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Effects of Shape Changing of Morphing Rotary Wing Aircraft on Longitudinal and Lateral Flight

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Abstract

Unmanned aerial vehicles are aerial robots controlled by commands sent from the ground control station. While fixed-wing aircraft have the advantages of long range and high altitude, they need a runway to create sufficient lift on the wings. The advantage of Rotary Wing Aircraft is that it does not need a runway, it can perform vertical take-off and landing. It can hover. Thanks to these features, it is used in tasks such as surveillance, search and rescue, and reconnaissance. In areas with chemical wastes or in closed environments without risking the human element; Desired tasks can be performed in places such as sewers, caves, and collapsed houses. For this, there is a flight control computer and software on the aircraft. Rotary-wing aircraft are more unstable than fixed-wing aircraft. Thanks to the flight controller, its stability and controllability are increased. In this study, a quadcopter, multicopter aircraft structure is used. The variation of the angle between the arms of a quadcopter aircraft and its effects on forward and sideways flight are examined. It is required that the aircraft be symmetrical in the longitudinal and lateral axis in order to cope with the disturbances to which it is exposed in external environments. In closed environments, atmospheric events are replaced by obstacles. One of the desirable features of the aircraft is that it can pass through narrow places. For this, the aircraft must perform a shape change. The change in structure will cause it to change in the dynamic's equations, causing the rotors to react differently during linear and rotational movements of the aircraft. This study focuses on the system design and control of the aircraft. The geometric features obtained from the aircraft designed in the CATIA program were used in the creation of the mathematical model. The obtained values were created using the MATLAB Simulink program to create a digital twin of the aircraft. When the intersection angle between the arms is 90 degrees, the settling time of the 2-degree pitch angle is 7.48 seconds, and when it is 45 degrees, it is 10.3 seconds.

1. Introduction

Unmanned aerial vehicles (UAVs) are aircraft that are autonomous or controlled by commands transmitted from a ground control station. It consists of classes such as fixed-wing and rotary-wing aircraft. Rotary-wing aircraft are classified by the word ' copter ', which derives from the ancient Greek word ' pteron ‘. This classification is named according to the number of propellers it has (Boulet, 1991). These are tricopter, quadcopter, hexacopter, octocopter and helicopter. Rotary wing aircraft are of unstable structure and flight control card and flight control software are used in order to be stable and controllable. Its job is to control the rotors and actuators and to make the movement happen. There is no cockpit and pilot on the unmanned aerial vehicle. Control is provided by modulating the commands sent from the ground control station to radio waves and capturing the waves of the antenna on the aircraft. The information is transmitted from the antenna to the receiver and demodulated to the relevant avionics' element. The information sent from the ground is processed by the flight control card (FCC) and transmitted (TX) to the rotors, the rotation speed of the rotors is controlled (Coban et al., 2019).

As with manned aircraft, unmanned aerial vehicles have control surfaces and propulsion system to perform linear and rotational movements. However, control is transmitted by the operator in the ground control station, not by the pilot in the cockpit. Unmanned aerial vehicles have become a popular topic (Coban et al., 2020) thanks to the development and accessibility of electronics, software and material technology. It is widely used in civil and military aviation. Generally, these systems are used for outdoor scenarios. Indoor applications; cave, rescue in collapsed buildings, intervening in terrorist activities in closed areas are some of them (Desbiez et al., 2017). This often involves traveling between small cracks or gaps in confined spaces; they cause situations that are very difficult for conventional quadcopter aircraft, possibly resulting in catastrophe (Falanga et al., 2018). It enables it to pass through narrow spaces by imitating the birds that can be observed in nature (Di Luca et al., 2017). Thanks to image identification, sensor fusion and artificial intelligence applications, it can be made suitable for indoor use (Bai et al., 2019). These are according to the obstacles; It is to change the shape of the quadcopter aircraft, to prevent collisions and to provide a more suitable shape. In quadcopter unmanned aerial vehicles, shaping is done by methods such as arm extension or shortening, or by changing the angles between the arms (Köse et al. 2020; Oktay et al., 2021) It can be used as a morphing control element to change flight dynamics (Prisacariu, et al., 2011). If morphing is done before the flight of the Four Propellers, it is called passive morphing. If morphing occurs during flight, this type is called active morphing (Oktay et al., 2016). In this study, studies that perform active and passive morphing (Oktay et al., 2017) were examined and modeling and simulation were carried out.

There is a mechanism structure that can rotate around the z axis at the intersection point of the two arms of the vehicle and the arms (Figure 1). The intersection angle is driven by the actuator (Figure 3), allowing the vehicle to expand and contract. In this case, changes in vehicle dynamics are controlled by the designed controller.

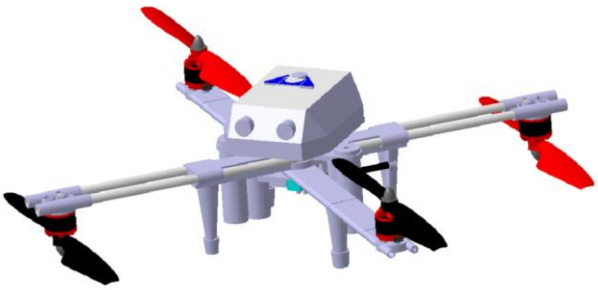

Figure 1. X1 Non-Morphing Configuration

2. Materials and Methods

The position, velocity and acceleration information of the moving objects are calculated by means of the sensors on it. These are elements such as GPS, accelerometer, gyroscope, telemetry, 3D flow camera, INS. In the INS system, it does not need to communicate or reference any station on the ground or in space. It is the only long-range navigation system that does not use radio waves. It works in conjunction with a computer and works completely independently. The ability of the aircraft to travel from one point to another by the shortest route serves the purpose of determining its position and location at any time of the flight (Kekeç et al. 2020).
According to the kinematic theory, all the motion parameters of an object in motion can be easily calculated if its acceleration, initial position and velocity at every instant are known. Two sets of axes are used for this. These are the fixed pivot assembly and the body pivot assembly. The aircraft is calibrated at the starting point and matched with the fixed axis set. After that, each movement is calculated by the accelerometer and gyroscope on the aircraft and position information is obtained (Köse et al., 2021).

2.1. Quadcopter Features

The rotary-wing unmanned aerial vehicle takes off with the lift force obtained by the rotors turning the propellers (Eraslan et al., 2020). The rotation of the rotor at different speeds, the rotation movements performed in the fuselage axis set in the center of the aircraft, enable it to move in the horizontal or vertical axis. This change in the angular velocity of the rotors transmits a signal to the rotors to provide the necessary orientation by the flight controller from the sensors and the compilation of the commands (Oktay et al., 2021). The configuration information that determines the rotor placement and rotation directions of the quadcopter unmanned aerial vehicle is important. There are two types of configurations, plus and cross configurations. In this study, the X (cross) (Figure 2) configuration was preferred.

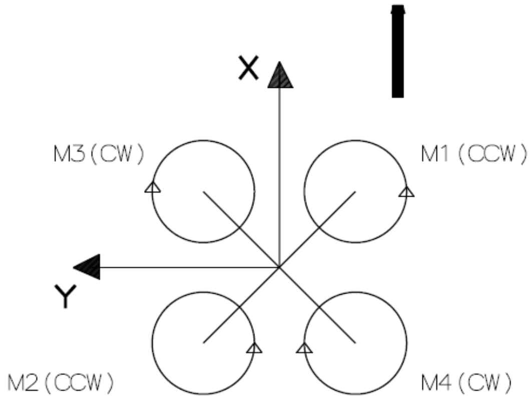

Figure 2. X Frame Configuration

The configuration information that determines the rotor placement and rotation directions of the quadcopter unmanned aerial vehicle is important. There are two types of configurations, plus and cross configurations. In this study, the X (cross) (Figure 2) configuration was preferred.

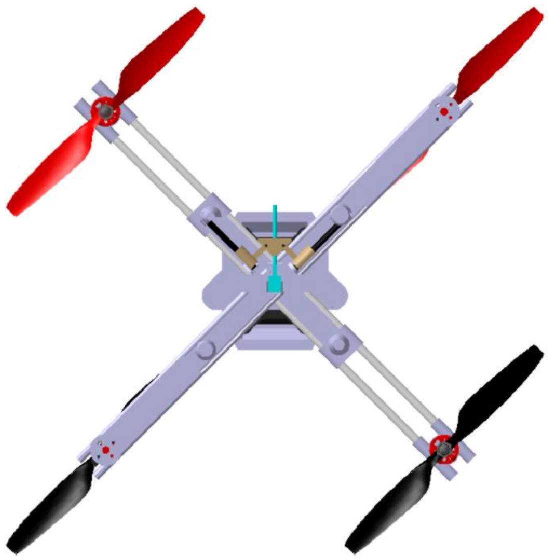

Figure 3. Quadcopter Bottom View

As seen in Figure 4, the aircraft moves the linear bearings on both arms with a fixed linear motor under the fuselage. As a result of the forward movement of the linear bearing, the angle between the arms decreases. The smallest value that the intersection angle can take is 45°. If the intersection angle is 45°, the configuration of the aircraft changes to X2. This situation changes the moment of inertia of the aircraft relative to the x-axis and y-axis. It changes the x and y distances of the rotation centers of the rotors from the center of gravity of the aircraft. It requires the change of dynamic forces on the aircraft and the updating of the mathematical model.

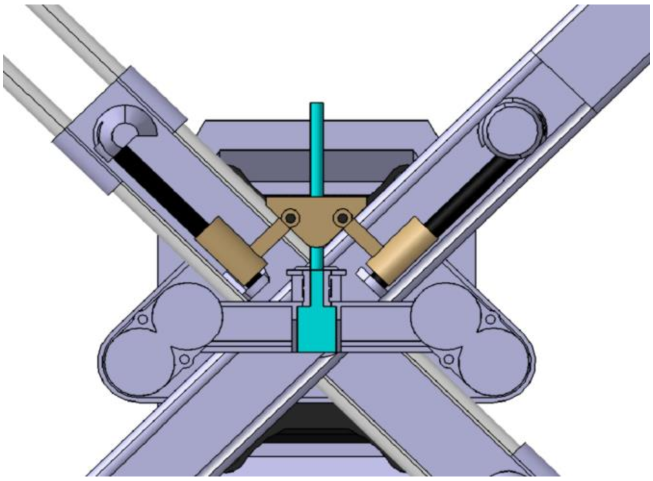

Figure 4. Quadcopter Bottom View-Mechanism

Batteries were placed vertically on both sides of the fuselage to act as a constraint during the variation of the intersection angle between the arms of the fuselage design of the aircraft. Li-ion 18650 battery cells have a voltage of 3.7 V. Sufficient voltage to create the necessary lifting force for the aircraft to fly was determined as 14.8 V. As seen in Figure 5, the required voltage was obtained by connecting the battery cells in series.

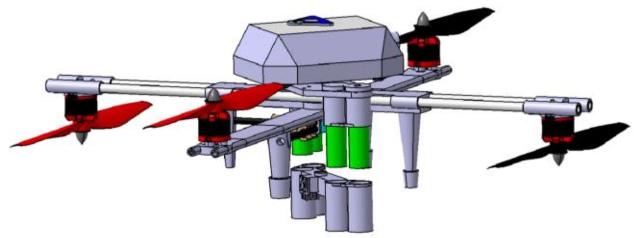

Figure 5. Quadcopter Battery Box Design – Li ion Battery

2.1. Quadcopter Moment of Inertia

In linear algebra, the diagonal matrix (↘) is a matrix whose entries outside the first diagonal are all zero and usually a square matrix. The matrix D = (di,j) consisting of n columns and n rows is as follows: If i≠j ∀i,j∈{1,2,….,n} then d_(i,j)=0. The structure of the aircraft is symmetrical. The mass distribution is considered homogeneous. The body axis is coincident with the center of gravity (1).

$$I = \text{diag}([\,I_{xx}\ I_{yy}\ I_{zz}\,]) \qquad (1)$$

When the intersection angle of the aircraft changes, some values also change. This change affects the control of the rotation movements of the aircraft and the rotor rotation speeds. The general characteristics of the quadcopter aircraft are given in Table 1.

Table 1. X1 and X2 Configuration Geometries

Symbol	Definition	X1 Config	X2 Config	Unit
∠	Intersection Angle	90	45	degree
m	Aircraft Mass	750	750	gram
l	Arm Length	0.225	0.225	m

The angle of intersection between the arms of the quadcopter aircraft is 90 °. The link has 1 DOF movement around the z-axis. The angle between the arms can be changed by servo or linear actuator.

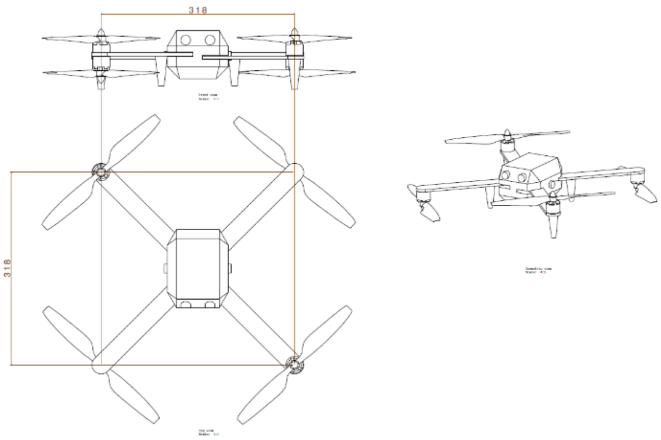

Figure 6.a) X1 Configuration Intersection Angle 90° (Non-Morphing)

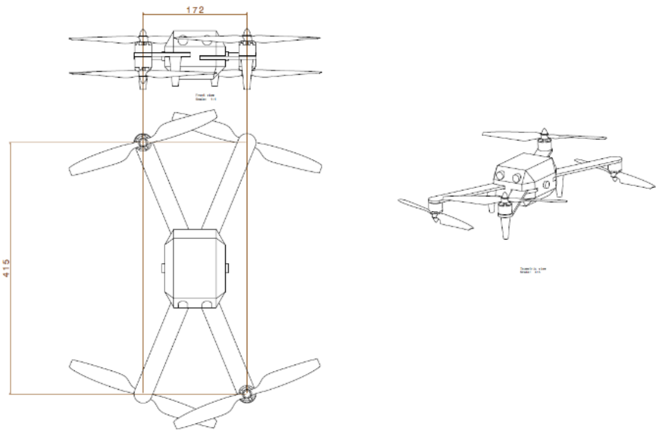

Figure 6.b) X2 Configuration Intersection Angle 45° (Morphing)

This change and its effect on moments of inertia are given in Table 2. Some assumptions were made while preparing the table. The structure of the aircraft is the joining of 2 arms with each other at their midpoints and the rotors mounted on the ends of each arm. Arm, fasteners, rotor and propellers; considered as homogeneous arm. The weight of each arm was calculated as m=0.75/4 kg. The moment of inertia of a homogeneous rod is calculated by equation (2).

$$I = \frac{1}{3}ml^2 \qquad (2)$$

m; arm mass, l; arm length is accepted. Since the system is symmetrical, it is calculated from equation (1). l is accepted as the distance of the arms from the center in the x and y directions, and the system is considered symmetrical when the intersection angle is 90° (Figure 7). I_z when the intersection angle is 45° (Figure 8) does not change; I_x (decreasing), I_y (increasing) varies. Shape change function;

$$y = f(x) \qquad (3)$$

In the function y; while the variable x defines the moments of inertia, it defines the intersection angle.

$$I_{x,y} = \frac{1}{3}ml^2 \sin\theta \qquad (4)$$

Table 2, the change in the moment of inertia is obtained from equation (4).

Table 2. The Effect of Change in Intersection Angle of Laterally Contrasting Aircraft on Moment of Inertia

Symbol	Non-Morphing	Morphing	Unit
∠/2	90	45	degree
m	0.75	0.75	kg
l	0.225	0.225	meter
w	0.318	0.172	meter
b	0.318	0.415	meter
I_x	0.005	0.003	kgm^2
I_y	0.005	0.008	kgm^2
I_z	0.009	0.009	kgm^2

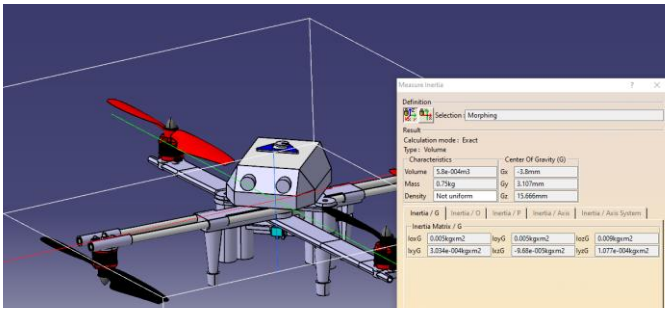

Figure 7. X1 Configuration Intersection Angle 90° (Non Morphing)

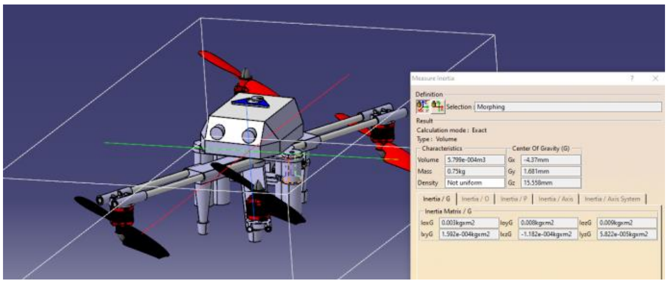

Figure 8. X2 Configuration Intersection Angle 45° (Morphing)

2.1. State Space Model

The obtained mathematical equations show that the quadcopter UAV is a multi-input multiple-output (MIMO) nonlinear system. In order to examine such a system, the state variables of the system must be determined. State space notation is used to express it with first-order differential equations (Köse et al., 2021)

$$\dot{x}=Ax(t)+Bu(t)$$
$$y=Cx(t)+Du(t) \tag{5}$$

Here, x(t) is the state vector (15), u(t) is the control or input vector (16), y(t) is the output vector, A is the system matrix, B is the input matrix, C is the output matrix, and D is the feedforward matrix. The state vector and control vector of the quadcopter are as given below.

$$x = [x\ \dot{x}\ y\ \dot{y}\ z\ \dot{z}\ \emptyset\ \dot{\emptyset}\ \theta\ \dot{\theta}\ \varphi\ \dot{\varphi}] \tag{6}$$

$$u = [U_1 U_2\ U_3\ U_4]^T \tag{7}$$

$$\begin{bmatrix}U_1\\U_2\\U_3\\U_4\end{bmatrix}=\begin{bmatrix}b & b & b & b\\ \frac{-lb}{\sqrt{2}} & \frac{lb}{\sqrt{2}} & \frac{lb}{\sqrt{2}} & \frac{-lb}{\sqrt{2}}\\ \frac{lb}{\sqrt{2}} & \frac{-lb}{\sqrt{2}} & \frac{lb}{\sqrt{2}} & \frac{-lb}{\sqrt{2}}\\ d & d & -d & -d\end{bmatrix}\begin{bmatrix}\omega_1^2\\\omega_2^2\\\omega_3^2\\\omega_4^2\end{bmatrix} \tag{8}$$

In this case, the quadcopter forward flight state space model would be as shown below. In the longitudinal state space model output matrix, the outputs followed in this study are given as outputs since z and θ are followed.

$$\begin{bmatrix}\dot{x}\\\dot{z}\\\dot{u}\\\dot{w}\\\dot{q}\\\dot{\theta}\end{bmatrix}=\begin{bmatrix}0&0&1&0&0&0\\0&0&0&1&0&0\\0&0&0&0&0&-g\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&1&0\end{bmatrix}\begin{bmatrix}x\\z\\u\\w\\q\\\theta\end{bmatrix}+\begin{bmatrix}0&0\\0&0\\0&0\\1/m&0\\0&1/I_y\\0&0\end{bmatrix}\begin{bmatrix}U_1\\U_3\end{bmatrix} \tag{9}$$

$$y=\begin{bmatrix}0&0&0&0&0&0\\0&1&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&1\end{bmatrix}\begin{bmatrix}x\\z\\u\\w\\q\\\theta\end{bmatrix}$$

The state space model represents the moment of inertia I_y in the input matrix. The moment of inertia is a diagonal matrix. This matrix is produced because the four arms of the Quadcopter are symmetrical and aligned on the x and y axes. The initial matrix is as shown in (1).

The lateral flight state space model is given as output because z and θ are followed in the output matrix.

$$\begin{bmatrix}\dot{y}\\\dot{v}\\\dot{p}\\\dot{r}\\\dot{\emptyset}\\\dot{\varphi}\end{bmatrix}=\begin{bmatrix}0&1&0&0&0&0\\0&0&0&0&g&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&1&0&0&0\\0&0&0&1&0&0\end{bmatrix}\begin{bmatrix}y\\v\\p\\r\\\emptyset\\\varphi\end{bmatrix}+\begin{bmatrix}0&0\\0&0\\1/I_x&0\\0&1/I_z\\0&0\\0&0\end{bmatrix}\begin{bmatrix}U_2\\U_4\end{bmatrix} \tag{10}$$

$$y=\begin{bmatrix}0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&1&0\\0&0&0&0&0&0\end{bmatrix}\begin{bmatrix}y\\v\\p\\r\\\emptyset\\\varphi\end{bmatrix}$$

The state space model is I_x in the input matrix and I_z represents the moment of inertia . The moment of inertia is a diagonal matrix. This matrix is produced because the four arms of the Quadcopter are symmetrical and aligned on the x and y axes. The initial matrix is as shown in (1).

2.5. PID Control

Longitudinal movement, which is the movement in the y-axis for forward movement, is provided by control inputs U_3 . The four rotors perform their longitudinal movement between the values of π /2 and π /2. The PID equation for the quadcopter longitudinal motion can be written as:

$$U_3 = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \quad (11)$$

For lateral movement, lateral movement, which is the movement in the x-axis, is provided by the U_2 and U_4 control inputs. It performs the four-rotor lateral movement between $-\pi$ and π values. The PID equation for quadcopter lateral motion can be written as:

$$U_2 = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \quad (12)$$

3. Result and Discussion

Since this study is about forward flight and lateral flight, different flight characteristics are created by decreasing or increasing the intersection angle between the arms at different times. As the volume of the quadcopter changes during the conversion process, there are also changes in the moments of inertia. Usually, to reach the x and y positions, the roll and pitch angles are determined, which causes the quadcopter to steer the aircraft to that position, rather than sending a controller signal directly to its rotors. Assume that the body frame and the inertial frame coincide. In this case, when the roll angle is met, the quadcopter moves eastward ( ) on the globe; when it achieves a pitch attitude, it moves to the north ( ) direction on the earth. Thus, the controller designed to take the aircraft to the desired x and y positions is used to derive the roll and pitch angle requirements that must be made according to the current position. In order for the quadcopter to perform its longitudinal motion, U_3 given in equation (8) is applied as input. In the state space model, θ is shown as the output for the longitudinal motion. The Simulink model, designed for a 2° longitudinal angle, was examined under the headings of non-morphing and morphing. U_2 given in equation (8) is applied as input for the quadcopter to perform its lateral movement. In the state space model, $\emptyset$ it is shown as the output for its lateral movement. The Simulink model, designed for a lateral angle of 2°, was examined under the headings of non-morphing and morphing.

3.1. Non-Morphing

Simulated in MATLAB / Simulink using the values given in the Table 3 without changing the intersection angle between the arms of the aircraft. Matlab The block diagram in SIMULINK is as shown in the figure. Input data were obtained from u,w,q , pitch , X,Y graphs by entering the state space model.

Table 3. Overall Dimensions of the Aircraft (Intersection Angle; 90°)

Symbol	Non-Morphing	Unit
∠ /2	90	degree
m	0.75	kg
l	0.225	meter
w	0.318	meter
b	0.318	meter
I_x	0.005	kgm^2
I_y	0.005	kgm^2
I_z	0.009	kgm^2

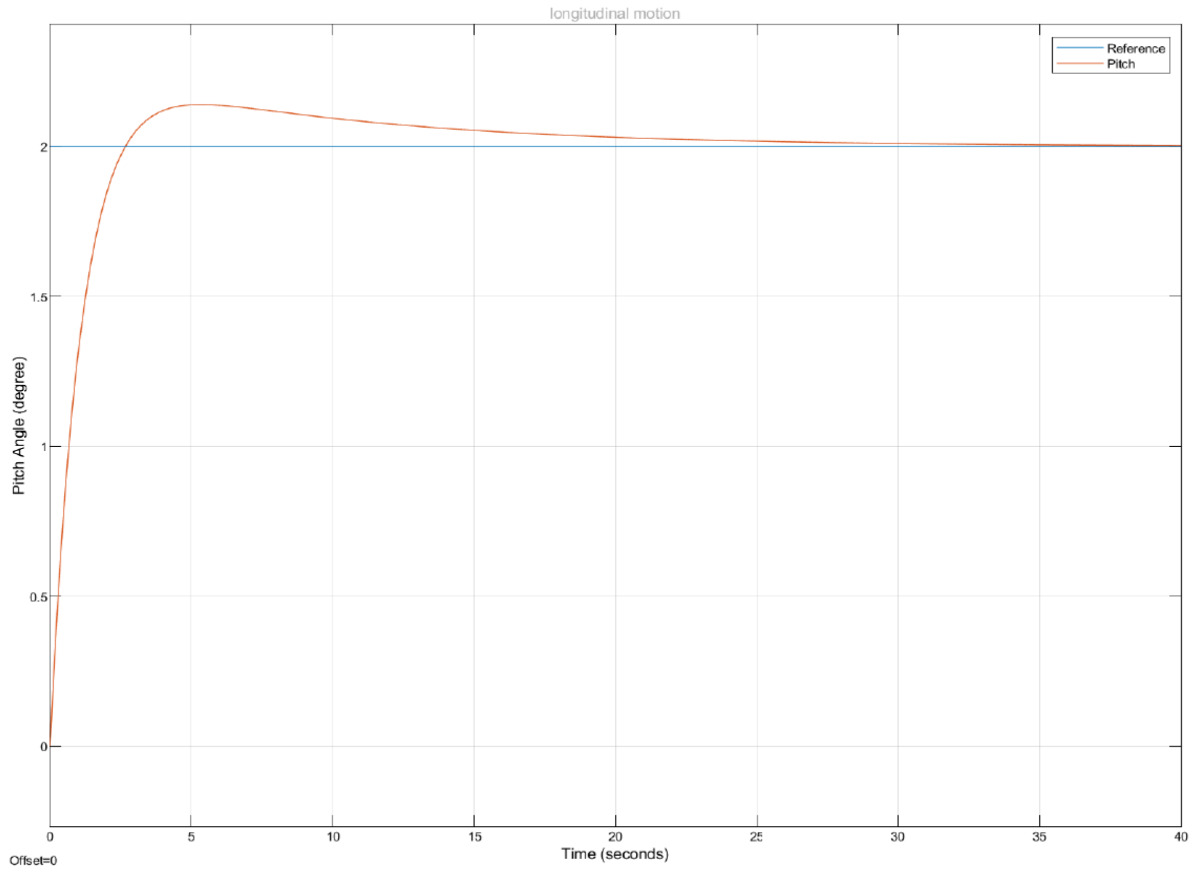

Figure 9. Forward Movement (Intersection Angle; 90°). PID (50,5,50)

In the simulation, an angle of 2° is given as a reference value. Longitudinal movement PID values P=50; I=5; Values were entered as D=50 by making use of previous studies (Oktay et al.,2017). The graph was obtained by running the simulation for 40 seconds. The longitudinal motion simulation result is as in figure 9.

3.2. Morphing

Lateral morphing occurs as the angle between the arms of the quadcopter UAV decreases. The changes that occur with the effect of contraction are given in Table 4. While the intersection angle is 45°, the width of the aircraft is 86 mm and the length is 207 mm. This causes the I_x and I_y values to change. Pitch degree of 2° is given for the longitudinal movement of the aircraft after contraction. The simulation results are as follows (Figure 10).

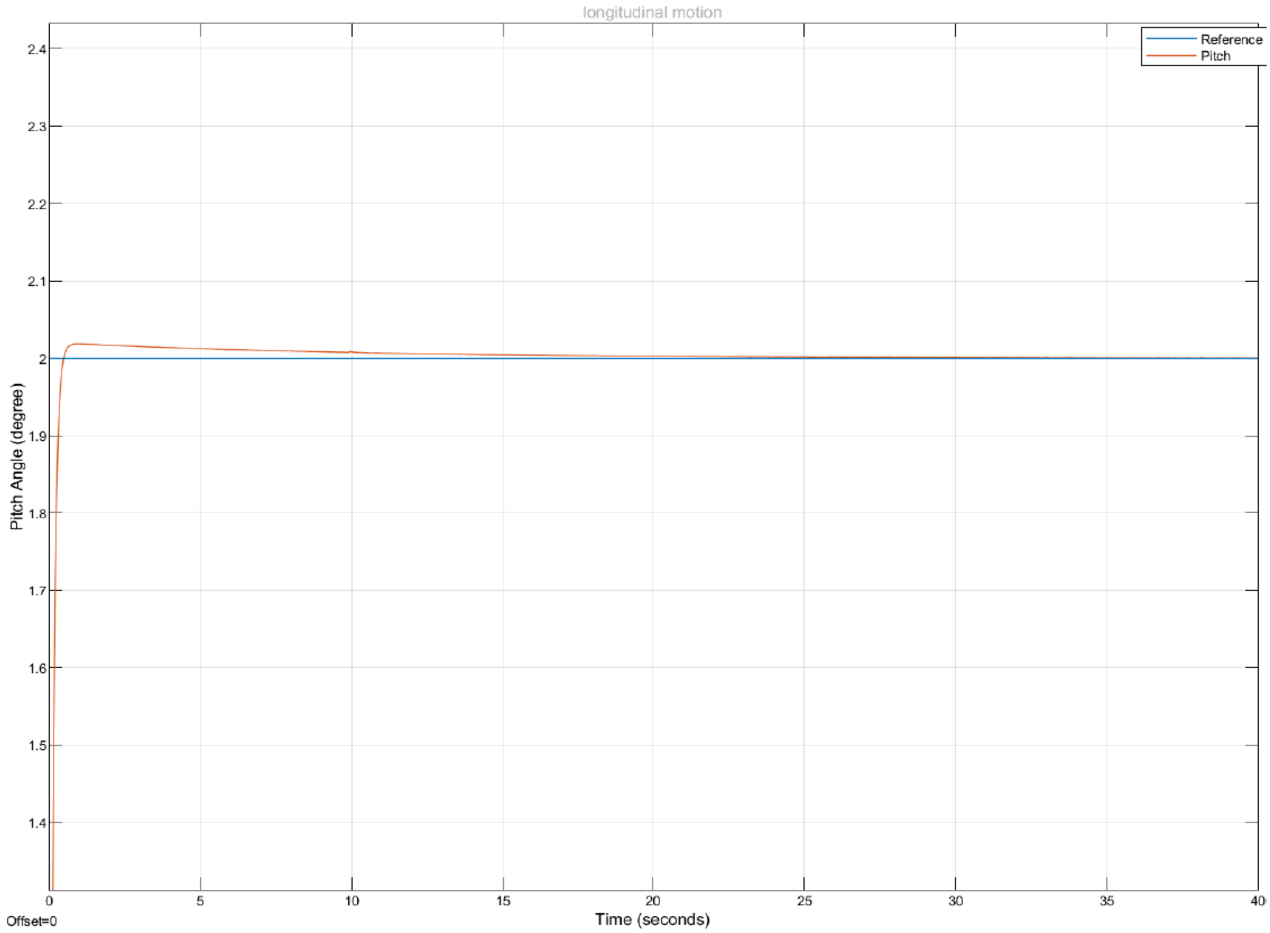

Figure 10. Forward Movement (Intersection Angle; 45°)

The effect of shape changes on performance, rise time, settling time and overshoot values in the simulation carried out are shared in the table.

Table 4. General Dimensions and Performance Criteria of the Aircraft

Symbol	Non-Morphing	Morphing	Unit
∠ /2	90	45	degree
I_x	0.005	0.003	kgm^2
I_y	0.005	0.008	kgm^2
I_z	0.009	0.009	kgm^2
Rise Time	1.403	1.765	s
Settling Time	13.9	10.3	s
Overshoot	14.773 %	6.989 %	

Since this work is related to lateral flight. different deformation is created by decreasing or increasing the intersection angle between the arms at different times. As the volume of the quadcopter changes during the conversion process. there are also changes in the moments of inertia.

Lateral movement is the movement of the quadcopter on the x-axis. U_2 given in equation (8) is applied as input for the quadcopter to perform its lateral movement. In the state space model. $\emptyset$ is shown as the output for the lateral movement. The Simulink model. designed for a 2° pitch angle longitudinal. was examined under the headings of non-morphing and morphing .

3.3. Non Morphing

Simulated in MATLAB / SIMULINK using the values given in the Table without changing the intersection angle between the arms of the aircraft. Matlab The block diagram in SIMULINK is as shown in the figure. Input data were obtained from u.w.q . pitch . X.Y graphs by entering the state space model.

In the simulation. an angle of 2° is given as a reference value. Longitudinal movement PID values P=50; I=5; Values were entered as D=50 by making use of previous studies (Oktay et al.. 2017). The graph was obtained by running the simulation for 40 seconds. Lateral motion simulation result is as in figure 11.

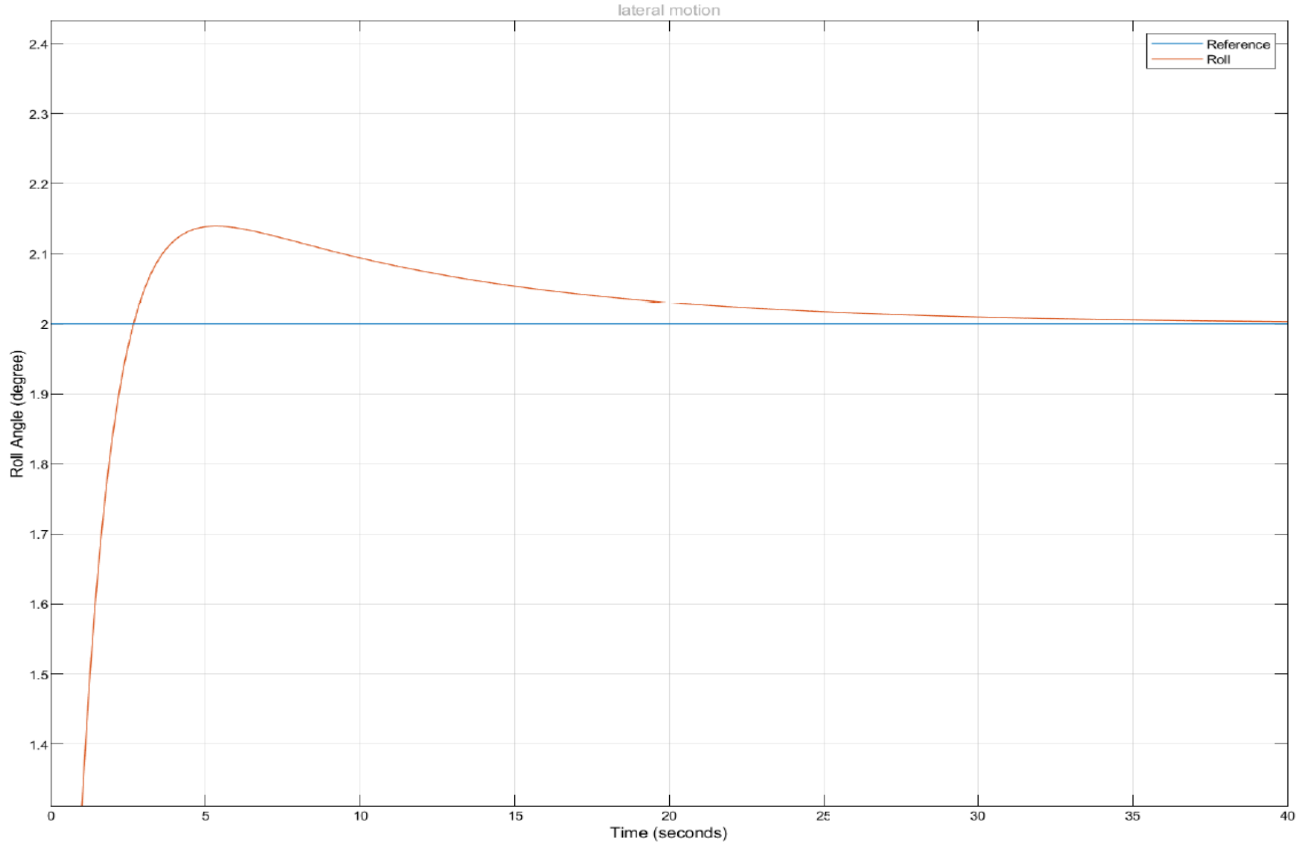

Figure 11. Lateral Movement (Intersection Angle 90°). PID (50.5.50)

3.4. Morphing

Lateral morphing occurs as the angle between the arms of the quadcopter UAV decreases. The changes that occur with the effect of contraction are given in Table 5. While the intersection angle is 45°. the width of the aircraft is 86 mm and the length is 207 mm. This causes the I_x and I_y values to change. An angle of 2° is given for the lateral movement of the aircraft after contraction. The simulation results are as follows.

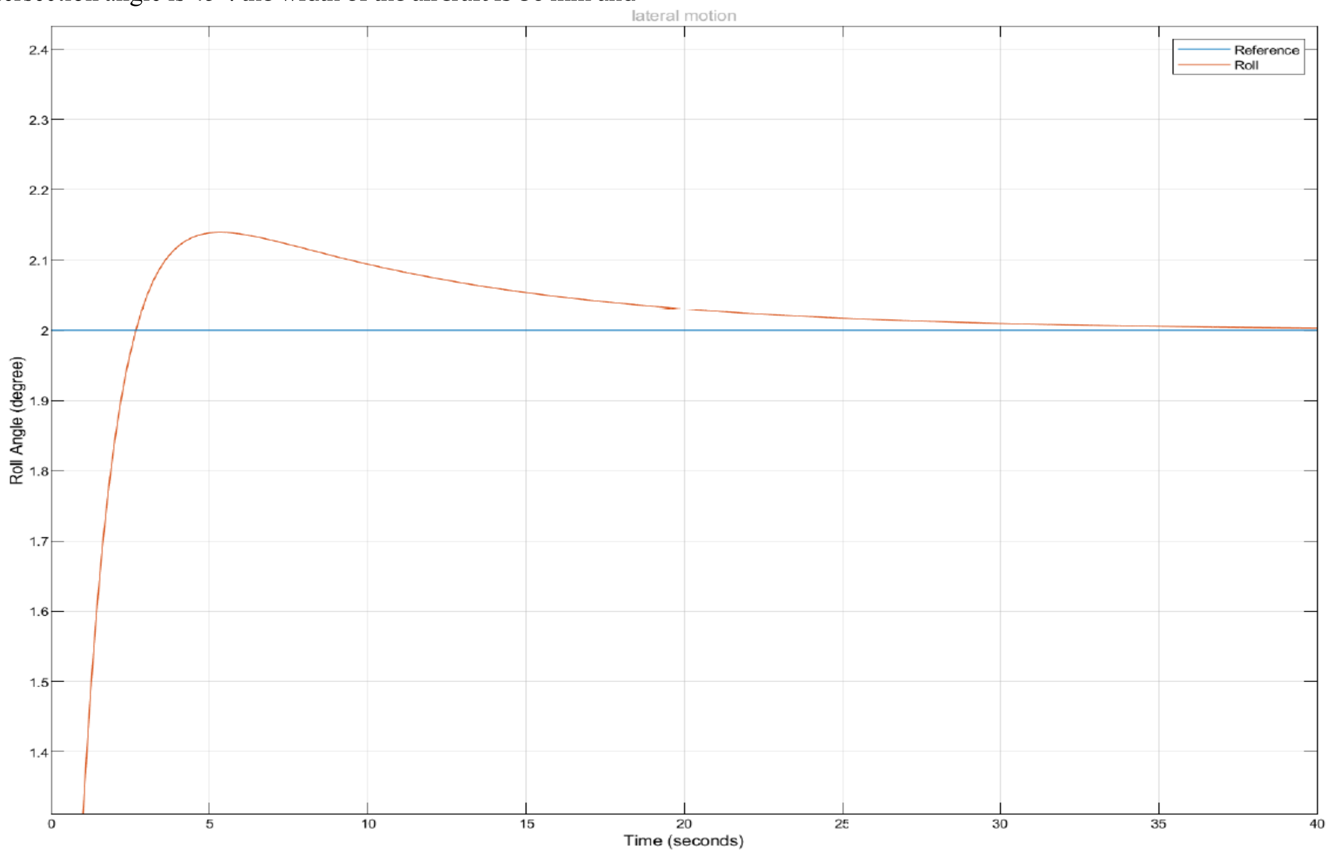

Figure 12. Lateral Movement (45° Intersection Angle)

The effect of shape changes on performance. rise time. settling time and overshoot values in the simulation carried out are shared in the table.

Table 5. General Dimensions and Performance Criteria of the Aircraft

Symbol	Non-Morphing	Morphing	Unit
∠/2	90	45	degree
I_x	0.005	0.003	kgm^2
I_y	0.005	0.008	kgm^2
I_z	0.009	0.009	kgm^2
Rise Time	1.437	1.402	s
Settling Time			
Overshoot	13.830 %	14.773 %	

4. Conclusion

In this study. the actively morphing aircraft X1 (non-morphing) and X2 (morphing) can fly in two different configurations. The geometry. mass and moments of inertia were obtained from the study designed in the CATIA program for the X1 and X2 configurations. In the next section. the state space model for the aircraft's lateral flight is constructed. It was simulated in MATLAB/SIMULINK environment and the results of rise. overshoot and settling times were compared.

The change in the intersection angle of the aircraft changes the moment of inertia values as given in Table 2. This change is also shown graphically (Figure 5-6) in the simulation studies. It has been seen that greater moment force is needed to perform the pitching motion. that is. the forward motion. increasing I_y as a result of the pitching of the intersection angle of the aircraft from 90° to 45°. It has been determined that the aircraft settles to the reference value and performs its movement when the study is carried out in a noise-free environment.
Changing the intersection angle of the aircraft changes the moment of inertia values as given in Table 3. This change is also shown graphically (Figure 2-3) in the simulation studies. It has been observed that smaller moment force is needed to realize the reduced I_x lateral movement as a result of the rolling of the intersection angle of the aircraft from 90° to 45°. It has been determined that the aircraft settles to the reference value and performs its movement when the study is carried out in a noise-free environment.
In this study. the dynamics of a rotary wing quadcopter aircraft were investigated. A PID controller has been verified in simulation studies to be well adapted to the aircraft while hovering. PID coefficients used for forward motion in the study of O. Köse and T. Oktay ; 12.12.5 are given. Scope data obtained in this study (Figure 6). equivalent data were obtained. Data from different PID values were shared (Figure 6). The PID controller was able to control the aircraft when it was hovering and in the absence of atmospheric noises. It was observed that the overshoot value and the rise time increased when the umbilical angle was 45°. In future studies. the effects of lateral movement and different configurations will be examined.
In this study. the dynamics of a rotary wing quadcopter aircraft were investigated. A PID controller has been verified in simulation studies to be well adapted to the aircraft while hovering. PID coefficients used for forward motion in the study of O. Köse and T. Oktay; 1.1.1.1.1.65 are given (Oktay et al.. 2020). The PID controller was able to control the aircraft when it was hovering and in the absence of atmospheric noises. It was observed that the overshoot value increased and the rise time decreased when the umbilical angle was 45°. In future studies. the behavior of longitudinal and lateral movements in noisy environments will be examined using different PID coefficients. and maximum control and stability behaviors.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Bai. Y. Gururajan. S. (2019). Evaluation of A Baseline Controller For Autonomous “Figure-8” Flights Of A Morphing Geometry Quadcopter: Flight Performance. Drones 2019. 3. 70

Coban. S. Bilgic. H. H. & Akan. E. (2020). Improving Autonomous Performance of a Passive Morphing Fixed Wing UAV. Information Technology and Control. 49(1). 28-35.

Çoban S. Bilgiç H.H. Oktay T. (2019). Designing. dynamic modeling and simulation of ISTECOPTER. Journal of Aviation. 3 (1). 38-44. DOI: 10.30518/jav.564376

Desbiez. A. Expert. F. Boyron. M. Diperi. J. Viollet.S. Ruffier. F. (2017). X-Morf: A Crash-Separable Dört Pervaneli That Morfs Its X-Geometry in Flight. 2017 Workshop on Research. Education And Development Of Unmanned Aerial systems (red uas)

Di Luca M. Mintchev S. Heitz G. Noca F. Floreano D. (2017). Bioinspired Morphing Wings for Extended Flight Envelope And Roll Control Of Small Drones. Interface Focus 7: 20160092.

Eraslan. Y. Özen. E. Oktay. T. (2020) A Literature Review on Determination of Dört Pervaneli Unmanned Aerial Vehicles Propeller Thrust and Power Coefficients. Ejons X – International Conference on Mathematics – Engineering – Natural & Medical Sciences Proceeding Book. 2020 Batumi. Georgia

Eraslan. Y. Özen. E. Oktay. T. (2020) The Effect of Change in Angle Between Rotor Arms on Trajectory Tracking Quality of A Pid Controlled Quadcopter. Ejons X – International Conference on Mathematics – Engineering – Natural & Medical Sciences Proceeding Book. 2020 Batumi. Georgia

Falanga. D. Kleber. K. Mintchev. S. Floreano. D. Scaramuzza. D. (2018) The Foldable Drone: A Morphing Dört Pervaneli That Can Squeeze and Fly. IEEE Robotics and Automation Letters. Preprint Version. Accepted November. 2018

J. Boulet. (1991). Histoire De l’Hélicoptère. France-Empire.

Kekeç E.T. Konar M. Dalkıran F. (2020). Sportif Havacılık İçin Düşük Maliyetli. Kullanışlı Variometre Tasarımı Ve Gerçekleştirimi J. Aviat. 4 (1). 79-88.

Köse O. Oktay T. (2020 Investigation of The Effect of Differential Morphing on Forward Flight by Using PID Algorithm in Quadcopters J. Aviat. 4 (1). 15-21.

Köse.O. Oktay.T.(2021) İnovatif Yöntemlerle Kuadkopter Modellenmesi. Kontrolü Ve Gerçek Zamanlı

Uygulamaları. Doktora Tezi. Erciyes Üniversitesi. Fen Bilimleri Enstitüsü. KAYSERİ

Oktay. T. & Sal. F. (2016). Combined Passive and Active Helicopter Main Rotor Morphing for Helicopter Energy Save. Journal Of The Brazilian Society Of Mechanical Sciences And Engineering. 38(6). 1511-1525

Oktay. T. Özen. E. (2021). Döner Kanatlı İnsansız Hava Aracının Sistem Tasarımı Ve Kontrolü. Avrupa Bilim Ve Teknoloji Dergisi. (27). 318-324.

Oktay.T. Özen. E. (2021). Kapalı Ortamlarda Arama Kurtarma Görevi İçin Gelistirilen Şekil Değistirebilen Quadcopterin Sistem Modellemesi Ve Tasarımı. Mas 14th International European Conference on Mathematics. Engineering. Natural&Medical Sciences March 26-28. 2021/Széchenyi István University/HUNGARY

Prisacariu. V. Sandru. V. & Rău. C. (2011). Introduction Morphing Technology in Unmanned Aircraft Vehicles (UAV). Paper Presented at The International Conference of Scientific Paper. AFASES.

Oktay. T. Uzun. M. Çelik. H. Konar. M. (2017). Pid Based Hierarchical Autonomous System Performance Maximization of a Hybrid Unmanned Aerial Vehicle (Huav). Anadolu University Journal of Science and Technology A- Applied Sciences and Engineering

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Artificial Intelligence Supported Aircraft Maintenance Strategy Selection with q-Rung Orthopair Fuzzy TOPSIS Method

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Abstract

In the aviation sector as unscheduled maintenance, repair and overhaul cost too much and these activities also negatively affect the prestige of the companies, deciding the most appropriate maintenance strategy is crucial. Today artificial intelligence methods, especially machine learning techniques facilitate failure detection and predict the wear and tear of the equipment before the occurrence of a serious failure. In this paper, artificial intelligence-supported corrective, predictive, and prescriptive maintenance methods are examined. Those most common aircraft maintenance approaches are compared regarding cost, reliability, failure detection, and downtime period using decision makers' subjective evaluations with the help of the q-rung orthopair fuzzy TOPSIS method which mitigates the drawbacks of uncertainty in human decision making. Stable and efficient results are obtained regarding the selection of an appropriate maintenance strategy. This article might be the first quantitative research that evaluates and compares AI-supported aircraft maintenance strategies.

1. Introduction

Since the end of the Second World War to today, maintenance has been transformed from failure repairment to preventing and predicting the overall failure process. In the 21st century, maintenance approaches are mostly based on system-level analysis which aims to preserve the functions of the equipment (Ahmadi et al., 2007). The aviation sector is a highly expensive and rapidly developing industry, and this rapid development has increased the expectations of preparedness of the aircraft and equipment. Aircraft maintenance provides us with safer and more reliable flights however, a minor failure in the air may cause fatal problems for all crew and passengers. The use of artificial intelligence (AI) in aviation, fuel saving, and successful management increase operational efficiency, and these issues can support to control of air traffic. Besides these benefits, AI techniques might also be used in aircraft maintenance to detect failures in advance and predict wear and tear before they cause a serious breakdown.

Adhikari and Buderath (2016) examines aircraft maintenance strategies and propose a framework for condition-based maintenance. They asserted that to decide the maintenance type, a maintenance strategy should include the criteria; failure characteristics (pattern, rate, consequence, severity), failure detectability and diagnosability, cost, system availability, and certifiability of the method. Regarding uncertainty; Samaranayake (2006) studied the aircraft maintenance issues and constraints of the new maintenance approaches including uncertainty. Samaranayake and Kiridena (2012) studied CBM under uncertainty and found that implementation of uncertain maintenance operations requires dynamic planning and scheduling which includes rectification, re-assembly, materials changes, re-scheduling spare parts, and other sources. They claimed that current ERP systems are not able to plan simultaneously and dynamically as they are not integrated into all data structures of whole aircraft maintenance operation, hence they proposed a unitary structure to mitigate this drawback.

Regarding AI techniques in aircraft maintenance; Delft University of Technology leads a Project that aims to modernize aircraft maintenance using AI techniques. For a 6-month real-time experiment duration they claim that they are successful in modeling the overall maintenance process, performing health predictions, and finally simplifying very complex maintenance planning. Regarding this project, Andrade et al. (2021) used Reinforcement Learning (RL) for optimization of the aircraft maintenance scheduling. In their real case study, the maintenance data of 45 aircraft were used. They found that with the help of this ML technique aircraft availability increases, and the number of checks reduces, and the fleet availability increases. Basora et al. (2021) used supervised machine learning techniques to describe the data workflow in aircraft maintenance to determine the difficulties regarding the health monitoring of the system.

Rengasamy et al. (2018) studied deep learning approaches to aircraft maintenance, and they identified four main architectures Convolutional Neural Networks, Deep Belief Networks, Long Short Term Memory, and Deep Autoencoders. Eickemeyer et al. (2013) claim that Bayesian

Networks (BNs) are one of the best AI techniques to solve the uncertainty problem of capacity planning in maintenance as BNs are suitable to solve new problems and process accurate forecasts with fewer data. Therefore Dinis et al. (2019) apply big data and predictive analytics to aircraft maintenance and get positive results in deciding maintenance workloads. From this literature review it can be inferred that there are many studies on AI supported maintenance however there is almost no research on the comparison of these maintenance strategies conducted with quantitative decision making methods.

In this paper, in the second section aircraft maintenance strategies are examined in an artificial intelligence context. In the third section, with a case study, the three most common maintenance approaches are compared using a quantitative multi-criteria decision-making technique, besides results and discussions are given. In the last chapter, the research is concluded.

2. Maintenance in Aviation

2.1. Maintenance Types in Aviation

There are many maintenance classifications in the aviation industry, main breakdowns are; preventive, predictive, prescriptive, and corrective/breakdown maintenance. Corrective or breakdown maintenance is performed after the failure occurs, it may interrupt flight schedules and might cause serious negative effects on the reputation of the company, and certainly costs far more expensive than the scheduled maintenance. According to its complexity light, heavy, base, and hangar maintenance is another classification. Regarding periodic checking types, divided into A, B, C, and D checks which depend on the scope, duration, and frequency of the maintenance requirement. A check is the most frequent and has to be done about every 65 hours (Sriram & Haghani, 2003), however, a D-check consists of painting, stripping, and cabin refurbishment, which is performed only one time in 4 years (Beliën et al., 2012).

Regarding scheduling, it can be classified as scheduled/routine/preventive and unscheduled/non-routine maintenance. Generally, preventive and scheduled maintenance terms are used interchangeably, as predictive and condition-based maintenance is used (Van den Bergh et al., 2013).

Prescriptive maintenance combines the advantages of descriptive and predictive analyses to predict the failures, functionalities, wear and tears. This improves the reliability of equipment and saves cost (Koukaras et al., 2022). Prescriptive maintenance is more than providing real-time recommendations, but having the most appropriate course of action during the operation continues. It analyses data patterns and trends to provide the best recommendation (Marques & Giacotto, 2019). Meissner et al. (2021) studied a prescriptive maintenance approach using a simulation model of 30 days and found that it supports reducing waiting times of an aircraft on the ground.

Civil Aviation Authority (CAA) of the United Kingdom defines three types of maintenance: (1) Hard time; is preventive maintenance performed at specific times, mostly including overhaul, servicing, or replacement of spare parts according to manuals. (2) On condition; is also preventive maintenance but includes testing and inspecting the components in a periodical manner to be sure about the equipment's functional status. (3) Condition monitoring; is a non-preventive maintenance process that includes continuous data collection, analysis, and interpretation about the equipment's status (Knotts, 1999).

Three main aircraft maintenance strategies are explained with their advantages and disadvantages in Table 1. For the first alternative, all non-preventive maintenance like unscheduled, corrective maintenance and conditional monitoring techniques are merged, as their characteristics are similar.

Table 1 Aircraft Maintenance Strategies

No.	Maintenance Type	Pros&Cons	Sources
1	Corrective /Unscheduled Maintenance and Condition monitoring	• Low cost • Non-preventive maintenance process • Problem-based repairment process • Risk for long and unplanned breakdown durations	(Knotts, 1999) (Paz & Leigh, 1994) (Basri et al., 2017) (Chen et al., 2012)
2	Predictive Maintenance	• Failure detection and prediction • Identify problems in critical components (turbines, landing gear, etc.) • Analyze data and predict the components potential failure • Develop inspection • Provides advance warnings for some failures	(Karthik & Kamala, 2021) (sparkcognition.com)
3	Prescriptive Maintenance	• Identify the best course of action for failures and supports root cause analysis • Provides AI-driven analysis of historical maintenance • Reducing turnarounds by an average of 20 minutes per incident • Predicts the remaining useful life of items • High cost	(Meissner et al., 2021) (Marques & Giacotto, 2019) (Koukaras et al., 2022) (sparkcognition.com)

2.2. AI Techniques in Aviation Maintenance

Airlines suffer from high costs stemming from delays and cancellations 30 percent of which are caused by unplanned maintenance activities. In the aviation industry, artificial intelligence techniques support predictive maintenance to predict failures and reduce unscheduled activities by managing big data. In the aircraft maintenance process, a serious amount of data is generated and processed during the planning stage. Especially in unscheduled maintenance, the uncertainty of capacity planning affects budgeting, materials management, capacity planning, and resource allocation (Samaranayake & Kiridena, 2012).

Many artificial intelligence techniques support the prediction and early detection of failures. Artificial Neural

Network (ANN) algorithms are applicable to older machines and adaptable to new machines. ANN gives satisfactory results in measuring equipment failures e.g. classifies fault with a %92 success rate (Biswal & Sabareesh, 2015; Hesser & Markert, 2019). Random Forest technique is successful at fault detection, prediction of machine states, and identification of disk failure (Paolanti et al., 2018). Support Vector Machine algorithm which performs regression analysis and pattern recognition has the advantage of being low-cost compared to classical maintenance, besides its high detection accuracy it needs a long training time (Cawley & Talbot, 2010). K-means algorithm used for clustering for fault detection which has a 93% of prediction accuracy in maintenance. It is easy to implement however, it has difficult to decide the number of clusters (Durbhaka & Selvaraj, 2016; Amruthnath & Gupta, 2018). After reviewing the studies on AI Techniques and maintenance types in aviation, to the best of my knowledge, this study is unique in the literature regarding the comparison of artificial intelligence-supported aircraft maintenance approaches.

3. Case Study

To determine the most appropriate alternative for aircraft maintenance a multi-criteria decision-making method is adopted. Regarding the uncertain nature of the maintenance operations, q-ROF TOPSIS method (Pinar & Boran, 2020) is applied which is successful in modeling and quantifying human subjective decision making. Then Pinar et al. (2021) and Taghipour et al.(2022) used q-ROF TOPSIS method in their research on supplier selection and speech recognition product selection. In this section first, the basics of fuzzy sets are mentioned, then the methodology is briefly given and finally, a case study is presented.

3.1. Fuzzy Set Theory

Zadeh (1965) proposed the fuzzy set, Atanassov (1986) extended it to intuitionistic fuzzy set (IFS), in which A in X can be described as:

$$A=\{\langle x,\mu_A(x),v_A(x)\rangle \mid x\in X\} \tag{1}$$

where the functions; $\mu_A(x): X\rightarrow[0,1]$ is the degree of membership of x, $v_A(x): X\rightarrow[0,1]$ is the degree of non-membership of x, and,

$$0\le \mu_A(x)+v_A(x)\le 1 \tag{2}$$

Yager (2013) extended IFS to Pythagorean fuzzy sets (PFS) and then (Yager, 2016); Yager and Alajlan (2017) generalized IFS and PFS and proposed q-rung orthopair fuzzy sets (q-ROFs). In these fuzzy sets, the sum of the q^{th} powers of the membership and non-membership degrees is equal to or less than one and they are formulized as follows:

$$A=\{\langle x,\mu_A(x),v_A(x)\rangle \mid x\in X\} \tag{3}$$

where $\mu_A: X\rightarrow[0,1]$ and $v_A: X\rightarrow[0,1]$ are membership and non-membership degrees of $x\in X$ to A respectively and:

$$(\mu_A(x))^q+(v_A(x))^q\le 1 \tag{4}$$

The hesitation degree $\pi_A(x)$ is as follows:

$$\pi_A(x)=\left(1-(\mu_A(x))^q-(v_A(x))^q\right)^{1/q} \tag{5}$$

3.2. Methodology

In this subsection to save some space q-ROF TOPSIS methodology (Pinar & Boran, 2020) is briefly mentioned. Let A = $\{A_1,A_2,A_3,...,A_m\}$ be a set of alternatives and X = $\{X_1,X_2,X_3,...,X_n\}$ be a set of criteria the steps are:

Step 1: Decision makers' weights are calculated using linguistic terms as described in (Pinar & Boran, 2020).

Step 2: Criteria are determined by DMs and alternatives are evaluated in linguistic terms. These terms are converted to q-ROF numbers like $\alpha_k=\langle\mu_k(x),v_k(x)\rangle(k=1,2,3,...,l)$ and aggregated by the q-ROFWA aggregation operator (Liu & Wang, 2018). So, aggregated q-ROF decision matrix is obtained.

Step 3: Criteria weights are determined in linguistic terms and calculated according to q-ROF TOPSIS method.

Step 4: Build up the aggregated weighted q-ROF decision matrix aggregating the criteria weights with the decision matrix obtained in the second step.

Step 5: Calculate the Positive Ideal Solution (q-ROFPIS) and Negative Ideal Solution (q-ROFNIS) as usual in TOPSIS method. While calculating take into consideration the benefit and cost criteria.

Step 6. Determine the separation measures by calculating the difference between maintenance strategy alternatives using Euclid distance.

Step 7. Calculate the relative closeness coefficient C_{i*} using Eq.(6) and rank all the alternatives.

$$C_{i*}=\frac{S_i^-}{S_i^++S_i^-} \quad where \quad 0\le C_{i*}\le 1 \tag{6}$$

3.3. Case Study of Maintenance Strategy Selection

Corrective, predictive, and prescriptive maintenance which are the most common three aircraft maintenance strategies are determined as alternatives. There are also some other maintenance methods such as A-D checks or preventive maintenance in the aviation industry. These approaches are excluded in this study as they are mostly routine checks or time based/periodic maintenance methods.

In the first step, the decision makers' expertise is determined as DM1:Very High, DM2:High, and DM3: Medium High and converted to numbers as DM1: 0.384, DM2: 0.331, and DM3: 0.285.

Table 2.a Linguistic Term Scale

Linguistic terms	Abbreviation
-Extremely High level	(EH)
-Very high level	(VH)
-High level	(H)
-Medium High level	(MH)
-Medium level	(M)
-Medium Low level	(ML)
-Low level	(L)
-Very low level	(VL)
-Extremely Low level	(EL)

In the second step after a literature search (Kumar et al., 2013; Parida & Chattopadhyay, 2007; Syan & Ramsoobag, 2019) and using my maintenance job experience following evaluation criteria are determined as performance indicators; (1) maintenance cost, (2) reliability (minimization of the failure rate), (3) failure detection (identifying the failure in advance with high accuracy), (4) downtime period (maximization of the readiness of the aircraft). Then DMs evaluate all alternatives regarding these criteria with linguistic terms as indicated in Table 2.b. using the scale in Table 2.a.

Table 2.b DMs Evaluations in Linguistic Terms

	KV1			KV2			KV3		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
X_1	M	H	VH	ML	MH	H	ML	H	EH
X_2	MH	H	VH	H	VH	EH	H	VH	VH
X_3	M	VH	EH	M	H	VH	M	VH	VH
X_4	EH	MH	M	H	M	M	VH	MH	M

After the conversion of these terms to q-ROF numbers, all three DMs evaluations are aggregated, and the decision matrix (R) is obtained as follows:

R=		X_1	X_2	X_3	X_4
	A_1	[0.494;0.610;0.867]	[0.717;0.385;0.831]	[0.550;0.550;0.874]	[0.887;0.230;0.661]
	A_2	[0.722;0.380;0.828]	[0.819;0.284;0.753]	[0.824;0.279;0.748]	[0.622;0.481;0.865]
	A_3	[0.874;0.242;0.683]	[0.897;0.211;0.645]	[0.903;0.205;0.634]	[0.550;0.550;0.874]

In the third step, importance degrees are evaluated by DMs and their weights are determined as:

X_1	X_2	X_3	X_4
0.225	0.287	0.226	0.262

In the fourth step criteria weights are aggregated with the decision matrix obtained in the second step and as a result, the weighted aggregated q-ROF decision matrix (R') is obtained as follows:

R'=		X_1	X_2	X_3	X_4
	A_1	[0.305;0.895;0.634]	[0.498;0.761;0.758]	[0.343;0.873;0.664]	[0.646;0.680;0.746]
	A_2	[0.465;0.805;0.723]	[0.589;0.697;0.770]	[0.553;0.749;0.743]	[0.411;0.825;0.717]
	A_3	[0.603;0.727;0.735]	[0.675;0.640;0.755]	[0.639;0.699;0.735]	[0.360;0.855;0.690]

In the fifth step the positive (A^+) and negative (A^-) ideal solutions are calculated and presented in Table 3 (a-b):

Table 3.a. Positive Ideal Solutions

	μ	v	π
X_1	0.305	0.895	0.634
$A^+ =$ X_2	0.675	0.640	0.755
X_3	0.639	0.699	0.735
X_4	0.360	0.855	0.690

Table 3.b. Negative Ideal Solutions

	μ	v	π
X_1	0.603	0.727	0.735
$A^- =$ X_2	0.498	0.761	0.758
X_3	0.343	0.873	0.664
X_4	0.646	0.680	0.746

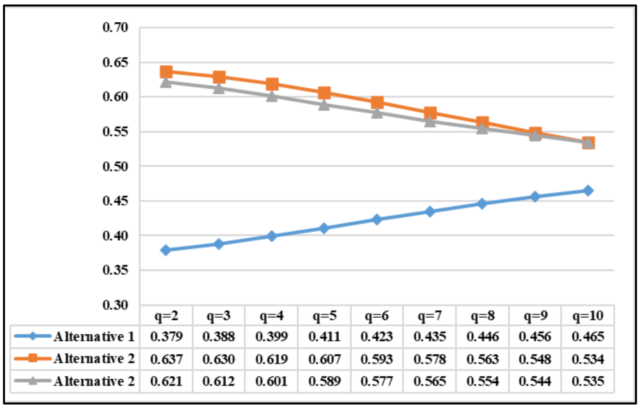
In the sixth step the differences between three maintenance strategy alternatives are calculated by the help of Euclid distance, S_i^+ and S_i^- values and results (C_{i*}) are indicated in Table 4.

Table 4. Results

	S_i^+	S_i^-	C_{i*}
A_1	0.214	0.136	0.388
A_2	0.099	0.169	0.630
A_3	0.136	0.214	0.612

In the last step we calculate and rank all the alternatives from the most appropriate aircraft maintenance strategy to less appropriate one as $\mathbf{A_2 > A_3 > A_1}$ which indicates that predictive maintenance is better than other strategies.

To validate the results parameter analysis is performed using the q parameter values between 2 and 10 as indicated in Figure 1.



	q=2	q=3	q=4	q=5	q=6	q=7	q=8	q=9	q=10
Alternative 1	0.379	0.388	0.399	0.411	0.423	0.435	0.446	0.456	0.465
Alternative 2	0.637	0.630	0.619	0.607	0.593	0.578	0.563	0.548	0.534
Alternative 2	0.621	0.612	0.601	0.589	0.577	0.565	0.554	0.544	0.535

Figure 1. Results of Parameter Analyses

3.4. Results and Discussion

As three maintenance approaches are examined and compared it's obviously seen that the first alternative (corrective /unscheduled maintenance and condition monitoring) has a lower performance than the other two approaches. The main reason might be the nature of the corrective maintenance which has no preventive action and begins its performance after a problem occurred. Even some AI techniques are used, it might be too late to take measures after a failure occurs and increases the suspension period of the flight schedule. Although the maintenance cost is relatively high in both two methods, reliability and readiness of the aircraft, and failure detection performance are far better compared with the first alternative maintenance approach.

Comparing predictive and prescriptive maintenance there seems a minor difference on behalf of predictive maintenance which may come from the effect of prescriptive maintenance costs a bit higher than the other one. In both approaches AI methods especially machine learning techniques such as RF, ANN, SVM, and k-means algorithm support the maintenance process positively and make the aircraft maintenance performance better.

Regarding the results of the parameter analyses, due to the nature of the q-ROF sets, while the q level increases the ratings of the alternatives approach to 0.5. Hence, q=3 generally gives us the most stable results, however in between 2-10 its obviously seen that the Alternative 2 and 3 are far more better than Alternative 1. Therefore, these results of the parameter analyses clearly shows the validity of our method and the positive effect of AI in aircraft maintenance.

4. Conclusion

Maintenance is a serious and expensive process in the aviation industry different from other sectors. Losing time with repair and unscheduled maintenance also costs too much for aviation companies. Even though they have some costs in the beginning phase, predictive and prescriptive maintenance strategies help these companies on preventing aircraft failures and reduce breakdown periods. Therefore, a decision method for an optimum aircraft maintenance strategy is proposed and three strategies are compared concerning cost, reliability, failure detection, and downtime period. The results of q-ROF TOPSIS method show that the support of AI techniques is highly important for aircraft maintenance. A parameter analysis is also performed to validate the method. The main contributions of this article are (1) reviews the AI supported aircraft maintenance strategies (2) evaluates and compares Artificial Intelligence-supported aircraft maintenance strategies with a fuzzy quantitative decision making method.

As a future study, specifically machine learning techniques effects on aircraft maintenance might be studied. Besides, other q-ROF decision making methods can be applied on AI supported aircraft maintenance approaches to make quantitative comparisons.

Ethical approval

Not applicable.

Conflicts of Interest

The author declares that there is no conflict of interest concerning the publication of this paper.

References

Adhikari, P. P., & Buderath, M. (2016). A framework for aircraft maintenance strategy including CBM. PHM Society European Conference,

Ahmadi, A., Söderholm, P., & Kumar, U. (2007). An overview of trends in aircraft maintenance program development: past, present, and future. European Safety and Reliability Conference: 25/06/2007-27/06/2007,

Amruthnath, N., & Gupta, T. (2018). A research study on unsupervised machine learning algorithms for early fault detection in predictive maintenance. 2018 5th international conference on industrial engineering and applications (ICIEA),

Andrade, P., Silva, C., Ribeiro, B., & Santos, B. F. (2021). Aircraft maintenance check scheduling using reinforcement learning. Aerospace, 8(4), 113.

Atanassov, K. T. (1986). Intuitionistic fuzzy sets. Fuzzy Sets and Systems, 20(1), 87-96.

Basora, L., Bry, P., Olive, X., & Freeman, F. (2021). Aircraft fleet health monitoring with anomaly detection techniques. Aerospace, 8(4), 103.

Basri, E. I., Razak, I. H. A., Ab-Samat, H., & Kamaruddin, S. (2017). Preventive maintenance (PM) planning: a review. Journal of quality in maintenance engineering.

Beliën, J., Cardoen, B., & Demeulemeester, E. (2012). Improving workforce scheduling of aircraft line maintenance at Sabena Technics. Interfaces, 42(4), 352-364.

Biswal, S., & Sabareesh, G. (2015). Design and development of a wind turbine test rig for condition monitoring studies. 2015 international conference on industrial instrumentation and control (icic),

Cawley, G. C., & Talbot, N. L. (2010). On over-fitting in model selection and subsequent selection bias in performance evaluation. The Journal of Machine Learning Research, 11, 2079-2107.

Chen, D., Wang, X., & Zhao, J. (2012). Aircraft maintenance decision system based on real-time condition monitoring. Procedia Engineering, 29, 765-769.

Dinis, D., Barbosa-Póvoa, A., & Teixeira, Â. P. (2019). Valuing data in aircraft maintenance through big data analytics: A probabilistic approach for capacity planning using Bayesian networks. Computers & Industrial Engineering, 128, 920-936.

Durbhaka, G. K., & Selvaraj, B. (2016). Predictive maintenance for wind turbine diagnostics using vibration signal analysis based on collaborative recommendation approach. 2016 International Conference on Advances in Computing, Communications and Informatics (ICACCI),

Eickemeyer, S. C., Borcherding, T., Schäfer, S., & Nyhuis, P. (2013). Validation of data fusion as a method for forecasting the regeneration workload for complex capital goods. Production Engineering, 7(2), 131-139.

Hesser, D. F., & Markert, B. (2019). Tool wear monitoring of a retrofitted CNC milling machine using artificial neural networks. Manufacturing letters, 19, 1-4.

Karthik, T., & Kamala, B. (2021). Cloud based AI approach for predictive maintenance and failure prevention. Journal of Physics: Conference Series,

Knotts, R. M. (1999). Civil aircraft maintenance and support Fault diagnosis from a business perspective. Journal of quality in maintenance engineering.

Koukaras, P., Dimara, A., Herrera, S., Zangrando, N., Krinidis, S., Ioannidis, D., Fraternali, P., Tjortjis, C., Anagnostopoulos, C.-N., & Tzovaras, D. (2022). Proactive Buildings: A Prescriptive Maintenance Approach. IFIP International Conference on Artificial Intelligence Applications and Innovations,

Kumar, U., Galar, D., Parida, A., Stenström, C., & Berges, L. (2013). Maintenance performance metrics: a state-of-the-art review. Journal of quality in maintenance engineering.

Liu, P. D., & Wang, P. (2018). Some q-Rung Orthopair Fuzzy Aggregation Operators and their Applications to Multiple-Attribute Decision Making. International Journal of Intelligent Systems, 33(2), 259-280.

Marques, H., & Giacotto, A. (2019). Prescriptive maintenance: Building alternative plans for smart operations. FT2019. Proceedings of the 10th Aerospace Technology Congress, October 8-9, 2019, Stockholm, Sweden,

Meissner, R., Meyer, H., & Wicke, K. (2021). Concept and economic evaluation of prescriptive maintenance strategies for an automated condition monitoring system. International Journal of Prognostics and Health Management, 12(3).

Paolanti, M., Romeo, L., Felicetti, A., Mancini, A., Frontoni, E., & Loncarski, J. (2018). Machine learning approach for predictive maintenance in industry 4.0. 2018 14th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA),

Parida, A., & Chattopadhyay, G. (2007). Development of a multi-criteria hierarchical framework for maintenance performance measurement (MPM). Journal of quality in maintenance engineering.

Paz, N. M., & Leigh, W. (1994). Maintenance scheduling: issues, results and research needs. International Journal of Operations & Production Management.

Pınar, A., Babak Daneshvar, R., & Özdemir, Y. S. (2021). q-Rung orthopair fuzzy TOPSIS method for green supplier selection problem. Sustainability, 13(2), 985.

Pinar, A., & Boran, F. E. (2020). A q-rung orthopair fuzzy multi-criteria group decision making method for supplier selection based on a novel distance measure. International Journal of Machine Learning and Cybernetics, 11(8), 1749-1780.

Rengasamy, D., Morvan, H. P., & Figueredo, G. P. (2018). Deep learning approaches to aircraft maintenance, repair and overhaul: A review. 2018 21st International Conference on Intelligent Transportation Systems (ITSC),

Samaranayake, P. (2006). Current practices and problem areas in aircraft maintenance planning and scheduling–interfaced/integrated system perspective. Proceedings of the 7th Asia Pacific Industrial Engineering and Management Systems Conference,

Samaranayake, P., & Kiridena, S. (2012). Aircraft maintenance planning and scheduling: an integrated framework. Journal of Quality in Maintenance Engineering.

Sriram, C., & Haghani, A. (2003). An optimization model for aircraft maintenance scheduling and re-assignment. Transportation Research Part A: Policy and Practice, 37(1), 29-48.

Syan, C. S., & Ramsoobag, G. (2019). Maintenance applications of multi-criteria optimization: A review. Reliability Engineering & System Safety, 190, 106520. "

Taghipour, A., Rouyendegh, B. D., Ünal, A., & Piya, S. (2022). Selection of suppliers for speech recognition products in IT projects by combining techniques with an integrated fuzzy MCDM. Sustainability, 14(3), 1777.

Van den Bergh, J., De Bruecker, P., Beliën, J., & Peeters, J. (2013). Aircraft maintenance operations: state of the art. HUB Research Paper 2013/09.

Yager, R. R. (2013). Pythagorean Membership Grades in Multicriteria Decision Making. Ieee Transactions on Fuzzy Systems, 22(4), 958-965.

Yager, R. R. (2016). Generalized orthopair fuzzy sets. Ieee Transactions on Fuzzy Systems, 25(5), 1222-1230.

Yager, R. R., & Alajlan, N. (2017). Approximate reasoning with generalized orthopair fuzzy sets. Information Fusion, 38, 65-73.

Zadeh, L. A. (1965). Fuzzy sets. Information control, 8(3), 338-353.

