP(\$F14&"- "&\$B14;Tables!\$B:\$AO;36;0)	=SUM(L14:O14)	=VLOOKUP(\$F14&"- "&\$B14;Tables!\$B:\$AO;38;0)	=C14-(O14+L14)	=D14-(N14+M14)	=E14-Q14

Table 12. The Section Where Manual Data Entry is Made to TOOL for Case 1

SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType
IST-MUC	22	143	5000	TYPE 2
MUC-IST	13	133	1000	TYPE 2
MANUEL Subtype Selection			TYPE 4	

Table 13. The Section Where TOOL Transfers the Cost, Income, and Profit Difference for Case 1

	Best Option	Manuel
Total Cost Difference \$	3.695.70	6.773.61
Total Income Difference \$	5.579.80	5.894.30
Total Profit Difference \$	1.884.10	-879.31

Table 14. The Section Where Data for Case 1 is Transferred by TOOL for the Current Aircraft Subtype, Best Option, and Manually Selected Aircraft Subtype**Note:** The Data Transferred by TOOL Based on the Demands for Case 1 (It consists of Table12, 13, 14)

											Able to Transport						Unable to Transport		
Selections	SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType	Bussines Pax Capacity	Economy Pax Capacity	Cost \$	Income \$	Profit \$	Bussines Pax	Economy Pax	Upgrade Economy to Bussines	Downgrade Bussines to Economy	Total Pax	Cargo	Bussines Pax	Economy Pax	Cargo
Current	IST-MUC	22	143	5000	TYPE 2	16	135	14857.63	34428.7	19571.07	16	135	0	0	151	3002	6	8	1998
	MUC-IST	13	133	1000	TYPE 2	16	135	13875.71	27163	13287.29	13	133	0	0	146	1000	0	0	0
Best Choice	IST-MUC	22	143	5000	TYPE 3	16	153	17800.15	40008.5	22208.35	16	143	0	6	165	4830	0	0	170
	MUC-IST	13	133	1000	TYPE 3	16	153	14628.89	27163	12534.11	13	133	0	0	146	1000	0	0	0
Manuel Selection	IST-MUC	22	143	5000	TYPE 4	16	164	18791.32	40323	21531.68	16	143	0	6	165	5000	0	0	0
	MUC-IST	13	133	1000	TYPE 4	16	164	16715.63	27163	10447.37	13	133	0	0	146	1000	0	0	0

Table 15. Manual Data Entry Section for Case 2 According to TOOL

“SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType
IST-ALG	8	118	1000	TYPE 4
ALG-IST	5	125	500	TYPE 4
MANUEL Subtype Selection			TYPE 2	

Table 16. Section Where TOOL Transfers Cost, Revenue, and Profit Difference for Case 2

	Best Option	Manuel
Total Cost Difference \$	-9.977.23	-2.129.72
Total Income Difference \$	-2.772.00	0.00
Total Profit Difference \$	7.205.23	2.129.72

Table 17. Section Where TOOL Transfers Data for Current Aircraft Type, Best Option, and Manual Selection Aircraft Type for Case 2

											Able to Transport						Unable to Transport		
Selections	SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType	Bussines Pax Capacity	Economy Pax Capacity	Cost \$	Income \$	Profit \$	Bussines Pax	Economy Pax	Upgrade Economy to Bussines	Downgrade Bussines to Economy	Total Pax	Cargo (kg)	Bussines Pax	Economy Pax	Cargo (kg)
Current	IST-ALG	8	118	1000	TYPE 4	16	164	20481.29	39804	19322.71	8	118	0	0	126	1000	0	0	0
	ALG-IST	5	125	500	TYPE 4	16	164	21953.69	37520	15566.31	5	125	0	0	130	500	0	0	0
Best Choice	IST-ALG	8	118	1000	TYPE 1	12	114	17092.66	38104	21011.34	8	114	4	0	126	0	0	0	1000
	ALG-IST	5	125	500	TYPE 1	12	114	15365.09	36448	21082.91	5	114	7	0	126	500	0	4	0
Manuel Selection	IST-ALG	8	118	1000	TYPE 2	16	135	20059.63	39804	19744.37	8	118	0	0	126	1000	0	0	0
	ALG-IST	5	125	500	TYPE 2	16	135	20245.63	37520	17274.37	5	125	0	0	130	500	0	0	0

Table 18. Section Where Manual Input is Made to TOOL for Case 3

SECTOR	PASSENGER NUMBER Bussines	PASSENGER NUMBER Economy	CARGO QUANTITY (kg)	SubType
IST-ADA	15	118	1000	TYPE 1
ADA-IST	12	125	500	TYPE 1
MANUEL Subtype Selection			TYPE 5	

Table 19. Section Where TOOL Transfers Cost, Revenue, and Profit Difference for Case 3.

	Best Option	Manuel
Total Cost Difference \$	-172.55	-11.782.34
Total Income Difference \$	946.00	-15.966.00
Total Profit Difference \$	1.118.55	Not Authorized

Post-Pandemic Trends in Corporate Risk Management: A Bibliometric Review in the Context of the Aviation Industry

Tuğçe Çopur^{1*}, Ayşe Küçük Yılmaz²

^{1*}Alanya Alaaddin Keykubat University, Civil Aviation Cabin Services program, Gazipaşa, Antalya, Türkiye. (tugce.copur@alanya.edu.tr)

²Eskisehir Technical University, Aviation Management Department, Eskisehir, Türkiye. (akucukyilmaz@eskisehir.edu.tr)

Article Info

Received: 24 April 2025

Revised: 15 July 2025

Accepted: 21 July 2025

Published Online: 18 October 2025

Keywords:

Corporate Risk Management

Enterprise Risk Management

Risk Management

Covid 19

Post Pandemic

Aviation Industry

Air Transportation

Corresponding Author: Tuğçe Çopur

<https://doi.org/10.30518/jav.1682362>

Abstract

The COVID-19 pandemic has profoundly transformed global economic and managerial dynamics, leading to significant changes in corporate risk perceptions and management strategies. The uncertainties experienced during the pandemic highlighted factors such as business continuity, supply chain vulnerabilities, and financial instability, necessitating more comprehensive and flexible enterprise risk management (ERM) approaches. During this period, companies enhanced their capacities especially in occupational health and safety, while striving to integrate traditional risk management strategies with digitalization, sustainability, and crisis scenarios. This study aims to comprehensively examine the current state of the literature on enterprise risk management published after COVID-19 through a bibliometric analysis. Publications from various sectors were evaluated, with particular emphasis on the aviation industry as an illustrative example to highlight transformation processes during the pandemic. In this context, the aviation sector emerges as one of the key themes of the study, strengthening both its originality and scope. By analyzing academic publications released between 2020 and 2025, this study identifies prominent themes and publication trends for the post-pandemic period, thereby aiming to guide future research in the field of enterprise risk management.

1. Introduction

The COVID-19 pandemic has had profound effects on global health, the economy, and social life, exposing significant shortcomings in the management of uncertainty. Businesses were confronted with unforeseen risks such as supply chain disruptions, financial volatility, and operational setbacks, all of which once again emphasized the critical importance of risk management strategies (Oktaysoy, Topçuoğlu, & Kaygın, 2022). It became evident that mechanisms ensuring resilience during crises must be established in advance, and that proactive risk management approaches are essential for corporate sustainability (Küçük Yılmaz & Kafalı, 2017). While many businesses that were unprepared for the pandemic suffered substantial financial losses, firms that effectively implemented enterprise risk management (ERM) were more successful in managing the crisis.

ERM offers a holistic approach that encompasses not only financial risks, but also operational, strategic, and environmental risks. During the COVID-19 period, key components of ERM included business continuity planning, the development of crisis scenarios, and digitalization. Companies had to quickly adapt to remote working systems, enhance digital security measures, and develop alternative

In the post-pandemic period, it has become clear that ERM needs to be more comprehensive and sustainable. Next-generation risk management strategies aim to enhance companies' long-term resilience by addressing not only the financial effects of crises but also their social and environmental dimensions. The experiences gained during the pandemic underscore the need for continuously evolving risk management approaches to ensure businesses are better prepared for future crises (Eurocontrol, 2020). Therefore, companies are increasingly compelled to adopt more data-driven, flexible, and innovative risk management models to strengthen their capabilities in navigating uncertainty.

2. COVID 19 and Global Impact

Initially emerging in Wuhan, China, and rapidly spreading worldwide, COVID-19 was declared a Public Health Emergency of International Concern by the World Health Organization (WHO) on January 30, 2020, and later classified as a pandemic on March 11, 2020. This process profoundly affected numerous industries—especially the air transport sector—triggering fundamental changes in economic and operational dynamics (Zhuang, 2020).

The air transport sector, by facilitating rapid travel and enabling the intercontinental movement of passengers and cargo, contributed significantly to the global spread of COVID-19 (Akça, 2020). Airports function not only as transfer hubs between air and ground transportation, but also as centers of life, commerce, and trade. This role increases regional human mobility and contact density, thereby influencing the dynamics of viral transmission (Kasarda, 2019).

One of the primary subjects addressed in this study is the impact of the COVID-19 pandemic on the air transport industry. The measures implemented during the pandemic, along with government policies and economic factors, have initiated structural transformations in the sector and laid the groundwork for long-term changes.

During health crises, countries develop national aviation strategies and facilitation programs to regulate aviation activities. Guided by WHO forecasts, recommendations, and advisories, states also hold the authority to restrict or completely suspend flights to protect public health. During this period, organizations such as the International Civil Aviation Organization (ICAO), International Air Transport Association (IATA), Airports Council International (ACI), European Aviation Crisis Coordination Cell (EACCC), European Union Aviation Safety Agency (EASA), Centers for Disease Control and Prevention (CDC), and the Federal Aviation Administration (FAA) played key roles in facilitating ongoing information sharing, coordination, and cooperation both internally and among member states (CAAC, 2025).

In the context of civil aviation, the Collaborative Arrangement for the Prevention and Management of Public Health Events in Civil Aviation (CAPSCA) works to prevent the spread of pandemics and protect global public health (Eurocontrol, 2020). International aviation authorities such as IATA and ICAO also publish up-to-date datasets monitoring national regulations and restrictions related to COVID-19 in the aviation sector (Akça, 2020).

Various public health regulations were implemented within aviation activities during the COVID-19 period. Procedures were established to ensure the safety of passengers and flight crews, accompanied by specific operational instructions. Detailed protocols were developed covering aircraft disinfection and the handling of potentially high-risk passengers (Akça, 2020). Airport operators conducted extensive disinfection of terminals and operational areas to protect passengers, flight crews, and other personnel (CAAC, 2025). Measures included thermal screening of passengers, use of protective masks and gloves by staff, routing aircraft carrying suspected or confirmed cases to designated areas, continuous ventilation of terminals, and enhanced hygiene protocols. Additionally, protocols for security and healthcare personnel were comprehensively structured (EASA, 2020).

In Türkiye, the Directorate General of Civil Aviation issued a Flight Operations Safety Bulletin on March 24, 2020, concerning COVID-19. This bulletin aimed to protect public health, minimize transmission risk, and safeguard the health of aviation personnel, offering a set of regulations, recommendations, and guidelines. The bulletin applied to all air transport operators, terminal operators, ground handling service providers, and representatives, supervisors, and management units, explaining in detail the procedures necessary for maintaining aviation activities during the COVID-19 pandemic. These procedures were prepared based

on the guidance of WHO, the Ministry of Health, the Public Health Directorate, ICAO, and IATA (SHGM, 2022).

At the beginning of 2020, COVID-19 posed a significant threat to the air transportation industry. In the following months, this threat escalated into a prolonged and severe crisis (Organization, 2020). Government-imposed restrictions and lockdowns significantly reduced the demand for air travel.

In this context, thermal cameras were used in airports to assess the health conditions of incoming passengers. Those with elevated body temperatures were evaluated by medical personnel, and, in suspected cases, entry into the country was restricted or denied. In some countries, travelers were required to carry health certificates confirming they were not infected with COVID-19 (Akça, 2020).

The civil aviation sector, in addition to its cultural benefits, is one of the critical transportation infrastructures that supports the global economy. Although the foundations of the aviation sector began to be laid in the early 20th century with the first use of aircraft for military purposes, the sector could not develop rapidly due to technological limitations and a lack of demand (Ito & Darin, L.; 2005). Therefore, global crises of the time, such as the influenza pandemic and the Great Depression, did not have a significant impact on the aviation sector. However, during World War II, the strategic importance of air transport was recognized, and since then, the sector has entered a continuous development process. Despite this, some events have hindered or reversed the development of the sector. For example, global economic shocks such as the 1973 Oil Crisis, the Gulf War, and the Asian Economic Crisis significantly affected the aviation industry. More recently, the September 11 attacks are recorded as one of the most important global crises with a direct impact on the aviation sector (Hopancı, Akdeniz, & Şahin, 2021).

In March 2020, as a result of the restrictions implemented, there was a significant decline in air traffic in our country, and this brought the aviation sector to the brink of a standstill. The decrease in passenger numbers naturally reflected in flight data as well (SHGM, 2022).

Figure 1 shows the number of passengers and aircraft traffic using airlines in Türkiye between 2015 and 2025. With the onset of the COVID-19 pandemic, countries implemented various protective measures. Due to its global structure, air transport is one of the sectors where the most intensive procedures were applied. The year 2020, when the pandemic began, was the most critical period in terms of the number of passengers using airlines and air traffic. During this period, air transport experienced the most critical phase in its history with the introduction of travel bans. In the following years, as normalization steps were taken, these figures started to show an upward trend (Pegasus, 3rd Quarter Investor Presentation, 2020).

With air transport reaching the brink of a standstill, airline companies also had to face significant losses. Airlines are organizations that primarily aim for profit by providing passenger, cargo, and mail transport services with aircraft, marketing these services, and selling them (Küçük Yılmaz, Air Transport, 2016). The challenging conditions caused by the pandemic and the decline in demand for the aviation sector directly affected airline companies. With the decrease in flights, many airlines around the world could not operate their aircraft, and these aircraft were left grounded. In Europe, in particular, more than 6,000 aircraft were out of operation in April and May (EUROCONTROL, 2020). This situation created a significant economic blow to airline companies,

leading to serious challenges, especially in terms of personnel costs and financial balances (Hopancı, Akdeniz, & Şahin, 2021).

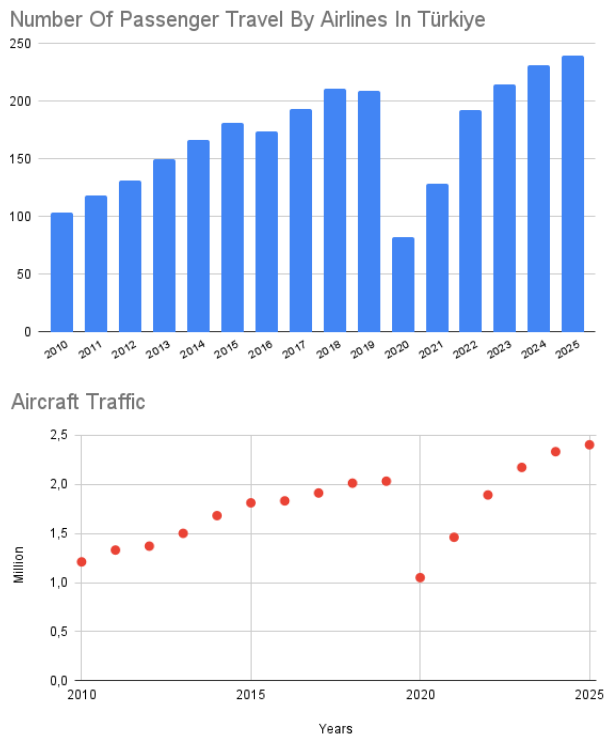


Figure 1. DHMI (2023). Air Traffic Expectations.

The grounding of airline aircraft without being operational added an extra cost item, which was an additional burden for airlines already struggling with economic difficulties. In addition to the decline in passenger transport, the increased need for international medical material shipments directed airlines towards cargo and freight transportation. As a result, some airlines experienced growth in the cargo market during the pandemic (EUROCONTROL, Aviation Intelligence Portal, 2020).

Some airlines in our country have adopted different measures to maintain their existing positions. In this context, they have taken various measures such as optimizing personnel costs by benefiting from the short-term work allowance provided by the government, ensuring that staff transition to remote work systems to save on fixed costs, reducing expense budgets, postponing non-critical investments and projects, and revising aircraft maintenance schedules according to the current usage plans (Pegasus, 2020). The unpaid leave policy applied under the short-term work allowance reflected a significant reduction in personnel costs (Pegasus, 3rd Quarter Investor Presentation, 2020).

Airport operators have also been affected by this process. Airports are complex facilities designed to accommodate the landing and takeoff of aircraft, as well as to meet the maintenance and other operational requirements of these vehicles, and to facilitate the transfer of passengers and cargo (Durmaz, 2018). In Türkiye, airports are operated both publicly by the General Directorate of State Airports Authority (DHMI) and by the private sector. Airports play a crucial role in economic development by serving as critical intermediate stations for cargo and passenger transport, and by hosting airline companies, thereby contributing significantly to the economic development of cities, regions, and countries

(DHMI, 2022). Airport operators are supported by two types of economic resources: aviation revenues (fees collected from airlines, ground services fees, etc.) and non-aviation revenues (real estate rental income, parking revenues, etc.) (Hopancı, Akdeniz, & Şahin, 2021).

During the pandemic, airports not only had to endure economic difficulties due to the above-mentioned reasons, but some had to close runways and taxiways to accommodate grounded aircraft. Some airports were temporarily closed for use (ACI, 2020).

As can be understood from the information provided above, the COVID-19 pandemic has caused mostly negative impacts on every stakeholder within the aviation sector. However, for some areas, particularly in cargo transportation, it had a positive effect. Moreover, it has allowed for the emergence of new areas and a more in-depth examination of existing ones.

3. Corporate Risk Management Perspective and its Importance

In traditional societies, belief and the concept of fate played a dominant role in determining individuals' actions, and the term "risk" was associated with "bravery and heroism." However, in modern times, the concept of risk began to come to the forefront, especially after the 1970s. During these periods, the term risk was used in various academic fields such as labor economics, social psychology, medicine, finance, law, business life, ecology, etc. (COSO, 2017). From the 1980s to the late 1990s, international financial markets underwent a major transformation, and the emergence of increasingly complex and evolving transactions led to increased uncertainty in the markets. Greater uncertainty means greater risk, and as differences in the fields in which firms operate and the varying needs of sectors were added to the equation, diversity in addressing financial needs became inevitable (Koç & Çelik, 2017).

By the late 1990s, it was observed that the number of risks organizations needed to manage had increased, and over time, the scope of risk management continued to expand. This expansion of the scope of risk was a primary factor in the emergence of risk management. By the early 2000s, risk management was conceptualized as corporate risk management, becoming a tool used by all organizations to manage risk. Thus, it can be said that during this period, the scope of risk reached its broadest form. Indeed, in addition to financial and loss risks, risks such as strategic, managerial, reputational, and operational risks were also included in the scope (Arslan, 2008).

All companies investing in markets were initially forced to accept certain risks to achieve profitability. However, companies prefer corporate risk management as a method for measuring the alignment between the cost of their investments and the returns on the risks they assume. This is because corporate risk management provides a process that enables a broad understanding of the relationship between risk and its returns, the interaction of various risk sources, and the probability and impact of these sources (Küçük Yılmaz, 2017).

Corporate risk management is a systematic approach conducted to identify, measure, prioritize, control, manage, and monitor risks across the organization in alignment with corporate goals. Therefore, risks must be managed considering the organization's risk appetite. From this perspective, corporate risk management ensures a reasonable level of

assurance in achieving goals related to strategy, operations, reporting, and compliance (Arifler & Haşit, 2024).

Recent studies have shown that organizations are eager to incorporate corporate risk management practices into their corporate priorities. Furthermore, while in previous years, risk management consisted mainly of insurance operations such as fixed assets and liabilities in government agencies and businesses with a classical structure, it has been observed that over time, many organizations have turned their focus toward other types of risks, such as operational and strategic risks, and have actively started analyzing and managing them (Küçük Yılmaz, 2017).

The needs for corporate risk management in an organization and the benefits that properly implemented practices provide to the business can be summarized as follows: First, risk management, which significantly ensures the continuity of the organization's operations, keeps the probability and impact of potential losses below the critical threshold that threatens the continuation of operations. At the same time, it plays an important role in ensuring that business operations continue with minimal delays after a loss (Ganishti, Wennadi, & Santoso, 2025).

A well-established risk management system can significantly reduce both the quantitative and qualitative risks a business may face. In this way, business managers can focus their attention and energy on the organization's priority problems rather than solving immediate issues, providing a clearer outlook for the future (Tanrıverdi & Küçük Yılmaz, A., 2018).

Through corporate risk management, the effects of potential losses in businesses are kept under control, reducing costs and helping increase business profits. By taking much lower-cost measures against potential losses that can lead to significant losses for the business, the effects on operating costs can be minimized.

Risk management helps the business reduce any possible decreases in its revenues or cash flows to acceptable levels. In other words, risk management ensures that the losses caused by unwanted and unexpected risks in the annual profits or revenues of the business are kept at specific levels, enabling long-term planning for the business. In this way, the business's income level becomes stable (Ganishti, Wennadi, & Santoso, 2025).

Effective risk management plays a significant role in the stable growth of businesses. Without it, businesses will be significantly affected by risks and experience substantial deviations from their stable growth and in achieving corporate goals.

One of the important purposes of corporate risk management is to minimize the harm that may come to employees, commercial suppliers, customers, and other stakeholders. In other words, it aims to ensure the creation of a positive image of the business in the public eye. Thus, resources that would otherwise be spent on other goals, under the awareness of social responsibility, can be allocated to risk management activities.

Corporate risk management is an important tool for ensuring compliance with legal and administrative regulations. Businesses are subject to numerous legal regulations depending on the sectors in which they operate. Organizations that violate these regulations must avoid risks that could jeopardize their legal existence. Therefore, top management in organizations must have an infrastructure that allows them to control their activities in this area at the desired level through

an effective risk management system (Fan, Wu, & Yang, 2025).

The requirements for risk management change daily based on the organization's characteristics, structure, and the sector in which it operates. In today's globalized world, business executives are reluctant to take positions in senior management due to the increasing risks and responsibilities they face. The reason for this is that, while risk management is the responsibility of department managers in each business unit, the monitoring task in a corporate organization rests with the organization's top management. The managers of various business units within the organization are responsible for identifying and measuring existing and potential risks based on their activities and reporting them to the board of directors. In this way, they are tasked with reflecting the organization's financial outcomes, in line with the institution's strategic plans, to their stakeholders in terms of transparency and accountability.

4. Materials and Methods

The COVID-19 pandemic has fundamentally changed businesses' risk perception and corporate risk management approaches at a global level. Since the onset of the pandemic, the uncertainty environment has deeply affected many sectors, demonstrating that risk management should be addressed within a holistic framework that includes not only financial sustainability but also operational resilience. In this context, corporate risk management has become a critical factor in enhancing companies' resilience to crises during and after the pandemic.

This study aims to examine academic publications in the field of corporate risk management post-COVID-19 using bibliometric analysis to reveal the current state of the literature. A comprehensive study addressing the relationship between COVID-19 and corporate risk management through bibliometric analysis has not been found in the existing literature. In this regard, the study aims to analyze academic works published between 2020 and 2025 to identify post-pandemic publication trends, emerging themes, and research gaps. The findings are thought to provide direction for future studies in the field of corporate risk management, contributing to making businesses more resilient to crises.

In this study, the data collection tool used is Google Scholar, a search engine that provides access to a wide range of academic publications, including articles published in peer-reviewed journals, conference proceedings, books, and other scientific sources. The works analyzed in this study were examined using bibliometric analysis, a qualitative research method with a multidimensional perspective. The concept of bibliometrics was introduced by Pritchard in 1969. Pritchard's need to redefine the concept of statistical bibliography allowed for the emergence of a new qualitative research method. Pritchard defines bibliometrics as a mathematical and statistical method used to determine the characteristics of books and other sources (Lawani, 1981). Bibliometric analysis is considered a fundamental interdisciplinary tool that allows for a broader perspective on enhancing the development level of scientific research (Samiee & Chabowski, 2012). Huang and others stated that bibliometric data is an effective method for identifying and evaluating countries, universities, research institutions, journals, specific research topics, and the characteristics of various disciplines (Huang, Ya-Li; Ho, Yuh-Shan; Chuang, Kun-Yang, 2006). Citation indexes are used as

data sources in bibliometric research (Savrun & Mutlu, 2019). This study is limited to works published in the Google Scholar database.

The findings obtained in this study provide significant insights into understanding academic trends in corporate risk management after the pandemic and offer a framework for future research.

5. Result and Discussion

In this study, academic publications in the field of corporate risk management after the COVID-19 pandemic were examined using bibliometric analysis. The study analyzed works published between 2020 and 2025, attempting to determine academic trends in this field during the post-pandemic period.

The study includes sources published in both Turkish and foreign languages, without any language restrictions. Thus, the academic contributions on the subject in the global literature were evaluated from a comprehensive perspective. Furthermore, the types of studies examined were limited to articles. In this context, the study aimed to determine which types of works are most prominent in the academic literature and which aspects of the subject have been addressed more frequently.

In the study, data were searched using keywords. Searches were conducted with the following keywords: “COVID-19” and “Corporate Risk Management,” “Enterprise Risk Management” and “Pandemic,” “Post pandemic” and “Risk Management,” and “Business Continuity” and “COVID-19.” The data obtained were tabulated using Google Forms, and the findings are presented below.

The findings provide significant insights into understanding academic trends in corporate risk management after the pandemic and offer a framework for future research.

An examination using the keyword “COVID-19” and “Corporate Risk Management” resulted in a total of 159 articles published between 2020 and 2025. The distribution of article numbers by year is provided in Figure 2 below.

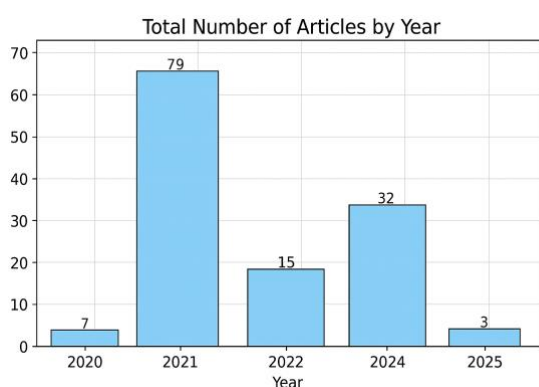


Figure 2. Data from the Analysis Covering the Years 2020 to 2025 Using the Keywords “COVID-19” and “Corporate Risk Management”

An examination using the keyword “Enterprise Risk Management” and “Pandemic” resulted in a total of 707 articles published between 2020 and 2025. The distribution of article numbers by year is provided in Figure 3 below.

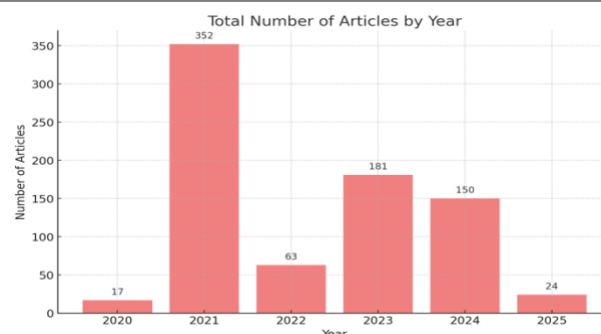


Figure 3. Data from the Review Conducted Between 2020 and 2025 Using the Keywords “Enterprise Risk Management” and “Pandemic”

An examination using the keyword “Post pandemic” and “Risk Management” resulted in a total of 1,649 articles published between 2020 and 2025. The distribution of article numbers by year is provided in Figure 4 below.

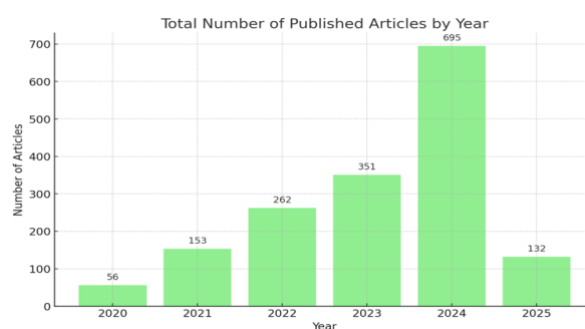


Figure 4. Data from the Analysis Covering the Years 2020 to 2025 Using the Keywords “Post-Pandemic” and “Risk Management”

An examination using the keyword “Business Continuity” and “COVID-19” resulted in a total of 2,945 articles published between 2020 and 2025. The distribution of article numbers by year is provided in Figure 5 below.

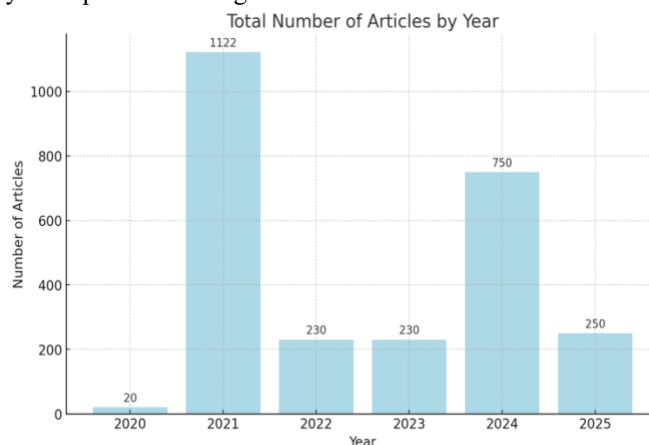


Figure 5. Data from the Analysis Covering the Years 2020 to 2025 Using the Keywords “Business Continuity” and “COVID-19”

In the study, the change in the number of publications over the years is first shown. In the next phase, an evaluation is made on an annual basis. For each year, the subject headings of the current publication trends are examined, and a percentage ratio is provided. Each figure will be explained in detail below.

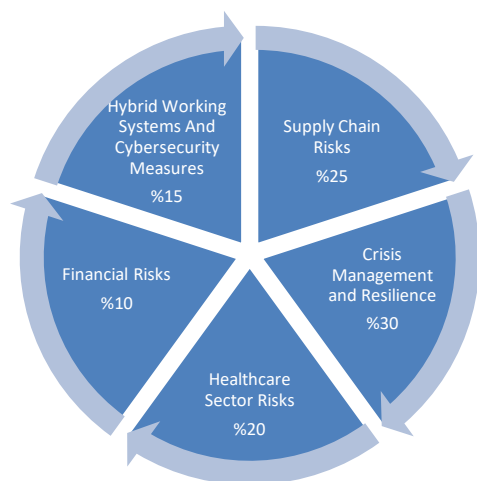


Figure 6. Corporate Risk Management Trend for 2020.

The year 2020 was marked by efforts to manage uncertainties and develop rapid response mechanisms to sudden crises for companies (Pegasus, Q3 Investor Presentation, 2020). In this context, a total of 207 articles related to corporate risk management and COVID-19 were identified for the year 2020. Of these, 62 focused on crisis management and business continuity, 52 on supply chain-related risks, 41 on risks faced by the healthcare sector, 31 on hybrid working systems and cybersecurity measures, and 21 on financial risks.

During the COVID-19 period, the primary priority for businesses was to maintain ongoing operations and remain resilient against the crisis. Companies revised their emergency plans during this time, highlighting the growing importance of flexibility and rapid adaptation. For example, many airports accelerated their digital transformation initiatives to cope with new health regulations and passenger flow restrictions (Airport Council International, 2021). Legal travel restrictions caused major disruptions in global supply chains, especially impacting aircraft manufacturers such as Boeing, which faced significant delays and challenges in their supply networks (Global Supply Chain Review, 2020).

In addition, cybersecurity risks increased as hybrid work models became widespread, requiring companies to implement new security measures (Cybersecurity Review, 2021). The healthcare sector drew attention to capacity management, patient care, vaccine development, and medical equipment supply (WHO, 2020). The International Air Transport Association (IATA) also reported that airlines had to rapidly adapt their operational and risk management strategies in response to these unprecedented challenges (IATA, 2020).

Overall, these examples from the aviation industry highlight the importance of flexibility, resilience, and comprehensive risk management during the pandemic period.

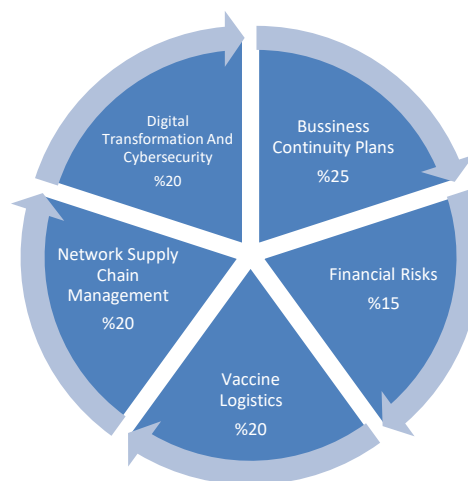


Figure 7. Corporate Risk Management Trend for 2021.

With the imposition of long-term lockdowns, digital transformation processes accelerated and remote working models emerged. This brought about increased concerns regarding data security and cyberattack risks, necessitating the implementation of new cybersecurity measures. Financial imbalances occurred in many businesses due to COVID-19, and industries such as aviation experienced significant revenue losses. For example, major airlines like Lufthansa and British Airways struggled with reduced passenger volumes, while Singapore Changi Airport implemented biometric check-in solutions as part of its digital transformation (Changi Airport Group, 2021). The logistics of vaccine distribution also posed significant challenges; companies such as DHL, Emirates SkyCargo, and Qatar Airways played a critical role in transporting COVID-19 vaccines globally (IATA, 2021). In Turkey, Turkish Airlines gradually resumed operations and achieved record volumes in air cargo, becoming a vital player in pandemic logistics (Turkish Airlines, 2021). Istanbul Airport was also recognized for its rapid adaptation to digitalization and hygiene protocols. According to DHMİ data, the number of domestic passengers increased in 2021, indicating a recovery in local aviation activity (DHMİ, 2022).

Consequently, there was a notable increase in pandemic-related compensation claims in the insurance sector, and the scope of insurance policies became a topic of debate. In 2021, the uncertainties that caused a shock effect in 2020 began to transform into more systematically managed risk factors, and companies were observed to shift their focus toward developing long-term solutions. In this context, a total of 1,764 articles related to corporate risk management and COVID-19 were published in 2021. Among them, 441 articles focused on plans aimed at ensuring business continuity. Topics such as digital transformation, supply chain research, and vaccine logistics were also studied with similar intensity. Additionally, 264 articles focused on insurance and financial risks.

The year 2021 marked a period in which, beyond simply reacting to emerging crises, there was a shift toward proactive risk management strategies in response to the ongoing pandemic. Following the uncertainties experienced by businesses in 2020, there was an increased emphasis on crisis scenarios, remote working policies, and investments aimed at enhancing operational agility. During this time, digitalization accelerated significantly, and remote working became a permanent feature across many industries. It is known that businesses invested in data security during this period. The distribution of COVID-19 vaccines presented a major

challenge for global logistics. Many sectors, particularly the healthcare industry, had to plan their business processes in accordance with vaccine supply logistics.

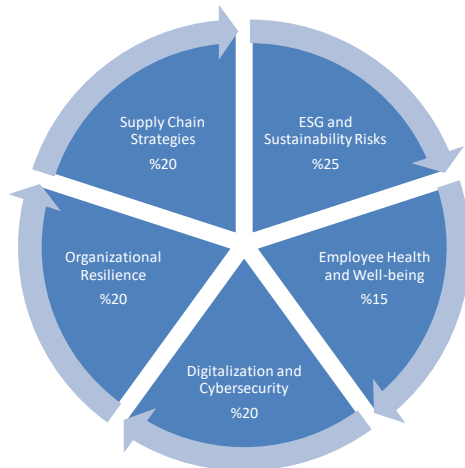


Figure 8. Corporate Risk Management Trend for 2022.