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Investigation of Characterization of Zerodur Glass Ceramics Used in Aerospace to Predict the Relationship between Surface Roughness and Subsurface Damage

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Abstract

Due to the brittle nature of the optical parts used in the grinding process to obtain a good surface quality, surface roughness and subsurface damage occur after the machining. These subsurface damages must be detected and destroyed with the help of post-process processes such as polishing. Because detecting these damages is time-consuming and costly, many researchers have tried relationship between subsurface damage and surface roughness since it is easier to detect and measure. In this study, Zerodur glass ceramic material characterization tests were carried out to predict the surface roughness and damage under the surface, and the material properties were determined to be specific to the sample. The grinding parameters taken from the previous studies and the values given for surface roughness and subsurface damage were examined with the help of the Lambropoulos theoretical model. The results theoretically showed that with the characterization of material properties different from those given in the literature, even if the parameters used in the experimental study do not change, much more severe subsurface damage will be created on the sample, and the load value applied to the material will increase significantly. For this reason, it is crucial to determine the material's mechanical properties by performing characterization tests before all material grinding and post-processing processes.

1. Introduction

Zerodur glass-ceramic materials, which have a broad history in aerospace applications, stand out among precision optical materials to meet optomechanical requirements. Precision optical materials in satellite camera mirrors require high shape and geometric accuracy under production performance and desired design tolerances (Esmaeilzare, Rahimi, and Rezaei 2014). Zerodur glass ceramic material, developed by the German Schott company, is an optical material that has been widely used in advanced optics applications in space for decades due to its excellent mechanical, thermal, and chemical properties (Döhring et al. 2009)(Xavier Tonnellier n.d.). The most important feature of the Zerodur material developed by Schott is its very low expansion coefficient, as well as the homogeneous behavior of this coefficient throughout the part (Döhring et al. 2009). Zerodur material plays a critical role in many space missions due to its history and is used as a mirror material in earth observation satellites. Although optical production is constantly evolving, some manufacturing processes remain unchanged. The production of an optical material continues with the grinding of the material and the subsequent polishing process. Polishing is the final fine grinding stage in which the optical surface and shape are made according to requirements.

On the other hand, although precision grinding is the most effective method used in producing glass-ceramic materials, it is crucial to consider the surface quality and strength requirements during the grinding process. In addition to its hard and brittle nature (Li and Liao 1996), micro-wheels on the abrasive cause surface roughness on the surface of the material and defects known as subsurface damage (Steele et al. 2021) in the grinding of glass ceramics due to its low fracture toughness. Subsurface damage significantly reduces the optical material's mechanical and thermal properties, image quality, reliability, and lifetime. In addition, subsurface damage can cause breakage under the influence of a small load applied to the material. For this reason, many researchers have tried to detect these damages with the help of experimental, theoretical, and simulations in order to investigate the effect of grinding parameters such as grinding depth, wheel speed, and feed rate, which cause the formation of subsurface damage depth during grinding of optical glasses.

Malkin and Hwang (Komanduri, Lucca, and Tani 1997) provided a basic approach with a comprehensive review in this area. According to their research, two basic crack systems, lateral and radial/median cracks, have been introduced for the brittle mode indentation and scratching process. Lambropoulos (Esmaeilzare, Rahimi, and Rezaei 2014) conducted an experimental study on the ratio between subsurface damage and surface roughness under the abrasive process. Based on micro indentation mechanics made, an assumption about the relationship between subsurface damage and surface roughness. The ratio of median crack depth to lateral crack depth during indentation was accepted as equal to the ratio between subsurface damage and surface roughness. This model is a function of material properties such as Hardness, Young's Modulus, and Fracture toughness and depends on the applied normal load and the wheel geometry. Since obtaining the normal load requires an experimental process, there are limitations to the application of this model (Esmaeilzare, Rahimi, and Rezaei 2014). One possible explanation for associating lateral cracks, which represent surface roughness rather than radial cracks, with subsurface damage depth is that lateral cracks are deeper than radial cracks (Steele et al. 2021). Based on the model developed by Lambropoulos, Li et al. established a nonlinear relationship between force-independent subsurface damage and surface roughness to examine the subsurface damage morphology and distribution on the Fused Silica sample. However, the grinding wheels move both normally and tangentially during grinding. There have been observed deviations between the theoretical model and experimental results since the indenter moves only in the normal direction during indentation.

Fracture mechanics were used to study subsurface damage to the machining surface. Different types of cracks were defined depending on the type of indentation (Xavier Tonnellier n.d.). Suratwala et al. (Steele et al. 2021) measured the subsurface mechanical damage characteristic with magnetorheological finishing (MRF) slowly tapering wedge technique (chemical etching is performed by polishing the wedge on the machined workpiece for each sample). As a result, they scaled the subsurface damage depth for most optical workpieces based on the relationship between the elastic modulus and hardness of the material, “$E_1^{1/2} / H_1$”. This material scale suggests lateral cracks are the dominant source of subsurface damage rather than radial and median cracks, as previously suggested.

In addition, the kinetic relationship between the grinding wheel and the specimen must be considered. Based on the kinematic characteristics of horizontal surface grinding and the characteristics of grinding-induced cracks, four different grinding modes were proposed by Gu et al.; brittle, semi brittle, and semi ductile mod and ductile mod. While the formation of both lateral and median cracks continues to grow below the grinding surface plane in brittle and semi-brittle modes, lateral cracks have little effect on surface roughness in semi-ductile and ductile modes. It is stated that the forms of surface formation in the semi-brittle mode are both brittle fracture and plastic flow. In general, the surface crack depth is greater than that of the plastic groove and significantly influences the surface roughness. On the other hand, subsurface cracks are observed under the machining surface. Consequently, when grinding modes are brittle and semi-brittle, the lateral and median crack depth can be used to evaluate the relationship between surface roughness and subsurface damage (Zhenqiang Yao, Weibin Gu n.d.).

Machining in the ductile mode can be performed if the adequate depth of cut does not advance continuously below the cutting surface plane. Therefore, higher hardness or lower fracture toughness must be lower than the critical depth of cut to be able to machine in the ductile mode. When using a critical depth of cut between tool and workpiece in a cutting system with high cycle resistance, hard and brittle materials such as Zerodur glass-ceramic can be chipped sparingly with abrasives high-speed milling-grinding. This approach can allow material removal from the material under a ductile regime without the occurrence of microcracks (Chen and Yang 2022)

H.Wang et al. studied the effect of subsurface damage on the nanomechanical properties of lapped BK7 glass. As a result, the indentation depth increased with subsurface damage. Hardness and Modulus increased exponentially and gained the value of their counterparts with the increase of subsurface damage depth. However, H/E decreases when the cracks disappear and approach a constant value. In addition, the H reduction rate curve was approximated to the distribution of subsurface cracks, which provides a potential method to characterize the H variant in the subsurface damage layer by measuring the crack distribution (Wang et al. 2021).

Conventionally used indenters include spherical, round-tipped conical, and pyramid-tipped indenters. These indentations are used in experiments to show contact stiffness and other material properties. For example, by analyzing the P-h, a-h, and a-P relationship, the properties of the tested material can be determined, or predictions can be made about the material properties. Besides, in the simple linear relationship, the indentation contact area "A" plays an essential role in indentation contact mechanics in elastic and elastoplastic/viscoelastic regimes.

The geometric similarity of conical/pyramid indenters is quantitatively crucial in determining material properties in elastic and elastoplastic/viscoelastic regimes. This is why conical/pyramid indenters are traditionally used in indenter contact mechanics (Sakai 2020).

Engineering materials, including ceramics, deform elastically under strain. The mechanical work that drives the elastic deformation of these materials can increase the Gibbs Free Energy through the increase in enthalpy with the reversible deformation of the interatomic separation of these materials. When this elastic material's load or displacement constraints are removed, the material returns to its original shape and size. In the case defined as yield stress or yield strength, the non-linear state begins. It begins as elastoplastic, where deformation beyond elastic limits occurs not only elastically but also as plastic flows.

The onset of plastic flow begins below the contact surface of the indenter. Plastic yielding appears along the penetration axis, i.e., the z-axis, because the principal stresses ($\sigma 1= \sigma r$, $\sigma 2= \sigma\theta$, $\sigma 3= \sigma z$) have a maximum value in the z-axis for indentation contact an elastic half-space. The elastoplastic material with high yield strength and low elastic modulus resists the onset of plastic flow under Hertzian indentation contact.

Most plastic deformation under the indentation contact surface occurs in the elastic area surrounding the plastic core of the indenter. However, plastic deformation becomes very important as the elastic field in which the plastic deformation takes place begins to become insufficient. Expansion of the plastic deformation into the undeformed region leads to an indentation deposit. On the other hand, the surface energy of the free surface limits this plastic flow.

In this article, the characterization of commercial Zerodur glass ceramic material used as optical material in aerospace applications is conducted to predict the relationship between surface roughness and subsurface damage. Material properties were experimentally determined and based on the Lambropoulos theoretical model, the surface roughness and subsurface damage values were obtained by referring to the grinding parameters in the previous experimental study. These values were compared with the results of the previous experimental study. As a result, it is essential to characterize the material properties to more compatibly determine the surface roughness and subsurface damage obtained with the established theoretical model.

2. Materials and Methods

This section reviews the experimental determination of material properties and the Lambropoulos theoretical model.

2.1. Problem Definition

Various researchers have developed theoretical models showing the relationship between subsurface damage and surface roughness due to the difficulty of detecting subsurface damage, usually with the help of material properties (E, H, K) and indentation tool properties (such as sharpening angle) and sometimes load-dependent variables. However, the large number of variable parameters involved in the process has been quite challenging in developing these estimates.

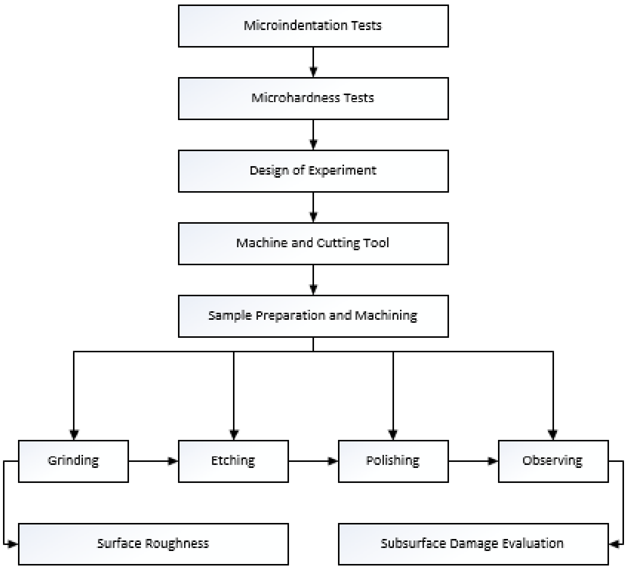

Figure 1. Methodology for the Zerodur Material Characterization Process & SSD Evaluation

In this study, nanoindentation and microhardness experimental tests were carried out to determine the characterization of Zerodur glass ceramic material with Ø50 mm diameter x 15 mm thickness. Following the material characterization studies on the model developed by Lambropoulos, which examines the relationship between surface roughness and subsurface damage, the experimental work samples previously carried out using Zerodur material were compared, and the differences were evaluated.

Before the tests, the sample material was checked for surface integrity (0.7 x / 5 x magnification) with a Leica MZ16 microscope.

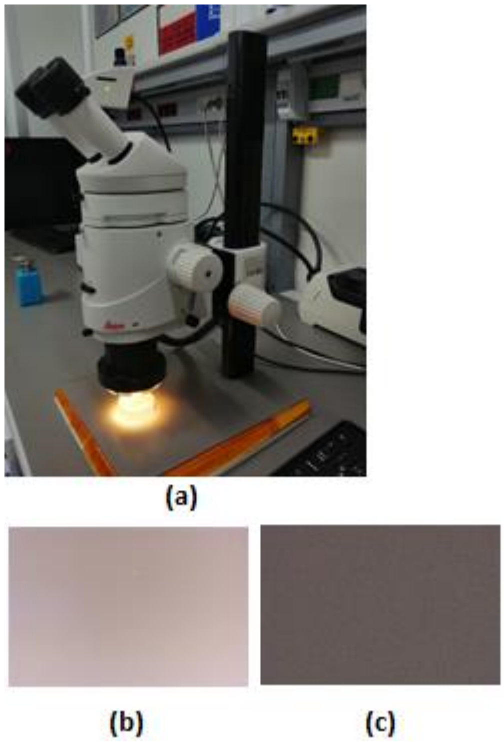

Figure 2. (a) LEICA MZ16 Optical Microscope (b) 0.7x Magnification of the Surface (c) 5x Magnification of the Surface

The cutting processes of the workpiece samples were completed with a spindle speed of 975 rpm in the Buehler Precision Saw the cutting device.

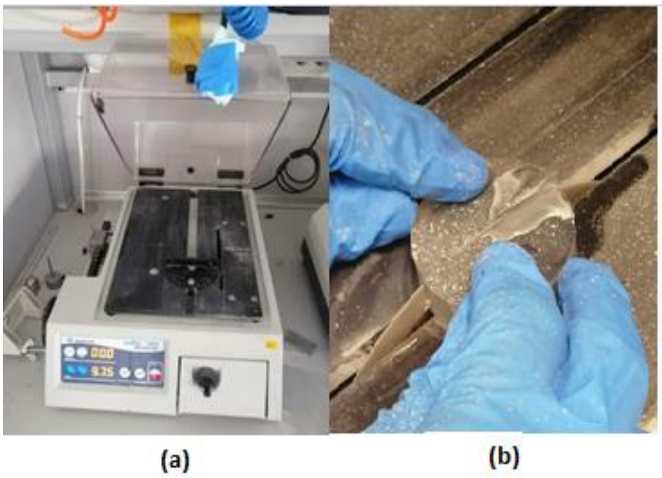

Figure 3. (a) BUEHLER ISOMET 1000 Precision Saw (b) Specimen Cutting Process

The surface with a BUEHLER Grinder Polisher was polished with P300 abrasive at 200 rpm for 1 minute. Then, the polishing process was carried out with P600 abrasive at 250 rpm and P1200 abrasive at 300 rpm. Each polishing process was carried out for “1~1.5” minutes.

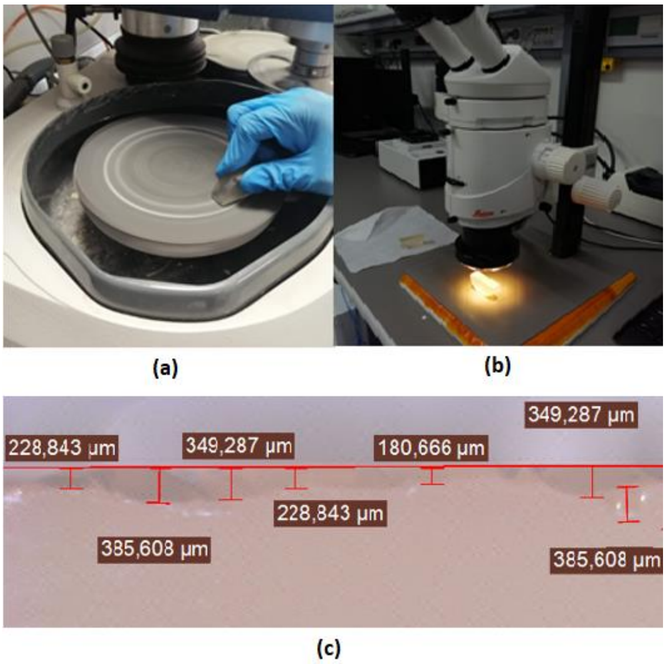

Figure 4. (a) Polishing Process of the Cutting Specimen (b) Inspection with Microscope (c) Parts Removed from The Surface After the Cutting Process

Table 1. Shaker and Peripherals

Property	**Value**
Sine Force	50 kN
Random Force	50 kN
Shock Force	100 kN
Usable frequency range	DC~2700 Hz
Maximum Displacement (p-p)	51 mm
Maximum Speed	2 m/sn
Maximum acceleration (sine)	980 m/sn^2
Maximum static test mass	800 kg
Power amplifier power	60 kVA
Clean room standard where the system is installed	Class 100.000
Armature / Sliding table dimensions	Ø445 / 600×600 mm

Table 2. Control and Data Collection System

Property	**Value**
Equipment	LMS SACADAS III
Software	LMS Test.Lab Rev 11B
Number of Channels	40
Sampling Rate	204.8 kHz
Resolution	24 bit
Bandwidth	93 kHz

The test sample was isolated with Kapton tape and bonded to the fixture with LOCTITE 454 adhesive.

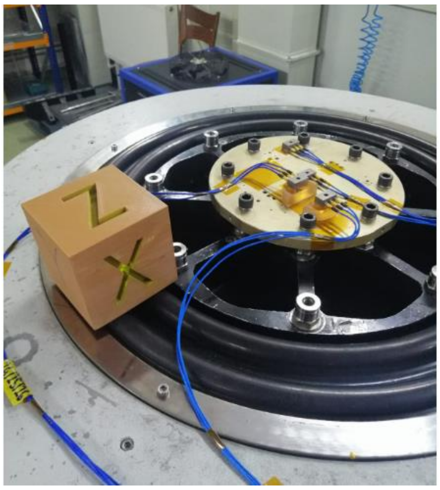

Figure 5. Sinus and Random Vibration Test Configuration

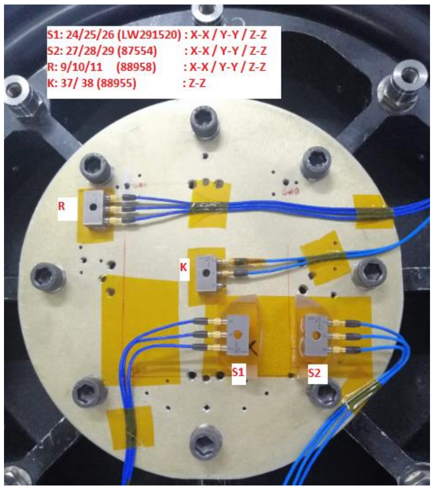

Figure 6. Vibration Test Accelerometer Positions

Information about the shaker and its peripherals and the control and data collection system are given in Table 1 and Table 2. RS1; Scanned between 5-2000 Hz with 1g constant acceleration. In RS2, the same process is repeated as in RS1. The random test was tested for 2 minutes by the ECSS test standard (Ecss 2012) according to the loads given below.

Table 3. Random Vibration Profile (Smith 2004).

Hz	**g^2 / Hz**
20	0.03158
100	0.7808
400	0.7808
2000	0.15902

The load profile was adjusted according to the case that the test sample was ~75 grams, but the sample was 300 grams due to the system's capacity. The test was performed as σ = 2.8.

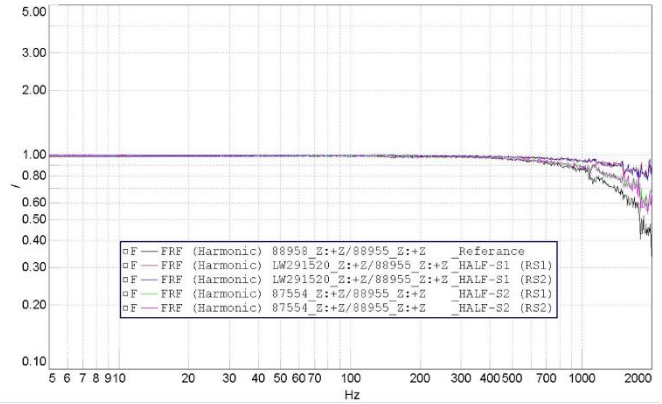

Figure 7. Zerodur Sample Vibration Test Result Graph

A Micro hardness test was carried out to evaluate the mechanical properties of Zerodur glass ceramic material. The tests were carried out with the CSM Instrument Nano hardness measuring device.

Figure 8. CSM Instrument Microindentation Hardness Tester

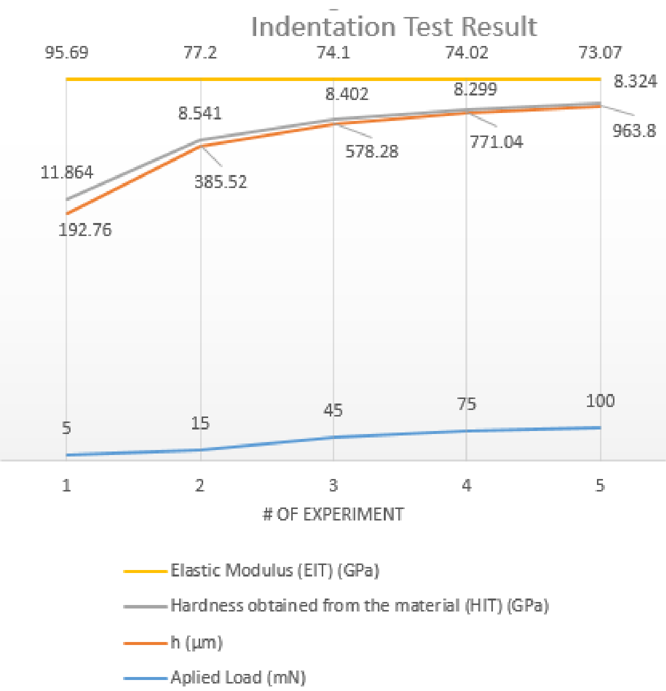

Figure 8. Indentation Experimental Test Results

The measurement results, excluding the first measurement (Figure 9) show that the modulus of elasticity is approximately E ~75 GPa, and the hardness value is H~8.3 GPa. This situation, shown in Table 4, differs from the Zerodur material properties used in the literature.

Table 4. Nanoindentation Experimental Test Results

Serial No	Aplied Load (mN)	h (µm)	Hardness obtained from the material (HIT) (GPa)	Elastic Modulus (EIT) (GPa)
1	5	192.76	11.864	95.69
2	15	385.52	8.541	77.2
3	45	578.28	8.402	74.1
4	75	771.04	8.299	74.02
5	100	963.8	8.324	73.07

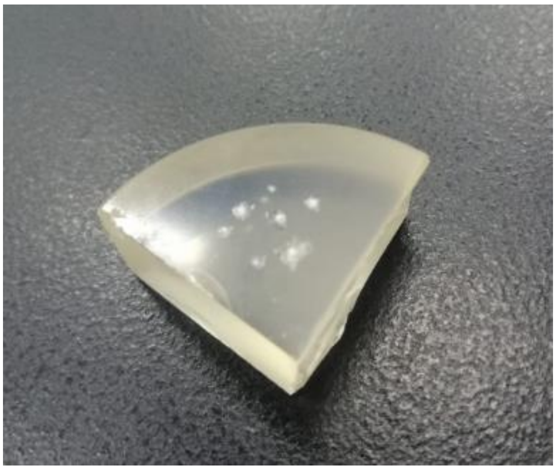

Figure 9. Example of Pile-up Formation on Sample Surface

In addition to being time-consuming and costly (Antwi, Liu, and Wang 2018), grinding brittle materials in ductile mode is one of the most critical methods that provide an adequate formation of smooth machining surface with nanometer or sub-nanometer level surface roughness. Experimental studies have shown that hard and brittle materials can be machined in the ductile mode if the depth of cut is small enough. The material is removed as plastic chip flow without any extra crack formation in this case. Bifono et al. developed a model between critical surface roughness and material properties E, Kc, and H. (Solhtalab et al. 2019)

$$SR_c = 0.37 \left(\frac{E}{H}\right)\left(\frac{K_c}{H}\right)^2 \quad (1)$$

Even if there is no crack formation on the surface as a result of the applied loads in Table 4, if there is a pile formation as in Figure 10 with the applied load, the depth of cut without piling should be considered as the depth of cut when determining the cutting depth from the grinding parameters.

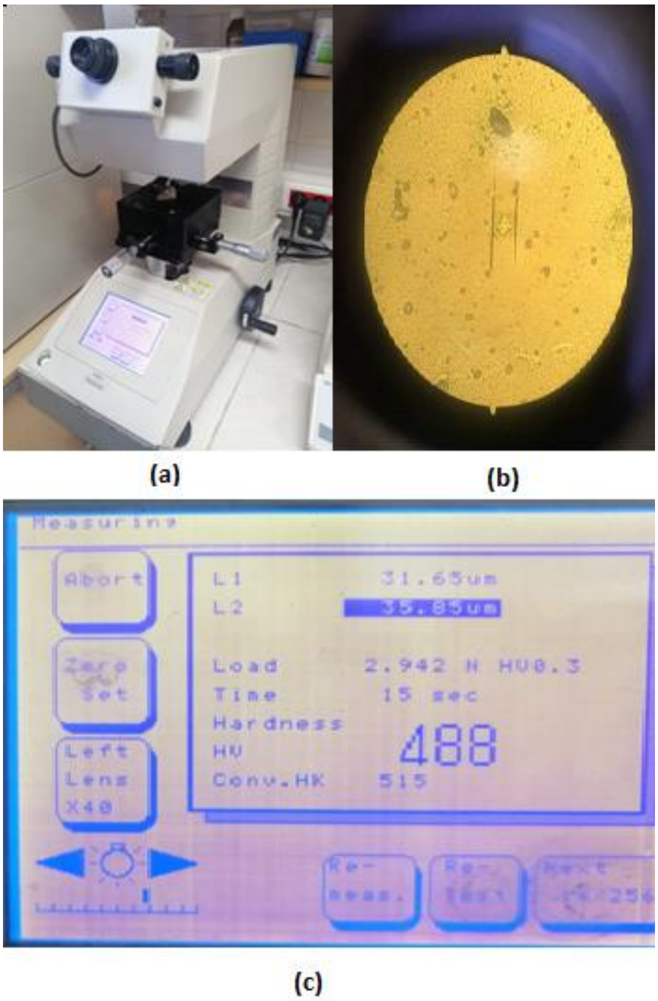

Figure 10. (a) SHIMADZU HMV Micro hardness Tester (b) Vickers Indenter Trace on Sample Surface (c) 12th sample Indent Size (L1-L2) & Indentation Test Result

A Micro hardness test was performed with a Shimadzu HMV micro hardness device. Measurements were taken from 12 different points on the sample surface and the indentation dimensions obtained are given in Table 5. Each indentation was performed by applying a load of 2.942 N for 15 seconds.

Table 5. Microhardness Vickers HV0.3 (Force:2.942, Time: 15sec)

#	Indent Size (µm)		HV	#	Indent Size (µm)		HV
	L1	L2			L1	L2	
1	35.9	35.9	432	7	38.11	38.11	383
2	37.76	36.5	404	8	37.36	37.36	399
3	35.26	36	438	9	33.95	33.95	483
4	37.1	37.1	464	10	34.68	32.97	486
5	35.52	35.5	441	11	39.52	35.26	398
6	35.5	35.5	441	12	31.65	35.85	488

As a result of the micro hardness measurement, the average HV value was obtained as “438.1 ~ 4.3 GPa”. Figure 11 shows the HV and corresponding GPa values obtained from the measurements.

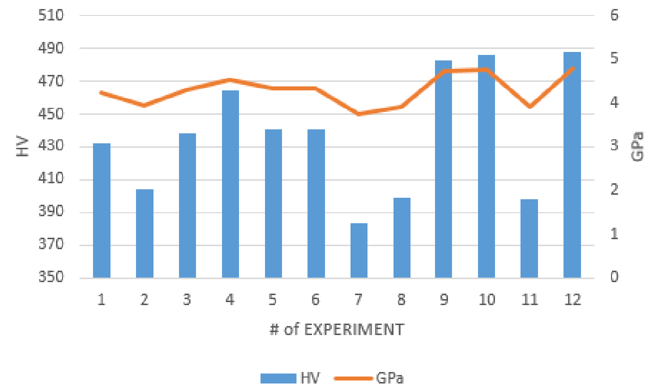

Figure 11. Microhardness HV~GPa Experimental Test Results

2.2. LambropoulosTheoretical Model

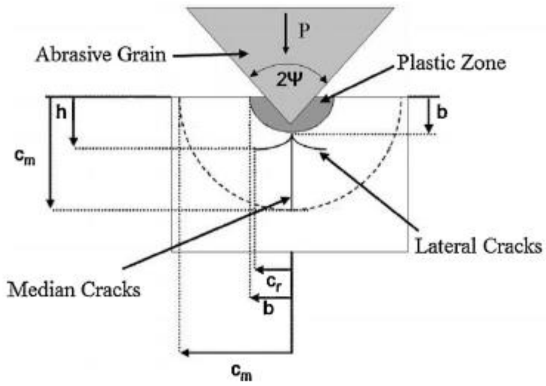

Figure 12. Schematic Representation of Lateral and Median Crack System in the Grinding Process (Esmaeilzare, Rahimi, and Rezaei 2014).

Considering the static/dynamic indentation processes for brittle materials, the crack system is

- the plastic zone under the indenter tip,
- lateral cracks formed under the plastic zone spreading parallel to the sample surface,
- median cracks formed under the plastic zone perpendicular to the sample surface.

It consists of three stages. The plastic region's shape is considered a semicircle with radius b (Lawn and Swain 1975).

Table 6. Zerodur Mechanical Properties (Karcı and Beldek 2021), (Esmaeilzare, Rahimi, and Rezaei 2014)

Material Properties	Symbol	Unit	Zerodur (Lit.)	Zerodur (Exp.)
Modulus of Elasticity	E	GPa	91	75
Poisson's Ratio	ν	-	0.24	0.24
Density	ρ	gr / cm^3	2.53	2.58
Hardness, knoop	H	GPa	6.2	8.3
Fracture Toughness	K_{IC}	MPa.m$^{1/2}$	0.9	0.86

Lambropoulos derived theoretical equations for lateral and median cracks based on micro-indentation mechanics and sharp-indentation according to the Hill model. Accordingly, the theoretical equation of the median crack depth is;

$$c_m = {\alpha_k}^{2/3} \left(\frac{E}{H}\right)^{(1-m)2/3} (\cot\psi)^{4/9} \left(\frac{P}{K_c}\right)^{2/3} \quad (2)$$

$$\alpha_k = 0.027 + 0.09\,(m - \frac{1}{3}) \quad (3)$$

Cm; median crack depth, P; indentation load, ψ; indentation sharpness angle, E; modulus of elasticity, H; hardness, Kc; workpiece fracture toughness is a constant without m (values between 1/3 and 1/2. Analyzes suggest 1/3 of this value (Sheng-yi, Zhuo, and Yu-lie 2014).) and αk; It is defined as a unitless constant that changes depending on m (Esmaeilzare, Rahimi, and Rezaei 2014).

Theoretical equation of lateral crack depth;

$$h = 0.43\,(\sin\psi)^{1/2}(\cot\psi)^{1/3} \left(\frac{E}{H}\right)^{m} \left(\frac{P}{H}\right)^{1/2} \quad (4)$$

In these equations, Lambropoulos assumed that subsurface damage and surface roughness were equal to median cracks or anal cracks, respectively, and established a relationship between subsurface damage, SSD, and surface roughness,SR,.

$$\frac{SSD}{SR} = \frac{c_m}{h} = 2.326\,(\alpha_k)^{\frac{2}{3}} \left(\frac{E}{H}\right)^{\frac{(2-5m)}{3}} \frac{(\cot\psi)^{\frac{1}{9}}}{(\sin\psi)^{\frac{1}{2}}} \left(\frac{P}{{K_c}^4/H^3}\right)^{\frac{1}{6}} (5)$$

Since the force in the Lambropoulos model can only be obtained by experimental methods and is difficult to measure, the following equations are obtained by combining the subsurface damage and surface roughness in the Lambropoulos model, leaving the force value alone in the equations.

$$P = \left(\frac{c_m}{\left({\alpha_k}^{2/3} \left(\frac{E}{H}\right)^{(1-m)2/3} (\cot\psi)^{4/9} \left(\frac{1}{K_c}\right)^{2/3}\right)}\right)^{3/2} \quad (6)$$

$$P = \left(\frac{h}{0.43\,(\sin\psi)^{1/2}(\cot\psi)^{1/3} \left(\frac{E}{H}\right)^{m} \left(\frac{1}{H}\right)^{1/2}}\right)^{2} \quad (7)$$

$$\left(\frac{c_m}{\left({\alpha_k}^{2/3} \left(\frac{E}{H}\right)^{(1-m)2/3} (\cot\psi)^{4/9} \left(\frac{1}{K_c}\right)^{2/3}\right)}\right)^{3/2} = \left(\frac{h}{0.43\,(\sin\psi)^{1/2}(\cot\psi)^{1/3} \left(\frac{E}{H}\right)^{m} \left(\frac{1}{H}\right)^{1/2}}\right)^{2} \quad (8)$$

$$\frac{{c_m}^{3/2}}{h^2} = \left(\frac{\alpha_k \left(\frac{E}{H}\right)^{(1-m)} (\cot\psi)^{2/3} \left(\frac{1}{K_c}\right)}{0.185\,(\sin\psi)(\cot\psi)^{2/3} \left(\frac{E}{H}\right)^{2m} \left(\frac{1}{H}\right)}\right) \quad (9)$$

$${c_m}^{3/2} = \left(\frac{\alpha_k \left(\frac{E}{H}\right)^{(1-m)} (\cot\psi)^{2/3} \left(\frac{1}{K_c}\right)}{0.185\,(\sin\psi)(\cot\psi)^{2/3} \left(\frac{E}{H}\right)^{2m} \left(\frac{1}{H}\right)}\right) h^2 \quad (10)$$

$$c_m = \left(\frac{\alpha_k \left(\frac{E}{H}\right)^{(1-m)} (\cot\psi)^{2/3} \left(\frac{1}{K_c}\right)}{0.185\,(\sin\psi)(\cot\psi)^{2/3} \left(\frac{E}{H}\right)^{2m} \left(\frac{1}{H}\right)}\right)^{2/3} h^{4/3} \quad (11)$$

$$SSD = 3.08\,(\alpha_k)^{\frac{2}{3}} \frac{1}{(\sin\psi)^{2/3}} \frac{H^{2m}}{E^{(2m-2/3)}\,K_c^{2/3}} SR^{4/3} \quad (12)$$

3. Result and Discussion

Due to the expensive and challenging supply of Zerodur material and the limitations of the workbenches and tools required for the grinding process, the studies involving the grinding process were carried out by taking into account the results obtained by different researchers before. If the brittle fracture is the dominant mechanism during chip removal, lateral cracks cause chip removal and surface roughness. However, median cracks also cause subsurface damage. In this context, Ref. in (Esmaeilzare, Rahimi, and Rezaei 2014), surface roughness values were obtained with a Hommel Etamic T8000 RC profilometer, and subsurface damage values were obtained from an AIS2000 scanning electron microscope using a metal bonded grinding wheel made of Ø30 mm x 10 mm Zerodur material were taken into account. In order to observe the cracks, etching was performed in HF solution for 10-12 seconds at room temperature (Esmaeilzare, Rahimi, and Rezaei 2014).

Table 7. Surface Roughness and Subsurface Damage Values Obtained in Experimental Study with Grinding Parameters (Esmaeilzare, Rahimi, and Rezaei 2014)

Depth of Cut (ae) (μm)	Feed Rate (Vw) (mm / rev)	Cutting Speed (Vc) (m/s)	SR (μm)	SSD (μm)
250	0.04	5	14.5	41.8
250	0.24	9	18	55.4
250	0.6	13	32	120
100	0.24	5	16.5	48.25
100	0.6	9	29	105
100	0.04	13	10.5	26.7
50	0.6	5	28	103.4
50	0.04	9	10	25.2
50	0.24	13	12	32.7

The grinding parameters given in the experimental study are as in Table 7. The sample is placed perpendicular to the machining surface. By positioning the sample surface, the sample surface is processed. The surface is then improved by polishing. The polished surface must also remain flat and perpendicular to the machined surface.

After the grinding process, the samples are cleaned with the help of acetone in an ultrasonic bath by melting the adhesive. Finally, the test surface is placed in the etching solution for SEM microscopy.

Table 8. Zerodur Material Properties Obtained from Literature and Experimental Studies and Ref. Lambropoulos Theoretical Model P and SSD Results According to SR Experimental Results from (Esmaeilzare, Rahimi, and Rezaei 2014)

Indenter Sharpness Angle	ψ	68	Indenter Sharpness Angle	ψ	68
Material Properties	E	91	Material Properties	E	75
(Literature)	H	6.2	(Experiment)	H	8.3
	K_{IC}	0.9		K_{IC}	0.85
LAMBROPOULOS THEORETICAL MODEL RESULTS					
SR (μm)	SSD (μm)	P (N)	SR (μm)	SSD (μm)	P (N)
14.5	37.7	2360	14.5	47.40	4350
18	50.41	3650	18	63.35	6720
32	108.35	11500	32	136.7	21300
16.5	45.02	3080	16.5	56.76	5700
29	95.39	9500	29	119.9	17500
10.5	24.68	1250	10.5	31	2300
28	90.99	8850	28	114.12	16250
10	23.34	1150	10	30.09	2200
12	29.69	1650	12	37	3000

Figure 13. shows the surface roughness and subsurface damage values obtained after this grinding process.

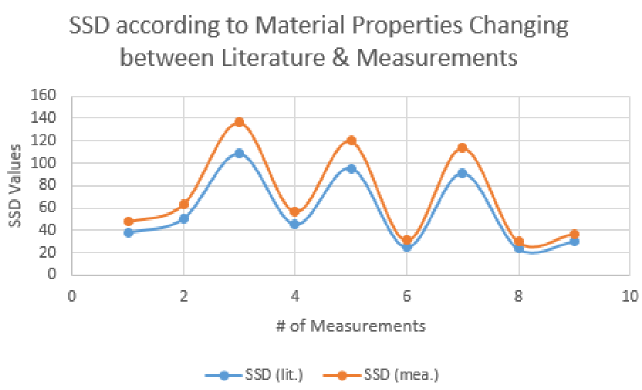

Figure 13. Subsurface Damage Change According to Change in Material Properties Comparison of Literature and Experimental Results

When the subsurface damage change graph in Figure 13 is calculated according to the change in material properties given in Table 6, the depth of subsurface damage in the material for which the characterization study was carried out with the experimental study is calculated as ~20% higher in all measurements.

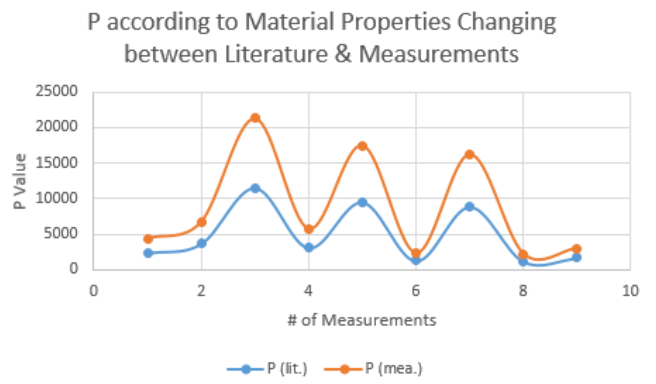

Figure 14. Change in Force Value According to Change in Material Properties Comparison of Literature and Experimental Results

Figure 14. shows the relationship between the force values calculated according to the change in material properties given in the literature in Table 6 and obtained as a result of the measurement. Accordingly, all measured force values were higher than those calculated in the literature.

4. Conclusion

This study aims to try to predict the relationship between surface roughness and subsurface damage based on Lambropoulos's theory by verifying the mechanical properties of Zerodur glass-ceramic material for the sample with experimental characterization tests. The theoretical model was used, considering the experimental results obtained earlier, and the following results were obtained.

- Zerodur material, which has structural integrity due to nanoindentation, microhardness, and vibration tests, has mechanical properties that are different from the material properties given in the literature. Differences in modulus of elasticity, hardness, density, and fracture toughness exist. Since this study is based on an exploratory study, the results can be further optimized by supporting the results with different experimental studies.

- It is crucial to perform characterization tests before grinding.

- The processing parameters of the sample with the characterization test should be optimized accordingly.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Antwi, Elijah Kwabena, Kui Liu, and Hao Wang. 2018. "A Review on Ductile Mode Cutting of Brittle Materials." Frontiers of Mechanical Engineering 13(2): 251–63.

Chen, Shun Tong, and Kai Chieh Yang. 2022. Semi-Ductile Cutting Regime Technology for Machining Zerodur Glass-Ceramic Microstructures. Precision Engineering 74(2022): 92–109.

Döhring, Thorsten et al. 2009. Heritage of ZERODUR® Glass Ceramic for Space Applications. Optical Materials and Structures Technologies IV 7425 (2009)

Ecss. 2012. Space Engineering - Testing. Ecss-E-St-10-03C (2012): 1–128.

Esmaeilzare, A., A. Rahimi, and S. M. Rezaei. 2014. Investigation of Subsurface Damages and Surface Roughness in Grinding Process of Zerodur ® Glass-Ceramic. Applied Surface Science 313: 67–75.

Komanduri, R., D. A. Lucca, and Y. Tani. 1997. Technological Advances in Fine Abrasive Processes. CIRP Annals - Manufacturing Technology.

Lawn, B. R., and M. V. Swain. 1975. Microfracture beneath Point Indentations in Brittle Solids. Journal of Materials Science 10(1): 113–22.

Li, Kun, and T. Warren Liao. 1996. Surface/Subsurface Damage and the Fracture Strength of Ground Ceramics. Journal of Materials Processing Technology 57(3–4): 207–20.

Sakai, Mototsugu. 2020. INDENTATION CONTACT Micro / Nano Physics of Materials. REVISED ED.

Steele, William A et al. 2021. Subsurface Mechanical Damage Correlations after Grinding of Various Optical Materials. 58(9).

Wang, Huadong et al. 2021. Evaluation of Subsurface Damage Layer of BK7 Glass via Cross-Sectional

Surface Nanoindentation. Precision Engineering 67(October 2020): 293–300.

Xavier Tonnellier. Precision Grinding for Rapid Manufacturing of Large Optics, PhD Thesis.

Zhenqiang Yao, Weibin Gu, Kangmei Li. Relationship between Surface Roughness and Subsurface Crack Depth during Grinding of Optical Glass BK7.

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Experimental Investigation of Performance and Emission Characteristics on Mini-scale Turbojet Engine Fueled with JetA1-Canola Methyl Ester (CME) Fuel Blends

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Abstract

The focus of this study is the experimental investigation of the effects of canola methyl ester (CME) and Jet-A1 fuel blends on performance and emissions of the mini-scale turbojet engine at different blend ratios and real flight power levels. Accordingly, $B_{2.5}$ (2.5% CME-97.5% Jet-A1), B_5 (5% CME-95% Jet-A1) and B_{10} (10% CME-90% Jet-A1) fuel blends and pure Jet-A1 fuel and power rates of taxi (7%), approach (30%), climb (85%) and take-off (100%) were tested and examined for static thrust, TSFC, EGT, emissions, noise and thermal efficiency. The results obtained show that up to 5% CME addition in turbojet engine has a maximum reduction effect of 19.6% on thrust, while this ratio is much less in partial power situations. This effect also causes an increase in the TSFC value. While the CO_2 value increased with the addition of CME, it caused a decrease in the CO and unburned HC values. However, the addition of CME caused increasing on noise level especially in taxi power state (about 7.8%), while no significant noise increase was observed in other power states. In terms of thermal efficiency, it has been observed that all fuel blends reduce efficiency in different power states, and it can be said that especially B_5 fuel blend can be used as a blend fuel in gas turbine engines at partial loads.

1. Introduction

The indispensable energy source of the aviation industry on a global scale is petroleum-based fuels. Meeting the high power needed by aircraft from another energy source does not seem possible at today's technology level. The fact that petroleum-based fuels have a high number of harmful emissions and that the petroleum resource will decrease over time in the future perspective motivates the studies for alternative fuels to meet this need.

Gas turbine engines, which operate according to the thermodynamic basis of the Brayton cycle, are used as the main power source of aircraft due to their high power/volume ratio. Although the basic structures of gas turbine engines are the same, they are divided into various types according to needs. The most important of these are Turbo-jet, Turbo-prop, Turbo-fan engines. These engines have structural changes with the needs of the aircraft. While the basic structure of a gas turbine engine is the compressor, combustion chamber and turbine. In a turbojet engine the thrust is generated as high velocity exhaust gases exit the jet nozzle. In turboprop and turbofan gas turbine engines, the energy of the exhaust gases is transferred to the shaft by means of a high-stage turbine, and thus, this shaft power is used to rotate the propellers in the turboprop engine and while a large diameter fan is rotated in the turbofan engine.

The main fuel of gas turbine engines was kerosene in the early years. Over time, kerosene-based fuels have been produced in line with the needs. The fuels of Jet-A, Jet-A1 and Jet-B are used in civil aviation, JP-4, JP-5 and JP-8 are used in military aviation.

According to estimates, it is thought that CO_2 emissions will increase by 51% in 2030 (Manigandan et al., 2020). Considering both the need for petroleum-based fuels and harmful emissions, it is essential to find natural resources that can be alternatives to petroleum-based fuels. Biologically sourced alternative fuels form the basis of research in this field. Fuels obtained from biological sources are used as additives to petroleum-based fuels, thus both a certain amount of fuel need is met from biological sources and a reduction in harmful emission gases is achieved. Vegetable oils obtained from oilseed plants, which have the most popular use as a fuel of biological origin. The use of these oils directly in gas turbine engines is not possible due to their low combustion rates (Arenas et al., 2017). For this reason, it is used as an additional fuel in engines by applying the transesterification process to the obtained biologically sourced oils (Enagi et al., 2018).

In the study of Kegl and Hribemik, it was observed that the viscosity and density of the fuel mixture increased with the addition of oil obtained from rapeseed to the fuel, while serious reductions in CO, HC and soot formation (Kegl et al., 2006). Hemighaus et al. investigated the usability of ethanol, methanol and oil methyl esters as an alternative fuel in gas turbine engines (Heminghaus et al., 2006). Manigandan et al. have shown that oxygen and fuel atomization in the fuel have serious effects on gas turbine engine performance and pollutant emissions (Manigandan et al., 2020). In this study, combustion, performance and emission parameters under different engine loads were investigated in a micro gas turbine engine by forming JET-A fuel blends with canola and sunflower oil. They showed that the biofuel blends used had a reducing effect on NO_x, CO and HC emissions. Similar results were obtained by Wang et al. and Moliere et al. (Wang et al., 2020; Moliere et al., 2009). In the study, a 50% reduction in CO emissions was observed. Biofuels obtained from jojoba and palm oil were tested by El-Zoheiry et al. and Talero et al. in a gas turbine engine at different power ratios (El-Zoheiry et al., 2020; Talero et al., 2020). In this studies with the addition of biofuel, there was a decrease in NO_x emission, while there was an increase in CO emission. It has also been observed that the use of palm oil causes serious reductions in thrust. This resulted in an increase in the amount of fuel required for a unit thrust. In their study, Chong and Hochgreb stated that due to the higher viscosity of biofuels, spray droplet structures and densities are larger, which has negative effects on fuel atomization and evaporation becomes more difficult (Chong and Hochgreb, 2014).

Within the literature review, due to the risk of damage to the turbine in gas turbine engines, much less experimental work has been done using full-size gas turbine engines (Chiaramonti et al., 2013; Habib et al., 2010; Nascimento et al., 2008; Allouis et al., 2010; Moore et al., 2017). it is possible to use alternative biological source oils in internal combustion engines, to grow canola which is an oilseed plant in non-food agricultural lands. To show the characteristics expected from jet fuels in terms of fuel properties of bio jet obtained from canola oil with Jet-A1 blends has been fundamental to focus on this study to show that it is alternative gas turbine engine fuel for the real power ratio values (taxi-approach- climb-take off) on a real mini scale jet engine.

2. Materials and Methods

2.1. Turbojet Gas Turbine Engine

Considering the high fuel consumption of gas turbine engines, the Jetcat P160 Rxi-B model, which is a mini gas turbine jet engine that can produce a maximum thrust of 160 N, was used in the study. Technical specifications of the Jet Engine are given in Table 1. And the schematic representation of the experimental setup and the experimental system in Selçuk University Civil Aviation School are given in Figure 1 and Figure 2, respectively.

Table 1. Specifications of the Jet engine used in experiments (Jetcat, 2022)

Specification	Value
Pressure ratio	3.1
Mass flow (kg/s)	0.38
Consumption Full load (ml/min)	510
Consumption idle (ml/min)	120
Weight [g]	1530
Dimensions of the diameter (mm)	112
Length (mm)	297
Compressor type	Single stage radial
Turbine type	Single stage axial
Idle rpm (1/min)	32000
Max rpm (1/min)	123000
Exhaust gas temperature (°C)	520-750
Exhaust gas velocity (km/h)	1590
Exhaust gas power output (kW)	37.5
Thrust at idle (N)	7
Thrust @ max Rpm (N)	160
SFC @ max Rpm (kg/N)	0.160

In the experiments, a flow-meter was used to determine the fuel consumption, loadcell-transmitter was used to measure static thrust, K type thermocouple was used for measurement of exhaust gas temperature (EGT), a specially designed sample probe and emission analyzer were used for determination of emission. Hall-effect rpm sensor was used for engine speed measurement and also ECU-pc and Arduino-pc hardware-software kits were used for data collection, recording and engine control. In addition, a linear roller bearing assembly used for create minimum friction ın order to measure the static thrust data without loss.

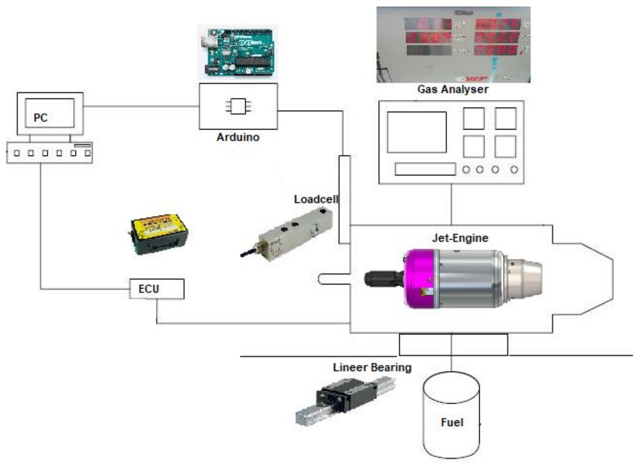

Figure 1. Schematic view of the experimental setup

In order to not to damage the jet engine during the experiments and to ensure a long life, the engine was run for 5 minutes with pure Jet-A1 fuel until the engine reached the regime temperature and after each experiment. Thus, before each experiment, the fuel system and engine met with pure Jet-A1 fuel.

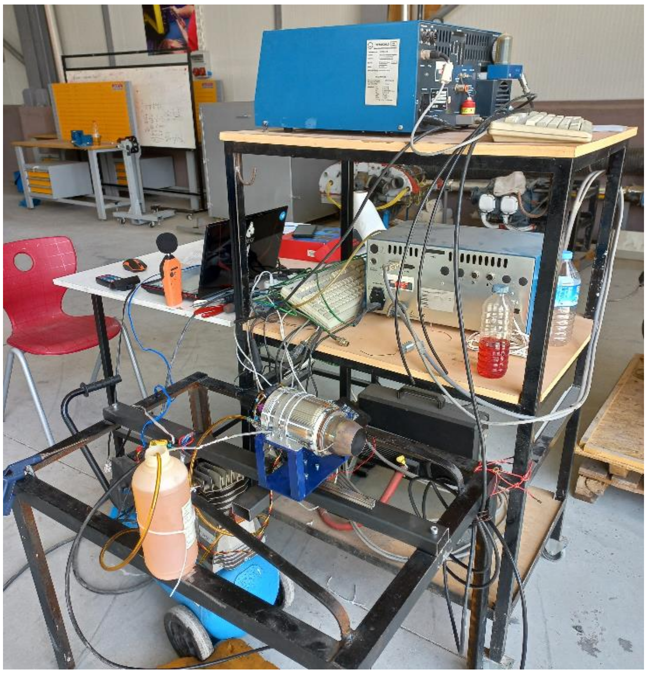

Figure 2. Experimental system of the Jet Engine

2.2. Fuel Blends Used in Experiments

Since vegetable oils have high viscosity and contain glycerine, they are not suitable for direct use in gas turbine engines. If used directly in engines, combustion will deteriorate and cause serious problems in engine performance and fuel system. For this reason, the canola oil used in the experiments was brought into the form of biofuel suitable for use in gas turbine engines by the method of transesterification (mixing, heating, washing and boiling steps). In the transesterification method, methanol is used as alcohol and KOH is used as catalyst. The important point here is that the amount of KOH used is less than 1% by weight (Aldhaidhawi et al., 2017). Otherwise, disruptions occur in the transesterification process.

Canola methyl ester (CME) and Jet-A1 fuel blends were prepared at the rates of 2.5%, 5.0%, 10% CME, considering the future production perspective of the canola plant and international legal regulations. In order to fully blend the prepared fuels, the mechanical and ultrasonic mixing technique was applied at room temperature and homogenization was achieved. The properties of Jet-A1, CME and their blends are given in Table 2.

Table 2. Properties of the Jet-A1, CME and their blends

Properties	Jet-A1	CME	$B_{2.5}$	$B_{5.0}$	B_{10}
Density (g/cm3, 15°C)	0.775	0.912	0.795	0.810	0.825
Viscosity (mm^2/s, 40°C)	1.37	3.5	1.67	2.85	3.14
Lower calorific value (kJ/kg)	42676	38492	42258	41317	40584
Flash Point (°C)	38	245	44	58	65
Freezing Point (°C)	-47	-8	-45	-42	-40
Cetane number	42	39.5	41.8	41.5	41

The addition of CME increased the densities of the fuel blends and caused a decrease in the calorific values. Besides, the addition of CME, which has a high flash point and freezing point, significantly increased the flash points and freezing temperatures of the blended fuels. However, when the properties of all blended fuels are examined, it can be said that up to 10% CME fuel addition will be suitable for use in gas turbine engines.

2.3. Experimental Procedure

In order to investigate the effects of different fuel blends on engine performance and emissions, experiments were carried out by applying the power values of the turbojet engine in real flight conditions. These power values are 7%, 30%, 85% and 100% for taxi, approach, climb and take-off, respectively. In the experiments carried out at these power values, the performance and emission measurements were recorded instantly. In addition, each experiment was repeated 3 times and the analytical average was taken.

In order to ensure the same environmental conditions in each experiment, the experiments were completed within a few days and in the same time zone. In the ambient condition measurements, it was observed that the temperature, humidity and pressure values in the environment deviated by about 1% during the experiments. Before starting the engine experiments, the jet engine was run with pure Jet-A1 fuel in idle state for 5 minutes. Thus, both the engine is heated and the fuel system is purified from the Jet-A1-bio fuel blends. Then the prepared fuel blend was given to the engine. When it was ensured that the fuel system was completely filled with the new blend fuel after a fixed 1-minute operation, experiments were carried out for different power values and measurements were taken. Before each experiment, the initial test conditions were met by running for 5 minutes with pure Jet-A1 fuel.

Even if the measurement values are recorded instantly, measurement uncertainties occur due to various reasons such as measurement equipment, environmental conditions and human errors. For this reason, it is necessary to evaluate the measurement results together with uncertainty analysis. We can generally define the uncertainty that occurs for all measurements with the following Equation 1 (Holman, 2001). The measurement uncertainties calculated using Equation 1 are presented in Table 3.

$$w_R = \pm\left[\left(\frac{\partial R}{\partial x_1}w_{x_1}\right)^2 + \left(\frac{\partial R}{\partial x_2}w_{x_2}\right)^2 + \left(\frac{\partial R}{\partial x_3}w_{x_3}\right)^2 + \dots + \left(\frac{\partial R}{\partial x_n}w_{x_n}\right)^2\right]^{1/2} \quad (1)$$

Table 3. Uncertainties of the experimental results

Parameter	Uncertainty
Static thrust (N)	±0.019
Fuel consumption (ml/min)	±0.020
EGT (ºC)	±0.001
Carbon monoxide (% Vol)	±0.002
Carbon dioxide (%Vol)	±0.002
Hydrocarbon (ppm)	±0.020
Noise level	±0.024

When the uncertainty analysis results were examined, it was seen that the measurement uncertainty values were sufficient for the experimental measurements and the data collected and the experiments were carried out.

In addition, the thermal efficiency of the turbojet engine, which is the ratio of the exhaust kinetic energy to the heat content of the fuel used, was calculated by Equation 2 using the exhaust gas output velocities measured from the experiments.

$$\eta_{th} = \frac{(1+f)\frac{V_e^2}{2}}{fQ_R} \quad (2)$$

In this equation, Q_R is the heat value of the fuel, V_e represents the exhaust velocity, and f is the fuel/air ratio. These data needed for calculation are transferred to the computer software by means of the electronic control unit of the jet engine. In a jet engine operating according to the Brayton cycle, the thermal efficiency is expected to be between 2.2% and 5% at small compression ratios obtained with a single-stage turbine according to calculations (Patricio and Tavares, 2010).

3. Result and Discussion

To investigate the usability of bio derived fuels like $B_{2.5}$ (97.5% Jet-A1, 2.5% CME), B_5 (95% Jet-A1, 5% CME), B_{10} (90% Jet-A1, 10%CME) as aviation fuel, the effects of fuel blends on jet engine performance and emissions were investigated. In addition, comparisons were made by performing experiments with pure Jet-A1 fuel.

3.1. Static Thrust

Static thrust measurements were performed by operating the jet engine for different flight power conditions for each fuel blend and pure Jet-A1 fuel. Obtained static thrust values are given in Figure 3.

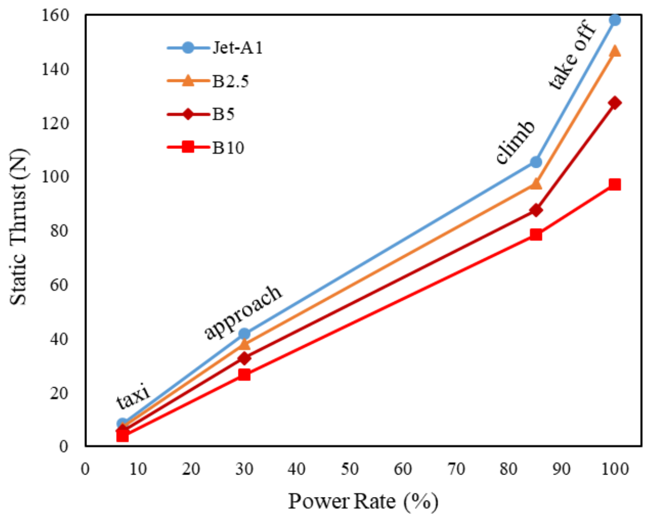

Figure 3. Static thrust developed as a function of engine power loads for fuel blends

When the Figure 3 is examined, the maximum thrust reduction occurs as 25.71% for B_{10} fuel in partial power situations, while this decrease is 38.61% for the same fuel blend at full power. Thrust reduction for B_5 fuel is 17.1% at partial loads and 19.6% at full power. The reason for this decrease in thrust can be explained by the delay in combustion at high engine speeds. The difficulty in evaporation as the biofuel ratio in the fuel blend increases, the inability to complete the combustion event in the combustion chamber with the prolonged combustion time, and the decrease in the exhaust velocity as the energy of the fuel continues to be released after the exhaust nozzle by continuing after the turbine.

3.2. Thrust Specific Fuel Consumption (TSFC)

The amount of fuel required to generate 1N thrust in aircraft engines is called thrust specific fuel consumption (TSFC). TSFC values were obtained for different fuel blends at different power states are given in Figure 4.

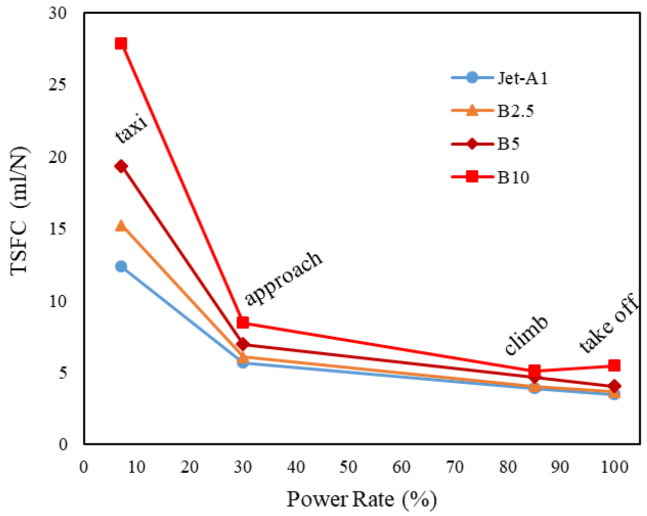

Figure 4. Thrust specific fuel consumptions as a function of engine power loads for fuel blends

When Figure 4 is examined, the amount of fuel required for unit thrust decreases as the speed increases, in accordance with the characteristics of the jet engine. This situation is seen similarly for all fuel blends. However, as the biofuel ratio increases, there is a significant increase in the fuel consumption required for the unit thrust, especially for the taxi situation. This is due to the decrease in the calorific values of the biofuel blends and the combustion delay, and the combustion not taking place in accordance with the engine characteristics. In addition, it is seen that the increase in TSFC values at higher partial power conditions and at full power the maximum increase is around of 36%.

3.3. Exhaust Gas Temperature (EGT)

Exhaust gas temperatures for the different fuel blends tested are given in Figure 5. A decrease in EGT value was observed at all power levels except the Taxi situation. This decrease was 2% for approach, 1.6% for climb and 7.3% for takeoff. The reason for this decrease in the exhaust gas is due to the fact that the combustion characteristics of bio jet fuel are worse than that of Jet A1 fuel, and therefore the combustion chamber temperatures are low.

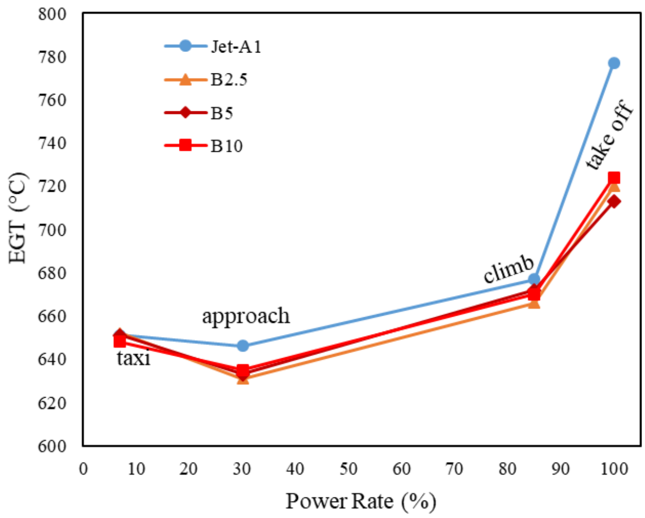

Figure 5. Exhaust gas temperature as a function of engine power loads for fuel blends

The EGT values for all fuels varied between 631 °C and 777 °C from taxi to takeoff power levels. While EGT is lower at low power loads, and increase with the increase of power levels. High EGT value means high energy exhaust gas fluid, that is, higher thrust. This shows that at the same power level, higher temperature will create more thrust. However, in terms of material strength, exceeding the design temperatures will seriously reduce the engine life.

3.4. Emission Measurements

In internal combustion engines such as turbojet engines, carbon dioxide (CO_2) and water vapor (H_2O) occur mainly in the end products of combustion (Turns, 2000). Besides, other emission parameters like carbon monoxide (CO) and unburned hydrocarbons (HC) showing how the combustion occurs physically and chemically. The presence of CO and HC in the end of combustion products is the most basic indicator that the combustion is not fully realized. If the combustion were theoretical complete, these emissions would not be included in the end products of combustion and only the basic emissions, CO_2 and H_2O, would occur. In Figures 6, 7 and 8, CO_2, CO and HC emissions are given for different power levels, respectively.

As the amount of CME in the fuel mixture increases, the CO_2 emission increases. Although this situation is seen in all power levels as seen in Figure 6. The CO_2 emissions are approximately the same for Jet-A1 and $B_{2.5}$ fuels, especially at high power levels. The opposite situation is seen for CO emission in Figure 7. The increase in CME in fuel mixtures causes a decrease in CO emissions. This is explained by the improvement of combustion, which is associated with the high amount of O_2 in the CME, as in all biofuels.

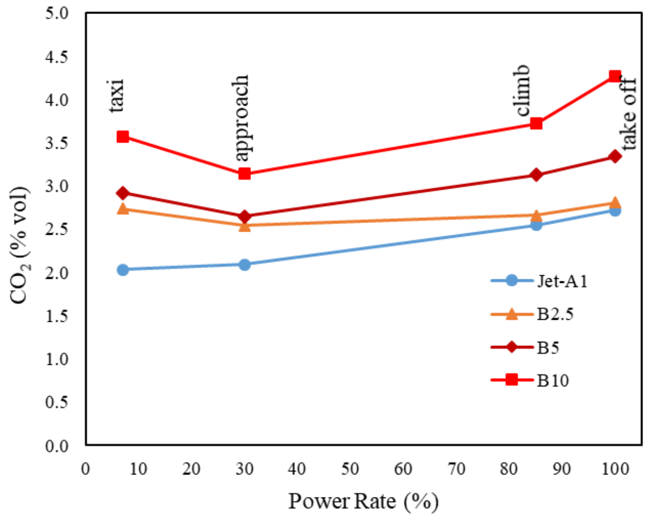

Figure 6. The effect of biojet blends at different power ratios on CO_2 emission

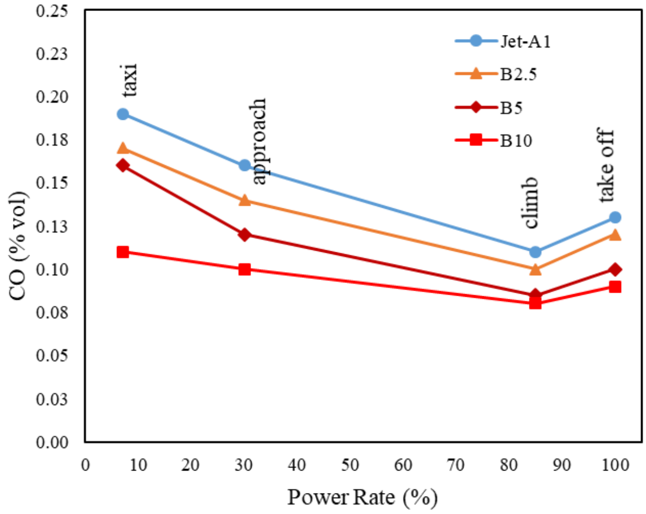

Figure 7. The effect of biojet blends at different power ratios on CO emission

However, as can be seen in Figure 7, the decrease in the amount of CO valid for all fuel mixtures increased for all fuel mixtures at high power cycles. This can be explained by the relative deterioration of the combustion phenomenon, especially at load power cycles, and the insufficient time required for combustion.

When Figure 8 is examined, there is a decrease in unburned HC emissions at all power levels. This is associated with increased CO_2 and reduced CO emissions, as a result of more efficient combustion of fuel blends. In addition, a decrease in the HC decreasing trend was observed at high power levels. This is explained by the decrease in combustion efficiency at high engine speeds.

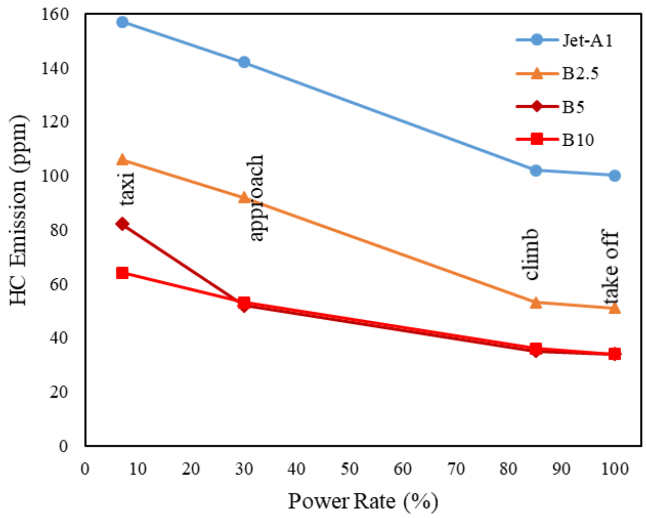

Figure 8. The effect of biojet blends at different power ratios on HC emission

3.5. Noise Emission

Noise emission is mostly produced by turbojet engines among gas turbine engines. Due to its nature, high-speed jet exhaust flow brings high sound levels and poses a problem for high-speed passenger and military aircraft using turbojet engines. For this reason, measurement of sound levels for different fuels is a necessity. Figure 9 shows the sound level (noise) values released from the turbojet engine of the fuel blends at different power levels.

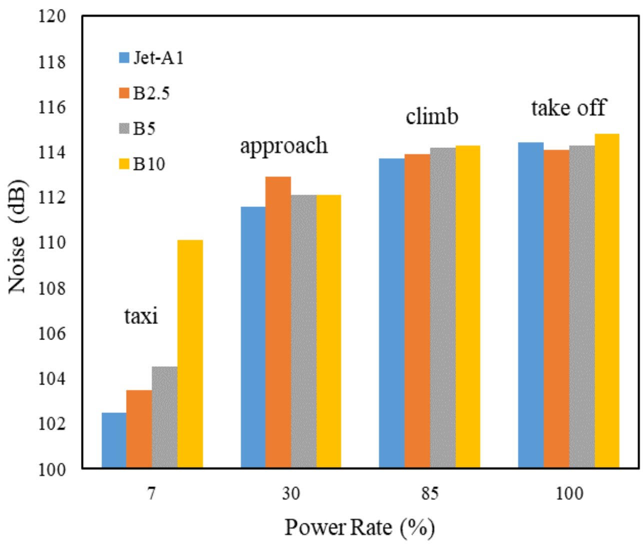

Figure 9. The effect of biojet blends at different power ratios on noise levels

When Figure 9 is examined, it is seen that the increase in the CME ratio in the fuel blend increases the noise, especially in the case of taxi, and the maximum increase is 7.8% in the B_{10} fuel. When looking at other power levels, it is seen that the noise levels are very close to each other for fuel blends, with a maximum deviation of 1.1%.

3.6. Thermal Efficiency

Thermal efficiency is one of the parameters that shows the conversion of the chemical energy of the fuel into kinetic energy with taking into account of the thermodynamic cycle efficiency. Kinetic energy consists of the exit velocity of the exhaust gases in accordance with the characteristics of the jet engine. In Figure 10, the thermal efficiency for different fuel blends is given for different load conditions.

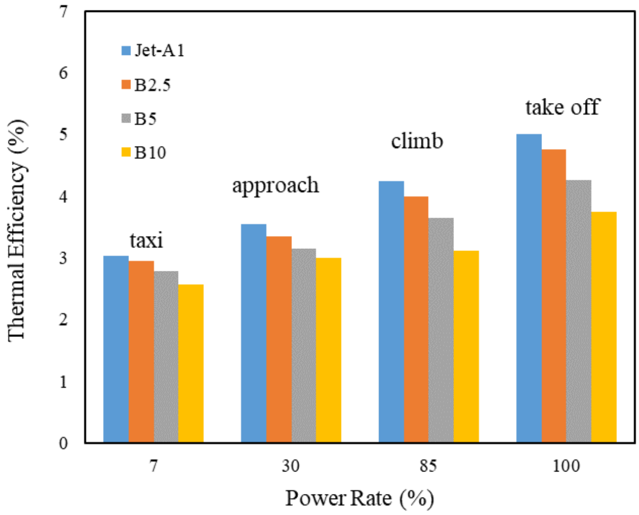

Figure 10. The effect of biojet blends at different power ratios on thermal efficiency

As seen in Figure 10, the thermal efficiency decreases with the addition of CME in all load cases. Since the thermal efficiency is expressed as the ratio of the kinetic energy of the exhaust gases to the thermal value of the fuel, the decrease in the calorific values in Table 2 is expected to increase the thermal efficiency, while the rapid decrease in the output velocity of the exhaust gases caused a decrease in the thermal efficiency. In other words, this is due to the fact that the decrease in the exhaust gas velocity with the addition of CME occurs faster than the decrease in the calorific values of the fuel blends. For this reason, the decrease in thermal efficiency occurred more at take-off than at partial loads.

4. Conclusion

The rapid development of aviation in the world and the dependence of the aviation industry on internal combustion engines cause the demand for petroleum and petroleum-derived fuels to increase gradually, despite the decrease in their reserves. In the future perspective, a part of the fuel need of the aviation industry is met by a small rate of bio-based fuels, which corresponds to large amounts of fuel. The findings obtained in this study, which was carried out as a part of the search for alternative gas turbine engine fuels in terms of performance and emissions, can be summarized as follows;

- Up to 5% CME addition in turbojet engine has a maximum reduction effect of 19.6% on thrust, while this ratio is much less in partial power situations. B_5 is a suitable fuel for partial load situations without exceeding 5% as an alternative fuel addition, as there is a significant reduction in thrust when the CME addition is greater than 5%.

- It has been observed that the addition of CME causes significant increases in TSFC value at partial power conditions (especially before 30% power rate).

- Exhaust gas temperatures decreased with the addition of CME for all power states. While this situation is welcomed in terms of material strength, it creates a disadvantage for the thrust due to the kinetic energy of the gases.

- With the addition of CME, there was an increase in CO_2 emissions in all power situations, while there was a decrease in CO and unburned HC emissions. This shows that the combustion is improved with O_2 in the CME and the addition of CME has a positive effect on combustion and emissions.

- It was observed that the addition of CME increased the noise emission, especially in the case of taxi (7% power) and this increase was 7.8%. In all other power conditions, the noise increase was below 1.1%. This shows that the addition of CME does not cause a significant increase in noise emissions, especially for jet engines with high noise levels.

- A reduction in thermal efficiency is observed at all power states for all fuel blends. While it is thought that the reduction of the fuel specific heats with the addition of CME will increase the thermal efficiency, the deterioration in the combustion characteristics reduces the kinetic energy of the exhaust gases faster. This resulted in a decrease in thermal efficiency.

Nomenclature

CME	Canola methyl ester
TSFC	Thrust specific fuel consumption, ml/N
CO_2	Carbon dioxide, %vol
CO	Carbon monoxide, %vol
O_2	Oxygen
HC	Hydro carbon (ppm)
EGT	Exhaust gas temperature °C
Ecu	Electronic control unit
η_{th}	Thermal efficiency

Ethical approval

Not applicable.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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References

Aldhaidhawi, M., Chiriac, R., Badescu, V. (2017). Ignition delay, combustion and emission characteristics of Diesel engine fueled with rapeseed biodiesel–A literature review. Renewable and Sustainable Energy Reviews, 1(73), 178-86.

Allouis, C., Beretta, F., Minutolo, P., Pagliara, R., Sirignano, M., Sgro, L. and D'Anna, A. (2010). Measurements of ultrafine particles from a gas-turbine burning biofuels. Experimental Thermal and Fluid Science, 34 (3), 258-261.

Arenas, E.G., Rodriguez Palacio, M.C., Juantorena, A.U., Fernando, S.E., Sebastian, P.J. (2017). Microalgae as a potential source for biodiesel production: techniques, methods, and other challenges. International Journal of Energy Research, 41(6),761-89.

Chiaramonti, D., Rizzo, A.M., Spadi, A., Prussi, M., Riccio, G. and Martelli, F. (2013). Exhaust emissions from liquid fuel micro gas turbine fed with diesel oil, biodiesel and vegetable oil. Applied Energy, 101, 349-356.