The year 2022 stands out as a period during which the post-pandemic recovery accelerated, while global uncertainties persisted. In this context, a total of 764 articles related to corporate risk management and COVID-19 were published in 2022. Among these, 191 articles focused on ESG (Environmental, Social, and Governance) and sustainability-related risks. Topics such as digitalization and data security, supply chain strategies, and corporate resilience were explored in similar proportions, each appearing in approximately 150 to 153 publications. Furthermore, 115 articles focused on employee health and well-being.

During the COVID-19 period, the primary priority for businesses was to maintain ongoing operations and remain resilient against the crisis. Companies revised their emergency plans during this time, highlighting the growing importance of flexibility and rapid adaptation. Travel restrictions imposed through legal regulations led to major disruptions in global supply chains. In the healthcare sector, attention was drawn to issues such as capacity management, patient care conditions, vaccine development processes, and the supply of medical equipment.

For example, in the aviation industry, airlines like Turkish Airlines adapted quickly by revising health protocols and adjusting flight schedules to maintain operations despite global travel bans and restrictions (Turkish Airlines, 2021). Similarly, global carriers such as Lufthansa implemented comprehensive crisis management strategies to ensure passenger safety and business continuity during the initial shock of the pandemic (Lufthansa Group, 2020).

Moreover, the pandemic's impact on supply chains was exemplified by the disruption in aircraft part supplies and maintenance services, which affected operational capacities worldwide (IATA, 2020). In Turkey, DHMI (State Airports Authority) reported significant drops in passenger numbers, forcing airports to enhance their crisis preparedness and adjust risk management approaches accordingly (DHMI, 2020).

These examples illustrate how the aviation sector, as a critical part of global transportation infrastructure, faced unique risks during the COVID-19 crisis, underscoring the necessity for flexible and resilient corporate risk management strategies.

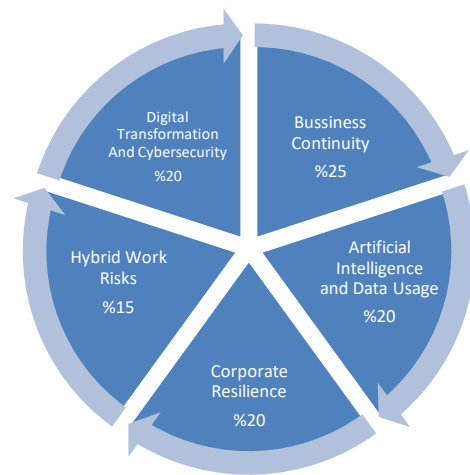


Figure 9. Corporate Risk Management Trend for 2023.

The year 2023 marked a period of post-pandemic restructuring, during which newly emerging regulations—particularly in the contexts of digitalization and sustainability—became central to risk management processes. In this context, a total of 925 articles related to corporate risk management and COVID-19 were identified in 2023. Of these, 231 focused on regulations and compliance issues. Topics such as corporate resilience, cybersecurity and data privacy, and the use of artificial intelligence and big data were examined in approximately 180 to 185 articles each. Additionally, 139 articles focused on risks associated with hybrid work models.

In 2023, corporate risk management evolved into a multidimensional framework, showing significant development particularly around compliance, digital security, and technology adoption. Regulatory compliance and data protection became top priorities, while the risks and opportunities presented by artificial intelligence were brought to the forefront. More “systemic” approaches such as corporate resilience served as the cornerstone of this transformation. The hybrid work models that became permanent after the pandemic introduced new types of risks—not only in terms of human resources policies but also concerning information security, occupational health, and communication efficiency.

In the aviation industry, 2023 was a year of accelerated recovery and increased focus on digitalization and sustainability. Globally, many airlines strengthened ESG compliance to improve operations and reduce environmental impact. For example, Airbus and Lufthansa in Europe expanded the use of sustainable aviation fuels (SAF) to meet carbon reduction targets (ICAO, 2023). In Türkiye, Turkish Airlines accelerated digital transformation projects and developed AI-powered systems to increase operational efficiency (Turkish Airlines, 2023).

Remote and hybrid work models became permanent in the aviation sector as well. While administrative and support staff continued working remotely, increased cybersecurity risks led airlines to invest significantly in digital protection. Both in Türkiye and globally, aviation companies implemented new cybersecurity protocols to safeguard employee data and ensure business continuity (Pegasus, 2023). Moreover, the hybrid working model's impact on occupational health and communication efficiency led to new risk assessments across the industry.

In summary, corporate risk management in 2023 was shaped around digital transformation, sustainability, and new working

models in the aviation industry. The sector experienced substantial progress both operationally and strategically.

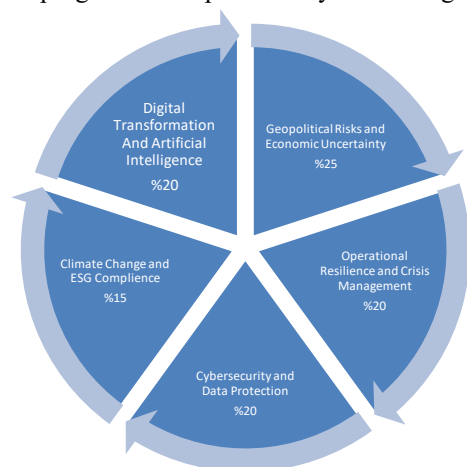


Figure 10. Corporate Risk Management Trend for 2024.

The year 2024 has emerged as a period characterized by forward-looking risk management strategies and intensified digital transformation efforts. In this context, a total of 1,542 articles related to corporate risk management and COVID-19 were published during 2024. Among them, 386 focused on geopolitical risks and economic uncertainties. Topics such as digital transformation and artificial intelligence, cybersecurity and data protection, and corporate resilience were each examined in approximately 300 to 310 articles. Additionally, 231 articles focused on climate change and ESG compliance.

In 2024, organizations began to reshape their risk management strategies in response to an increasingly uncertain global environment. Rising geopolitical tensions, armed conflicts, trade restrictions, and economic volatility posed threats to the operational stability of companies, necessitating a more cautious and proactive approach to risk management. At the same time, rapid advancements in artificial intelligence and digital transformation led to fundamental changes in the way businesses operate. While organizations aim to leverage these technologies for greater efficiency, they also face unavoidable new risks, such as ethical concerns, challenges related to adaptation, and the potential loss of control.

In 2024, rising geopolitical conflicts, war zones, and economic instability had a direct impact on the aviation sector. In particular, ongoing conflicts in the Middle East and Eastern Europe led to restricted airspaces and route adjustments, increasing operating costs and elevating risk levels (IATA, 2024). According to IATA reports, some airlines suspended operations in specific regions due to safety concerns. Advancements in digital transformation and artificial intelligence led airline companies to adopt smart technologies to optimize operations. AI-supported route planning, predictive maintenance, and AI-based customer service tools became more widespread (Airbus, 2024).

Cybersecurity and data protection gained further prominence in this period. As digital infrastructure became more integrated into aviation systems, airports and airlines invested in advanced cybersecurity protocols. Several major airports in Europe experienced data breaches that disrupted operations and raised concerns about system vulnerabilities (EASA, 2024).

In terms of corporate resilience, post-pandemic recovery efforts were supported by flexible supply chain strategies and

scenario-based operational planning models tailored to traffic fluctuations. Airlines increasingly adopted real-time data analytics to respond swiftly to operational disruptions (Turkish Airlines, 2024).

Within the scope of climate change and ESG compliance, sustainability became a more critical topic for the aviation industry. In 2024, airlines like Turkish Airlines and Pegasus launched pilot projects involving Sustainable Aviation Fuels (SAF), aiming to reduce carbon emissions (Pegasus Airlines, 2024). Aircraft manufacturers also accelerated their R&D efforts toward more environmentally friendly, low-emission aircraft models (Boeing, 2024).

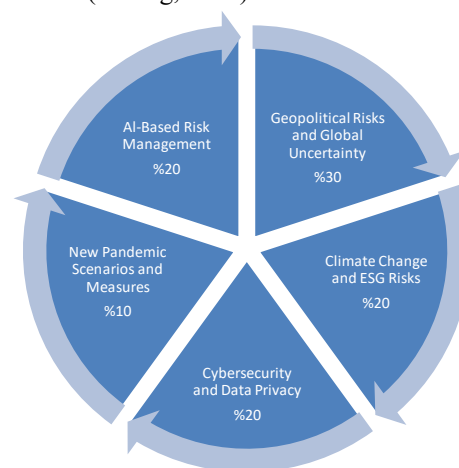


Figure 11. Corporate Risk Management Trend for 2025.

In 2025, a total of 258 articles related to corporate risk management and COVID-19 were identified. Among these, 77 articles focused on geopolitical risks and global uncertainties. Topics such as digital transformation and artificial intelligence, cybersecurity and data protection, and corporate resilience were each investigated in approximately 300 to 310 articles. Additionally, 231 articles centered on climate change and ESG compliance.

The year 2025 can be characterized as a period in which global uncertainties and geopolitical risks gained prominence in corporate risk management trends, reflecting increased organizational vulnerability to external factors. The growing emphasis on AI-based risk management systems demonstrates the importance of more proactive and predictive models, fueled by rapid technological advancements. With increasing digitalization, cybersecurity and data privacy have become central concerns—not only for operational continuity but also for reputational risk.

The rising significance of climate change and ESG-related risks reflects the strategic priority that sustainability has become for both investors and regulatory authorities. Furthermore, preparedness for potential future pandemics has become a critical consideration, underlining the need to build more resilient systems in the post-COVID-19 era. These trends indicate that risk management is no longer confined to financial threats but is now approached within a multi-layered framework encompassing social, environmental, and technological dimensions (THY, 2024).

In parallel, the aviation sector also experienced significant developments during 2025. Geopolitical tensions in the Middle East and conflicts in the Asia-Pacific region led to temporary airspace closures, forcing airlines to revise flight routes and increasing operational costs (IATA, 2020).

Artificial intelligence applications became widespread in areas such as flight safety, maintenance processes, and passenger experience. Airlines like Turkish Airlines (THY) and others adopted these technologies to enhance operational flexibility and efficiency (THY, 2024).

In Europe, cyberattacks on several major airports caused data breaches and flight disruptions, leading to increased investment in cybersecurity infrastructure (EASA, 2024).

In terms of environmental sustainability, airlines such as Lufthansa, Air France, and Turkish Airlines expanded the use of Sustainable Aviation Fuel (SAF) and implemented digital systems for carbon tracking, reinforcing compliance with ESG standards (Turkish Airlines, 2024).

Furthermore, to strengthen pandemic preparedness, new health and safety protocols were introduced at airport facilities, reshaping post-COVID-19 travel norms.

6. Conclusion

The COVID-19 pandemic marked a period that disrupted numerous economic, social, and sectoral balances on a global scale, necessitating a comprehensive reassessment of risk management approaches. Reports published during this period indicate that the aviation industry, in particular, was exposed to multilayered risks such as demand contraction, flight bans, revenue loss, and operational uncertainty. The unexpected magnitude of the crisis highlighted the inadequacy of traditional risk management models and underscored the need for more flexible and predictive systems.

Short-term financial strategies implemented during the crisis—such as cost reduction, utilization of government support, and postponement of investments—played a critical role in helping many airlines survive. However, one of the most important lessons learned from the crisis was that organizations must be prepared not only for financial risks but also for social, environmental, and technological risks. The pandemic clearly revealed the vital importance of a comprehensive and integrated corporate risk management approach (OECD, 2021).

In a time when digitalization and data-driven management systems are reshaping risk perceptions, organizations are increasingly required to focus on emerging risk areas such as cybersecurity, data privacy, business continuity, and remote working. In this regard, next-generation approaches like AI-supported decision-making systems and scenario-based planning have enabled organizations to position themselves more effectively against uncertainty (THY, 2024).

Furthermore, the integration of ESG (Environmental, Social, and Governance) criteria into corporate risk management is expected to become a significant source of competitive advantage for organizations in the future. Issues such as climate change, employee well-being, societal expectations, and the transparency of governance structures have emerged as key risk factors not only in terms of sustainability but also for corporate reputation and long-term value creation (PwC, 2021).

The experiences of the aviation sector present a model that can be adapted across industries. The management of uncertainty should not be limited to crisis periods; rather, it must enhance institutional flexibility and adaptability even under normal conditions. Therefore, corporate risk management must become an integral part of strategic decision-making processes (Economic, 2022).

One of the original aspects of this study is that it is not limited to a conceptual literature analysis but also integrates bibliometric findings with current sector-specific examples from the aviation industry. In this context, the pandemic-era strategies of airlines such as Pegasus, Turkish Airlines, Lufthansa, Emirates, and Singapore Airlines were analyzed in detail. As a result, the study transcends the role of a pure literature review and is enriched with practical applications.

In conclusion, the COVID-19 pandemic has served as a turning point that accelerated the transformation of risk perception and management strategies. The lessons learned from this period provide a roadmap for institutions to become more resilient, sustainable, and agile in the face of future crisis scenarios. The newly developed methods and integrated systems not only enable the management of risks but also allow for the transformation of those risks into strategic opportunities.

Methodologically, the study also draws on content analysis to reflect sectoral trends. The themes identified through bibliometric analysis were compared and interpreted alongside real-world developments in the aviation sector. In this way, the study gains a semi-applied qualitative dimension that complements its bibliometric base.

Furthermore, the study offers a valuable starting point for future research. When supported by additional methods such as surveys, interviews, or case studies, its academic depth and practical value can be significantly enhanced. In particular, aviation sector executives can benefit from such multi-layered approaches when developing pre- and post-crisis strategies.

In this regard, the scientific contribution of the study to the aviation field lies in its ability to broaden the risk management perspective beyond financial concerns and include digital, environmental, and organizational dimensions, providing a multi-dimensional framework for corporate resilience.

This study fills a significant gap in the literature by examining how corporate risk management strategies in the aviation industry evolved in the aftermath of the COVID-19 pandemic and what measures companies adopted in terms of sustainability, resilience, and financial robustness during crisis periods. It particularly emphasizes that crisis management should not be confined to financial measures, and that digitalization, ESG criteria, and integrated risk management approaches must be incorporated into the process. In this respect, the study aims to contribute to the existing literature both theoretically and practically. Additionally, it seeks to provide a valuable perspective on post-2020 risk management trends, offering guidance for both practitioners and researchers.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- ACI. (2020). ACI Advisory Bulletin: Economic impact assessment of COVID-19 on the airport business.
- Akça, M. (2020). COVID-19'un Havacılık Sektörüne Etkisi. *Eurasian Journal of Researches in Social and Economics*, 7(5), s. 45-64.
- Akca, M. (2020). Havalimanı Şehri Modeli. *International Journal of Management and Administration*, 4(7), 178-188.