Chong, C.T. and Hochgreb, S. (2014). Spray flame structure of rapeseed biodiesel and Jet-A1 fuel. Fuel, 115, 551-558.

El-Zoheiry, R.M., EL-Seesy, A.I., Attia, A.M., He, Z. and El-Batsh, H.M. (2020). Combustion and emission characteristics of Jojoba biodiesel-jet A1 mixtures applying a lean premixed pre-vaporized combustion technique: An experimental investigation. Renewable Energy, Vol 162, 2227-2245.

Enagi, II., Al-Attab, K.A., Zainal, Z.A. (2018). Liquid biofuels utilization for gas turbines: a review. Renewable and Sustainable Energy Reviews, 1(90), 43-55.

Habib, Z., Parthasarathy, R. and Gollahalli, S. (2010). Performance and emission characteristics of biofuel in a small-scale gas turbine engine. Applied Energy, 87 (5), 1701-1709.

Hemighaus, G., Boval, T., Bosley, C., Organ, R., Lind, J., Brouette, R., Thompson, T., Lynch, J. and Jones, J. (2006). Alternative jet fuels. Chevron Corporation Addendum 1.

Holman, J. P. (2001). Experimental methods for engineers. Mc-Graw Hill, New York.

Jetcat, (2022). https://www.jetcat.de/en/productdetails/ produkte /jetcat/produkte/hobby/Engines/P160_rxi_b (Access Date: 14.November.2022).

Kegl, B. and Hribernik, A. (2006). Experimental analysis of injection characteristics using biodiesel fuel. Energy Fuels, 20(5), 2239-2248.

Manigandan, S., Atabani, A., Ponnusamy, V.K. and Gunasekar, P. (2020). Impact of additives in Jet-A fuel blends on combustion, emission and exergetic analysis using a micro-gas turbine engine. Fuel, 276, 118104.

Moliere, M., Vierling, M., Aboujaib, M., Patil, P., Eranki, A., Campbell, A. (2009). Gas turbine in alternative fuel applications: bio-ethanol field test. In: ASME turbo expo 2009: power for land, Sea and Air. GT2009-59047. Orlando, Florida, ASME, 1-8.

Moore, R.H., Thornhill, K.L., Weinzierl, B., Sauer, D., D'Ascoli, E., Kim, J., Lichtenstern, M., Scheibe, M., Beaton, B. and Beyersdorf, A.J. (2017). Biofuel blending reduces particle emissions from aircraft engines at cruise conditions. Nature, 543 (7645), 411-415.

Nascimento, M.A., Lora, E.S., Corrêa, P.S., Andrade, R.V., Rendon, M.A., Venturini, O.J. and Ramirez, G.A. (2008). Biodiesel fuel in diesel micro-turbine engines: Modelling and experimental evaluation. Energy, 33 (2), 233-240.

Patricio, P., and Tavares J.M. (2010). Simple thermodynamics of jet engines. American Journal of Physics, 78 (809), 809-8014.

Talero, G., Bayona-Roa, C., Silva, V., Mayorga, M., Pava, J. and Lopez, M. (2020). Biodiesel substitution in a J69 aeronautic turbine engine: An experimental assessment of the effects on energy efficiency, technical performance and emissions. Sustainable Energy Technologies and Assessments, Vol 40, 100746.

Turns, S.R. (2000). An introduction to combustion. Mc-Graw Hill, New York, 2nd edition.

Wang, Z., Feser, J.S., Lei, T. and Gupta A.K. (2020). Performance and emissions of camelina oil derived jet fuel blends under distributed combustion condition. Fuel, 271, 117685.

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Cancer Awareness Among Airline Pilots

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Abstract

A high level of cancer awareness may contribute to early diagnosis and improve cancer survival. This study is aimed to assess the level of awareness of occupational cancer among airline pilots. To the best of the authors' knowledge, this study has examined pilots' occupational cancer awareness levels for the first time. A brand-new cancer awareness survey was used to examine the awareness level of airline pilots on cancer. The analysis of variance (ANOVA) method was employed to analyze the survey results. The response rate was % 43.6. Data had been collected from 523 individuals, 48 of whom were female pilots. Of the participants 67.3% were long-haul pilots. Female airline pilots were much more aware of cancer in comparison to male airline pilots. Pilots flying 81-90 hours per month were much more aware of cancer in comparison to other participants. Academic articles, magazines and social media were sources of knowledge for 64.6 % of pilots whereas 39.5% of pilots were informed by e-learnings and recurrent trainings regarding the occupational cancer. According to the findings of this study, there is a need for training and media-based interventions to raise awareness and instil safe and healthy lifestyle practices at the workplace in the airline industry.

1. Introduction

Cancer is a major area of interest within the field of occupationally related diseases. Occupational diseases have been extensively examined for decades (Şen et al., 2019). The term "De morbis artificium diatriba" (Diseases of workers) was first introduced by Bernardino Ramazzini in 1700 (Ramazzini, 2001). After that, a great number of studies have been carried out on this particular subject (Van Tongeren et al., 2012).

In 1775, Percival Pott reported the first occupational cancer (Herr, 2011). Aircrews, miners and quarry and construction workers are among the high-risk occupations which are exposed to work related carcinogens.

Cancer is one of the most common causes of mortality among pilots and incidence is increasing worldwide (Hammer et al., 2012; Bagshaw & Cucinotta, 2008). Incidence studies suggest that cancer is accounted for a larger mortality among United States commercial pilots. It has been reported that airline crew in Germany had the highest radiation exposure among the occupational groups (Wollschläger et al., 2018). Moreover, a considerable amount of literature has been published on cancer incidence among airline pilots from several European countries (Irvine & Davies, 1999; ,Haldorsen et al., 2000; Hammer et al., 2012) and Japan (Kaji et al., 1993). It has been reported that three most common cancers among airline pilots are skin cancer, prostate cancer and brain cancer (Gudmundsdottir et al., 2017).

Medical status of pilots is of great importance for safe piloting to ensure the maintenance of aviation safety (Kilic, 2021). Airline pilots are occupationally exposed to specific occupational risk factors (carcinogens) such as cosmic radiation, circadian dysrhythmia, non-ionizing radiation, electromagnetic fields and jet fuel combustion products (McCartney et al., 1986) potentially leading to cancer (Raslau et al., 2016).

Cosmic radiation is an ionizing radiation originates outside the solar system and interacts with the earth's atmosphere (ICAO, 2012). Airline pilots are exposed to elevated levels of radiation (cosmic galactic radiation) at aircraft cruising altitudes in comparison to the exposure at sea level (Bagshaw & Illig, 2018). It has been reported that the highest radiation dose levels were measured on polar routes and at high altitudes (Langner et al., 2004). Hammer et al reported that there was a positive trend of all cancer with radiation dose (Hammer et al., 2012).

Low-frequency electromagnetic fields in the cockpit is one of the environmental factors which may be attributed to cancer (Nicholas et al., 1998). This electromagnetic field is generated by the aircraft's electrical system. It has been suggested that there may be an association between electromagnetic field exposure and reduced melatonin level (Stevens et al., 1992) which is known for impeding prostate cancer metathesis (Wang et al., 2020).

Non-ionizing radiation is known as a series of energy waves such as ultraviolet radiation from sunlight, infrared radiation from mobile phones, radiofrequency and microwave radiation, extremely low frequency radiation from electrical equipment and electrical wiring (United States Department of Labor, 2021). Exposure to non-ionizing radiation may give rise to serious burns, permanent eye damages (e.g., cataracts), and malignant diseases (e.g., skin cancer)(Dyro & Morris, 2004; Cadilhac et al., 2017).

Disruption of circadian rhythms is one of the most important factors causing fatigue among pilots (Goffeng et al., 2019) and has been associated with several types of cancer (Cadilhac et al., 2017).

Pilots operating long-haul aircraft are exposed to time zone displacements and disturbed sleep which might impede their performance and cause insomnia (Gander et al., 2014). Furthermore, the International Agency for Research on Cancer (IARC) described the circadian rhythm disruption as a potential carcinogenic to humans (WHO-International Agency for Research on Cancer, 2010)

Jet fuel combustion products are among the occupational risk factors and they contain carcinogenic compounds including polycyclic aromatic hydrocarbons (Ritchie et al., 2003). It has been reported that exposure to kerosene type fuel (aviation fuels), which is widely used in civil aviation, may cause cancer (Siemiatycki et al., 1988).

Smoking (Carbone, 1992), imbalanced diet (Key et al., 2020), and recreational sun exposure (Newman et al., 1996) are among the factors associated with cancer. It has been reported that smoking, including passive exposure gives rise to 80% of lung cancer (Alberg & Samet, 2003). Previous studies on pilot have reported that smoking prevalence among pilots are predominant (Ahsan MA et al., 2016) (Hall et al., 2018). However, other researchers have reported that the prevalence of smoking among pilots is lower than smoking prevalence in Swedish normal population (Lindgren et al., 2008). Several studies highlighted that there were strong correlations between several types of cancer and dietary factors (Armstrong & Doll, 1975). A number of studies have reported that there was a strong association between recreational sunburn and risk of skin cancer (Oliveria et al., 2006).

Piloting profession is a sedentary occupation. Long-term sitting in the cockpit may give rise to sorts of problems such as venous thromboembolism (Kilic & Soran, 2020), back strain (Rodriguez & Ortiz Mayorga, 2016), and colon cancer (Garabrant et al., 1984). Another important factor associated with cancer is the duration of the employment. It was shown that there was a positive correlation between the duration of employment and cancer (Hammer et al., 2014).

A great number of airlines launched cancer awareness campaigns and raised money to support cancer research projects. For instance, each October, Delta airlines hosts its annual campaign to encourage employees to generate cancer awareness and support breast cancer research fundraising (Staff Writer, 2021). Cargolux Airlines participated in the Fly Pink fundraising initiative (Rachelle Harry, 2019).

Although extensive research has been carried out on cancer incidence among pilots, no single study exists which examine cancer awareness of airline pilots. With these consideration in mind, the aim of this study is to investigate the awareness level of airline pilots on cancer and occupational risk factors.

Based on the issues mentioned above, we offered the following hypotheses. The first hypothesis proposed that the awareness level of airline pilots on occupational cancer may vary based on the demographics. The second hypothesis was “the effort of airline pilots to be informed on occupational cancer may vary based on demographics.” The third hypothesis proposed that the risk factors of occupational cancer for airline pilots may vary based on the demographics.

2. Materials and Methods

2.1. Subjects

The study sample consisted of 523 airline pilots from 5 different airline companies, all based in Turkey. Participation in this study was voluntary and unpaid. The majority of the subjects (59.7%, *N*= 312) were airline captains. Of the respondents, 29.4% (*N*=154) were first officers and 10.7% (*N*=56) senior first officers (cruise relief pilots). Of the participants, 475 (90.8%) were men and 48 (9.2%) were women. Approximately, one half of the participants had more than 20 years flight experience. Almost two-thirds of the participants (68.1%, *N*=352) fly long-haul aircrafts (e.g., Boeing 777,787, 777-Freighter, Boeing 747, Airbus A330, Airbus 340 and Airbus 350). 9,9% of those who were interviewed (*N*=52) were 20-30 yr of age, 40% (*N*=209) of the participants were 31–40 yr of age, (*N*=134) of the participants were 41-50 yr of age, and 24.5% (*N*=128) of the subjects were older than 50.

2.2. Survey

The questionnaire was developed based on input from field experts and the research literature on occupational cancer and aviation medicine. Cronbach’s alpha test was performed to test the reliability of 13 expressions and factor analysis was used to determine the consistency. The questionnaire was distributed online to 1200 airline pilots who are based in Turkey. 523 of them responded to the questionnaires. The response rate was % 43.6. The questionnaire consisted of 20 items and 4 sections. The first section consists of questions regarding the demographics of subjects, such as gender, age, total flying experience, ranking, current type rating (Questions 1-6). In the second part, the participants were asked whether they had been informed about occupational cancer through e-learnings and recurrent trainings, whether they had read books, academic articles, and magazines on the subject and whether they had used of social media as an informative source were questioned (Questions 7 and 8). In the third section, eight items were used to assess the awareness level of participants on occupational cancer and carcinogens (Questions 9-16,20). The final section of the questionnaire asked if they wear sunscreen in the cockpit, can maintain a balanced diet during the flight and layover and smoke cigarettes were questioned (Questions 18 and 19). The participants answered the questions on a 5-point Likert-type scale that ranges from “1- strongly disagree” to “5- strongly agree”.

2.3. Statistical analysis

Data analyses were performed using SPSS (the Statistical Package for the Social Sciences) for Windows 24.0. Kolmogorov-Smirnov test was performed to examine the compliance of the parameters with normal distribution. A one-way ANOVA was used to assess the results of the survey. Prior to ANOVA test, the Levene’s test was conducted to test the equality of variances. For unequal variances, the Tamhane T2 test was performed. The Bonferroni correction was used for equal variances. A 95% confidence interval and a significance level of $P < 0.05$ were used for the interpretation of the results.

3. Result and Discussion

The results revealed that pilots had little knowledge of occupational cancer. Of those participants, 45.5% (N=238) reported that they could maintain a balanced diet during the flight and layover. Almost half of the respondents (47.6%, N=249) indicated that they did not wear sunscreen in the flight deck. The results are in the line of earlier literature that found a minority of airline pilots (14%1) use sunscreen (Yong et al., 2022). Of those respondents, 45.7% (N=239) reported that they smoked cigarettes The finding is consistent with findings of past studies by Ahsan et al. which found almost half of the pilots (42%) were smokers (Ahsan MA et al., 2016). A minority of participants (20.1%, *N*=105) indicated that they had been informed about occupational cancer by e-learning and recurrent trainings. Approximately one-third of those surveyed (30%, N=157) said that they read books, academic articles, and magazines about occupational cancer and follow the topic on social media.

The most striking results from the data is that 68.2% (N=357) of those questioned were aware of the recreational sun exposure (during the holidays and layovers) which accounts for many acute and chronic dermatological diseases, including skin cancer.

Table 1. Study results based on the demographic factors

		Risk Factors			Awareness			Information Sources		
	N	Mean	F	P	Mean	F	P	Mean	F	P
Gender										
Male	475	3.211	10.526	0.001	3.400	4.352	0.037	2.598	3.469	0.063
Female	48	3.677			3.648			2.844		
Age										
20-30 years old	52	3.663	6.192	0.000	3.483	1.291	0.277	2.750	10.208	0.000
31-40 years old	209	3.093			3.398			2.488		
41-50 years old	134	3.216			3.344			2.459		
51 or older	128	3.387			3.522			2.953		
Rank										
Senior First Officer	56	2.973	3.292	0.038	3.387	0.698	0.498	2.482	1.589	0.205
Commander	312	3.253			3.456			2.673		
First Officer	155	3.355			3.369			2.565		
Experience										
Less than 5 years	78	3.474	2.822	0.025	3.353	1.243	0.292	2.776	6.108	0.000
5 to 10 years	157	3.073			3.345			2.347		
11 to 15 years	42	3.369			3.389			2.833		
16 to 20 years	32	3.406			3.573			2.594		
More than 20 years	214	3.259			3.490			2.727		
Aircraft Type										
Long haul	352	3.220	1.110	0.293	3.435	0.471	0.493	2.588	0.661	0.416
Short haul	165	3.315			3.384			2.655		
Flying in a month										
Up to 60 hours	85	3.094	2.567	0.054	3.169	7.085	0.000	2.371	3.669	0.012
61-70 hours	210	3.274			3.427			2.612		
71-80 hours	180	3.222			3.435			2.694		
81-90 hours	48	3.563			3.810			2.823		

Based on the findings illustrated in Table I, there was a significant difference between male and female participants. Female pilots were found to be much more aware about cancer than male pilots. There were no significant differences in the awareness levels of participants based on their age (e.g., 20-30 years old, 31-40 years old, 41-50 years old, and 51 or older), total flying experience (e.g., less than 5 years, 5-10 years, 11-15 years, 16 to 20 years, more than 20 years), ranking (e.g., commander, senior first officer, first officer), and type of aircraft (e.g., long-haul and short-haul). As shown in Table 1, pilots flying 81-90 hours in a month were much more aware than those among the remaining participants. These findings provided support for our first hypothesis.

Based on the results of one-way ANOVA, there was a significant difference in the effort of participants to get information on occupational cancer (reading newspaper, magazines and following social media sources) based on their age (e.g., 20-30 years old, 31-40 years old, 41-50 years old, and 51 or older). It was found that pilots aged 51 and older made much more effort to keep themselves informed about occupational cancer than pilots aged 31-40 and 41-50. According to the results of the one-way ANOVA, there was no significant difference in the mean results of informative sources based on ranking of pilots (e.g., commander, senior first officer, first officer) and type of aircraft (e.g., long-haul and short-haul) ($P > 0.05$). Interestingly, there were significant differences in the efforts of participants to be informed about occupational cancer based on their total flying experience (e.g., less than 5 years, 5-10 years, 11-15 years, 16 to 20 years, more than 20 years). Pilots with 5-10 years of flying experience made much less effort to get information about occupational cancer than experienced pilots. These findings provided strong support for the second hypothesis “the effort of airline pilots to be informed on occupational cancer may vary based on demographics.

The results, as shown in Table I, indicated that female airline pilots were much more aware of the risk than male airline pilots. It was also shown that there were significant differences in the risk level of participants based on their age, ranking, flying experience. Pilots in the 20-30 age group at greater risk in comparison to pilots in the 31-40 and 41-50 age groups. On the other hand, pilots aged 51 and older exhibited more risk than pilots in the 31-40 age groups. First officers were at greater risk than senior first officers. There was no significant difference in the risk level between commanders and first officers. Pilots with less flying experience (e.g., less than 5 years) were found at greater risk compared to pilots with flying experience of 5 to 10 years. Furthermore, there was no significant difference in the risk level of participants based on the type of aircraft (e.g., long-haul and short-haul).

The current study found that the awareness level of airline pilots was low. It is interesting to note that the awareness levels of pilot flying 81-90 hours in a month higher than those among the pilots flying less than 80 hours in a month.

Contrary to expectations, the older pilots (51-65) were much more interested in getting information on occupational cancer than the younger pilots. One possible explanation for this might be that short-haul pilots and long-haul pilots had almost the same level of occupational cancer awareness.

These findings suggest that pilots should be informed on occupational cancer, risk factors, and preventive actions through recurrent trainings and e-learnings. The flight training departments of airlines should pay special attention to this particular issue in order to increase awareness of pilots on occupational cancer. Targeted educational efforts should be implemented to increase awareness among airline pilots. Pilots should be encouraged to wear sunscreen in the flight deck. Pilot unions, airline pilots' associations and airline companies should call for more educational efforts. Flight schools and flight training departments of universities should inform their students (ab-initio pilots) about occupational cancer, risk factors, and preventive actions. Civil aviation authorities may publish informative documents for aviators.

As mentioned in the introductory section of this paper, high cancer awareness may contribute to early diagnosis and improve cancer survival. Therefore, it is highly important that organizations (e.g., airlines, civil aviation authorities, flight training organizations, and pilot training departments of universities) should provide adequate supervision.

4. Conclusion

This study set out with the aim of examining the awareness levels of airline pilots on occupational cancer. To the best of our knowledge, no research has been conducted so far to investigate the awareness level of airline pilots on occupational cancer. The findings from this study made several contributions to the current literature. First, it has demonstrated, for the first time, that the level of awareness on occupational cancer among airline pilots was low. Second, the need for supervisory support (e.g., recurrent trainings, e-learnings, webinar, and seminar) has increased.

The most important limitation is that a cross sectional design was used in this study. A further study could assess the cancer incidence among airline pilots to determine whether workplace factors play a role. Another limitation of our study was the language of the survey. Although the English proficiency of airline pilots is at good level, the survey should have been applied in Turkish language to overcome language-related misconceptions and misunderstandings. In summary, these results indicated that implications (e.g., cancer awareness programs such as pink chain campaigns and training programs) to inculcate healthy lifestyle among pilots and to increase their level of knowledge about occupational cancer may help to create awareness about occupational cancer among airline pilots, reduce cancer risks, and enhance overall safety in aviation.

Appendix

1. Gender
   a. Female
   b. Male
2. Which of the following categories describes your age?
   a. 20-30
   b. 31-40
   c. 41-50
   d. 51-60
   e. 61 and older
3. Which position do you hold?
   a. Second officer
   b. First Officer
   c. Senior First Officer
   d. Commander
4. How long have you been flying?
   a. Less than 5 years
   b. 5 to 10 years
   c. 11 to 15 years
   d. 16 to 20 years
   e. More than 20 years
5. What type of aircraft do you fly?
   a. Short-haul (Airbus A320, Boeing 737 etc.)
   b. Long-haul (Airbus A330, A380, A350, Boeing 777,787, 747 etc.)
6. How many hours do you usually fly in a month?
   a. Up to 60 hours
   b. 61-70 hours
   c. 71-80 hours
   d. 81-90 hours
   e. More than 90 hours
7. I read books, academic articles and magazines on aviation-related cancer and follow social media for this issue?
8. I have been informed about aviation-related cancer by e-learnings and recurrent trainings
9. My knowledge of the cosmic radiation contributing to cancer is...
10. My knowledge of the UV radiation contributing to cancer is...
11. My knowledge of the circadian rhythm disruption/ shift work contributing to cancer is...
12. My knowledge of the exhaust gases from the engine contributing to cancer is...
13. My knowledge of the electromagnetic fields (from cockpit instruments) contributing to cancer is...
14. My knowledge of the inadequate diet contributing to cancer is...
15. My knowledge of the job stress/psychological demand contributing to cancer is...

16. My knowledge of that airline pilots are occupationally exposed to higher level of UV radiation and cosmic radiation
17. Do you smoke or have you ever smoked cigarettes?
    a. Yes
    b. No
18. I wear sunscreen in the flight deck
19. I can maintain a balanced diet during the flight and layover. Balanced Diet: a) Protein in fish, meat, poultry, dairy products, eggs, nuts. b) Fat found in animal and dairy products. c) Carbohydrates found in fruits, vegetables, whole grains, and beans. d) Vitamins. e) Minerals and f) water.
20. I am aware of the recreational sun exposure (during the holidays and layovers) which accounts for a large number of acute and chronic dermatological diseases, including skin cancer

Ethical approval

The study protocol received ethical approval from the Özyeğin University's Human Research Ethics Board (2020/12/02).

Conflicts of Interest

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

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References

Ahsan MA, Munir UR, Ahmad M, & Shahidullah M. (2016). Effects of Smoking on Pilots of Bangladesh Air Force in Dhaka Area. Journal of Armed Forces Medical College Bangladesh, 12(1), 22–27.

Alberg, A. J., & Samet, J. M. (2003). Epidemiology of lung cancer. Chest, 123, 21–49.

Armstrong, B., & Doll, R. (1975). Environmental factors and cancer incidence and mortality in different countries, with special reference to dietary practices. International Journal of Cancer, 15(4), 617–631.

Bagshaw, M., & Cucinotta, F. A. (2008). Cosmic Radiation. In Fundamentals of Aerospace Medicine (4th ed., pp. 221–235). Lippincott Williams & Wilkins.

Bagshaw, M., & Illig, P. (2018). The aircraft cabin environment. In Travel Medicine (Fourth Edi, pp. 429–436). Elsevier Inc. https://doi.org/10.1016/B978-0-323-54696-6.00047-1

Cadilhac, P., Bouton, M. C., Cantegril, M., Cardines, C., Gisquet, A., Kaufman, N., & Klerlein, M. (2017). In-flight ultraviolet radiation on commercial airplanes. Aerospace Medicine and Human Performance, 88(10), 947–951.

Carbone, D. (1992). Smoking and Cancer. The American Journal of Medicine, 93(1), S13–S17.

Dyro, J. F., & Morris, R. L. (2004). Medical Device Troubleshooting. In Clinical Engineering Handbook (pp. 436–447). Elsevier Inc.

Gander, P. H., Mulrine, H. M., van den Berg, M. J., Smith, A. A. T., Signal, T. L., Wu, L. J., & Belenky, G. (2014). Pilot fatigue: Relationships with departure and arrival times, flight duration, and direction. Aviation Space and Environmental Medicine, 85(8), 833–840.

Garabrant, D. H., Peters, J. M., Mack, T. M., & Bernstein, L. (1984). Job Activity and Colon Cancer Risk. American Journal Op Epidemiology, 119(6), 1005–1014.

Goffeng, E. M., Wagstaff, A., Nordby, K. C., Meland, A., Goffeng, L. O., Skare, Ø., Lilja, D., & Lie, J. A. S. (2019). Risk of fatigue among airline crew during 4 consecutive days of flight duty. Aerospace Medicine and Human Performance, 90(5), 466–474.

Gudmundsdottir, E. M., Hrafnkelsson, J., & Rafnsson, V. (2017). Incidence of cancer among licenced commercial pilots flying North Atlantic routes. Environmental Health: A Global Access Science Source, 16(1).

Haldorsen, T., Reitan, J. B., & Tveten, U. (2000). Cancer incidence among Norwegian airline pilots. Scandinavian Journal of Work, Environment & Health, 26(2), 106–111.

Hall, M. T., Austin, R. P., Do, T. A., & McGlynn, A. (2018). Vape and Aviate: Electronic-Cigarette Use and Misuse in Naval Aviation. Military Medicine, 183(3–4), E165–E170.

Hammer, G. P., Auvinen, A., de Stavola, B. L., Grajewski, B., Gundestrup, M., Haldorsen, T., Hammar, N., Lagorio, S., Linnersjö, A., Pinkerton, L., Pukkala, E., Rafnsson, V., Dos-Santos-Silva, I., Storm, H. H., Strand, T. E., Tzonou, A., Zeeb, H., & Blettner, M. (2014). Mortality from cancer and other causes in commercial airline crews: A joint analysis of cohorts from 10 countries. Occupational and Environmental Medicine, 71(5), 313–322.

Hammer, G. P., Blettner, M., Langner, I., & Zeeb, H. (2012). Cosmic radiation and mortality from cancer among male German airline pilots: Extended cohort follow-up. European Journal of Epidemiology, 27(6), 419–429.

Herr, H. W. (2011). Percivall Pott, the environment and cancer. BJU International, 108(4), 479–481.

ICAO. (2012). Manual of Civil Aviation Medicine-Doc 8984.

Irvine, D., & Davies, D. M. (1999). British Airways flightdeck mortality study, 1950-1992. Aviat Space Environ Med, 70(6), 548–555.

Kaji, M., Tango, T., Asukata, I., Tajima, N., Yamamoto, K., Yamamoto, Y., & Hokari, M. (1993). Mortality experience of cockpit crewmembers from Japan Airlines. Aviation, Space, and Environmental Medicine, 64(8), 748–750.

Key, T. J., Bradbury, K. E., Perez-Cornago, A., Sinha, R., Tsilidis, K. K., & Tsugane, S. (2020). Diet, nutrition, and cancer risk: What do we know and what is the way forward? The BMJ, 368(March), 1–9.

Kilic, B. (2021). Self-Medication Among Ab Initio Pilots. Aerospace Medicine and Human Performance, 92(13), 1–6.

Kilic, B., & Soran, S. (2020). Awareness level of airline pilots on flight-associated venous thromboembolism. Aerospace Medicine and Human Performance, 91(4), 1–5.

Langner, I., Blettner, M., Gundestrup, M., Storm, H., Aspholm, R., Auvinen, A., Pukkala, E., Hammer, G. P., Zeeb, H., Hrafnkelsson, J., Rafnsson, V., Tulinius, H., De Angelis, G., Verdecchia, A., Haldorsen, T., Tveten, U., Eliasch, H., Hammar, N., & Linnersjö, A. (2004). Cosmic radiation and cancer mortality among airline pilots: Results from a European cohort study (ESCAPE). Radiation and Environmental Biophysics, 42(4), 247–256.

Lindgren, T., Wieslander, G., Dammstrom, B. G., & Norback, D. (2008). Hearing status among commercial pilots in a Swedish Airline Company. International Journal of Audiology, 47(8), 515–519.

McCartney, M. A., Chatterjee, B. F., McCoy, E. C., Mortimer, E. A., & Rosenkranz, H. S. (1986). Airplane emissions: A source of mutagenic nitrated polycyclic aromatic hydrocarbons. Mutation Research, 171(2–3), 99–104.

Newman, W. G., Agro, A. D., Woodruff, S. I., & Mayer, J. A. (1996). A Survey of Recreational Sun Exposure of Residents of San Diego, California. American Journal of Preventive Medicine, 12(3), 186–194.

Nicholas, J. S., Lackland, D. T., Butler, G. C., Mohr, L. C., Dunbar, J. B., Kaune, W. T., Grosche, B., & Hoel, D. G. (1998). Cosmic radiation and magnetic field exposure to airline flight crews. American Journal of Industrial Medicine, 34(6), 574–580.

Oliveria, S. A., Saraiya, M., Geller, A. C., Heneghan, M. K., & Jorgensen, C. (2006). Sun exposure and risk of melanoma. Archives of Disease in Childhood, 91(2), 131–138.

Rachelle Harry. (2019). Cargolux Airlines joins fight against cancer with Fly Pink initiative. https://www.aircargonews.net/off-the-record/cargolux-airlines-joins-fight-against-cancer-with-fly-pink-initiative/

Ramazzini, B. (2001). De morbis artificum diatriba [Diseases of workers]. American Journal of Public Health, 91(9), 1380–1382.

Raslau, D., Dabrh, A. M. A., Summerfield, D. T., Wang, Z., Steinkraus, L. W., & Murad, M. H. (2016). Prostate cancer in pilots. Aerospace Medicine and Human Performance, 87(6), 565–570.

Ritchie, G. D., Still, K. R., Rossi, J., Bekkedal, M. Y. V., Bobb, A. J., & Arfsten, D. P. (2003). Biological and health effects of exposure to kerosene-based jet fuels and performance additives. Journal of Toxicology and Environmental Health - Part B: Critical Reviews, 6(4), 357–451.

Rodriguez, H. A. F., & Ortiz Mayorga, V. A. (2016). Characterization of low back pain in pilots and maintenance technicians on a commercial airline. Aerospace Medicine and Human Performance, 87(9), 795–799.

Şen, S., Barlas, G., Yakıştıran, S., Derin, İ. G., Şerifi, B. A., Özlü, A., Braeckman, L., van der Laan, G., & van Dijk, F. (2019). Prevention of Occupational Diseases in Turkey: Deriving Lessons From Journey of Surveillance. Safety and Health at Work, 10(4), 420–427.

Siemiatycki, J., Gerin, M., Steward, P., Nadon, L., Dewar, R., & Richardson, L. (1988). Associations between several sites of cancer and ten types of exhaust and combustion products. Results from a case-referent study in Montreal. Scandinavian Journal of Work, Environment and Health, 14(2), 79–90.

Staff Writer. (2021). How you can support breast cancer research fundraising. https://news.delta.com/how-you-can-support-breast-cancer-research-fundraising

Stevens, R. G., Davis, S., Thomas, D. B., Anderson, L. E., & Wilson, B. W. (1992). Electric power, pineal function, and the risk of breast cancer. The FASEB Journal, 6(3), 853–860.

United States Department of Labor. (2021). Non-Ionizing Radiation. Safety and Health Topics. https://www.osha.gov/non-ionizing-radiation

Van Tongeren, M., Jimenez, A. S., Hutchings, S. J., MacCalman, L., Rushton, L., & Cherrie, J. W. (2012). Occupational cancer in Britain: Exposure assessment methodology. British Journal of Cancer, 107, S18–S26.

Wang, S. W., Tai, H. C., Tang, C. H., Lin, L. W., Lin, T. H., Chang, A. C., Chen, P. C., Chen, Y. H., Wang, P. C., Lai, Y. W., & Chen, S. S. (2020). Melatonin impedes prostate cancer metastasis by suppressing MMP-13 expression. Journal of Cellular Physiology, August, 1–12.

WHO-International Agency for Research on Cancer. (2010). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 98. http://publications.lib.chalmers.se/records/fulltext/245180/245180.pdf/0Ahttps://hdl.handle.net/20.500.12380/245180/0A

Wollschläger, D., Hammer, G. P., Schafft, T., Dreger, S., Blettner, M., & Zeeb, H. (2018). Estimated radiation exposure of German commercial airline cabin crew in the years 1960-2003 modeled using dose registry data for 2004-2015. Journal of Exposure Science and Environmental Epidemiology, 28(3), 275–280.

Yong, S. S., Han, W. H., Faheem, N. A. A., Puvan, N., Tan, L. L., Wong, S., & Kwan, Z. (2022). Predictive factors of sun protection behaviour among global airline pilots. Photodermatology, Photoimmunology & Photomedicine.

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The Evolution of the Low-Cost Carriers in the Trans-Tasman Aviation Market

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Abstract

This research examined the evolution of low-cost carriers (LCCs) in the Trans-Tasman aviation market, quantifying their impact and qualifying their influence on the market. New Zealand is Australia's second largest tourist market, and the air routes to Australia are New Zealand's busiest; as such, the trans-Tasman passenger traffic is of significant economic and strategic interest. This study utilized an exploratory research design and an in-depth longitudinal research approach to examine the evolution of the market and to understand the process of market development. The qualitative data was examined by document analysis. The study period was from 1995 to 2020. The low-cost carriers (LCCs) first entered the market in 1995. The case study revealed that since that time, the market has broadly had four discrete phases. The first phase was from 1995 to 2003 when the first low-cost carriers (LCCs) entered the market; the second phase saw the rapid growth in traffic following the launch of services by Pacific Blue Airlines (a subsidiary of Virgin Blue) and Jetstar Airways. An important development in the market took place in 2010, when Pacific Blue was rebranded Virgin Australia, and, as such, implemented the full-service network carrier (FSNC) business model. In 2016, AirAsia-X entered the market, utilizing fifth freedom traffic rights, to provide daily Airbus A330 services from Coolangatta to Auckland. AirAsia-X exited the market in early 2019 leaving Jetstar Airways as the sole low-cost carrier operating in the market (Phase 4).

1. Introduction

The low-cost carriers (LCCs) or low airfare airlines have become a global phenomenon, with virtually all travel markets containing at least some low-cost carriers (LCCs) today (Vasigh, Fleming & Tacker, 2013). Indeed, one of the most significant trends in the world airline industry over the past three decades or so has been the phenomenal growth of the low-cost carriers (LCCs). The low-cost carriers (LCCs) are often viewed as one of the most successful business concepts that have happened within contemporary travel. The astute business model of these airlines by offering significantly lower prices through the elimination all the in-flight extras together with their strict focus on cost-control has enabled them to capture significant market share. USA-based Southwest Airlines operated its first low-cost domestic US flight in 1973 (Kua & Baum, 2004). In more recent times, the low-cost carrier (LCC) business model has evolved with several low-cost carriers (LCCs) commencing long-haul, scheduled, no frill services (Daft & Albers, 2012; De Poret, O'Connell & Warnock-Smith, 2015; Morrell, 2008; Wensveen & Leick, 2009; Whyte & Lohmann, 2015a). Jetstar Airways, for example, has implemented international, no-frills service in addition to their domestic Australian services (Jiang, 2013; Taneja, 2016; Whyte & Lohmann, 2015b). Like many other countries, since 1995, Australia has seen the introduction of international services by not only Australia-based low-cost carriers (LCCs), such as, Jetstar Airways, but also the provision of services from Asia-based low-cost carriers (LCCs), for example, Air Asia-X, Cebu Pacific, and Scoot.

The low-cost carriers (LCCs) first entered the Trans-Tasman aviation market in 1995 with the introduction of a low-cost, no-frills services by Kiwi Travel International Airlines. Since the inception of these services, the market has continued to evolve, and has seen the entry of Pacific Blue, a subsidiary of Virgin Blue, in 2004 and Jetstar Airways, the Qantas Group low-cost carrier (LCC) in 2005. Air New Zealand followed the carrier-within-carrier (CWC) strategy launching Freedom Air International Airlines as its Trans-Tasman low-cost carrier (LCC) in December 1995 (Knibb, 2004b). AirAsia-X entered the market in March 2016 operating daily Airbus A330-300 services from Kuala Lumpur to Auckland via Coolangatta (the Gold Coast), using fifth freedom rights to operate their services over the Coolangatta to Auckland and Auckland to Coolangatta sectors (Freed, 2016).

Despite the growth of the low-cost carriers in the Trans-Tasman aviation market, there has been no reported study that has examined their evolution since the inception of their low-fare services in 1995. Thus, a key aim of this study was to address this apparent gap in the literature. The objective of this paper is to examine the evolution of low-cost carriers (LCCs) in the Trans-Tasman aviation market in terms of the annual number of inbound and outbound enplaned passengers, the annual inbound and outbound enplaned passenger growth rates, and the low-cost carriers (LCCs) annual share of the inbound and outbound Trans-Tasman passenger market share. In order to achieve the research objectives, this study addressed the following research questions.

1. How have the low-cost carriers (LCCs) evolved in the Trans-Tasman aviation market over the period 1995 to 2020?
2. How have the low-cost carriers (LCCs) competing in the Trans-Tasman market structured their route networks to optimize their passenger traffic?
3. Have the low-cost carriers (LCCs) competing in the Trans-Tasman aviation market focused on the use secondary airports as a key part of their service offering?
4. Have the low-cost carriers (LCCs) competing in the Trans-Tasman aviation market utilized a homogenous aircraft fleet strategy?

The remainder of the paper is structured as follows: Section 2 presents an overview of the low-cost carrier (LCC) business model, the international air transport industry regulatory framework, and airline competition and market share. Section 3 outlines the research method that underpinned the in-depth case study. The case study results are presented in Section 4. Section 5 provides the concluding remarks on the research findings.

2. Literature Review

2.1. The low-cost carrier business model: A brief overview

Doganis (2006) suggests that a low-cost carrier (LCC) is an airline that offers low air fares but eliminates all unnecessary services. A critical focus of the low-cost carriers (LCCs) business model is cost reduction. By minimizing their costs, low-cost carriers (LCCs) can implement a price leadership strategy in the markets which they serve (Acar & Karabulak, 2015; Vidović, Štimac & Vince, 2013).

Low-cost carriers (LCCs) costs are minimized by the operation of a single-type aircraft fleet (Koch, 2010; Schlumberger & Weisskopf, 2014; Vasigh & Rowe, 2020). The low-cost carriers (LCCs) operating short-to-medium-haul flights typically use a homogeneous fleet, for example, Jetstar operates a fleet of Airbus A320 and A321 aircraft on its domestic Australia and Trans-Tasman services. The use of a young and homogenous fleet of medium-sized aircraft (usually Boeing 737-700/800 or Airbus 320/321 aircraft) normally results in a reduction in the low-cost carriers (LCCs) fuel, maintenance, and staff costs (Ehmer et al., 2008).

The low-cost carriers (LCCs) typically configure their aircraft with a high-density, all-economy seating arrangement (Bowen, 2019; Leick & Wensveen, 2014; Wilken & Berster, 2016). However, not all low-cost carriers (LCCs) adhere to his principle, with some airlines offering seat pitches of between 31 to 34 inches (Schlumberger & Weisskopf, 2014). In addition, some low-cost carriers (LCCs) also offer a business or premium economy class. AirAsia-X, for example, offers a 'Premium Flatbed' class on its Airbus A330-300 aircraft (Lennon, 2016; Vasigh, Taleghani & Jenkins, 2012).

The network features of air transportation are critical to those whose supply and use air services (Button & Stough, 2000). Every airline is endowed with a unique route structure, traffic catchment area, cost base, productivity levels and management skills that are the result of its path and pace of historical development, strategic intent, the characteristics of its home and regional markets, and the international regulatory system (Baxter, 2015). From an airline's perspective, there are many possibilities in providing its route network. Which network form is selected is likely to be a function of external institutional factors, for example, controls over flight paths, available airport landing and aircraft take-off slots, and air service agreements (ASAs) stipulations, as well as economic considerations (Button, 2002). An airline's network design encompasses the strategic decisions made on an airline's network shape and the route flight frequencies (Hsu & Wen, 2000).

The operation and profitability of an airline, whether it be passenger or a freight operator, is highly dependent on the network over which its services are operated, and thus, the airline's network represents at once its production plan and its product' (Reynolds-Feighan 1994, p.197). The multiple roles of an airline's route networks make it a critical strategic and competitive variable for airlines (Cento, 2009). The size of an airline's network is a competitive variable. An airline's route network is a collection of origins-and-destinations (O&Ds), often called city pairs. If a single city-pair is regarded as one product of the airline, then, the larger the airline route network, the greater is its range of products. Route networks are therefore a factor in differentiating airlines (Kleymann & Seristö, 2016). Linear (P2) route networks simply link separate airports (Button, Haynes & Stough, 1998). Many low-cost carriers (LCCs) operate route networks that are principally based on a point-to-point (P2P) network design (Birolini et al., 2022; Franke, 2018; Gross & Klemmer, 2014; Whyte & Lohmann, 2017). A linear route, point-to-point (P2P) airline therefore tends to focus its services on dense markets with sufficient origin and destination (O & D) traffic to sustain non-stop operations (Dempsey & Gesell, 1997). The low-cost carriers (LCC) model is based on simplicity. To maintain a low-cost base and to increase efficiencies the low-cost carriers (LCC) must remove all complicating factors from their business environment. As such, point-to-point (P2P) operations they provide low-cost carriers (LCCs) with the simplest network building block (Doganis, 2006).

Many airlines structure their route networks on short haul, medium-haul, and long-haul services (Baxter & Bardell, 2017). In addition, as the numbers of passengers increase on a route, it becomes possible for airlines to deploy larger aircraft types and/or offer a more frequent service. In the airline industry, there are "thin" routes, that is, routes that have a small number of passengers per day, and "dense" routes, where there are substantial numbers of passengers per day. Typically, dense air routes receive a point-to-point (P2P) service, whilst thin routes are combined using the hub-and-spoke system (Morrison, 2007).

In international markets, however, the airline is often constrained by the various 'Freedoms of the Air' and cabotage restrictions as to how many stops it can make en-route (Wensveen, 2016).

The low-cost carriers (LCCs) often operate services from secondary airports (Beria, Laurino & Postorino, 2017; Dobruszkes, Givoni & Vowles, 2017; Pan & Truong, 2018), which are normally located farther from the main urban area than primary airports. Strategically low-cost carriers (LCCs) are endeavoring to broaden their traffic catchment area and increase their market shares by offering flights at lower air fares (de Wit & Zuidberg, 2014). Less congested secondary airports help airlines to maintain their flight schedules and avoid delay costs. By utilizing less congested airports aircraft turnaround times can be optimized which helps keep costs low and increases operational efficiency and productivity (Barrett, 2004; Gillen & Lall, 2004).

Apart from the lack of congestion at smaller airports, secondary airports usually charge lower fees than the more established airports and, where permitted, are more willing to co-finance the promotion of new routes. Using secondary airports not only reduces costs but enhances low-cost carriers (LCCs) competitive advantage in several aspects. The use of secondary airports overcomes slot availability problems allowing the low-cost carriers (LCCs) to design flight schedules that maximize their aircraft fleet utilization (Barbot, 2006). This is also relevant to the present study, as the case study will show that several LCCs launched services from regional airports, such as, Hamilton and Dunedin in New Zealand to Australia's major gateway airports – Brisbane, Melbourne, and Sydney.

2.2. The international air transport industry regulatory framework: a brief overview

International air transport operates within the framework of the 1944 Chicago *Convention on International Civil Aviation* and is traditionally administered by a complex network of multilateral government air services agreements (ASA's) and International Air Transport Association (IATA) rules (Oum & Yu, 2012). Based on the principle that "every state has complete and exclusive sovereignty over the air space above its territory" (Wensveen, 2016), the 1944 Chicago *Convention on International Civil Aviation* established multilateral agreements in some areas, mainly concerning an airline's right to overfly and make technical stops in a foreign country, but not in areas of commercial rights. Commercial air rights were left to bilateral agreements to be negotiated between individual countries (Martin & Román, 2011; Oum & Yu, 2012; Rochat, 1995).

Air Services Agreements (ASAs) (often called "bilaterals" in the industry) are government to government negotiated agreements governing the conduct of trade in international air services between two respective countries (Bureau of Transport and Communication Economics, 1994). Scheduled airline services/capacity between nations is determined through a legal framework of bilateral negotiations of air services agreements (ASA's) (Jones & Collett, 2001). Bilateral air services agreements (ASAs) are negotiated on the principle of reciprocity (Graham, 2016; Law, Zhang & Zhang, 2019; Zhang et al., 2017), and equal and fair exchange of air services traffic rights between countries that are very different in size and with airlines of varying sizes.

Scheduled airline capacity between nations is therefore determined through bilateral negotiations of air services agreements (ASA's). Bilateral air services agreements (ASA's) vary in form, but in general, these agreements establish a country's market access (entitlement of capacity), airline designation, capacity (the level of flight frequencies, the authorized routings, and whether dedicated freight services would be permitted). These agreements can also determine tariffs, the types of aircraft that can be use, and what airports can be utilized by airlines for their services (Chang & Williams, 2001). Most air services agreements (ASAs) include broadly similar clauses or articles, dating back to the original 'Bermuda 1' agreement signed between the United States and the United Kingdom (Morrell & Klein, 2020).

International aviation rights consist of the "Eight Freedoms of the Skies"(Wensveen, 2016). The fifth freedom of the air is of relevance to this study as the case study will reveal that Air Asia-X used fifth freedom traffic rights to operate its services between Coolangatta, The Gold Coast, Queensland to Auckland, New Zealand. The "fifth freedom" is the right of the airline of State A to operate beyond State B and to take on and put down passengers and mail travelling between State B and State C (that is, carriage of third country traffic, not originating or terminating in the home country of the airline (Bartlik, 2007; Haanappel, 2003).

2.3. Airline competition and market share

In the global airline industry, airlines compete for both passengers and market-share. These commercial and strategic objectives are achieved through the following factors:

- The frequency of flights offered and the departure schedule on each route served;
- Price (air fare) charged, relative to competitors, to the degree to which the regulatory framework permits price competition; and
- Quality of service and products offered by the carrier, including airport and in-flight amenities, and/or restrictions on discount fare products (Belobaba, 2016, p. 67).

3. Research Methodology

3.1. Research method

The research undertaken in this study was exploratory in nature (Dawes Farquhar, 2012; Stebbins, 2001) and was underpinned by an in-depth longitudinal case study research design (Baxter & Srisaeng, 2021; Derrington, 2019; Hassett & Paavilainen-Mäntymäki, 2013; Neale, 2019). The primary advantage of this research technique is that it reveals change and growth in an outcome over time (Kalaian & Kasim, 2008). A qualitative case study also allows for the exploration of complex phenomena (Remenyi et al. 2010; Yin, 2018). In addition, a case study enables a researcher(s) to gather and use rich, explanatory information in their study (Ang, 2014; Mentzer & Flint, 1997). Furthermore, a case study research approach also enables researchers to connect with real world practice (McCutchen & Meredith, 1993).

3.2. Data collection

The qualitative data for this study was obtained from a range of documents, which included official Government reports, relevant low-cost carrier (LCC)-related articles in the authoritative industry magazines, such as *Air Transport World, Airline Business, Aviation Week & Space Technology* and *Flight International* and air transport industry-related journals, books, and the low-cost carriers (LCCs) websites. The enplaned passenger data was sourced from the Bureau of Infrastructure, Transport and Regional Economics (BITRE). The study therefore used secondary data. The three principles of data collection as recommended by Yin (2018) were followed: the use of multiple sources of case evidence, creation of a database on the subject and the establishment of a chain of evidence.

3.3. Data analysis

The empirical data collected for the case studies was examined using document analysis. Document analysis is often employed in case studies (Grant, 2019; Monios, 2016) and focuses on the information and data from formal documents and company records that have been gathered by the researcher(s) (Baxter, 2021; Oates, 2006; Ramon Gil-Garcia, 2012). The documents gathered for the study were examined and assessed by four key criteria: authenticity, credibility, representativeness and meaning (Fulcher & Scott, 2011; Scott, 2014; Scott & Marshall, 2009).

The document analysis was undertaken in six discrete phases. The first phase involved planning the types and required documentation and their availability for the study. Phase two represented the data collection phase and this involved sourcing the documents and developing and implementing a scheme for the document management. In Phase 3 of the document analysis, the collected documents were examined to assess their authenticity, credibility and to identify any potential bias that may be present in the documents. During Phase 4, the contents of the collected documents was carefully examined, and the key themes and issues were identified. Phase 5 involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content. In Phase 6, the final phase, the analysis of the data was completed, and the case study was updated accordingly (O'Leary, 2004, p. 179).

Following the recommendation of Yin (2018), all the collected documents were downloaded and stored in a case study database. The documents gathered for the study were all in English. Each document was carefully read, and key themes were coded and recorded in the case study (Baxter, 2021; Baxter & Srisaeng, 2020).

4. Results

4.1. Evolution of Australia's Trans-Tasman single aviation market policy

Air services between Australia and New Zealand were initially regulated by an air services agreement (ASA) that was signed in 1961 by the respective governments (Duval, 2005; Findlay & Kissling, 1997), and the subsequent Memoranda of Understanding (MOU). The arrangements were originally very restrictive. Air New Zealand and Qantas were the only two designated airlines and the governments of both countries had to agree on air fares, flight frequencies and capacity. Some of these restrictive features were relaxed during the 1980s (Findlay, 1996). However, since the Australia–New Zealand Closer Economic Relations Trade Agreement (known as the CER Agreement) entered effect in 1983, the Australian and New Zealand economies have become progressively integrated (International Civil Aviation Organization, 2007).

In 1992, Australia and New Zealand agreed to the formation of a "Single Aviation Market" (SAM) as part of the Australia–New Zealand Closer Economic Relations Trade Agreement (Productivity Commission, 1998). Notwithstanding, in 1988, following the conclusion of the CER Trade in Services Protocol, Australia chose to exclude international and domestic air services from its application. In contrast, the only air services exclusion by New Zealand was international airlines flying cabotage route within New Zealand. As a result, liberalization of air services across the Tasman continued to be dealt with through a bilateral air services (ASA) agreement and related understandings. For instance, the 1989 understanding agreed to multiple designation for all-cargo services with no capacity constraints. Importantly, the integration process has been significantly affected by the progress of domestic deregulation and privatization of both country's national airlines (International Civil Aviation Organization, 2007). In Australia, the domestic aviation market was deregulated on the 30th of October 1990 (Mills, 2017; Quiggin, 1997; Srisaeng, Baxter & Wild, 2014). The Australian Government owned Qantas Airways was partially privatized in 1993, when the Australian Government sold 25 per cent of its shares to British Airways (Marquardt, Berger &; Loan, 2004). In New Zealand, the domestic market was deregulated in 1983 (Lyon & Francis, 2016; Mecham, 1994a; Wolfe, 1999). In 1987, the New Zealand Government invited Australia-based carrier Ansett Australia to establish a New Zealand subsidiary – Ansett NZ (Mecham, 1994a) and State-owned Air New Zealand (ANZ) was fully privatized in 1989, and subsequently re-nationalized in 2002 (Hunziker, 2005).

In 1992, Australia and New Zealand concluded a Memorandum of Understanding (MOU). This agreement lifted capacity restrictions across the Tasman Sea, introduced multiple designation and a double disapproval tariff regime (International Civil Aviation Organization, 2007; Productivity Commission, 1998). The ratification of the Memorandum of Understanding (MOU) opened the Trans-Tasman air travel market to Australasian airlines other than Air New Zealand and Qantas and provided a phased introduction (with a limit up to of 12 Boeing 747s per week) of an all-points exchange so that by November 1st, 1994, all Australasian airlines could operate to, from or between and designated international airport in either country (Pearce, 1995). The Memorandum of Understanding (MOU) also contained a commitment by both States to consult on the subsequent full exchange of beyond rights and cabotage rights, the ownership and control of designated airlines, and the possibility of forming a joint bloc for negotiating international traffic rights (Productivity Commission, 1998, p.69). Airlines were permitted to set their own air fares and flight frequencies (Wolfe, 1999). In addition, by November 1, 1994, there was multiple designation for passenger and air cargo services with no limit on the number of cities that an airline(s) could serve (Findlay, 1996). The joint air services agreement was due to take effect on November 1, 1984. In October 1994, Australia withdrew its commitment (Findlay, 1996; (International Civil Aviation Organization, 2007; Mecham, 1994b).

In 1996, Australia and New Zealand ratified the "Single Aviation Market" (SAM) arrangements, which was incorporated into the CER Protocol. The arrangements permitted a "SAM carrier" to operate without restrictions trans-Tasman and domestic services in either State. Unlimited beyond rights were excluded from the agreement, and which were subsequently governed by the bilateral air services (ASA) agreements and the 1992 Memorandum of Understanding (MOU) (International Civil Aviation Organization, 2007). Effective from November 2006, any airline with 50 per cent or more Australian and/or New Zealand ownership was permitted to operate services freely between the two countries or within them, subject only to border restrictions (Phelan, 1997a, 1997b).

In 2000, Australia and New Zealand ratified an "open skies" agreement, which was officially signed in 2002

(International Civil Aviation Organization, 2007). This agreement liberalized air traffic between the two States and opened the Trans-Tasman market to other airlines from other countries, thus raising the connectivity of both countries with foreign markets (Vowles & Mertens, 2014, p. 118).

The aviation arrangements were further relaxed by Australia in 2006 when the *Civil Aviation Legislation Amendment (Mutual Recognition with New Zealand) Act 2006* came into effect. This act amends the *Civil Aviation Act 1988* to permit Australia and New Zealand to mutually recognize air operator's certificates (AOCs) for aircraft with more than 30 seats or having a Maximum Take-Off Weight (MTOW) of more than 15,000kg. The mutual recognition enables Australian and New Zealand operators to operate to, from and within either country based on their home certification (Civil Aviation Safety Authority, 2007).

4.2. Evolution of Australia's Trans-Tasman single aviation market

The low-cost carriers (LCCs) entered the Trans-Tasman air travel market in 1995. The initial services were pioneered by low-cost carrier (LCC), New Zealand-based, Kiwi Travel Airlines International, who commenced Trans-Tasman services around September 1995. Air New Zealand established Freedom Air Airlines in 1996 to compete with Kiwi Travel Airlines International (Francis et al., 2006; Taumoepeau, 2016; Williams, 2016). Figure 1 shows the development of the number of inbound and outbound Trans-Tasman enplaned passengers carried by the low-cost carriers (LCCs) for the period 1995 to 2020. One passenger enplanement measures the embarkation of a revenue passenger, whether originating, stop-over, connecting or returning (Holloway, 2016).As can be observed in Figure 1, the Trans-Tasman low-cost carriers (LCC) market development has occurred in four discrete phases; Phase 1 (1995-2004) was the initial entry of New Zealand-based carriers Kiwi Travel International Airlines and Freedom Air International; Phase 2 (2004 to 2010) saw the introduction of services by Pacific Blue (an off-shoot of Virgin Blue) and Australian-based Jetstar Airways. In 2010 (Phase 3: 2010-2016), Pacific Blue was re-branded as Virgin Australia and the carrier's business model evolved from a low-cost carrier (LCC) business model to that of a full-service network carrier (FSNC). This strategic change by Virgin Australia saw a marked drop in the low-cost carriers (LCC's) share of inbound and outbound Trans-Tasman passengers (Figure 1). Another important develop in Phase 3 was the introduction of fifth freedom services from Coolangatta to Auckland by AirAsia-X. The "fifth freedom" air services rights allow foreign airlines to fly between Australia and New Zealand on a flight originating or ending in their own country (Freed, 2016). In Phase 4, Air Asia-X exited the Trans-Tasman air travel market during 2019 thereby leaving Jetstar Airways as the sole low-cost carrier (LCC) competing in the market. The outbound Trans-Tasman low-cost carriers (LCC) passengers also follows the same market development phases as that for the inbound Trans-Tasman low-cost carriers (LCC) passengers.

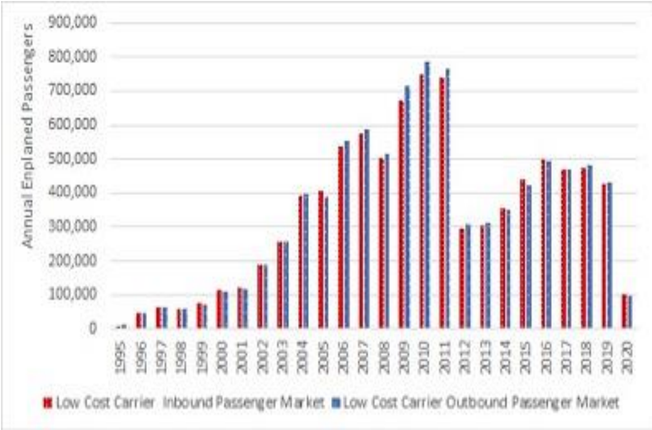

Figure 1. Low-cost carriers (LCCs) annual enplaned inbound and outbound Trans-Tasman passengers: 1995-2020.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2006), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008-2021), Department of Transport and Regional Services (2001).

Figure 1 shows that there was a downturn in both inbound and outbound passengers in 2008. The 2008 recession and global financial crisis resulted in a downturn in air travel demand (Daley, 2010; Pearce, 2012; Yu, 2020). Also, as can be observed in Figure 1, there was a very significant reduction in the number of inbound and outbound passengers in 2020. The Australian international air travel market was impacted by the corona virus pandemic in 2020 (Bureau of Infrastructure, Transport and Regional Economics, 2021). During 2020, the COVID-19 pandemic caused a decline in economic activity around the world, and this resulted in disruptions in the air travel market supply and demand chain (Dube et al., 2021). In addition, because of the global coronavirus crisis, most countries placed restrictive measures to confine the pandemia (Maria Iacus et al., 2020), and these restrictions had an adverse impact on airline passenger demand. Australia's borders and entry points were closed to non-New Zealand residents on March 19th, 2020, as part of the government's strategy to deal with the pandemic (Fitzgerald & Wong, 2020). On 19 March 2020, New Zealand closes its border and only New Zealand residents and a very select group of essential workers were permitted to enter the country after this date (Fairweather et al., 2021).

Australia's Productivity Commission (1998) has noted that following the entry of new competitors in the Trans-Tasman air travel market there were substantial consumer benefits in terms of new services and lower air fares. As can be seen in Figure 1, the commencement of low-cost carrier (LCC) services by Kiwi Travel International Airlines and Freedom Air International resulted in significant passenger traffic growth. This was because there were many first-time travelers who were attracted by the availability of some highly discounted air fares. The total origin–destination (O & D) passenger traffic between Australia and New Zealand increased from around 1.8 million in 1995 to around 2.2 million passengers in 1996 (Productivity Commission, 1998).

The Trans-Tasman strategies of Jetstar Airways and Freedom Air International differed to that of Pacific Blue Airlines. Upon their inception of Trans-Tasman services, Jetstar Airways and Freedom Air International focused on secondary routes, for instance, Hamilton-Sydney and Auckland to Newcastle; these were city pairs that their parent company did not fly to. In contrast, Pacific Blue by 2005 had launched services such as Auckland to Brisbane, a major route historically operated by the full-service network carriers (FSNCs), such as Air New Zealand and Qantas Airways, whilst they also competed in other Trans-Tasman leisure markets (Knibb, 2005b). Following the withdrawal of services by Kiwi Travel International Airlines in September 1996, passenger traffic growth slowed markedly (Figure 1).

As noted earlier, in January 2004, Pacific Blue commenced Trans-Tasman operations and in December 2005, Jetstar Airways started their Trans-Tasman services. Following the introduction of services by Pacific Blue Airlines, the low- cost carriers (LCCs) inbound and outbound traffic grew by 53.1 and 55 per cent, respectively in 2004. A similar increase in traffic growth was recorded in 2006, the first full year of operations by Jetstar Airways, when inbound and outbound traffic grew by 31.6 and 35.8 per cent, respectively (Figure 1). As noted earlier, in January 2004, Pacific Blue commenced Trans-Tasman operations and in December 2005, Jetstar Airways started Trans-Tasman services. Following the introduction of services by Pacific Blue Airlines, the low- cost carriers (LCCs) inbound and outbound traffic grew by 53.1 and 55 per cent, respectively in 2004. A similar increase in traffic growth was recorded in 2006, the first full year of operations by Jetstar Airways, when inbound and outbound traffic grew by 31.6 and 35.8 per cent, respectively (Figure 1).

A significant development occurred in December 2011 when Virgin Australia decided to re-brand its subsidiary companies "Pacific Blue" and "V-Australia" under the Virgin Australia brand (Centre for Aviation, 2011; Walton, 2011). At the same time, the airline's business model changed towards a full-service network carrier (FSNC) (Whyte, Prideaux & Sakata, 2012). This was part of the airline's transformation process. From 2012 to 2015, Jetstar Airways was the sole low-cost carrier (LCC) operating Trans-Tasman services. In 2016, AirAsia-X entered the market. However, 2019, Air Asia-X exited the market. At the time of the current study, Jetstar Airways was the only low-cost carrier (LCC) providing Trans-Tasman services.

Like many other air travel markets, the Trans-Tasman market is served by both full-service network carriers (FSNCs) and low-cost carriers (LCCs). The major full-service network carriers are Air New Zealand, Qantas Airways and Virgin Australia. The Trans-Tasman air travel market is also served by foreign-based airlines, such as Taiwan-based China Airlines, Emirates Airline, and LATAM Airlines, who have exercised fifth freedom traffic rights to provide their Trans-Tasman services from key cities in Australia and New Zealand. Figure 2 presents the annual full-service network carriers (FSNCs) and low-cost carriers (LCCs) Trans-Tasman inbound passenger market shares from 1995 to 2020. The inbound market is comprised of passengers arriving in Australia from New Zealand. As can be observed in Figure 2, the full-service network carriers (FSNCs) annual market share declined from 1995 to 2007, increased slightly in 2008, and once again declined from 2009 to 2011. The full-service network carriers (FSNCs) market share increased significantly in 2012 to 89.61% and remained relatively steady from 2012 to 2020 (Figure 2). As noted earlier, the low-cost carrier (LCC) market share displayed an upward trend from 1995 to 2011 and declined quite significantly following the change in Pacific Blue Airlines business model to that of a full-service network carrier (rebranded as Virgin Australia). The low-cost carriers (LCCs) inbound passenger market share increased from a low of 0.72% in 1995 to a high of 27.07% in 2010. Figure 2 shows that the annual number of inbound passengers carried by the low-cost carriers (LCCs) decreased from 740,419 (26.29% of the market) in 2011 to 297,761 passengers (10.39% of the market) in 2012. This large decline reflected the change in business model by Virgin Australia. From 2012 to 2020, there were six years where the low-cost carriers (LCCs) annual enplaned inbound passengers decreased on a year-on-year basis. These decreases occurred in 2012 (-60.47%), 2013 (-0.48%), 2017 (-6.57%), 2018 (-0.82%), 2019 (-10.87 %), and 2020 (-1.77%) (Figure 2). The significant decrease recorded in 2012 (-60.47%) reflected the change in business model by Pacific Blue. As noted, Air Asia-X exited the Trans-Tasman aviation market in 2019.

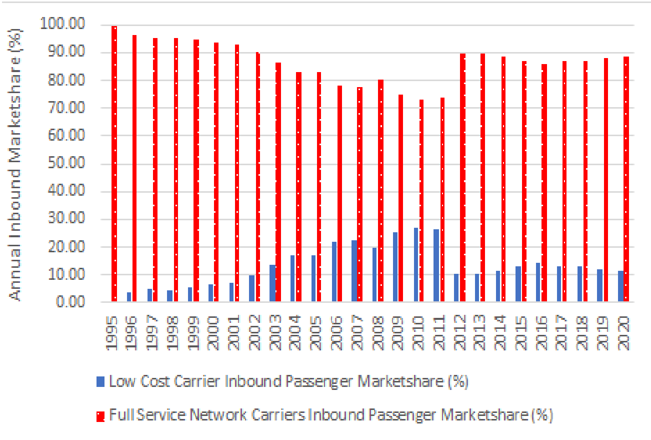

Figure 2. Low-cost carriers and full-service network carriers Trans-Tasman inbound passenger market share (%): 1995-2020.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2006), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008-2021), Department of Transport and Regional Services (2001).

The annual full-service network carriers (FSNCs) and low-cost carriers (LCCs) outbound, that is, passengers from Australia to New Zealand, Trans-Tasman passenger market shares from 1995 to 2020 are depicted in Figure 3. As can be observed in Figure 3, both the full-service network carriers (FSNCs) and low-cost carriers (LCCs) outbound Trans-Tasman passenger market shares have followed a similar trend to their inbound passenger market, that is, the full-service network carriers annual market share declined from 1995 to 2007, increased slightly in 2008, and once again declined from 2009 to 2011. The full-service network carriers (FSNCs) market share increased significantly in 2012 to 89.15% (Figure 3). From 2013 to 2020, the full-service network carriers (FSNCs) outbound market share averaged around 88.80%. The low-cost carrier (LCC) market share displayed an upward trajectory from 1995 to 2011 and then significantly declined when Pacific Blue Airlines changed its business model to that of a full-service network carrier (FSNC). The low-cost carriers (LCCs) outbound passenger market share increased from a low of 0.90% in 1995 to a high of 28.50% in 2010. The low-cost carriers (LCCs) annual enplaned outbound passengers declined significantly in 2012, decreasing by 60.18% on the 2011 levels. Once again, this large decrease in passenger traffic reflected the change in business model by Virgin Australia. From 2013 to 2020, there were four years where the low-cost carriers (LCCs) annual enplaned outbound passengers decreased on a year-on-year basis. These decreases occurred in 2013 (-2.58%), 2017 (-05.62%), 2019 (-11.36%), and 2020 (-1.51%). As noted earlier, Air Asia-X exited the market in 2019.

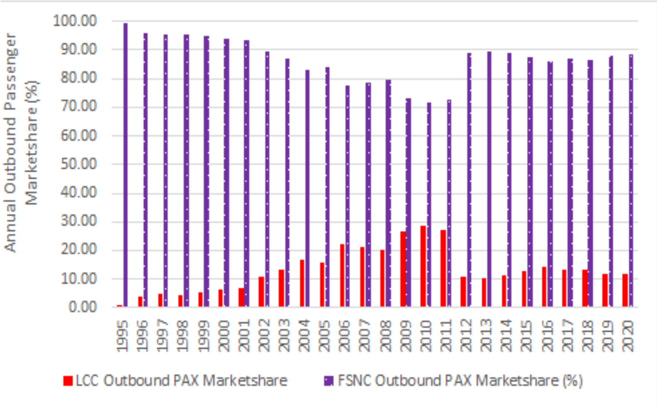

Figure 3. Low-cost carriers and full-service network carriers Trans-Tasman outbound passenger market share (%): 1995-2020.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2006), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008-2021), Department of Transport and Regional Services (2001).

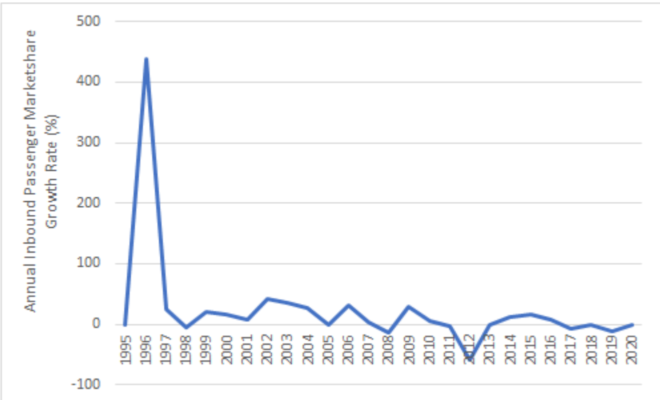

Figure 4. Low-cost carriers Trans-Tasman inbound passenger market share (%) annual growth rate: 1995-2020.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2006), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008-2021), Department of Transport and Regional Services (2001).

Figure 4 presents the low-cost carriers (LCCs) annual inbound passenger market share growth for the period 1995 to 2020. As can be observed in Figure 4, the low-cost carriers (LCCs) annual inbound passenger market share oscillated throughout the study period reflecting differing levels of passenger demand. There was a very pronounced spike in the low-cost carriers (LCCs) inbound passenger market share in 1996 (+438.88%) (Figure 4). This large increase in 1996 could be attributed to the first full year of operations in the market by the low-cost carriers (LCCs) plus Freedom Air International entered the market in 1996. Figure 4 also reveals that there were significant increases in this metric in 1997 (+25.51%), 2002 (+41.66%), 2006 (+31.02%), and 2015 (+16.46%), respectively. In 1997 and 2002, Freedom Air International increased the number of enplaned passengers quite significantly. In 2006, Jetstar Airways uplifted 178,516 passengers, which was much higher than the 13,187 passengers uplifted by the airline in 2005. In 2015, Jetstar Airways carried considerably more inbound passengers, which enabled it to capture greater market share. Figure 4 also shows that there were two years in the study period where the low-cost carriers (LCCs) inbound passenger market share decreased quite substantially on a year-on-year basis. These decreases were recorded in 2012 (-58.73%), and in 2019 (-77.79%) (Figure 4). The decrease in 2012 reflected the change in business model by Pacific Blue (Virgin Australia), whilst the decrease in 2019 could be attributed to the substantial decrease in the number of passengers carried by Air Asia-X on its services from Auckland to Coolangatta (Queensland). Air Asia-X enplaned passengers decreased by 86.90% in 2019.

The low-cost carriers (LCCs) annual outbound passenger market share growth from 1995 to 2020 is depicted in Figure 5. As can be observed in Figure 5, the low-cost carriers (LCCs) annual outbound passenger market share growth rates have fluctuated quite markedly over the study period. Like the Trans-Tasman inbound passenger air travel market, there was a pronounced spike in the low-cost carriers (LCCs) outbound passenger market share in 1996 (+336.66%). As has been previously noted, Freedom Air International entered the market in 1996. From 1998 to 2003, the low-cost carriers (LCCs) increased their annual market share on a year-on-year basis, with the most significant increase occurring in 2002 (+59.64%). In 2002, Freedom Air International attracted strong customer patronage on its Trans-Tasman services. In 2004, Pacific Blue entered the market and also captured market share. There was strong growth in 2006 (+40.83%), following the entry of Jetstar Airways into the market (Figure 5). Following a decrease in market share in 2008 of 5.87%, the low-cost carriers were able to grow their market share in 2009, when they increased it by 32.33% (Figure 5). Figure 5 also shows that there were two quite pronounced decreases in the low-cost carriers (LCCs) market share in 2012, when it declined by 60.18% on the 2011 level, and in 2019 when it decreased by 11.36% on the 2018 levels. The decrease in 2012 could be attributed to the change in Pacific Blue's business model. Whilst the decrease in 2019 could be attributed to the exit of Air Asia-X from the market plus there were also smaller volumes of outbound travelers from Australia to New Zealand in 2019.

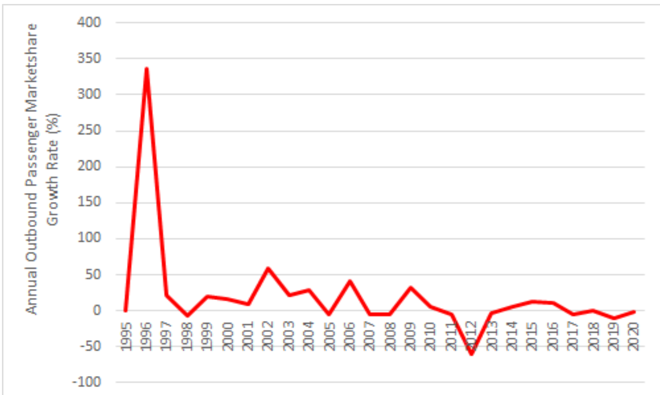

Figure 5. Low-cost carriers Trans-Tasman outbound passenger market share (%) annual growth rate: 1995-2020.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2006), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008-2021), Department of Transport and Regional Services (2001).

The major milestones in the development of the Trans-Tasman low-cost carrier (LCC) aviation market are presented in Figure 6.

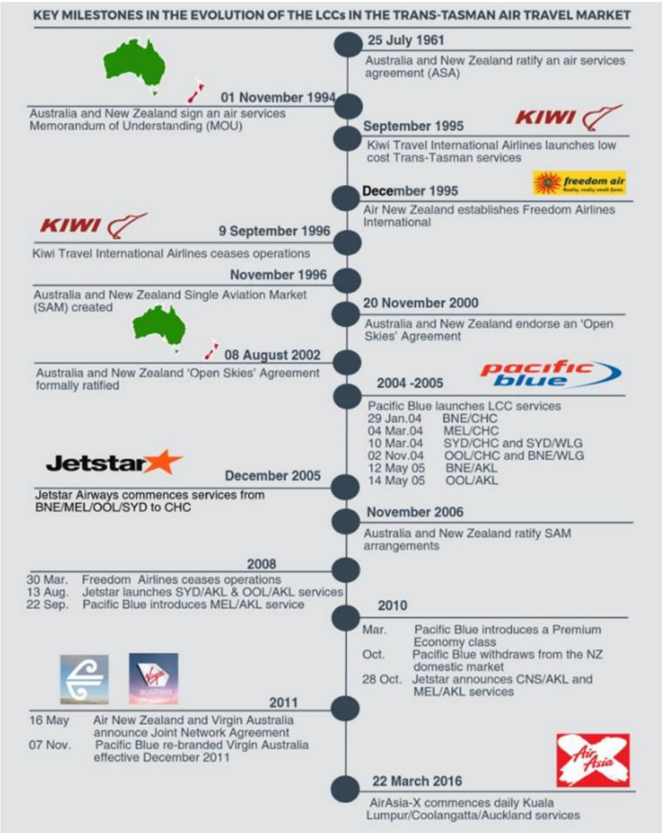

Figure 6. The key milestones in the development of the Trans-Tasman low-cost carrier air travel market. Legend: AKL=Auckland, BNE=Brisbane, CHC=Christchurch, CNS=Cairns, MEL=Melbourne, OOL=Coolangatta, SAM=Single Aviation Market, SYD=Sydney, WLG=Wellington.

4.2. The development of Australia's low-cost carriers (LCCs) Trans-Tasman services

4.2.1. Pacific Blue (Later Virgin Australia)

Virgin Blue Airlines commenced operations in Australia in August 2000 with two Boeing B737 aircraft. The airline initially operated 7 flights per day between Brisbane and Sydney. Its original owner and founder were British businessman, Sir Richard Branson. Following the collapse of Ansett Australia in 2001, Virgin Blue sought a capital injection. Patrick Corporation purchased a 50 per cent stake in Virgin Blue in 2002. The airline was subsequently publicly listed on the Sydney Stock Exchange in 2003 (Thomas, 2006). Toll Holdings bought control of Virgin Blue in 2006 (Knibb, 2008a). However, in July 2008, Toll Holdings decided to transfer its 62.7 per cent stake in Virgin Blue to the company's other shareholders (Knibb, 2008b). In March 2020, Virgin Australia filed for bankruptcy and was subsequently acquired by Bain Capital from the executors (Baer, 2021; Morrell, 2021).

Virgin Blue Airlines was granted authority by the Australian Government to commence New Zealand flights in 2003. In accordance with the "Open Skies" agreement ratified between Australia and New Zealand, Virgin Blue acquired unlimited capacity to New Zealand (Knibb, 2003). Prior to commencing its international services, Virgin Blue confronted a branding issue. This was because when Singapore Airlines purchased an equity stake in Virgin Atlantic in 1999, part of the deal was that the "Virgin" name could not be used internationally without Singapore Airlines permission (Knibb, 2003; Pilling, 2007).