- Airbus. (2024). Future Aviation Technologies and Emissions Reductions.
- Airport Council International. (2021). Digital transformation in airports during the pandemic. .
- Arifler, M., & Haşit, G. (2024). Türkiye’de Covid-19 Ve Kriz Yönetimi Konulu Lisansüstü Tezlerin Bibliyometrik Analizi. 1st Bilsel International World Science And Research Congress. İstanbul.
- Arslan, I. (2008). Kurumsal risk yönetimi (Uzmanlık Tezi). s. 22.
- Boeing. (2024). Sustainable Aircraft Development and Innovation Report.
- CAAC. (2025, 01 12). Preventing Spread of Coronavirus Disease 2019 (COVID-19) Guideline for Airports (the 2nd Version): <https://www.iata.org/airport-preventing-spread-of-coronavirus-disease-2019.pdf> adresinden alındı
- Changi Airport Group. (2021). Biometric innovations during the pandemic.
- COSO. (2017). Applying COSO’s Enterprise Risk Management — Integrated Framework.
- Cybersecurity Review. (2021). Increasing cybersecurity risks with hybrid work models. .
- DHMI. (2020). Annual report 2020.
- DHMI. (2022). Hava trafik istatistikleri 2021.
- DHMI. (2022). Kalite El Kitabı. Ankara.
- Durmaz, V. (2018). Havaalanlarının Çevre İle İlişkilerinin Yönetimi ve Türkiye’de Uluslararası Trafiğe Açık Havaalanlar. Nisan Kitabevi Yayınları.
- EASA. (2020). Safety Information Bulltein. Easa Publication, s. 1-4.
- EASA. (2024). Cybersecurity in Aviation Infrastructure: 2024 Risk Report.
- Economic, F. W. (2022). Global Risks Report 2022.
- EUROCONTROL. (2020). Aviation Intelligence Portal. 01.20.2025 tarihinde <https://ansperformance.eu/> adresinden alındı
- EUROCONTROL. (2020). COVID19 Grounded aircraft in the EUROCONTROL area. 01.22. 2025 tarihinde https://ansperformance.eu/covid/acft_ground/ adresinden alındı
- Eurocontrol. (2020). EACCC Pandemics Factsheet. Brussels: Eurocontrol Press.
- Fan, s., Wu., Y., & Yang., R. (2025). Measuring firm-level supply chain risk using a generative large language model. Finance Research Letters, 77.
- Ganishti, F., Wennadi., L., & Santoso., H. (2025). The Impact of Enterprise Risk Management and Sustainability Disclosures on Corporate Value with Corporate Governance as a Moderating Variables. International Journal of Informatics, Economics, Management and Science, 4(1), s. 42-53.
- Global Supply Chain Review. (2020). Impact of COVID-19 on Boeing’s supply chain. .
- Hopancı, B., Akdeniz., H., & Şahin., Ö. (2021). COVID19 Pandemisinin Havacılık Sektörü Üzerine Etkileri. Mühendis ve Makina, 62(704), s. 446-467.
- Huang, Ya-Li ; Ho, Yuh-Shan ; Chuang, Kun-Yang . (2006). Bibliometric Analysis of Nursing Research in Taiwan 1991-2004. Journal of Nursing Research, 75-81.
- IATA. (2020). Airline industry impact report on COVID-19. .
- IATA. (2021). Air cargo and the COVID-19 vaccine: Industry readiness for vaccine logistics and distribution.
- IATA. (2024). Safety and Risk Report: Global Airspace and Geopolitical Impacts.
- ICAO. (2023). Sustainable Aviation and Carbon Reduction Strategies.
- Ito, H., & Darin, L.;. (2005). Assessing the impact of the September 11 terrorist attacks on U.S. airline demand. Journal of economics and business, 57(1), s. 75-95.
- Küçük Yılmaz, A. (2016). Hava Taşımacılığı. Eskişehir: Anadolu Üniversitesi Yayınları.
- Küçük Yılmaz, A. (2017). Uluslararası İşletmelerde Kurumsal Risk Yönetimi: Strateji ve Örgütsel Kültür Odaklı Paradigma. Konya: Literatürk Yayınları.
- Küçük Yılmaz, A., & Kafalı,H. (2017). Emniyet Risk Yönetiminin Organizasyonel Ve Stratejik Amaçlar Açısından Etkileri: Havalimanları Örnek Olayı. International Journal of Academic Value Studies, 3(13), s. 239-250.
- Kasarda, J. D. (2019). Aerotropolis. The Wiley Blackwell Encyclopedia of Urban and Regional Studies, 1-7.
- Koç, S., & Çelik, ., A. (2017). Kurumsal Risk Yönetimi:Türkiye’de Bankacılık Sektöründe Bir Uygulama. C.Ü.İkdisadi Ve İdari Bilimler Dergisi, 16(2), s. 311-335.
- Lawani, S. M. (1981). Bibliometrics: Its Theoretical Foundations, Methods and Applications. International Journal of Libraries and Information Services, 294-315.
- Lufthansa Group. (2020). Sustainability report and crisis management during COVID-19.
- OECD. (2021). Corporate Governance, Risk Management and Resilience Post-COVID-19.
- Oktaysoy, O., Topçuoğlu,E., & Kaygın,E. (2022). Sivil havacılıkta risk yönetimine bibliyometrik bakış. Sakarya Üniversitesi İşletme Enstitüsü Dergisi, 4(2), s. 77-79.
- Organization, I. C. (2020). Operational Impact on Air Transport. 01.13. Retrieved on 2025 from <https://data.icao.int/COVID-19/>
- Pegasus. (2020). Q2 Investor Presentation. İstanbul.
- Pegasus. (2020). Q3 Investor Presentation. İstanbul.
- Pegasus. (2023). 2023 Annual Report. Pegasus Airlines.
- Pegasus Airlines. (2024). Annual ESG Report.
- PwC. (2021). Resilience and Recovery in the Aviation Sector.
- Samiee, S., & Chabowski, B. R. (2012). Knowledge Structure in International Marketing: A Multi-Method Bibliometric Analysis. Journal of the Academy of , 364-386.
- Savrun, B., & Mutlu, H. (2019). Kent Lojistiği Üzerine Bibliyometrik Analiz. Kent , 364-386.
- SHGM. (2022). Faaliyet Raporu 2021. Ankara.
- Tanrıverdi, G., & Küçük Yılmaz, A. (2018). Coopetition Strategy: A Research on Traditional Airlines. Gaziantep University Journal of Social Sciences, 17(1), s. 319-325.
- THY. (2024). 2024 Sürdürülebilirlik Raporu. İstanbul.

- THY. (2024). Annual sustainability and risk management report 2024. Turkish Airlines Corporate Publications.
- Turkish Airlines. (2021). Annual report 2021.
- Turkish Airlines. (2023). Digital Transformation Projects. THY Corporate Publications.
- Turkish Airlines. (2024). Sustainability Initiatives: SAF Usage and Carbon Strategy.
- Zhuang, Z. Z. (2020). Preliminary estimation of the novel coronavirus disease (COVID-19) cases in Iran: a modelling analysis based on overseas cases and air travel data. *International Journal of Infectious Diseases*, 29-31.
- WHO.(2020). Global health response and vaccine development.

Cite this article: Copur, T., Kucuk Yilmaz, A. (2025). Post-Pandemic Trends in Corporate Risk Management: A Bibliometric Review in the Context of the Aviation Industry. *Journal of Aviation*, 9(3), 797-807.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 *Journal of Aviation* <https://javsci.com> - <http://dergipark.gov.tr/jav>

Towards International Standardization in UAS Pilot Licensing: A Comparative Analysis of EASA and FAA Frameworks

Anastasia Tsotra¹ 

¹Department of Surveying and Geoinformatics Engineers, University of West Attica, Athens, Greece (email: atsotra@uniwa.gr)

Article Info

Received: 25 June 2022
Revised: 12 September 2025
Accepted: 24 September 2025
Published Online: 19 October 2025

Keywords:

UAS Licensing
ICAO
FAA
EASA
Unmanned aviation

Corresponding Author: *Anastasia Tsotra*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1727378>

Abstract

This study aims to examine critical issues and gaps in main regulatory frameworks (European Union Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA)), concerning the training, licensing, and certification of Unmanned Aircraft Systems (UAS) pilots. Particular attention is given to issues such as the minimal age requirement for pilots, the absence of observers and practical flight examinations to ensure operational competence. The paper, mainly using research articles, regulation etc., highlights the lack of regulatory harmonization between the European Union and United States, especially concerning the mutual recognition of foreign certifications, underlining the need for unified standards as advocated by the International Civil Aviation Organization (ICAO). Furthermore, the study criticizes the oversimplification of EASA's requirements, where self-training and lack of qualified examiners may compromise the operational proficiency of UAS pilots. Through comparative analysis of FAA and EASA approaches in theoretical and practical training, risk-based categorization, adherence to safety standards and critical role of Artificial Intelligence (AI), this paper identifies the need for enhancing an international unified framework for UAS pilot licensing, proposing practices.

1. Introduction

The legislative frameworks regarding UAS have emerged as a response to the rapid development of UAS over the past decade. These systems have found applications across various sectors, influencing daily life, professional activities, and social functions. Consequently, regulatory authorities such as EASA and FAA have established procedures for the licensing and certification of UAS pilots.

In recent years, Unmanned Aircraft Systems (UAS) have increasingly been used for terrorist and criminal activities, leading to a significant number of incidents with malicious intent. This growing threat highlights the urgent need for the development of regulatory standards for pilot certification, as well as the strict enforcement of relevant legislation. Throughout this article, the terms "Unmanned Aircraft Systems (UAS)" and "drones" are used interchangeably, while UAS is considered as the primary term.

Aiming to ensure flight safety and the integration of manned and unmanned aircraft within shared airspace, ICAO pioneered guidelines in 2015 with the publication of ICAO DOC 10019, AN/507—particularly Chapter 8, which provided guidelines for the certification of UAS pilots and observers. In 2017, the release of the Concept of Operations (CONOPS) manual offered more specific guidance on these matters (ICAO, 2018).

FAA introduced Part 107 regulations in 2016, outlining the process for obtaining a UAS pilot license (FAA, 2021). FAA Reauthorization Act further supported this initiative by allocating substantial funding to colleges and universities for the development of UAS operator training programs (Skydio, 2024).

In Europe, the former EASA Basic Regulation EC 216/2008 authorized Member States to develop national legislation for UAS with a Maximum Take-Off Mass (MTOM) up to 150 kg. As a consequence, EASA countries adopted their own regulations for UAS pilot certification. Furthermore, the adoption of the new EASA Basic Regulation EC 1139/2018 introduced a unified European regulatory framework for UAS, Regulation EC 947/2019, which focuses on risk management and defines licensing and certification requirements for the pilots of open and specific categories of UAS operations, effective from 2021 (EASA, 2019).

As of August 8, 2024, there were 388.838 recreational UAS pilots registered in USA. In addition, 390.027 commercial UAS had been registered, as well (FAA, 2025). On the other hand, EASA has not so far made any official announcements about the exact number of registered pilots in EASA. In EASA's website, it is mentioned that there are 1,6 million registered UAS operators, operating under the EASA rules (EASA, 2025).

A study by Ljungblad et al. (2021), addressing ten experienced professional UAS pilots, identifies UAS-pilot interaction and flight safety as the top priorities for these pilots.

Similarly, Schmidt et al. (2022) implement research on German professional UAS pilots and identify competencies and training needs of them. Blagodaryashchev et al., (2022) conduct research on training programs for UAS pilots in the EU and USA, which are based on risk levels, and compare them with Russian training programs that are categorized as private, state, and experimental.

The regulatory frameworks and the results of similar research studies define the content and steps for training, examination, and certification of UAS pilots. This study investigates and compares EASA and FAA standards regarding skills and knowledge of certified remote pilots, as well as relative ICAO guidelines. It therefore, aims to identify similarities and differences that could inform the evolution of dynamic legislative frameworks, ensuring that remote pilots possess the necessary qualifications to guarantee flight safety.

2. Methods

Lobo et al. (2021) investigate the effectiveness of active and interactive training methods for UAS pilots. Herrington, Zahed and Fields (2021) deal with students from the University of Missouri, who flew UASs before and after receiving theoretical and practical training, and demonstrate the effectiveness of such training.

Descriptive studies by Ateş (2022), Ateş et al. (2022) and Doroftei et al. (2021) emphasize the significant role of human factors in UAS pilot training programs. Further research by Doroftei et al. (2022, 2024) uses quantitative and qualitative tools, to assess UAS pilot performance in real flight environments. The utility of simulators in UAS pilot training is demonstrated in studies by Gabriel, Ramallo, and Cervantes (2016), Somerville, Lynar, Joiner and Wild (2024) and Chan et al (2024). Additionally, Cardona et al. (2021) explore the use of virtual environments in UAS pilot training.

In this study, a qualitative comparative research approach is conducted, based on the systematic analysis of official laws, regulatory documents (issued by ICAO, EASA, FAA), rules, notifications, guidelines and scientific research articles. That study examines mainly the FAA pilot UAS framework in the United States and the corresponding one in EASA, in relation to the ICAO guidelines. Other national or international pilot UAS regulations (e.g., Asia, Africa, Australia) are beyond the scope of that analysis.

The comparative analysis of developments in EASA and FAA regulations is presented, focusing on the core thematic dimensions: eligibility, English language – medical certificate, theoretical education, practical training and exams, UAS pilots certificates' categories, ratings, and endorsements, operational limitations, durability/validation of pilot certifications, UAS student–observer, UAS examiners, trainers and training centers. These themes were detected through a heuristic method, that navigated the complex regulatory landscape of the UAS sector. Researcher experience supported the interpretation and comparison of the above-mentioned regulatory frameworks regarding UAS civil pilot licencing, excluding military and technological aspects (Brisola & Cury 2016).

Few studies have examined the latest modifications made on the UAS pilot licences. The scope of that paper aims to identify good and bad practices of FAA and EASA and

consequently, the corrective actions that should be adopted to make the optimum framework.

3. Results and Discussion

3.1. UAS Pilot's Eligibility, English Language Assessment and Medical Certificate

3.1.1. Results

According to the guidance provided by ICAO (DOC 10019/2015), the minimum age for this type of certification should be eighteen (18) years. However, this guidance came into force in 2016 and was evidently influenced by manned aircraft pilot standards. Since then, the requirements and conditions have changed. Both FAA and EASA have reduced the minimum age to sixteen (16) years. Furthermore, EASA member states may lower this age by four years, in other words, as low as twelve (12), as presented in Table 1.

On the other hand, in manned aviation, it is often considered that older age correlates with more experience but also increased risk, whereas it seems so far that no significant percentage in accidents caused by older pilots. UAS regulations do not set an upper age limit for the certification of pilots.

ICAO mandates English proficiency and a Class 3 medical certificate for UAS pilots. FAA requires English proficiency and good health, though a formal medical certificate is not required. Nevertheless, EASA, by contrast, does not require any language or medical certification, diverging from ICAO standards.

3.1.2. Discussion

Granting UAS pilot licenses to individuals under 18 years of age, and in some EASA countries even as young as twelve (12), raises serious concerns related to flight safety, counter, terrorism and data protection. The accessibility of UAS and the ease with which they may be operated, increase the risk of misuse or inadequate risk awareness among minor pilots. This raises the question of whether minors can be capable of risk management and safe operation of UAS, or even handling emergency situations.

Although research (Li et al., 2002) shows no clear correlation between pilot age and accident rates in manned aviation, unmanned aviation poses distinct risks, due to the lack of pilot flight experience, lower oversight, and often minimal training. The permissiveness of EASA policies may reduce barriers to entry, but increases the public's negative perception of unmanned aviation, due to the economic and social burden of supervising UAS operations to ensure their responsible use. On the other hand, Bazargan and Guzhva (2011) note that older general aviation pilots do appear more often in accident data.

EASA's removal of language and medical assessment requirements, despite earlier inclusion in national frameworks of EASA countries, undermines standardization. ICAO and FAA guidelines still require English proficiency and a basic health standard. These omissions may lower entry barriers but compromise preparedness in high stakes or shared airspace operations, where physical fitness, decision making, and communication competence are essential. The key differences are highlighted in Table 3.

Table 1. UAS pilot licensing process EASA vs FAA

EASA (European Union)	FAA (USA)
1. Eligibility confirmation (age ≥ 16) and even lower by four years	1. Eligibility confirmation (age ≥ 16 , English proficiency, good physical condition)
2. Completion of theoretical training (for A1/A3 and A2 categories)	2. Completion of Part 107 theoretical training
3. Online exam /Self-practical training for A2	3. Passing the FAA knowledge test (UAG)
4. Registration of the pilot on national authorities' platform	4. Application for certification via web-based certification application
5. Acquisition of Remote Pilot Certificate of Competency	5. Acquisition of Remote Pilot Certificate

3.2. UAS Pilots' Theoretical Education, Practical Training and Exams

3.2.1. Results

Table 1 illustrates the main procedures of UAS pilot certification. ICAO requires UAS pilots to study areas such as meteorology, operational procedures, and human factors and to pass official exams. Upon recommendation by a certified instructor or certified training center, the UAS pilot participates in certification exams and pass with at least the minimum success rate set by each state. FAA applicants must study FAA provided materials, obtain an FAA tracking number (FTN) and pass the Unmanned Aircraft General – Small (UAG) test.

As shown in Table 1, EASA Open A1/A3 pilots complete online training and an exam of (40) multiple, choice questions, covering flight safety, human factors, data protection, etc. For A2 category, additional theory on topics such as meteorology, UAS flight performance and ground risk mitigation and exams are required as well. Tables 2 and 3 outline that in the Specific category, theoretical exams depend on the scenarios and are more advanced. FAA does not require any practical training or testing for certification.

EASA allows self-practical training in the open category with no skill test or supervision. Only in the Specific category (especially for standard scenarios) there is practical training and assessment required by an authority or certified training organization (Table 1).

3.2.2. Discussion

Table 3 illustrates the differences on theoretical and practical training programs. Both FAA and EASA allow self-training for lower risk operations, with multiple attempts on theoretical tests. This compromises the validity of the certification process, particularly when human factors, in other words decision making and situational awareness, are not properly evaluated. Theoretical training should also include psychological competencies and essential elements (attention, workload management, focus) for safe UAS operation in dynamic airspace (Ateş, 2022). In both frameworks, practical training and testing are poorly regulated. FAA does not require flight testing at all. EASA allows unsupervised self-training in the Open Category.

3.3. UAS Pilots Certificates' Categories, Ratings, and Endorsements

3.3.1. Results

Table 1 sets out the UAS pilot regulatory approaches between USA and EASA. FAA distinguishes between recreational and professional pilots under Part 107.

Recreational users must pass a basic knowledge test and comply with limited rules, while professional operators must

be 16+, speak English, be in physical and mental health and pass a knowledge exam. They can operate UAS under broader conditions (e.g., at night, over people).

EASA categorizes licenses based on UAS mass and risk. Lighter UASs (<250g) require no formal training. Heavier UASs (C1 to C3 categories) involve online training, theoretical testing, and sometimes self-practical training. In the Specific category, training is tailored to the operation's complexity and must be approved by authorities. Moreover, EASA pilots licenses are also categorized according to the maximum take-off mass of the UAS and UAS compliance with the specific European Class Identification (CE) label.

According to ICAO, a remote pilot license may include ratings, categories, endorsements, related to the types of UAS the pilot is authorized to operate. Licensing authorities define and issue these type ratings and class ratings, and may also certify pilots for special operations such as night flights. This model mirrors the established structure used in manned aviation pilot licensing. However, such distinctions are not applied in FAA or EASA regulatory frameworks. Neither system issues ratings or operational endorsements specific to UAS categories, types, or missions. Instead, both agencies manage complexity through risk or usage, with a more general certification process.

3.3.2. Discussion

The risk-based classification (low, medium, high) and training by EASA promotes safety. In contrast, FAA is based on use categorization (recreational vs. professional) and may allow high risk flights by insufficiently trained recreational users. The Tables 2 and 3 emphasize these main differences. On the other hand, it is very likely that flights conducted by professional UAS pilots might not involve high risk, while recreational users could perform high risk flights. Hence, the FAA categorization does not seem to be particularly effective and should be revised to adjust the training requirements for each category based on risk (Tsotra, 2024).

The use of CE labels in EASA also introduces trade protectionism concerns, potentially limiting market competition (e.g., from non-European UAS manufacturers), while complicating compliance and enforcement for national aviation authorities (Cygañcz & Roguski, 2023). However, beyond this objective, CE compliance also seems to aim at limiting competition in the unmanned aircraft market, especially from China, and appears to have little to do with actual flight and product safety. The fragmentation of EASA Open Category into CE labels that also denote operational

conditions and pilot certifications, create considerable confusion among operators and the UAS industry. Further observation is needed to determine whether the subcategories of the European Open Category have achieved the expected results so far.

ICAO guidelines recommend classifying UAS licenses with specific endorsements—such as night operations, BVLOS, or aircraft types—similar to manned pilot licenses. FAA and EASA have largely ignored this guidance, issuing generic authorizations instead. This limits pilot specialization and the ability to match operational scope with certified capabilities, especially in advanced missions or commercial UAS operations.

3.4. Operational Limitations, Durability and Validation of Remote Pilot Certifications

3.4.1. Results

ICAO allows each state to determine certificate validity and accept prior manned or unmanned experience. In EASA, licenses for the Open and Specific categories are valid for five (5) years and are renewed through refresher courses. However, certifications outside EASA area or previous pilot experience are not recognized. FAA issues certificates valid for 24 months, renewed by an online recurrent test. It does not recognize any foreign UAS pilot certifications but only previous manned aviation experience.

FAA applies general operational rules for all UAS operators. On the other hand, EASA categorizes operations within the Open category into subcategories (A1, A2, A3), each with distinct operational limitations—such as proximity to people, flight altitude, and overflight conditions. This risk-based approach provides a safety-oriented framework, as illustrated in Table 2.

3.4.2. Discussion

EASA risk-based operational model is a strength. By tailoring rules to specific categories (Open, Specific, Certified), it promotes safety practices. FAA's generalized regulations lack such categorization. Yet, safety management systems (SMS) and risk analysis tools—well established in manned aviation—remain underdeveloped in UAS sector, particularly in the FAA framework. EASA's guidance moves forward to fill this gap. UAS pilots are subject to human error, and therefore a UAS flight can be dangerous of causing fatal accidents as a manned flight. Consequently, the development of a SMS for every natural or legal person enforce the cultivation of a safety culture among them and are necessary procedures, to minimize human error (Weldon, et al., 2021).

The renewal of UAS pilot certificates, whether via theoretical refreshers (EASA) or recurrent knowledge tests (FAA), lacks emphasis on practical skill demonstration. This deviates from manned aviation licensing models, where recurrent flight evaluations are standard. Also, in unmanned aviation, repeated practical training and testing by certified instructors is the most appropriate method that should be adopted across all international UAS regulatory frameworks.

Moreover, international certificate validation remains undeveloped. FAA and EASA do not recognize each other's UAS certifications, even though ICAO promotes mutual recognition. This lack of harmonization hinders global interoperability, cross border UAS missions, and professional mobility for UAS pilots. This analysis shows that the creation of common standards for the certification of UAS pilots by

both EASA and the FAA, will promote international UAS mobility.

3.5. UAS Student Pilot – UAS Observer

3.5.1. Results

ICAO introduces the concepts of the "UAS student pilot" and the "UAS observer." A student pilot should be supervised by an instructor and holds a medical certificate, while an observer must undergo competency-based training. EASA, however, omits these roles and requirements from its framework. FAA defines the "UAS observer" as an assistant to the remote pilot responsible for detecting and assessing collision risks. This individual supports the pilot by maintaining visual line of sight (VLOS) during flight (Bridewell, Anderson, Concannon and Cline, n.d.).

3.5.2. Discussion

Both FAA and EASA omit the formal role and training of a UAS observer, despite ICAO recommendations and the critical role of observers in Beyond Visual Line of Sight (BVLOS) operations. Regulatory reliance on visual line of sight (VLOS) fails to address limitations of human vision (Calandrillo & Webb, 2020). Modern camera systems and automated tracking tools often surpass the capabilities of human observers. As AI continues to evolve in unmanned aviation, it will increasingly supplement or even replace traditional human support roles as those of the observers (Heydarian Pashakhanlou, 2019).

3.6. UAS Examiners, Trainers and Training Centres

3.6.1. Results

According to ICAO, UAS instructors must hold a remote pilot license and demonstrate experience on the specific UAS type and class. In addition, they should receive training in safety management and instructional methodology. Examiners are required to have prior experience as instructors and are granted special authority to conduct skill tests. ICAO also recommends that Approved Training Organizations (ATOs), already active in manned aviation, may extend their scope to deliver training for unmanned aviation. Under the FAA framework, examiners and instructors are certified and operate within Part 107 provisions. In contrast, EASA does not provide a common definition of trainer or examiner qualifications. Instead, each Member State establishes its own rules in this area.

Table 2. UAS pilots certifications' comparison under ICAO's guidelines

Factor (Reference)	ICAO	FAA (USA)	EASA
Eligibility (3.1)	Standardized eligibility guidelines	Part 107 defines specific eligibility (age, English proficiency, background check)	Categories (Open, Specific, Certified) with different eligibility requirements
English Language and Medical Assessment (3.1)	Requires English proficiency and medical fitness	English proficiency required; no medical certificate for Part 107	No foreign language or medical assessment required
Theoretical Education – Exams (3.2)	Recommends knowledge exams;	Requires passing a knowledge test for Part 107	Requires theoretical exams with category,specific subjects
Practical Education – Exams (3.2)	Guidelines for practical exams	No flight test required; practical knowledge expected	Practical training and assessment required for Specific/Certified; self,training for Open category
UAS Pilot Certificate Categories (3.3)	No defined UAS license categories	Part 107 applies to small UAS (<55 lbs); waivers required for larger or special operations	Certificates categorized by risk level: Open, Specific, Certified
Ratings, Categories, Endorsements (3.3)	Guidelines for standardization	Waivers for BVLOS, night operations, etc.	Endorsements based on risk and operational needs
Operational Limitations (3.4)	Defined by member states	Restrictions based on weight, altitude (400 ft AGL), and airspace	Operations categorized by risk (Open, Specific, Certified) with varying restrictions
Remote Pilot Certificate Durability and Validation (3.4)	Certification validation depends on national regulations	Part 107 certificate valid for 24 months; requires renewal; no validation	Certificates have durations based on category; refresher training required; no validation
UAS Student Pilot / Observer (3.5)	Guidelines for these roles	Student pilots under supervision; observers not recognized	No definition of these roles
UAS Examiners, Trainers, and Training Centers (3.6)	Specific guidelines exist	FAA approves but not regulate testing centers; does not regulate training schools	No structured system of recognized UAS training organizations or examiners

3.6.2. Discussion

As illustrated in Table 3, while ICAO defines structured criteria for instructor certification and training center approval, EASA's open category does not impose training, with direct oversight or assessment. In the European open category licenses, pilots engage in practical self-training without the need for experienced instructors. That creates inconsistencies in pilot competency across Member States. Without trained examiners and certified instructors, remote pilots risk being unprepared for emergency situations, cooperative missions, or risk mitigation strategies, which are critical competencies in increasingly complex urban airspaces (Ates, 2022). In USA, UAS training centers may operate as university departments or under FAA's Part 107 framework. In EASA, they are considered simply as entities they provide training, with no specific certification process mentioned.

Table 3. UAS pilots certifications' evaluation

Reference	Title	Key Topics	Evaluation
3.1	Eligibility	-Minimum age requirements (FAA>=16 EASA>=12) -no upper threshold	Granting licenses to minors increases legal and security risks regarding misuse, insufficient accountability.
3.1	Language & Medical Certification	-ICAO guidelines -national vs EU requirements	Medical and language requirements were lacked in EASA's unified framework. This compromises operator readiness in critical scenarios.
3.2	Theoretical Education & Exams	-Self-training -test attempts -human factors inclusion	EASA's self - paced learning undermines certification credibility. Human factors not sufficiently integrated.
3.2	Practical Education & Skill Testing	-Practical training requirements -examination standards -EASA Open vs Specific Category	Practical testing is inadequately addressed. Only in the Specific Category (EU) of EASA is required. FAA omits practice entirely. This undermines skills standard of UAS pilots.
3.3	Pilot Certificate Categories	-EASA risk levels vs FAA usage classification -CE marking -SMS	Risk -based categories better align training with flight safety. FAA classification is outdated. CE marking creates confusion in enforcement and compliance
3.3	Ratings – Endorsements	-ICAO guidance on endorsements -FAA/EASA omission	FAA and EASA neglect ICAO's recommendation for certification per rating or endorsement. This reduces the ability to match pilot qualifications to operational needs.
3.4	Operational Limitations	-Airspace management (FAA) -Risk - based categorization (EASA)	FAA's rules lack the nuanced approach needed for complex environments EASA's risk -based framework enhances safety.
3.4	Certificate Durability & Validation	-Renewal process -practical exams -international recognition	Little emphasis on practical testing and lack of clear recertification rules. Lack of international license recognition hinders global harmonization.
3.5	UAS Observer	-Observer role omission -human factors -AI evolution	Regulatory omission of observers is problematic. Human vision is overemphasized. AI's evolution calls for rethinking observer and pilot roles.
3.6	Examiners, Trainers, Training Centres	-Instructor/ examiner certification -training center standards	Absence of certified instructors and examiners in EASA weakens pilot preparation.

4. Conclusions

Table 4 sets out the main conclusions and all the recommended practices that obtained from the present study. The primary objective of UAS regulatory frameworks worldwide is to achieve safety levels comparable to those of manned aviation. Enabling UAS operations in both controlled and uncontrolled airspace without compromising the safety of manned aircraft, remains the most critical goal. Accordingly, air traffic rules must be clear, consistent, and understandable for all airspace users and air traffic controllers.

The categorization of UAS licenses by risk level, as adopted by EASA, represents a significant advancement that is likely to enhance flight safety outcomes in European airspace. Conversely, the U.S. regulatory framework for UAS pilot licensing requires modernization, as it still relies on an outdated distinction between recreational and commercial use.

Safety risks are not inherently tied to whether a flight is conducted for hobbyist or professional purposes (Tsotra, 2024).

Nevertheless, the fragmentation of EASA pilot licenses categories based on CE compliance labels, generates confusion and complicates enforcement and monitoring by authorities (e.g., police). It also presents challenges for manufacturers, including European ones, while limiting the participation of non-European competitors.

Table 4. Conclusions and Practices

Conclusions	Recommended Practices
Safety alignment with manned aviation is essential	Clear, harmonised air traffic rules
EASA's risk-based categories improve safety	Maintain risk-oriented licensing
FAA licensing outdated (hobbyist vs. professional)	Adopt risk-oriented licensing by FAA
CE-label fragmentation causes confusion	Simplify categories to ease enforcement
Lack of practical training	Introduce mandatory practical training & exams
Simulators improve readiness	Incorporate simulators in training
BVLOS critical in UAS operations	Relax restrictions, integrate BVLOS training
AI reduces pilot role	Prepare pilots for supervisory roles
Global harmonization remains incomplete	ICAO standards & mutual recognition between countries across the world
Fragmented national registration systems	A unified global registration system of UAS pilots

Self-training plays a central role in both the U.S. and EASA contexts and covers theoretical knowledge in both systems and practical skills in the EASA framework. However, the lack of mandatory practical training with certified instructors and the absence of practical skill tests reduce the perceived professionalism of UAS pilots compared to manned aircraft pilots. This gap negatively impacts safety, as new operators enter the field without adequate preparation or readiness to respond to emergencies.

The integration of flight simulators into training programs provides valuable opportunities to practice in realistic operational environments, while it reduces the risks and logistical challenges of training in urban airspace. Incorporating simulator-based training in the European open category and in the U.S. recreational pilots' sector would be a practical solution. Similar benefits are highlighted in the studies of Gabriel et al. (2016), Somerville et al. (2024), and Chan et al. (2024).

Furthermore, the use of active learning methods in both theoretical and practical training could better address the competency requirements of UAS pilots. Legislation should guide training programs toward a stronger emphasis on safety and human factors, rather than technical aspects.

Training in Beyond Visual Line of Sight (BVLOS) operations has become essential. Advances in artificial intelligence (AI) and automation are reducing the complexity of BVLOS flights, suggesting that regulatory frameworks should adopt more flexible approaches rather than imposing restrictive measures on these flights.

The growing role of AI and automation in unmanned aviation has raised concerns that the human pilot's role will gradually diminish. By 2030, UAS operations in the European Union are expected to require only minimal human

intervention. While pilots will continue to make critical decisions, AI-driven systems will increasingly support them (Nawaz, 2023). In the near future, pilots may have supervisory roles, overseeing and coordinating autonomous missions rather than directly operate the aircraft. Such positions will require expertise in both manned and unmanned aviation (Gauci et al., 2021).

In general, although substantial progress has been made in UAS pilot licensing, significant gaps remain. As presented in Table 4, it is crucial for ICAO to adopt minimum training standards and establish comprehensive guidelines, ensuring harmonization of the global regulatory framework. Mutual recognition of UAS pilot licenses between FAA, EASA, and other authorities worldwide would further enable safe cross-border operations. A unified global registration system for UAS pilots could facilitate the integration of the sector at the international level.

Through international cooperation and adoption of common standards, along with recurrent certification and robust training programs, the industry can ensure the development of highly skilled and competent UAS pilots. This can only be achieved by harmonizing training standards between the U.S. and EASA, fostering global license validation as in manned aviation, and making regulatory compliance more effective. Further research should particularly focus on the standardization of practical training and other aspects of pilot certification, not omitting the developing role of UAS pilots in the era of AI and automation.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

References

- Ateş, H. (2022). Important issues in unmanned aerial vehicle user education and training. *Journal of Aviation*, 6(1), 80–86.
- Ateş, S. S., Uzgör, M., & Yüsek, K. (2022). UAV tracking module proposal based on a regulative comparison between manned and unmanned aviation. *Journal of Airline and Airport Management*, 12(1), 29–47.
- Bazargan, M. & Guzhva, V. S. (2011). Impact of gender, age and experience of pilots on general aviation accidents. *Accident Analysis & Prevention*, 43(3), 962–970.
- Blagodaryashchev, I. V., Kiselev, M. A., Naumov, R. S., & Shapkin, V. S. (2022). Topical issues of personnel training in the field of unmanned aircraft systems. *Scientific Bulletin of the Moscow State Technical University of Civil Aviation*, 25(4), 8–19.
- Bridewell, J., Anderson, E., Concannon, R., & Cline, P. (n.d.). Appendix F—UAS pilot and visual observer training and certification. [Unpublished manuscript].
- Brisola, E. B. V., & Cury, V. E. (2016). Researcher experience as an instrument of investigation of a phenomenon: An example of heuristic research. *Estudos de Psicologia (Campinas)*, 33(1), 95–105.
- Calandrillo, S., Oh, J., & Webb, A. (2020). Deadly drones: Why FAA regulations miss the mark on drone safety. *Stanford Technology Law Review*, 23(1), 182–231. https://law.stanford.edu/wp-content/uploads/2020/03/2020-04-07_Calandrillo_Final.pdf.

- Cardona, Reyes, H., Trujillo, Espinoza, C., Arevalo, Mercado, C., & Muñoz, Arteaga, J. (2021). Training of drone pilots through virtual reality environments under the gamification approach in a university context. *Interaction Design and Architecture(s)*, 49, 64–83.
- Chan, J. H., Liu, K., Chen, Y., Sagar, A. S., & Kim, Y. G. (2024). Reinforcement learning-based drone simulators: Survey, practice, and challenge. *Artificial Intelligence Review*, 57(10), 281–312.
- Cygańczuk, K., & Roguski, J. (2023). New challenges in the operation of unmanned aerial vehicles: Changes in legal regulations regarding the safety of unmanned aviation. *Zeszyty Naukowe SGSP/Szkoła Główna Służby Pożarniczej*, 72(2), 45–59.
- Doroftei, D., De Cubber, G., & De Smet, H. (2021). Reducing drone incidents by incorporating human factors in the drone and drone pilot accreditation process. In J. Chen et al. (Eds.). *Advances in human factors in robots, drones and unmanned systems* (pp. 71–77). Springer.
- Doroftei, D., De Cubber, G., & De Smet, H. (2022). Assessing human factors for drones operations in a simulation environment. *Human Factors in Robots, Drones and Unmanned Systems*, 57(1), 35–43.
- Doroftei, D., De Cubber, G., Lo Bue, S., & De Smet, H. (2024). Performance assessment of drones operators. *Drones*, 8(9), 482.
- European Union Aviation Safety Agency. (2019). Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft. *Official Journal of the European Union*, L 152, 45–71. <https://eur.lex.europa.eu/legal.content/EN/TXT/?uri=CELEX%3A32019R0947>.
- European Union Aviation Safety Agency. (2025). Drones & Air Mobility. Retrieved September 15, 2025, from <https://www.easa.europa.eu/en/domains/civil-drones>.
- Federal Aviation Administration. (2021). Summary of Small Unmanned Aircraft Rule (Part 107). U.S. Department of Transportation. https://www.faa.gov/uas/getting_started/part_107.
- Federal Aviation Administration. (2025). Air traffic by the numbers: FY2024 Fact Book. U.S. Department Transportation. https://www.faa.gov/air_traffic/by_the_numbers/air-traffic-by-the-numbersFY2024.pdf.
- Gabriel, G., Ramallo, M. A., & Cervantes, E. (2016). Workload perception in drone flight training simulators. *Computers in Human Behavior*, 64, 449–454.
- Gauci, J., De Carlo, J., Golfetti, A., Tomasello, P., Napoletan, L., Turhan, U., & Drogoul, F. (2021, May). From education and training to the workplace: Gaps and challenges in aviation. In *Contemporary EHF 2021 Conference Proceedings* (pp. 101–110).
- Herrington, S. M., Zahed, M. J. H., & Fields, T. (2021, January). Pilot training and task-based performance evaluation of an unmanned aerial vehicle. In *AIAA Scitech 2021 Forum* (Paper No. 0595).
- Heydarian Pashakhanlou, A. (2019). AI, autonomy, and airpower: The end of pilots? *Defence Studies*, 19(4), 337–352.
- International Civil Aviation Organization. (2018). Manual on remotely piloted aircraft systems (RPAS) (Doc 10019). ICAO. <https://store.icao.int/en/manual-on-remotely-piloted-aircraft-systems-rpas-doc-10019>.
- Li, G., Baker, S. P., Lamb, M. W., Grabowski, J. G., & Rebok, G. W. (2002). Human factors in aviation crashes involving older pilots. *Aviation, Space, and Environmental Medicine*, 73(2), 134–138. <https://pubmed.ncbi.nlm.nih.gov/11846182>.
- Ljungblad, S., Man, Y., Baytaş, M. A., Gamboa, M., Obaid, M., & Fjeld, M. (2021). What matters in professional drone pilots' practice? An interview study to understand the complexity of their work and inform human drone-interaction research. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (pp. 1–16).
- Lobo, D., Patel, D., Morainville, J., Shekhar, P., & Abichandani, P. (2021). Preparing students for drones careers using active learning instruction. *IEEE Access*, 9, 126216–126230.
- Nawaz, S. A. (2023). Conflicting visions around technology integration: A look at recent EU UAS policies. *Contemporary European Politics*, 1(2).
- Schmidt, R., Schadow, J., Eißfeldt, H., & Pecena, Y. (2022). Insights on remote pilot competences and training needs of civil drone pilots. *Transportation Research Procedia*, 66, 17–29.
- Skydio. (2024, February 12). 2024 FAA reauthorization and drones: What you need to know. Skydio. <https://www.skydio.com/blog/2024-faa-reauthorization-and-drones-what-you-need-to-know>.
- Somerville, A., Lynar, T., Joiner, K., & Wild, G. (2024). Use of simulation for pre-training of drones pilots. *Drones*, 8(11), 640.
- Tsotra, A. (2024). Critical comparative analysis of UAS legislative developments. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 10, 223–230.
- Weldon, W. T., Hupy, J., Lercel, D., & Gould, K. (2021). The use of aviation safety practices in UAS operations: A review. *The Collegiate Aviation Review International*, 39(1), 1–11.