Virgin Blue Airlines launched its Christchurch, New Zealand leisure-based airline, Pacific Blue in January 2004 (Knibb, 2005a, 2005c). Pacific Blue commenced daily services from Christchurch to Brisbane on the 29th of January 2004. Christchurch to Melbourne services were introduced on March 4th, 2004. Pacific Blue continued its expansion of Trans-Tasman services in 2004 commencing daily services from Sydney to Christchurch and Wellington on the 10th of May 2004. On the 2nd of November 2004, Pacific Blue commenced services between Christchurch and Coolangatta (Gold Coast) and Wellington and Brisbane. Pacific Blue continued to expand its Trans-Tasman services in 2005. The airline introduced Brisbane to Auckland and Coolangatta (Gold Coast) to Auckland on the 12th and 14th May, respectively. Pacific Blue gained entry to Auckland Airport, New Zealand's principal gateway airport, in 2005 (Airline Business, 2005a).

On the 22nd of September 2008, Pacific Blue launched flights from Melbourne to Auckland and, in so doing, became the first LCC to provide services on this important air route (Virgin Australia, 2008). Air New Zealand and Virgin Australia announced a new joint network strategy on the 16th of May 2011, whereby Air New Zealand would operate services equal to 70 per cent of the total capacity and Pacific Blue would provide the remaining 30 per cent. These were like the market shares held by the two airlines prior to the agreement. Also, both airline's flights were aligned under the agreement to ensure more convenient schedules for passengers (Virgin Australia, 2011).

On the 7th of December 2011, the "Virgin Australia" group of airlines officially launched its international airlines V-Australia and Pacific Blue under the new brand, "Virgin Australia". The decision to change the names of V-Australia and Pacific Blue came following an agreement with Singapore Airlines to allow the use of the Virgin name on V Australia and Pacific Blue services (Creedy, 2011). During the company's history, Pacific Blue's Trans-Tasman services were operated by the airline's "Next Generation" Boeing B737-800 aircraft (Knibb, 2004a).

Figure 7 shows Pacific Blue Airlines total annual inbound Trans-Tasman passengers and the year-on-year change (%) for the period 2004 to 2011. As can be observed in Figure 7, there was an upward trend in the number of inbound passengers carried by Pacific Blue from New Zealand to Australia from 2004 to 2010. In the final year of their Trans-Tasman services, the annual number of inbound passengers decreased by 5.88% in 2011 for a total of 433,723 passengers. The overall upward trend in the annual inbound passenger volumes is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than below. There was just the single year (2011) when the airline's annual enplaned inbound passengers decreased on a year-on-year basis. Figure 7 also shows that Pacific Blue's annual enplaned inbound passengers increased from a low of 137,326 passengers in 2004 to a high of 460,848 passengers in 2010. The most significant annual increase in this metric was recorded in 2009, when the airline's annual inbound passenger volumes increased by 51.09% on the 2008 levels (Figure 7).

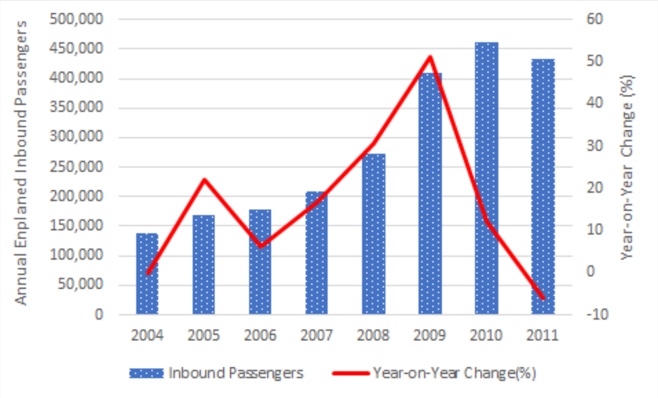

Figure 7. Pacific Blue annual enplaned Trans-Tasman inbound passengers and year-on-year change (%): 2004-2011. Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2005-2012).

Pacific Blue Airlines total annual outbound Trans-Tasman passengers from Australia to New Zealand and the year-on-year growth (%) from 2004 to 2011 is presented in Figure 8. Pacific Blue's annual enplaned outbound passengers from Australia to New Zealand followed a similar trend to the airline's annual inbound passengers, that is, there was an upward trend in the number of outbound passengers from 2004 to 2010. The overall upward trend in the annual outbound passenger volumes is also demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than below. Indeed, as can be observed in Figure 8, there was just a single year when the airline's annual outbound passengers decreased on a year-on-year basis. This decrease was recorded in 2011, when the total number of outbound passengers decreased by 7.71% on the 2010 levels. Figure 8 shows that Pacific Blue's annual enplaned outbound passengers increased from a low of 143,305 passengers in 2004 to a high of 487,669 passengers in 2010. The most significant annual increase in the annual number of enplaned outbound passengers from Australia to New Zealand was recorded in 2009, when the airline's annual outbound passenger volumes increased by 52.33% on the 2008 levels (Figure 8).

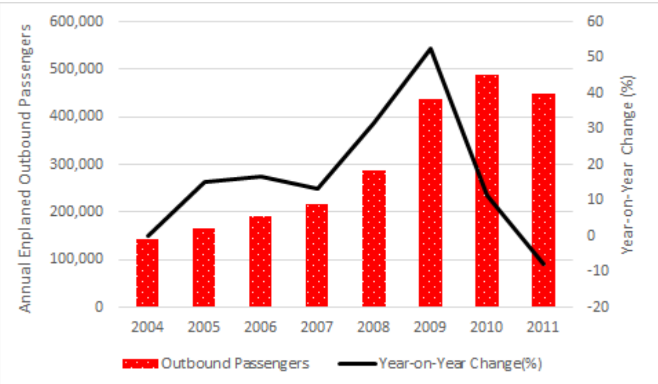

Figure 8. Pacific Blue annual enplaned Trans-Tasman outbound passengers and year-on-year change (%): 2004-2011.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2005-2012).

Pacific Blue Airlines annual inbound Trans-Tasman passenger market share and the year-on-year growth (%) from 2004 to 2011 is presented in Figure 9. Figure 9 shows that there was an upward trend in the airline's annual inbound passenger market share when it increased from a low of 5.93% in 2004 to a high of 16.70% in 2010. During the study period, there was just a single year when Pacific Blue's annual inbound passenger market share decreased on a year-on-year basis. This decrease occurred in 2011, when the airline's annual inbound market share decreased by 7.78% on the 2010 level. The most significant annual increase in the airline's annual inbound passenger market share was recorded in 2009, when it increased by 45.09% on the 2008 level (Figure 9).

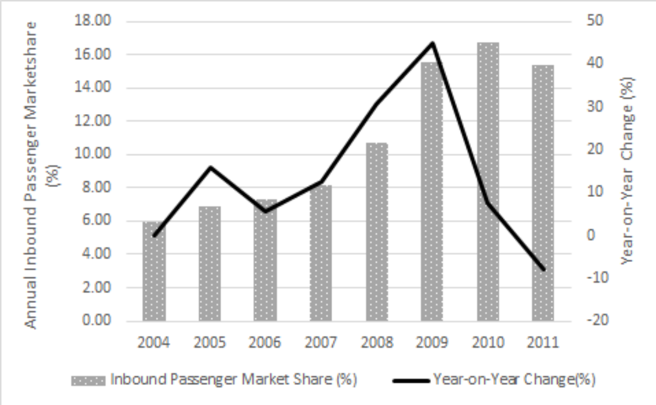

Figure 9. Pacific Blue annual Trans-Tasman inbound passengers market share and year-on-year change (%): 2004-2011.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2005-2012).

Figure 10 presents Pacific Blue Airlines annual outbound Trans-Tasman passenger market share and the year-on-year growth (%) for the period 2004 to 2011. Pacific Blue Airlines annual outbound Trans-Tasman passenger market share exhibited an upward trend over the period 2004 to 2010 before decreasing by 9.51% in 2011. The airline's annual outbound Trans-Tasman passenger market share increased from a low of 6.09% in 2004 to a high of 17.66% in 2010. Figure 10 shows that there were two quite pronounced year-on-year increases in 2008 (+43.29%), and 2009 (+45.58%), respectively (Figure 10). The smallest annual increase in this metric occurred in 2007, when the airline's annual outbound Trans-Tasman passenger market share increased by 1.41% on the 2006 level (Figure 10).

Figure 10. Pacific Blue annual Trans-Tasman outbound passengers market share and year-on-year change (%): 2004-2011.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2005-2012).

4.2.2. Jetstar Airways

In 2003, to address Virgin Australia's success and strong growth, Qantas Airways established Jetstar Airways. This followed a similar strategy of full-service network carriers (FSNCs) based in North America and Europe (Homsombat, Lei & Fu, 2014). Jetstar Airways is a wholly owned subsidiary of the Qantas Group. The aim of the Qantas low-cost offshoot was to be Australia's lowest cost operator (Kelly, 2003). The airline commenced low fare operations in May 2004 (Collins, Hensher & Li, 2010; Forsyth, 2018; Lück & Gross, 2016), with a fleet of 14 Boeing 717 aircraft. Qantas had inherited these Boeing 717 aircraft from its acquisition of Impulse Airlines. Qantas purchased Impulse Airlines in the 2002/2002 financial year (Fletcher & Crawford, 2014). At the launch of Jetstar Airways, Qantas announced an order for 23 Airbus A320 aircraft (Airline Business, 2004a) as the Qantas Group had decided to move Jetstar Airways into a standardized fleet of 177 seat Airbus A320 aircraft (Airline Business, 2004b).

Jetstar Airways later expanded to include international services, commencing services from Brisbane, Coolangatta (Gold Coast), Melbourne and Sydney to Christchurch, New Zealand, in December 2005 (Thomas, 2007). On 13 October 2008, Jetstar Airways unveiled plans to provide daily flights from Auckland to Sydney and the Coolangatta (Gold Coast). to Auckland (Ritchie, 2008). In July 2010, Jetstar Airways announced the expansion of its Trans-Tasman service with the introduction of new Airbus A320 services from Cairns and Melbourne to Auckland (Jetstar Airways, 2010a). Jetstar introduced Airbus A320 services from Melbourne and Coolangatta (Gold Coast) to Queenstown that commenced on the 16th and 17th December 2010, respectively (Jetstar Airways, 2010b). On the 15th of November 2012, Jetstar Airways increased the number of flights between Melbourne and Sydney to Queenstown to 4 and 3 per week, respectively (Jetstar Airways, 2012). Jetstar further expanded their Trans-Tasman on December 12, 2015 with the launch of its first flights from Coolangatta (Gold Coast) to Wellington. Services from Wellington were expanded on March 30, 2016, with the introduction of four weekly flights between Melbourne and Wellington (Schofield, 2015).

At the time of the present study, Jetstar Airways served Auckland and Wellington on the North Island of New Zealand and Christchurch, Dunedin, and Queenstown in New Zealand's South Island (Jetstar Airways, 2021b). Jetstar operates a fleet of Airbus A320 and A321 aircraft that are configured in an all-economy configuration. The Airbus A320 aircraft holds 180 passengers whilst the Airbus A321 aircraft can carry between 220 and 230 passengers (Jetstar Airways, 2021a).

Figure 11 shows Jetstar Airways annual enplaned Trans-Tasman inbound passenger traffic and the annual year-on-year change (%) from 2006 through to 2020. As can be observed in Figure 11, there was an upward trend in Jetstar Airways annual enplaned Trans-Tasman inbound passengers from 2005 to 2016, this was followed by a decrease in the annual passenger volumes in 2017 and 2018 and an increase again in 2019, when they grew by 1.66% on the 2018 levels. Figure 11 shows that the annual Trans-Tasman enplaned inbound passengers declined substantially in 2020, decreasing by 76.31% on the 2019 levels. This significant decrease could be attributed to the impact of the COVID-19 pandemic on air travel demand together with the related government response measures. There was a very pronounced spike in the number of passengers carried in 2006, when they increased by 989.8% on the 2005 levels. This large increase in 2006 reflected the first full year of services in the market by Jetstar Airways. There were three other significant annual increases in the enplaned Trans-Tasman inbound passengers throughout the study period. These increases occurred in 2009 (+38.96%), 2014 (+16.43%), and 2015 (+22.85%), respectively, and reflected greater passenger demand during these years (Figure 11). As noted earlier, the largest single annual decrease in enplaned Trans-Tasman inbound passengers occurred in 2020 (-76.31%). Figure 11 shows that the highest annual number of enplaned Trans-Tasman inbound passengers was recorded in 2016, when the airline carried 461,105 passengers on its services from New Zealand to Australia.

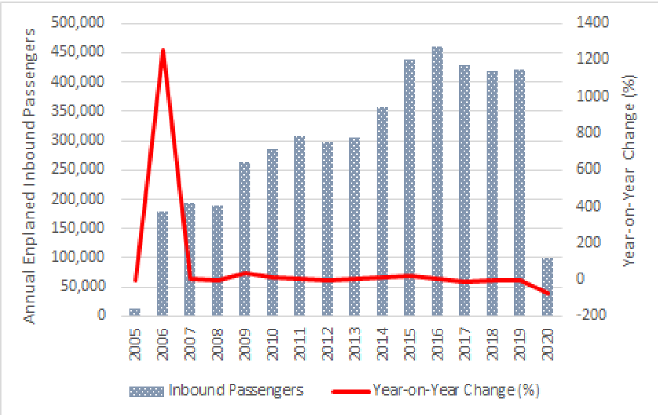

Figure 11. Jetstar Airways annual enplaned Trans-Tasman inbound passengers and year-on-year change (%): 2005-2020. Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2006-2021).

Jetstar Airways annual enplaned Trans-Tasman outbound passengers and the annual year-on-year change (%) from 2006 through to 2020 are depicted in Figure 12. Figure 12 shows that Jetstar Airways increased the annual number of Trans-Tasman passengers on its services from Australia to New Zealand over the period 2005 to 2016. This overall upward trend was interrupted in 2018 and 2019 when the airline's annual Trans-Tasman out bound passengers decreased by 7.02% in 2017 and 2.30% in 2018. The airline grew the number of Trans-Tasman outbound passengers during 2019, when they increased by 1.66% on the 2018 levels. There was 77.34% decrease in the number of passengers carried in 2020, with this decrease possibly attributed to the effects of the Corona virus pandemic and the closure of borders by the Australian and New Zealand governments. Figure 12 shows that there were some significant annual increases in the airline's annual Trans-Tasman outbound passenger volumes. These increases were recorded in 2009 (+46.69%), 2014 (+12.36%), and 2015 (21.47%), and reflected higher levels of passenger demand for the airline's services throughout these years (Figure 12). Figure 12 shows that the highest annual number of outbound enplaned Trans-Tasman passengers was recorded in 2016, when the airline carried 450,539 passengers on its services from Australia to New Zealand.

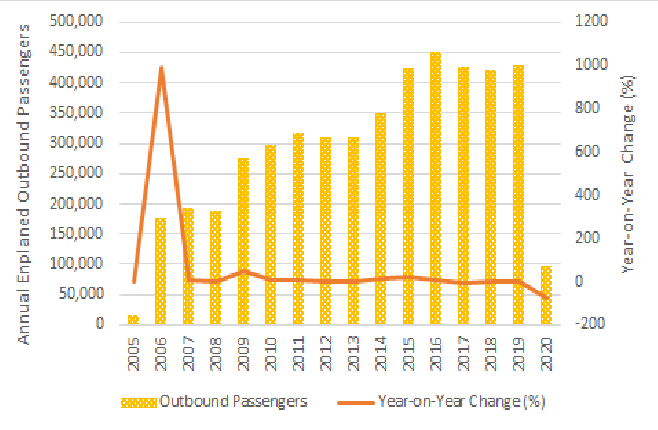

Figure 12. Jetstar Airways annual enplaned Trans-Tasman outbound passengers and year-on-year change (%): 2005-2020.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2006-2021).

Jetstar Airways annual enplaned Trans-Tasman inbound passengers market share from 2006 through to 2020 are depicted in Figure 13. It can be observed in Figure 13 that Jetstar Airways annual enplaned Trans-Tasman inbound passengers market exhibited an upward trend over the period 2005 to 2016, increasing from a low of 0.54% in 2005 to a high of 13.36% in 2015. The airline's annual market share decreased on a year-on-year basis in each of the latter years of the study, that is, from 2016 to 2020. In 2020, Jetstar Airways carried 11.59% of the passengers travelling from New Zealand to Australia. Figure 13 shows that there was a very large increase in the airline's market share in 2006, when it increased by 1,450% from 0.54% in 2005 to 7.29% in 2006. 2006 marked the first full year of commercial services between New Zealand and Australia and vice versa. There were three other significant increases in this metric, with these increases occurring in 2009 (+33.46%), 2014 (+11.02%), and 2015 (+16.37), with these increases reflecting higher levels of passenger demand (Figure 13). Apart from the decreases recorded in the latter years of the study, the airline's annual Trans-Tasman inbound passenger market share decreased in 2008 (-2.74%), 2012 (-4.68%), and 2013 (-0.38%), with lower levels of passenger demand during these years. It is important to note that an airline market share can vary (Yan, Tang & Lee, 2007), such as the Trans-Tasman aviation market.

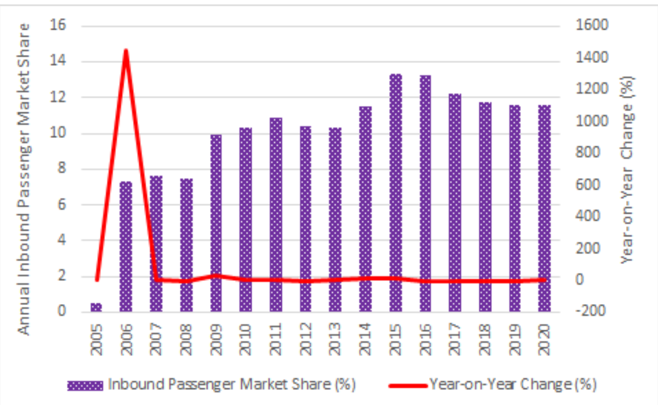

Figure 13. Jetstar Airways annual Trans-Tasman inbound passenger market share and year-on-year change (%): 2005-2020.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2006-2021).

Jetstar Airways annual enplaned Trans-Tasman outbound passenger market share from 2006 through to 2020 are presented in Figure 14. Figure 14 shows that Jetstar Airways Trans-Tasman outbound passenger followed a similar trend to the airline's annual Trans-Tasman inbound market share, that is, the market share displayed an upward trend from 2005 to 2016 before declining in the latter years of the study (2017-2020). Jetstar Airways annual enplaned Trans-Tasman outbound passenger market share increased from a low of 0.66% in 2005 to a high of 12.84% in 2016. In 2020, Jetstar Airways carried around 11.68% of the passengers travelling by air between Australia and New Zealand. Figure 14 shows that there was a very pronounced spike in the airline's market share in 2006, when it increased by 987.87% on the 2005 levels. As previously noted, 2006 marked the first full year of commercial services between Australia and New Zealand and vice versa. There were two other significant annual increases in the airline's annual Trans-Tasman outbound passenger market share. These increases occurred in 2009 (+40.16%), and 2015 (12.95%), respectively (Figure 14). During 2009 and 2015, Jetstar Airways was able to attract greater patronage of its Trans-Tasman services. Figure 14 also reveals that Jetstar Airways decreased on a year-on-year basis in the early years of the study, that is, 2007 (-2.64%), mid-way through the study period, that is, 2012 (-3.64%) and 2013 (-2.67%), and during the latter years, which include 2017 (-6.38%), 2018 (-2.66%), and 2020 (-0.34%) (Figure 14). These annual decreases in market share reflect the fluctuating nature of airline market share and passenger travelling behavior and the associated demand patterns.

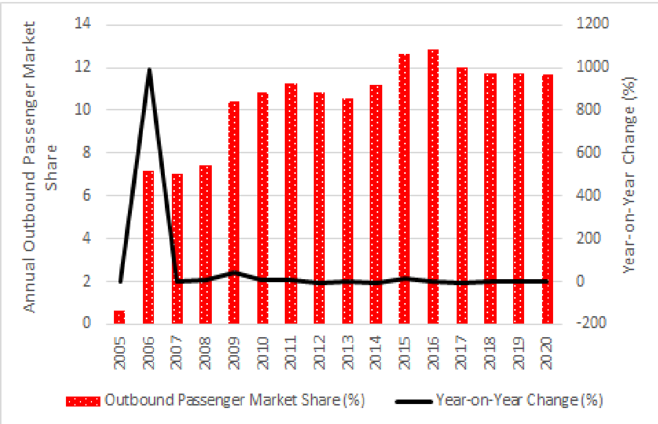

Figure 14. Jetstar Airways annual Trans-Tasman outbound passenger market share and year-on-year change (%): 2005-2020.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2006-2021).

4.3. Entry of New Zealand-based low-cost carriers (LCCs) into the Trans-Tasman aviation market

4.3.1. Freedom Air International

Freedom Air International, which was owned by the Mount Cook Airline Group (who in turn was owned by Air New Zealand), was established in December 1995 as a domestic discount carrier for Air New Zealand (Knibb, 2004b). By 1997, the airline was operating 17 weekly round-trip services from Hamilton, Palmerston North, and Dunedin to Brisbane, Coolangatta and Sydney (Phelan, 1997b). Prior to March 1998, the airline operated a single-class Boeing B737-300 aircraft that was "damp-leased" from the El Salvadorian airline TACA. In March 1998, the airline replaced this aircraft with a B737-300 that was dry-leased for a period of five years through a Hong Kong-based leasing firm. Freedom Air International boosted services from Christchurch in 2004 in response to Pacific Blue entering the market. The airline also announced plans for new services from Christchurch to Brisbane and Coolangatta (Gold Coast) in Queensland (Knibb, 2004b).

Pacific Blue launched domestic services in New Zealand in mid-November 2007, operating Boeing B737-800 aircraft between Auckland, Christchurch and Wellington, Flight frequencies ranged from two to five flights per day (Knibb, 2007a). The introduction of domestic New Zealand services by Pacific Blue prompted Air New Zealand to close Freedom Air and to fold its operations into the main airline (Knibb, 2007b). Thus, in 2005, Air New Zealand announced its intention to integrate its operations with its low-cost subsidiary, Freedom Air. Air New Zealand also decided to replace Freedom Air's Boeing B737-300 aircraft with four new Airbus A320 aircraft. These aircraft were merged into Air new Zealand's fleet of nine Airbus A320 aircraft. This fleet alignment enabled Air New Zealand to reduce its costs by ten per cent. Freedom Air International retained its brand and its own in-flight services under the plan. It was also decided that Freedom Air should add a business class cabin in its fleet of Airbus A320 aircraft (Airline Business, 2005b). In 2006, Freedom Air cancelled its services to Brisbane as they were competing against Air New Zealand (Airline Business, 2007).

Air New Zealand decided to close Freedom Air International at the end of March 2008. This decision followed Air New Zealand's strategy to divide its own economy class into two sections on both the Trans-Tasman routes and domestic services as well. The rear section of the company's aircraft has tighter seating, and with snacks and in-flight entertainment provided on a user's pay basis. By emulating the low-cost carriers (LCCs) service standards and offering air fares comparable to the low-cost carriers (LCCs), Air New Zealand concluded that it had no strategic reason to keep Freedom Air as a separate brand (Airline Business, 2007).

Freedom Air International maintained a strategy of cut-price capacity-controlled air fares, with around half of the airline's bookings sold through direct telephone sales, with the remainder coming from travel agents, who received a $NZ 20 "finder's fee" (Phelan, 1997b).

Figure 15 shows Freedom Air International annual enplaned inbound Trans-Tasman passengers and the annual growth rate from 1996 to 2008. Like their counterparts Jetstar Airways and Pacific Blue Airlines, Freedom Air International annual enplaned inbound Trans-Tasman passengers largely displayed an upward trend, increasing from a low of 9,989 passengers in 1996 to a high of 254,355 passengers in 2004. During the latter years of the airline's operations in the Trans-Tasman aviation market, Freedom Air International Airlines annual enplaned inbound Trans-Tasman passengers decreased from 2005 to 2008. As discussed previously, the decline in passenger numbers in these latter study years is due to the 2005 announcement that Air New Zealand would integrate Freedom Air International back into its operations. This was also compounded by the entry of Pacific Blue Airlines into the market space in 2004, and then Jetstar Airways in 2005/2006. It can be seen in Figure 15, that there was a very pronounced spike in the airline's annual inbound passengers in 1997 (+531.23%). This large increase reflected the first full year of operations by the airline in the Trans-Tasman aviation market. Figure 15 shows that there were also four other significant annual increase in the airline's Trans-Tasman enplaned inbound passengers during the study period. These increases were recorded in 1999 (+23.16%), 2000 (+53.93%), 2002 (+54.05%), and 2005 (+35.63%) (Figure 15). During these years, the airline was able to grow its outbound passenger patronage from New Zealand to Australia. In the latter years of the airlines Trans-Tasman operations there were quite significant decreases in the annual number of passengers carried between New Zealand and Australia, with the most significant decrease occurring in 2006 (-20.53%) and 2008 (-76.44%). As previously noted, the decision by Air New Zealand to integrate Freedom Air International back into its operations impacted the annual passenger volumes. Also, Freedom Air International confronted the additional competition by Pacific Blue and Jetstar Airways.

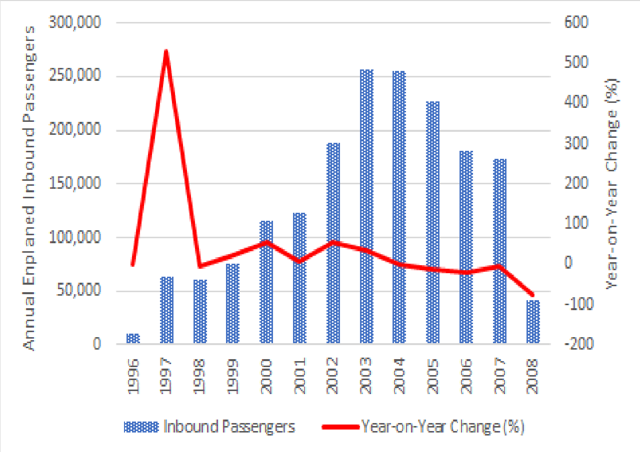

Figure 15. Freedom Air International annual enplaned Trans-Tasman inbound passengers and year-on-year change (%): 1996-2008.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2007), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008, 2009).

Freedom Air International annual enplaned outbound Trans-Tasman passengers and the annual growth rate from 1996 to 2008 are depicted in Figure 16. Figure 16 shows that Freedom Air International annual enplaned outbound Trans-Tasman passengers displayed an upward trajectory from 1996 to 2004, increasing from a low of 9,989 passengers in 1996 to a high of 254,355 passengers in 2004 (Figure 16). Figure 16 also shows that from 2005 to the cessation of operations by the airline in 2008 that the annual volume of passengers carried decreased on a year-on-year basis in 2005 (-10.8%), 2006, (-10.8), 2007 (-3.43%), and 2008 (-76.44%). The largest single annual decrease in outbound Trans-Tasman passengers was the 76.44% decrease recorded in 2008. Figure 16 shows that there was a pronounced spike in the annual number of passengers carried from Australia to New Zealand in 1997, when this metric increased by 531.23% on the 1996 levels. 1996 was the first full year of operations by the airline in the Trans-Tasman aviation market. There were four other significant increases in the airline's passenger volumes in the Trans-Tasman outbound air travel market. These significant increases were recorded in 1999 (+23.16%), 2000 (+53.93), 2002 (+54.05%), and 2003 (35.63%), respectively (Figure

16). The airline was able to grow its passenger traffic in these years because of a strong demand for its services.

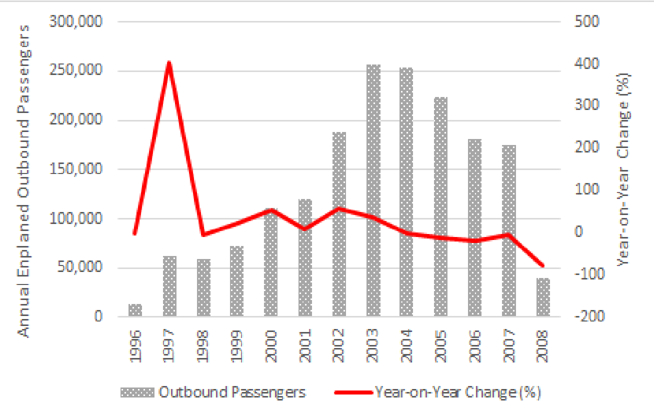

Figure 16. Freedom Air International annual enplaned Trans-Tasman outbound passengers and year-on-year change (%): 1996-2008.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2007), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008, 2009).

Freedom Air International annual enplaned inbound Trans-Tasman passenger market share and the annual change (%) from 1996 to 2008 are presented in Figure 17. Figure 17 shows that Freedom Air International enplaned inbound Trans-Tasman passenger market share grew strongly from 1996 to 2003, when it increased from a low of 0.85% in 1996 to a high of 13.36% in 2003. In the latter years of the airline's operations, its annual enplaned inbound Trans-Tasman passenger market share decreased from 13.36% in 2003 to 1.61% in 2008, which was the airline's final year of operations in the Trans-Tasman aviation market.

Figure 17. Freedom Air International annual enplaned Trans-Tasman inbound passengers market share and year-on-year change (%): 1996-2008.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2007), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008, 2009).

Figure 17 shows that there was a pronounced spike in this metric in 1997, when it increased by 472.94% on the 1996 level. As noted earlier, 1996 was the first full year of operations by the airline in the Trans-Tasman aviation market. Figure 17 also shows that there were four years during the study period where there was a substantial increase in market share recorded by the airline. These increases occurred in 1999 (+20.39%), 2000 (16.39), 2002 (41.72) and 2003 (+35.63%), with these increases reflecting higher levels of passenger demand for the airline's services from New Zealand to Australia. There were four quite significant annual decreases in the airline's annual enplaned Trans-Tasman inbound passengers market share in the study period. These decreases were recorded in 2004 (-17.73%), 2005 (-15.19%), 2006 (-20.92%), and 2008 (-76.53%) (Figure 17). The cause of these decreases in market share followed Air New Zealand's decision to integrate Freedom Air International back into its operations plus the Additional competition in the market following the entry of Pacific Blue Airlines into the market in 2004, and then Jetstar Airways in 2005.

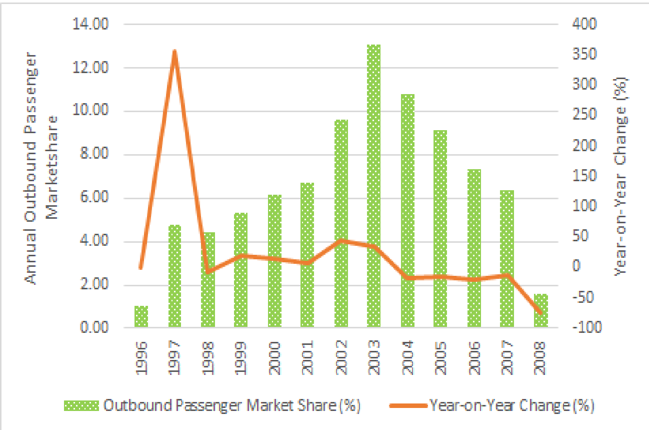

Figure 18. Freedom Air International annual enplaned Trans-Tasman outbound passengers market share and year-on-year change (%): 1996-2008.
Source: Data derived from Bureau of Transport and Regional Economics (2002-2007), Bureau of Infrastructure, Transport and Regional Economics (1998, 2008, 2009).

Figure 18 presents Freedom Air International annual enplaned outbound Trans-Tasman passenger market share and the annual change (%) for the period 1996 to 2008. As can be seen in Figure 18, Freedom Air International steadily increased its annual enplaned outbound Trans-Tasman passenger market share from 1996 to 2013, at which time the airline had secured 13.07% of the total passenger market between Australia and New Zealand. This was the highest market share that Freedom Air International had captured during the time that it competed in the Trans-Tasman aviation market. Like the airline's annual inbound Trans-Tasman market passenger market share, there was also a pronounced spike in the airline's outbound air travel market share in 1997, when it increased by 356.19% on the 1996 levels. Figure 18 also shows that during the study period, there were four years where the airline's annual enplaned outbound Trans-Tasman passenger market share increased quite substantially on a year-on-year basis. These substantial increases were recorded in 1999 (+19.77%), 2000 (+15.57%), 2002 (+44.16%), and 2003 (+35.72%), and reflected greater patronage of the airline's services (Figure 18). Figure 18 shows that the airline's outbound Trans-Tasman passenger market share declined on an annual basis from 2005 to 2008, with the most significant decrease recorded in 2008 (-75.35%). As noted earlier, the outbound market dynamics between Australia and New Zealand had changed following the introduction of services by Pacific Blue and Jetstar Airways. Also, the reintegration of Freedom Air International back into Air New Zealand operations was also a contributing factor.

4.3.2. Kiwi Airlines International

The earliest airline that introduced the low-cost carrier (LCC) business model in the Trans-Tasman air travel market was Hamilton, New Zealand-based Kiwi Travel International Airlines. The airline received approval to commence scheduled services between New Zealand and Australia around September 1995. Originally, the air services license was granted to AvAtlantic for a period of 6 months. AvAtlantic provided Kiwi Travel International Airlines with a United States registered Boeing B727-200 aircraft. Upon receipt of its approval to operate Trans-Tasman services, the airline announced that it would provide services between Hamilton and Brisbane, Hamilton to Sydney, and Dunedin to Brisbane, using the hush-kitted Boeing B727-200 aircraft. The license also granted the airline the opportunity to apply for other international air traffic rights (Flight International, 1995).

In July 1996, Kiwi Travel International Airlines became the first New Zealand-based operator of an Airbus type, when the carrier leased an Airbus A320 aircraft from Orix Leasing. This aircraft was used for flights to Brisbane and Sydney, and for new services to Melbourne and Perth (Flight International, 1996).

Due to sustained losses, Kiwi Travel International Airlines entered voluntary liquidation having accrued losses estimated to be around NZ$ 3 million for the operating period June to September 1996. Prior to entering voluntary liquidation, the airline had been operating 30 scheduled weekly trans-Tasman services from the New Zealand regional centres of Hamilton and Invercargill to Brisbane, Perth, Sydney and from Christchurch to Sydney (Phelan, 1996). Kiwi Travel International Airlines also operated services from Dunedin (Vowles & Tierney, 2007). The airline was grounded on September 6, 1996, following court action taken by Airservices Australia to recover unpaid air navigation service charges (Phelan, 1996). The collapse of the airline occurred just two months prior to the Single Aviation Market (SAM) taking effect (Phelan, 1997a).

In its brief history as a scheduled low-cost carrier (LCC), Kiwi Travel International Airlines had identified quite a large low-cost travel market originating from Hamilton, New Zealand's fourth largest urban population as well as being a major regional population centre. The airline also pioneered low-cost routes from Invercargill, located in the South Island to Brisbane, Perth, and Sydney. The airlines decision to launch flights from Christchurch, New Zealand's second busiest airport, resulted in Air New Zealand implementing a defensive strategy by launching Freedom Air International (Phelan, 1997a).

Kiwi Travel International Airlines operated services in the Trans-Tasman market from October 1995 to June 1996. In 1995, the airline carried 8,363 passengers between New Zealand and Australia, which equated to a market share of 0.91%. The airline uplifted 10,695 passengers on its services from Australia to New Zealand in 1995, and, in so doing, captured a market share of 0.70%. In 1996, Kiwi Travel International Airlines uplifted 35,336 passengers from New Zealand to Australia, this was an increase of 322.52% on the number of Trans-Tasman inbound passengers carried in 1995. In 1996, the airline's Trans-Tasman inbound passenger market share was 2.98%, an increase of 322.52% on the 1995 level. In 1996, the airline carried 34,047 passengers from Australia to New Zealand, which was an increase of 218.81% on the 1995 levels. The airline's Trans-Tasman outbound enplaned passengers market share was 2.91%, an increase of 219.78% on the 1995 level.

4.4. Entry of foreign-based LCCs into the Trans-Tasman aviation market

In January 2016, Malaysia-based low-cost carrier (LCC) AirAsia-X announced plans for a daily Gold Coast-Auckland service. These services were to be provided by densely configured Airbus A330 aircraft (Freed, 2016). Daily services between Kuala Lumpur to Auckland via Coolangatta (Gold Coast) in Queensland commenced on March 22, 2016 (Boot, 2016). The AirAsia X Airbus A330-300 aircraft has been configured with 12 Premium seats and 365 standard sized economy seats. AirAsia-X offers a premium flat-bed product on its Airbus A330 services (Allen, 2019; Bright, 2019). In late 2018, Air Asia-X announced that it would suspend its daily services from the Gold Coast to Auckland in early 2019 (Centre for Aviation, 2018).

Air Asia-X annual enplaned Trans-Tasman inbound passengers and the year-on-year change (%) from 2016 to 2019 is presented in Figure 19. During the short period of time that Air Asia- X competed in the market, the airline was able to grow its passenger volumes, which increased from 36,618 in 2016 to a high of 53,467 passengers in 2018. During 2019, its final year of operations in the market, the airline carried 6,999 passengers between New Zealand and Australia, which equated to a reduction of 86.9% on the 2018 passenger volumes. The most significant annual increase in Trans-Tasman enplaned inbound passengers was recorded in 2018, when this metric increased by 32.29% on the 2017 levels (Figure 19).

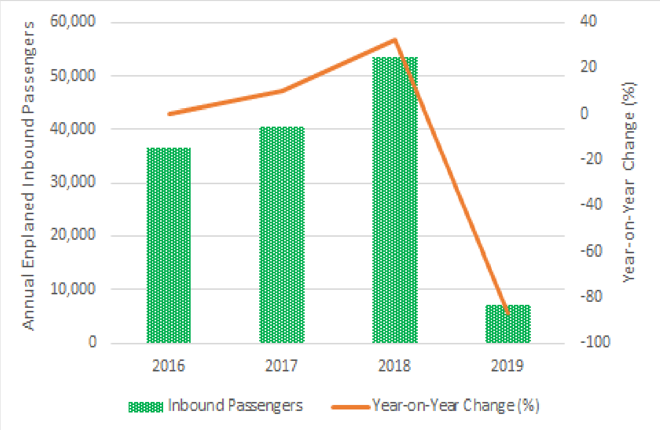

Figure 19. Air-Asia-X annual enplaned Trans-Tasman inbound passengers and year-on-year change (%): 2016-2019. Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2017-2020).

Air Asia-X annual enplaned Trans-Tasman outbound passengers and the year-on-year change (%) from 2016 to 2019 is depicted in Figure 20. As can be observed in Figure 20, Air Asia-X increased its annual passenger volumes from Australia to New Zealand in 2017 (+3.53%) and 2018 (+37.36%), with the latter being the most significant annual increase in passenger volumes recorded during the study period. The largest number of Trans-Tasman outbound passengers carried occurred in 2018, when the airline uplifted 60,385 passengers (Figure 20). Figure 20 shows that in the final year of operations between Australia and New Zealand, Air Asia-X annual passenger traffic between Australia and

New Zealand decreased by 91.48% on the 2018 levels. In 2019, the airline uplifted 5, 141 passengers between Coolangatta (The Gold Coast) and Auckland.

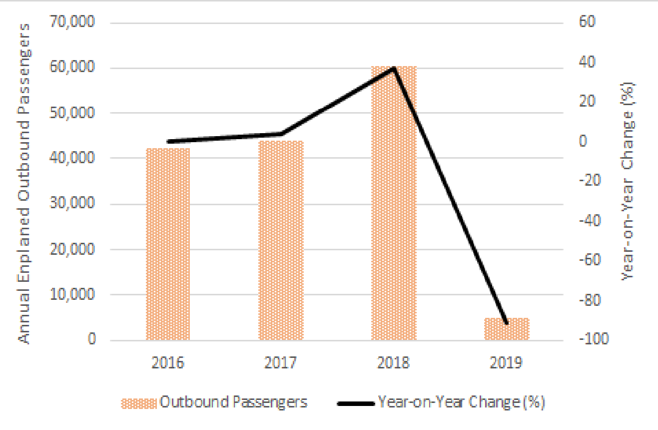

Figure 20. Air-Asia-X annual enplaned Trans-Tasman outbound passengers and year-on-year change (%): 2016-2019.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2017-2020).].

Air Asia-X annual enplaned Trans-Tasman inbound passengers market share and year-on-year change (%) from 2016-2019 is depicted in Figure 21. As can be observed in Figure 21, Air Asia-X annual enplaned Trans-Tasman inbound passengers market share displayed an upward trend from 2016 to 2918 before declining in 2019 (Figure 21). The airline's largest annual Trans-Tasman inbound passenger market share was recorded in 2018, when it had a market share of 1.49% (Figure 21). The largest single annual increase in the airline's market share occurred in 2018, when it increased by 29.56% on the 2017 levels. In 2019, the airline's Trans-Tasman inbound passengers market share decreased by 87.24% to 0.19% (Figure 21).

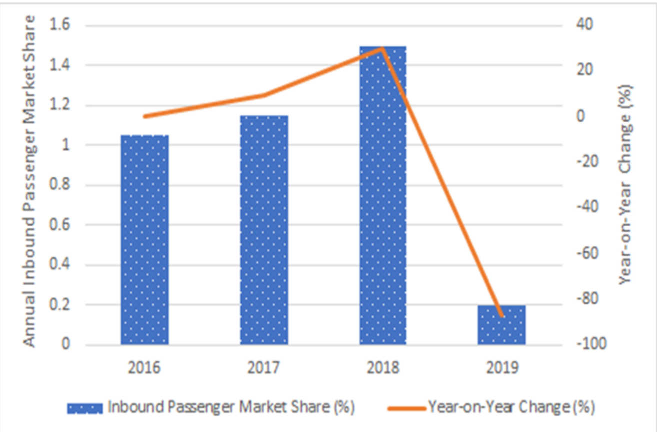

Figure 21. 21. Air Asia-X annual enplaned Trans-Tasman inbound passengers market share and year-on-year change (%): 2016-2019.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2017-2020).

Figure 22 presents Air Asia-X annual enplaned Trans-Tasman outbound passengers market share and year-on-year change (%) for the period 2016-2019. Air Asia-X annual enplaned Trans-Tasman outbound passengers market share followed a similar trend to its inbound Trans-Tasman passenger market share, that is, it displayed an upward trajectory from 2016 to 2018 before declining in 2019 (Figure 22). The airline's largest annual Trans-Tasman outbound passenger market share was recorded in 2018, when it had a market share of 1.68% (Figure 22). The largest single annual increase in the airline's market share occurred in 2018, when it increased by 36.58% on the 2017 levels. In 2019, the airline's Trans-Tasman inbound passengers market share decreased by 91.66% to 0.14% (Figure 22).

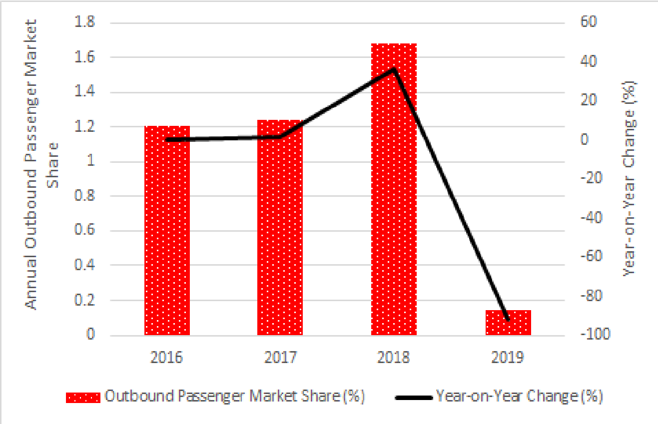

Figure 22. Air Asia-X annual enplaned Trans-Tasman outbound passengers market share and year-on-year change (%): 2016-2019.
Source: Data derived from Bureau of Infrastructure, Transport and Regional Economics (2017-2020).

5. Discussion

Historically, the low-cost carriers tended to operate a homogeneous aircraft fleet, with their aircraft deployed on a point-to-point route network (Vidovic, Śtimac & Vince, 2013). This study has found that the low cost carriers (LCCs) competing in the Trans-Tasman aviation market followed a similar aircraft fleet strategy as those low-cost carriers (LCCs) that entered the Canadian market (for example, West Jet), the European market (for example, Easyjet and Ryanair), the Japanese market (for example, Skymark Airlines), Asia/Malaysia (for example, Air Asia), the Brazilian market (for example, GOL Airlines), the Middle East market (for example, Air Arabia), the Thailand market (for example, Nok Air and Thai Air Asia), the Singapore market (for example, Tiger Airways and Valueair), and the China market (for example, Spring Airlines) (Gross, Lück & Schröder, 2016). In the United States, a key element of the low-cost carriers (LCCs) business model is the use of a single aircraft type (Zhang et al., 2016). As previously noted, a key feature of the low-cost carrier (LCC) business model is the point-to-point (P2P) route network (Birolini et al., 2022; Franke, 2018; Whyte & Lohmann, 2017). The present study found that the low-cost carriers (LCCs) competing in the Trans-Tasman aviation market had adopted a similar route network strategy, and thus, they have focused on linking key cities in both Australia and New Zealand. A further feature of the low-cost carriers (LCCs) business model is their use of secondary airports (Choo & Oum, 2013; Dziedzic & Warnock-Smith, 2016; Whyte & Lohmann, 2017). The present study found that the low-cost carriers (LCCs) competing in the Trans-Tasman aviation market have served not only secondary, regional centres in New Zealand, for example, Palmerston North and Hamilton, but have also offered services to both country's major gateway airports, for example, Auckland and Christchurch in New Zealand and Brisbane, Melbourne, and Sydney in Australia. In recent times, low-cost carriers have established their operations at major airports (Choo & Oum, 2013; Dobruszkes, Givoni & Vowles, 2017) and this strategy is reflective of the low-cost carriers (LCCs) providing services in the Trans-Tasman aviation market. De Neufville (2006) has also noted that the low-cost carriers (LCCs) may decide to serve major airports in order to capture market opportunities.

6. Conclusion

This paper has examined the evolution of low-cost carriers (LCCs) in the Trans-Tasman air travel market. The low-cost carriers (LCCs) first entered the market in 1995 following the launch of services by Hamilton, New Zealand-based Kiwi Travel International Airlines. Since that time, the market has broadly had four discrete phases. The first phase was from 1995 to 2003; the second phase saw the rapid growth in traffic following the launch of services by Pacific Blue Airlines (a subsidiary of Virgin Blue) and Jetstar Airways. An important development in the market took place in 2010, when Pacific Blue was rebranded Virgin Australia, and, as such, implemented the full-service network carrier (FSNC) business model. More recently, AirAsia-X entered the market, utilizing fifth freedom traffic rights, to provide daily Airbus A330 services from Coolangatta to Auckland. AirAsia-X exited the market in 2019 leaving Jetstar Airways as the sole low-cost carrier operating in the market (Phase 4).

Following the inception of low-cost carrier (LCC) services by Kiwi Travel International Airlines in 1995, the market displayed quite robust growth, peaking in 2010 prior to the departure of Pacific Blue Airlines from the Trans-Tasman low-cost carrier (LCC) marketplace. The significant growth in the market is clearly attributable to the carrier within a carrier, Freedom Air International a subsidiary of Air New Zealand. Similarly, the arrival of the Australian equivalent, Jetstar Airways a subsidiary of Qantas Airways, in 2005 (a decade later), has facilitated the continued growth of the market, illustrating the importance of this business model for leisure market. The departure of Pacific Blue Airlines resulted in a drop in the Trans-Tasman market share of the low-cost carriers LCCs, suggesting that Virgin Australia was able to capture and retain its market share even when offering a premium product rather than a low-cost product. In contrast, the departure of Air New Zealand's Freedom Air International did not result in a notable distortion of the low-cost carrier (LCC) passenger demand in the Trans-Tasman air travel market.

The case study revealed that the low-cost carrier's (LCCs) outbound and inbound passenger market shares grew quite strongly over the period 1995 to 2010. In 2010, the low-cost carriers (LCCs) had an inbound Trans-Tasman passenger market share of 27.07% and an outbound Trans-Tasman passenger market share of 28.50%. These were the highest recorded market shares during the study period. The low-cost carrier's annual inbound Trans-Tasman and outbound Trans-Tasman market shares both decreased from the high in 2010, and in 2020, the final year of the study period, the low-cost carrier's (LCCs) carried 11.59% of the passengers between New Zealand and Australia, and 11.68% of the passengers travelling from Australia to New Zealand.

The low-cost carriers (LCCs) competing in this market have followed many of the attributes of the "traditional" low-cost carrier (LCC) business model – single homogeneous aircraft type, high-density seating, no-frills in-flight product, and low air fares. During the duration of the study period – 1995 to 2020 – the incumbent carriers have not only provided point-to-point (P2P) services to secondary, regional centers in New Zealand, for example, Palmerston North and Hamilton, but have also offered services to both country's major gateway airports, for example, Auckland and Christchurch in New Zealand and Brisbane, Melbourne, and Sydney in Australia.

A limitation of the study was that it was not possible to analyze the effect that air fares (pricing) has played in the development of low-cost carrier services in the Trans-Tasman marketplace as this data was not publicly available. The low-cost carriers usually have simple fare structures and often use pricing initiatives to stimulate passenger demand for their services. Thus, should these data become available then a future study could examine the impact that pricing has played in the development of the Trans-Tasman LCC marketplace. A further limitation of the study was that it was restricted to a single market.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Acar, A.Z. and Karabulak, S. (2015). Competition between full-service network carriers and low-cost carriers in Turkish Airline Market. Procedia - Social and Behavioral Sciences, 207, 642-651.

Airline Business (2004a). Jetstar takes shape for May start. Airline Business, 20(1), 21.

Airline Business. (2004b). Qantas launches low-cost Jetstar. Airline Business, 20(6), 30.

Airline Business. (2004c). Pacific Blue reaches out to islands. Airline Business, 20(11), 30.

Airline Business. (2005a). Trans-Tasman rivalry heats up. Airline Business, 21(5), 228.

Airline Business. (2005b). Freedom joins forces with ANZ. Airline Business, 21(8), 28.

Airline Business. (2007). Freedom Air to fold. Airline Business, 23(10), 34.

Allen, M. (2019). Air Asia X launches Bangkok-Brisbane flights, with Premium Flatbed seats. Retrieved from: https://www.businesstraveller.com/airlines/air-asia/2019/06/26/airasia-x-launches-bangkok-brisbane-flights -with-premium-flatbed-seats/.

Ang, S.H. (2014). Research design for business & management. London: SAGE Publications.

Baer, H.A. (2021). Grappling with societies and institutions in an era of social-ecological crisis: Journey of a radical anthropologist. Lanham: Lexington Books.

Barbot, C. (2006). Low-cost airlines, secondary airports, and state aid: An economic assessment of the Ryanair-Charleroi Airport agreement. Journal of Air Transport Management, 12(4), 197–203.

Barrett, S. D. (2004). The sustainability of the Ryanair model. International Journal of Transport Management, 2(2), 89–98.

Bartlik, M. (2007). The impact of EU Law on the regulation of international air transportation. Aldershot: Ashgate Publishing.

Baxter, G. (2015). AERO2426 Air cargo management and operations: Topic 4 learning guide: Airline air cargo hubs and route networks. Melbourne: RMIT University.

Baxter, G. (2021). Achieving carbon neutral airport operations by 2025: The case of Sydney Airport, Australia. Transport and Telecommunication, 22(1), 1-14.

Baxter, G.S. and Bardell, N.S. (2017). Can the renewed interest in ultra-long-range passenger flights be satisfied by the current generation of civil aircraft? Aviation, 21(2), 42-54.

Baxter, G. and Srisaeng, P. (2020). Environmentally sustainable hotel operations: The case of the Shangri-La Group. Journal of Sustainable Tourism Development, 2(2), 1-26.

Baxter, G. and Srisaeng, P. (2021). Environmentally sustainable waste management at a major global hub airport. In N.G. Sahoo (Ed.), Waste management: Strategies, challenges, and future directions (pp. 151-185). New York, NY: Nova Scientific Publishing.

Beria, P., Laurino, A. and Postorino, M.N. (2017). Low-cost carriers and airports: A complex relationship. In J.D. Bitzan and J. H. Peoples (Eds.), Economics of airport operations (pp. 361-386). Bingley: Emerald Group Publishing.

Belobaba, P.P. (2016). Overview of airline economics, markets and demand. In P. Belobaba, A. Odoni and C. Barnhart (Eds.), The global airline industry (pp. 47-74) (2nd ed.). Chichester: John Wiley & Sons.

Beria, P., Laurino, A. and Postorino, M.N. (2017). Low-cost carriers and airports: A complex relationship. In J.D. Bitzan and J. H. Peoples (Eds.), Economics of airport operations (pp. 361-386). Bingley: Emerald Group Publishing.

Birolini, S., Besana, E., Cattaneo, M., Redondi, R. and Sallan, J.M. (2022). An integrated connection planning and passenger allocation model for low-cost carriers. Journal of Air Transport Management, 99, 102160.

Boot, S. (2016). Trans-Tasman airline rivalry increases. Retrieved from: http://www.news.com.au/finance/business/trans-tasman-airline-rivalry-increases/news-story/1b43219e9a7a143487be106d755c4907.

Bowen, J. (2019). Low-cost carriers in emerging countries. Amsterdam: Elsevier.

Bright, C. (2019). Air Asia X launching Bangkok-Brisbane flights in June. Retrieved from: https://www.businesstraveller.com/businesstravel/2019/02/08/airasia-x-launching-bangkok-brisbane-flights-in-june/.

Bureau of Transport and Regional Economics. (2002). International scheduled air transport 2001, Issue 1/113. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY01.pdf.

Bureau of Transport and Regional Economics. (2003). International scheduled air transport 2002, Issue 1/115. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY02.pdf.

Bureau of Transport and Regional Economics. (2004). International scheduled air transport 2003, Issue 1/117. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY03_Y.pdf.

Bureau of Transport and Regional Economics. (2005). International scheduled air transport 2004, Issue 1/119. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY04.pdf.

Bureau of Transport and Regional Economics. (2006). International scheduled air transport 2005, Issue 1/121. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY05.pdf.

Bureau of Transport and Regional Economics. (2007). International scheduled air transport 2006, Issue 1/123. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY06.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (1998). Airline by country of port data Passengers, freight, and mail 1994 to 1998. Retrieved from: https://bitre.gov.au/publications/ongoing/international_airline_activity-time_series.aspx.

Bureau of Infrastructure, Transport and Regional Economics. (2008). International scheduled air transport 2007, Document Number IAA 125. Retrieved from: https://www.bitre.gov.au/sites/default/files/International_airline_activity_CY07.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2009). International scheduled air transport 2008, Document Number IAM 127. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY08.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2010). International airline activity 2009, Statistical report. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY09.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2011). International airline activity 2010, Statistical report. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY10.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2012). International airline activity 2011, Statistical report. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY11.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2013). International airline activity 2012, Statistical report. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY12.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2014). International airline activity 2013, Statistical report. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY2013.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2015). International Airline Activity 2014, Statistical report. Retrieved from: https://bitre.gov.au/publications/ongoing/files/International_airline_activity_CY14.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2016). International airline activity 2015, Statistical report. Retrieved from: https://bitre.gov.au/ publications/ongoing/files/International_airline_activity_CY2015.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2017). International airline Activity 2016, Statistical report. Retrieved from: https://bitre.gov.au/ publications/ongoing/files/International_airline_activity_CY2016.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2018). International airline Activity 2017, Statistical report. Retrieved from: https://www.bitre.gov.au/ sites/default/files/International_airline_activity_CY2017.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2019). International airline Activity 2018, Statistical report. Retrieved from: https://www.bitre.gov.au/sites/ default/files/documents/international_airline_activity_cy2019.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2020). International airline Activity 2019, Statistical report. Retrieved from: https://www.bitre.gov.au/sites/ default/files/documents/international_airline_activity_cy2019.pdf.

Bureau of Infrastructure, Transport and Regional Economics. (2021). International airline Activity 2020, Statistical report. Retrieved from: https://www.bitre.gov.au/sites/ default/files/documents/international_airline_activity_cy2020.pdf.

Bureau of Transport and Communication Economics. (1994). International aviation: Trends and issues. Report 86. Canberra: Australian Government Publishing Service.

Button, K.J. (2002). Airline network economics. In D. Jenkins (Ed.), Handbook of airline economics (pp. 27-33) (2nd ed.). New York, NY: McGraw-Hill.

Button, K.J. and Stough, R. (2000). Air transport networks: Theory and policy implications. Cheltenham: Edward Elgar Publishing.

Button, K.J., Haynes, K. and Stough, R. (1998). Flying into the future: Air transport policy in the European Union. Cheltenham: Edward Elgar Publishing.

Cento, A. (2009). The airline industry: Challenges in the 21st century. Heidelberg: Physica-Springer.

Centre for Aviation. (2011). Virgin Australia completes re-branding with the introduction of Virgin Samoa. Retrieved from: https://centreforaviation.com/analysis/ reports/virgin-australia-completes-re-branding-with-the-introduction-of-virgin-samoa-64233.

Centre for Aviation. (2018). New Zealand LCC market: AirAsia pulls out again, leaving only Jetstar. Retrieved from: https://centreforaviation.com/analysis/reports/ new-zealand-lcc-market-airasia-pulls-out-again-leaving-only-jetstar-449001.

Chang, Y.C. and Williams, G. (2001). Changing the rules – amending nationality clauses in air services agreements. Journal of Air Transport Management, 7(4), 207-216.

Choo, Y.Y. and Oum, T.H. (2013). Impacts of low-cost carrier services on efficiency of the major U.S. airports. Journal of Air Transport Management, 33, 60-67.

Civil Aviation Safety Authority. (2007). Arrangement between the Australian and New Zealand governments on mutual recognition of aviation-related certification. Retrieved from: https://www.casa.gov.au/arrangement-mutual-recognition-aviation-related-certification-between australia-and-new-zealand.pdf.

Collins, A., Hensher, D.A. and Li, Z. (2010). Regional airports and opportunities for low-cost carriers in Australia. In M.N. Postorino (Ed.), Development of regional airports: Theoretical analyses and case studies (pp. 149-174). Southampton: WIT Press.

Creedy, S. (2011). Virgin Airlines rebranded to take on Qantas, The Australian, 4 May 2011, 51

Daft, J. and Albers, S. (2012). A profitability analysis of low-cost long-haul flight operations. Journal of Air Transport Management, 19, 49-54.

Daley, B. (2010). Air transport and the environment. Abingdon: Routledge.

Dawes Farquhar, J. (2012). Case study research for business. London: SAGE Publications.

Dempsey, P. S. and Gesell, L. E. (1997). Air transportation: Foundations for the 21st century. Chandler: Coast Aire Publications.

De Neufville, R. (2006). Accommodating low-cost airlines at main airports. International Airport Review, 1, 62-65.

Department of Transport and Regional Services. (2001). International scheduled air transport 2000, Issue 1/111. Retrieved from: https://bitre.gov.au /publications/ongoing/files/International_airline_activity_CY00_Y.pdf.

De Poret, M, O'Connell, J.F. and Warnock-Smith, D. (2015). The economic viability of long-haul low-cost operations: Evidence from the transatlantic market. Journal of Air Transport Management, 42, 272-281.

Derrington, M.L. (2019). Qualitative longitudinal methods: Researching, implementation and change. Thousand Oaks: SAGE Publications.

de Wit, J.G. and Zuidberg, J. (2014). The growth limits of the low cost carrier model. In L. Budd and S. Ison (Eds.), Low cost carriers: Emergence, expansion and evolution (pp. 383-390). Abingdon: Routledge.

Dziedzic, M., and Warnock-Smith, D. (2016). The role of secondary airports for today's low-cost carrier business models: The European case. Research in Transportation Business & Management, 21, 19-32.

Dobruszkes, F., Givoni, M. and Vowles, T. (2017). Hello major airports, goodbye regional airports? Recent changes in European and US low-cost airline airport choice. Journal of Air Transport Management, 59, 50-62.

Doganis, R. (2006). The airline business (2nd ed.). Abingdon: Routledge.

Dube, K., Nhamo, G. and Chikodzi, D. (2021). COVID-19 pandemic and prospects for recovery of the global aviation industry. Journal of Air Transport Management, 92, 102022.

Duval, D.T. (2005). Tourism and air transport in Oceania. In C. Cooper and C. Michael Hall (Eds.), Oceania: A tourism handbook (pp. 321-334). Clevedon: Channel View Publications.

Ehmer, H., Berster, P., Bischoff, G., Grimme, W., Grunewald, E. and Maertens, S. (2008). Analyses of the European air transport market – Airline business models. Report 1.01. Retrieved from: https://ec.europa.eu/transport/sites/transport/files/modes/air/doc/abm_report_2008.pdf.

Fairweather, S.M., Chang, C.L., Mansell, C.J., Shafuddin, E. and Hancox, R.J. (2021). Impact of COVID-19 pandemic restrictions on the cardio-respiratory health of New Zealanders. Respirology, 26(11), 1041-1048.

Findlay, C. (1996). The Trans-Tasman Single Aviation Market. Journal of Transport Economics and Policy, 30(3), 329-334.

Findlay, C. and Kissling, C. (1997). Flying towards a single aviation market across the Tasman. In C. Findlay, C.L. Sien., and K. Singh (Eds.), Asia Pacific air transport: Challenges and policy reforms (pp. 181-191). Singapore: SNP Printing Pte Ltd.

Fitzgerald, D.A. and Wong, G.W.K. (2020). COVID-19: A tale of two pandemics across the Asia Pacific region. Pediatric Respiratory Reviews, 35, 75-80.

Fletcher, R. and Crawford, H. (2014). International marketing: An Asia Pacific perspective (6th ed). Frenchs Forest: Pearson

Flight International. (1995). Kiwi Travel wins' approval for trans-Tasman services. Flight International, 148(4487), 16.

Flight International. (1996). First New Zealand Airbus goes to Kiwi International. Flight International, 150(4532), 11.

Forsyth, P. (2018). Predatory behaviour in Australian aviation markets. In P. Forsyth, D.W. Gillen, O.G. Mayer and H.M. Niemeier (Eds.), Competition verses predation in aviation markets: A survey of experiences in North America, Europe and Australia (pp. 81-94). Abingdon: Routledge.

Francis, G., Humphreys, I., Ison, S. and Aicken, M. (2006). Where next for low-cost carriers? A spatial and temporal study. Journal of Transport Geography, 14(2), 83-94.

Franke, M. (2018). Network design strategies. In P.J. Bruce, Y. Gao and J.M.C. King (Eds.), Airline operations: A practical guide (pp. 44-61). Abingdon: Routledge.

Freed, J. (2016). Trans-Tasman competition heats up as foreign airlines enter market, Sydney Morning Herald, 25 January 2016. Retrieved from: http://www.smh.com.au/business/aviation/transtasman-competition-heats-up-as-foreign-airlines-enter-market-20160121-gmbib3.html.

Fulcher, J. and Scott, J. (2011). Sociology (4th ed.). Oxford: Oxford University Press.

Gillen, D. and Lall, A. (2004). Competitive advantage of low cost carriers: Some implications for airports. Journal of Air Transport Management, 10(1), 41–50.

Graham, B. (2016). Foreword: Business travel in the global economy. In J.V. Beaverstock, B. Derudder, J. Faulconbridge, and F. Witlox (Eds.), International business travel in the global economy (pp. xvii-xxv). Abingdon: Routledge.

Grant, A. (2019). Doing excellent social research with documents: Practical examples and guidance for qualitative researchers. Abingdon: Routledge.

Gross, S. and Klemmer, L. (2014). Introduction to tourism transport. Wallingford: CABI.

Gross, S., Lück, M., and Schrõder, A. (2016). The low cost carrier – a worldwide phenomenon. In S. Gross and M. Lück (Eds.), The low cost carrier worldwide (pp. 3-18). Abingdon: Routledge.

Haanappel, P.C. (2003). The law and policy of air space and outer space: A comparative approach. The Hague: Kluwer Law International.

Hassett, M.E. and Paavilainen-Mäntymäki, E. (2013). Longitudinal research in organizations: An introduction. In: M.E. Hassett and E. Paavilainen-Mäntymäki (Eds.), Handbook of longitudinal research methods in organisation and business studies (pp. 1-22). Cheltenham: Edward Elgar Publishing.

Holloway, S. (2016). Straight and level: Practical airline economics (3rd ed.). Abingdon: Routledge.

Homsombat, W., Lei, Z. and Fu, X. (2014). Competitive effects of the airlines-within-airlines strategy: Pricing and route entry patterns. Transportation Research Part E: Logistics and Transportation Review, 63, 1-16.

Hsu, C. and Wen, Y.H. (2000). Application of Grey theory and multi-objective programming towards airline network design. European Journal of Operations Research, 127(1), 44-68.

Hunziker, D.O. (2005). Air New Zealand. In M. Beisheim, E.U. von Weizsacker, O.R. Young and M. Finger (Eds.), Limits to privatization: How to avoid too much of a good thing (pp. 102-103). London: Earthscan Books.

International Civil Aviation Organization. (2007). Trans-Tasman Single Aviation Market. Retrieved from: https://www.icao.int/sustainability/CaseStudies/StatesReplies/Trans-Tasman_EN.pdf.

Jetstar Airways. (2010a). Jetstar takes off to Auckland from Melbourne and Cairns, Press Release 28 July 2010. Retrieved from: http://www.jetstar.com/mediacentre/latest-announcements/~/_media/DADB0AAE28704843A3052A93DC447F25.pdf.

Jetstar Airways. (2010b). Jetstar takes off with three new Trans-Tasman routes, Press Release 13 December 2010. Retrieved from: http://www.jetstar.com/mediacentre/latest-announcements/~/_media/E486DCB52D684BE5869D44D778B4BA4C.pdf.

Jetstar Airways. (2012). Jetstar spreads its wings in New Zealand, Press Release 19 September 2012. Retrieved from: http://newsroom.jetstar.com/jetstar-spreads-its-wings-in-new-zealand/

Jetstar Airways. (2021a). Jetstar Group fleet. Retrieved from: https://www.jetstar.com/au/en/about-us/our-fleet.

Jetstar Airways. (2021b). Where we fly in New Zealand. Retrieved from: https://www.jetstar.com/au/en/inspiration/destinations/new-zealand?adults=1&children=0&flexible=1&flighttype=2&infants=0&origin=MEL.

Jiang, H. (2013). Service quality of low-cost long-haul airlines – The case of Jetstar Airways and AirAsia X. Journal of Air Transport Management, 26, 20-24.

Jones, D. and Collett, N. (2001). Open skies—a global view. Airfinance Journal, 236(February), 24.

Kalaian, S.A. and Kasim, R.M. (2008). Longitudinal studies. In: P.J. Lavrakas (Ed.), Encyclopaedia of survey research methods (pp. 439-440). Thousand Oaks: SAGE Publications.

Kelly, E. (2003). Qantas aims for rock bottom Jetstar prices, but unions fear erosion of pay at parent company. Flight International, 164(4912), 14.

Kleymann, B. and Seristö, H. (2016). Managing strategic airline alliances. Abingdon: Routledge.

Knibb, D. (2003). Australian carriers jockey for New Zealand positions. Airline Business, 19(8), 26.

Knibb, D. (2004a). Discounters fly offshore. Airline Business, 20(2), 22.

Knibb, D. (2004b). ANZ on the defensive. Airline Business, 20(10), 26.

Knibb, D. (2005a). Growing pains. Airline Business, 21(6), 37-41.

Knibb, D. (2005b). Low-cost battle across the Tasman. Airline Business, 21(7), 24.

Knibb, D. (2005c). Virgin Blue seeks home for cheap 737s. Airline Business, 21(9), 30.

Knibb, D. (2007a). Virgin Blue's New Zealand move. Airline Business, 23(10), 34.

Knibb, D. (2007b). Reinvention time in Australia. Airline Business, 23(12), 28.

Knibb, D. (2008a). Toll seeks to reduce Virgin stake. Airline Business, 24(4), 28.

Knibb, D. (2008b). Silver lining. Airline Business, 24(9), 54-55.

Koch, B. (2010). Aviation strategy and business models. In A. Wald, C. Fay and R. Gleich (Eds.), Introduction to aviation management (pp. 143-184). Münster: LIT Verlag.

Kua, J. and Baum, T. (2004). Perspectives on the development of low-cost airlines in South-east Asia. Current Issues in Tourism, 7(3), 262–276.

Law, C.C.H., Zhang, Y. and Zhang, A. (2019). Regulatory changes in international air transport and their impact on tourism development in Asia Pacific. In X. Fu and J. Peoples (Eds.), Airline economics in Asia (pp. 123-144). Bingley: Emerald Group Publishing.

Leick, R. and Wensveen, J.G. (2014). The airline business. In D. Prokop (Ed.), The business of transportation, Volume 1: Modes and markets (pp. 65-99). Santa Barbara: Praeger Publishing.

Lennon, M. (2016). Review: AirAsia X Airbus A330 premium flatbed class (Kuala Lumpur-Sydney), Australian Business Traveller, 9 September 2016. Retrieved from: https://www.ausbt.com.au/airasia-x-airbus-a330-premium-flatbed-class-kuala-lumpur-sydney.

Lück, M. and Gross, S. (2016). Low cost carriers in Australia and New Zealand. In S. Gross and M. Lück (Eds.), The low cost carrier worldwide (pp. 155-174). Abingdon: Routledge.

Lyon, D. and Francis, G. (2016). Current issues in airport management in New Zealand. In D.T. Duval (Ed.), Air transport in the Asia Pacific (pp. 53-72). Abingdon: Routledge.

Marquardt, M., Berger, N. and Loan, P. (2004). HRD in the age of globalization: A practical guide to workplace learning in the third millennium. Cambridge: Perseus Books.

Maria Iacus, S., Natale, F., Santamaria, C., Spyratos, S. and Vespe, M. (2020). Estimating and projecting air passenger traffic during the COVID-19 coronavirus outbreak and its socio-economic impact. Safety Science, 129, 104791.

Martin, J.C. and Román, C. (2011). Airlines and their focus on cost control and productivity. In R. Macário and E. Van de Voorde (Eds.), Critical issues in air transport economics and business (pp. 29-50). Abingdon: Routledge.

McCutchen, D.M. and Meredith, J.R. (1993). Conducting case study research in operations management. Journal of Operations Management, 11(3), 239-256.

Mecham, M. (1994a). New Zealand embraces aviation pragmatism. Aviation Week & Space Technology, 141(2), 42.

Mecham, M. (1994b). Australia's pullout threatens single market. Aviation Week & Space Technology, 141(19), 40.

Mentzer, J.T. and Flint, D.J. (1997). Validity in logistics research. Journal of Business Logistics, 18(1), 199-216.

Mills, G. (2017). The airline revolution: Economic analysis of airline performance and public policy. Abingdon: Routledge.

Monios, J. (2016). Institutional challenges to intermodal transport and logistics: Governance in port regionalization and hinterland integration. Abingdon: Routledge.

Morrell, P. (2008). Can long-haul low-cost airlines be successful? Research in Transportation Economics, 24(1), 61-67.

Morrell, P.S. (2021). Airline finance (5th ed.). Abingdon: Routledge.

Morrell, P.S. and Klein, T. (2020). Moving boxes by air: The economics of international air cargo (2nd ed.). Abingdon: Routledge.

Morrison, S. A. (2007). Airline service: The evolution of competition since de-regulation. In V.J. Tremblay and C.H. Tremblay (Eds.), Industry and firm studies (pp. 3-29). Abingdon: Routledge.

Neale, B. (2019). What is qualitative longitudinal research? London: Bloomsbury Academic.

Oates, B.J. (2006). Researching information systems and computing. London, UK: SAGE Publications.

O'Leary, Z. (2004). The essential guide to doing research. London: SAGE Publications.

Oum, T.H. and Yu, C. (2012). Winning airlines: Productivity and cost competitiveness of the world's major airlines. New York: Springer Science + Business Media.

Pan, J.Y. and Truong, D. (2018). Passengers' intentions to use low-cost carriers: An extended theory of planned behavior model. Journal of Air Transport Management, 69, 38-48.

Pearce, B. (2012). The state of air transport markets and the airline industry after the great recession. Journal of Air Transport Management, 21, 3-9.

Pearce, D.G. (1995). CER, trans-Tasman tourism and a single aviation market. Tourism Management, 16(2), 111-120.

Phelan, P. (1996). Losses make New Zealand's Kiwi flightless. Flight International, 150(4541), 22.

Phelan, P. (1997a). Strong market. Flight International, 151(4561), 40.

Phelan, P. (1997b). Tussle to rule the Tasman. Flight International, 152(4598), 77-78.

Pilling, M. (2007). Virgin's dating game. Airline Business, 23(8), 11.

Productivity Commission. (1998). International air services. Inquiry; Report No. 2. Canberra: Ausinfo.

Quiggin, J. (1997). Evaluating airline deregulation in Australia. The Australian Economic Review, 30(1), 45-56.

Ramon Gil-Garcia, J. (2012). Enacting electronic government success: An integrative study of government-wide websites, organizational capabilities, and institutions. New York: Springer Science + Business Media.

Remenyi, D., Williams, B., Money, A. and Swartz, E. A. (2010). Doing research in business and management: An introduction to process and method. London: SAGE Publications.

Reynolds-Feighan, A.J. (1994). The E.U. and U.S. air freight markets: Network organization in a deregulated environment. Transport Reviews, 14(3), 193-217.

Ritchie, K. (2008). Jetstar to expand NZ operations, ABC News, 13 October 2008.

Rochat, P. (1996). The challenges of the future for the International Civil Aviation Organization. In D. Jenkins (Ed.), Handbook of airline economics (pp. 55-61). New York: McGraw-Hill.

Schlumberger, C.E. and Weisskopf, N. (2014). Ready for takeoff? The potential for low-cost carriers in developing countries. Washington: The World Bank Publications.

Schofield, A. (2015). Jetstar continues New Zealand growth with new flight, Aviation Week Intelligence Network, 17 December 2015. Retrieved from: http://aviationweek.com/awin-only/jetstar-continues-new-zealand-growth-new-flight.

Scott, J. (2014). A dictionary of sociology (4th ed.). Oxford: Oxford University Press.

Scott, J. and Marshall, G. (2009). A dictionary of sociology (3rd ed.). New York: Oxford University Press.

Srisaeng, P., Baxter, G.S. and Wild, G. (2014). The evolution of low cost carriers in Australia. Aviation, 18(4), 203-216.

Stebbins, R.A. (2001). Exploratory research in the social sciences. Thousand Oaks: SAGE Publications.

Taneja, N.K. (2016). Designing future-oriented airline businesses. Abingdon: Routledge.

Taumoepeau, S. (2016). Low cost carriers in Asia and the Pacific. In S. Gross and M. Lück (Eds.), The low cost carrier worldwide (pp. 113-138). Abingdon: Routledge.

Thomas, G. (2006). Taking care of business. Air Transport World, 43(10), 54-58.

Thomas, G. (2007). Jetting to the top. Air Transport World, 44(11), 57-60.

Vasigh, B. and Rowe, Z.C. (2020). Foundations of airline finance: Methodology and practice (3rd ed.). Abingdon: Routledge.