Cite this article: Tsotra, A. (2025). Towards International Standardization in UAS Pilot Licensing: A Comparative Analysis of EASA and FAA Frameworks. *Journal of Aviation*, 9(3), 808-815.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>

Comparison of Customer Reviews Between Traditional Airlines and Low-Cost Carriers: A Case Study from Türkiye

Nursel Cebişli¹, Kemal Enes², Mustafa Öztürkel³

¹ Tarsus University, Business management, 33400, Tarsus, Mersin, Türkiye. Master Student (230907005@tarsus.edu.tr)

² Tarsus University, Civil Aviation Management Department, 33400, Tarsus, Mersin, Türkiye. (kemalenes@tarsus.edu.tr)

³ Tarsus University, Business Management, 33400, Tarsus, Mersin, Türkiye. Phd. Student (mustafaozturk3342@gmail.com)

Article Info

Received: 04 March 202
Revised: 25 September 2025
Accepted: 09 October 2025
Published Online: 19 October 2025

Keywords:

Airline
Flight service
Qualitative Analysis
Low-cost carriers

Corresponding Author: *Kemal Enes*

RESEARCH ARTICLE

<https://doi.org/10.30518/jav.1650500>

Abstract

This study compares the customer complaints of traditional airlines and low-cost carriers in Türkiye through a qualitative analysis of online reviews. The aviation industry has experienced significant growth, leading to increased competition and focus on customer satisfaction. Online reviews play a crucial role in shaping brand image and influencing customer preference. This study examines reviews posted by TripAdvisor between January and August 2024 for Turkish Airlines (traditional carriers) and Pegasus Airlines (low-cost carriers). Content analysis was employed to categorize the data into specific groups, with an interpretive approach used to holistically evaluate the meanings of sentences and paragraphs. The findings reveal that flight delays are a primary concern for customers of both the airlines. For Pegasus Airlines, extra charges and good service are also significant themes, while Turkish Airlines faces issues with inadequate help desks and rude behavior. This study highlights the importance of addressing customer complaints, investing in customer service training, and adopting strategies to meet evolving customer expectations. The results suggest that airlines should focus on improving their customer-centric approach, analyzing customer feedback, and implementing measures to enhance service quality. This study contributes to the understanding of customer satisfaction in the airline industry and provides valuable insights for airlines seeking to gain competitive advantage.

1. Introduction

The aviation industry has experienced significant growth worldwide owing to its advantages, such as comfort and speed. This growth has substantially increased the number of passengers and airlines. In Türkiye, although over 181 million passengers were served in 2015, this figure exceeded 213 million by 2023 (Devlet Hava Meydanları İşletmesi [DHMI] 2023). As the aviation sector has expanded, competitive dynamics have become more pronounced. Ensuring customer satisfaction is the most crucial aspect of airline operations in competitive markets (Küçükaltan & Topçu, 2019).

To remain competitive and ensure that clients are satisfied with their services, airlines must understand and improve the elements that affect customer satisfaction (Sarılğan & Bakır, 2023). Identifying and improving the elements that affect passengers' choice of airlines form the foundation of customer satisfaction (Chen & Chao, 2015). Consequently, to attract more customers and sustain a competitive edge, airlines must understand the criteria that customers use when selecting an airline (Kim & Park, 2017). A thorough understanding of these criteria enables airlines to serve various passenger classes and develop strategic plans to increase profit margins (Wen & Lai, 2010).

Airline passengers consider numerous factors when choosing a carrier for their travel, including the company's corporate image, service quality, and pricing (Sarılğan & Bakır, 2023). Passenger preferences and expectations may vary according to diverse sociodemographic characteristics (Milioti et al. 2015). Consequently, research on airlines serving multiple consumer segments should focus on customer preferences and expectations rather than general customer profiles. For instance, business travellers may prioritize punctual and reliable travel, families might seek comfort and entertainment for children, young people may desire technological services, while elderly passengers may require assistance and guidance (Chen & Chao, 2015).

For this reason, airlines should conduct market research, considering passenger feedback, to understand the diverse needs of customer segments and offer tailored services to travellers (Kim & Park, 2017). Providing appropriate services to customers in this manner can enhance customer satisfaction and provide competitive advantage. Airlines seeking to achieve a competitive edge adopt strategies to increase product diversity, and stand out in terms of the desirability of gaining superiority over their rivals (Chen, 2008). Companies are expected to possess performance capabilities that enable them to demonstrate high levels of success against competitors in fulfilling their desire for competitive advantage, and to show

professionalism in customer relations and communication (Küçükergin, 2012). In other words, competitive advantage is associated with businesses' ability to take predictable and strong steps by considering not only today's consumers but also tomorrow's consumers and changing environmental factors (Lee & Carter, 2005).

Similar to other businesses, airlines have found it necessary to develop a high-level perspective on their service approach to generate profits by ensuring customer satisfaction (Çam, 2009). The services provided at airports and onboard aircrafts, which are linked to customer satisfaction, are considered crucial factors for gaining a competitive advantage (Tsaour et al., 2002). Consequently, airlines are compelled to enhance their service concepts in accordance with their customer expectations and feedback.

This study aims to evaluate online customer reviews regarding the services provided by airlines, both at airports and onboard aircrafts. This analysis will enable a better understanding of passengers' expectations of the services offered at airports and during flights, thereby providing access to valuable information regarding the service process. Within the scope of this aim, by identifying the areas the examined customer reviews predominantly focus on, it is anticipated that this study will positively contribute to the improvement of airlines' airports and in-flight services.

2. Airline Industry and Online Reviews

Customer reviews posted online significantly impact Turkish Airlines' brand image, satisfaction levels, and perceived service quality. The aviation industry involves transporting individuals, postal items, or freight between destinations using aircrafts (Gerde, 2002). Airlines provide both passenger and cargo delivery services. Regardless of the specific service provided, it encompasses a broad spectrum beyond aircrafts and flights. All civil aviation activities, including design, manufacturing, maintenance, ground services, navigation, air traffic control, and communication, ensure efficient, safe, and secure air transportation (Wells, 1999).

While the primary objective of air transportation is to facilitate passenger travel, the service extends beyond the confines of the aircraft. The process begins with booking a reservation and encompasses a broad network of services, including transportation to the airport, completion of airport procedures, in-flight travel, and departure from the airport. When evaluating passenger satisfaction resulting from the quality of the service provided or the service process, it is essential to consider the entire experience holistically (Thomas, 1997).

Online reviews play a crucial role in determining customer satisfaction and quality of service. Passengers provide feedback to airlines by sharing their experiences, which can be utilized to enhance service standards. For instance, major airlines such as Turkish Airlines (THY) and Pegasus Airlines regularly analyze online reviews to improve customer satisfaction and service quality (Chen & Xie, 2008).

Online reviews posted by passengers can significantly affect airlines' brand image and reputation. Negative feedback diminishes a company's prestige, whereas positive feedback enhances it. For instance, favorable reviews of SunExpress's customer service have strengthened the company's brand image (Dellarocas, 2003). Conversely, negative comments about AtlasGlobal's service quality have damaged the brand's

reputation (Hu et al., 2006). Potential customers consider these online reviews when evaluating airlines and making purchase decisions. Consequently, online feedback directly influences customer airline preferences. For example, positive reviews highlighting AnadoluJet's high-quality services at affordable prices have increased the likelihood of customers choosing an airline (Park & Lee, 2009).

According to Belobaba (2009), air transportation is a service process that begins with the demand for flight information and continues with reservation and ticket purchases. Owing to the widespread use of the Internet today, passengers can obtain tickets from airline websites, relevant departments, or travel agencies. On the scheduled flight date, the passenger goes to the airport, utilizes the services, and boards the plane. These stages constitute the pre-flight process. The services received until the passenger completes their journey and disembarks from the plane from the in-flight process, whereas the period from disembarking to leaving the airport comprises the post-flight process (Thomas, 1997). The entirety of these processes encompasses service quality.

Although not a factor that can be directly controlled by the air transportation service provider, access to the airport also affects customer satisfaction (Smith, 2020). Additionally, the time spent on baggage and security checks after the flight, as well as the process of leaving the airport, can influence the perception of service quality, even if it is not directly under the airline's responsibility (Belobaba, 2009). Therefore, airlines aiming to ensure customer satisfaction should not consider their service as limited to the flight alone but should evaluate all factors that may affect customer contentment.

According to Wells (1999), the components that influence the perception of airline services include accessibility, price, schedule, comfort, and the image of the service provider. Accessibility components encompass the ease of reaching ticket offices, flight information, and quality of services provided during ticket purchases. The price components include payments and ticket costs. The schedule components include flight frequency to the intended destination and whether the flight is direct or involves connections. The comfort component encompasses numerous factors such as cabin space utilization, passenger seats, refreshments, and the number of cabin crew members (Wells, 1999). Pre- and post-flight services along with ground services were also considered within this component. Company image is a brand perception that can be influenced by factors such as advertisements and sponsorships and is directly linked to the general customer opinion of previously provided services. All these components, along with their sub-factors, impact the customer's evaluation of the service offered.

In recent years, low-cost carriers have captured a significant market share in the airline industry, attracting customers by offering affordable services. However, the level of customer satisfaction and service quality provided by traditional airlines may differ from those of low-cost carriers. Therefore, it is important to examine customer complaints and analyze the differences between low-cost carriers and traditional airlines (Jones, 2021).

Traditional airlines typically offer comprehensive service networks that provide personalized communication through various channels to ensure customer satisfaction. These airlines are known for their solution-oriented approaches to respond to customer complaints quickly and effectively. For instance, major carriers, such as Turkish Airlines, regularly examine customer feedback and utilize these comments to

enhance their service quality (Chen & Xie, 2008). In the process of addressing customer complaints, traditional airlines aim to enhance customer loyalty and improve negative experience. Companies focus on resolving customer issues by establishing comprehensive customer service systems and support teams. Furthermore, they analyze and respond to customer feedback on digital platforms and social media (Dellarocas 2003).

Budget airlines streamline their operations and impose limitations on customer services in order to maintain low expenses (Smith, 2020). However, they can swiftly respond to customer complaints by providing efficient and rapid customer support services on digital platforms. For instance, low-cost carriers such as AnadoluJet and Pegasus effectively manage online feedback to enhance customer satisfaction (Hu et al. 2006). Budget airlines may face limitations in addressing customer complaints because of the need to control their costs (Jones, 2021). However, these carriers typically analyze customer feedback swiftly and use it to make operational adjustments. This approach helps low-cost carriers maintain their competitive edge (Park & Lee, 2009).

3. Literature

Customer complaints regarding low-cost carriers and traditional airlines have been compared through various findings and research. The airline industry has a complex and competitive structure in terms of customer services. While customer satisfaction provides a significant competitive advantage for airlines, issues such as flight delays and cancellations, luggage damage or loss, staff behavior and service quality, in-flight services, and seat comfort are frequent complaints (Yılmaz, 2020). Yılmaz (2020) examined the most common complaint topics in the Turkish airline industry and concluded that baggage and delay problems were leading issues.

Low-cost carriers offer cheaper ticket prices but provide limited services and comfort. However, they charge extra fees for additional services (Doganis 2010). Zahari et al. (2011) found in their study that due to the higher cost of airline payments compared to other transportation methods, service expectations are greater. Gillen and Morrison (2003) concluded in their research that low-cost carriers demand more fees than traditional airlines, resulting in an increase in customer complaints. Traditional airlines, on the other hand, generally offer more services and comfort in exchange for higher ticket prices (Gillen and Morrison, 2003).

An analysis of customer complaints regarding airlines in Türkiye has revealed varying levels of service quality and customer satisfaction. In their study examining reviews of Pegasus Airlines, Kara and Demir (2019) concluded that, while low-cost carriers are preferred because of their affordable prices, they receive more complaints because of deficiencies in service quality and additional fees. Turkish Airlines (THY), on the other hand, stands out with its high customer satisfaction and superior service quality, although its higher ticket prices may be a disadvantage for some customers (Aydemir, 2018).

In-flight services play a crucial role in customer satisfaction. Yao and Vink (2019) found that passengers' taste perception changes during high-altitude flights, and concluded that refreshments should be designed to suit the flight style. Dölekoğlu et al. (2017) determined in their study that passengers tend to prefer consuming foods such as sandwiches

and fruits. Seidenberg et al. (2020) discovered that passengers consider allergen risks and religious sensitivity when selecting food. Yousaf and Xiucheng (2018) established that airlines providing in-flight services should offer food and beverage options to accommodate the religious beliefs and personal needs of passengers.

An and Noh (2009) determined that in-flight food and beverage services play a crucial role in evaluating airlines' service quality. Saha and Theingi (2009) found a direct correlation between service quality and customer satisfaction in airlines. Their study concluded that passengers tend to avoid choosing airlines with unsatisfactory service quality, leading to potential customer loss. Mills and Clay (2001) emphasized that passenger needs and desires are constantly changing owing to the dynamic nature of the airline industry. King (2001) noted that offering meals tailored to special needs prevents customer attrition. Sundarakani et al. (2018) state that in-flight food and beverage services are important for developing competitive strategies. Yabancı (2018) highlighted that catering services differ between short- and long-haul flights, with many airlines considering catering services on short-haul flights.

In conclusion, comparing customer complaints between low-cost carriers and traditional airlines reveals significant differences in customer satisfaction, service quality, and pricing strategies. Kara and Demir (2019) found that Pegasus Airlines, which adopts a low-cost business model, receives numerous customer complaints, but appeals to a broad customer base because of its low fares. Yılmaz (2020) emphasized that airlines need to improve their customer-centric approach and consider customer complaints to enhance service quality.

Roszkowska et al. (2024) introduce the SMOD (Synthetic Measure for Ordinal Data) method for the analysis of online consumer reviews measured on ordinal scales. This method, grounded in the Hellwig approach and the GDM2 distance metric, facilitates reliable rankings even in the presence of missing and uncertain data. An application using TripAdvisor data reveals that Singapore Airlines ranks highest, while Air China ranks lowest in service quality among Star Alliance members. Güngör et al. (2019) examine 647 TripAdvisor reviews for Turkish Airlines posted during the first four months of 2017. The Mann–Whitney U test indicates that passenger gender significantly influences overall rating, customer service, in-flight entertainment, and value-for-money. The Kruskal–Wallis H test reveals that passengers from Russia and Ukraine report the highest satisfaction, whereas those from the United Kingdom, Central Asia, and the Far East report the lowest.

Çallı et al. (2022) observe that the COVID-19 pandemic exerted financial pressure on the airline industry and increased consumer complaints. In their study, 10,594 complaints concerning two major airlines are decomposed into core topics using Latent Dirichlet Allocation. The analysis provides managerial and scholarly insights into service failures and proposes the development of a decision-support system that leverages passenger complaints during irregular operations.

Brochado, Rita, Oliveira, and Oliveira (2019) investigate the main themes in airline passengers' online reviews and their relationship with value-for-money ratings. Based on 1,200 reviews, the study identifies nine core themes, with perceptions of low value particularly associated with airport and in-flight services. The findings offer guidance for understanding passenger experiences from social media data and for enhancing service quality and perceived value.

Ercan (2020) analyzes TripAdvisor reviews of Turkish Airlines to identify sources of dissatisfaction. Seven main categories emerge: service issues, physical factors, reservation problems, cabin crew, flight-related problems, lack of foreign-language proficiency, and check-in problems. The results highlight pronounced negative attitudes, especially in international economy class, and underscore the importance of incorporating complaints into service-quality improvement.

Sulu et al. (2022) explore how the COVID-19 pandemic affected passenger behavior and satisfaction by qualitatively analyzing TripAdvisor reviews posted during the pandemic. Ten themes are prominent—"flight," "service," "staff," "food," "check-in," "cancellation," "COVID-19," "airport," "class," and "baggage." Dissatisfaction is particularly associated with "cancellation," "check-in," "refund," and "airport." The study provides actionable insights for improving service quality under pandemic conditions. Kaya and Duygun (2023) contend that passenger reviews significantly impact both airlines and prospective travelers. Through content and statistical analysis of TripAdvisor reviews for Delta, Emirates, and Turkish Airlines, the study finds that Emirates outperforms the others across all categories and that the rating categories are positively interrelated.

In this context, it is crucial for airlines to invest in customer service training and review their strategies to meet customer expectations (Kotler, 2012).

Through a comprehensive literature review, it is evident that a theoretical gap exists, which this study addresses by integrating online customer feedback with established models of service quality and customer satisfaction, such as SERVQUAL and Expectation-Confirmation Theory. From a practical standpoint, the study offers actionable insights for airline managers and policymakers on strategies to reduce complaints, enhance service delivery, and improve customer relationship management in a highly competitive market.