Vasigh, B, Fleming, K. and Tacker, T. (2013). Introduction to air transport economics: From theory to applications (2nd ed.). Abingdon: Routledge.

Vasigh, B., Taleghani, R. and Jenkins, D. (2012). Aircraft finance: Strategies for managing capital costs in a turbulent industry. Fort Lauderdale: J. Ross Publishing.

Vidović, A., Štimac, I. and Vince, D. (2013). Development of business models of low-cost airlines. International Journal for Traffic and Transportation Engineering, 3(1), 69–81.

Virgin Australia. (2008). New daily Melbourne-Auckland service takes off, Press Release 22 September 2008. Brisbane: Virgin Australia.

Virgin Australia. (2011). Air New Zealand and Virgin Australia Airlines announce joint network, Press Release 16 May 2011. Brisbane: Virgin Australia.

Vowles, T. and Mertens, D. (2014). Gateway airports and international and regional connectivity of air transport in the Asia Pacific. In D.T. Duval (Ed.), Air transport in the Asia Pacific (pp. 113-123). Abingdon: Routledge.

Vowles, T. M. and Tierney, S. (2007). The geographic impact of 'open skies' policies on Trans-Tasman air passenger service. Asia Pacific Viewpoint, 48(3), 344-354.

Walton, J. (2011). Virgin Australia to replace Virgin Blue, V Australia, Pacific Blue names -- Polynesian Blue too? Retrieved from: https://www.executivetraveller.com/virgin-australia-to-replace-virgin-blue-v-australia-pacific-blue-names-what-about-polynesian-blue.

Wensveen, J.G. (2016). Air transportation: A management perspective (8th ed.). Abingdon: Routledge.

Wensveen, J.G. and Leick, R. (2009). The long-haul low-cost carrier: A unique business model. Journal of Air Transport Management, 15(3), 127-133.

Whyte, R. and Lohmann, G. (2015a). Low-cost long-haul carriers: A hypothetical analysis of a 'Kangaroo route'. Case Studies on Transport Policy, 3(2), 159-165.

Whyte, R. and Lohmann, G. (2015b). The carrier-within-a-carrier strategy: An analysis of Jetstar. Journal of Air Transport Management, 42, 141-148.

Whyte, R. and Lohmann, G. (2017). Airline business models. In L. Budd and S. Ison (Eds), Air transport management: An international perspective (pp. 107-121). Abingdon: Routledge.

Whyte, R., Prideaux, B. and Sakata, H. (2012). The evolution of Virgin Australia from a low-cost carrier to a full-service airline – Implications for the tourism industry. In J.S. Chen (Ed.), Advances in hospitality and leisure (pp. 215-231). Bingley: Emerald Group Publishing Limited.

Wilken, D. and Berster, P. (2016). Low-cost carrier services in Germany and Europe – From novel to normal. In P. Forsyth, D. Gillen, K. Huschelrath, H.M. Niemeier and H. Wolf (Eds.), Liberalization in aviation: Competition, cooperation, and public policy (pp. 157-184). Abingdon: Routledge.

Williams, A. (2016). Developing strategies for the modern international airport: East Asia and beyond. Abingdon: Routledge.

Wolfe, J. (1999). The record in Australasia. In M. Gaudry and R.R. Mayes (Eds.), Taking stock of air liberalization (pp. 27-38). New York: Springer Science + Businesss Media.

Yan, S., Tang, C.H. and Lee, M.C. (2007). A flight scheduling model for Taiwan airlines under market competitions. Omega, 35(1), 61-74.

Yin, R.K. (2018). Case study research and applications (6th ed). Thousand Oaks: SAGE Publications.

Yu, D. (2020). Aircraft valuations: Airplane investments as an asset class. Singapore: Springer Nature Singapore.

Zhang, A., Hanaoka, S., Inamura, H. and Ishikura, T. (2016). Low-cost carriers in Asia: Deregulation, regional liberalization and secondary airports. In L. Budd and S. Ison (Eds.), Low-cost carriers: Emergence, expansion and evolution (pp. 55-72). Abingdon: Routledge.

Zhang, A, Hui, G.W.L., Leung, L.C., Cheung, W. and Van Hui, Y. (2017). Air cargo in Mainland China and Hong Kong. Abingdon: Routledge.

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Using Environmental Cost to Evaluate Air Freight Traffic in a Turkish International Airport

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Abstract

Air freight transportation has major advantages such as rapid and safe transit of goods compared to other transportation modes. As well as other transportation sectors growth rate of air freight transportation is related to global supply chain. Air freight sector fundamentally includes freight forwarders, integrators, warehousing, customs, agents, airport terminal operators, and air freight carriers. Cost of air freight transportation is dependent to carrier expenses including costs of ground and flight crew, fuel, aircraft maintenance and insurance. But environmental prevention costs are usually missed out and disregarded. But environmental costs gained importance for many enterprises as well as airway companies after Kyoto and Paris Agreements. The current paper describes an approach to calculate prevention cost of air freight operations induced air pollutants. For this purpose, air freight traffic in an International Airport located in Isparta, Turkey is considered to present the approach. At the end of the study environmental cost of each air pollutant emissions, annual environmental cost of flight operations in the airport, and annual environmental cost per unit freight are calculated and compared in terms of yearly variation. The presented approach is employed to evaluate environmental costs related to air freight traffic in an International Airport for the first time.

1. Introduction

Regarding the recent advances in global trade and business world supply chain management gains importance. Supply chain management is defined to be planning and management of all sourcing, procurement, conversion, and logistic activities in addition to coordination of suppliers and all other third-party service providers (Stank et al., 2005). Thus, logistics activities are the main element of global trade from of old. In logistic activities railway and intermodal transportation is the most preferred option. But air freight transportation is always the most prominent one among others if rapid and safe transit of goods is required. On the other hand, growth rate of air transportation is closely linked to global supply chain. Air freight industry mainly includes freight forwarders, integrators, warehousing, customs, agents, airport terminal operators, and air freight carriers. Cost of air freight transportation is mainly related to carrier expenses. Here we can consider ground and flight crew, fuel, aircraft maintenance and insurance costs as the major factors of carrier costs (Leung et al., 2000; Chao and Hsu, 2014). Most of the previous studies discussed effect of passenger numbers and fuel prices on air freight costs (Tsoukalas et al., 2008; Takebayashi, 2011; Mayer and Scholz, 2012; Chao and Hsu, 2014;). However environmental cost is mostly disregarded.

After the Kyoto and Paris Agreements climate change and global warming concern of the mankind is comprehended in a better way. So sustainable depletion of sources and deceleration of environmental effects have been the main objective of many industries. Aviation industry has a small percentage among all others with a global average value of 2.5% in 2007 in terms of CO_2 emissions. But it is expected to increase 4.8% each year according to ICAO reports (ICAO, 2010).

Lu (2011) focused on economic gains from airports due to environmental costs. In this case Taiwan Taoyuan International airport was evaluated in terms of both environmental and social costs induced by aircraft noise and engine emissions. At the end of the research the economic benefits obtained from the airport operations were found to outweigh the negative side effects. In a former study of Konuralp (2020) showed a particular interest to the environmental degradation caused by commercial aviation. And pricing of carbon via tax was also asserted. Ekici and Sohret (2021) discussed the environmental cost of aircraft emissions at the Antalya Airport during the busiest period of 2018 year. It was concluded that B737 family aircraft has the highest environmental cost with value of 39,723.4 Euros.

Sustainable development problem related to environmental concerns in aviation industry is discussed by a group of researchers (Ekici et al., 2022). In this research how to employ environmental impact and financial values for policymakers and build new regulations is presented.

To understand relationship between environment and economy of aviation sector international organizations and aircraft manufacturers started different projects to decrease emissions. Prevention and elimination of emissions from the environment is another issue. As well as many other processes prevention and elimination of emissions from the environment lead costs. To understand and evaluate this cost environmental accounting is considered as a beneficial tool.

Environmental pollution is linked to in efficiency, and it is associated to economic disadvantage in terms of utilization of sources. So it is an opportunity for business to improve their financial performance by minimization or prevention of pollution. Particularly in last decade this approach plays a key role for sustainable management and development of firms. On the other hand prevention of pollution has a cost but it can be absorbed by winnings from more efficient use of sources. Understanding of this idea has been the driving force for many leading companies that aim to achieve sustainability (Burrit and Christ, 2016; Deegan, 2017). From this point of view environmental accounting attracts attention both industry and academia. In environmental accounting prevention or lamination cost environmental pollutions including air, water, and land pollution induced by each process is considered. The main goal of the environmental accounting is determining environmental cost whereas minimization or absorption of them by winnings from process improvements.

In the current paper the main goal is determination of air pollution cost of emissions from air freight traffic in an International Airport located in Isparta, Turkey. For this purpose, air traffic data is obtained from the Ministry of Transport and Infrastructure of the Republic of Turkey. Obtained air freight traffic data is evaluated in conjunction with aircraft fleet in Turkey with consideration of aircraft and its engine type. At the end of the study achieving environmental cost of air traffic in the investigated airport per carried freight is purposed.

2. Methodology

2.1. Environmental Accounting

Accounting is information and document collection, classification, financially assessment, and reporting of all activities in any enterprise. Account has a responsibility to consider rights of society instead of a person or a part of the society. From this point of view social responsibility accounting merged related to social responsibility of the accounting. Environmental accounting is one of the subsidiary branches of the social accounting. Environmental accounting plays a key role in documentation, reporting, and auditing expenses associated with environmental activities in an enterprise (Ergin and Okutmuş, 2007). Considering recent advances in environmental policy and environmental sensitivity of enterprises environmental accounting has gained significance to evaluate environmental impact and to obtain required information for decision making. Environmental accounting fundamentally aims to describe relation and interaction between economy and environment in addition to developing profile of resources, depletion of resources in the stock, and analyzing balance sheet (Adediran and Alade, 2013; Moorthy and Yacob, 2013; Ascui, 2014; Magablih, 2017).

On the basis of an enterprise, environmental accounting can be considered to appreciate the value of activities at each level of the organization affecting environment in the bad manner. Within this framework environmental impact of an air transportation operation should be considered as activities of flight attendants, activities in airport terminal building, activities during flight operation, and so on. However the flight operation takes the lion's share among all other activities of the airway enterprise due to emitted polluting gases from the aircraft engine during the operation

2.2. Overview of Air Transportation in Turkey

In the last ten years investment on transportation sector has an increasing trend in Turkey. As the most significant digit of this progress Turkey purposes to be the main hub of both air passenger and freight in next years by opening of Istanbul Grand Airport. Carried air freight and passenger from Turkish airports in the years of 2019 and 2020 is tabulated in Table 1. According to the table total passenger number is decreased 60.8% from 2019 to 2020 whereas decrease in flight number and air freight are 45.1% and 10.1%, respectively.

Table 1. Air traffic data in Turkey in the years of 2019 and 2020 (General Directorate of State Airports Authority, 2022).

	2019			2020		
	Domestic	**International**	**Total**	**Domestic**	**International**	**Total**
Flight number	839.894	716.523	1.556.417	572.994	280.756	853.750
Passenger number	99.946.572	108.427.124	208.373.696	49.740.303	31.875.837	81.616.140
Air freight (tons)	65.667	1.456.737	1.522.404	51.043	1.317.533	1.368.577

In Table 2, a detailed air freight data for each airport in Turkey is also presented. In accordance with the table the most freight is transported by Istanbul Grand Airport (ISL) in both years of 2019 and 2020. However, in the current paper Isparta Suleyman Demirel International Airport (ISE) is evaluated despite its low freight amount. Isparta Suleyman Demirel Airport is in the service of West Mediterranean Region of Turkey for air transportation. But a high amount of exported goods from this region is transported by seaway, roadway or railway to East Asia, Europe, and Africa countries. Additionally, role of the Isparta Suleyman Demirel International Airport in the global trading potential of the region increases regarding a project development for a freight village integrated to the airport. If the freight transportation by the airway from Isparta Suleyman Demirel International Airport the air traffic and its environmental impact should be a concern.

Table 2. Air freight data of Turkish Airports in the years of 2019 and 2020 (General Directorate of State Airports Authority, 2022).

Airport (IATA Code)	2019			2020		
	Domestic	**International**	**Total**	**Domestic**	**International**	**Total**
ISL	8.662	816.833	825.495	1.965	795.179	797.144
IST	15.814	575.149	590.962	18.292	476.310	494.602
SAW	8.004	52.044	60.048	5.585	34.438	40.022
ESB	8.544	3.310	11.853	5.599	5.350	10.949
ADB	11.775	5.140	16.915	10.616	3.353	13.969
AYT	4.626	3.079	7.705	2.179	745	2.924
GZP	0.2	0.0	0.2	1.0	0.0	1.0
DLM	25	0.1	25	20	11	30
BJV	53	0.1	53	41	0.0	41
ADA	2.884	709	3.593	2.726	615	3.341
TZX	751	2	754	462	8	470
ERZ	190	0.0	190	129	0.0	129
GZT	779	2	781	595	369	964
ADF	64	0.0	64	60	0.0	60
AJI	4	0.0	4	4	0.0	4
MZH	18	0.001	18	16	0.0	16
CII	0.0	0.0	0.0	0.0	0.0	0.0
EDO	1.0	0.0	1.0	0.02	0.0	0.02
BZI	0.0	0.0	0.0	0.0	0.0	0.0
BAL	264	0.0	264	248	0.0	248
BGG	2	0.001	2	8	0.0	8
YEI	45	6.0	51	0.4	0.0	0.4
CKZ	1.0	0.0	1.0	1.0	0.0	1.0
GKD	0.0	0.0	0.0	0.0	0.0	0.0
DNZ	338	0.02	338	288	0.0	288
DIY	423	0.01	423	348	20	368
EZS	128	0.2	128	100	0.5	100
ERC	36	0.0	36	30	0.0	30
AOE	0.0	3	3	0.0	3	3
YKO	0.0	0.0	0.0	0.0	0.0	0.0
HTY	9	1	10	23	1	24
IGD	27	0.0	27	20	0	20
ISE	7	0.01	7	2	0.0	2
KCM	56	0.0	56	21	0.0	21
KSY	21	0.0	21	8	0.0	8
KFS	2	0.0	2	2	0.0	2
ASR	615	15	630	595	11	606
KCO	0.1	7	7	0.0	0	0
KYA	239	0.9	240	222	0.1	222
MLX	141	0.0	141	71	0.0	71
MQM	82	0.0	82	68	0.0	68
MSR	45	0.0	45	38	0.0	38
NAV	17	0.0	17	11	1	12
OGU	123	0.2	123	72	0.0	72
SZF	390	4	393	274	4	278
SXZ	0.4	0.0	0.4	5	0.0	5
NOP	11	0.0	11	6	0.0	6
VAS	29	0.0	29	15	7	22
GNY	109	0.0	109	55	0.0	55
NKT	2	0.0	2	4	0.0	4
TEQ	0.01	430	430	0.0	1.109	1.109
TJK	0.0	0.0	0.0	0.0	0.0	0.0
USQ	0.1	0	0.1	0.0	0	0.0
VAN	305	1	306	218	0	218
KZR	3.5	0	3.5	0.1	0	0.1
ONQ	0.3	0	0.3	0.0	0	0.0

2.3. Conceptual Framework

The flag carrier and the block holder of the air freight transportation in Turkey and operating freight carrier airway in Isparta Suleyman Demirel International Airport is currently Turkish Cargo. Based on the obtained data freight is carried in the years of 2019 and 2020 by 3 and 1 separate flights, respectively. In other words, freight transportation corresponds to 3 and 1 landing and take-off (LTO) count in the years of 2019 and 2020, respectively According to data provided by Turkish Cargo fleet distribution is given in Table 3. According to the table the widely in-service cargo aircraft type is A330-200F.

Also, in Table 4 main features of A330-200F aircraft are listed. According to the table net cargo payload of the aircraft is 64.48 tones. According to datasheet of Airbus the main power unit of A330-200F is one of these engines: PW4000, Trent700, or CF6 series. In the current paper environmental accounting of emissions is performed regarding CF6-45A2 engine.

Table 3. Cargo aircraft fleet of Turkish Cargo (Turkish Airlines, 2022)

Aircraft Type	Number of Aircraft
A330-200F	10
B777F	6
B747-400F	4
A310-300F	2
A300-600F	1

Table 4. Features of A330-200F type cargo aircraft (Turkish Airlines, 2022)

Net Cargo Payload	**64480 kg / 330 m³**
Main Deck Door Dimensions	358 x 257 cm
Lower Deck Front Door Dimensions	270 x 170 cm
Lower Deck After Door Dimensions	273 x 168 cm
Bulk Cargo Compartiment Door Dimensions	95 x 90 cm
Height Limits in Aircraft	240 cm Max
Maximum Cargo Capacity (Main Deck)	58.532 kg / 242 m³
Maximum Cargo Capacity (Lower Deck Front)	18.869 kg / 52 m³
Maximum Cargo Capacity (Lower Deck After)	16.828 kg / 44 m³
Maximum Capacity (Bulk Cargo Compartment)	2.770 kg / 19 m³

According to the ICAO emission measurement procedure LTO cycle is shown in Fig. 1. In this context approach phase is operated for 4 minutes at 30% engine load, taxi phase is operated for 26 minutes at 7% engine load whereas duration of take-off and climb phases are 0.7, and 2.2 minutes, respectively.

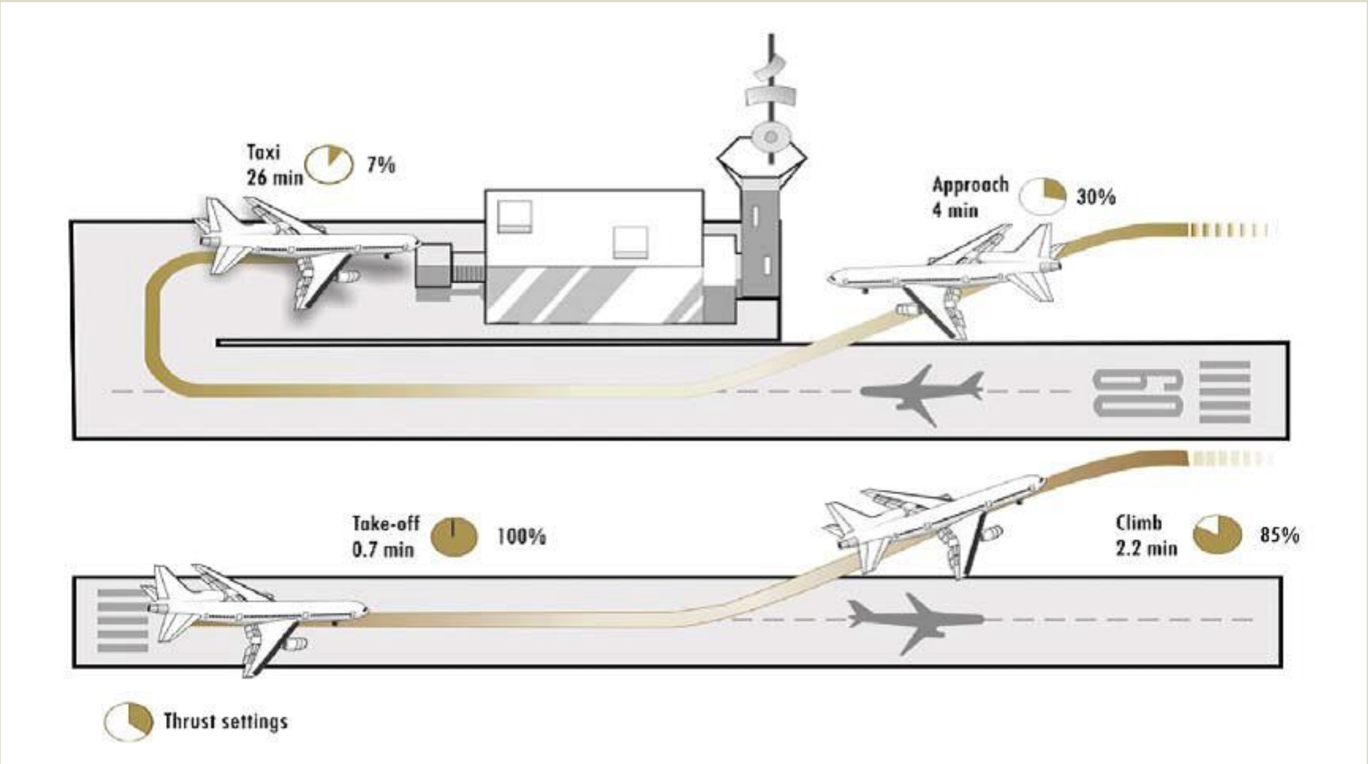

Figure 1. LTO schematic illustration for the ICAO emissions certification procedure (ICAO, 2022)

In Table 5 LTO emissions of CF6-45A2 engine is listed. Herein emissions data is obtained from EASA emissions inventory regarding ICAO emissions certification procedure illustrated in Fig. 1. Here emissions index of each exhaust gas and fuel flow rate is given. In the current study environmental accounting of each exhaust gas is evaluated by considering prevention costs determined by Vogtlander (2019). Within this context prevention cost of CO, HC, and NOx are 0.27 €/kg, 3.538 €/kg, and 6.65 €/kg.

Table 5. LTO emissions characteristics of CF6-45A2 engine (EASA, 2022)

Flight Phase	Emissions Index (g/kg)			Fuel Flow Mass (kg/sec)
	HC	CO	NOx	
Take-off	0.09	0.43	25.45	2.027
Climb-out	0.14	0.54	21.61	1.663
Approach	0.35	5.01	9.36	0.592
Idle	2.72	24.04	3.4	0.163

3. Results and Discussion

In the current paper, environmental accounting of the freight air traffic in the Isparta Suleyman Demirel International Airport is presented. In Table 6 emissions amount of 45A2 engine is given. According to Table 6 the highest emitted gas is NOx during LTO cycle excluding idle phase whereas HC is the least emitted gas.

Table 6. LTO emissions of CF6-45A2 engine

Flight Phase	Emissions Flow Mass (g/sec)		
	HC	**CO**	**NOx**
Take-off	0.18243	0.87161	51.58715
Climb-out	0.23282	0.89802	35.93743
Approach	0.2072	2.96592	5.54112
Idle	0.44336	3.91852	0.5542

In Table 7 environmental cost of the engine per second during a LTO cycle is tabulated. According to Table the highest environmental cost per second is calculated as 0.623 €/sec for NOx while the lowest environmental cost per second is determined as 0.0023 €/sec for CO. Additionally environmental cost of HC is found to be 0.00378 €/sec. On the other hand take-off phase of LTO is the main source of the environmental cost per second as it is understood from Table 7.

Table 7. LTO environmental cost of CF6-45A2 engine

Flight Phase	Environmental Cost (€/sec)		
	HC	**CO**	**NOx**
Take-off	0.000645	0.000235	0.343055
Climb-out	0.000824	0.000242	0.238984
Approach	0.000733	0.000801	0.036848
Idle	0.001569	0.001058	0.003685

Fig. 2 shows environmental cost of emissions at LTO phases regarding operation durations given in Fig. 1. Here, the highest environmental cost is determined for NOx emissions whereas the lowest environmental cost is found for CO emissions. On the other hand the highest environmental cost is determined for the emissions released at climb-out phase. The lowest environmental cost of emissions is calculated for the approach phase with the value of 9.212 €. At each phase of LTO NOx induced cost is the highest one among all emissions. Also cost related to HC is higher than CO induced cost. If total cost of emissions is evaluted NOx, HC, and CO correspond to 60.546 €, 2.759 €, and 1.885 €, respectively during LTO cycle.

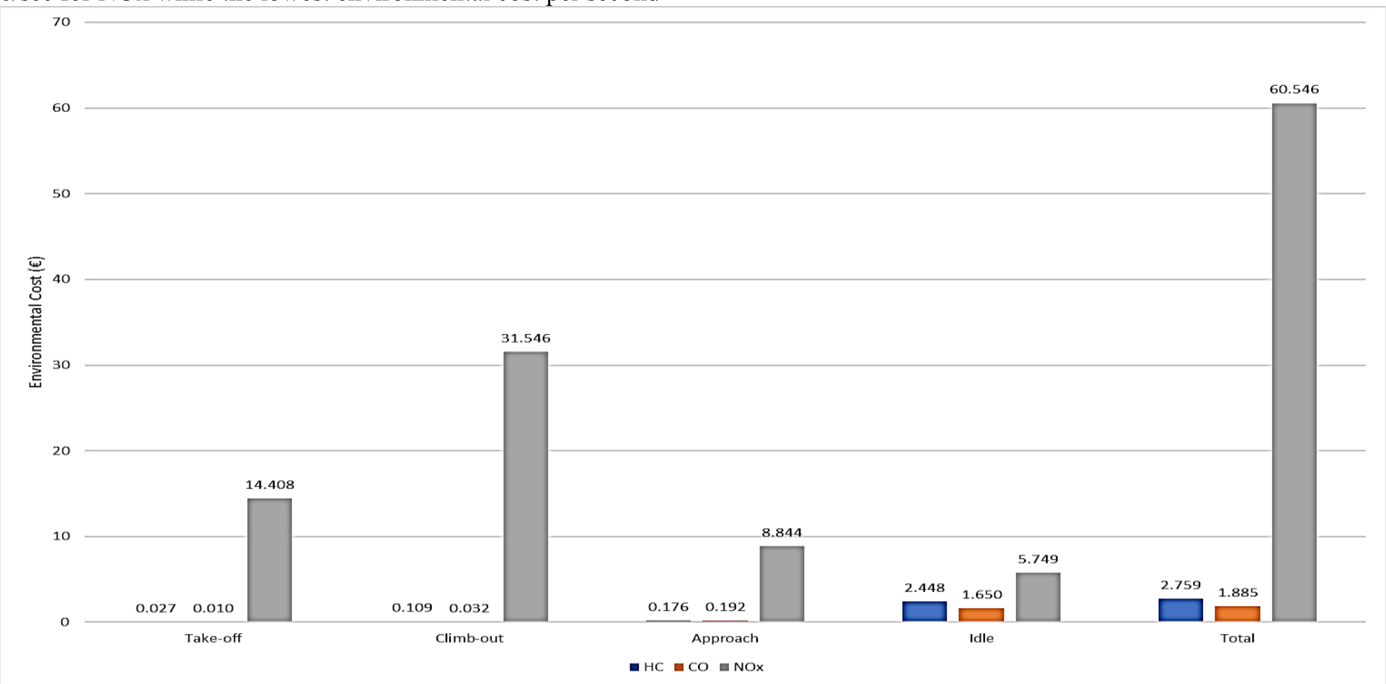

Figure 2. Environmental cost of emissions at LTO phases

In Fig. 3 calculation results are graphed considering annual operation of the freight aircraft and annual LTO count. Regarding higher LTO count in 2019 than 2020 environmental cost in the year of 2019 is found to be higher than the environmental cost in the year of 2020. If the calculation results are compared total environmental cost decreased by 66% from 2019 to 2020. Herein decerase in flight operations is a natural result of the pandemic regulations and restraints.

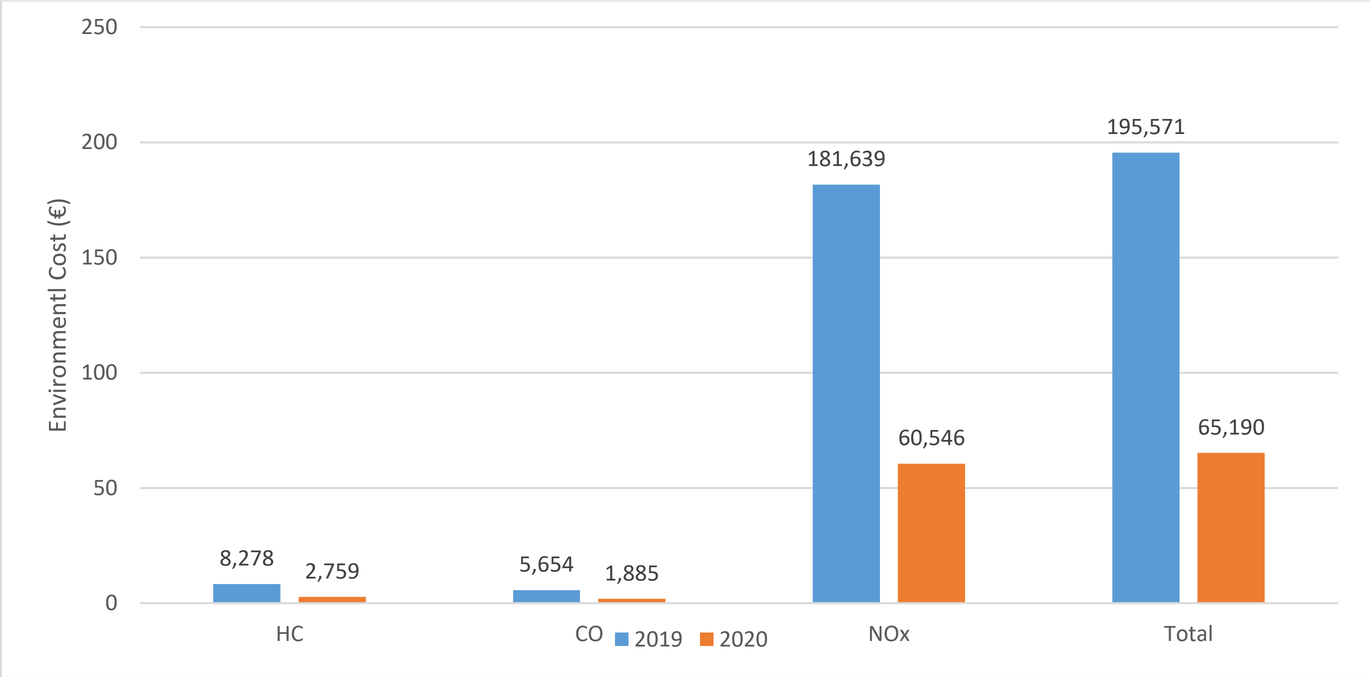

Figure 3. Annual environmental cost of emissions

If Fig. 4 is evaluated environmental cost per unit freight variation with the year can be understood. Environmental cost per unit freight increases from 2019 to 2020 whereas annual environmental cost decreases. Considering carried freight amount in 2019 and 2020 calculation result is meaningfull. Annual environmental cost per unit freight increases from 0.028 €/kg to 0.033 €/kg with an increase rate of 18% while the freight amount is decerased by 71% from 2019 to 2020.

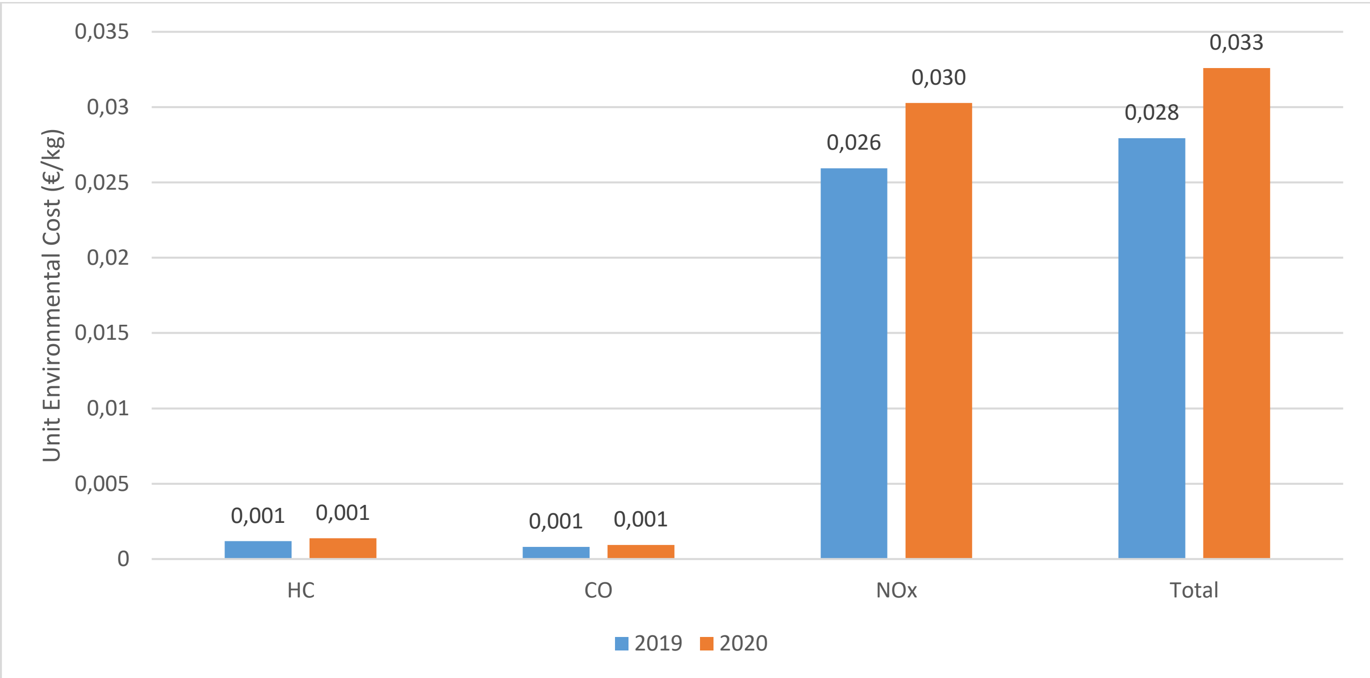

Figure 4. Annual environmental cost of emissions per unit freight

4. Conclusion

The present study asserts an approach to determine air pollution cost of emissions from air freight traffic in Isparta Suleyman Demirel International Airport. In this framework, air traffic data obtained from the Ministry of Transport and Infrastructure of the Republic of Turkey is evaluated considering aircraft and its engine type in terms of environmental cost of each air pollutant emissions, annual environmental cost of flight operations in the airport, and annual environmental cost per unit freight. The main implications can be deduced regarding the results of the study:

- NOx is the highest emitted gas is during LTO cycle excluding idle phase whereas HC is the lowest emitted gas.
- The highest environmental cost per second is calculated for NOx.
- The lowest environmental cost per second is determined for CO.

- Environmental cost in the year of 2019 is found to be higher than the environmental cost in the year of 2020.
- Environmental cost per unit freight increases from 2019 to 2020.

In a future study a comparison of environmental costs of emissions induced by different transportation modes including railway, airway, and roadway is planned by the author.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Airbus (2014), A330-200F The right freighter, right now, Airbus S.A.S., France.

Ascui, F. (2014), A review of carbon accounting in the social and environmental accounting literature: what can it contribute to the debate? Social and Environmental Accountability Journal, 34(1), 6-28.

Burritt, R. and Christ, K. (2016), Industry 4.0 and environmental accounting: a new revolution? Asian Journal of Sustainability and Social Responsibility, 1(1), 23-38.

Chao, C. C., and Hsu, C. W. (2014), Cost analysis of air cargo transport and effects of fluctuations in fuel price, Journal of Air Transport Management, 35, 51-56.

Deegan, C. (2017), Twenty-five years of social and environmental accounting research within Critical Perspectives of Accounting: Hits, misses and ways forward, Critical Perspectives on Accounting, 43, 65-87.

EASA (2022), ICAO Aircraft Engine Emissions Databank, Available at: https://www.easa.europa.eu/domains/environment/icao-aircraft-engine-emissions-databank (accessed 29 March 2022)

Ergin, H., Okutmuş, E. (2007), Environmental Accounting: Environmental Cost and Environmental Reporting, Journal of Administrative Sciences, 5 (1), 131-152.

Ekici, F., Orhan, G., Gumus, O., Bahce, A. B. (2022), A policy on the externality problem and solution suggestions in air transportation: The environment and sustainability, Energy, 258, 124827.

Ekici, S., Sohret, Y. (2020). Environmental impact and cost assessment of commercial flight induced exhaust emissions at Isparta Süleyman Demirel Airport, Journal of Engineering Sciences and Design, 8(2), 597-604.

Ekici, S., Sohret, Y. (2021), A study on the environmental and economic aspects of aircraft emissions at the Antalya International Airport, Environmental Science and Pollution Research, 28(9), 10847-10859.

General Directorate of State Airports Authority (2022), Airport Statistics, Available at: https://www.dhmi.gov.tr/Sayfalar/Istatistikler.aspx (accessed 25 March 2022)

ICAO. (2010), ICAO Environmental Report 2010: Aviation and Climate Change, Available at: http://www.icao.int/icao/en/env2010/Pubs/EnvReport10.htm. (Accessed 23 March 2022)

ICAO. (2022), Local Air Quality Technology Standards, Avaliable at: https://www.icao.int/environmental-protection/Pages/LAQ_TechnologyStandards.aspx (accessed 23 March 2022)

Konuralp, E. (2020). Between neoliberal appetence and environmentalist reservations: The political economy of sustainable aviation, International Journal of Sustainable Aviation, 6(2), 134-147.

Leung, L.C., Cheung, W., and Van Hai, Y. (2000), A framework for a logistics e-commerce community network: The Hong Kong air cargo industry, IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 30(4), 446-455.

Lu, C. (2011), The economic benefits and environmental costs of airport operations: Taiwan Taoyuan International Airport, Journal of Air Transport Management, 17(6), 360-363.

Magablih, A. M. (2017), The Impact of Green Accounting for Reducing the Environmental Cost in Production Companies, Journal of Modern Accounting and Auditing, 13(6), 249-265.

Mayer, M., and Scholz, A. B. (2012), An assessment of economic costs of cargo transporting airlines by the use of a structural cost function, Journal of Air Transport Management, 25, 30-32.

Moorthy, K., and Yacob, P. (2013), Green accounting: Cost measures, Open Journal of Accounting, 2(1), 4-7.

Perl, A., Patterson, J., & Perez, M. (1997), Pricing aircraft emissions at Lyon-Satolas airport, Transportation Research Part D: Transport and Environment, 2(2), 89-105.

Stank, T. P., Davis, B. R., and Fugate, B. S. (2005), A strategic framework for supply chain-oriented logistics, Journal of Business Logistics, 26(2), 27-46.

Takebayashi, M. (2011), The runway capacity constraint and airlines' behavior: Choice of aircraft size and network design, Transportation Research Part E: Logistics and Transportation Review, 47(3), 390-400.

Tsoukalas, G., Belobaba, P., & Swelbar, W. (2008), Cost convergence in the US airline industry: An analysis of unit costs 1995–2006, Journal of Air Transport Management, 14(4), 179-187.

Turkish Airlines (2022), Aircraft Fleet, Available at: https://www.turkishcargo.com.tr/en/about-us/fleet/cargo-aircrafts (accessed 25 March 2022)

Vogtlander, J. (2019), Data on Eco-Costs, Delft University of Technology, Netherlands.

Wolfe, P. J., Yim, S. H., Lee, G., Ashok, A., Barrett, S. R., & Waitz, I. A. (2014), Near-airport distribution of the environmental costs of aviation, Transport Policy, 34, 102-108.

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The Mediator Role of Proactive Personality in the Effect of Psychological Empowerment on Self-Leadership: A Study for the Aviation Industry

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Abstract

In recent years, psychological empowerment has been a tool to solve management problems arising from the need for creativity, innovation, and flexibility. In an environment where competition is intense, meeting the needs and expectations of conscious customers is only possible with a working style that can benefit from the initiative of the personnel. The concept of self-leadership consists of the theory of self-control and includes the concepts of self-influence and self-leadership. This study examines the mediating role of proactive personality in the effect of psychological empowerment on self-leadership. In this direction, a questionnaire was applied to 406 people in the province of Istanbul, including the cabin cockpit, ground services, operations, and general directorate in the civil aviation industry. The study used a structural equation model for the analysis. As a result, it concludes that personality has a partial mediating role in the effect of psychological empowerment on self-leadership. It suggests a need for personnel who can take the initiative, manage themselves, and adapt quickly to change, especially in the aviation sector, where safety and security are the most critical factors. Accordingly, there is a need for appropriate industry professionals in recruitment, selection and placement, training and development, and talent and career management. This need will continue to grow in the future.

This article was produced from the author's doctoral thesis.

1. Introduction

Leadership has become an increasingly important driving force. Regardless of technological advancement and automated systems facilitating decision-making, leadership remains one of the basic units in the decision-making process, and it will remain an integral part now and then. Therefore, there have been several ongoing research studies on leadership despite many previous studies already conducted in the field. With the advent of globalization during the 1980s, leadership gained a different dimension. Globalization forced international companies to compete and survive in different regional markets. They needed to boost their production capacity, respond to modernization's emerging needs, and adapt to change. This emerging situation created a need for people with change management skills to interpret the signs of change in the markets. Nowadays, competition is even fiercer than ever, rapidly transforming the business environment. As the level of education rises, employees' expectations and requirements change. When it is impossible to respond correctly to the emerging conditions, the classical hierarchy based on command and control weakens. All combined create an organizational need to respond to their customers' demands faster. In order to meet these demands on-site and on time, companies resort to human resources empowerment practices. Employee empowerment is a process in which employees feel motivated, trust their knowledge and abilities, take the initiative in relevant matters, believe they can control events, and do the jobs they see fit.

Psychological empowerment, a stimulating method of empowerment, depends on the individual's perception. It refers to the feeling of competency, the ability to act independently and effectively in the decision-making process. Leadership can help employees feel energetic and motivated when appropriately applied. It can facilitate the production of more talented staff when combined with empowerment since empowerment boosts organizational energy and motivation.

Today, the new management approach has been trending, and therefore, new management techniques emerged, giving more importance to the relationship between managers and employees. However, several personal and organizational factors have a direct or indirect impact on this relationship. Some include organizational commitment, performance, and organizational success. Besides, the employees' personality and characteristics are also important. Recent research on organizational behavior has been focusing on employees' personality traits. When the individual's personality aligns with his business life, organizational integration and employee attitude help regulate organizational commitment. The individual will be able to make the best use of his mental and physical characteristics and thus work more efficiently and achieve business objectives.

Furthermore, establishing a link between an individual's social structure and personality will make him readily comply with the group's standards. Establishing a link between an individual's behavior and relationship with the group members will help the management process. Creating the desired link between individual expectations and corporate goals is critical to organizational sustainability. An employee's personality has a vital role in this process since it can influence one's perception and evaluation of his business and environment. Therefore, the civil aviation industry has been one of such sectors adapting to this rapid change and transformation. The civil aviation industry is one of the most significant industries globally and in Turkey. As an industry based on safety and security concepts, the 'human' factor is the most important in the civil aviation industry - similar to other industries. It is a prerequisite to offer the best service for an aviation company to distinguish itself from its competitors in this fierce market. This context predicts that the effect of psychological empowerment on self-leadership and proactive personality might play a mediating role. Hence, this study examines the moderation of proactive personality in psychological empowerment on self-leadership through a holistic model on demographic variables such as age, gender, department, sectoral experience, and working style of aviation employees in civil aviation enterprises in Istanbul.

2. Conceptual Framework

2.1. Psychological Empowerment

The study analyzes two types of empowerments for the concept within this scope. One represents the empowerment that makes it possible to distribute power within the scope of a hierarchical structure and imposes responsibility on the activities and actions of the employees; on the other hand, the other is the empowerment that concerns the psychological aspects of the employees (Tolay et al., 2012: 449). Structural enforcement refers to the input, whereas psychological enforcement refers to the output. They are both said to complement (Torun, 2016: 146). In addition, psychological empowerment provides employees with responsibility, authority, opportunity, and freedom to be involved in decisions. Psychological empowerment is the identification and elimination of obstacles and limitations making employees feel powerless, and the feeling of self-efficacy of employees by increasing their sense of self-efficacy (Erdem, Gökmen, & Türen, 2016: 163). Empowerment enables employees to make better decisions, seize opportunities, increase their motivation, and increase their authority.

Empowerment is effective in the process of implementing organizational opportunities. Employees should have a control center and be empowered. In this context, it is easier for employees to achieve success. Psychological empowerment enables employees to feel better psychologically with their responsibilities and achievements. A psychologically empowered person can take the initiative, see the risks ahead of time, create a policy against them, be innovative and lead to innovation for his teammates and employees. Psychological empowerment can lead to the emergence of desired behavioral changes in employees. Employees psychologically empowered see their activities as more valuable and meaningful. They see themselves as more talented and happier and reflect their positive feelings to their colleagues. It is possible to list the outcomes of psychological empowerment as follows (Doğan and Demiral, 2009: 54; Ergeneli et al., 2007:42; Hill and Huq, 2004:1028; Akçakaya, 2010: 160; Chang and Liu, 2008:1444):

• In organizations adopting psychological empowerment, there are fewer interpersonal problems, and employees and managers are more willing to take steps towards company objectives.

• Psychological empowerment enables employees to trust their managers and organizations.

2.2. Self-leadership

Groups comprise those with different abilities, labor potential (professional competence, leadership, creative, communicative, moral, and motivational components), mental characteristics, motives, needs, expectations, and character. Groups made up of different people should be managed in such a way that the organization achieves its objectives (Polat and Arabacı, 2015: 208; Kırmaz, 2010: 213; Uzun, 2005: 4; Öztırak, 2017). The role of the leader or manager is thus significant in business enterprises. Leadership is a stage where the leader directs others towards either personal or organizational goals through influence (Ataman, 2009: 544). Self-leadership motivates individuals by using certain aspects of their understanding and behavior, controlling their behavior, and guiding and motivating them to achieve success (Manz, 1986: 589).

Self-leadership is an approach focusing on the “what,” “how,” and “why” of a task (Durnali, 2020: 129).

Self-leadership positively affects personal activities and consists of behavioral and cognitive strategies. Modern researchers think that there are three different strategies of self-leadership that will modify the attitude (Prussia et al., 1998: 105). Self-leading individuals tend to keep their motivations high in business life and thus increase their performance.

Self-leading individuals become more successful individuals in business and social life because they can provide their self-control without the need for warning and direction from others. Individuals working under the direction and control of a leader may be deficient in revealing their potential. At this point, self-leadership benefits individuals in terms of individual performance, motivation, and job satisfaction.

2.3. Proactive Personality

Personality refers to characteristic behaviors and cognitive and emotional patterns deriving from biological and environmental factors. Although there is no consensus on the definition of personality, most theories focus on motivation and psychological interactions with one's environment. Personality refers to the consistent features influencing human behaviors that make people unique (Sığrı and Gürbüz, 2011: 31; Deniz, 2011: 99). It is highly distinctive for each individual, including abilities, interests, communication styles, attitudes, external appearance, and environmental adaptation (Güney, 2006: 15). Proactive behavior involves acting in advance for a future situation rather than reacting (Adam, 2008: 34). It means taking control of a situation and making early changes rather than adapting to it. Proactive personality refers to an individual's ability to initiate the change he deems necessary without taking any orders (Bolino et al., 2010: 327). A proactive personality is a person who sees opportunities before everyone else and refuses to remain patient and thus takes the initiative to improve the conditions while remaining patient until the formation of an ideal environment (Crant, 2000: 435-462). What proactive behaviors have in common is that they focus on taking control by looking forward and initiating change. This whole process is under the impact of disposition and situational forces.

In terms of individual importance, individual differences and contextual factors are accepted as precursors of proactive work behaviors, while researchers mainly highlight individual differences. For example, general self-efficacy and a sense of responsibility are associated with a desire for control and proactive personality proactive work behaviors (Crant, 2000: 452; Parker, Bindl and Strauss, 2010: 42; Parker and Collins, 2010: 67; Ashford and Black, 1996: 201; Morrison and Phelps, 1999: 419). Proactive personality varies from individual to individual.

2. Data Collection Tools and Analysis of Data

2.2. Data Collection Tools

Measurement tools used in the study were personal information forms and scales for psychological empowerment, self-leadership, and proactive personality. Personal information forms consist of a questionnaire on gender, age, marital status, education, position in the sector, and the employment period in the aviation industry.

The study used Spreitzer's "Perception of Psychological Empowerment" scale to measure psychological empowerment. The scale consists of 12 items gathered under four dimensions: meaning, adequacy, choice, and effect. Although the original scale consisted of a 7-point Likert scale, a 5-point Likert scale was used in the study, and the Cronbach alpha value was found to be 0.84 (1= strongly disagree, 5= strongly agree) (Üner & Turan, 2010: 10).

In the measurement of self-leadership, the Turkish version of Turkoz's 35-item revised self-leadership scale was used in addition to reliability and validity studies. A total of 29 items, obtained by subtracting six items, were used. It consists of eight dimensions: self-reward, clue reminder, self-punishment, self-observation, evaluation of thoughts and ideas, self-talk, imagining successful performance by setting one's own goals and focusing on thinking through natural rewards. In the study, the total reliability value of the scale was 0.88, consistent with the result. The study concludes that the scale could be a measurement tool for self-leadership (Türköz, 2010: 22).

Researchers prepared a scale to measure proactive working behavior, consisting of 9 questions used in the second part of the questionnaire by Şahbazoğlu (Şahbazoğlu, 2014: 16).

A 5-point Likert-type scale is used to evaluate the expressions in these three parts of the survey. The Cronbach's Alpha reliability coefficient of the scale was .86. The test-retest reliability coefficient was .95, and the corrected item-total correlations were between .50 and .66. The participants answered questions in three sections on proactive personality, proactive work, and person-to-job fit. They were asked to mark one of the options: 1-Strongly Disagree, 2- Disagree, 3- Not Sure, 4- Agree, 5- Completely Agree (Akgündüz, Gök, & Alkan, 2017: 50-68).

2.3. Analysis of Data

A structural equation model measuring the participation of proactive personality as a mediator role of employees in the Effect of Psychological Empowerment on Self-Leadership was created. In so doing, the status of the relationship between them will be tested through a statistical program. Analyzes were performed using SPSS 21.0 and AMOS 21.0 and were studied with a 95% confidence level. The kurtosis and skewness values obtained from the scales included in the items are considered sufficient for the normal distribution (Groeneandld and Meeden, 1984: 27; Moors, 1986: 86; Hopkins and Weeks, 1990: 10; De Carlo, 1997: 30).

As a result, independent t-test, ANOVA, and Pearson correlation test groups, considered parametric, were used in the analyses. The difference between the scale scores according to the two-group variables was analyzed with the t-test. The difference between the variables with 3 or more groups was analyzed with the ANOVA test. Tukey's pairwise comparison test (ANOVA) was used for the difference. The relationship between scale scores was analyzed using the Pearson correlation test. Mediation was analyzed using the structural equation model.

3. Findings

This section includes the findings of the study. All tests performed are detailed in the tables.

Table 1. Conformity Index

Conformity Index
$\chi 2$/sd <5
GFI >0.90
AGFI >0.90
CFI >0.90
RMSEA <0.08
RMR <0.08

Conformity index of the study is shown in the table above.

Table 2. Validity Reliability Analysis

	Cronbach's Alfa
Proactive Personality	0.761
Self-Reward	0.867
Tips Reminder	0.855
Self-Punishment	0.798
Self-Observation	0.667
Evaluating Thoughts and Ideas	0.627
Self-Talk	0.815
Imagining Successful Performance by Setting a Goal for Oneself	0.799
Focus on Natural Rewards	0.305
Self-Leadership	0.894
Meaning	0.823
Competence	0.831
Autonomy	0.825
Effect	0.888
Psychological Empowerment	0.840

The general reliability value of the variables is well above 0.700, which is the threshold value of Cronbach's Alpha coefficient. This value obtained from the research scale consisting of 59 questions, nine demographic questions, and 50 scale questions is more than sufficient for research in social sciences. In addition, all scale groups were analyzed separately, and the results were well above the threshold value of Cronbach's Alpha coefficient. It can be stated that the scales are meaningful.

Since the skewness and kurtosis values obtained from the scale and sub-dimension scores of proactive Personality, self-leadership and psychological empowerment were between +3 and -3, normality was ensured and parametric test techniques were used in our analysis.

Table 3. Test of Normality

	n	Skewness	Kurtosis
Proactive Personality	406	-.518	.609
Self-Reward	406	-1.437	2.568
Tips Reminder	406	-1.107	.590
Self-Punishment	406	-.657	.030
Self-Observation	406	-.375	-.195
Behavior-Oriented Strategies	406	-.038	1.261
Evaluating Thoughts and Ideas	406	-.714	1.050
Self-Talk	406	-1.221	1.557
Imagining Successful Performance by Setting a Goal for Oneself	406	-.641	.818
Constructive Thinking Strategies	406	-.652	.681
Focus on Natural Rewards	406	-1.003	1.639
Self-Leadership	406	-.568	1.170
Meaning	406	-.669	.250
Competence	406	-.905	1.235
Autonomy	406	-.926	.882
Effect	406	-.836	.242
Psychological Empowerment	406	-.396	.102

Table 4. Information on Demographic Variables

		n	%
Gender	Male	194	47.8
	Woman	212	52.2
Educational Status High	High School	21	5.2
	associate degree	110	27.1
	License	182	44.8
	graduate	93	22.9
Age	less than 25 years old	123	30.3
	25-30	132	32.5
	31-35	55	13.5
	greater than 35	96	23.6
Marital Status	Married	89	21.9
	single	317	78.1
Your monthly income	2000 TL or less	53	13.1
	2001-3000 TL	58	14.3
	3001-4000 TL	47	11.6
	4001 TL and above	248	61.1
The Airline You Are Working With	The Airline You Are Working With	187	46.1
International or National	International	219	53.9
Your Department/Department	National	70	17.2
	Airport		
	Operation	40	9.9
	cabin/cockpit	208	51.2
	Headquarters	88	21.7
How Many Years Have You Worked/Worked in the Aviation Industry?	1-5 years	245	60.3
	6-10 years	51	12.6
	11-15 years	59	14.5
	15-20 years	20	4.9
	20 years and above	31	7.6
Your Position (Duty Level)	Officer	268	66.0
	Manager/Supervisor	114	28.1
	senior manager	24	5.9
Your Place of Duty, Your Working	Apron/Office/Head Office/Cargo/Technical (Shift)	114	28.1
	Cockpit/ Flight Staff	208	51.2
	Office / Education Department / Head Office / Cargo (working between 09:00-17:00)	84	20.7

The proportion of women was 52.2%. The rate of those with a bachelor's degree is 44.8%. The proportion of those aged 25-30 is 32.5%, and the rate of single participants is 78.1%. The rate of those with a monthly income of 4001 TL or more is 61.1%. 53.9% works in international airline companies. The ratio of employees in the cabin/cockpit department is 51.2%. 60.3% have worked in the aviation sector for 1-5 years. The rate of civil servants is 66.0%. The ratio of employees in Cockpit / Flying Personnel is 51.2%.

Hypothesis

H1: Psychological empowerment affects self-leadership positively and significantly.

H2: Psychological empowerment affects proactive personality positively and significantly.

H3: Proactive personality has a mediating role in the effect of psychological empowerment on self-leadership.

Table 5. Examining the Effect of Psychological Empowerment on Self-Leadership

			Beta	S.E.	P
Self-leadership	<---	Psychological Empowerment	.514	.029	***

When the first hypothesis of the research is evaluated, it is seen that psychological empowerment directly affects self-leadership positively (β=0.514, p=0.000≤0.01). The more psychologically empowered employees are, the more their self-leadership increases. Therefore, the explanation of the relevant hypothesis is given below. The hypothesis "H1: Psychological empowerment has an effect on self-leadership" is accepted.

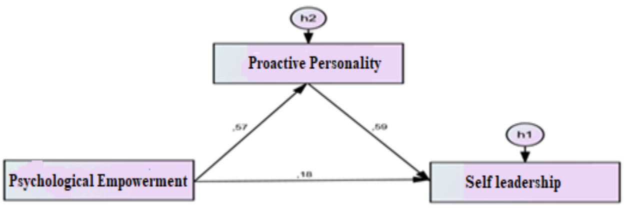

Figure 1. Examining the Mediating Role of Proactive Personality in the Effect of Psychological Empowerment on Self-Leadership

Regression coefficients were calculated, and all relationships are established in the structural equation model examining the mediating role of personality in the effect of psychological empowerment on self-leadership, which confirms the consistency of the model.

Table 6. Examination of the Mediating Role of Personality in the Effect of Psychological Empowerment on Self-Leadership

			Beta	S.E.	P
Proactive Personality	<---	Psychological Empowerment	.567	.033	***
Self-leadership	<---	Psychological Empowerment	.177	.029	***
Self-leadership	<---	Proactive Personality	.594	.036	***

An analysis of the second hypothesis reveals that psychological empowerment has a positive effect on proactive personality (β=0.567, p=0.033≤0.05), confirming the hypothesis of "H2: psychological empowerment affects proactive personality positively and significantly". Psychological empowerment has a positive effect on self-leadership (β=0.177, p=0.029≤0.05), and proactive personality has a positive effect on self-leadership (β=0.594, p=0.036≤0.05). An analysis of the effect of psychological empowerment on self-leadership puts forward that the effect is β=0.514 (Table 17), and the effect is β=0.177 with the inclusion of the proactive personality mediator variable in the model, confirming the significance of the effect and decrease in its level. Therefore, the third hypothesis is determined. The hypothesis "H3: personality has a partial mediating role in the effect of psychological empowerment on self-leadership".

4. Conclusion

Below is a summary of the results of the relationship between the variables:

For proactive individuals, the significance and importance of work and work-related activities in the business environment, the level of competence and decision-making, and their impact on all kinds of changes and developments in business increase altogether.

We can say that aviation industry employees with a high level of self-reward have proactive personality traits. That is to say, employees with a high level of self-reward have more meaning and importance at work and in work-related activities. They have a higher level of competence, affecting their work-related decisions and overall psychological resilience.

The study concludes that those who use tips and reminders for work-related tasks have higher proactive personality traits. The findings determine that using reminders and tips for the tasks to be done and work-related activities increase occupational competency, boosts decision-making, and has a meaningful effect on work-related changes and developments.

Leaders who self-punish for work-related mistakes have more positive personality traits. They find their jobs more meaningful and vital. They have better decision-making skills on their own, and they have more influence on all kinds of changes and developments related to their jobs. In other words, leaders with self-punishment have more general psychological empowerment.

Leaders with self-observation features have more positive personality traits, give more meaning and importance to their work, have more competencies for their work, make more decisions about their work by themselves, and have more influence on all kinds of changes and developments related to their work. Their overall psychological empowerment levels are also high.

Leaders with better behavior-oriented strategies have positive personality traits, give more meaning and importance to their work, have more competence for their work, are more effective in all kinds of changes and developments related to their work, and have more general psychological empowerment features.

The leaders in aviation -with more advanced skills in evaluating the thoughts and ideas- have positive personality traits, they find their jobs more meaningful and essential, they are more competent in their profession, they can make their own decisions, and they have a more significant impact on the development and change of their jobs. The general psychological empowerment aspect of leaders who evaluate thoughts and ideas correctly is robust.

The personality traits of the leaders who talk to themselves while performing their work in the working environment are optimistic; they give more meaning and importance to their work, and they have excellent competencies. Their ability to make decisions on their own is high, and they have more effects on the development and change of their work. Self-talk leaders have overall psychological empowerment.

Leaders who set goals for themselves and dream of successful performance can develop positive personality traits, give more importance to their work, be more competent, be skilled in making their own decisions, and significantly impact development and change. Leaders who dream of successful performance by setting goals for themselves have higher general psychological empowerment characteristics.

Leaders with constructive thinking strategies have positive personality traits. They think that their work is meaningful and vital, their competence in their work is high, their ability to make their own decisions increases, they have a more significant effect on the realization of their work, and their overall psychological empowerment will increase.

Leaders with a strong focus on natural rewards show positive personality traits. Apart from this, they may find their job meaningful and vital. Their competence in their job increases, their ability to make their own decisions may increase, they can take a more active role in their jobs, and their overall psychological empowerment features may intensify.

The personality traits of aviation employees with strong self-leadership traits are positive. The meaning and importance they attach to their job's increases, and their competencies increase. Their ability to make their own decisions has increased, and their active role in getting things done can increase. Leaders with great self-leadership features also have more psychological empowerment features.

As a result of structural equation modeling to determine the mediating role of proactive personality trait in the effect of psychological empowerment on self-leadership, one might say that proactive personality trait has a partial mediating role in the effect of psychological empowerment on self-leadership. There is no study examining the mediating role of personality in the relationship between psychological empowerment and self-leadership. Therefore, this thesis will help further research. A study investigating the relationship between psychological empowerment and self-leadership concluded that self-leadership has both direct and indirect effects on psychological empowerment.

As a result, the psychological empowerment of employees affects their self-leadership tendencies, and proactive personality traits have a partial mediation effect. The employees' personality also plays a role in the impact of these two variables.

5. Suggestions

The civil aviation industry is highly competitive and demanding in terms of time management, crisis management, and communication management. Therefore, there is a need for employees and personnel who can take action quickly and proactively in the face of events.

Therefore, selecting the personnel with these characteristics requires meticulous work filled with tests such as the DISC personality inventory used during recruitment, selection, and placement.

Personnel empowerment is about assigning the responsibility of the job to the individual. Therefore, civil aviation personnel must take the initiative and take action during any crisis.

Civil aviation personnel should have developed leadership skills. For example, the cabin chief's authority over the cabin crew is essential for the passengers to provide a good service (time, comfort, quality).

As a result of the study, while the psychological empowerment rate of the cabin cockpit personnel was the lowest, it was the highest among the general directorate employees. This situation shows that cabin crews must adapt to their leader and cabin chief and fulfill their directives.

Civil aviation personnel such as loadmasters and dispatchers working in the field must intervene immediately in situations they encounter while performing their jobs. Sometimes, there may not be time to reach their top managers and get approval due to time pressure. Therefore, competent personnel should be selected, and a full delegation of authority should be carried out.

Civil aviation sector personnel should be certified by national and international organizations such as IATA, ICAO, SHGM (Directorate General of Civil Aviation)

As in the world aviation companies, it is necessary to give importance to sector experience. People with sectoral experience will be able to take the initiative and act proactively readily since they have experienced similar events before.

This study focuses on the employees operating in the civil aviation sector in Istanbul. It will be a source for future studies on the proactive personality, whose positive effects on the psychological empowerment and self-leadership of the employees, which increase the performance and productivity of the employees, have been scientifically proven.

Ethical approval

Approved by the Ethics committee, with the decision of Istanbul Aydın University Ethics Commission, dd 22.12.2020, no 2020/11.

Conflicts of Interest

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

References

Adam, G. And Ashford, S. (2008). The Dynamics of Proactivity At Work, Research in Organizational Behavior, volume 28, pp. 3–34.

Akgunduz, Y., Alkan, C., & Gök, Ö. A. (2018). Perceived organizational support, employee creativity and proactive personality: The mediating effect of meaning of work. Journal of Hospitality and Tourism Management, volüme 34, pp. 105-114.

Ataman, G. (2009). İşletme Yönetimi Temel Kavramlar ve Yeni Yaklaşımlar, İstanbul, Türkmen Kitabevi.

Akçakaya, M. (2010). Örgütlerde uygulanan personel güçlendirme yöntemleri: Türk kamu yönetiminde personel güçlendirme. Karadeniz Araştırmaları, (25), 145-174.

Bolıno, M., Valcea, S. And Harvey, J. (2010). Employee, Manage Thyself: The Potentially Negative Implications Of Expecting Employees To Behave Proactively, Business Faculty Publications, Volume 6, Number 1, Pp. 3

Black, J.S. And Ashford, S.J. (1995). Fitting İn Or Making Jobs Fit: Factors Affecting Mode Of Adjustment For New Hires, Human Relations, number 48, pp. 421–437.

Chang, L.C. and Liı, C.H. (2008). Employee Empowerment, Innovative Behaviour and Job Productivity of Public Health Nurses: A Cross-Sectional Questionnaire Survey, International Journal of Nursing Studies, 45, 1442-1448.

Crant, J. M. (2000).Proactive Behavior In Organizations, Journal of Management, 26, pp. 435-462.

Durnali, M. (2020). The effect of self-directed learning on the relationship between self-leadership and online learning among university students in Turkey. Tuning Journal for Higher Education, 8(1), 129-165.

Doğan, S., & Demiral, Ö. (2009). Örgütsel Bağliliğin Sağlanmasinda Personel Güçlendirme ve Psikolojik Sözleşmenin Etkisine Ilişkin Bir Araştirma. Erciyes Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, (32), 47-80.

Erdem, H., Gökmen, Y. Ve Türen, U. (2016). Psikolojik Güçlendirme Boyutlarının İş Performansı Üzerine Etkisinde Örgütsel Bağlılığın Aracılık Rolü: Görgül Bir Araştırma, Doğuş Üniversitesi Dergisi, cilt 17, sayı 2, ss. 161-176.

Ergeneli, A., Arı, G.S. Ve Metin, S. (2007). Psychological Empowerment ve Its Relationship to Trust in Immediate Managers, Journal of Business Research, number 60, pp. 41-49.

Hıll, F. And Huq, R. (2004). Employee Empowerment: Conceptualizations, Aims and Outcomes, Total Quality Management, volume 15, number 8, pp. 1025-1041.

Güney, S (2020). Temel ve Genel İşletme, İstanbul, Nobel Yayınevi.

Groeneveld, R.A. And Meeden, G. (1984) Measuring Skewness and Kurtosis. The Statistician, volüme 33, pp. 391-399.

Manz, C. and Sims, H.P. Jr (1986). Leading Self-Managed Groups: A Conceptual Analysis Of A Paradox, Economic And İndustrial Democracy, volume 7, pp. 141-165.

Meyer, G. D., Neck, H. M., & Meeks, M. D. (2017). The entrepreneurship-strategic management interface. Strategic entrepreneurship: Creating a new mindset, 17-44.

Morrıson, E. W. And Phelps, C. C. (1999). Taking Charge At Work: Extrarole Efforts To İnitiate Workplace Change, Academy of Management Journal, volume 42, pp. 403-419.

Neck, C. P., & Manz, C. C. (1996). Thought self-leadership: The impact of mental strategies training on employee cognition, behavior, and affect. Journal of organizational behavior, 17(5), 445-467.

Prussıa, G.E., Veerson, J.S. and Manz, C.C. (1998). Self-leadership and Performance Outcomes: The Mediating Influence of Self-efficacy, Journal of Organizational Behavior, volume 19, number 5, pp. 523-538.

Parker, S. K., Bındl, U. K. And Strauss, K. (2010). Making Things Happen: A Model Of Proactive Motivation, Journal of Management, volume 36, pp. 827-856.

Polat, M. Ve Arabacı, İ. B. (2015), Liderliğin Kısa Tarihi ve Açık Liderlik, Route Educational ve Social Science Journal, cilt 2, sayı 1, ss. 207-232.

Torun, Y. (2016). Personel Güçlendirme ve İşten Ayrılma Niyeti İlişkisinde Örgütsel Sinizmin Aracılık Rolü: Örgütsel Sinizm Ölçeği Geliştirmeye Yönelik Bir Araştırma, (Yayınlanmamış Doktora Tezi), Marmara Üniversitesi Sosyal Bilimler Enstitüsü.

Kırmaz, B. (2010). Bilgi çağı lideri. Ankara Barosu Dergisi, cilt 3, ss. 207-222.

Uzun, G. (2005). Kadın ve erkek yöneticilerin liderlik davranışları arasındaki farklılıklar ve bankacılık sektöründe uygulama (Yayımlanmamış Yüksek Lisans Tezi). Çukurova Üniversitesi Sosyal Bilimler Enstitüsü.

Öztırak, M. (2017). Kurumsal Eğitim Veren Eğitmenlerde Girişimci Kişilik ile İşkoliklik İlişkisi, (Yayımlanmamış Yüksek Lisans Tezi), İstanbul Aydın Üniversitesi Sosyal Bilimler Enstitüsü.

Sığrı, Ü. Ve Gürbüz, S. (2011). Akademik Başarı ve Kişilik İlişkisi: Üniversite Öğrencileri Üzerinde Bir Araştırma, Savunma Bilimleri Dergisi, cilt 10, sayı 1, 30-48.

Üner, S. Ve Turan, S. (2010). The Construct Validity and Reliability of the Turkish Version of Spreitzer's Psychological Empowerment Scale, BMC Public Health, number 117, pp. 1-8.

Türkoz, T (2010). Çalışanların Öz Liderlik Algısının İzlenim Yönetimi Taktiklerini Kullanımlarına Olan Etkileri: Savunma Sanayinde Uygulamalı Bir Araştırma, (Yayımlanmamış Yüksek Lisans Tezi), KHO Savunma Bilimleri Enstitüsü.

Şahbazoğlu, Meltem (2014), The Relationship between Proactive Personality, Empowerment and Proactive Work Behavior, (Yayımlanmamış Doktora Tezi), Yeditepe Üniversitesi SBE.

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The Nexus Between COVID-19 Government Responses and Aviation Stock Prices in Turkey: OxCGRT Stringency Index-Based Analysis

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Abstract

Air transportation is the significant mode of transmission, enabling the worldwide spread of infectious diseases through the mobility of infected persons. Therefore, governments applied the most comprehensive restrictions and preventions in civil aviation during COVID-19. The industry is one of the most economically impacted due to travel, and flight restrictions. This paper aims to investigate the long- and short-term nexuses between government responses to COVID-19 and the aviation stock prices traded in Borsa Istanbul. The OxCGRT stringency Turkey index is used to measure the Turkish government responses and policies to COVID-19. In the study, the daily data of Turkish Airlines, Pegasus Airlines, Do&Co Catering, TAV Airport Holding, Celebi Ground Handling stock prices, and the OxCGRT stringency Turkey index for the 24.01.2020-11.11.2021 period were used, and Granger causality and Engle-Granger cointegration tests were applied to reveal the nexuses. In conclusion, there is a cointegration nexus and one-way causality from the index to all Turkish aviation stock prices, except the Celebi Ground Handling stock prices. The contribution of this study is that it is probably the first one in Turkey to reveal the nexus between the government's policy and responses to COVID-19 and aviation stock prices.

It is the revised and edited version of the paper presented in Atlas International Congress on Social Sciences 8th and published only as an abstract in the proceedings book

1. Introduction

In recent years, the aviation industry has shown steady growth due to the increase in tourism and cargo demand around the world. In many regions, the aviation industry has become a strategic sector that contributes to social development and economic growth. In 2019, the total number of scheduled passengers in the world was 4.5 billion, while the operating income of the global aviation industry was approximately 900 billion dollars (IATA, 2020).

The increase in international passenger and cargo traffic has also increased the risk of the spread of infectious diseases. The industry has often had to deal with biosecurity threats and faced various epidemics and pandemics in history such as SARS, MERS, H1N1, H5N1, as it is the fastest route for human and cargo mobility globally (Amankwah-Amoah et al., 2021; Chung, 2015). The outbreaks have dramatically demonstrated the key role of aviation in mitigating the spread of infectious diseases and their impact on global public health and the economy. Lastly, the COVID-19 emerged in China in the last months of 2019 and spread rapidly worldwide, initiated one of the biggest crises experienced by the global aviation industry.

On December 31, 2019, the World Health Organization (WHO) reported the existence of a virus that spreads in an epidemic in China, and on January 7, 2020, stated that this virus is a new type of Corona virus and announced the name of the disease as "COVID-19". On January 30, the WHO declared a global emergency, and on March 11, a "pandemic", which means a global epidemic. After the declaration of the pandemic, in order to slow the spread of the epidemic, countries first decided to stop international flights and then imposed restrictions on domestic flights (WHO, 2021). The COVID-19 has brought business operations to a standstill in all industries worldwide. Air transport was one of the first to be interrupted and thus most affected, because it would increase the spread of the disease on a global scale. The market values of airlines have decreased significantly with the onset of the pandemic.

The paper aims to reveal the nexus between COVID-19 restrictions and policies on aviation stock prices in Turkey. For this purpose, the long- and short-term nexus between the OxCGRT stringency index (SI) and the aviation stock prices traded in Borsa Istanbul analyzed through Granger causality and Engle-Granger cointegration tests.

This study contributes to the literature by revealing the economic and operational effects of COVID-19 on the aviation industry after 16 months in the pandemic, as well as the long and short-term nexuses between the Turkish government responses to COVID-19 and aviation stock prices through the causality and cointegration tests. Thus, it is revealing the impact of the COVID-19 on the civil aviation industry from a different viewpoint. This is probably the first study revealing the nexus between the OxCGRT stringency index and aviation stock prices in Turkey.

The study consists of six sections: The first section includes the introduction, the second section explains the operational and economic effects of COVID-19 on the aviation industry in the world and in Turkey, the third section summarizes literature studies on the subject, the fourth section describes the dataset and method used in the research, the fifth section presents the findings and the final section discusses the conclusion of the research.

2. Impact of COVID-19 on Civil Aviation

COVID-19 has posed major challenges to human health and economies worldwide. In addition to the high mortality rates, the supply chain disruptions, inflation, and global economic recession it causes are estimated to be the worst global economic crisis since the Great Depression of the 1930s. The restrictions implemented to prevent the spread of the disease and the anxiety of the disease in people led to a decrease in flight traffic worldwide and caused the aviation industry to suffer significant economic losses. Obviously, the aviation industry is one of the sectors most affected due to travel and flight restrictions. Thus, COVID-19 is the preeminent crisis experienced in the history of civil aviation.

2.1. The Global Impact of COVID-19 on Civil Aviation

Although the aviation industry has been repeatedly tested by infectious diseases (SARS, MERS, avian flu and swine flu) over the past 20 years, it is for the first time facing a major crisis of the scale created by COVID-19. The most significant feature that distinguishes COVID-19 from other epidemics is that the rate of contagion is very fast and high (Gössling, 2020). According to the data of the WHO, as of March 30, 2022, the number of confirmed cases worldwide is 483.556.595 and the number of deaths is 6.132.461(WHO, 2022).

In order to reveal the dramatic impact of COVID-19 on the aviation industry in a striking way; The oil crisis, Iran-Iraq War, the Gulf Crisis, the Asian Crisis, the 9/11 attack, the SARS, the 2008 financial crisis and COVID-19 period the global airline passenger numbers are displayed in Figure 1 (ICAO, 2022).

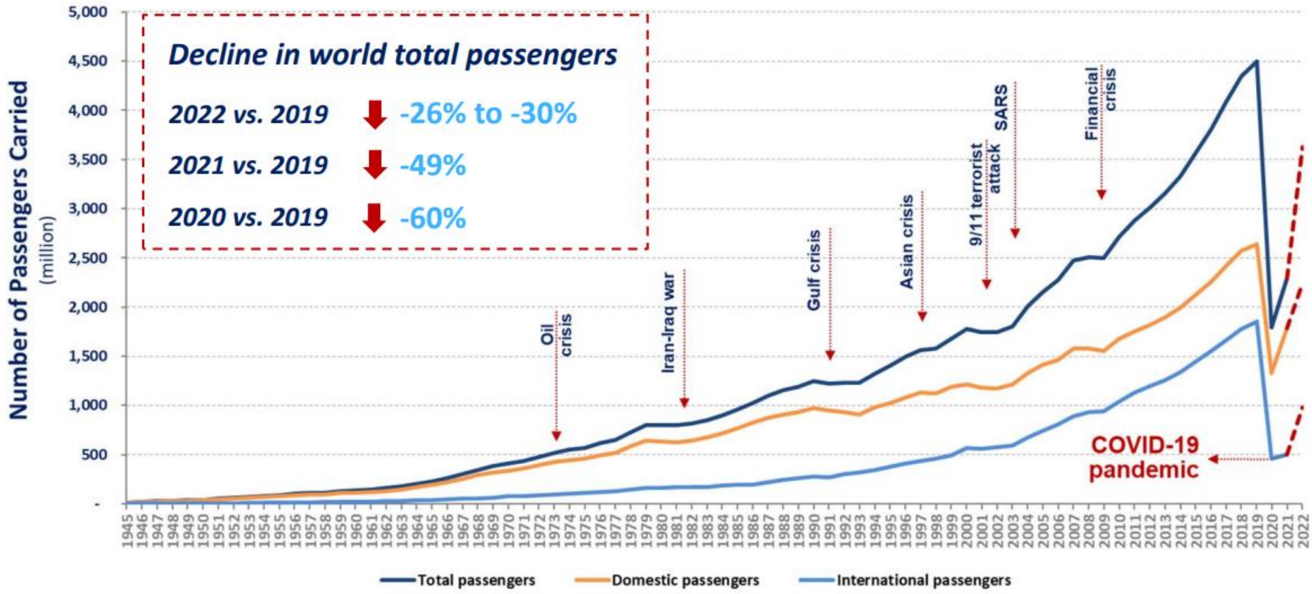

Figure 1. The Global Air Passenger Traffic in Crisis Periods (1945- March 2022).
Source: ICAO, (2022),8th March, "Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis".

Fig. 1 displays the decreasing impact of the major crises affecting the global civil aviation industry on the total number of passengers carried. However, no crisis since 1945 has caused such a great decline as COVID-19.

During the COVID-19 pandemic, the decrease in seat supply, number of passengers and gross operating income in global civil aviation in 2020, 2021 and estimation for 2022 compared to 2019 presented in Table 1.

Table 1: Global Civil Aviation in 2020-2021-2022* Compared to 2019

	2020	2021	2022*
Seat supply	-50%	-40%	-20-23%
Number of passengers	-60%	-49%	-26-30%
Operating income (billion $)	-372	-324	-182-205

Note: *Estimated data.
Source: ICAO, (2022),8th March, "Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis".

Compared to 2019, the COVID-19 caused a 60% decrease in the total number of passengers in 2020 and 49% in 2021. Estimates indicate that the decrease will continue between 26-30% in 2022. Hence, the operating income of the industry decreased by 372 billion dollars in 2020 and 324 billion dollars in 2021 compared to 2019. In 2022, it will close with approximately182-205 billion dollars loss of revenue. The table clearly reveals that the civil aviation industry is facing the biggest crisis in the history of the world. Monthly global air passenger numbers for January 2020-February 2022 compared to 2019 are displayed in Figure 2 (ICAO, 2022).

In Figure 2, the number of international airline passengers decreased significantly by 74% in 2020, and decreased by 49% in 2021 compared to 2019. While the number of domestic airline passengers decreased by 50% in 2020 compared to 2019, it approximately reduced to 26% in February 2022 (ICAO, 2022). Estimation studies on how long the effects of this crisis can be eliminated are that the industry will not reach 2019 traffic and passenger figures before 2024-2025 (Çetin, 2021).

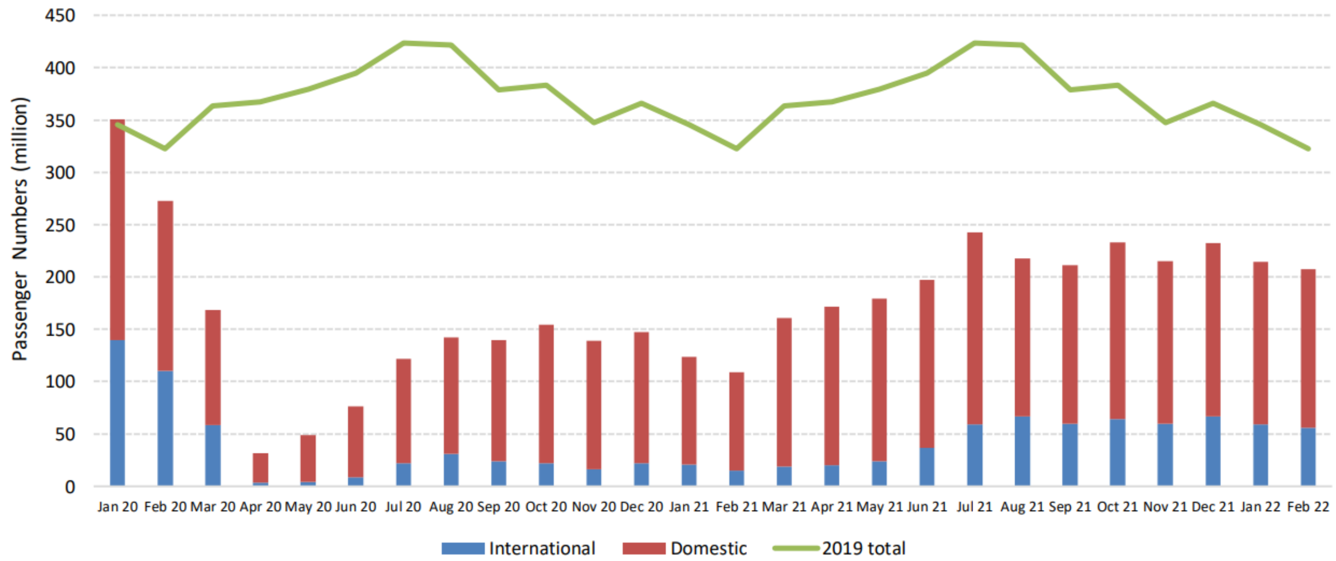

Figure 2. Monthly Global Air Passenger Numbers (January 2020- Feb 2022, compared to 2019)
Source: ICAO, (2022),8th March, "Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis".

2.2. Impact of COVID-19 on Turkish Civil Aviation

The Turkish aviation industry has achieved a steady growth momentum in last decade; a striking fracture experienced in 2020 with the effect of the pandemic. Turkey closely followed the course of the COVID-19 and took precautions by acting pro-actively before the first case detected on 11th March 2020. In response to COVID-19, it was decided to phase out international flights from 3rd February 2020 on international flights and only restarted after June 2020 with a low seat supply. Curfews and travel restrictions implemented in this process caused a serious decrease in airline passenger demand as well as all over the world. The change in passenger traffic in 2021 compared to 2019 is presented in Table2 (DHMI, 2021).

Table 2: Aircraft, Passenger and Freight Traffic in Turkey (2020, compared to 2019)

Years	2019	2021	Comparing to 2019	2022*	Comparing to 2019	2023*	Comparing to 2019
Passenger Traffic (Including Direct Transit)	208,911,338	123,026,132	-41.1%	178,761,572	-14.4%	203,679,026	-2.5%
Passenger Traffic	208,373,696	122,645,456	-41.1%	178,287,562	-14.4%	203,095,824	-2.5%
- Domestic line	99,946,572	64,876,212	-35.1%	91,805,844	-8.1%	100,785,844	0.8%
- International line	108,427,124	57,769,244	-46.7%	86,481,718	-20.2%	102,309,980	-5.6%
Direct Transit Passenger	537,642	380,676	-29.2%	474,010	-11.8%	583,202	8.5%
All Aircraft (Including Overflight)	2,034,430	1,359,194	-33.2%	1,716,947	-15.6%	1,982,480	-2.6%
Aircraft Traffic	1,556,417	1,109,406	-28.7%	1,378,492	-11.4%	1,561,043	0.3%
- Domestic line	839,894	646,403	-23.0%	791,175	-5.8%	874,099	4.1%
- International line	716,523	463,003	-35.4%	587,317	-18.0%	686,944	-4.1%
Overflight Aircraft Traffic	478,013	249,788	-47.7%	338,455	-29.2%	421,437	-11.8%
Freight Traffic (Ton) (Cargo+Mail+Baggage)	4,090,168	3,454,700	-15.5%	3,972,102	-2.9%	4,134,992	1.1%
- Domestic line	833,768	713,238	-14.5%	814,382	-2.3%	841,690	1.0%
- International line	3,256,399	2,741,462	-15.8%	3,157,720	-3.0%	3,293,302	1.1%
Cargo Traffic	1,522,404	1,282,556	-15.8%	1,476,733	-3.0%	1,539,536	1.1%
- Domestic line	65,667	56,174	-14.5%	64,140	-2.3%	66,291	1.0%
- International line	1,456,737	1,226,382	-15.8%	1,412,593	-3.0%	1,473,245	1.1%

*Estimated data.
Source: DHMI (2021), Airports in Turkey Aircraft, Passenger and Freight Traffic Statistics (2002-2023), Turkey.

In Table 2, the total number of airline passengers across Turkey decreased by 60% in 2020 compared to 2019. Due to travel restrictions, the decrease in international flights was much higher and was 70.6%. With the effect of the controlled normalization period that started in May 2020 in domestic routes, the decrease occurred compared to 2019 was 50.2%. In the table, the most dramatic decrease in the number of passengers in 2020 was in the number of transit passengers with 83.7%.

Based on the statistics published by the General Directorate of State Airports Authority (DHMI), the number of airline passengers in Turkey for the period of 2011-2020 is displayed in Figure 3, showing the numbers of domestic and international passengers separately (DHMI, 2021).

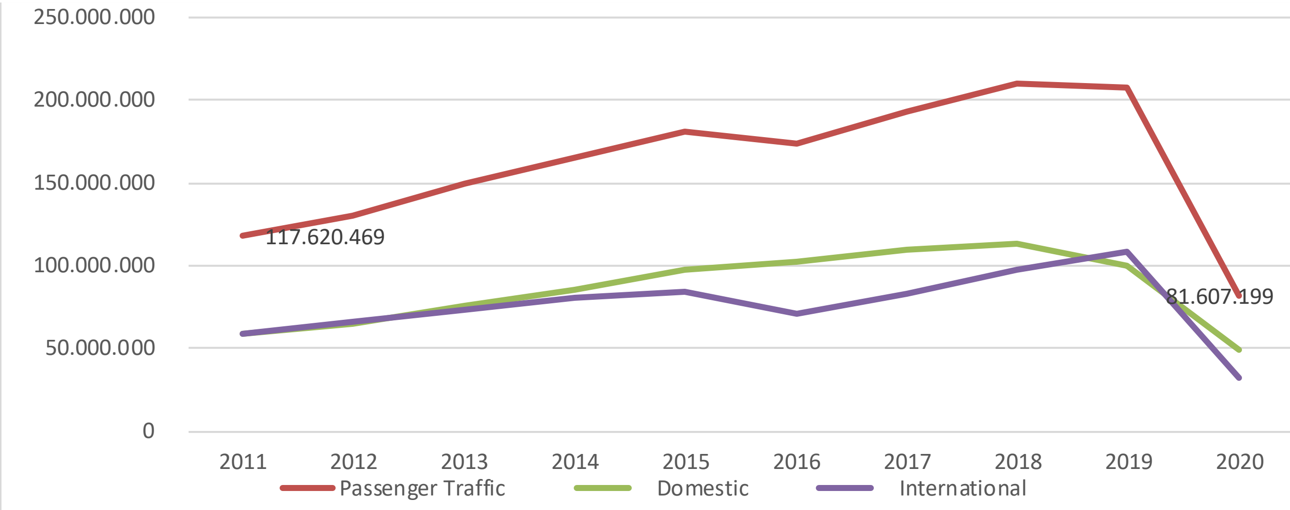

Figure 3. Turkey Air Passenger Numbers (2011-2020)
Source: DHMI (2021), Airports in Turkey Aircraft, Passenger and Freight Traffic Statistics (2002-2023), Turkey.

Figure 3 limpidly shows the decline in the number of airline passengers caused by the COVID-19 in Turkey. The total number of passengers decreased in 2020 with a major break compared to the number of passengers in 2019. On the other hand, the decrease in international flights is much more striking than the number of domestic passengers.

3. Literature Review

The civil aviation industry has survived a wide variety of crises (SARS epidemic, tsunamis, etc.) in the last few decades, but none has exposed civil aviation to such a profound shock from the travel restrictions and border closures imposed by governments due to Covid-19. The civil aviation industry has survived a wide variety of crises (SARS epidemic, tsunamis, etc.) in the last few decades, but none has exposed civil aviation to such a profound shock from the travel restrictions and border closures imposed by governments due to COVID-19 (Gössling et al., 2020). Considering that international air transportation is a significant factor in the spread of the disease, restricting air travel has been accepted as one of the most effective measures (Boldog et al., 2020; Chinazzi et al., 2020; Nikolaou & Dimitriou, 2020).

Civil aviation operations have decreased significantly due to travel bans and curfews. The social distancing rule imposed due to COVID-19 has resulted in further reductions in seat capacity supply and passenger volume due to the spaced seating arrangement in the cabin (Beh & Lin, 2022; Gössling, 2020). Tourists, who take into account the highly contagious and deadly effects of the COVID-19 virus, avoided traveling during the periods when the cases were high (Teeroovengadum et al., 2021; Yang et al., 2021). Increasing vaccination rates worldwide has led many countries to reopen their borders and relax international travel restrictions (Zhang et al., 2020). Still, some studies suggest that the negative impact of COVID-19 on global civil aviation will continue in the long term (Czerny et al., 2021; Dube et al., 2021; Škare et al., 2021).

Early studies conducted at the beginning of the pandemic revealed that COVID-19 has led to a decline: in passenger traffic was 70-80% (Macilree & Duval, 2020), on the number of flights was more than 89% in EU (Nižetić, 2020). In addition, it has led to a decline in the market value of airlines was 22% on average (Maneenop & Kotcharin, 2020), in market share value was 49% on average (Dube et al., 2021)as of April 2020. When the relationship between COVID-19 cases and airline passenger traffic was analyzed, it was determined that there was a 92% correlation in domestic flights and 98% in international flights (Lau et al., 2020) in global civil aviation. Maneenop & Kotcharin, (2020) investigated the short-term impact of COVID-19 on 52 listed airlines worldwide and found that airline stock returns decreased more than stock market returns after COVID-19 announcements.

Due to COVID-19, a decrease of 64.07% in the number of passengers, 54.75% in the number of traffic and 43.99% in the amount of cargo carried was detected in Turkey's six largest airports (Taşdemir, 2020). Although there are many theoretical or case studies (Akca, 2020; Kalkın, 2021; Keskin & Ercoşkun Yalçıner, 2021; Şen & Bütün, 2021) investigating the effects of COVID-19 on the aviation industry in the national literature, there are few empirical studies. The existence of a long-term relationship between the number of deaths caused by COVID-19 and BIST Tourism and BIST Transportation Indices was revealed by ARDL Boundary Test (Gümüş & Hacievliyagil, 2020) and RALS Engle and Granger Cointegration Test (Güngör et al., 2021). Deveci et al., (2022), revealed in their studies that COVID-19 affected the Turkish civil aviation industry to a large extent and it was reshaped with fewer carriers during the recovery phase. Airline workers have faced significant salary cuts due to the decline in airlines' revenues. However, there is an increase in air cargo traffic in Turkey.

Scherf et al., (2022) used the OXCGRT index to measure the effect of government interventions in their study where they analyzed the responses of OECD and BRICS country stock markets to the COVID-19 quarantine restrictions. The results revealed that the Covid-19 restrictions caused an overall decline in stock markets of all analyzed countries. Markets overreacted to the first national-level restrictions, while later a few days delayed and more controlled responses to the announcement of restrictions. When restrictions were relaxed, stock markets reacted differently. While it reacted negatively to the easing decisions in January and end of March, it reacted positively to the later ones. In addition, the study revealed that there is no relationship between the number of COVID-19 cases and stock market returns. In studies with OxCGRT stringency index; it was determined that COVID-19 restrictions positively affects the market quality of Vietnam

(Vo & Doan, 2021). It restrains the exchange rate volatility of 20 developed countries (Feng et al., 2021), and reduces herd behavior in Indian stock market (Bharti & Kumar, 2021).

4. Data and Methodology

4.1. Dataset

The closing prices of Turkish Airlines (THYAO), Pegasus Airlines (PGSUS), THY Do&Co Catering (DOCO), TAV Airport Holding (TAV), and Celebi Ground Handling (CLEBI) traded on Borsa Istanbul (BIST) was used to investigate the nexus between the Turkish government COVID-19 restrictions and policies and aviation stocks.

To measure the impact of government restrictions and policies, we used the OxCGRT Stringency Turkey Index (SI-Turkey). The index, calculated by the University of Oxford (OxCGRT), scales the restrictions and policies implemented by countries across thirteen categories from 0-100. These restriction and policy categories are: (1) school closures, (2) workplace closures, (3) cancel public events, (4) restrictions on gatherings, (5) close public transport, (6) public information campaigns, (7) stay at home, (8) restrictions on internal movement, (9) international travel controls, (10) testing policy, (11) contact tracing, (12) face coverings, (13) vaccination policy (Hale et al., 2021).

The analysis period covers the daily data between 24.01.2020, when the index started to be calculated for Turkey, and 11.11.2021, when the data was analyzed. In order to avoid the effects of extreme increases in exchange rates, interest rates and geopolitical risks on stock market prices, taking into consideration the dates of 12 November 2021, when the dollar/TRY exchange rate suddenly increased, and 24 February 2022, the date of Russia's invasion of Ukraine, analysis period is limited to 24.01.2020-11.11.2021. After removing the missing data, 449 daily data obtained. Five datasets consisting of each aviation stock prices and SI-Turkey values created. The detailed information regarding the variables presented in Table 3.

Table 3: Variables

Ticker	Variables	Data Type	Data Source
SI_TURKEY	OxCGRT Stringency Index-Turkey	Index value	OxCGRT*
THYAO	Turkish Airlines	Closing price	BIST**
PGSUS	Pegasus Airlines	Closing price	BIST**
TAV	TAV Airport Holding	Closing price	BIST**
CLEBI	Celebi Ground Handling	Closing price	BIST**
DOCO	THY Do&Co Catering	Closing price	BIST**

*Source: OxCGRT, (2021), The Oxford COVID-19 Government Response Tracker

**Source: Investing Database, https://tr.investing.com/.

Table 4 shows the descriptive statistics for the data used in the study.

Table 4: Descriptive Statistics

	SI_Turkey	THYAO	PGSUS	TAVHL	CLEBI	DOCO
Mean	58.1052	14.4757	69.8084	151.9119	23.4891	659.0445
Median	62.5000	12.6850	71.0500	163.5000	22.5300	612.5500
Maximum	87.0400	29.9600	111.0000	330.0000	41.2000	1465.0000
Minimum	2.7800	7.7100	23.6200	47.0200	13.7900	221.0000
Std. Dev.	17.2723	5.1943	18.8341	69.2407	6.5151	318.3220
Skewness	-1.1043	1.7085	0.0775	0.3577	0.8415	0.8433
Kurtosis	4.0114	4.8644	2.3656	2.1290	3.0102	2.8132
Jarque-Bera	134	345	10	29	64	66
Probability	0.0000	0.0000	0.0078	0.0000	0.0000	0.0000
Observations	449	449	449	449	449	449

According to Table 4, only the SI Turkey data skewed to the left, while the data of THYAO, PGSUS, TAV, CLEBI and DOCO slightly skewed to the right. In terms of kurtosis values, SI Turkey and THYAO data have thicker tails compared to the normal distribution, while other data have thinner tails. The results of the Jarque-Bera test performed to test the normality assumption reveal that all series are not normally distributed.

To analyze the long-run nexus between the SI-Turkey index and the aviation stock prices, the Engle and Granger (1987) co-integration test and for the short-run nexus, the VAR-based Granger (1969) causality test applied for each dataset. The stationarity of the series tested before applying these tests. In the study, Augmented Dickey and Fuller (ADF) (1981) and Phillips-Perron (PP) (1988) unit-root tests used to determine the stationarity of the series.

4.2. Stationarity

In order to detect econometrically meaningful relationships between the variables, the series should be stationary. Stationarity can be briefly defined as converge of variables towards a certain value over time. If there is a trend in the time series of the variables and this trend is caused by permanent shocks, the series will not converge to a certain value. It is generally accepted that series cannot be evaluated with standard statistical theory when they are not stationary (Gujarati & Porter, 1999). ADF and PP unit root tests are commonly used to determine whether the variables are stationary (Chris, 2014).

Dickey and Fuller (1981) stated that if the residuals obtained by estimating the equations have autocorrelation, the unit-root test results applied would be misleading. Therefore, they developed the ADF test, in which the lagged value of the dependent variable added to the right side of the equation. The ADF formula is in Equation 1.

$$\Delta Y_t = \alpha + \beta_t + \gamma Y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

In Equation 1, α denotes a constant, β_t denotes the coefficient of a time trend. Equation aims to include the difference term in the model with enough lag to ensure that the error term is free from autocorrelation.

Phillips and Perron (1988) developed a unit root test that widely used in financial time series. The regression model used by the PP test is presented in Equation 2 (Çelik et al., 2021).

$$Y_t = \alpha + \beta\left(t - \frac{1}{2}T\right) + \delta y_{t-1} + u_t \quad (2)$$

In Equation 2, α denotes a constant, β_t denotes the coefficient of a time trend, T refers to t-statistics. This test differs from ADF in solving the problem of autocorrelation and varying variance in errors. Instead of adding lagged values to the equation for avoiding autocorrelation, they reorganized the t statistics by estimating the Dickey-Fuller equation (Neusser, 2016).

4.3. Long-Term Nexus: Engle-Granger Cointegration Test

The spurious regression problem is encountered in analyzes with non-stationary time series. When the difference of the series is taken to make it stationary, information loss occurs in the original observations (Dufour & Raj, 2012). Thus, cointegration analysis is applied, which states that non-stationary series can have a stationary composition. Co-integration explains the existence of a long-run equilibrium nexus of the variables by providing a stable relationship between two or more non-stationary variables (Chris, 2014). According to Engle and Granger (1987), if there is a tendency to move together in long-run term between two and more datasets that become stationary at the first difference (I_1), then these datasets could be analyzed with raw data.

Engle Granger cointegration test prioritizes testing the stationarity of the error term obtained from the regression equation to determine the long-term relationship between two variables. A two-stage predictor, which is asymptotically efficient, proposed in the test.

In the first step, the stationarity degrees of the variables investigated with unit root tests. If the variables are stationary at the first difference, the error terms obtained by predicting the Ordinary Least Squares (OLS) using the cointegration regression model. If not, it means that there is no cointegration nexus between the variables (Engle & Granger, 1987). The OLS predicted regression model of the Engle Granger cointegration test presented in Equation 3. In Equation 3, r_t^y and r_t^z variables are stationary at the I_1 level.

$$r_t^y = \beta_0 + \beta_1 r_t^z + \varepsilon_t \quad (3)$$

In the second step, the error terms of the variables with the I_1 stationarity degree tested for stationarity. The model used to test the stationarity of the error terms is formulated in Equation 4 (Çelik et al., 2021).

$$\Delta\varepsilon_t = \psi\varepsilon_{t-1} + v_t \quad (4)$$

In case of the error-terms are stationary; it means there is a long-run equilibrium relation within the series, otherwise, not.

4.4. Short-Term Nexus: Granger Causality Test

The Granger causality test designed to find the short-run nexus between the pairs of variables. It is a statistical hypothesis test whether one time series is useful in predicting another time series. The test used to determine the direction of causality statistically if there is a time-lagged relationship between two variables.

Granger causality is the correlation between the current value of one variable and the past values of others, and it does not mean that the movements of one variable cause the movements of another. "X is the Granger cause of Y," if using the past values of the variable X for the prediction of variable Y provides better performance than not using it (Freeman, 1983). Granger's definition of causality based on the following assumptions (Granger, 1969):

• The future cannot be the cause of the past. Exact causation is possible only when the past causes the present or the future. The cause always precedes the effect. This necessitates a time delay between cause and effect.

• For series that are completely deterministic, that is, non-stochastic and that can be predicted exactly from the past terms, there is no causality effect other than its own history effect.

The Granger equations presented in Equations 5 and 6.

$$Y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_i Y_{t-i} + \sum_{i=1}^{k} \beta_i X_{t-i} + \varepsilon_{1t} \quad (5)$$

$$X_t = \theta_0 + \sum_{i=1}^{k} \theta_i X_{t-i} + \sum_{i=1}^{k} \gamma_i Y_{t-i} + u_{2t} \quad (6)$$

In equations five and six, $\alpha_i, \beta_i, \theta_i, \gamma_i$ are the delay coefficients, k is the common lag length for all variables, ε and u are uncorrelated white noise error terms. It assumed that the error terms are independent of each other in the equations.

5. Findings

In the research, the impacts of the policies and restrictions applied in Turkey during the COVID-19 period on aviation stocks were investigated. The OxCGRT Stringency Turkey Index is used to represent the COVID-19 policy and restrictions variable. Datasets were analyzed using the EViews 12 program.

Before examining the nexus between the SI Turkey index and aviation stock prices, the stationarity of the series is tested. It is possible to encounter the problem of spurious regression in econometric analyzes with non-stationary series. This affects the reliability of the research results. The stationarity of the series examined by ADF and PP unit root tests and the results presented in Table 5.

Table 5: Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) Unit Root Tests

	Variables	Level (I_0)		First Difference (I_1)	
	t-Statistics *Prob.*	ADF	PP	ADF	PP
Trend& Intercept	SI_Turkey	-2,7459	-2,8126	-17,2287	-17,2699
	Prob.	(0,2189)	(0,1938)	(0,0000)	(0,0000)
	THYAO	-2,5086	-2,8966	-16,6291	-17,1225
	Prob.	(0,3238)	(0,1650)	(0,0000)	(0,0000)
	PGSUS	-2,4796	-2,6850	-16,0234	-16,2238
	Prob.	(0,3381)	(0,2436)	(0,0000)	(0,0000)
	TAV	-2,7922	-2,8370	-16,8227	-17,0245
	Prob.	(0,2013)	(0,1851)	(0,0000)	(0,0000)
	CLEBI	-1,8984	-2,0513	-15,0076	-15,4442
	Prob.	(0,6530)	(0,5704)	(0,0000)	(0,0000)
	DOCO	-2,0595	-2,1269	-14,3818	-14,8749
	Prob.	(0,5659)	(0,5283)	(0,0000)	(0,0000)

In Table 5, it observed that the series are not stationary at level (I_0) and contain a unit root. For this reason, the first differences of the series were taken and their stationarity was retested and it was determined that all series were stationary in the first order (I_1).

It is possible to determine whether there is a long-term nexus between the two series with the Engle Granger cointegration test in case the series are stationary at the same level. In the test, the stationarity of the error term obtained from the regression equation to be set between two variables is tested. If the error term is stationary, it concluded that the two series tend to move together in the long-run term, that is, there is a cointegration relationship. Engle Granger cointegration test results regarding the long-term relationship between each aviation stock and SI Turkey given in Table 6.

Table 6: Engle Granger Co-integration Test Results

Series	tau-statistic	Prob.*	z-statistic	Prob.*
THYAO & SI_Turkey	-4.409864	0.0008	-94.36896	0.0194
PGSUS & SI_Turkey	-4.258743	0.0137	-93.12037	0.0199
TAV & SI_Turkey	-3.881398	0.0019	-97.26261	0.0183
CLEBI & SI_Turkey	*-2.466380*	*0.4820*	*-34.93908*	*0.0612*
DOCO & SI_Turkey	-3.968917	0.0304	-93.58762	0.0198

*MacKinnon (1996) p-values.

In Table 6, the Engle Granger cointegration test results revealed that there is a cointegration relationship between all aviation stocks and SI Turkey, except for Celebi Ground Handling (CLEBI) stocks. Upon determining that there is a long-term relationship between aviation stock prices and SI Turkey, Pairwise Granger causality test applied to the series in order to determine whether there is a short-term nexus between the series. Since a causality relationship from aviation stock prices to SI Turkey is theoretically illogical, only causality results from SI Turkey to aviation stock prices given in Table 7.

Table 7: Pairwise Granger Causality Test Results

Null Hypothesis	F-Statistics	p-Probability	Lag Length
The SI_Turkey Index is not the Granger cause of THYAO.	4.2747	0.0148	2
The SI_Turkey Index is not the Granger cause of PGSUS.	5.0409	0.0070	2
The SI_Turkey Index is not Granger cause of TAV.	3.4554	0.0336	3
The SI_Turkey Index is not the Granger cause of DOCO.	5.3019	0.0054	2

Since there is no long-term nexus between CLEBI and SI Turkey in the cointegration analysis, it was not necessary to conduct a causality analysis for CLEBI. In Table 7, Pairwise Granger causality test results proved that SI Turkey is the Granger cause of the THYAO, PGSUS, TAV, and DOCO. In other words, there is a short-term relationship between SI Turkey and Turkish aviation stocks.

6. Conclusion and Discussion

In the last 20 years, the aviation industry has struggled with epidemics many times. The whole world has embarked on a tough fight against COVID-19 since the WHO declared a pandemic on March 11, 2020. The rapid and easy transmissions of the disease and its deadly effects have required governments to take strict restrictive and prohibitive measures. COVID-19 has brought many sectors to a standstill all over the world, but it has affected the civil aviation industry the most because it will increase the spread of the disease. While the global civil aviation industry closed the year 2021 with a 49% decrease in the total number of passengers and a loss of 324 billion dollars in operational income, it will close the year 2022 with approximately182-205 billion dollars loss of revenue (ICAO, 2022). The operational losses caused by COVID-19, described as the biggest economic crisis in aviation history. In this process, the course and predictability of aviation stock prices have become more significant than ever for investors have.

In this study, the short- and long-term relationship between the restrictions and policies implemented in Turkey due to

COVID-19 and the aviation stock prices listed on the Istanbul stock exchange examined. The OxCGRT Stringency Index used to measure restrictions and policies regarding COVID-19. The nexus between the variables analyzed separately for each stock with Engle Granger cointegration and Granger causality tests. The findings revealed that there is a long-term cointegration nexus between all aviation stocks and the index, except for CLEBI Ground Handling (CLEBI) stock. In addition, the causality test examined the short-run nexus to the variables and it concluded that there was a one-way causality relationship from the index to aviation stock prices in all.

Co-integration tests reveal the existence of a long-term equilibrium nexus between the variables and the tendency of the variables to act together. Causality tests, on the other hand, mainly express the ability of one variable to predict another variable. In this context, according to the results of cointegration and causality tests, OxCGRT Stringency Index is a predictor in forecasting aviation stock prices.

In future works, based on the results of this study, the prediction performance of the index could be evaluated by designing a forecasting model for aviation stock prices with the OxCGRT Stringency Index as the input variable.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Akca, M. (2020). Covid-19'un havacılık sektörüne etkisi. Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi, 7(4), 45–64. https://dergipark.org.tr/en/pub/asead/issue/54055/723434

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

Beh, L. S., & Lin, W. L. (2022). Impact of COVID-19 on ASEAN tourism industry. Journal of Asian Public Policy, 15(2), 300–320.

Bharti, & Kumar, A. (2021). Exploring Herding Behaviour in Indian Equity Market during COVID-19 Pandemic: Impact of Volatility and Government Response. Millennial Asia, 1–19.

Boldog, P., Tekeli, T., Vizi, Z., Dénes, A., Bartha, F. A., & Röst, G. (2020). Risk assessment of novel coronavirus COVID-19 outbreaks outside China. Journal of Clinical Medicine, 9(2), 571.

Çelik, İ., Bozkus Kahyaoglu, S., Yilmaz, T., Kaya, M., Özdemir Höl, A., Akkuş, H., & Gülcan, N. (2021). Finansal Zaman Serisi Analizi Finansçılar İçin Temel Yaklaşımlar (First).

Çetin, D. T. (2021). COVID-19'da Bir Yılın Ardından Sivil Havacılık Sektörünün Operasyonel ve Finansal Durumu: 2021-2025 Yıllarına İlişkin Tahminler. In İ. Karabıyık (Ed.), Ekonomi ve Yönetim Bilimleri Çalışmaları (1st ed., pp. 129–145). Livre De Lyon.

Chinazzi, M., Davis, J. T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., Pastore y Piontti, A., Mu, K., Rossi, L., Sun, K., Viboud, C., Xiong, X., Yu, H., Elizabeth Halloran, M., Longini, I. M., & Vespignani, A. (2020). The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. Science, 368(6489), 395–400.

Chris, B. (2014). Introductory econometrics for finance (3rd ed.). United Kingdom: Cambridge University Press. www.cambridge.org/9780521873062

Chung, L. H. (2015). Impact of pandemic control over airport economics: Reconciling public health with airport business through a streamlined approach in pandemic control. Journal of Air Transport Management, 44, 42–53.

Czerny, A. I., Fu, X., Lei, Z., & Oum, T. H. (2021). Post pandemic aviation market recovery: Experience and lessons from China. Journal of Air Transport Management, 90, 101971.

Deveci, M., Çiftçi, M. E., Akyurt, İ. Z., & Gonzalez, E. D. R. S. (2022). Impact of COVID-19 pandemic on the Turkish civil aviation industry. Sustainable Operations and Computers, 3, 93–102.

DHMI. (2021). Airport Statistics and Short-Term Forecasts in Turkey. In General Directorate of State Airports Authority. https://www.dhmi.gov.tr/Sayfalar/Istatistikler.aspx.

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.

Dufour, J.-M., & Raj, B. (2012). New developments in time series econometrics. Springer-Verlag Company.

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: representation, estimation, and testing. Econometrica: Journal of the Econometric Society, 251–276.

Feng, G.-F., Yang, H.-C., Gong, Q., & Chang, C.-P. (2021). What is the exchange rate volatility response to COVID-19 and government interventions? Economic Analysis and Policy, 69, 705–719.

Freeman, J. R. (1983). Granger causality and the times series analysis of political relationships. American Journal of Political Science, 327–358.

Gössling, S. (2020). Risks, resilience, and pathways to sustainable aviation: A COVID-19 perspective. Journal of Air Transport Management, 89, 101933.

Gössling, S., Scott, D., & Hall, C. M. (2020). Pandemics, tourism and global change: a rapid assessment of COVID-19. Journal of Sustainable Tourism, 1–20.

Gujarati, D. N., & Porter, D. C. (1999). Essentials of econometrics (Vol. 2). Irwin/McGraw-Hill Singapore.

Gümüş, A., & Hacievliyagil, N. (2020). Covid-19 salgın hastalığının borsaya etkisi: Turizm ve ulaştırma endeksleri üzerine bir uygulama. Akademik Yaklaşımlar Dergisi, 11(1), 76–97. https://dergipark.org.tr/en/pub/ayd/issue/56831/772209

Güngör, S., Aydin, N., & İnak, A. (2021). COVID-19 salgınının turizm, ulaştırma ve yiyecek & içecek sektörlerine etkisi: RALS Engle ve Granger eşbütünleşme testi. Sosyal Bilimler Araştırmaları Dergisi, 16(1), 95–107.

Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., Webster, S., Cameron-Blake, E., Hallas, L., & Majumdar, S. (2021). A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). Nature Human Behaviour, 5(4), 529–538.

IATA. (2020). Annual Review 2020: 76th Annual General

Meeting. In International Air Transport Association (IATA). https://www.iata.org/contentassets/c81222d96c9a4e0bb4ff6ced0126f0bb/iata-annual-review-2020.pdf

ICAO. (2022). Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis. In International Civil Aviation Organization (ICAO). https://www.icao.int/sustainability/Documents/Covid-19/ICAO_coronavirus_Econ_Impact.pdf

Kalkın, G. (2021). COVID-19 ve havacılık sektörünün geleceği: Havacılık yönetimi kapsamında bir değerlendirme. Journal of Aviation, 5(1), 53–63.

Keskin, B. N., & Ercoşkun Yalçıner, Ö. (2021). Covid-19'un havacılık sektörüne çevresel etkisi: Adnan Menderes Havalimanı örneği. Akıllı Ulaşım Sistemleri ve Uygulamaları Dergisi, 4(1), 74–86.

Lau, H., Khosrawipour, V., Kocbach, P., Mikolajczyk, A., Ichii, H., Zacharski, M., Bania, J., & Khosrawipour, T. (2020). The association between international and domestic air traffic and the coronavirus (COVID-19) outbreak. Journal of Microbiology, Immunology and Infection, 53(3), 467–472.

Macilree, J., & Duval, D. T. (2020). Aeropolitics in a post-COVID-19 world. Journal of Air Transport Management, 88, 101864.

Maneenop, S., & Kotcharin, S. (2020). The impacts of COVID-19 on the global airline industry: An event study approach. Journal of Air Transport Management, 89, 101920.

Neusser, K. (2016). Time series econometrics. Springer. https://doi.org/10.1017/cbo9780511814839.012

Nikolaou, P., & Dimitriou, L. (2020). Identification of critical airports for controlling global infectious disease outbreaks: Stress-tests focusing in Europe. Journal of Air Transport Management, 85.

Nižetić, S. (2020). Impact of coronavirus (COVID-19) pandemic on air transport mobility, energy, and environment: A case study. International Journal of Energy Research, 44(13), 10953–10961.

OxCGRT. (2021). COVID-19 Government Response Tracker. Oxford University, Blavatnik School of Government. https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker

Scherf, M., Matschke, X., & Rieger, M. O. (2022). Stock market reactions to COVID-19 lockdown: A global analysis. Finance Research Letters, 102245.

Şen, G., & Bütün, E. (2021). Covid-19'un Pandemi Salgınının Havacılık Sektörüne Etkisi: Gig Ekonomisi Alternatifi. Journal of Aviation Research, 3(1), 106–127.

Škare, M., Soriano, D. R., & Porada-Rochoń, M. (2021). Impact of COVID-19 on the travel and tourism industry. Technological Forecasting and Social Change, 163, 120469.

Taşdemir, M. (2020). COVID-19 salgınının havacılık sektörüne etkileri ve Türkiye'deki yoğun havalimanlarının salgın öncesi ve salgın koşullarında etkinlik değişimlerinin veri zarflama analizi yöntemi ile tespiti. Social Mentality and Researcher Thinkers Journal, 6(39), 2691–2707.

Teeroovengadum, V., Seetanah, B., Bindah, E., Pooloo, A., & Veerasawmy, I. (2021). Minimising perceived travel risk in the aftermath of the COVID-19 pandemic to boost travel and tourism. Tourism Review, 76(4), 910–928.

Vo, D. H., & Doan, B. (2021). Effects from containment and closure policies to market quality: Do they really matter in Vietnam during Covid-19? Plos One, 16(4), e0248703.

WHO. (2021). WHO Coronavirus Disease (COVID-19) Dashboard. World Health Organization. https://covid19.who.int/

WHO. (2022). Coronavirus (COVID-19) Dashboard. World Health Organization. https://covid19.who.int/

Yang, T. T., Ruan, W. Q., Zhang, S. N., & Li, Y. Q. (2021). The influence of the COVID-19 pandemic on tourism demand for destinations: an analysis of spatial heterogeneity from a multi-scale perspective. Asia Pacific Journal of Tourism Research, 26(7), 793–810.

Zhang, L., Yang, H., Wang, K., Zhan, Y., & Bian, L. (2020). Measuring imported case risk of COVID-19 from inbound international flights --- A case study on China. Journal of Air Transport Management, 89, 101918.

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Contribution of Scientific Production to Air Logistics: A Bibliometric Analysis from the 70s to the Present

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Abstract

With increased performance expectations based on speed and agility in logistics flow and supply chain processes, air logistics has gained popularity as a research area. Although more and more papers are published each year on this subject, to the best of our knowledge, a comprehensive bibliometric academic publication review has not been presented so far to contribute to the intellectual structure of the literature. Therefore, this study aims to investigate the last 5 decades' intellectual basis of air logistics studies that can be evaluated in the field of social sciences. For this purpose, a total of 398 articles have been accessed to be used in the bibliometric analysis of studies published in the literature of air logistics, and these data have been provided from the Core Collection Database of Web of Science (WOS). The research data consists of articles published in English in the WOS database between 1971 and 2019. Books and papers published in all other languages were not included in the research. The Bibliometrix (Biblioshiny) package of the statistical software program R was used for the analysis and visualization of the data. Research findings indicate that air logistics research has increased greatly, especially in the last 10 years. The most productive countries are the United States, China, and Canada, respectively, while the most published journal is the Journal of Air Transport Management, which has continued to increase its number of publications since 1995. Although there are no tear restrictions in this study, the number of publications on air logistics in the field of social sciences is still insufficient.

1. Introduction

The sectoral share of air transportation, which is one of the highly developed and dynamically growing types of transportation, is huge and contributes directly to the economic, political, and social processes of international trade (Kwasiborska, 2016: 51; Yilmaz and Flouris, 2017: 25). The rapid globalization of the world after the 1980s increased functional interactions between countries, and this caused air transport in particular to gain popularity (Wang et al., 2019). Thanks to the advances in technology, the increase in the number of aircraft and the establishment of new airline companies have reduced the airline costs, making it easier for real and legal persons to carry out their transportation and shipment activities by air (Lin et al., 2019: 43). In 2017, 53.9 million metric tons of freight valued at approximately 5.6 trillion dollars, which corresponds to 35% of the world's total trade volume, were transported (IATA, 2018: 48). Therefore, air transport plays a vital role in the global economy (Lin et al., 2019: 43).

Especially in recent years, studies such as model development for location and mode selection at airports, timing and routing optimization for airline companies and air transportation, special substance transportation by airline, team, and operations management are frequently discussed in the literature (Gokasar and Gunay, 2017; Wei and Vaze, 2018; Munari and Alvarez, 2019; Padrón and Guimarans, 2019; Zhao and Zhang, 2019; Kinene et al., 2020). Although the increase in research on air logistics in the literature is noticeable, a bibliometric analysis research has not been conducted by revealing the intellectual structure in this regard in a comprehensive way. In order to eliminate the related deficiency, in this study, it was aimed to present an overview of author, journal, citation, keyword, and country information of the air logistics research published in the Web of Science database between 1971 and 2019 using various bibliometric analysis techniques and to identify trends in this regard.

2. Theoretical Review

2.1. Air Transportation

Air transportation, which has become one of the important competitive parameters of this age, provides the fastest delivery of goods and services to the point of consumption while creating a great economy with both passenger and freight transportation (Erturgut, 2016). Air transportation is an essential part of air logistics and can most simply be defined as the transposition of people, cargo, or mail over the air by an air vehicle, providing space and time benefit (Wensveen, 2016: 13; Gerede, 2002: 9).

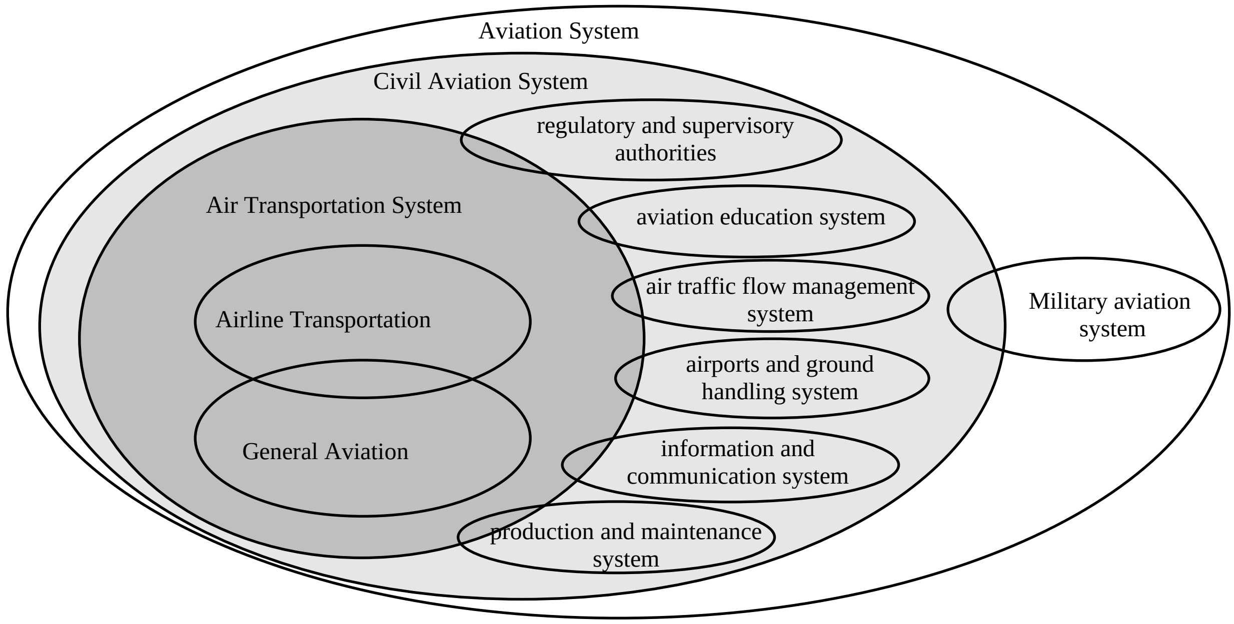

Figure 1. Aviation System and Subsystems

Source: (Gerede, 2002: 8).

The concepts of airline transportation and aerial transportation are different concepts and often confused. The concept of aerial transportation covers air transport and general aviation activities in general. Airline transportation, on the other hand, has a commercial purpose and is defined as "the transport of passengers, freight and mail by air vehicles on a scheduled or non-scheduled basis" (Erturgut, 2016). A general overview of the aviation system (Gerede, 2002: 6), which houses all components of aviation as interdependent but in separate series of parts, is presented in Fig. 1.

Aerial transportation has been mostly associated with cargo and shipping in literature. Aerial cargo transportation is carried by large aircraft such as passenger aircraft, cargo aircraft, or charter aircraft. In terms of passenger aircraft, cargo transportation is carried out at the scheduled dates and times for passengers in general (Tomanne, 2012). In the air cargo supply chain, forwarders, airlines, and shippers are the main actors. Forwarders are divided into IATA forwarders and other forwarders. IATA forwarders promote cargo and receive cargo and make it suitable for transportation. Other Forwarders have not been approved by IATA even though they do the same work as IATA forwarders (Chalermkiat et al., 2013). The freight designated as cargo is delivered to the shippers by the forwarders. The shippers load the cargo onto the aircraft on the tariff determined by the airlines (Singhaseni et al., 2013). A general framework of airline cargo transport is shown in Fig. 2.

The following are three main topics of air logistics literature reviewed: (1) The selection of hub-and-spoke location problems at airports, (2) optimization models in air transportation, and (3) economic impacts of international air transportation and the airline industry. These subjects are frequently studied in air logistics literature.

2.1.1. Hub-and-spoke Location Problem

In the literature, the hub location problems at airports are studied quite frequently. Parsa et al. (2019: 1379) stated that studies aimed at identifying and formulating single-purpose models such as p-hub median, hub covering, and p-hub center were widely included in the literature especially before 2000. The hub location problem has become the field of research for the first time with a quadratic mathematical formulation that O'Kelly founded in 1987 to minimize transportation costs (Bryan and O'Kelly, 1999: 275; O'Kelly 1987: 393). Aykin (1995), Campbell (1994), and Ernst and Krishnamoorthy (1996) are other important studies in which formulations were developed for the hub location problem before the 2000s. Bryan and O'Kelly (1999), on the other hand, aimed to highlight the most important ones by making a general review of the formulations developed until that day.

Today, the hub location and rotation problem studies, which are mostly more compatible with real-life and take into account sustainability and uncertainties in logistical flow, are conducted. Yang et al. (2016) addressed the planning and optimization of the intermodal hub-and-spoke network, taking into account the mixed uncertainties in both shipping cost and travel time. Real et al. (2018) presented a mixed integer programming formulation to model both local and global streams, highlighting that networks developed for routing local or global streams contain different factors. Alamur and Kara (2008), Adler and Smilowitz (2007), Shen et al. (2021), and Parsa et al. (2019) are the examples of other studies carried out in the context of aeronautical base hub location problems.

2.1.2. Planning and Modelling of Air Transportation Networks

Although air transportation is less affected by geographical conditions than road and rail (Lin, 2012), it emerges in a wide range of contexts, such as technological and transport infrastructure, social phenomena, and biological systems, and its network structure is becoming more and more complex (Barrat et al., 2004). Guimera et al. (2005), who analyzes the global structure of the worldwide air transport network highlighting the relevant complexity, determined the central locations in the global air transport network and stated that the existence of these structures cannot be explained solely on the basis of geographical constraints and that cultural and geopolitical considerations should also be taken into account.

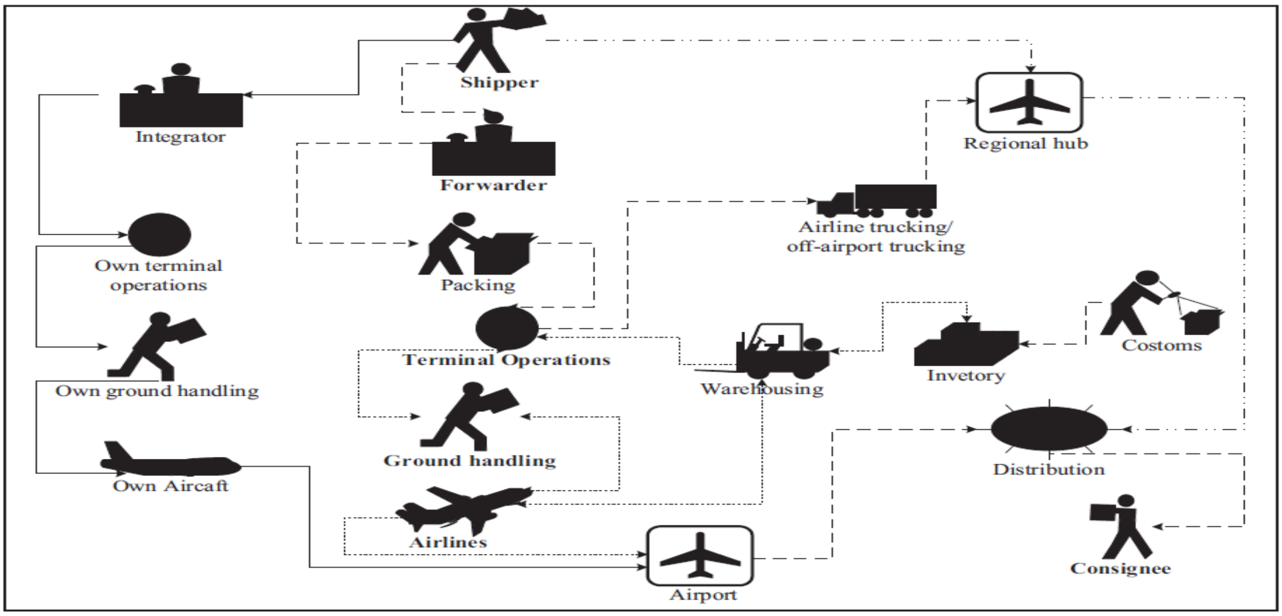

Figure 2. A General Overview of Airline Cargo Transportation

Source: (Bo Feng et al., 2015).

There are many regional studies about air transportation planning and modeling in the literature. Xu and Harris (2008) examined all connections of the US intercity passenger air transport network, as well as average daily passenger traffic, the amount of distances reached, and average road fares using a weighted complex network methodology. Lin (2012) explored weekly flight plans with a complex network approach to study the statistical characteristics of the Chinese aviation system. Burghouwt and Wit (2005) investigated the effects of the fluctuation system implemented in the European air transport network after the deregulation in aviation. Cardillo et al. (2013), another European network modeling study, examined the dynamics of the European air transport network using a multiplexing network formalism.

2.1.3. Economic Effects of the Aviation Industry

International air transportation is vital to the economic development and global competitive advantage of many countries and regions. This importance given to air transport should not be regarded solely at the point of passenger transportation. Air transportation also offers important economic advantages and is frequently preferred for businesses that have goals such as providing quality service to their customers, making production and delivery on time, and in industries where mostly interpersonal communication is important (Button and Taylor, 2000). All this increased the importance of the aviation industry’s economic impacts and led it to become a subject frequently researched in air logistics literature. Borenstein (1989), one of these studies, estimated the importance of route and airport control in determining the degree of airline market power. Brueckner (2003), on the other hand, emphasized that air transportation service is an important factor in urban economic development and investigated the relationship between air traffic and the level of employment in the US metropolitan areas.

3. Methodology

3.1. Analysis Method

In this study, the bibliometric analysis was used as the analysis method. Bibliometric analysis was used as a method especially in recent years in studies about the logistics and supply chain performance (Mishra et al., 2018), humanitarian logistics (Zary et al., 2014), urban logistics (Hajduk, 2017; de Carvalho et al., 2019; Neghabadi et al., 2019; Voigt et al., 2019), reverse logistics (Wang et al., 2017; de Campos et al., 2017; Kazemi et al., 2019; da Silva et al., 2019; Bensalem and Kin, 2019), marine logistics (Davarzani et al., 2016), sustainable logistics (Qaiser et al., 2017; Winter and Knemeyer, 2013) and many more logistics issues (Lin and Zhao, 2019; Georgi et al., 2013; Dolati et al., 2019; Charvet et al., 2008; Wang et al., 2019).

The first applications of bibliometric analysis (Osareh, 1996: 149), which emerged with the statistical analysis of bibliographies, date back to the 1890s (Sengupta, 1992). It was first used by E. Wyndham Hulme in 1922 with the term statistical biography (Pitchard, 1969). The term bibliometric was coined by Pichard in 1969. The term has two roots, “biblio” and “metric.” The word “biblio” is a word derived from the Latin and Greek word “biblion,” which means the book. The term “metrics,” which means measurement science, is derived from the Latin or Greek word “metric” or “metricos” (Sengupta, 1992: 76).

The first definition of bibliometric analysis was made by Miles Raising in 1962 using the term statistical biography as “collecting statistics on books and periodicals to demonstrate historical movements, to determine the national or universal research use of books and journals, and to determine and interpret the general use of books and journals of many local statuses” (Raising, 1992). In 1969, Pritchard defined the bibliometric analysis as “to shed light on the written communication processes and nature and development process of discipline (to the extent this is shown through written communication) by measuring and analyzing various aspects of written communication resources" (Pritchard, 1969). According to the University of Maryland (2019), bibliometric analysis is "quantitative analysis of citations, and content as content for scientific journals, books, and researchers."

3.2. Data Collection Tool

The data set, created for use in research analysis on February 3, 2022, was obtained from the Web of Science Core Collection (WOS) database. The search range is selected as "Subject." In order to acquire comprehensive access to air logistics studies, Boolean logic is applied by typing "Air Logistics" or "Air Transportation" or "Aviation Logistics". Before the filtering process, the WOS database offered a total of 2134 resources. As most of the publications were related to the Covid-19 pandemic and inclusion of these studies in the data set would detract from the main purpose of the research, studies that were published in 2020 and 2021 were excluded, and filtering was carried out over all sources between 1971 and 2019. Since the bibliometric analysis carried out in the research will address the field of social sciences, studies that have been published in fields such as engineering, architecture, medicine, computer science, physics, biology, and meteorology were also excluded. To perform this operation, the following categories were selected in the WOS categories, and the other categories were excluded. These categories are as follows:

- Transportation,
- Operation Research Management Sciences,
- Economics,
- Transportation Science Technology,
- Management,
- Environmental Studies,
- Business,
- Green Sustainable Science Technology,
- Urban Studies,
- Business Finance,
- Environmental Sciences,
- Social Sciences Mathematical Methods,
- Social Sciences Interdisciplinary,
- Ecology
- Biodiversity Conservation
- Regional Urban Planning.

After the category filtering process, "Article" was selected as document type, and all other document types were excluded. Only articles written in English were included in the data set. After all filtering processes, it was understood that a total of 398 articles constituting the data set were published in the journals scanned in Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-EXPANDED), and Emerging Sources Citation Index (ESCI).

3.1. Analysis Tools

The bibliometric analysis performed in this study was carried out with the Bibliometrix and Biblioshiny packages developed in the R programming language. Bibliometrix and Biblioshiny packages were developed by the Italian scientist Massimo Aria in the R language environment. Bibliometrix and Biblioshiny packages are open sources and free. Aria and Cuccurullo (2017) stated that Bibliometrix used in the R language environment is more flexible than other bibliometric tools and that most bibliometric tools integrate network analysis and visualization functions into one software. Xie et al. (2020) suggested that bibliometric analysis can be run with a range of software such as Citespace, Vosviewer, Bibexcel, SciMat, Sci2, CiNetExplorer, but most of this software are cumbersome and do not help researchers to perform a literature analysis in a full workflow.

4. Results

4.1. Features of the Data Set

The data obtained in this study consists of bibliometric information from articles published in 122 different journals and written in the field of air logistics from 1971 to 2019. As shown in Table 1, 398 articles were written by 795 authors. Of these studies, 317 were multi-authored, and only 81 were single-authored. Siamaki et al. (2014) stated that the collaboration index among authors shows the average number of authors per article. Hence, each article in our data set was prepared by an average of 2.28 authors.

Table 1. Key Features of the Data Set

Features	Results
Number of Publications	398
Number of Journals	122
Number of Citations	11179
Average Number of Citations per Publication	15.5
Average Number of Citations per Year of a Publication	1.659
Number of Keywords	1175
Period	1971-2019
Average Number of Publications Per Year	9.41
Average Number of Citations Per Publication	15.5
Number of Authors	795
Number of Authors Publishing in Multi-authored Publications	724
Number of Single-authored Publications	81
Number of Multi-authored Publications	317
Publication Rate Per Author	0.501
Per Publication Co-Author Rate	2.53
Collaboration Index among Authors	2.28
Annual Scientific Productivity Rate	9.78%

4.1. Number of Publications by Year

Numbers of published articles by year are presented in Fig. 3. The first paper on air logistics indexed in the WOS database was published in 1971. From 1971 to 2003, the number of articles was very limited. The low number of airports, airplanes and employment levels and the lack of implementation of privatization policies between the relevant years prevented the aviation industry from benefiting from economies of scale. Such situations are probable explanation for the low numbers of studies published on air logistics before 2004. While the number of articles published in 2003 was 2, this number increased to 17 in 2008. Although the number of articles published in 2009 fell to 8, this decrease has not gained continuity. During the 10-year period covering 2010-2019, the number of articles in air logistics had a continuous upward trend.

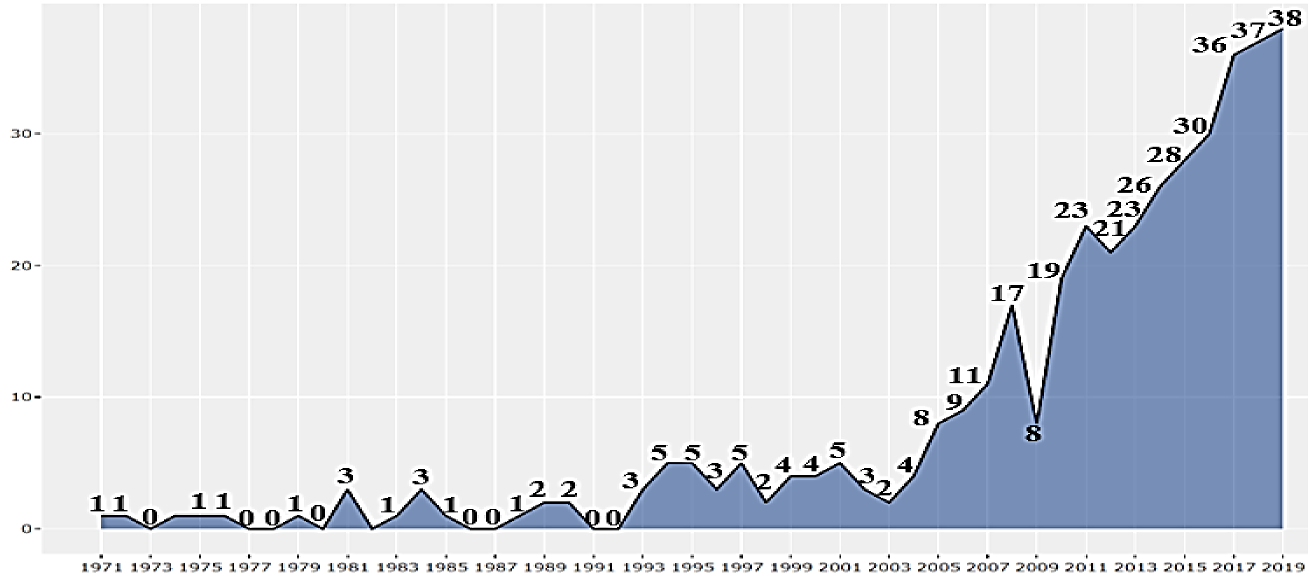

Figure 3. Number of Publications by Year

4.3. Data on Citation Numbers

The data for the 20 years with the highest annual average number of article citations are included in Table 2. The annual average number of citations in Table 2 is obtained by dividing the average number of citations per article by the number of years passed. The year with the highest average of total citations is 1988, with 111 citations. However, it is clear that only one article has been published in the relevant year, leading to this result. The year with the highest one-year average number of citations is 1999, with 3.726. Only 4 articles were published in the corresponding year, many more cited works were published in 1999 compared to other years. Although only 4 articles were published in 1999, these articles were cited much more than articles published in other years. The year closest to the present and highest in citation productivity was 2017 during when 36 studies were published.

Table 2. Annual Average Article Citations

Year	Number of Articles Published per Year (N)	Average Number of Citations per Article	Number of Years Passed	Annual Average Number of Citations
1999	4	78.25	21	3.726
1988	1	111	32	3.468
2001	5	58.2	19	3.063
2017	36	8.305	3	2.768
2012	21	21.952	8	2.744
2004	4	43.75	16	2.734
2011	23	23.434	9	2.603
2015	28	12.107	5	2.421
2014	26	14.153	6	2.358
2016	30	8.733	4	2.183
2005	8	32.625	15	2.175
2013	23	15.217	7	2.173
2010	19	21.263	10	2.126
2019	38	1.815	1	1.815
2007	11	23.454	13	1.804
2008	17	21.588	12	1.799
2018	37	3.5675	2	1.783
1994	5	43.6	26	1.676
1997	5	36.6	23	1.591
1989	2	46.5	31	1.5

With a total of 147 Web of Science citations, Bryan DL, together with O'Kelly ME, published the highest-cited study in the field of air logistics in 1999. Despite Bryan DL has the most cited publication, the author has never published another article in the same area. Aykin T was ranked 2nd with 129 cited studies published in 1995, and 4th with another study published in 1994 with 107 cited research. Both studies conducted by the author are single-authored. Sun XQ's study, published in 2015, has a global citation of 30, although it has been recently published, and ranks first in the average annual citation with 9.2. Sun et al. (2015) aimed to help stakeholders in air transportation systems monitor network performance over time and better understand network dynamics (Table 3).

Table 3. Most Cited Studies

Paper	Year	Number of Global Citations	Number of Local Citations	Annual Average Number of Citations
D. L. Bryan	1999	147	16	6.6818
T. Aykin	1995	129	13	7.2
J.F. Campbell	2005	114	6	4.9615
T. Aykin	1994	107	6	7.125
T. Grosche	2007	104	7	3.3636
P. Malighetti	2008	71	7	4.8636
K.G. Debbage	2001	61	7	3.963
N. Adler	2001	57	6	6.1765
K. P. Li	2005	46	10	7.4286
J. Y. Lin	2012	45	9	4.3333
T. C. Matisziw	2010	37	8	3.6667
X. Q. Sun	2015	30	5	9.2
C. Y. Hsiao	2011	29	5	2.7812
T. C. Matisziw	2012	28	8	5.8571
C. Barnhart	2014	28	6	7.1818
F. Allroggen	2015	27	5	12.1667
S. Wandelt	2015	25	5	5.4615
K. A. Alkaabi	2007	23	5	6.6
P. Wei	2014	22	5	3.05
D. Espinoza	2008	20	4	3.1579

Fig. 4 shows the co-citation network. Citing a publication by two different publications is defined as co-citation (Aria and Cuccurullo, 2017). The network is divided into 6 sections in total, to be displayed in red, brown, purple, yellow, green, and blue colors. In other words, publications in each color group are cited together in different publications. Studies on the location and routing problems for hub-and-spoke networks at airports in the purple group, air transportation network planning and modeling in the red group, international air transportation and economic effects in the brown group, economic effects of the airline industry in the yellow group, structural equation modeling in the blue group, and finally the competition between the airline and the railway in the green group are available.

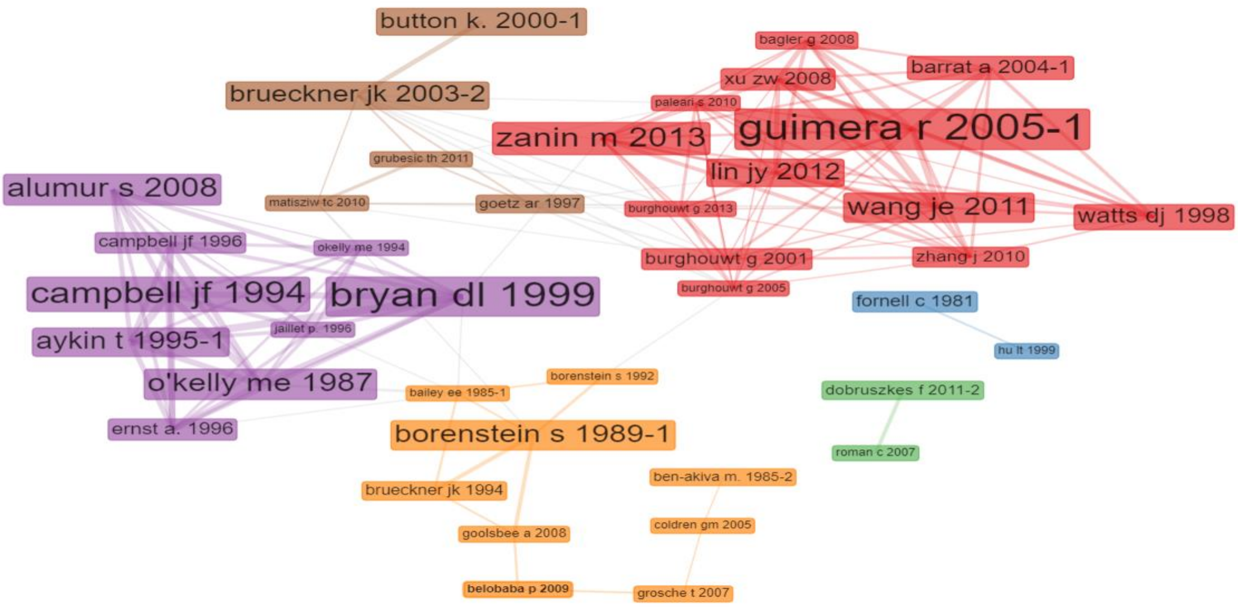

Figure 4. Co-Citation Network

4.4. Author Productivity

The author who produced the most publications is Button K, with 12 articles. Button K is followed by Fugate X with 10 publications, Hansen M with 9 publications, and Sun XQ with 8 publications. Fig. 5 presents the connections of the most co-authored researchers with each other. The size of each box on the network is related to the number of publications by the author. The larger the box, the higher the number of publications belonging to the author. The authors who took part in the same study were shown in the same colors. The authors with the highest level of co-authorship are Martini G, Scotti D and Button K, followed by Sun X and Wandelt S.

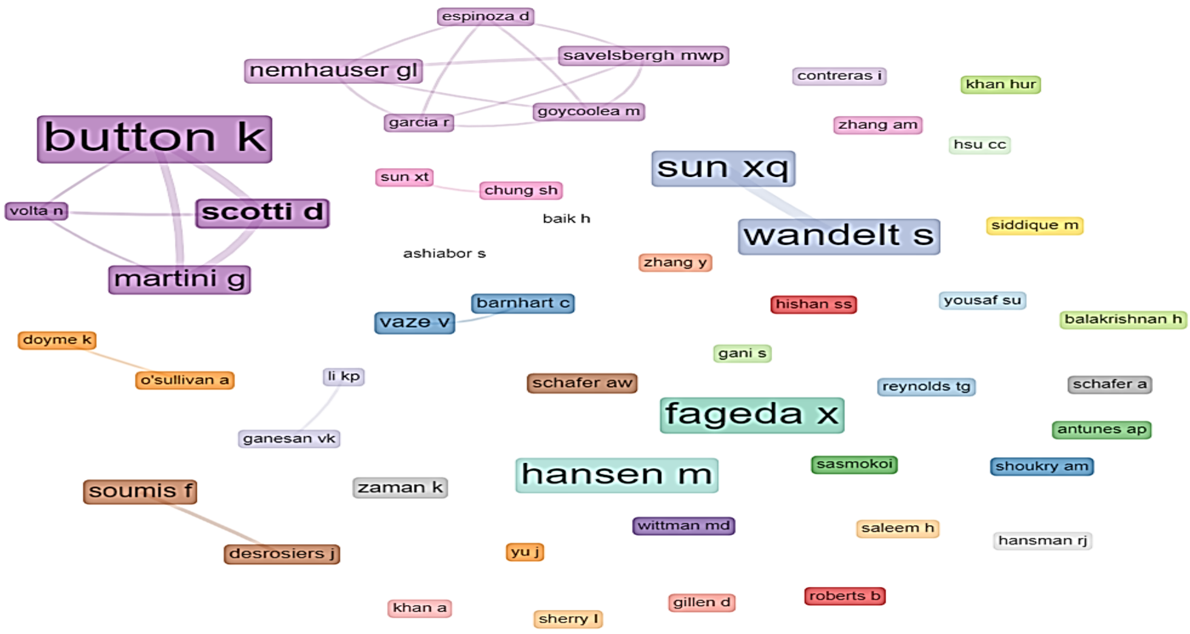

Figure 5. Researchers with the Most Co-Authors

Among the 795 authors included in the data set, the publication performance of the most published authors on a yearly basis is shown in Fig. 6. Author productivity is determined by the calculation of the number of publications and the total number of citations received annually by the authors in the relevant time period (Aria et al., 2017: 6). Considering the year-based author productivity, it is seen that the most published and cited publications were published in 2015. The most productive authors are Sun XQ and Wandelt S, with their studies published in 2015. The number of publications published by both authors in 2015 is 3, the total number of citations is 76, and the annual average number of citations is 12,667.

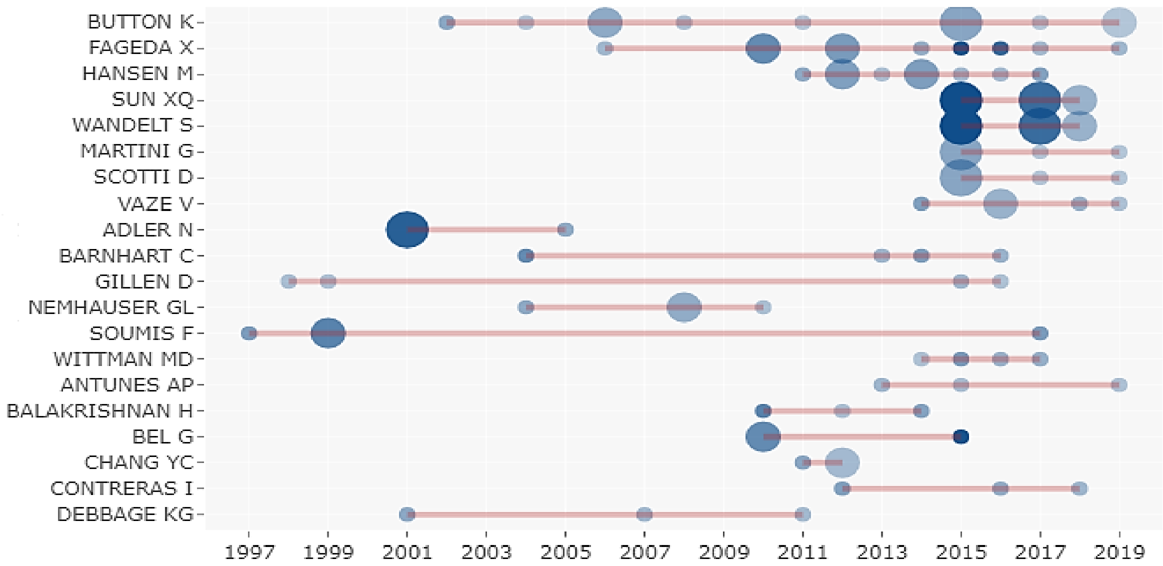

Figure 6. Time-Based Productivity Graphics of Most Publishing Authors

4.5. Data on Journals

In Table 4, the list of the top 20 journals preferred by the researchers, the number of articles published, the h-indices, the g-indices, and the m-indices are presented. The productivity shares of the top 10 journals that publish the most studies in the field of air logistics is 51.5%. 7 of these 10 journals are registered with Elsevier database. The journal with the highest values in air logistics studies, both in the number of articles and in the indexes showing scientific productivity, is the Journal of Air Transport Management. The other two journals with the highest scientific productivity are Transportation Science and Transportation Research Part E-Logistics and Transportation Review, respectively. Although the number of articles published by Transportation Research Part E-Logistics and Transportation Review is lower than the European Journal of Operational Research ve Transportation Research Part A-Policy and Practice, their scientific productivity performance is higher (Table 4).

Table 4. Top Publishing Journals in Air Logistics

Journal	Articles	Citations	h-Index	g-Index	m-Index
Journal of Air Transport Management	58	900	17	17	28
Transportation Research Record	25	104	6	6	9
Transportation Research Part E-Logistics and Transportation Review	23	373	13	13	19
Transportation Science	20	614	14	14	20
Transportation Research Part A-Policy and Practice	19	420	11	11	19
European Journal of Operational Research	17	637	11	11	17
Journal of Transport Geography	16	363	10	10	16
Transportation Research Part D-Transport and Environment	10	67	5	5	7
Transportation Journal	9	29	3	3	5
Safety Science	8	143	5	5	8
Transportation Quarterly	8	23	3	3	4
Operations Research	7	362	7	7	7
Sustainability	7	18	3	3	4
Transport Policy	7	49	3	3	7
Logistics and Transportation Review	6	9	2	2	2
Transportation Research Part B-Methodological	6	65	5	5	6
International Journal of Transport Economics	5	15	1	1	3
European Journal of Transport and Infrastructure Research	4	18	2	2	4
Expert Systems with Applications	4	107	3	3	4

Fig. 7 shows the development graphics of the most publishing journals in the field of air logistics on the basis of years. Especially with the 2000s, there was a notable increase in air logistics studies. Although the number of articles published by the Journal of Air Transport Management before 1995 was lower than in other journals, it started to grow steadily as of that year. After 2000, it became the journal that published the most articles on air logistics, and in the 2010s, it was able to publish more articles than any other journal. Another journal notable for their work in the field of air logistics is Transportation Research Part E-Logistics and Transportation Review. Especially after 2004, the number of publications has steadily increased, and by 2013 it became the 2nd most published journal in the field of air logistics and the 1st fastest developing journal.