This research fills a significant gap by conducting a comparative analysis of customer complaints directed at two major carriers, recognized as pioneers in the Turkish airline market—a context that has been scarcely examined in existing literature. It further investigates how online customer evaluations influence perceived service quality. Given the predominance of studies focused on Europe, Asia, and North America (Park, Robertson, & Wu, 2004; Chen & Xie, 2021; Zhang et al., 2022; Clemes et al., 2008; Gilbert & Wong, 2003; Forgas et al., 2010; Taneja, 2017), this comparative analysis within the Turkish context offers a novel contribution to the field.

4. Method

The primary research question of this study sought to identify the differences in online complaints and satisfaction between traditional and budgetary airline customers. Additionally, this study explores disparities in expectations between traditional and low-cost airline passengers based on online reviews.

This study employed a qualitative research approach to examine, investigate, and elucidate the reviews of airline passengers to address the research questions. (Creswell, 2020). In this context, customer reviews on www.tripadvisor.com were subjected to content analysis, focusing on comments made between January and August 2024 by travelers who flew with Turkish Airlines (representing traditional carriers) and Pegasus Airlines (representing low-cost carriers). The content analysis method employed in this study aims to condense the

data by categorizing them into specific groups (Matthews & Ross, 2010).

An Interpretive Content Analysis approach was adopted in the process of analyzing passenger reviews. This method aims to evaluate the meanings of sentences and paragraphs from a holistic perspective rather than focusing solely on the dictionary definitions of words. In other words, this technique is characterized as an analytical method that allows the drawing of reproducible and valid conclusions about the context in which texts are employed (Drisko & Maschi, 2016).

The primary objective of this study is to investigate how online customer reviews reflect variations in service perceptions between a traditional full-service airline (Turkish Airlines) and a low-cost carrier (Pegasus Airlines) in Türkiye. By analyzing passenger evaluations shared on digital platforms, this research aims to identify recurring themes of satisfaction and dissatisfaction and to understand how airline business models influence customer experiences.

The main contribution of this research lies in its focus on the Turkish aviation market, which has been underrepresented in the literature compared to studies conducted in Europe and North America. While there is a growing body of research analyzing online reviews in the airline industry, very few studies have systematically compared traditional and low-cost carriers within the same national context using qualitative content analysis. In this regard, the study addresses a gap by providing empirical evidence on how different airline strategies are perceived by passengers in Türkiye.

5. Findings

The coding process involved analyzing 57,223 words and 362,635 characters, resulting in 631 codes. The findings reveal a mix of positive and negative codes. This segment presents the results of customer feedback regarding Pegasus and Turkish Airlines collected from www.Tripadvisor.com.

Data were collected from www.tripadvisor.com in September, 2024. During the collection process, data were restricted to the period between January and August 2024. Owing to the pandemic, 2021–2023 was identified as a period of crisis for airlines (Li & Wang, 2023). Consequently, the analyses started from the beginning of 2024.

Table 1. Positive and Negative Reviews Regarding Airline Companies

Categories	PEGASUS	THY
Positive	68	34
Negative	235	278

Table 1 shows that 68 positive reviews were categorized as Pegasus Airlines and 34 were classified as THY. Conversely, 235 negative reviews were attributed to Pegasus and 278 were associated with THY. Wu et al. (2016) indicated that individuals have a stronger tendency to publicize their adverse experiences, particularly via online platforms. Based on this information, the table suggests that consumers are most likely to post reviews, particularly when they have had negative experiences. Additionally, TripAdvisor platforms enable air travelers to evaluate their journeys using a star rating system. Table 2 displays the information regarding the scores associated with the number of stars.

Table 2. Frequency of Stars of the comments

	Pegasus	THY
	208	237
	16	23
	9	12
	23	16
	41	17
Unidentified	11	8
Total	308	313

When categorizing reviews as positive or negative, those with four or five stars were considered positive, whereas those with lower ratings were deemed negative. An exception was made for neutral responses, with nine individuals from Pegasus Airlines and 12 from Turkish Airlines (THY) opting for 3-star ratings. In these cases, the content of the 3 stars reviews was examined, revealing that all of them expressed negative sentiments

The analysis yielded a total of 52 codes. A detailed overview of all the identified codes and their associated coding frameworks is provided in Table 3.

Table 3 shows the frequency of codes related to airlines' customer reviews. An analysis of the reviews reveals that for Pegasus Airlines, the most common complaints were about "Extra charges" (83), "Flight delays" (59), and "Good service" (58). For Turkish Airlines (THY), the most frequently reported issues were "Inadequate help desk" (60), "Flight delays" (43), Baggage Problem (42) and "Rude behavior" Rude behavior(41). Flight delays have emerged as a primary concern for the customers of both airlines. Additionally, for Pegasus Airlines, extra charges are cited as a significant complaint, along with flight delays. When examining the themes of Turkish Airlines, inadequate help desks are mentioned as a major issue, in addition to flight delays.

Complaints on Pegasus Airlines primarily focus on additional charges, particularly post-flight ticket fees and food. Examples;

Review one: "I've been flying with Pegasus for a long time and had a few negative experiences, which led me to stop using their services for a while. Recently, I purchased a ticket from Pegasus to Istanbul, and encountered another unpleasant situation. Initially, I bought a ticket without checking for baggage, and attempted to add cabin baggage. When I downloaded my ticket, it showed no cabin baggage, so I asked a friend from Türkiye to verify it. They confirmed that I had cabin baggage. At the airport, I was charged 44 £ baggage. I recall several instances where they took my cabin baggage due to a full flight and then tried to sell something, but this was not clear and the information provided was inaccurate. I believe this will be my last flight with Pegasus. There are numerous airlines flying to Türkiye, and it is easier for me to understand exactly what I purchased. I wanted to share this experience with those who considered buying a ticket from Pegasus and were worried about their trips being ruined. Additionally, the woman who was eager to blame me for this was quite rude, so I requested that they speak with someone who might better understand me, while the other person was the same. I was simply trying to explain, but they were not very willing to listen."

Review Two "This airline faces two significant issues: 1. The seats were uncomfortable, and did not recline. 2.

Passengers were not provided with free water. In addition, no power outlets are available for the charging devices. This is strongly discouraged for long-distance travels.!"

The other popular complains are flight delay and "good service" one of the customers review is "Throughout my life, this was the most terrible flight experience I've had, and I fly frequently, about 2-3 times a month. Due to a delay in check-in, I missed my flight to Istanbul despite arriving three hours earlier. When I got there, they would not let me board, with just four minutes left before the gate was closed. They told me to rebook my Pegasus flight at their counter where I found several others facing the same issue. Staff members were unhelpful, cunned, and impolite. The Pegasus Airlines are fraudulent. I will never fly with them again; they are undoubtedly the worst airline I have used. I spent an additional \$500 to reach my destination, and they refused to refund or compensate me, even though the fault was entirely their own. If you consider flying with them, be aware that you cannot count on their assistance if problems arise. Even if tickets cost less than a dollar, I will never set foot on the pegasus plane again. They ruined perceptions of Türkiye and its hospitality. I used to love Türkiye, but now, I might not visit it again. Shame on you, Pegasus, and your service. Your staff are too incompetent to work in customer service, completely rude, and far from professional in every aspect."

Turkish Airlines receives the most complaints regarding inadequate help desk services, baggage problems, and rude people. This examples could be sample for three reason ; "To anyone considering flying with this airline: Look elsewhere. My pregnant wife and I experienced every possible shortcoming that an airline could have: subpar seating, terrible hospitality, misleading policies, constant seat changes, useless/incorrect notifications, and unappetizing meals. To begin with, they claim to provide a hotel room if you have a 12-hour layover. This is absolutely false. The "help desk" representative said their system indicated we were only eligible for meal vouchers. We were appalled. She said that she would call the hotel to check availability, but her brief conversation proved impossible. This was approximately 1:00 AM. She then told us to call customer service for further assistance. That is what she was supposed to be! During our flight from Paris to Istanbul, our plane was delayed without any communication regarding reason. We received several messages stating that our seats had changed; however, the gate agents said that the original seats were correct. However, this is extremely difficult. Upon boarding, the woman in front of my wife reclined her seat, and when my wife tried to recline hers to compensate, it would not move. This was incredibly uncomfortable for her; while trying to watch the tilted screen, it froze and never played it. When the meal service time came, the woman in front did not raise her seat, and the flight attendants seemed indifferent. The tray table had to be pushed into our baby for my wife to eat (understandably, she did not eat much... she had little appetite during this experience). The woman in front of me did not lean forward, so my meal kept sliding onto my lap. On many legs of our flights, we were behind people with extra legroom's, and these passengers kept falling into our laps. We are currently sitting at the airport for 11 more hours with fast-food vouchers as consolation, so I have plenty of time to write this. Perhaps, we can use our burgers as pillows. The help desk was full of people who had experienced similar issues. Thus, business classes may be more effective. However, if you are going to spend that much time, you will be better off choosing another airline.

Table 3. Frequency of Stars of the comments

Theme	PEGASUS	THY	THY theme's arrangement
Extra Charges	83	28	10
Flight Delays	59	43	2
Good Service	58	33	7
Baggage problem, lost/broken	51	42	3
Insufficient service	49	28	11
Incorrect Fee Policy	44	16	17
Rude behavior	33	41	4
Check-in problem	26	33	8
Inadequate help desk	26	60	1
Lack of support	25	4	33
Stress panic/health problem	24	17	16
Reservation problem	23	34	6
Seat problem	23	25	13
Lack of comfort	17	12	21
Unaffordable ticket price	16	2	40
Lack of service at the airport	15	9	26
Useless online application	13	15	18
Confirmation code and language problem	12	11	24
Unsafe Flight	11	40	5
Flawless check-in	11	3	37
Good staff	8	12	22
Ticket/flight cancellation	7	21	14
Clean Aircraft	6	4	34
Ticket problem	4	6	28
Noise	4	2	41
Fee without invoice	4	0	53
Visa problem	3	6	29
Dirty aircraft	3	4	35
Refund problem	2	29	9
Missing/wrong information	2	10	25
Positive experience	1	14	19
Lack of entertainment	1	8	27
Passport problem	1	5	31
Security violation	1	1	45
Other passenger problem	1	1	46
Influence from other customers	1	1	47
Servicing on long flight	1	0	54
Physical attack	1	0	55
Food and beverage problem	0	28	12
Too much wait for food and beverage	0	19	15
Lack of Service in business class	0	13	20
Transfer problem	0	12	23
Fresh airless plane	0	6	30
Technical failure	0	5	32
Different ticket	0	4	36
Complicated process	0	3	38
Racist behavior	0	3	39
Mileage problem	0	2	42
Lack of service for the disabled	0	2	43
High ticket price	0	2	44
On-time arrival	0	1	48
Discrimination against female athletes	0	1	49
Landing at different airport	0	1	50
No boarding pass	0	1	51
Not enough entertainment	0	1	52

6. Result and Discussion

This study analyzes and compares customer reviews of Pegasus and Turkish Airlines, the two most significant airlines operating in Türkiye. According to this study's findings, Turkish Airlines received the most customer complaints regarding "Inadequate help desk" (60), "Flight delay" (43), and "Rude behavior" (41). For Pegasus, the most frequent complaints were about "Extra charges" (83), "Flight delay" (59), and "Good service" (58).

Upon examining customer complaints, it is evident that flight delays are a common theme for both the airlines. Flight delays are considered as one of the most critical issues from the perspective of passengers. Consistent with our results, prior studies—Song et al. (2024), Oliveira et al. (2023), Edvarson (1992), Masorgo et al. (2022), and Britto et al. (2012)—also document that flight delays are a salient driver of passenger dissatisfaction. According to Perez and Garcia (2016), although low-cost airlines can maintain customer loyalty by avoiding mishaps and ensuring satisfaction, traditional airlines prefer service quality, sensitivity, and effective communication. Notably, two of the top three complaints about Turkish Airlines (THY) (inadequate help desk and rude behavior) were related to communication issues. This indicates that airline managers should focus on the communication demands of customers who choose not to use budgeted airlines. In particular, it highlights the importance of addressing communication-related concerns of passengers who opt for full-service carriers.

It appears that the most frequently reported issue by customers regarding THY airlines is inadequate help from desks. These results are consistent with the findings of Güreş et al. (2020). This commonly voiced concern in customer complaints highlights the critical importance of the airline company making necessary investments in technological infrastructure and employing staff at their help desk, who are attentive, solution-oriented, knowledgeable about the industry, patient, proficient in foreign languages, and possess excellent communication skills.

Rude behavior is identified as the third most common complaint among customers regarding Turkish Airlines (THY). These results are consistent with the findings reported by Sezgen et al. (2019) and Pınarbaşı (2025). The prevalence of this issue in leading aviation companies such as THY is a significant problem. To address this concern and enhance service quality, the THY should prioritize hiring individuals with characteristics suitable for the service industry such as friendliness, patience, presentability, and positivity. This approach could play a crucial role in resolving the issue of rude behavior reported by customers. Furthermore, providing effective and efficient orientation training for newly hired staff is essential for increasing passenger satisfaction and boosting employee motivation. Additionally, creating an organizational climate that encourages all personnel to participate in educational and training activities for self-improvement, along with supporting relevant staff members, will significantly contribute to enhancing the service quality in the aviation sector.

Customers of the budget airline Pegasus primarily complain about additional fees, flight delays, and poor overall service. Although it is understandable that price-sensitive passengers are most concerned about extra charges, issues such as flight delays, subpar services, and baggage problems require further attention. Airline managers should take measures to address these concerns, particularly by focusing

on improving luggage handling. Moreover, the extra fees requested can be perceived as a source of stress for customers, potentially negatively affecting the quality of their travel experiences. A Pegasus airline's lack of transparency regarding additional charges may harm the trust relationship between the company and its customers. This mistrust atmosphere could lead to problems throughout the passengers' journeys. It is crucial for airlines to provide the necessary information about pricing extra services before travel.

When examining complaints about Pegasus Airlines, it was evident that the third most frequently mentioned topic was good service. Similarly, Pınarbaşı, (2025) reported comparable findings regarding good services. Customer satisfaction is of paramount importance for airlines; therefore, companies should better analyze customer expectations and achieve service quality standards that meet these expectations. In this context, customers appreciate the services provided by Pegasus Airlines. Consequently, ensuring continuity in Pegasus Airlines' service processes, meticulously evaluating customer feedback, and continuously training staff on customer satisfaction-focused approaches are crucial for maintaining this success in the eyes of customers. The fact that the complaints are grouped under the heading of "good service" indicates that customer expectations are high, and that the company has significant potential in terms of service. In this regard, Pegasus Airlines' transparent sharing of steps taken to improve customer experience may contribute to increasing customer loyalty.

7. Limitation

This study acknowledges several limitations that warrant consideration. Firstly, the analysis was confined to customer reviews of two airlines operating within Türkiye, namely Turkish Airlines and Pegasus. Consequently, the findings may not be entirely generalizable to the broader international aviation industry. Additionally, the data were derived solely from online reviews, lacking access to passengers' demographic characteristics, travel purposes, or flight classes, which could have influenced their satisfaction levels. This limitation constrains the ability to develop a more comprehensive perspective on customer experiences.

From a methodological perspective, the study employed a qualitative content analysis approach. While this method is instrumental in providing in-depth insights into passenger experiences, it inherently relies on subjective interpretations. The coding process may have been influenced by the researcher's judgments, posing a potential risk of bias. Furthermore, the study analyzed reviews from a limited time frame (January 2024 – August 2024), thereby excluding customer experiences from other periods that might reveal seasonal or contextual variations.

Future research could expand the scope by incorporating comparative analyses of airlines across different countries to capture cross-cultural differences in customer satisfaction. Employing quantitative or mixed-method approaches would also enable researchers to statistically test the factors influencing passenger satisfaction. Moreover, utilizing big data from social media platforms, online forums, or mobile applications—combined with advanced techniques such as sentiment analysis or topic modeling—could provide more nuanced categorizations of customer feedback. Finally, integrating demographic variables and travel motivations into the analysis would contribute to a more comprehensive

understanding of service quality dimensions in the airline industry.

Several recommendations are offered for researchers interested in this area. It is advisable to include a larger set of airlines in the scope of analysis. Studies should also compare different business models (full-service vs. low-cost) and account for varying organizational/network configurations. Extending the temporal horizon and employing multi-year data would enable more robust identification of trends. Finally, data collection should not be limited to a single platform; it is important to compile reviews concurrently from multiple sources such as TripAdvisor, Google Reviews, Şikayetvar, and Skytrax.