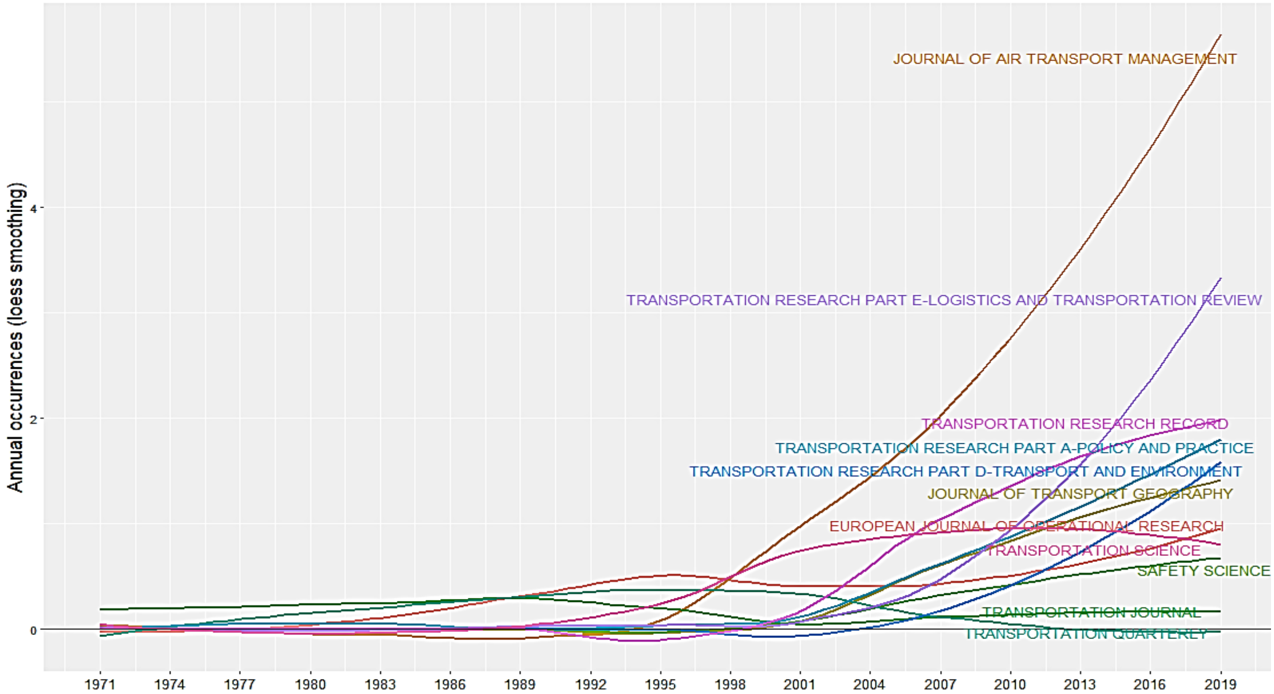

Figure 7. Development Graphics of Most Publishing Journals

4.6. Data on Countries

The number of articles published by the countries may, to some extent, reflect the importance that the country gives to the subject and its success in this subject (Xie, 2019). As seen in Fig. 8, there are two North American countries (the USA and Canada), 5 European countries (Spain, England, Germany, France, and Turkey), two Asian countries (China and Taiwan) and one South American country (Brazil) among the top 10 countries. While the USA ranks first with 236 publications, China ranks second with 86 publications, and Canada and Spain rank third with 44 publications. Among the top 10 countries, there are 3 developing countries (China, Brazil, and Turkey), while the other 7 have developed country status. The articles published by the USA had 2382 citations, and Canada took second place with 433 citations and Taiwan the third place with 423 citations. Israel ranked 6th in the number of citations, with 286 citations received by 8 articles, and ranked first in the average number of citations per article (47.67). In the USA, which has the highest number of articles and citations, the average number of citations per article is 16.89.

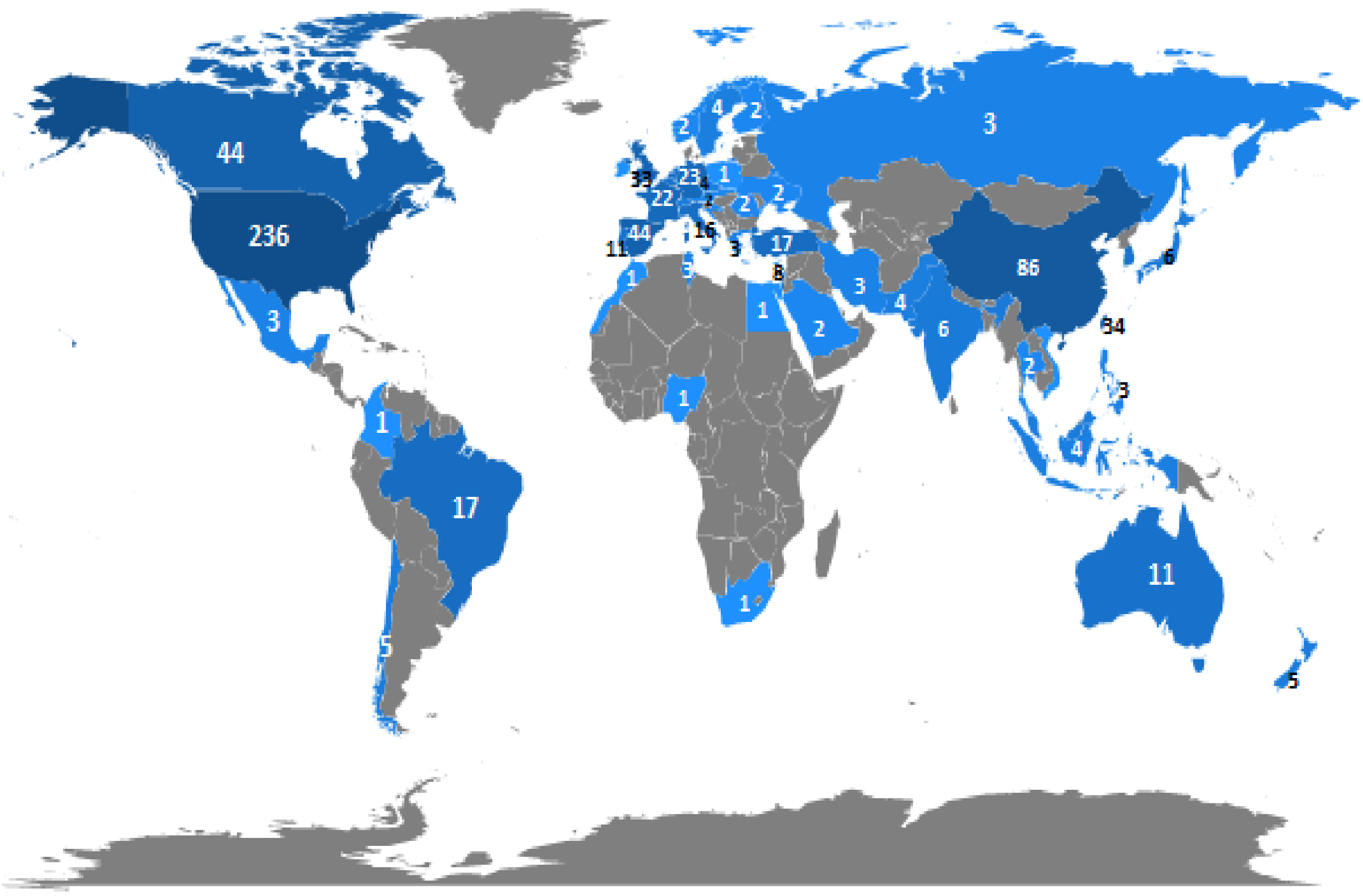

Figure 8. Countries with the Most Publications on Air Logistics

4.7 Data on Keywords

In Fig. 9, there is a network of most used keywords in air logistics. The size of each node on the network reflects the frequency of keywords. The thickness of the line is proportional to the closeness of the links between the two keywords. If there are bold lines between the two words, the two related keywords are more closely related (Chen et al., 2016). The fact that the words in this common keyword network are related to air logistics shows that the abstract analysis process carried out to select the sources in the dataset has been carried out correctly (Shonhe, 2020: 3). “Air transportation,” which is preferred as a keyword in 85 different studies, is the most frequently used keyword in the data set. In the 2nd, 3rd and 4th ranks are the words airport, aviation, and transportation, which have been used as keywords a total of 14 times.

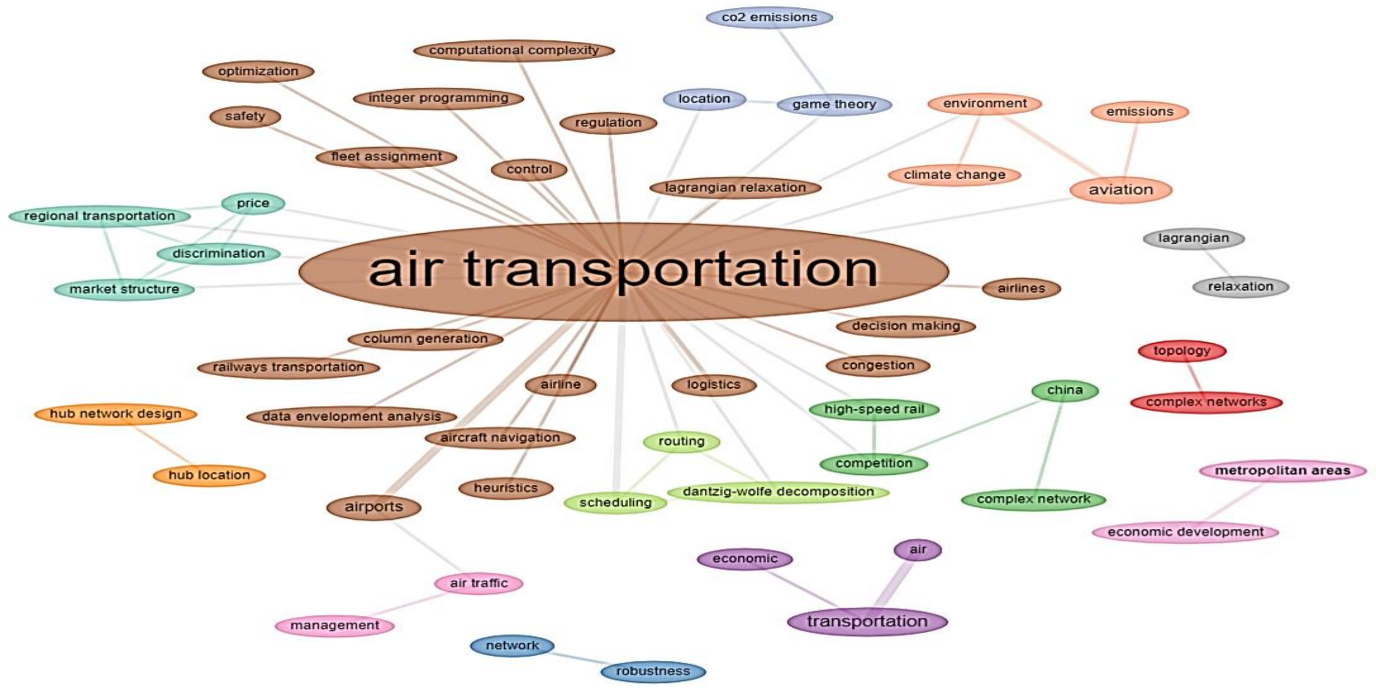

Figure 9. Most Commonly Used Keywords

5. Conclusions, Limitations and Future Research

This study provides a systematic review and bibliometric analysis of articles published in the Web of Science database on air logistics issues between 1971 and 2019 that can be examined in the field of social sciences. Although numerous articles on air logistics have been published, especially in recent years, they are still on an upward trend and far from scientific saturation. On the other hand, at the time of the creation of the data set, it was determined that the vast majority of the studies in the literature on air logistics were related to science. Although 2134 articles were accessed in the first literature review, this number decreased to 398 (approximately 81% decrease) after filtering was done by selecting categories that could be examined under the context of social sciences.

It was observed that there had been a great increase in the number of air logistics studies, especially in the last 10 years, and the number of citations received in the studies published in these years has increased at a higher rate compared to the number of citations published in the previous years. 80% of the studies are multi-author. 91% of the authors have published in multi-author studies. Although the number of citations received by the studies published before the millennium is higher, the number of citations received by the studies published after 2010 is higher than the previous studies. The most productive researchers in the literature are K. Button, X. Fageda, and M. Hansen. The most cited authors are X. Fageda, N. Adler, and J. Desrosiers, respectively.

This study determined that the studies on location-selection and routing problems for hub-and-spoke networks and air transport network planning and modeling at airports were more cited than other subjects. The journal that publishes the most articles is the Journal of Air Transport Management. When analyzed by countries, it is the USA that publishes the most and gets the most citation. The most publishing countries after the USA are China, Canada, and Spain, respectively. The most frequently used keyword is air transportation.

The fact that air logistics was subjected to bibliometric research for the first time reflects the authenticity of this study. Sources subject to research consist only of articles, while papers, books or dissertations were not included in the analysis. A categorical limitation was conducted by analyzing only the studies that could be the subject of research of social sciences. On the other hand, articles published in the field of air logistics in 2020 and 2021 were not included in the data set of this study, since it is thought that the inclusion of articles published after the Covid-19 pandemic in the bibliometric analysis does not fit the main purpose of this research. Considering all these limitations, more and more publications and other publications published in other disciplines can be added to the analysis process of future studies, and thus the scope of this research can be extended.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Adler, N., and Smilowitz, K. (2007). Hub-and-spoke network alliances and mergers: Price-location competition in the airline industry. Transportation Research Part B: Methodological, 41(4), 394-409.

Alumur, S., and Kara, B. Y. (2008). Network hub location problems: The state of the art. European Journal of Operational Research, 190(1), 1-21.

Aria, M., and Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959-975.

Aria M, Cuccurullo C, and Aria M. M. (2017). Package 'bibliometrix'.

Aykin, T. (1995). Networking policies for hub-and-spoke systems with application to the air transportation system. Transportation Science, 29(3), 201-221.

Barrat, A., Barthelemy, M., Pastor-Satorras, R., & Vespignani, A. (2004). The architecture of complex weighted networks. Proceedings of the National Academy of Sciences, 101(11), 3747-3752.

Bensalem, A., and Kin, V. (2019, January). A bibliometric analysis of reverse logistics from 1992 to 2017. In Supply Chain Forum: An International Journal (Vol. 20, No. 1, pp. 15-28). Taylor & Francis.

Borenstein, S. (1989). Hubs and high fares: dominance and market power in the US airline industry. The RAND Journal of Economics, 344-365.

Brueckner, J. K. (2003). Airline traffic and urban economic development. Urban Studies, 40(8), 1455-1469.

Bryan, D. L., and O'kelly, M. E. (1999). Hub‐and‐spoke networks in air transportation: an analytical review. Journal of Regional Science, 39(2), 275-295.

Burghouwt, G., and de Wit, J. (2005). Temporal configurations of European airline networks. Journal of Air Transport Management, 11(3), 185-198.

Button, K., and Taylor, S. (2000). International air transportation and economic development. Journal of Air Transport Management, 6(4), 209-222.

Campbell, J. F. (1994). Integer programming formulations of discrete hub location problems. European Journal of Operational Research, 72(2), 387-405.

Cardillo, A., Zanin, M., Gómez-Gardenes, J., Romance, M., García del Amo, A. J., and Boccaletti, S. (2013). Modeling the multi-layer nature of the European Air Transport Network: Resilience and passengers re-scheduling under random failures. The European Physical Journal Special Topics, 215(1), 23-33.

Charvet, F. F., Cooper, M. C., and Gardner, J. T. (2008). The intellectual structure of supply chain management: A bibliometric approach. Journal of Business Logistics, 29(1), 47-73.

Chen, X., Chen, J., Wu, D., Xie, Y., and Li, J. (2016). Mapping the research trends by co-word analysis based on keywords from funded project. Procedia Computer Science, 91, 547-555.

Silva, R. G., Dias, I. C. P., & Gonçalves, M. C. (2019). A bibliometric contribution of the strategies of reverse logistics in waste electrical and electronic equipment (weee) management. Engrxiv, 1-13.

Davarzani, H., Fahimnia, B., Bell, M., and Sarkis, J. (2016). Greening ports and maritime logistics: A review. Transportation Research Part D: Transport and Environment, 48, 473-487.

de Campos, E. A. R., de Paula, I. C., Pagani, R. N., and Guarnieri, P. (2017). Reverse logistics for the end-of-life and end-of-use products in the pharmaceutical industry: a systematic literature review. Supply Chain Management: An International Journal. 22(4): 375-392.

de Carvalho, P. P. S., de Araújo Kalid, R., Rodríguez, J. L. M., and Santiago, S. B. (2019). Interactions among stakeholders in the processes of city logistics: a systematic review of the literature. Scientometrics, 120(2), 567-607.

Dolati Neghabadi, P., Evrard Samuel, K., and Espinouse, M. L. (2019). Systematic literature review on city logistics: overview, classification and analysis. International Journal of Production Research, 57(3), 865-887.

Ernst, A. T., and Krishnamoorthy, M. (1996). Efficient algorithms for the uncapacitated single allocation p-hub median problem. Location Science, 4(3), 139-154.

Erturgut R. (2016). Lojistik ve Tedarik Zinciri Yönetimi [Logistics and Supply Chain Management]. Nobel Yayıncılık. Ankara.

Feng, B., Li, Y., and Shen, Z. J. M. (2015). Air cargo operations: Literature review and comparison with practices. Transportation Research Part C: Emerging Technologies, 56, 263-280.

Georgi, C., Darkow, I. L., and Kotzab, H. (2013). Foundations of logistics and supply chain research: a bibliometric analysis of four international journals. International Journal of Logistics Research and Applications, 16(6), 522-533.

Gerede E. (2002). Havayolu Taşımacılığında Küreselleşme ve Havayolu İşbirlikleri-THY AO'da Bir Uygulama [Globalization In Airline Industry and Airline Alliances- A Case Study At Turkish Airline], Doctoral dissertation, Anadolu University, Sosyal Bilimler Enstitüsü, Turkey.

Gokasar, I., and Gunay, G. (2017). Mode choice behavior modeling of ground access to airports: A case study in Istanbul, Turkey. Journal of Air Transport Management, 59, 1-7.

Guimera, R., Mossa, S., Turtschi, A., and Amaral, L. N. (2005). The worldwide air transportation network: Anomalous centrality, community structure, and cities' global roles. Proceedings of the National Academy of Sciences, 102(22), 7794-7799.

Hajduk, S. (2017). Bibliometric analysis of publications on city logistics in international scientific literature. Procedia Engineering, 182, 282-290.

IATA. (2018). In Annual Review 2018. 74th Annual General Meeting.

Kazemi, N., Modak, N. M., and Govindan, K. (2019). A review of reverse logistics and closed loop supply chain management studies published in IJPR: a bibliometric and content analysis. International Journal of Production Research, 57(15-16), 4937-4960.

Kinene, A., Granberg, T. A., Polishchuk, V., and Rydergren, C. (2020). Decision support for an optimal choice of subsidised routes in air transportation. Journal of Air Transport Management, 82, 101724.

Kwasiborska, A. (2016, May). Idea of Sustainable Development of Transport with Special Reference to Air Transportation. In TranSopot Conference (pp. 47-55). Springer, Cham.

Lin, J. (2012). Network analysis of China's aviation system, statistical and spatial structure. Journal of Transport Geography, 22, 109-117.

Lin, Y. K., Nguyen, T. P., and Yeng, L. C. L. (2019). Reliability evaluation of a multi-state air transportation network meeting multiple travel demands. Annals of Operations Research, 277(1), 63-82.

Lin, Y., and Zhao, Q. (2019, March). Analysis of agricultural logistics literatures based on Cnki. In International Academic Conference on Frontiers in Social Sciences and Management Innovation (IAFSM 2018) (pp. 86-91). Atlantis Press.

Mishra, D., Gunasekaran, A., Papadopoulos, T., and Dubey, R. (2018). Supply chain performance measures and metrics: a bibliometric study. Benchmarking: An International Journal.

Munari, P., and Alvarez, A. (2019). Aircraft routing for on-demand air transportation with service upgrade and maintenance events: Compact model and case study. Journal of Air Transport Management, 75, 75-84.

O'kelly, M. E. (1987). A quadratic integer program for the location of interacting hub facilities. European Journal of Operational Research, 32(3), 393-404.

Osareh, F. (1996). Bibliometrics, citation analysis and co-citation analysis: A review of literature I. Libri. 46(3), 149-58.

Padrón, S., and Guimarans, D. (2019). An improved method for scheduling aircraft ground handling operations from a global perspective. Asia-Pacific Journal of Operational Research, 36(04), 1-25, 1950020.

Parsa, M., Nookabadi, A. S., Flapper, S. D., and Atan, Z. (2019). Green hub-and-spoke network design for aviation industry. Journal of Cleaner Production, 229, 1377-1396.

Pritchard, A. (1969). Statistical bibliography or bibliometrics. Journal of Documentation, 25(4), 348-349.

Qaiser, F. H., Ahmed, K., Sykora, M., Choudhary, A., and Simpson, M. (2017). Decision support systems for sustainable logistics: a review and bibliometric analysis. Industrial Management & Data Systems.

Raisig, L. M. (1962). Statistical bibliography in the health sciences. Bulletin of the Medical Library Association, 50(3), 450.

Real, L. B., O'Kelly, M., de Miranda, G., and de Camargo, R. S. (2018). The gateway hub location problem. Journal of Air Transport Management, 73, 95-112.

Sengupta, I. N. (1992). Bibliometrics, informetrics, scientometrics and librametrics: an overview, 42(2), 75-98.

Shen, H., Liang, Y., and Shen, Z. J. M. (2021). Reliable hub location model for air transportation networks under random disruptions. Manufacturing & Service Operations Management, 23(2), 388-406.

Shonhe, L. (2020). Continuous Professional Development (CPD) of librarians: A bibliometric analysis of research productivity viewed through WoS. The Journal of Academic Librarianship, 46(2), 102106.

Siamaki, S., Geraei, E., and Zare-Farashbandi, F. (2014). A study on scientific collaboration and co-authorship patterns in library and information science studies in Iran between 2005 and 2009. Journal of education and health promotion, 3.

Singhaseni, C., Wu, Y., and Ojiako, U. (2013). Modeling overbookings on air cargo transportation. International Journal of Physical Distribution & Logistics Management.

Sun, X., Wandelt, S., and Linke, F. (2015). Temporal evolution analysis of the European air transportation system: air navigation route network and airport network. Transportmetrica B: Transport Dynamics, 3(2), 153-168.

Totamane, R., Dasgupta, A., and Rao, S. (2012). Air cargo demand modeling and prediction. IEEE Systems Journal, 8(1), 52-62.

University of Maryland. LibGuides: Bibliometrics and altmetrics: measuring the impact of knowledge. Available from: https://lib.guides.umd.edu/ bibliometrics/.

Voigt, D., Casarotto Filho, N., Macedo, M. A., Braga, T. G., and da Rocha, R. U. G. (2019). Performance Evaluation of Reverse Logistics: Opportunities for Future Research. Sustainability, 11(19), 5291.

Wang, C., Lim, M. K., and Lyons, A. (2019). Twenty years of the International Journal of Logistics Research and Applications: a bibliometric overview. International Journal of Logistics Research and Applications, 22(3), 304-323.

Wang, J. J., Chen, H., Rogers, D. S., Ellram, L. M., and Grawe, S. J. (2017). A bibliometric analysis of reverse logistics research (1992-2015) and opportunities for future research. International Journal of Physical Distribution & Logistics Management.

Wei, K., and Vaze, V. (2018). Modeling crew itineraries and delays in the national air transportation system. Transportation Science, 52(5), 1276-1296.

Wensveen, J. G. (2018). Air transportation: A management perspective. Routledge.

Winter, M., and Knemeyer, A. M. (2013). Exploring the integration of sustainability and supply chain management: Current state and opportunities for future inquiry. International Journal of Physical Distribution & Logistics Management, 43(1), 18-38.

Xie, H., Zhang, Y., Zeng, X., and He, Y. (2020). Sustainable land use and management research: a scientometric review. Landscape Ecology, 35(11), 2381-2411.

Xu, Z., and Harriss, R. (2008). Exploring the structure of the US intercity passenger air transportation network: a weighted complex network approach. GeoJournal, 73(2), 87-102.

Yang, K., Yang, L., and Gao, Z. (2016). Planning and optimization of intermodal hub-and-spoke network under mixed uncertainty. Transportation Research Part E: Logistics and Transportation Review, 95, 248-266.

Zary, B., Bandeira, R., and Campos, V. (2014). The contribution of scientific productions at the beginning of the third millennium (2001–2014) for humanitarian logistics: A bibliometric analysis. transportation research procedia, 3, 537-546.

Zhao, H., and Zhang, N. (2019). Who is the main influencer on safety performance of dangerous goods air transportation in China? Journal of Air Transport Management, 75, 198-203.

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The Impact of the Ukraine-Russia Conflict on the Aviation Sector: February-May 2022

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Abstract

Aviation; it is a global sector that affects many areas such as education, trade, tourism, and is also affected by many situations such as epidemics, economic fluctuations, political disagreements and military intervention. For this reason, the disagreement between Ukraine and Russia also quietly affects the aviation industry. Although disagreements seem to continue between the two countries, issues such as the closure of airspaces, changes in flight costs as a result of changing routes, the situation of aircraft and component manufacturers, tourism and aviation security concern aviation globally. In this study, which was conducted to reveal the impact of the Ukraine-Russia conflict on the aviation sector, case study research, one of the qualitative research methods, was used. In a four-month period, sources such as newspaper news, internet news sites, websites of authorities were scanned, and it was tried to reveal how the conflict was reflected in the aviation industry. This method was chosen considering that it is suitable for this study in terms of revealing what happened in the past, how people were affected, how the processes took place, and what the results were. Between February 24 and March 2, when the disagreements between the two countries began, all flights to Ukraine were stopped, while air traffic in neighbouring countries decreased. International passenger traffic of Russian airlines decreased by at least four times in March 2022 compared to March 2021, and by sixteen times compared to March 2019. The Ukraine-Russia conflict also negatively affected the flight times of passenger flights between East and West. As a result of the study, the great impact of the four-month period, which is thought to be short, on the aviation sector has been tried to be revealed.

1. Introduction

Although aviation is a global sector that contributes to technological, economic and social developments between countries at both national and international level, it is affected by all kinds of economic, political, social and technological developments taking place around it. An example of this is the effects of the Covid-19 pandemic, which started at the end of 2019, on the aviation industry. The aviation sector, which has not yet overcome the negative effects of the Covid-19 pandemic, is experiencing the negative effects of the conflict between Russia and Ukraine that started in February 2022.

With the beginning of the Russia-Ukraine conflict, sanctions against Russia were started to be implemented, especially by western countries. On February 24, European air traffic stopped flights to Ukraine, European Union airspace was closed to Russian planes (Euronews, 2022). As a result, other airlines had to divert their planes to different airspaces. Airline companies and passengers flying over Russian airspace to save time and fuel were adversely affected by this situation. However, rising fuel prices also affected flight costs. Other sanctions, such as the prohibition of the supply of civilian aircraft-spare parts to Russia, the obligation to terminate the contracts of companies that lease aircraft to Russia, and the prohibition of aircraft maintenance-insurance services, have also begun to be implemented. Although these sanctions are aimed at disarming Russia, aircraft parts manufacturers, airline companies and businesses providing aircraft maintenance and insurance services have been adversely affected financially.

She gave advice to the citizens of Russia, who faced heavy sanctions as a result of the disagreement between Ukraine and Russia, not to go to the countries that imposed sanctions. This has had a negative impact on the tourism sector, as the majority of tourists in Europe, Asia and the Middle East are Russian tourists.

In addition to the factors mentioned above such as airspace, rerouting and costs, aircraft and aircraft component manufacturers were also affected by this conflict. Especially large engine manufacturers and military aircraft manufacturers were adversely affected in both countries.

Within the scope of this study, the effect of the conflict between Ukraine and Russia on the aviation sector in the period of February-May 2022 was examined. The problems experienced by the sector with the closure of airspaces and changing routes were determined, and answers were sought to questions such as how this situation affected the costs, how it was reflected on the aircraft manufacturers, and its return to the tourism sector. When the literature was searched, no other study was found in the field, since the conflict started a short time ago and is still ongoing. In addition, there is no answer in the literature to the question of how similar political problems between other countries recently affected the aviation industry. It is thought that this study is important in terms of completing this deficiency in the literature and revealing the negative effects of political disagreements on the aviation industry.

2. Methods

In this article, which aims to examine the effects of the Ukraine-Russia conflict on aviation, case study has been chosen as the method. A case study is a methodological approach that involves in-depth examination of a limited system using multiple data collection to gather systematic information about how it works (Chmiliar, 2010). It is a qualitative research approach in which one or more situations are analyzed in depth by data collection tools such as audio-visuals, documents, reports that contain multiple sources, and situations and themes related to the situation are defined in a time-limited time. With the data obtained with this method, it reveals why the event occurred in that way and what should be focused on in future studies (Davey, 2009).

In this context, ~~in this study~~, the data about the dispute selected as the subject of the study between February 2022 and May 2022 were compiled from the news and reports. Within the framework of the collected data, the effects of this conflict on aviation, the closure of airspaces, the change of flight routes, the changes in flight costs, the effects on aviation security and finally its effects on tourism were completed.

3. Airspace Closure

Airspace is the mass of the atmosphere over any land or body of water, the dimensions of which are determined by various laws, rules and treaties (ICAO, 2001). According to the International Civil Aviation Convention (Chicago Convention), signed in Chicago in 1944, each state has absolute sovereignty over its airspace in its own country/region (ICAO,2013). The concept of airspace has also become important in the Ukraine-Russia conflict (IFALFA, 2022) and has affected the political and economic balances between the countries. As a result of the conflict between Ukraine and Russia, sanctions against Russia from western countries continued increasingly. According to the data shared by Eurocontrol, between February 24 and March 2, when the European air traffic disputes began, all flights to Ukraine were stopped, while there were decreases in air traffic in neighbouring countries (Haber.Aero, 2022). The Russian airline industry was adversely affected by the closing of the European Union's airspace to Russian aircraft.

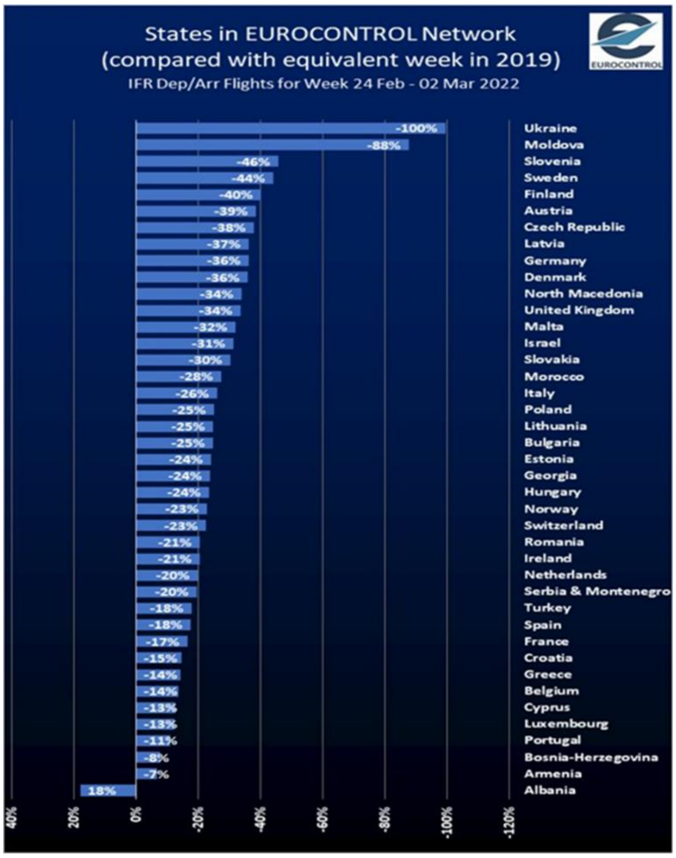

Figure 1. Comparison of IFR flight data from February 24 to March 2 2022 with the same period of 2019 (Eurocontrol,2022)

As seen in Figure 1, Moldova was followed by Slovenia, Sweden, Finland and Austria, which had an 88% decrease in the number of landings and take-offs compared to the same period of 2019. As seen in the list, Turkey experienced a decrease of 18%. Eurocontrol General Manager Eamonn Brennan explained: “There is no traffic in Ukraine, there is almost no traffic in Moldova”. In this period, Armenia with 7% and Bosnia and Herzegovina with 8% were the countries that experienced the least decline.

Russian airlines were most affected by these sanctions of European countries (Haber.Aero, 2022). The data shared by the authorities are as follows (IATA):

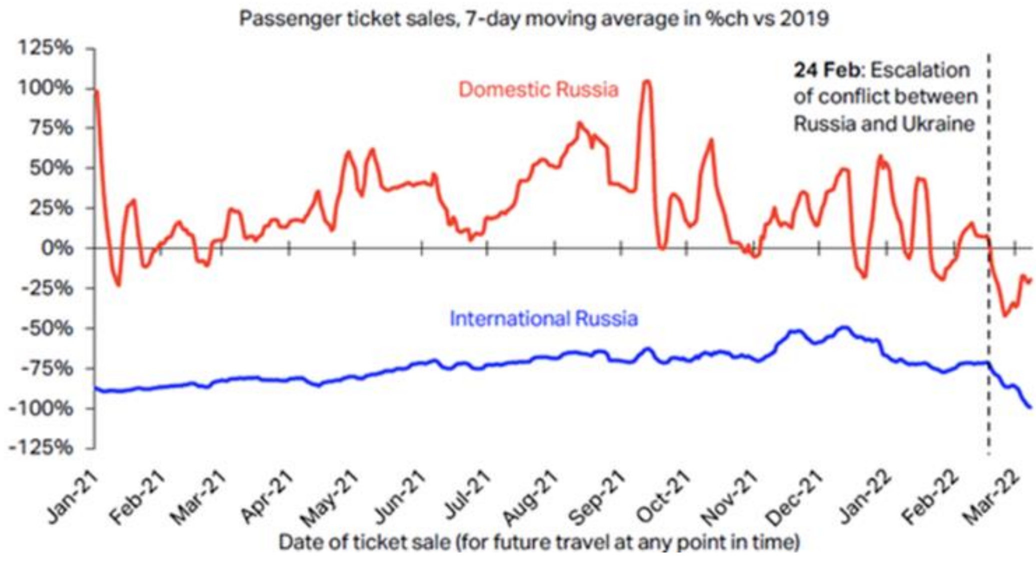

Figure 2. Status of tickets sold from Russia for future trips (IATA, 2022).

Figure 2 shows that domestic ticket sales in Russia decreased by 50%. In this period, there was a 25% decrease in ticket sales for international flights and this continued.

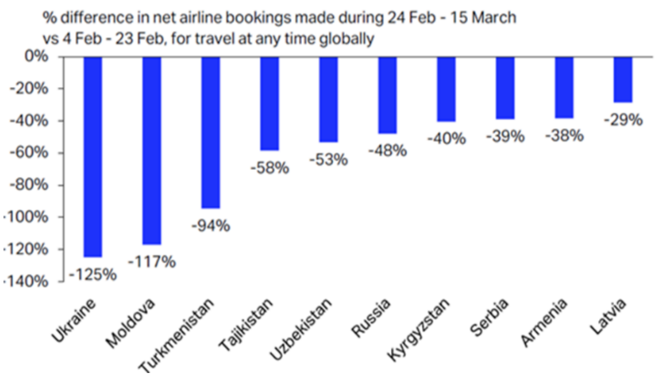

Figure 3. The ten countries most adversely affected by air travel demand in the Ukraine-Russia conflict. Source: (IATA,2022)

Figure 3 also shows the decline in the number of airline reservations of the ten countries most negatively affected by the demand for air travel from the Ukraine-Russia conflict. According to this graph of IATA, the country with the biggest decrease in the number of reservations was Ukraine, while Lithuania was the tenth affected country. The closure of the airspace has changed the routes and created troublesome processes for those who use the airline.

4. Changed Flight Routes

Airlines try to find the most suitable route between two destinations in order to fly their passengers safely, while minimizing fuel and other costs. This includes route planning. While considering the cost and time criteria, on the other hand, route planning is made according to the weather conditions and the rotation of the world. In crises experienced in aviation, especially in cases where airspaces are affected, routes are changed according to the instant situation of the flight.

In this dispute, according to the news in the Russian press, (Russian Association of Tour Operators, 2022) Russian airlines' international passenger traffic decreased at least four times in March 2022 compared to March 2021, and sixteen times compared to March 2019. Domestic flights and flights to Central Asian countries continued. While many airline companies were affected by the sanctions policies of European countries against Russia, regional flights were less affected.

The Ukraine-Russia conflicts negatively affected the flight times of passenger flights between the East and the West. The closure of Russia's airspace caused the journey from London to Tokyo to be extended by 4 hours and 30 minutes. At the same time, the flight time, which took 9 hours and 30 minutes when traveling from Tokyo to Helsinki over the Russian airspace, increased to 13 hours due to the new route. Table 1 contains other data on the changed routes.

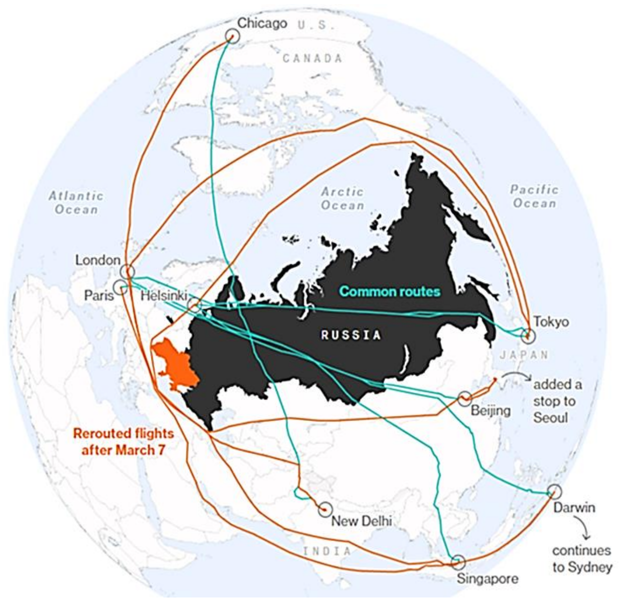

Figure 4. Changing travel routes of the six Airlines (Flightradar24, 2022).

Table 1. Travel times (Flightradar24, 2022)

Airlines	Departures	Arrivals	Flight time	Delay
Air France	Beijing	Paris	11 h 55 m	6 h 5 m
Japan Airlines	London	Tokyo	11 h 55 m	4 h 30 m
Finnair	Helsinki	Tokyo	9 h 30 m	3 h 30 m
Finnair	Singapore	Helsinki	11 h 50 m	1 h 25 m
United	Chicago	New Delhi	14 h 35 m	1 h
Qantas	Sydney	London	23 h 20 m	30 m

Due to the extended flight times and rising oil prices, it was inevitable that fuel and service costs would rise. All other airlines, as well as the airlines that experienced delays, were adversely affected by all these increased costs.

Since many companies did not use or did not want to use Russia's huge airspace, they had to fly from different routes to longer distances and costly. As a result, it has been observed that flight times are prolonged in the northern hemisphere. The Ukrainian-Russian disputes caused the distance between the western countries to open and diplomatic tensions. Many countries have expelled Russian diplomats from the country. It has been observed that the planes sent for the deported diplomats to return to Russia encountered altered routes. The plane that came to pick up the diplomats in Madrid and Athens had to travel thousands of extra kilometers.

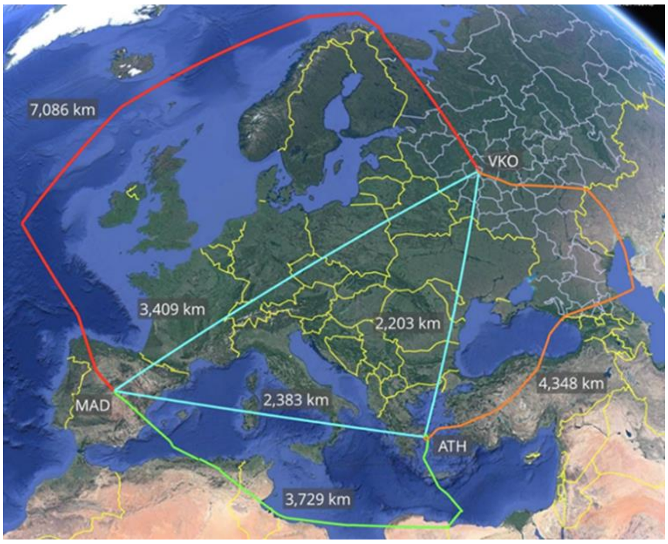

Figure 5. Delayed flight attempted for diplomats

This flight was first made from Moscow to Madrid. The flight, which took 3409 km in open European airspace, increased to 7086 km due to closed airspaces. When it came to Athens after Madrid, the plane, which had a 2383 km route in normal time, changed its route to 3729 km due to this conflict. While the distance between Athens and Moscow was 2203 km before, it increased to 4348 km after the disagreement. Thus, the route changes caused an additional 7168 km increase due to the closed airspaces. With this effect of changing routes, flight costs affect not only the countries where the conflict is experienced and the countries around them, but also the entire aviation industry.

5. Changes in Flight Costs

Airlines and all other stakeholders in the aviation industry are engaged in business and ultimately want to make a profit. They want to minimize their costs in order to make a profit. The costs of airline companies consist of components such as fuel, personnel, fleet renewal, maintenance, ground services, wear and tear, insurance, tax, fees, catering services, advertising and airport use. Increases in these components are also observed in the crises in the aviation sector.

One of the negative effects of the Ukraine-Russia conflict on the aviation sector is the changes in flight costs. In the statement made by the international credit rating agency Fitch Ratings, it was stated that the increasing tension between Ukraine and Russia hindered the recovery of the European aviation sector. In addition, it was stated that airline companies in Europe were adversely affected by the record-breaking increase in energy prices in the recent period and the mutual sanctions between western countries and Russia. In the Fitch statement, which stated that the flight traffic of airlines in Europe is expected to return to its pre-epidemic level in 2019 only in 2024, it is emphasized that the increase in commodity prices and inflation may make it difficult for airlines to meet the increased costs and pass it on to consumers (AnadoluAjans, 2022).

Fraport's CEO, Stefan Schulte, said in a statement that German airport services provider Fraport is operating in St. He stated that he would not be able to sell his airport stake in St. Petersburg before 2025. In Schulte's statement, he explained that the possible sale of the airport on the planned date would be conditional and would not help to stop the Ukraine-Russia conflict, which would mean an extra gain for Russia. Stefan Schulte stated that his concessions are linked to a sales ban until 2025. Answering questions about the concerns that military planes might take off from the civil airport, Schulte explained that they only have a 25 percent stake in the airport operation. He also stated that air traffic controllers have a say in landing and taking off at airports (Haber.Aero, 2022).

In a statement by the International Air Transport Association (IATA), it was predicted that Russia's military attack on Ukraine and retaliatory airspace closures would have a negative impact on the air cargo industry. However, this impact is expected to be low, as only 0.6% of global air transported cargo in 2021 is linked to Russia. Publishing January 2022 data for global air cargo markets, IATA general manager Willie Walsh stated that the 2.7% increase in demand in January remained below expectations after 9.3% in December 2021. It has been said that this likely reflects a shift towards the more normal 4.9% growth rate expected for 2022. Looking at the following periods, it has been stated that the cargo markets are expected to be affected by the Ukraine-Russia conflict (Airport-Technology, 2022).

Ukraine and Russia have a significant impact on the global economy. This global influence has manifested itself due to the disagreement between Ukraine and Russia. Flight and cargo costs have increased as most commercial air travel and freight flight routes have been redefined. Ukraine and Russia are major suppliers in a number of commodity markets in the global economy. Together, these two countries account for around 30% of wheat, 20% of corn, mineral fertilizers and natural gas, and 11% of oil in global exports. In addition, worldwide supply chains are dependent on metal exports from Ukraine and Russia. Russia is a major supplier of palladium, which is used in catalytic converters for automobiles, and nickel, which is used in the manufacture of steel and batteries. Ukraine and Russia are also sources of noble gases such as argon and neon used in semiconductor production, and large producers of titanium sponges used in aircraft. Both countries have significant uranium reserves globally. The prices of many of these commodities have risen sharply since the beginning of the war, although there was no significant cut in production or export volumes, as shown in Figure 6. Many multinational companies had to suspend their operations in Ukraine and Russia due to the increase in operating expenses affected by flight costs (OECD, 2022).

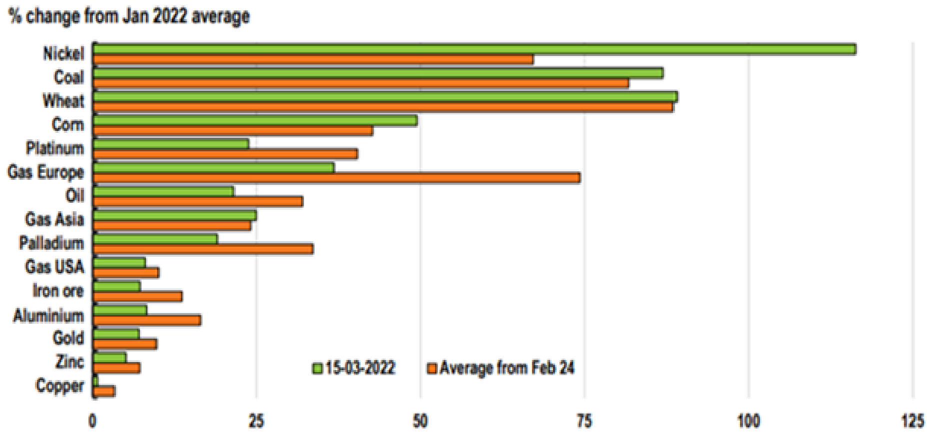

Figure 6. The sharp rise in prices of Russia and Ukraine's main exports (OECD, 2022).

In addition to these effects on the global economy, the aviation industry, which has not yet completely recovered from the effects of the Covid-19 epidemic, has faced numerous difficulties due to the disagreement between Ukraine and Russia. According to GlobalData, the pandemic has negatively impacted global revenue from full-service and low-cost airlines (Investmentmonitor,2022). Data from Globaldata, shown in Figure 7, shows that the industry saw steady growth in the pre-pandemic years, but global revenues from full-service and low-cost airlines fell sharply in 2020.

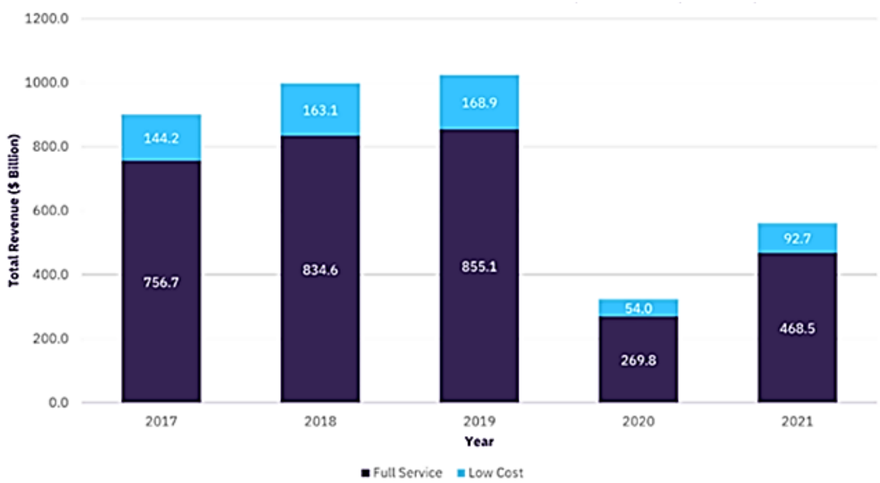

Figure 7. Global revenue from full service and low cost airlines (Globaldata,2022)

This recovery struggle is compounded by the sanctions and airspace restrictions imposed both by and against Russia. With the start of the Ukraine-Russia conflict, Russia retaliated against Canada, the EU, the UK, the USA and various other countries that banned Russian planes from their airspace, and banned the flight in the airspace of thirty-six countries. The reciprocal sanctions and airspace restrictions that have plagued the aviation industry have led to flight cancellations or rerouting, rising airfares, higher fuel costs, and problems with titanium supplies, among other issues. The combination of sanctions and airspace restrictions has forced many airlines to suspend or reroute their flights. Russia's flag carrier airline Aeroflot announced that it has stopped all international flights outside of Belarus, and that the country's second largest airline, S7, has also suspended international flights.

Airlines that avoided flying in Russian airspace had to change routes, while some European companies canceled their flights to Asia entirely. Finnair airlines, whose flights were initially canceled to Japan, China and South Korea, later resumed flights to Seoul, Tokyo and Shanghai, following a route that avoided Russian airspace. At that time, flights to Osaka and Hong Kong were canceled until the end of April. Longer routes and flight diversions have a significant impact on costs, including fuel prices and airline tickets.

This disagreement had a significant impact on fuel prices. According to research by GlobalData, rising fuel costs are thought to affect the profitability of airlines, which are still recovering after the drop in demand caused by the pandemic. Closed airspace means longer flight times, more fuel, more pilot hours, higher costs and therefore higher wages. Higher fares may adversely affect demand for the airline. Cancellation of flights, extension of routes, rising fuel prices and increasing inflation are just a few of the reasons for the increase in air ticket prices. Data from Google Flights in Figure 8 shows that the prices of flights from Russia have increased as a result of the sanctions. As a result, increasing ticket prices also harm many touristic destinations preferred by Russian tourists. This disagreement had a significant impact on fuel prices. According to research by GlobalData, rising fuel costs are thought to affect the profitability of airlines, which are still recovering after the drop in demand caused by the pandemic. Closed airspace means longer flight times, more fuel, more pilot hours, higher costs and therefore higher wages. Higher fares may adversely affect demand for the airline. Cancellation of flights, extension of routes, rising fuel prices and increasing inflation are just a few of the reasons for the increase in air ticket prices. Data from Google Flights in Figure 8 shows that the prices of flights from Russia have increased as a result of the sanctions. As a result, increasing ticket prices also harm many touristic destinations preferred by Russian tourists.

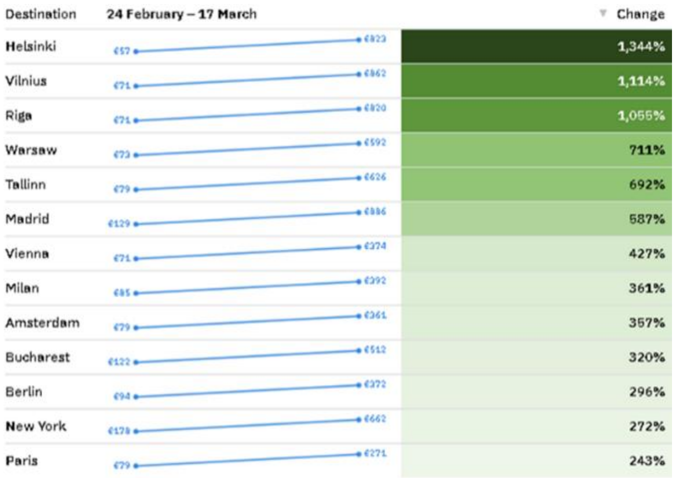

Figure 8. The prices of flights from Russia have increased as a result of the sanctions (Investmentmonitor,2022)

According to research by GlobalData, it has been stated that the ongoing crisis between Ukraine and Russia, which are among the leading producers of titanium, an important metal used in aircraft manufacturing, may interrupt supply in the short term. The Russian company VSMPO-Avista is the main supplier of titanium for Boeing and Airbus. In a recent statement by Airbus, it was stated that geopolitical risks are integrated into titanium procurement policies and therefore they are protected in the short/medium term.

These examples show how the Ukraine-Russia conflict will shape the future outlook of the aviation industry in many ways. It is expected that the hopes of the aviation industry, which has struggled with the negative effects of the Covid-19 epidemic in the last two years, to turn into a new normal will be delayed (Investmentmonitor,2022)

6. The Effects of Ukraine-Russia Conflict on Aviation Security

In the aviation industry, the concept of security is very important as well as the concept of safety. Ensuring flight security gives the airline company powers such as commercial superiority, prestige and preference, as in flight safety. Flight security covers the activities related to the protection of aviation operations without harming the passengers and cargo, aircraft, infrastructure in the civil aviation system, without being harmed by the physical and cyber dangers that carry criminal elements such as sabotage and terrorist attacks. Situations that threaten flight security have also emerged in the Ukraine-Russia conflict.

Russia has issued NOTAM (Notice to Airmen and Sailors) on February 24, 2022, following the military operation that started in Donbas, eastern Ukraine. In the statement in NOTAM, "Due to the use of weapons and military equipment, the use of airspace on Russia's western border with Ukraine and Belarus has been temporarily suspended due to the high threat to the safety of flights of civilian aircraft." statement is included. With the NOTAM published, it is seen in Figure 9 that the airspace is not used because the civil flights in the Ukrainian airspace pose a potential danger to the civil aviation.

Figure 9. Image from Flightradar24 data tracking website (TRT,2013)

Civil aircraft in Ukraine are also heavily damaged due to intense bombardment. In Figure 10, the "Antonov An-225 Mriya", located in the Antonov aircraft facility in the city of Gostomel, where heavy clashes took place, and divided into two as a result of the bombardments organized by Russia in the first days of the Ukraine-Russia war, is shown in its own hangar.

Figure 10. The final state of AN after the attack (NTV,2022)

These developments also reveal many security threats to aviation in the region. The increased airtime of aircraft also increases the potential for malfunctions in the air. In addition, Hong Kong-based airline company Cathay Pacific has announced that it is about to perform the longest commercial flight in the world. The company stated that after the Ukraine-Russia conflict, many airlines would redirect their New York flights over the Atlantic after bypassing the Russian airspace. This means that the journey is equivalent to 16,668 kilometers. A representative from Cathay Pacific airline told CNN that they always set up emergency routes for possible events or scenarios in the aviation world. He stated that since the Russian and Ukrainian airspaces cannot be used in an emergency, this situation would pose a significant risk for flight safety, by comparing daily flight routes, they planned the most efficient flight route of the day and lifted their planes (The Gurdian, 2022).

Figure 11. "Antonov An-225 Mriya", which was divided into two as a result of the bombardments organized by Russia (NTV,2022)

7. Impact On Tourism

While the countries that have experienced a decline in tourism in the last two years due to the Covid-19 pandemic have not yet recovered, the conflict between Ukraine and Russia has negatively affected the sector globally. With the beginning of this conflict, many countries started to apply deterrent sanctions against Russia. In response to this situation, Russia advised its citizens not to go to these countries. The data disclosed by GlobalData's Tourism Demands and Flows Database shows that the most preferred countries by Russian tourists are Turkey, China, Kazakhstan, Thailand, United Arab Emirates (UAE), Spain, Azerbaijan, Ukraine, Georgia and Italy, respectively. This behavior of Russia, which constitutes a large part of the tourist rate in European, Asian and Middle Eastern countries, has greatly affected tourism (Investmentmonitor, 2022) In addition, thousands of Russian and Ukrainian tourists have been stranded in Thailand as multiple airlines have canceled their return flights (BBC,2022).

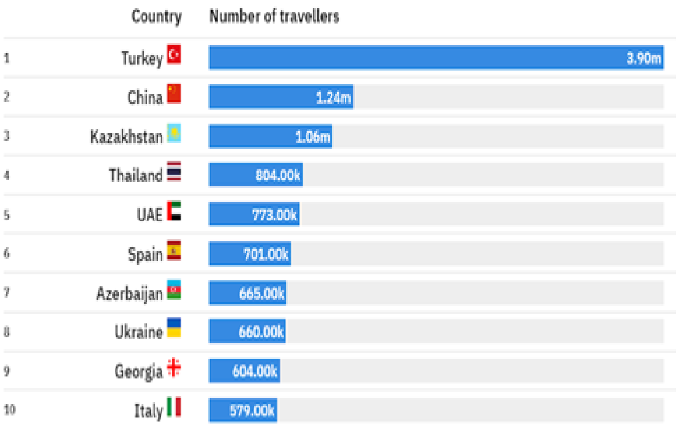

Figure 12. Top ten international departure number from Russia in 2021 (GlobalData, 2022)

Experts say that the industry cannot cope with this situation, which is only a short time away from the opening of the tourism season, and that a joint support and coordination is needed on a global scale. Considering the increase in energy and basic needs costs, inflation and employment around the world, it will be very difficult to predict the future of the tourism sector (Yeditepe, 2022).

Looking at the statistics of 6 million 750 thousand tourists coming to Turkey in 2021, Russia ranks first and Ukraine ranks third. Mehmet Gem, Chairman of the Board of Directors of the Travel Agencies Managers Association (SAYD), said that Turkey has lost two of its biggest markets in the tourism sector and that these markets will not be replaced in a short time until the tourism season, and that Turkey's tourism will experience a 40% loss this year. (Haberturk,2022)

President of Aegean Touristic Enterprises and Accommodations Union, stated that the ministry focused on Germany, England, Central Asia, Azerbaijan and Iran and the Middle East market together with Nevruz in order to compensate for market losses (Haberturk,2022)

8. Conclusion

Fighting the Covid-19 epidemic, aviation faced a new crisis in 2022. The disagreement that arose between Ukraine and Russia had a significant impact on the aviation industry, as well as on the people of Ukraine, Ukraine and all sectors in the world. Both countries have suffered many losses in the field of military aviation. Aviation is a sector that has dynamics in many fields, including political, economic, socio-cultural, between countries in the world. Even countries, institutions and companies that have superiority in the fields of production, marketing and passenger transportation in the field of aviation are affected by the emerging crises. Balances in aviation are like the butterfly effect. Due to the increasing fuel costs and the closure of the airspaces of the two countries with this disagreement, the extended routes put the airline companies in a difficult situation. These events, which affected each other one after the other, caused the routes to change afterward and had a significant impact on flight costs, aviation safety and tourism. The most important of these was a 25% decrease in ticket sales on international flights, and this affected the aviation industry all over the world.

In this study, which was carried out using the qualitative research method, aviation developments related to this dispute between February and May were examined with the situation research management. The study will contribute to other studies to be carried out as it is seen that the conflict between these two countries will continue and will continue to affect the aviation industry.

Ethical approval

Not applicable.

Conflicts of Interest

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

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References

AerCap, Rusya'daki uçaklara 3,5 milyar dolar tazminat istedi. (2022, April 1). Haberaero. Retrieved from https://haber.aero/sivil-havacilik/aercap-rusyadaki-ucaklari-35-milyar-dolar-tazminat-istedi/

Cathay Pacific plans world's longest passenger flight, avoiding Russia. (2022, March 30). The Gurdian. Retrieved from https://www.theguardian.com /business/2022/mar/30/cathay-pacific-plans-worlds-longest-passenger-flight-avoiding-russia

Chmiliar, I. (2010). Multiple-case designs. In A. J. Mills, G. Eurepas & E. Wiebe (Eds.), Encyclopedia of case study research (pp 582-583). USA: SAGE Publications.

COVID ve Savaş Sonrası En Uzun Uçuş. (2022, April 4). Haberaero. Retrieved from https://haber.aero/yazarlar/guntay-simsek/covid-ve-savas-sonrasi-en-uzun-ucus/

Davey, Lynn. (2009). The application of case study evaluations. (Çev: Tuba Gökçek). Elementary Educatıon Online, 8(2), 1-3

Dünyanın en büyük kargo uçağı: Rusya'nın vurduğu Antonov An-225'in enkazı görüntülendi. (2022, April 3). NTV. Retrieved from https://www.ntv.com.tr /amp/galeri/ukrayna-savasi/dunyanin-en-buyuk-kargo-ucagi-rusyanin-vurdugu-antonov-an-225in-enkazi-goruntulendi,iNK3SbX21US338znguKVmg

Eurocontrol. (2022, March 5) https://www.eurocontrol.int/

Fraport'tan Petersburg Havalimanı çıkmazı! (2022, April 4). Haberaero. Retrieved from https://haber.aero/sivil-havacilik/rusyanin-uluslararasi-hava-trafigi-2019a-gore-16-kat-azaldi/

Head, J. (2022, March 24). Ukrayna'daki işgal sebebiyle binlerce Rus ve Ukraynalı turist Tayland'da mahsur kaldı. BCC, Retrieved from https://www.bbc.com/ turkce/haberler-dunya-60852216

IATA predicts negative impact of Ukraine conflict on air cargo. (2022, March 10). Airport Technology. Retieved from https://www.airport-technology.com / news/iata-air-cargo

Impact of Russia-Ukraine Conflict on Airlines Industry. (2022, March 15). Globaldata. Retrieved from https://www.globaldata.com/data-insights/airlines-transportation-infrastructure-and-logistics/impact-of-russia-ukraine-conflict-on-the-airlines-industry/

International Civil Aviation Organization (ICAO). (2001). Annex 11- Air Traffic Services (13rded). Canada: International Civil Aviation Organization.

International Civil Aviation Organization. (2013, March 22). Worldwide Air Transport Conference (ATCONF). Retrieved from https://www.icao.int/Meetings/atconf6/Documents/WorkingPapers/ATConf.6.WP.080.1.en.pdf

Karadima, S. (2022, March 22). What impact will the Russia-Ukraine conflict have on the aviation sector? Investmentmonitor. Retrieved from https://www.investmentmonitor.ai/special-focus/ ukraine-crisis/russia-ukraine-conflict-aviation-sector-impact#:~:text=Since/20the/ 20invasion /20of/20Ukraine,from/20flying/20through/20its/20skies

Karadima, S. (2022, March 10). What impact will the Russia-Ukraine conflict have on the tourism industry? Investmentmonitor, https://www. investmentmonitor.ai/special-focus/ukraine-crisis/russia-ukraine-conflict-impact-tourism-industry

Korn, J. Muntean, P. Wallace, G. (2022, February 25) How the Russian invasion of Ukraine is impacting global aviation. CNN, Retrieved from https://edition.cnn.com/2022/02/25/tech/ukraine-russia-aviation-impact/index.html

Kurtaran, G. (2022, February 14). Fitch: Avrupalı hava yollarının toparlanması Rusya-Ukrayna gerilimiyle bozuluyor. Anadolu Ajansı. Retrieved from https://www.aa.com.tr/tr/ekonomi/fitch-avrupali-hava yollarinin-toparlanmasi-rusya-ukrayna-gerilimiyle-bozuluyor/2534874, Access Date: 15.03.2022

OECD. 2022. OECD Economic Outlook, Interim Report March 2022: Economic and Social Impacts and Policy Implications of the War in Ukraine. Paris: OECD Publishing.

Petchenik, I. (2022, March 10). Russian roundabout: how flights are avoiding Russian airspace. Flightradar24. Retrieved from https://www.flightradar24.com/blog/ russian-roundabout-how-flights-are-avoiding-russian - airspace/?utm_source=sendgrid.com&utm_ medium = email&utm_campaign=website

Российские авиакомпании сократили международный трафик в 16 раз в сравнении с докризисным. (2022, March 15). Atorus. Retrieved from https://www.atorus.ru/news/presscentre/new/59139.html

Rus işgali Eurocontrol verilerine yansıdı: Trafik durdu. (2022, Marc 3). Haber.Aero, Retrieved from https://haber.aero/sivil-havacilik/rus-isgali_eurocontrol -verilerine-yansidi-trafik-durdu/

Rus diplomatlar yaptırımlardan dolayı 15 bin km uçtu. (2022, April 22). Haberaero. Retrieved from https://haber.aero/sivil-havacilik/rus-diplomatlar-yaptirimlardan-dolayi-15-bin-km-uctu/

Rusya, 52 ülkeyle uçuşları tekrar başlatıyor. (2022, April 4). Haberaero. Retrieved from https://haber.aero/sivil-havacilik/rusya-52-ulkeyle-ucuslari-tekrar-baslatiyor/

Rusya'nın uluslararası hava trafiği 2019'a göre 16 kat azaldı. (2022, March 16). Haberaero. Retrieved from https://haber.aero/sivil-havacilik/rusyanin uluslararasi-hava-trafigi-2019a-gore-16-kat-azaldi

Rusya-Ukrayna savaşı uçuş rotalarını değiştirdi. (2022, March 5). Haberturk. Retrieved from https://www.haberturk.com/rusya-ukrayna-savasi-ucus-rotalarini-degistirdi-3365702

Rusya-Ukrayna savaşı, havacılık sektörünü de etkiledi: Uçuş süreleri uzadı. (2022, March 4). Sözcü. Retrieved from https://www.sozcu.com.tr/2022/dunya/rusya-ukrayna-savasi-havacilik-sektorunu-de-etkiledi-ucus-sureleri-uzadi-6988406/?utm_source=dahafazla_haber&utm_medium=free&utm_campaign=dahafazlahaber

Rusya-Ukrayna savaşı havacılık sektörünü etkiledi: Dünyanın en uzun ticari uçuşu geliyor. (2022, March 31). NTV. Retrieved from https://www.ntv.com.tr/amp/galeri/dunya/rusya-ukrayna- savasi-havacilik-sektorunu-etkiledi-dunyanin-en-uzun-ticari-ucusu-geliyor,DwF6XOcCiE6_z0f6TlhOtw

Rusya hava sahasını sivil uçuşlara kapattı. (2022, February 24). TRT. Retrieved from https://www.trthaber.com/haber/dunya/rusya-hava-sahasini-sivil-ucuslara-kapatti-657832.html

The International Air Transport Association (IATA)The impact of the war in Ukraine on the aviation industry. (2022, March 25). Retrieved from https://www.iata.org/en/iata-repository/publications/ economic-reports/the-impact-of-the-conflict-between - russia-and-ukraine-on-aviation/

The International Air Transport Association (IATA). The impact of the conflict between Russia and Ukraine on aviation. (2022, March 7). Retrieved from https://www.iata.org/en/iatarepository/publications/ec onomic-reports/the-impact-of-the-conflict-between-russia-and-ukraine-on-aviation/

Tüm yabancı kiralık uçaklar Rusya’da kalacak (2022, April 1). Haberaero. Retrieved from https://haber.aero/sivil-havacilik/tum-yabanci-kiralik -ucaklar-rusyada-kalacak/

Uçuşa yasak bölge ne demek, Batı niçin Rusya'nın işgal ettiği Ukrayna'da bu adımı atmaktan kaçınıyor? (2022, March 2) BBC, Retrieved from https://www.bbc.com/turkce/haberler-dunya-60586137

Ukrayna - Rusya savaşının bilançosu: Yaptırımlar sonrası dünya hava trafiği böyle değişecek! (2022, March 1). Hürriyet. Retrieved from https://www.hurriyet .com.tr/dunya/ukrayna-rusya-savasinin-bilancosu-yaptirimlar-sonrasi-dunya-hava-trafigi-boyle-degisecek-42013352

Ukraine closes its airspace to commercial flights as the country is declared a 'conflict zone'. (2022, February 24). Euronews. Retrieved from https://www.euronews.com/travel/2022/02/24/ukraine -closes-its-airspace-to-civilian-flights-as-the-country-is-declared-a-conflict-zone

Yeditepe (2022) Rusya - Ukrayna Savaşı Turizm Sektöründeki Beklentileri Tekrar Değiştirdi. Retrieved from https://yeditepe.edu.tr/tr/rusya-ukrayna-savasi-turizm-sektorundeki-beklentileri-tekrar-degistirdi.

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The Organizational Commitment of Different Generations-A Study on Cabin Crew

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Abstract

The aim of this study is to investigate the organizational commitments of flight attendants of different generations who work in airline companies operating in Turkey. The analysis stage of the study, a questionnaire was offered to 351 people, who work as flight attendants in the public and private airline companies operating in Turkey, and a study to identify the levels of organizational commitment in terms of generational differences was conducted.

The method of data collection using questionnaire, which was considered the most suitable method for the context of the study based on the literature search, was used. The questionnaire includes, in addition to the demographic information, questions which would support the main and sub-hypotheses and Organizational Commitment Questionnaire by Allen and Meyer (1984) to measure organizational commitment level. With the study, generational differences of the flight attendants who work in airline companies were studied within the scope of affective commitment, continuance commitment and normative commitment dimensions, which are the sub-dimensions of organizational commitment. Data were analysed using SPSS 21.0 software. The concept of organizational commitment is analysed based on these variables: sub-dimensions of organizational commitment, generational differences, gender, marital status, educational status and the duration of working in the industry. In the analyses, in addition to the descriptive statistics, t-test and unidirectional analysis of variance methods were used. At the end of the study, differences were observed among the organizational commitment sub-dimensions of the flight attendants working in airline companies in terms of generational differences.

This article was produced from the author's master thesis.

1. Introduction

Aviation, an intensely competitive and rapidly growing industry, has been developing progressively with the globalization. Companies adopt various changes in order to increase the number of passengers and profit per passenger. Positive or negative evaluation from the passengers of the service provided by the airline company depends on various factors. In addition to the quality of the service, the positive or negative effect of the service providers on the passenger should also be considered.

Flight attendants hired by the companies as a result of the exams and interviews for evaluation during the recruitment process are subjected to an intense training program. They receive numerous trainings, including personal development training, until their starting day of employment. These trainings bring an additional cost to the company in terms of employing the trainers, the process of planning, and financing. The most important problem of the businesses today is to access the source of qualified people, and even more importantly, to be able to retain that source. Organizational commitment begins when the employee accepts organizational values and starts the job with a psychological contract. It develops as the employee, as a member of the organization, learns about the goals, aims and the requirements of the job. From this point of view, organizational commitment is a union of forces established when an individual identifies with a certain organization (Northcraft & Neale, 1990). It is important for the organizations to know of the organizational commitment degrees of the generations with different characteristics, who work together at the same organization. Since it is not possible for the individuals in different age groups that constitute different generations to have the same level of organizational commitment, identification of the different characteristics of each generation is an important goal. In this context, organizational commitment levels of the flight attendants of different generations who work in airline companies will be investigated.

2. Literature Review

2.1. Organizational Commitment

The concept of organization is a management function where the efforts of individuals with certain objectives operate in a coordinated manner; a system in which human, objective and technology dimensions are intertwined; a structure with a distinctive culture that demonstrates the relationships between the work and people (Güçlü, 2003). On the other hand, commitment, as a concept and a form of understanding, emerges anywhere with a sense of community. Commitment is an emotional expression of the instinct of being a community and is an emotion experienced at its most intense form. Commitment, which means the loyalty of a slave to its master, of a servant to its duty, of a soldier to its homeland, expresses the state of being loyal. In general terms, it expresses our commitment, our liability to an individual, an organization, a thought, or something we consider greater than ourselves (Ergun, 1975).

Organizational commitment, which comprises the concepts of commitment and organization, expresses the employee's belief in the goals and values of the organization, desire to show effort toward the realization of the organization's goals, and wish to remain as a member of the organization (Mowday, Porter & Steers, 1979). Organizational commitment begins when the worker accepts organizational values and starts to work with a psychological contract. It develops as the employee, as a member of the organization, gains information on the goals, aims and the requirements of the job. From this point of view, organizational commitment is a union of forces which is established when an individual start to identify with a certain organization (Northcraft & Neale, 1990).

As described by Mowday, Steers and Porter for the first time, organizational commitment was defined as the emotional attachment of the worker toward his/her organization. It was suggested that the degree of commitment felt is equivalent to the degree of adoption of the values and goals of the organization. In other studies, organizational commitment was defined as the commitment that develops as a result of the workers' investment to their organization, and it was argued that the worker shows commitment to the organization because of the fear that his/her efforts and labors over the period of working at the organization will go to waste (Becker, 1960). Later, Meyer and Allen (1984) suggested a model that includes these two different organizational commitments, and defined the former as "affective commitment" and the latter as the "continuance commitment". By adding the "normative" or "ethical" commitment dimension suggested by Weiner and Vardi (1980) to this model, they have developed the three-dimensional organizational commitment model (Meyer & Allen, 1991). As normative commitment develops as a result of the worker's perception of showing commitment to the organization as a duty and the worker's idea that organizational commitment is "right", it represents a dimension separate from the other two types of commitments (Wasti, 2003).

Affective commitment comprises the workers' acceptance of organizational goals and values and their extraordinary efforts for the sake of the organization. In affective commitment, the reason that the workers remain with the organization is their identification with the goals and values of the organization. With strong affective commitment, those who remain with the organization do so not because they need to, but they want to (Allen & Meyer, 1990). In this type of commitment, the individual considers him/herself as a part of the organization and the organization signifies a great meaning and importance for him/her (İlsev, 1997).

In continuance commitment, worker continues to work in the organization primarily because he/she needs to do so (Meyer & Allen, 1990; Meyer & Allen, 1991). Continuance commitment is to continue being a member of the organization because of thinking that the cost of leaving the organization will be high. In this commitment type, the individual cannot leave the organization even if he/she wants to because leaving will cost him/her and he/she will face difficulties (Sökmen, 2000).

Allen and Meyer (1990) named the commitment type that involves obligation as normative commitment. Normative commitment is based on the individual's belief that he/she has responsibility and liability toward the organization and thus his/her perception that he/she is obliged to remain with the organization. Here, obligation is not based on organization-related benefits, unlike continuance commitment. Either the individual's family, society and organization have emphasized that loyalty is a virtue, or the individual is surrounded by people who work in the same organization for years. Thus, he/she believes that loyalty is important and feels a moral obligation. In summary, he/she is committed to the organization because he/she believes that it is right and moral to do so (İlsev, 1997).

Meyer and Allen (1997) have used this three dimensional approach to organizational commitment and stated that "the worker who remains with the organization on good and bad days, comes to work regularly, dedicates his/her whole day to the organization, protects the company assets and shares the company goals is a worker committed to the organization" (Song, 2009). In parallel to this, in professional life, workers with strong affective commitment remain with the organization "because they want to", workers with continuance commitment remain with the organization "because they need to", and workers with normative commitment remain with the organization "because they feel obliged to" (Lawler & Yoon, 1996).

2.2. The Concept of Generation

In the dictionary of sociology terminology, the concept of generation is defined as "group of individuals, lineage, breed comprising age groups of approximately twenty-five, thirty years". In Turkish Linguistic Society's Philosophy Terminology dictionary, the concept of generation is defined as "the group of individuals who were born approximately in the same years, shared the conditions, and thus, similar problems and destinies of the same era, and were responsible for the similar duties" (www.tdk.gov.tr). In the literature, generation is defined as the group who shares the same birth year and the same significant life events. Moreover, it is believed that various historical, political and social events shape the attitudes, beliefs and values of every generation. Each generation identifies their own personality, attitude against authority, values, beliefs, work ethics, reasons for working, goals and expectations from professional life (Kupperschmidt, 1998).

Generations are time intervals that are formed by the economic and social movements in the world. Generations, which are called so due to their upbringing and changes in their environment, can differ significantly in terms of character, working methods and their expectations from the workplace. Generation also means the average time interval between the birthdate of parents and the birthdate of their children. Biologically, within a millennium, a new generation arises in every 20-25 years. Today, with changing societies and values, this duration seems long. Because childbirth is delayed. While the age of becoming a mother was 25 in the 1980s, today, it is 30. This shows that the changes throughout the generations are sociological. In today's workplaces where different age groups work together, the majority of the problems arise due to intergenerational differences in perception, method, implementation and communication. Each generation has different characteristics, morals, attitudes, behaviors, weak and strong points (Keleş, 2011). In the literature, it can be seen that the start and end dates of generations differ. Throughout the history, generations of different historical periods are classified with different names. The most frequently used classification today divides the individuals into five generations. The table below demonstrates this classification (DeVaney, 2015)

Table 1. Classification of Generations

Generation	Birth of Year
Silent Generation	Born between 1925-1945
Baby Boomers Generation	Born between 1946-1964
Generation X	Born between 1965-1979
Generation Y	Born between 1980-1999
Generation Z	Born in 2000 or later

Workers from the silent generation exhibit behaviour that promotes the idea of "live to work", due to their personality structure that did not forget the post-war poverty and difficulties. Members of this generation, who are mostly retired from today's professional life, used to love to work hard, put work ahead of fun, and consider working to live as an obligation (Erden, 2012). Similar to the silent generation, baby boomers generation adopts the idea of "live to work" due to the difficulties faced when growing up, however, they are open-minded to the idea of working in jobs that they regard meaningful during their career. Workers from generation X, who are said to have a lower organizational commitment level than the workers from baby boomers generation, place importance on the work-life balance and believe in the importance of the idea of "work to live". Workers from generation Y have the idea of "live first, work later" (Berkup, 2015). In the organization, they are free-spirited, have selective attitude toward work, have poor sense of loyalty, and are against authority.