Conflicts of Interest

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

References

- Akpur, A., & Ulema, Ş. (2022). Türkiye'deki Havayolu İşletmelerinde Uygulanan Sadakat Programları Üzerine Bir Araştırma. *Bandırma Onyedil Eylül Üniversitesi Sosyal Bilimler Araştırmaları Dergisi*, 5(2), 45-56.
- Aksoyok, M. (2018). Havayolu Taşımacılığında Uzun Menzilli Düşük Maliyetli Taşıyıcılarda Uçak ve Hat Seçimi. *Eskişehir: Anadolu Üniversitesi*.
- An, M., & Noh, Y. (2009). Airline Customer Satisfaction and Loyalty: Impact of In-flight Service Quality. *Service Business*, 3(3), 293-307.
- Aydemir, M. (2018). Türk Hava Yolları Müşteri Memnuniyeti Analizi. *Turizm Araştırmaları Dergisi*, 9(1), 23-45.
- Aydın, K., & Özer, G. (2018). Havayolu İşletmelerinde Hizmet Kalitesinin Müşteri Memnuniyeti Üzerine Etkisi: Türk Hava Yolları Örneği. *Havacılık ve Uzay Teknolojileri Dergisi*, 12(2), 37-49.
- Baş, R. (2020). Yolcuların Düşük Maliyetli Havayolları Üzerine Hizmet Kalitesi Algısı: Tripadvisor'dan Toplanan Yorumların Analizi (Master's thesis, Eastern Mediterranean University (EMU)-Doğu Akdeniz Üniversitesi (DAÜ)).
- Battal, S., Kayalı, E., Ural, Ü. S., & Yetgin, D. (2019). A Survey on e-complaints: The case of Turkish Airlines. *Journal of Tourism Leisure and Hospitality*, 1(1), 15-21.
- Belobaba, P. (2009). *The Global Airline Industry*. John Wiley & Sons.
- Belobaba, P., Odoni, A., and Barnhart, C. (2009). *The Global Airline Industry*. Britain: Library of Congress Cataloging-in-Publication Data.
- Braun, V. & Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, 3(2), 77-101.
- Britto, R., Dresner, M., & Voltes, A. (2012). The impact of flight delays on passenger demand and societal welfare. *Transportation Research Part E: Logistics and Transportation Review*, 48(2), 460-469.
- Brochado, A., Rita, P., Oliveira, C., & Oliveira, F. (2019). Airline passengers' perceptions of service quality: Themes in online reviews. *International Journal of Contemporary Hospitality Management*, 31(2), 855-873.
- Chen, C.-F. (2008). Investigating Structural Relationships Between Service Quality, Perceived Value, Satisfaction, and Behavioral Intentions For Air Passengers: Evidence from Taiwan. *Transportation Research Part A: Policy and Practice*, 42(4), 709-717.
- Chen, H.-T., & Chao, C.-C. (2015). Airline Choice By Passengers From Taiwan and China: A Case Study of Outgoing Passengers From Kaohsiung International Airport. *Journal of Air Transport Management*(40), 53-63.
- Chen, Y., & Xie, K. L. (2021). Online consumer review factors affecting offline hotel popularity: Evidence from TripAdvisor. *International Journal of Hospitality Management*, 94, 102813.
- Chen, Y., & Xie, J. (2008). Online Consumer Review: Word-of-Mouth as a New Element of Marketing Communication Mix. *Management Science*, 54(3), 4-7.
- Chung, J. Y., & Petrick, J. F. (2013). Price fairness of airline ancillary fees. *Journal of Travel Research*, 52(4), 466-476.
- Clemes, M. D., Gan, C., Kao, T. H., & Choong, M. (2008). An empirical analysis of customer satisfaction in international air travel. *Innovative Marketing*, 4(2), 50-62.
- Creswell, J. W. (2020). Nitel araştırma yöntemleri: beş yaklaşıma göre nitel araştırma ve araştırma deseni. *Siyasal Kitabevi*.
- Cronin, J. J., Jr., & Taylor, S. A. (1992). Measuring service quality: A reexamination and extension. *Journal of Marketing*, 56(3), 55-68.
- Çallı, L., & Çallı, F. (2023). Understanding airline passengers during covid-19 outbreak to improve service quality: topic modeling approach to complaints with latent dirichlet allocation algorithm. *Transportation Research Record*, 2677(4), 656-673.
- Çam, M. (2009). Konaklama İşletmelerinde Yiyecek-İçecek Maliyet Kontrolünün Önemi ve Akdeniz Bölgesindeki Konaklama İşletmelerinde Bir Anket Çalışması. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 6(11), 503-524.
- Çetin, G., & Altuğ, Ö. (2019). Müşteri Geri Bildirimlerinin Havayolu Taşımacılığında Hizmet Kalitesi Üzerine Etkisi. *İşletme ve Ekonomi Araştırmaları Dergisi*, 20(3), 56-70.
- Dellarocas, C. (2003). The Digitization of Word of Mouth: Promise and Challenges of Online Feedback Mechanisms. *Management Science*, 49(10), 1407-1424.
- Demir, K., & Ertürk, E. (2017). Türk Hava Yolları'nın Hizmet Kalitesi Algısının Müşteri Yorumları Üzerinden Değerlendirilmesi. *Havacılık ve Uzay Teknolojileri Dergisi*, 13(1), 92-104.
- Drisko, J. W., & Maschi, T. (2016). Content Analysis. *Pocket Guides to Social Work Research Methods*. In Oxford University. Oxford: Oxford University Press.
- DHMI. (2023, 05). T.C. Ulaştırma ve Altyapı Bakanlığı Devlet Hava Meydanları İşletmesi Genel Müdürlüğü. 05 24, 2024 tarihinde Faaliyet Raporları: <https://www.dhmi.gov.tr/Sayfalar/FaaliyetRaporlari.aspx> adresinden alındı
- Edvardsson, B. (1992). Service breakdowns: A study of critical incidents in an airline. *International Journal of Service Industry Management*, 3(4), 17-29.
- Ercan, F., Efe, R., & Atasoy, E. (2020). An analysis of customer complaints for airline companies in TripAdvisor: The case of Turkish Airlines. *Advances in Social Science Research*, 500.

- Filieri, R., & McLeay, F. (2013). E-WOM ve Konaklama: Gezginlerin Çevrimiçi İncelemelerden Gelen Bilgileri Benimsemelerini Etkileyen Faktörlerin Analizi. *Journal of Travel Research*, 53(1), 44-57.
- Forgas, S., Moliner, M. A., Sánchez, J., & Palau, R. (2010). Antecedents of airline passenger loyalty: Low-cost versus traditional airlines. *Journal of Air Transport Management*, 16(4), 229-233.
- Gerede, E. (2002). Hava Taşımacılığı ve Hizmet Kalitesi. Beta Yayınları.
- Gerede, E. (2015). Hava Yolu Taşımacılığı Hizmet Süreci. *Journal of Transportation and Logistics*, 1(1), 80-92.
- Gilbert, D., & Wong, R. K. C. (2003). Passenger expectations and airline services: A Hong Kong based study. *Tourism Management*, 24(5), 519-532.
- Greenleaf, E. A., Johnson, E. J., Morwitz, V. G., & Shalev, E. (2016). The price does not include additional taxes, fees, and surcharges: A review of partitioned pricing. *Journal of Consumer Psychology*, 26(1), 105-124.
- Güngör, O., Yücel Güngör, M., & Doğan, S. (2019). Examining the evaluations in TripAdvisor about Turkish Airlines. *Journal of Tourism Theory and Research*, 5(2), 282-291.
- Gürbüz, S. and Aksaraylı, M. (2017). Çevrimiçi Yorumların Havayolu İşletmelerinin Hizmet Kalitesi Algısı Üzerine Etkisi. *İşletme Araştırmaları Dergisi*, 9(4), 21-35.
- Güreş, N., Arslan, S., Yüksel, C., & YILMAZ, H. (2020). Turistlerin TripAdvisor Üzerinden Havayolu İşletmelerine Yönelik E-Şikâyetlerinin İncelenmesi (Analysing E-Complaints of Tourists about Airline Companies via TripAdvisor). *Journal of Tourism & Gastronomy Studies*, 8(1), 211-230.
- Hu, N., Pavlou, P., Zhang, J. (2006). Can Online Reviews Reveal a Product's True Quality?: Empirical Findings and Analytical Modeling of Online Word-of-Mouth Communication. In *Proceedings of the 7th ACM Conference on Electronic Commerce*, 11(15), 324-330.
- Jones, M. (2021). Low-cost Carriers vs. Traditional Airlines: Service Quality and Customer Satisfaction. *Journal of Aviation Management*, 18(1), 55-70.
- Kaya, N., & Duygun, A. (2023). Dünyadan ve Türkiye'den Örneklerle Havayolu Şirketlerine Ait Yolcu Yorumlarının İncelenmesi. *Journal of Aviation Research*, 5(1), 16-31.
- Kim, S.-B., & Park, J.-W. (2017). A Study on The Importance of Airline Selection Attributes By Airline Type: An Emphasis on The Difference of Opinion in Between Korean and Overseas Aviation Experts. *Journal of Air Transport Management*(60), 76-83.
- King, C. (2001). Special Meals and Customer Satisfaction in Airline Catering. *International Journal of Hospitality Management*, 20(4), 399-408.
- Kızılcan, S., Hoşgör, H., & Güngördü, H. (2023). Analyzing e-complaints directed towards a specific airline company: The case of corendon airlines. *SSRJ| Social Sciences Research Journal| e-ISSN: 2147-5237| Frequency: Continuous Publication| Dates of Publication: 2012-9999| International Academic Journal*, 12(06), 787-794.
- Kozak, N., & Acar, A. (2019). Havayolu Müşteri Yorumlarının İncelenmesi: Hizmet Kalitesi Algısı ve Müşteri Memnuniyeti Üzerine Bir Araştırma. *Turizm ve Otelcilik Araştırmaları Dergisi*, 3(2), 67-82.
- Küçükaltan, B., & Topcu, İ. (2019). Assessment of Key Airline Selection Indicators in a Strategic Decision Model: Passengers' Perspective. *Journal of Enterprise Information Management*, 32(4), 646-667.
- Küçükergin, K. G. (2012). Müşteri Sadakatının Oluşum Sürecine Müşteri Tatmini ve Ataletin Etkisi: Yiyecek-İçecek İşletmelerine Yönelik Bir Uygulama. Gazi Üniversitesi. Ankara: Eğitim Bilimleri Enstitüsü.
- Lee, K., & Carter, S. (2005). *Global Marketing Management: Changes, Challenges and New Strategies*. London: Oxford University Press.
- Li, Y., & Wang, J. (2023). The impact of COVID-19 pandemic on air passenger travel: a focus on empirical findings. *Transport Reviews*, 44(2), 461-483. <https://doi.org/10.1080/01441647.2023.2244165>
- Litvin, S. W., Goldsmith, R., & Pan, B. (2008). Electronic Word-of-Mouth in Hospitality and Tourism Management. *Tourism Management*, 29(3), 458-468.
- Litvin, S. W., Goldsmith, R., & Pan, B. (2008). Electronic Word-of-Mouth in Hospitality and Tourism Management. *Tourism Management*, 29(3), 458-468.
- Liu, B. (2022). *Sentiment Analysis and Opinion Mining*. Springer Nature.
- Lucini, F. R., Tonetto, L. M., Fogliatto, F. S., & Anzanello, M. J. (2020). Text mining approach to explore dimensions of airline customer satisfaction using online customer reviews. *Journal of Air Transport Management*, 83, 101760.
- Masorgo, N., Mir, S., & Hofer, A. R. (2022). Expectations vs experience: Managing the adverse effects of service failures on customer satisfaction in the airline industry. *Transportation Journal*, 61(3), 231-262.
- Miles, M. B. and Huberman, A. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Thousand Oaks, CA: Sage Publications.
- Milioti, C. P., Karlaftis, M., & Akkogiounoglou, E. (2015). Traveler Perceptions And Airline Choice: A Multivariate Probit Approach. *Journal of Air Transport Management*, 49, 46-52.
- Mills, M., & Clay, J. (2001). The Dynamic Nature of Passenger Needs in the Airline Industry. *Transportation Journal*, 40(3), 23-34.
- Oliveira, A. V., Oliveira, B. F., & Vassallo, M. D. (2023). Airport service quality perception and flight delays: Examining the influence of psychosituational latent traits of respondents in passenger satisfaction surveys. *Research in Transportation Economics*, 102, 101371.
- Özdemir, B., & Şimşek, E. (2015). Çevrimiçi Müşteri Yorumlarının Havayolu İşletmelerinde Hizmet Kalitesinin Belirlenmesine Etkisi. *Pazarlama ve Pazarlama Araştırmaları Dergisi*, 14(4), 29-44.
- Pakdil, F., & Aydın, O. (2007). Expectations and perceptions in airline services: An analysis using SERVQUAL. *Managing Service Quality*, 17(2), 135-148.
- Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, 64(1), 12-40.
- Park, C., & Lee, T. (2009). Information Direction, Website Reputation and EWOM effect: A Moderating Role of Product Type. *Electronic Commerce Research and Applications*, 7(4), 386-398.
- Park, J., Robertson, R., & Wu, C. L. (2004). The effect of airline service quality on passengers' behavioural

- intentions: A Korean case study. *Journal of Air Transport Management*, 10(6), 435–439.
- Pınarbaşı, F. (2025). "Recommend or not Recommend" Topic Modelling of User Reviews in Airline Market. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 18(2), 586-599
- Roszkowska, E., Jefmański, B., & Kusterka-Jefmańska, M. (2024). A synthetic measure for ranking overall satisfaction based on multidimensional ordinal data: the case of airlines on the TripAdvisor website. *Operations Research and Decisions*, 34(3), 221-242.
- Saha, G. C., & Theingi, T. (2009). Service Quality, Satisfaction, and Behavioral Intentions: A Study of Low-Cost Airline Carriers in Thailand. *Managing Service Quality*, 19(3), 350-372.
- Sak, F. S. Havayolu işletmelerinde müşterilerin yaşadıkları kritik olayların incelenmesi. *Nevşehir Hacı Bektaş Veli Üniversitesi SBE Dergisi*, 14(3), 1384-1403.
- Sarılgan, A. E., & Bakır, M. (2023). Havayolu Taşımacılığında Havayolu İşletmesi Seçimi ve Memnuniyetin Belirleyicileri: Üniversite Öğrencileri Üzerine Bir Araştırma. *İzmir İktisat Dergisi*, 38(1), 158-174.
- Seidenberg, J., Stelljes, G., Lange, L., Blumchen, K., & Rietschel, E. (2020). Dietary Preferences and Food Allergies of Airline Passengers. *Journal of Travel Medicine*, 73, 34-45.
- Sezgen, E., Koç, E., & Yılmaz, M. (2019). A text mining approach to understand customer satisfaction in airline services. *Journal of Air Transport Management*, 77, 65–74
- Sezgen, E., Mason, K. J., & Mayer, R. (2019). Voice of airline passenger: A text mining approach to understand customer satisfaction. *Journal of Air Transport Management*, 77, 65-74.
- Smith, J. (2020). Customer Satisfaction in Air Travel. *Aviation Management Journal*, 15(3), 45-60.
- Smith, J. (2020). The Impact of Cost Reduction Strategies on Customer Service in Low-cost Carriers. *Aviation Management Review*, 25(2), 87-102.
- Song, C., Ma, X., Ardizzone, C., & Zhuang, J. (2024). The adverse impact of flight delays on passenger satisfaction: An innovative prediction model utilizing wide & deep learning. *Journal of Air Transport Management*, 114, 102511.
- Sundarakani, B., Razzak, H., & Manikandan, S. (2018). Competitive Strategies in Airline Catering Services: Enhancing Marketing and Sales Activities. *Journal of Air Transport Management*, 73, 15-23.
- Sulu, D., Arasli, H., & Saydam, M. B. (2021). Air-travelers' perceptions of service quality during the COVID-19 pandemic: evidence from tripadvisor sites. *Sustainability*, 14(1), 435.
- Taneja, N. K. (2017). *Airline industry: Strategies, operations and safety*. London: Routledge
- Thomas, M. L. (1997). *A Portfolio Management Approach to Strategic Airline Planning: an Exploratory Investigative Study on Services Management*.
- Torlak, Ö. (2020). Havayolu Taşımacılığında Müşteri Geri Bildirimlerinin Değerlendirilmesi ve Hizmet Kalitesinin İyileştirilmesi. *Sosyal ve Ekonomik Araştırmalar Dergisi*, 22(42), 123-140.
- Tsaur, S.-H., Chang, T.-Y., & Yen, C.-H. (2002). The Evaluation of Airline Service Quality By Fuzzy MCDM. *Tourism Management*, 23(2), 107-115.
- Veziroğlu, P., Dölekoğlu, C., Keiyinci, S. (2017). Uçak Yolcularının İkram Tercihleri Üzerine Bir Araştırma. *Yiyecek ve İçecek Araştırmaları Dergisi*, 5(2), 89-105.
- Wells, A. T. (1999). *Commercial Aviation Safety* (6. b.). McGraw-Hill.
- Wen, C.-H., & Lai, S.-C. (2010). Latent Class Models of International Air Carrier Choice. *Transportation Research Part E: Logistics and Transportation Review*, 46(2), 211-221.
- Wu, L., Mattila, A. S., Wang, C.-Y., & Hanks, L. (2016). The Impact of Power on Service Customers' Willingness to Post Online Reviews. *Journal of Service Research*, 19(2), 224-
https://www.tripadvisor.com.tr/Airline_Review-d8728979-Reviews-Pegasus-Airlines date of access 03.09.2024
- Yabacı, M. (2018). Uçak İçi İkram Hizmetlerinin Uçuş Mesafelerine Göre Farklılıkları. *Ulaşım Araştırmaları Dergisi*, 4(1), 44-59.
- Yao, R., & Vink, P. (2019). The Impact of High Altitude on Taste and Flavour Perception in Airline Catering. *Appetite*(138), 98-105.
- Yılmaz, E. (2019). Müşteri Deneyimlerinin Çevrimiçi Yorumlar Üzerinden Analizi: Türk Hava Yolları Örneği. *Pazarlama ve Pazarlama Araştırmaları Dergisi*, 22(1), 45-62.
- Yousaf, S. & Xiucheng, F. (2018). In-flight Service and Customer Satisfaction: A Study of International Airline Passengers. *Tourism Management*, 68, 23-32.
- Yücel, N., & Alpay, C. (2017). Viral pazarlama kapsamında havayolu işletmeleri müşterilerinin şikâyetlerinin incelenmesi üzerine bir araştırma. *Fırat Üniversitesi Uluslararası İktisadi ve İdari Bilimler Dergisi*, 1(2), 127-168.
- Zahari, M., & MS, Y. (2011). In-flight Meals, Passengers-Level of Satisfaction and Re-flying Intention. *International Journal of Humanities and Social Sciences*, 5(12), 1982-1989.
- Zhang, Y., Cheng, C., & Huang, J. (2022). Air-travelers' perceptions of service quality during the COVID-19 pandemic: Evidence from TripAdvisor reviews. *Tourism Management*, 88, 104405

Cite this article: Cebisli, N., Enes, K., Ozturkel, M. (2025). Comparison of Customer Reviews Between Traditional Airlines and Low-Cost Carriers: A Case Study from Türkiye. *Journal of Aviation*, 9(3), 816-825.



This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Licence

Copyright © 2025 Journal of Aviation <https://javsci.com> - <http://dergipark.gov.tr/jav>