2.3. General Overview of Flight Attendant Profession

The certified person other than the flight crew and technical personnel, who is provided with the required training and commissioned by the airline company to perform services regarding the safety of the flight and passengers during the operations is called flight attendant (SHT-CC).

Flight attendants are employees responsible for the implementation of the required security and safety measures and for passenger comfort in aircrafts used in passenger transportation. Flight Attendants who work at the cabin section of the aircraft for a secure, safe and comfortable flight, are people who have successfully completed their training by meeting the requirements listed in the relevant regulations issued by the Directorate General of Civil Aviation, and as a result, entitled to obtain "Flight Attendant Certificate".

While many professions require "Managing and Being Directive", most professions require "Serving and Adaptation". The flight attendant must bear certain amount of conflicting characteristics such as being directive and meeting the customer demands. A flight attendant is expected to show behaviors focused on the passenger's needs, whose success will be measured with customer satisfaction. On the other hand, the flight attendant must enforce the security rules in the plane, prevent behavior that will disrupt the comfort of other passengers, and stop the passenger when necessary (Baltaş, 2009).

The fact that flight attendants serve passengers during their duties leave the impression that their duty is not ensuring security but serving. However, in each flight, upon encountering an emergency, cabin crew make themselves ready for the emergency. They become a leader for passengers and become responsible for the security of every passenger on the plane (İşyapan, Gürbüz & Sözen, 2016).

3. Method

3.1. The Universe and Sample of the Research

Study population comprises flight attendants working in the airline companies in Turkey. A total of 455 people, who were working as flight attendants in public and private airline companies operating in Turkey, were given the questionnaire and due to missing information in 104 of these questionnaires, the study was based on the remaining 351 completed questionnaires.

3.2. Research Model

In airline companies, members of different generations work at the same time. The constructed model between these generations, who are different primarily in terms of their characteristics, as well as their points of view, and the subdimensions of organizational commitment, affective, continuance and normative commitment dimensions, is shown in Figure 1.

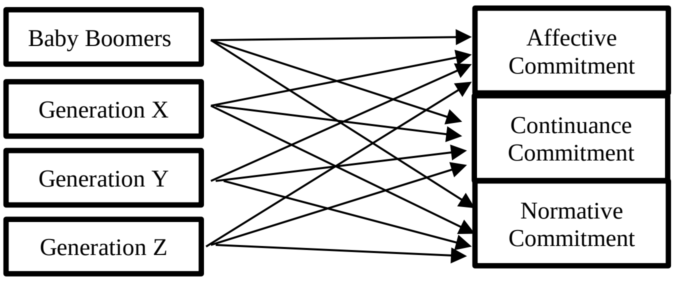

Figure 1. Model of the Study

3.3. Data Collection Tools

In the preparation process of this study, a literature review of domestic and foreign studies on this subject was performed, and the opinions of different researchers who perform scientific studies on the subject were analyzed. For this purpose, the method of data collection through questionnaire, which was considered the most suitable for the scope of the study, was utilized. In the questionnaire, in addition to the demographic information, there are questions which would support the main and sub-hypotheses and Organizational Commitment Questionnaire (OCQ) by Allen and Meyer (1984) to measure organizational commitment level. Organizational commitment model that includes affective, continuance and normative commitment dimensions, as classified by Meyer and Allen, is taken as a basis. With the study, generational differences of the flight attendants who work in airline companies were studied within the scope of affective commitment, continuance commitment and normative commitment dimensions, which are the sub-dimensions of organizational commitment. The first part of the questionnaire comprises demographic characteristics, and the second part comprises the organizational commitment scale. In data collection, for Allen and Meyer's Organizational Commitment Questionnaire, 5-point Likert-type scale was used. Items in the scale were scored as 1. Completely Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Absolutely Agree.

3.4. Hypotheses

In light of the provided information and the aims of study, hypotheses of the study are constructed as in Table 2.

Table 2. Hypotheses of the Study

H1: There is a significant difference between the affective commitment levels of flight attendants working in airline companies, who are from Baby Boomers Generation, Generation X, Y, and Z.

H2: There is a significant difference between the normative commitment levels of flight attendants working in airline companies, who are from Baby Boomers Generation, Generation X, Y, and Z.

H3: There is a significant difference between the continuance commitment levels of flight attendants in airline companies, who are from Baby Boomers Generation, Generation X, Y, and Z.

H4: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the gender variable.

H5: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the marital status variable.

H6: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the educational status variable.

H7: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the duration of working in the industry variable.

H8: There is a positive correlation between at least two of the organizational commitment sub-dimensions of the flight attendants working in airline companies.

3.5. Analysis of Data

In the study, various analysis methods were used depending on the data to be analyzed. For the analysis of demographic variables, descriptive statistics such as frequency and percentage distribution were used. In particular, in order to identify the correct method of analysis when testing the study hypotheses, it is useful to analyze whether the data fit a normal distribution, thus, normality test was performed. For this purpose, skewness and kurtosis values of the data were analyzed and the results are presented in Table 3. To measure the structural validity of the questionnaires, factor analysis was performed and Cronbach's Alpha values were calculated for their reliability. For testing the hypotheses in the study model, correlation and regression analyses were performed. To investigate the correlations between demographic variables and participants' perceptions, ANOVA and t-tests were used.

Table 3. Statistics Regarding the Skewness and Kurtosis Degrees of the Items Comprising the Scale

	Skewness	Kurtosis
1. I would be very happy to spend the rest of my career with this airline.	-.636	-.260
2. I really feel as if this airline's problems are my own	-.946	.560
3. I don't feel a strong sense of belonging to airline that I work for.	-.746	-.310
4. I don't feel like a part of this airline.	-.951	.303
5. This airline has a lot of personal meaning for me.	-.601	-.242
6. I do not feel "emotionally connected" to this airline.	-.849	.107
7. Even if I wanted to leave the airline I worked with, it would be very hard for me to do that right now.	-.844	-.079
8. At the moment, staying in this airline is a necessity as much as it is a request.	-.806	-.102
9. If I decide to quit this airline right now, most part of my life would be harmed.	-.353	-.944
10. I think I have little options to think about quitting the airline I work for.	-.279	-1.004
11. One of the negative consequences of quitting from the airline I work for is the lack of alternative job opportunities.	-.727	-.378
12. I don't feel any worries about what would happen if I quit from the airline I work before I find a job elsewhere.	-.448	-.726
13. I owe many things to the airline I work for.	-.907	.347
14. The airline I work for deserves my loyalty.	-.782	.165
15. I would feel guilty if I quit now from the airline I work for...	-.098	-1.160
16. Even if I have the advantage, quitting now from the airline I work for doesn't feel correct.	-.624	-.543
17. I can't quit from this airline now because of my responsibilities to other people working here.	-.135	-1.074
18. I don't feel a necessity to quit from the airline I work for.	-.851	-.221

4. Result

4.1. Results on Demographic Variables

In this section, demographic data related to the study population is explained. According to the data, frequencies and proportions of participants in terms of gender, marital status, the organization where the participant works, educational status, year of birth, and duration of working in the industry, will be determined. Demographic characteristics of the individuals participating in the study are given below.
Percentage and numeric distribution by gender is shown in the Table 4. Based on the table, 70.7% (248) of the participants are female and 29.3% (103) are male. The majority of participants are female.

Table 4. Numeric and Percentage Distribution by Gender

Gender	N	%
Female	248	70.7
Male	103	29.3

Numeric and percentage distribution bu marital status is shown in the table 5. Based on this, 31.6% (111) of the participants are single, 68.3% (240) are married. The majority of participants are single.

Table 5. Numeric and Percentage Distribution by Marital Status

Marital Status	N	%
Married	111	31.6
Single	240	68.4

Numeric and percentage distribution by the organization where the participant Works is seen in the table 6. Of the participants, 92.3% (324) work at the private sector, while 7.7% (27) work at the public sector. The majority of flight attendants participating in the study work at the private sector.

Table 6. Numeric and Percentage Distribution by the Organization

Sector	N	%
Private Sector	324	92.3
Public Sector	27	7.7

Numeric and percentage distribution by educational status is shown in the table 7. Of the participants, 19.7% (69) are high school graduates, 36.5% (128) have associate's degree, 38.5% (135) have bachelor's degree and 5.4% (19) have postgraduate degree. Based on this distribution, the majority of the participants have associate's and bachelor's degrees, and the proportion of participants who continue their education after the bachelor's degree is lower than the rest of the participants.

Table 7. Numeric and Percentage Distribution by Educational Status

Educational Status	N	%
High School	69	19.7
Associate's Degree	128	36.5
Bachelor's Degree	135	38.5
Postgraduate Degree	19	5.4

Numeric and percentage distribution by the year of birth is shown in the table 8. When the age intervals of the participants are organized according to the generational classification, it can be seen that 0.9% (3) of the participants are in Baby Boomers generation (1946-1964), 14.2% (50) are in generation X (1965-1979), 84% (295) are in generation Y (1980-1999), and 0.9% (3) are in generation Z (2000 or later). According to this distribution, the number of people in Baby Boomers generation who continue working is equal to the number of people in generation Z who completed 18 years of age and were employed. Moreover, the proportion of these employees to those in generations X and Y is low. The majority of participants are from generation Y.

Table 8. Numeric and Percentage Distribution by the Year of Birth

Year of Birth	N	%
1946-1964	3	,9
1965-1979	50	14.2
1980-1999	295	84
2000 and up	3	,9

Numeric and percentage distribution by the duration of working in the industry is seen in the table 9. The majority of the participants, 40.5% (142), have the highest duration, with 1-3 years. Of the remaining participants, 22.5% (79) have a duration of 4-6 years, 18.8% (66) have a duration of 7-10 years and 18.2% (64) have a duration of 11 years or longer.

Table 9. Numeric and Percentage Distribution by the Duration of Working in the Industry

Working in the Industry	N	%
1-3 Year	142	40.5
4-6 Year	79	22.5
7-10 Year	66	18.8
11 Year and up	64	18.2

4.2. Results on the Validity and Reliability of the Questionnaire

Before proceeding to the tests on hypotheses, the questionnaire was evaluated for its validity and reliability. The most frequently used method in the evaluation of reliability is Cronbach's Alpha Coefficient. The criteria for Cronbach's Alpha Coefficient are as follows (Özdamar, 2004):

- The questionnaire is not reliable if $0.00 \leq \alpha < 0.40$.
- The questionnaire has a low reliability if $0.40 \leq \alpha < 0.60$
- The questionnaire is reliable if $0.60 \leq \alpha < 0.80$
- The questionnaire is highly reliable if $0.80 \leq \alpha < 1.00$

At the end of the reliability analysis, overall reliability score (Cronbach's Alpha Coefficient) of the organizational commitment scale used in the study was found to be 0.835. The result demonstrates that the questionnaire is highly reliable. Based on the results of the Cronbach's Alpha, in order to identify the variables in a more reliable way and to test the structural validity of the scale, the data were subjected to factor analysis.

If KMO value is less than 0.50, factor analysis is not continued. Depending on the KMO value, the following comments can be made on sample size:

- Between 0.50-0.60 "bad",
- Between 0.60-0.70 "poor",
- Between 0.70-0.80 "reasonable",
- Between 0.80-0.90 "good",
- Over 0.90 "perfect".

If the KMO value is less than 0.50, more questionnaires must be included (Pullant, 2001). KMO value regarding the sampling of the questionnaire is 0.878 ($p<0.01$), which is within the acceptable range.

Whether the scale series have a normal distribution is evaluated using Bartlett Test. Significant results of the Bartlett test indicates the data are fit for factor analysis (Büyüköztürk, 2005). Thus, the obtained values are considered as an indicator of the adequacy of sample size and the fitness of the obtained data for factor analysis. The questionnaire has three sub-dimensions. Consistent with the literature, these dimensions are called Continuance Commitment, Affective Commitment and Normative Commitment. Continuance Commitment dimension comprises the first set of 6 questions, Affective Commitment dimension comprises the second set of 6 questions and Normative Commitment dimension comprises the final set of 6 questions. The Table 9 has a total of 18 questions.

Table 9. Organizational Commitment Scale Factor Analysis

	Factor Loading
Factor 1: Continuance Commitment	
15. I would feel guilty if I quit now from the airline I work for.	.825
16. Even if I have the advantage, quitting now from the airline I work for doesn't feel correct.	.793
17. I can't quit from this airline now because of my responsibilities to other people working here.	.783
14. The airline I work for deserves my loyalty.	.660
13. I owe many things to the airline I work for.	.597
18. I don't feel a necessity to quit from the airline I work for.	.428
Factor 2: Affective Commitment	
2. I really feel as if this airline's problems are my own	.331
1.I would be very happy to spend the rest of my career with this airline.	.448
5. This airline has a lot of personal meaning for me.	.490
4. I don't feel like a part of this airline.	.830
3. I don't feel a strong sense of belonging to airline that I work for.	.820
6. I do not feel “emotionally connected” to this airline.	.718
Factor 3: Normative Commitment	
10. I think I have little options to think about quitting the airline I work for.	.785
11. One of the negative consequences of quitting from the airline I work for is the lack of alternative job opportunities.	.766
9. If I decide to quit this airline right now, most part of my life would be harmed.	.693
12. I don't feel any worries about what would happen if I quit from the airline I work before I find a job elsewhere.	.656
7. Even if I wanted to leave the airline I worked with, it would be very hard for me to do that right now.	.584
8. At the moment, staying in this airline is a necessity as much as it is a request.	.492
Variance explained (%)	54.869
Self – values (eigenvalues)	5.831
Reliability (Cronbach's Alpha)	.835
Kaiser- Meyer-Olkin = .878 **Bartlett Test of Sphericity = 2553.425**	$p < 0.01$

4.3. Descriptive Statistics of the Scale

The mean values obtained as a result of the study are given in Table 10. The overall mean of the scale is 3.5. In terms of each of the sub-dimensions, the mean values of affective commitment sub-dimension are 3.73, continuance commitment sub-dimension is 3.46 and normative commitment sub-dimension is 3.56, respectively. As can be seen from these results, there is not much difference between the mean values. The highest mean value is of the affective commitment, and the lowest mean value is of the continuance commitment. It can be seen that the affective commitment of the participants is higher than the other types of commitment.

Table 10. Descriptive Statistics of the Scale

	X	S
1. I would be very happy to spend the rest of my career with this airline.	3.64	1.136
2. I really feel as if this airline's problems are my own	3.79	.972
3. I don't feel a strong sense of belonging to airline that I work for.	3.60	1.156
4. I don't feel like a part of this airline.	3.85	1.066
5. This airline has a lot of personal meaning for me.	3.73	.980
6. I do not feel "emotionally connected" to this airline.	3.78	1.056
7. Even if I wanted to leave the airline I worked with, it would be very hard for me to do that right now.	3.74	1.131
8. At the moment, staying in this airline is a necessity as much as it is a request.	3.91	1.046
9. If I decide to quit this airline right now, most part of my life would be harmed.	3.37	1.198
10. I think I have little options to think about quitting the airline I work for.	3.24	1.146
11. One of the negative consequences of quitting from the airline I work for is the lack of alternative job opportunities.	3.60	1.121
12. I don't feel any worries about what would happen if I quit from the airline I work before I find a job elsewhere.	3.54	1.088
13. I owe many things to the airline I work for.	3.80	1.021
14. The airline I work for deserves my loyalty.	3.64	1.037
15 I would feel guilty if I quit now from the airline I work for...	3.13	1.254
16. Even if I have the advantage, quitting now from the airline I work for doesn't feel correct.	3.48	1.163
17. I can't quit from this airline now because of my responsibilities to other people working here.	3.05	1.192
18. I don't feel a necessity to quit from the airline I work for.	3.70	1.028

Table 11. Correlations between variables

	AC	NC	CC
Affective Commitment (AC)	1	.028	.683**
Normative Commitment (NC)	.028	1	.063
Continuance Commitment (CC)	.683**	.063	1

p < 0,05*

p < 0,01**

4.4. Results of the Hypothesis

To test the hypotheses within the frame of the study model, difference tests were evaluated. To understand the correlation between the sub-dimensions of organizational commitment, correlation analysis was used. Correlation analysis is a method to determine the level of association or dependence between two variables measured at the lowest range. It also presents information regarding the direction, level and significance of the relationship between the variables (Büyüköztürk, 2005).
To understand the correlation between the organizational commitment sub-dimensions, correlation coefficients for Affective Commitment (AC), Normative Commitment (NC) and Continuance Commitment (CC) variables were evaluated. The results demonstrated a positive correlation between Continuance and Affective Commitment (r=0.683; p<0.01). (Table 11)
In order to test the research hypotheses, it is also possible to determine whether organizational commitment sub-dimensions are perceived differently among the participants in terms of generations and demographic variables. For this purpose, t-test and ANOVA were used.
In Table 12, based on the results obtained using ANOVA, it can be said that Affective Commitment of Baby Boomers generation is higher than generations X and Y. Moreover, no significant difference was detected between the generations in terms of Continuance and Normative Commitment.

Table 12. The effect of birth year on perceptions of affective commitment, normative commitment and continuance commitment

	1946-1964	1965-1979	1980-1999	2000 –up	Total	F	P
AC	4.888	3.863	3.706	3.444	3.736	2.811	.039*
NC	3.944	3.523	3.581	3.000	3.571	.913	.435
CC	4.277	3.560	3.445	3.722	3.471	1.364	.254

p<0,05

In Table 13, based on the results obtained using ANOVA, no significant difference was detected between the participants' organizational commitment sub-dimensions, Affective, Normative and Continuance Commitment, in terms of their educational levels.

Table 13. The effect of educational status on perceptions of affective commitment, normative commitment and continuance commitment

	High School	Associate's Degree	Bachelor's Degree	Postgraduate Degree	Total	F	P
AC	3.7440	3.7878	3.7370	3.3596	3.736	1.59	.191
NC	3.4324	3.6289	3.6272	3.2982	3.571	2.14	.094
CC	3.4251	3.5547	3.4556	3.1842	3.471	1.31	.269

In Table 14, based on the results obtained using ANOVA, no significant difference was detected between the participants' organizational commitment sub-dimensions, Affective Normative and Continuance Commitment, in terms of their duration of work.

Table 14. the effect of working time on perceptions of affective commitment, normative commitment and attendance commitment

	1-3 Years	4-6 Years	7-10 Years	11 Years and up	Total	F	P
AC	3.679	3.689	3.767	3.888	3.736	1.129	.337
NC	3.570	3.548	3.616	3.557	3.571	.109	.955
CC	3.485	3.495	3.497	3.380	3.471	.323	.809

p<0,05

In Table 15 based on the results obtained using t-test, it was found that the level of Continuance Commitment of single participants are higher than the level of Continuance Commitment of married participants

Table 15. The effect of marital status on perceptions of affective commitment, normative commitment and attendance commitment

	Average			
	Married	Single	t value	Significance level
AC	3.7402	3.734	.060	.852
NC	3.5991	3.559	.464	.643
CC	3.3438	3.529	-1.988	.048*

In Table 16, based on the results obtained using t-test, no difference was detected in participants' continuance, normative and affective commitments in terms of the organization the participant works in.

Table 16. The effect of organization on perceptions of affective commitment, normative commitment and attendance commitment

	Average			
	Private Sector	Public Sector	t value	Significance level
AC	3.7171	3.9691	-1.576	.116
NC	3.5643	3.6605	-.639	.523
CC	3.4614	3.5864	-.762	.447

p<0,05

In Table 17, based on the results obtained using t-test, it was found that the level of affective commitment of male participants is higher than the level of affective commitment of female participants.

Table 17. The effect of gender on perceptions of affective commitment, normative commitment and attendance commitment

	Average			
	Female	Male	t Value	Significance level
AC	3.6808	3.8706	-2.032	.043*
NC	3.5517	3.6197	-.772	.441
CC	3.4247	3.5825	-1.648	.180

p<0,05

In this part of the study, based on the tests, the results of the hypotheses used throughout the study are given. The findings regarding the results of the hypotheses used in the study are found in Table 18.

Table 18. Result of Hypotheses

H1: There is a significant difference between the affective commitment levels of flight attendants in airline companies, who are from Baby Boomers Generation, Generation X, Y, and Z.	Accepted.
H2: There is a significant difference between the normative commitment levels of flight attendants in airline companies, who are from Baby Boomers Generation, Generation X, Y, and Z.	Rejected.
H3: There is a significant difference between the continuance commitment levels of flight attendants in airline companies, who are from Baby Boomers Generation, Generation X, Y, and Z.	Rejected.
H4: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the gender variable.	Accepted.
H5: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the marital status variable.	Accepted.
H6: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the educational status variable.	Rejected.
H7: Organizational commitment levels of flight attendants working in airline companies differ significantly depending on the duration of working in the industry variable.	Rejected.
H8: There is a positive correlation between at least two of the organizational commitment sub-dimensions of the flight attendants working in airline companies.	Accepted.

5. Conclusion

Organizational commitment expresses the loyalty to the organization and the desire of continuance. The presence of individuals with high levels of organizational commitment is one of the most important factors for the organizations to exist and continue their existence effectively. Individuals with organizational commitment adopt the goals and aims of the organization they are in, make effort and want to remain in the organization.

When the recruitment of flight attendants is analyzed, it can be seen that they go through many different stages and similarly, successful candidates receive many trainings. Flight attendants have distinct duties and responsibilities in the plane. The most important but the least visible of these is to ensure the passengers' security. This main responsibility makes it necessary for the flight attendants to receive a continuous and special training. In addition to these trainings, they attend various personal development trainings to improve their self-confidence and to use this self-confidence when establishing the required authority, as well as to improve themselves. These trainings are provided by the airline companies and training the flight attendants cost a certain amount of money to the companies. Thus, flight attendants who have a low level of organizational commitment and leave the company will increase the costs. Leaving of an employee and recruitment of a new employee, recruitment advertisements, selection examinations, tests, hiring, placement, and services for employees such as training and payment create additional auxiliary services and all of these become additional costs (Buğra, 2014). Moreover, after each employee turnover, loss of efficiency, mistakes, occupational accidents and loss of production caused by the inexperience of the newly recruited employees lead to additional costs. Considering the fact that flight attendants directly interact with the passenger in the plane and have a direct influence on passenger satisfaction, loss of efficiency and mistakes will negatively affect the reputation of the airline and can lead to losing passengers. High quitting rate among flight attendants increase employee recruitment and job orientation costs for the airline.

According to the generation theory, generations are made up of individuals who live through similar political, economic and social events due to their birth year, develop unique moral values and belief systems, and show similar personality characteristics. Individuals from a certain generation have characteristics similar to the characteristic properties and moral values of the generation they were born to, but different from the other generation. Since Baby Boomers generation and generations X, Y and Z work simultaneously in today's professional life, this issue gains more importance. With this many different generations participating in the professional life, each bring their own attitudes, values and beliefs along and thus, the main subject of this study is the difference between the old and new generation in terms of organizational commitment. In this regard, since each generation's motivation, style of work, promotion and payment expectations differ, conflicts, incompatibilities and communication problems at the workplace becomes inevitable. Some researchers have observed that the views of generations on professional and business life differ.

Based on the result of the study, affective commitment level of baby boomers' generation was higher than the other generations. This result is consistent with the loyal characteristic of the members of baby boomers' generation. Moreover, in terms of the demographic factors, it can be seen that the continuance commitment level of 240 single participants was higher than 111 married participants. It can be said that single participants would like to remain in the organization as they think leaving the organization will have a high cost. In terms of the genders of the flight attendants participating in the study, it was found that the affective commitment level of 103 male participants was higher than 248 female participants. It can be said that male flight attendants see themselves as a part of the organization.

In this study, whether there is a difference between the affective, continuance and normative organizational commitment levels of flight attendants working in airline companies, who are from baby boomers generation and generations X, Y and Z, was investigated. In the study, classification of generations was made based on the age factor. Since the number of members of generation Z in today's professional life is low and there is not much information regarding their behaviors in the work environment, this can be investigated in the future studies. In terms of organizational commitment, affective commitment is the most desirable form of organizational commitment. Thus, the type of things that can be done to ensure the workers' affective commitment to the organization can be the subject of another study.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Baltaş, A. (2009). Kabin Memurunun Kişiliği. TASSA Hava Yolları Kabin Memurları Derneği Dergisi, 9, 22-23.

Becker, H.S. (1960). Notes On the Concept of Commitment. American Journal of Sociology, 66, 32-42.

Berkup, S. B. (2015). Sosyal Ağlarda Bireysel Mahremiyet Paylaşımı: X Ve Y Kuşakları Arasında Karşılaştırmalı Bir Analiz. (Unpublished dissertation). Ege University, İzmir.

Buğra, E. (2014). Sağlık Çalışanlarında Örgütsel Vatandaşlık Ve Örgütsel Bağlılık İlişkisi: Bir Uygulama. (Unpublished dissertation). Türk Hava Kurumu University, İzmir

Büyüköztürk, S. (2005). Sosyal Bilimler İçin Veri Analizi El Kitabı. Pegema Yayıncılık, Ankara

De vaney, S. A. (2015). Understanding The Millennial Generation. Society of Financial Service Professionals. (69), 6.

Erden, S. (2012). Kültürel Değişimlerin Örgütlerde Kuşaklararası Çatışmalara Etkisinin İncelenmesi: Akademisyenlere Yönelik Bir Araştırma. (Unpublished dissertation). Çanakkale On Sekiz Mart University, Çanakkale.

Ergun, T. (1975). Uluslararası Örgütlerde Bağlılık Kavramı. Todaie. Amme İdaresi Dergisi, 8 (4), 97-106.

Güçlü, N. (2003). Örgüt kültürü. Gazi Üniversitesi Sosyal Bilimler Dergisi, 23(2), 61-85.

İlsev, A. (1997). Örgütsel Bağlılık: Hizmet Sektöründe Bir Araştırma. (Unpublished dissertation). Hacettepe University, Ankara.

İşyapan, G.T. & Sözen, İ. (2016). Kabin Ekiplerinin Duygusal Zeka Yeteneklerinin Problem Çözme Becerilerine Etkisi Üzerine Bir Araştırma. Beykent Üniversitesi Sosyal Bilimler Dergisi. 9.1, 39-60.

Keleş, H.N. (2011). Y Kuşağı Çalışanlarının Motivasyon Profillerinin Belirlenmesine Yönelik Bir Araştırma. Organizasyon Ve Yönetim Bilimleri Dergisi, 3, (2), 129-139.

Kupperschmidt B. (1998). Understanding Generation X Employees. Journal of Nursing Administration, (28), 36-43.

Lawler, E.J. & Yoon, J. (1996). Commitment İn Exchange Relations: Test of A Theory of Relational Cohesion. American Sociological Review, Lxı, 89-108.

Meyer, J. P. & Allen N. J. (1984). Testing The ‘Side-Bet Theory’ Of Organizational Commitment: Some Methodological Considerations. Journal of Applied Psychology. 69 (3), 372-378.

Meyer, J. P. & Allen N. J. (1990). Affective and Continuance Commitment to The Organization: Evaluation of Measures and Analysis Of Concurrent And Time-Lagged Relations. Journal of Applied Psychology. 75 (6).

Meyer, J.P. & Allen, N.J. (1991). A Three Component Conceptualization of Organizational Commitment. Human Resources Management Review, (1) ,61-89.

Meyer, J.P., Stanley, D.J., Herscovıtch, L. & Topolnytsky, L. (2002). Affective, Continuance, And Normative Commitment to The Organization: A Meta-Analysis of Antecedents, Correlates, And Consequences. Journal of Vocational Behavior, (61), 20-52.

Mowday, R.T., Steers, R.M. & Porter, L. W. (1979). The Measurement of Organizational Commitment. Journal of Vocational Behavior. (14) ,224-247.

Northcraft, G.B. & Neale, M.A. (1990). Organizational Behavior, A Management Challenge, The Dryden Press, Usa

Özdamar, K. (2004). Paket Programlar ile İstatistiksel Veri Analizi 2, Kaan Kitabevi, Yenilenmiş 5. Baskı, İstanbul

Pullant, J. (2001). SPSS Survival Manual: A Step-By-Step Guide to Data Analysis Using SPSS for Windows. Open University Press, Philadelphia.

Shgm, (2012). Havacılık Personeli. Retrieved from: http://web.shgm.gov.tr/tr/havacilik-personeli/2138-kabin-memuru

Song, J., Hong, M. K., & Kolb, J. A. (2009). The Effect of Learning Organization Culture On The Relationship Between İnterpersonal Trust And Organizational Commitment. Human Resource Development Quarterly, 20(2), 147-167.

Sökmen, A. (2000). Ankara’daki Beş Yıldızlı Konaklama İşletmelerinde Örgütsel Bağlılık İle İşgören Performansı Arasındaki İlişkinin Belirlenmesine Yönelik Ampirik Bir Araştırma. (Unpublished Dissertation). Gazi University, Ankara.

Wasti, A. (2003). Kültürlerarası Çalışmalarda Yöntem: Örgütsel Bağlılık Yazınından Dersler. Yönetim Araştırmaları Dergisi. 2 (3), 125-145.

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Evaluation of The Relationship Between Drone Pilots and Humour in Türkiye

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Abstract

This study aims to analyse the sense of humour of drone pilots depending on the amount of time they have used the drones, the sort of instruction they have gotten, and their educational levels. The study covers 148 male drone pilots with drone education backgrounds. The Humour Styles Questionnaire is used to collect data for this study. The specified statistics, reliability analysis and MANOVA analyses were employed to analyse the collected data.

As a consequence of these analyses, there was no significant statistical difference between the humour questionnaire sub-dimensions of participative humour, self-developing humour, aggressive humour, and self-destructing humour. Participatory humour, self-enhancing humour, offensive humour, and self-defeating humour sub-dimensions were not significantly different by income level. There was no statistically significant difference in the sub-dimensions of the humour scale according to education level: participative humour, self-enhancing humour, offensive humour and self-defeating humour. As a result, the sense of humour of drone pilots does not differ based on the type of schooling, income level, or education level within the contents of this study.

1. Introduction

It is a well-known fact that the interactions developed between individuals play a significant role in people's life. There are already numerous behavioural components and lifestyles that incorporate a desire for life satisfaction and the enjoyment of quality time. The significance of interpersonal relationships in achieving life's goals should not be underestimated. It is a well-known fact that humans must continue to live their lives as social beings, and they do so through developing ways of communication in order to come to terms with other people. It is critical to perceive, analyse, synthesize, and assess human interactions in situations involving the initiation, growth, and maintenance of interpersonal relationships.

There are various qualities that shape an individual's behaviour patterns in terms of how he will make an impact on the other party. One of these attributes, "Humour," which has piqued the interest of researchers today, should be conceptually defined and addressed. When the term "humour" in English is questioned about its first use, it is noted that in Ancient Greek culture, physiological fluids in four distinct forms were referred to as "humour" (blood, phlegm, black bile, yellow bile) (Ruch, 1998). These four bodily fluids are considered to have physiological and psychological effects on humans.

Humour, a phrase borrowed from Arabic, is the skill of making people ponder, amuse, or laugh at the outcome of events by reflecting on the ludicrous, unexpected, and paradoxical qualities of such events. As time passed, humorous aspects started to be used as a technique to represent a mood, and in today's world, its significance has evolved to reflect an individual's understanding of amusement (Erentay, 2012). Among the definitions of humour, according to Adams, are those that allow an individual to have a good time, such as hilarious behaviour. When asked, "What is humour?" individuals frequently characterize it as something that makes them chuckle.

Humour is commonly defined as a scene that begins with a hilarious remark continues with a smile, and ends with a pleasant sensation (Susa, 2002). Sense of humour evolves as a personality attribute, according to Ruch. While some studies suggest that humour is intrinsic in humans, others argue that it may be cultivated (Martin, 1998). Einstein defined humour in the simplest and most concise manner: "Humour is thinking that laughs." To be properly presented or interpreted, humour requires logic and a well-planned attitude. Millspaugh (1979: 2644), as referenced by Özkan (2008), characterizes humour as "everything done to entertain."

Unmanned aerial vehicles, or drones in general, are one of the most indispensable technologies of the future. Even though its name is "unmanned", the most significant component in this ecosystem is humans. The most current drone regulation produced by the local aviation authority DGCA (General Directorate of Civil Aviation) to carry out efficient, regular, and safe drone flight operations in Turkey is the Unmanned Aerial Vehicle Systems Instruction (DGCA, 2021).

The most recent drone regulation produced by the local aviation authority DGCA in order to carry out efficient, regular, and safe drone flight operations in Turkey is the Unmanned Aerial Vehicle Systems Instruction (DGCA, 2021). The instruction, which was revised for the fourth time in 2020, has been prepared to establish procedures and principles for the import, sale, certification, and registration of civil UAV systems to be operated or used in Turkish airspace, ensuring airworthiness, qualifications of those who will use the systems, air traffic services, and UAV operations.

According to Turkish drone regulations, UAVs used for civilian purposes are categorized into four groups based on their maximum take-off weight:

- UAV 0: 500 gr (included) <MTOW <4kg,
- UAV 1: 4 kg (included) <MTOW <25kg,
- UAV 2: 25 kg (included) <MTOW <150kg,
- UAV 3: 150 kg (included) <MTOW < and more

Drones weighing 500 grams, or more are registered in Turkey. Regardless of weight, if a drone chooses to fly in Turkish civil airspace, it must first obtain flight permission from the DGCA up to 5 days before the commercial flight. Drone pilots must complete appropriate drone training to receive a flight permit.

Drones can be used in Turkish airspace in two ways: sportive/amateurly or commercially. Those who are to fly commercially in Turkish airspace must receive a training certificate from certified training institutes. Such institutions might be either universities or private entities. As of 2022, Turkey has 61 educational institutions and organizations, 36 of which are universities. Drone training differs depending on the type of UAV to be used. The types of training and the hours required are indicated in the table below (Table 1).

Table1. Training Hours of UAV Pilot Training

Hours	UAV 0	UAV 1	UAV 2	UAV 3
Theoretical Training	13	26	85	140
Practical Training	1	2	3	4
UAV Flight Training	2	4	36	54
Total Training	16	32	124	198

The drone market is constantly expanding due to the use of drones in civil applications in a variety of businesses. According to 2020 research, the drone industry, which had a production value of $ 20 billion in 2020, is anticipated to rise by 15% each year from 2021 to 2027. (Global Market, 2021). As a result, it is unavoidable that drone technology will grow in popularity and proliferate in the future. Some psychological features of humans, such as their sense of humour, maybe a key component in the development of this technology, as one of the significant aspects of this inevitable process.

1.1. The History of Humour

Western-oriented perspectives, the purpose, and type of comedy date back to the fourth and fifth centuries BC. It is said to have extended to Greece (Health, 1998). The use of humour may be traced back to the ancient Greek characters Oedipus and Theseus, and it can be found not just in the sources but also in everyday life. Riddles were employed to convince people with comedy during the era of Oedipus and Theseus. Until the end of the XX century, persuasion, knowledge transfer, learning, and success were all associated with humour. Moreover, it has been argued that it plays a key role in communication (Williams, 1987). When it comes to medieval Europe, religious groups abhor comedy and perceive it as a harsh reaction, believing that it will undercut the state's dominance. Laughter, which refers to the determination of heaven, one of the most fundamental tenets of religion, as a mocking, implies that heaven might be lived on earth. Because, according to Catholic doctrine, laughing is the equivalent of paradise. Given this, if one's laughter is restricted to the world, one is deemed to be mocking heaven (Sanders, 2001). Until the Renaissance period, the church and priests had a great influence on the sense of humour. With the coming of the Renaissance, this effect disappeared over time. With the disappearance of this effect, it was seen that humour gained a wider understanding. Works such as Don Quixote, Voltaire's Dictionary of Philosophy, and Moliere's works have been the precursors of the basic features of humour (Öngören, 1983).

1.2. Forms of Humour and Their Importance

Even though there is still no way to address the issue of how humour evolved and how humanity initially laughed, academics thoroughly investigate this topic. Humour, according to Snetsinger and Grabowski, comprises three stages. These are as follows: stimulation, problem solution, and result. The individual receives a hilarious cue during the stimulation stage. It can also be considered a symbol. The stimulation stage is related to social position. Form, simplicity, and the content of humour should be applicable for this stage. The confusion comes to an end after problem solutions are found. Laughter and enjoyment grow as the story progresses (Williams, 2001).

While humour may occasionally offer individuals amusing elements of life, it can also refer to problems in its own unique way. Humour is commonly used to relieve tension, improve communication, and pique people's attention. Although it is preferable to handle humour positively, it may also be used with negative views such as derision and dismissiveness. To be happy, individuals must be tranquil, physically, and mentally healthy, and, most notably, have the ability to laugh. Humour is the psychological fingerprint that separates people (Manning, 2002).

1.3. Types of Humour

The term "humour" refers to a broader concept. Humour has both positive and negative aspects, and many hypotheses that attempt to explain this feeling fall into two categories, which are both compatible and incompatible with humour (Martin et al., 2003). These two categories of humour are further subdivided into four sub-dimensions. While participative and self-enhancing humour falls within the compatible humour category, self-destructive and offensive humour fall into the maladaptive humour category.

Self-enhancing humour, also known as harmonized humour, encompasses a person's self-perception while also reflecting the humour style used to minimize negative thoughts and eradicate difficulties such as coping with stress and anxiety, taking into account the needs of others as well. This sense of humour does not have to be sensed separately and shared with others. When humour is employed in this manner, it allows for a hilarious outlook on life and the ability to maintain a sense of humour even in the face of difficulties (Kuiper, Martin, & Olinger, 1993).

Participatory humour: Participatory humour is a sub-dimension of adaptive humour. This kind of humour is intended to amuse and ease people (Hampes, 2006; Kazarian & Martin, 2004). Participatory humour improves interpersonal interactions and fosters a positive ambience. In addition, it has a crucial role in socializing individuals and forging communities (Romero and Cruthirds, 2006). This approach aims to leverage humour to be the understanding of oneself or other people. People that use this form of humour frequently have a positive vibe, which includes things like nice crafting phrases, being witty, encouraging conversation, and soothing the ambience (Martin et al., 2003; cited by Yerlikaya, 2007).

Offensive humour is a sub-dimension of maladaptive humour that is described as using an ethically hostile method with other people to satisfy and meet their requirements for one's own purposes. Referring to what Zillman has pointed out, this feature is employed detrimentally, such as humiliation and derision (cited by Martin et al., 2003). This type of humour undermines and complicates interpersonal contact and communication.

Self-Defeating Humour: People with this humour style may pretend to be joyful by assuming that these sentiments do not exist, regardless of how miserable and unhappy they look from the outside (Kuiper & Martin, 1993). Individuals with a self-defeating temperament have a conceptual framework that enables them to say or do things that will make them appear poor, which is one of the purposes of being valued and acceptable by other people's viewpoints (Martin, Puhlik, Doris et al. 2003).

1.4. Humour Theories

The supremacy theory: the aim of this theory is to consider oneself superior to others and to be in a better position. In interpersonal communication, the individual strives to consider himself superior to others by utilizing humiliating humour. In summary, this notion is an emotional condition that seeks to shame the individual or other people's flaws and failings (Fidanoğlu, 2006). Plato believes that the phenomenon that makes a person hilarious is that the person believes he is wealthier, wiser, and more popular than he actually is. Aristotle, who has an approach similar to Plato's, emphasizes that humour is based on not being a wealthy and upstanding person (Sanders, 2001). Because individuals dislike being laughed at, humour guarantees that people have a social regulatory element that will urge them to behave in a way that matches the desires of society (Bergson, 1996).

Conflict Theory: Beattie, a Scottish poet from the 18th century, provided key definitions of humour, stating that it is generated by irrelevant thoughts and unexpected occurrences. As a result of this formulation, he has been dubbed "the father of conflict theory" (cited by Keith-Spiegel, 1972). The progenitors of conflict theory associate humour with fancifulness and rationale (Martin, 1988). Aristotle was the first to assess this theory, but because it conflicted with the superiority theory, Aristotle did not pursue the notion of incompatibility any further. According to Aristotle's viewpoint, the speaker first serves as a beacon of hope for the listeners before surprising them with his or her sense of humour (Morreall, 1997). Because Aristotle's insights on the theory of conflict are few and far between, he is not considered a major figure in this theory. Schopenhauer and Kant were the most prominent proponents of this theory. According to Kant (1970), when a person's expectations for his status and knowledge are not satisfied, he develops an ambiguous condition, and humour is evident in such uncertain situations. Humour, on the other hand, is considered a result of the disparity between a person's ambitions and actual position (Martin, 1998).

Relaxation Theory: This theory is associated with the biological dimension of humour and the physiological condition of a humorous expression. According to Spencer (1980), humour is distinct from the body's relaxation processes and that humour relaxes just forty-three nerves since any of the physiological activities related to humour are not a baseline (Spencer, 1989). Descartes (1649) was the first to put this theory into existence. Descartes loves comedy; he claims that happiness exists when we remain mute about an unpleasant incident or recognize that we are not adversely impacted by that event (Türkmen, 1996). Laughter represents the departure of an unpleasant and unfavourable occurrence. Laughter follows us as a result of the constructive relaxation of our environment via behaviours such as humour and amusement. Laughter is constantly waiting to be disclosed behind the doors within us, and for it to be released, we must relax.

Researchers conducting studies on this particular theory sought to alleviate tension and challenges as well as relaxation. Laughing, according to researchers, relaxes the nerves in the body and is biologically comforting. Although the relaxation in question is not considered to be a focal point for theories, it exists for all of them (Dursun, 2019).

Psychoanalytic theory: Freud developed this theory based on one of his works. Humour, according to Freud, has two aspects. These are purposeful jokes delivered with a full heart. For purposeful jokes to be made, three elements are required: the person making the joke, the joke being made, and the person who provides the sensation of enjoyment. While jokes delivered with pure emotion elicit only a grin, jokes created with intent and purpose elicit more laughter (İkadin, 1998).

The individual expresses some facts that he is unable to express precisely through humour. As a result, he is freed of his difficulties in a way that everyone can agree on. There are three things to laugh at, according to Freud: humour, jokes, and quips. Other theories describe laughing in ways that differ from Freud's. According to this definition, what makes us laugh is not our readiness to argue with opposing viewpoints or our sentiments that we are superior to others. When the energy observed in the individual differs from the effort made by others to communicate his intention, the act of laughing develops (Freud, 1998).

Physiological theory: Physiological theory is concerned with humour in the context of biology. According to proponents of this view, humour is on the nerves, emanates from within, and contains characteristics such as simplicity of understanding. When the literature on humour is scrutinized, it is concluded that humour is related to behaviours that have existed since the beginning of human life and developed with humans, while also making it simpler for people to cling on to life. Humour and laughter, according to physiological theory, are beneficial to the organism and the body (Keith-Spiegel, 1972). The physiological theory was developed by Sigmund Freud. Freud defined humour as having a psychological content and highlighted that it arises as a result of coping with negative human sentiments and emotions (Cited by Sepetçi, 2010).

In his study, Yılmaz (2011) analysed the humour styles of school management in terms of several characteristics. As a finding of the studies, it was concluded that managers are close to the participatory humour style, taking into consideration the hobbies, reading, age, and several instructors, and this has a positive impact on the teachers and administrators. To identify the definition and types of humour in nurses, Sousa et al. (2019) studied the humoristic practices adopted by nurses. According to the findings, nurses define humour as follows: laughter, joy, state of mind, and well-being, while the types of humour are: optimistic/healthy humour and deleterious/unhealthy humour. Kramen-Kahn and Hansen (1998) discovered that humour is essential in sustaining a successful career at an 82 per cent rate in a study of psychotherapists on occupational hazards, incentives, and coping mechanisms.

2. Method

Sampling: The expedient sampling technique, one of the non - probability sampling technique methods, was used for sampling purposes. In this context, 148 male drone pilots (average age: 36.54 ± 9.59) who received drone training in recognized training institutions between 2018 and 2022 voluntarily participated in the study (Table 2).

2.1. Data Collection Tools

Personal information form: The researchers utilized the Personal Information Form to examine the characteristics of the drone pilots who took part in the study, such as age, drone usage time, kind of drone training they received, income and education levels.

Humour Styles Scale: Martin and Puhlik-Dorris (1999) developed a 60-item version of the Humor Styles Scale to analyse four types of humour. Martin et al. (2003) then updated the scale and generated a 32-item abridged version. The updated short version with 32 items was utilized in this investigation. The scale is classified into four categories: participatory humour, self-enhancing humour, offensive humour, and self-defeating humour. The Humour Styles Scale is a seven-point Likert scale with scores ranging from 1 (totally disagree) to 7 (totally agree). Yerlikaya performed the Turkish validity and reliability study of the scale for adolescents (2007). The internal consistency Cronbach alpha coefficients of the scale were calculated to be 0.75 for self-enhancing and participatory humour, 0.64 for aggressive humour, and 0.63 for self-defeating humour, as a result of the studies that proceeded with the adaptations to Turkish.

Data Collection: First and foremost, permission was received from the scale adaptors to use the scales. Due to the covid-19 epidemic experienced by the drone pilots, the personal information form and scale were taken via the internet by reaching out to the relevant groups using Google forms.

2.2. Data Analysis

Before delving into the analyses, missing and blank data were checked to find out whether there were any inaccurate data entries in the data set. There was no missing or empty data in the data set, which was discovered. Descriptive statistics, reliability analysis, and MANOVA analysis were used to scrutinize the data. The analyses were carried out using the SPSS 23 software package, and the significance level was set at 0.05.

3. Findings

The resulting tables, together with the data obtained by the study method, are listed as follows. Descriptive statistics for demographic variables for drone pilots are shown in table 2.

Table 2. Descriptive Statistics for the Demographic Variables for the Drone Pilots

	N	Min	Max	Mean	Std. Deviation
Age	148	19.00	69.00	36.5405	9.59902
Drone Usage Time	148	1.00	10.00	2.2973	1.83488
Type of Education	148	1.00	3.00	1.7635	.45716
Income Level	148	1.00	4.00	3.0000	1.17803
Education Level	148	1.00	3.00	2.1689	.61044

Table 3. MANOVA Table for Humoristic Scores Based on the Education Received

	Type Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Participatory Humour	.076	2	.038	.003	.997	.000
Self-Enhancing Humour	22.332	2	11.166	.401	.670	.006
Offensive Humour	34.530	2	17.265	.883	.416	.012
Self-Defeating Humour	111.641	2	55.281	.909	.405	.012

P<.05, p<.01

When Table 3 is analysed, there is no statistically significant difference in the sub-dimensions of the humour scale according to the type of education received: participatory humour [F(,003), p=,997)], self-enhancing humour [F(,401), p=,670)], offensive humour [F (.883), p=.416)] and self-defeating humour [F(.909), p=.405).

Table 4. MANOVA Table for Participatory Humour Based on Income Level

	Type Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Participatory Humour	52.954	3	17.651	1.310	.274	.027
Self-Enhancing Humour	106.844	3	35.615	1.298	.277	.277
Offensive Humour	96.817	3	32.272	1.677	.175	.175
Self-Defeating Humour	214.752	3	71.584	1.172	.323	.323

P<.05, p<.01

When Table 4 is analysed, there is observed to be no statistical difference among the sub-dimensions of the humour scale according to income level including participative humour [F(1.31, p=,274)], self-enhancing humour [F(,1,298), p=,277), offensive humour [F (1.677, p=.175)] and self-defeating humour [F(1,172), p=.323).

Table 5. MANOVA Table for Participatory Humour Based on Education Level

	Type Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squares
Participatory Humour	21.464	2	10.732	.789	.456	.011
Self-Enhancing Humour	35.11	2	17.555	.633	.533	.009
Offensive Humour	12.999	2	6.500	.330	.719	.005
Self-Defeating Humour	3.983	2	1.991	.032	.968	.000

P<.05, p<.01

When Table 5 is examined, there is no statistically significant difference between the sub-dimensions of the humour scales based on income level, which includes participative humour [F (1.31, p=.274)], self-enhancing humour [F (1,298, p=.277)], offensive humour [F (1.677, p=.175)] and self-defeating humour [F (1,172, p=.323).

4. Discussion and Commentation

The analysis conducted in this study, which sought to examine the humour understanding of drone pilots, found no statistically significant difference in the sub-dimensions of the humour scale, which are participatory humour, self-enhancing humour, offensive humour, and self-defeating humour, depending on the type of training received. In his study on university students, İlhan (2008) reported that there is no substantial correlation between humour types and grade levels. This particular finding might be construed as a result that supports the absence of a difference when the different forms of education received in the current study are evaluated as varied grade levels.

Moreover, students with a critical mindset may generate assumptions about a specific subject, summarize knowledge, generate new ideas, and participate in intellectual dialogues (Değer and Fidan, 2004). This study, conducted by Değer et al., does not confirm the current study's findings, but the fact that there was no difference in terms of humour concerning the quality of education received offers an important conclusion concerning the humour of the drone pilot trainers. It might provide a fresh viewpoint for evaluation. Students can be more capable of enhancing their perspectives of the subjects taught and recalling knowledge if they employ humour in learning exercises (Bipp, Kleingeld, Tooren and Schink, 2015).

Furthermore, as Greengross (2008) suggests, given that humour can be impacted by genetic variables, it is reasonable to assume that the perception of humour did not change based on the type of education received in the current study. According to another study, because one of the key functions of humour is to foster a pleasant learning environment, laughter in the classroom demonstrates that children like studying rather than being viewed as a foolish act by adults. Teachers that employ humour in their classes ensure that their students will learn while having fun (Hill, 1988).

Perhaps new findings on whether or not humour is dependent upon the type of education received, with a style of changing the level of humour depending on the type of education received, will emerge in future studies by evaluating the humour understanding of both the training and the training groups together. Krobkin (1988) discovered that humour promotes motivation and happiness in learning (Cited by Steele, 1998). According to this study, the type of schooling evaluated as a variable in the current investigation did not yield the predicted effect.

There is no statistically significant difference in levels of income in the sub-dimensions of the humour scale, such as participative humour, self-enhancing humour, offensive humour, and self-defeating humour. Sümer (2008) and Koçubaba (2019) discovered a relationship between humour style scores and income level in their study, and it was reported that participants with higher income levels had higher participant humour scores. These data fail to support the present study's conclusion. The fact that drone pilots' income levels aren't all that different may not have made a difference in their sense of humour.

According to education level, there is no statistically significant difference in the sub-dimensions of the humour scale, participative humour, self-enhancing humour, offensive humour, and self-defeating humour. According to McGhee (1983), childhood humour is simplified with maturity, resulting in more cognitive development. According to Zigler et al. (1966), what appears to be irrational for adults may be amusing to youngsters. According to the education department, when characterization of humour is performed, it has been concluded that the use of humour in cognitive processes is at its maximum for the students from the child development departments than in machine students (Akıl and Eker, 2018). This data refutes the present study's conclusion.

Since the type and level of education attained by drone pilots may be associated with their income level, likely,t it did not make a difference in terms of their sense of humour. There was no relationship between the father's education level and the participatory (social) humour style in Koçubaba's (2019) study on university students (Koçubaba, 2019). Likewise, no significant difference was observed between educational status and participatory (social) humour style in two studies with nurses (Ergözen, 2018; Ünal, 2018).

Satl (2019) noted a statistically significant difference in the mean scores of participatory (social) humour style according to education status in both healthy and risky pregnancies in his study comparing the humour styles of the husbands of healthy and risky pregnant women. The average participatory (social) humour style score of those with bachelor’s and higher education is greater than that of those with secondary and high school education. Unlike the study's findings, no significant relationship between education level and participative (social) humour style was identified in the literature (Satl, 2019). In line with previous studies, no significant relationship was observed between the sense of humour of drone pilots and their educational level. The reason for this might be that there is no criterion for the level of education for drone users, even though drones are a new and evolving technical aircraft.

As a conclusion, the concept of humour, which is examined in several domains, has the distinction of being the first study with drone pilots, in addition to this study. Although there is no difference in terms of education level, income level, or quality of education, which are assumed to be different in the perspective of senses of humour among drone pilots, educational studies indicate that sense of humour appears to affect the quality of education, whether they are trainers or those who take drone training, which is a significant factor in improving the quality of education. It is expected to serve as a foundation for future studies on this subject.

Ethical approval

Not applicable.

Conflicts of Interest

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

5. References

Akıl, A. M., and Eker, E., (2018). An analysis of the relationship between humor tendencies and demographic features among university students, Aydın Journal of Humanity and Society, Vol.4 No.2, pp.1-12.

Bergson, H. (1996). Laughter (p. 105). Peter Smith Publisher Inc.

Bipp, T., Kleingeld, A., Van Den Tooren, M., and Schinkel, S. (2015). The effect of self-set grade goals and core self-evaluations on academic performance: A diary study. Psychological Reports, Vol. 117 No. 3, pp.917-930.

Dursun, N. (2019). The comparison of humor style between physical education and sport school students and some faculties, Master's thesis.

Değer, A. and Fidan, O. (2004). Dil becerilerinin geliştirilmesinin aktif öğrenme sürecine katkısı, 1st Active Education Congress Proceedings Book, Dokuz Eylül Publications, pp.157-162.

Erentay S. (2012). Mizahi mizaç her derde ilaç, Psikeart Humor Magazine, Vol. 22, pp.36-38.

Ergözen Ö. (2018). The effects of nurses’ humor styles on job satisfaction, Master's thesis, Okan University, Institute of Health Sciences, p.97

Fidanoğlu, O. (2006). The relationship between marital adjustment, humor style and anxiety level, Master's thesis, Marmara University, Institute of Education Sciences, p.214

Freud, S. (1998). Jokes and Their Relation to the Unconscious, Payel Publishing House

Global Market (2021). Commercial Drone Market Growth—Industry Analysis Report 2024. available at: https://www.gminsights.com/industry-analysis/ unmanned-aerial-vehicles-UAV-commercialdrone-market (Accessed: 10 June 2021)

Greengross, G. (2008). Survival of the funniest [Review of the book Psychology of humor: An integrative approach, by R. Martin]. Evolutionary Psychology, Vol. 6 No. 1, pp. 90–95.

Hampes, W. (2006). Humor and shyness: The relation between humor styles and shyness, Humor. International Journal of Humor Research. Vol. 19, pp. 179–187.

Heath R. L. (1998). Humor Following Cerebrovascular Accident. University of Kentucky, Umi, Dissertation Information Service

İkadın, T. (1998). Humor and Psychoanalysis. Yüz Yılın Psikanalizi, Vol. 9, pp. 201- 204

Kramen-Kahn, B., and Hansen, N. D. (1998). Rafting The Rapids: Occupational Hazards, Rewards, And Coping Strategies of Psychotherapists, Professional Psychology: Research and Practice. Vol. 29, pp. 130–134.

Kazarian, S. S. and Martin, R. A. (2004). Humour Styles, Personality, And Wellbeing Among Lebanese University Students, Europen Journal of Personality, Vol. 18, No.3, pp. 209- 219.

Keith-Spiegel, P. (1972). Early conceptions of humor: Varieties and issues, The psychology of humor, Theoretical perspectives and empirical issues, pp.4-39.

Koçubaba, A., (2019). The effects of humor styles and perceived family attitudes on university students, Master's thesis, İstanbul: Üsküdar University, p. 100.

Kuiper, N. A., Martin R. A. and Olinger, L. J. (1993). Coping humor, stress and cognitive appraisals. Canadian Journal of Behavioural Science. Vol. 25, No. 1, pp. 81-96.

Martin, R. A. (1998). Approaches to the sense of humor: A historical review. The Sense of Humor: Explorations of a Personality Characteristic, pp.15– 60.

Martin, R. A., Puhlik-Doris, P., Larsen, G., Gray, J., and Weir, K. (2003). Individual Differences ın Uses of Humor and Their Relation to Psychological Well-Being: Development of the Humor Styles Questionnaire, Journal of Research in Personality, Vol. 37, No. 1, pp. 48-75.

Mannıng, K. (2002). Lighten Up! An Analysis of the Role of Humor as An Instructional Practice in The Urban And Culturally Diverse. Middle School Classroom, Unpublished Doctoral Dissertation, UMI Dissertation Information Service, Cleveland State University,

McGhee, P.E. (1983). Understanding and Promoting the Development of Children’s Humor, USA, Kendall/Hunt Publishing Company.

Morreall, J. (1997). Taking laughter seriously, İstanbul: İris Publishing.

Öngören, F. (1998). Cumhuriyet'in 75. Yılında Türk Mizahi ve Hicvi. İstanbul: Türkiye İş Bankası Kültür Publishing.

Özkan, H. İ. (2008). Öğretmen ve Öğrencideki Mizah Anlayışının Sınıf Atmosferine Etkisi. Master's thesis, Selcuk University, Konya, p.102

Romero, E. J., and Cruthirds, K. W. (2006). The Use of Humor in the Workplace, Academy of Management Perspectives, Vol. 20, No. 2, pp. 58-69.

Ruch, W. (1998). The sense of humor: explorations of a personality characteristic. HUMOR: International Journal of Humor Research (HR), Vol. 3, X-498.

Sanders, B. (2001). Kahkahanın Zaferi: Yıkıcı Tarih Olarak Gülme. Ayrıntı Publishing.

Satil, Y. E. (2019). Comparison of humor styles of the spouses of healthy and risky pregnant women, Master's thesis, Gaziantep University, Institute of Health Sciences, p.78

Sepetci, C. (2010). Okul Yöneticilerinin Mizah Tarzlarının Betimlenmesi, Master's thesis, Gaziosmanpasa University, Tokat, p.106

DGCA (2021). İnsansız Hava Aracı Sistemleri Talimatı (SHT-İHA)", Ankara, avaible at https://web.shgm.gov.tr/documents/sivilhavacilik/files/mevzuat/sektorel/talimatlar/2020/SHT-IHA_Rev-04.pdf Accessed: 25 September 2021.

Sousa, L. M. M., Marques-Vieira, C. M. A., Antunes, A. V., Frade, M. D. F. G., Severino, S. P. S., and Valentim, O. S. (2019). Humor intervention in the nurse-patient interaction. Revista Brasileira de Enfermagem, Vol. 72, pp.1078-1085.

Spencer, G. (1989). An Analysis of Jab-Baiting Humor On The College Campus, Humor, International Journal Of Humor Research, Vol. 2, pp. 329-348

Susa A. (2002). Humor type, orgnizational climate and outcomes; the shortest distance between an organization's environment and the bottomline is laughter. Unpublished Doctoral Dissertation. University of Nebraska, Umi Dissertation Information Service.

Sümer, M., (2008). Pre-school teaching students' styles of coping with stress and the comparison of their manners of humor in accordance with various variables. Master's thesis, Konya: Selçuk Üniversity, p.145

Steele, K. E. (1998). The Positive and negative effects of the use of humor classroom setting. Unpublished Master Thesis, Salem Teikyo University, The faculty of the master of art

Türkmen, F. (1996). Mizahta Üstünlük Teorisi ve Nasrettin Hoca Fıkraları. V. Milletlerarası Türk Halk Kültürü Kongresi Nasreddin Hoca Seksiyon Bildirileri, pp.24-25, Ankara.

Ünal D. (2018). Determination of the Relationship between the Humorous Styles and Burnout Levels of Nurses Working in Pediatric Clinics. Bülent Ecevit University, Health Sciences Institute, p.80

Yerlikaya, N. (2007). The relationship between humor styles and coping styles of high school students. Master's thesis, Çukurova University, Adana, p. 94

Yılmaz K. (2011). An Analysis of Humor Styles of School Administrators. Inonu University Journal of the Faculty of Education, Vol. 12, No. 1, pp. 27-44.

William F. (1987). Humor and Paradox. American Behavirol Scientist, Vol. 30, No. 3, pp.42-71

Williams, F. C. (2001). Humor and the retention of lecture material by student-athletes in a mentor information session. The Pennsylvania State University.

Zigler, E., Levine, J., and Gould, L. (1966). Cognitive Processes in the Development of Children's Appreciation of Humor, Child Development, Vol. 37, pp.507-518

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Birds vs. Metalic Birds: A review of Bird Strikes in Aviation

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Abstract

This study gathered statistical data about bird strikes from various countries, including Türkiye. The study aims to compare the bird strike events that occurred in Türkiye and other countries by investigating bird strike data analysis from targeted countries. In this context, data on bird strikes per 10000 flights, distribution of the number of birds strikes according to months, phases of flight, the components hit by the birds, and the time of the event occurred on a day were presented. The data includes findings from Türkiye, USA, UK, Australia, Finland, Iran, and Czechia. When the results were evaluated, it was concluded that bird strikes are an essential factor to consider for safety and risk management. It is crucial that countries must conduct regular reporting to manage this safety issue. With the help of appropriate modelling conducted via proper measurements, the industry will come a long way in solving the safety issues caused by bird strikes.

1. Introduction

According to the aviation industry, a bird strike is expressed as the collision of aircraft with birds during any phase of flight. Along with the increasing air traffic, the probability of collision is also increasing every day (Dolbeer et al., 2005; Hedayati & Sadighi, 2015). Even though collisions can occur during any phase of the flight, the fact that bird strikes occur more often during the take-off and landing phases due to the more intense bird activity (Juračka et al., 2021; Metz et al., 2021). In addition, it was observed that these impacts caused serious damage, especially on the surfaces of the aircraft that were first exposed to the flow, such as the radome, wing leading edges, and engines (Metz et al., 2020). Bird strikes are not only a severe problem affecting commercial air transport and general aviation but also an issue affecting military aviation. As a result of bird strikes, the flight decks or primary control surfaces of small single-engined aircraft used in general aviation activities were damaged, while engine damage was observed in aircraft used in commercial air transport. Many of these collisions have not been of such primary priority as to affect the control capabilities of pilots over the aircraft. When the collisions occurring in the engines are examined, it is observed that the cases of engine stops occur at low rates (Airbus, 2004). One of the important reasons for this situation is that general aviation aircraft are flying at a low altitude compared to commercial transport aircraft. The disadvantage of commercial passenger aircraft in this scenario is that they receive structural damage at a level that will prevent the sealing of any region that has been pressurized as a result of a bird strike. Also, due to the fact that they are primarily jet-powered, their high speed has reduced the avoidance reflexes of pilots and birds (Ucer, 2001).

It is estimated that the number of fatal accidents due to bird strike between 1912 and 2008 was 54, and a total of 276 people lost their lives in these accidents. Among these 54 accidents, 7 were caused by helicopters, 32 were caused by aircraft weighing 5700 kg and less, and 15 were caused by aircraft weighing more than 5700 kg and business jets. Having only one fatal accident of a jet-powered airliner around the world out of over 1.4 million flight hours shows the increased awareness about the bird strike and related measures (Thorpe, 2009).

Nowadays, researchers have focused on studies of bird strikes that directly affect flight safety, and aviation authorities have also issued bulletins. The search for solutions to the situation that has become a severe problem for the industry has intensified. Therefore, the effects of the bird strikes have been tried to be minimized. ICAO's Safety Management System (SMS) is a reflection of the new generation paradigm that sees the world as it is, and proactive steps are taken in this system, such as precautions that must be taken before accidents and incidents occur, root causes that lead to accidents and serious unsafe incidents. In this context, the proposed solution earlier, the newsletters published, and all the research in this direction are considered essential steps to increase the SMS success of the enterprises (ICAO, 2009, 2013).

When the history of the bird strike is examined, it is seen that events also left a mark on the history of aviation. One of the incidents which left a mark on history is US Airways flight 1549 on January 15, 2009. When the A320's engines ingested a flock of Canada geese and lost all power, the pilot had no option but to land in the cold Hudson River. (Wrigley, 2018). Considering the development of the bird strike events, they are not only events encountered in the recent past but, on the contrary, they date back to the early years of aviation. The event recorded by the Wright brothers in 1905 appears as the first written bird strike record (Coban & Bahar, 2018; Heimbs, 2011). In addition, a lot of data has been published containing statistical information on bird strikes.

Standards have been developed around the world about bird strikes and different solutions have been tried to be produced with effective risk management. States publishing information such as regions with a density of birds, migration routes, etc., in their Aviation Information Publications (AIP) and NOTAMs within the framework of ICAO standards can be considered examples of these solutions mentioned above. Radars are also used in the release of these NOTAMs. In addition, these publications are more specific under the name BIRDTAM. BIRDTAM includes possible bird strike risks, especially in low-level airspace. Risk levels are determined numerically from 0 to 8 according to the density of birds. The airport services manual (Doc 9137), Part 3 Wildlife Control and Reduction, Fourth edition, 2012, which ICAO published, was translated to Turkish by the Directorate General of Civil Aviation (SHGM, 2016). In the Airports Organization Services directive, under the Fight Against Wildlife and Birds title, the General Directorate of State Airports Authority (DHMI) stated that its goal is to gain, maintain and develop flight and ground safety (General Directorate of State Airports Authority, 2018). In addition, It is emphasized that this struggle is conducted in accordance with international standards. As it is known, it is essential to receive feedback from people, that is, to report it, to follow an interactive matter. For this reason, DHMI requests that systematical reports be published on cases or incidents related to bird strikes that the pilots will organize. These notifications are sent by DHMI to SHGM for evaluation and submission to ICAO within the scope of ICAO IBIS (Bird Strike Information System). Investigating the ecological structure on flight routes and around airports and taking precautions by following the activity intensities of birds according to the migration seasons are some of the crucial methods utilized to fight bird strikes (Cleary & Dickey., 2010). The following bullets can be shown as examples of precautions that can be followed against bird strikes around airports:

- It seems that habitat management stands out. For this reason, in order to prevent the concentration of bird flocks around airports or to distract them as far as possible, waste that may be a source of food for them should be placed in areas away from airports (Allan, 2000).
- In addition, precautions such as keeping trees that provide birds with shelter and food or water sources that they can drink, even for landscaping purposes, far away from airports should be taken seriously.
- Birds can be distracted with the help of devices that emit the sound of birds of prey which can be placed around the airport. The sounds at a frequency that the human ear cannot hear that causes birds to fly away can be considered in this context.
- Birds of prey or hunting dogs can be entangled against flocks of birds.
- It is recommended that light-reflecting objects be hung on the runway edges. (Those which do not adversely affect the flight crew and tower attendants)
- If there is no obligation, low-altitude flight planning should be done less; if it is otherwise, avoiding migration routes should be considered.
- Examples of fight against bird strikes include making the necessary warnings when intensive bird activities are detected using airport surveillance radar or established observation stations.

Some of the documents published by the aviation authorities of countries or international aviation organizations about wildlife or bird strikes are as follows (SKYbrary, 2022):

- ICAO Doc 9137: Airport Services Manual Part 3 - Wildlife Control and Reduction
- ICAO Electronic Bulletin: 2008 - 2015 Wildlife Strike Analyses
- Wildlife Control Procedures Manual, Transport Canada TP11500E (2002)
- Sharing the Skies Transport Canada TP 13549E second edition 2004
- UK CAA CAP 772 - Wildlife hazard management at aerodromes
- AC 150/5200-33B: Hazardous Wildlife Attractants on or Near Airports, FAA
- Wildlife Hazard Management at Airports FAA (2005)
- Airport Practice Note 6 'Managing bird strike risk', by the Australian Airport Association
- Bird strike, a European risk with local specificities GA (EASA, 2013).

The results of the bird strike analysis belonging to different countries were shared using open access resources within the scope of this study. The study aims to gather statistical data related to bird strikes from different countries to examine and compare them with bird strike events in Türkiye. As a result of the literature review, data on bird strikes belonging to some countries have not been reached. Some of the data on bird strikes are unavailable to reach because the civil aviation authorities in many countries have not shared their data, and the reporting by airline companies is insufficient. However, it is important that bird strikes belonging to pioneering states in aviation such as the United States, Great Britain and air traffic intensive states such as Türkiye are examined within the scope of this study in order to shed light on bird strikes in other states.

2. Materials and Methods

In this study, the comparison between Türkiye's and other selected countries' bird strike data has been made accordance with specific criteria. Accessibility of data was primarily effective in determining the list of the countries. In this context, the selected countries and dates are given in Table 1.

Table 1. Countries in the Study

Country	Years	Data
Turkey	2015-2020	DGCA
USA	2000-2020	FAA
UK	2012-2016	CAA
Australia	2008-2017	ATSB AU
Finland	2000-2011	Finnish Transport Safety Agency
Iran	2000-2014	Iran CAA
Czechia	2011-2020	Czech DGCA
ICAO	2008-2015	ICAO

According to the data in Table 1, Türkiye has been compared with developed countries such as the USA, UK, Australia, and Finland. Also, other countries such as Iran and Czechia have been made. When looking at the data set, since historically, the same years cannot be obtained for all countries, the research was evaluated based on common years and total numbers. In order to obtain the data, the web pages of the countries' civil aviation authorities and the official reports published by them were used. After determining the countries and regions, the comparison years, and the data sources, information about the criteria is presented in Table 2.

Table 2. Criteria Used in the Study

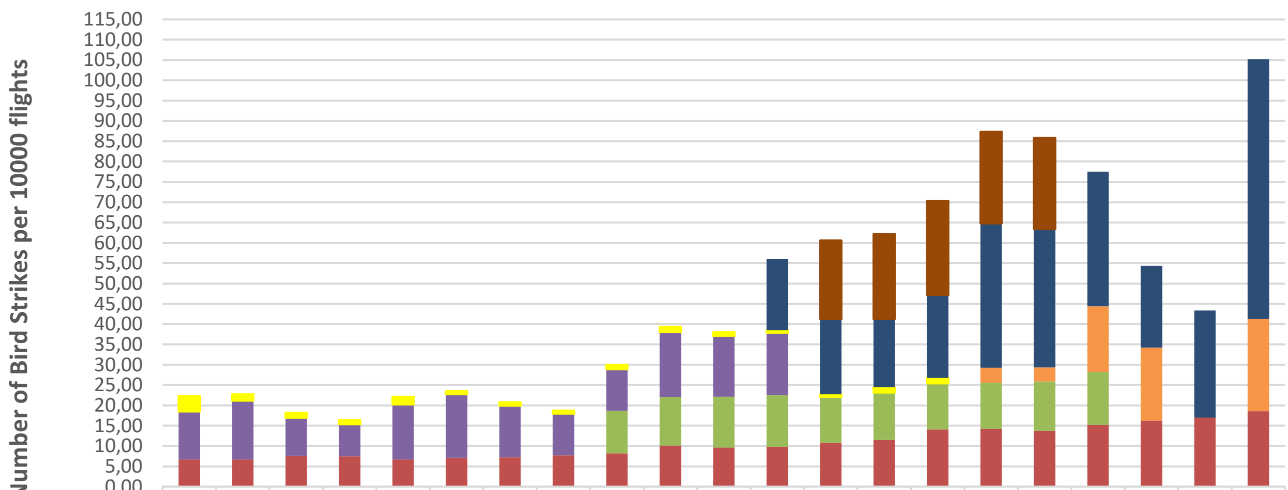
Comparison Criteria
Number of bird strikes per 10000 flights
Distribution by Months
Flight Phase
Aircraft Component
Time of the Day

According to Table 2, the criteria in this study are the data on bird strikes per 10000 flights, distribution of the number of birds strikes according to months, phases of flight, and the components hit by the birds. Finally, the time of the event occurred on a day.

In order to obtain the data of bird strike incidents occurring in every 10,000 flights, one of the criteria determined in the research, the total number of flights on a yearly basis, and the total bird strike incident data were converted into proportional data. Then, the number of bird strikes was arranged as per 10000 flights on the basis of countries. The reason for that is to make a more valid and reliable comparison since the numbers of flights between countries are different. It is quite natural that more incidents occur in a country with more flights than in those with a smaller number of flights. For this reason, as mentioned earlier, one can consider that a proportional comparison of the data will give more relevant results.

3. Findings

In this study, bird strike data occurring in USA, UK, Czech Republic, Türkiye, Iran, Finland and Australia were examined (Australian Transport Safety Bureau, 2019; CAA, n.d.; Dogan, 2019; FAA, 2021; Juračka et al., 2021; Nikolajeff, 2014; SHGM, 2020; Zadegan & Rezaiefar, 2016). It is considered that a more proper comparison requires bird strike numbers on 10 000 flights due to the fact that the annual flight numbers of aircraft belonging to certain countries differ. In this context, bird strike rates in 10 000 flights belonging to certain countries as a result of the investigations are shown in Figure 1.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
UK	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	19,31	20,95	23,17	22,59	22,50	0,00	0,00	0,00	0,00
Czech Republic	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	17,57	18,56	16,74	20,42	35,51	33,96	33,14	20,19	26,33	63,91
Türkiye	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,67	3,50	16,19	18,01	0,00	22,69
Iran	3,75	1,56	1,30	1,01	1,91	0,82	0,88	0,80	1,06	1,34	0,95	0,62	0,65	1,37	1,29	0,00	0,00	0,00	0,00	0,00	0,00
Finland	11,85	14,51	9,36	7,85	13,55	15,69	12,64	10,19	10,23	15,94	14,95	15,37	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Australia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	10,46	11,98	12,52	12,69	11,28	11,61	11,36	11,34	12,20	13,00	0,00	0,00	0,00
USA	6,66	6,67	7,56	7,51	6,69	7,06	7,26	7,73	8,20	10,06	9,57	9,78	10,78	11,50	14,08	14,26	13,68	15,17	16,19	17,01	18,58

Year

Figure 1. Number of bird strikes per 10000 flights by country between 2000 and 2020

In the data shown in Figure 1, 0 indicates no data on bird strikes for that year belonging to the specified countries. When Figure 1 was examined, it is clear that there was a serious increase in bird strike rates in Türkiye in the following years compared to 2015 and 2016. It is considered that the fact that the reporting event has been conducted electronically since

2017 is an important factor in this increase. In this context, one can say that the data of Türkiye before 2017 are not very reliable (Dogan, 2019). When looking at the United States, which has shared its data for all years, it can be observed that bird impact rates on 10,000 flights tend to increase overall compared to the years, and the data for 2020 are about three times higher compared to 2000. The FAA, the aviation in the United States, declares that as of 2012, according to FAA directive JO 7210.632, Air Traffic Organization (ATO) personnel must report all bird strikes that they have become aware of. In this context, it is normal for the numbers to be higher in 2012 and later years (FAA, 2021).

When one looks at Finland, Australia, Iran, and the United Kingdom, it is understood that bird strike rates show a uniform distribution as a whole in accordance with the years. For Iran, these rates are low because the total number of bird strikes in the 15-year period between 2000 and 2014 is 242, which is a very small number. While this number is 1392 in Türkiye in 2018 alone, it is a great value for the United States of America as 15998 in 2018.

There are many factors that affect bird strike rates. The presence of birds in the area of airports, the time period of the flights (Day and Night, etc.), the months in which aircraft are flying, the precautions taken to reduce bird strikes at airports or flight routes, and the types of birds near airports, are some of the data in an effective reporting must include. Figure 2 shows the distribution of bird strikes by month.

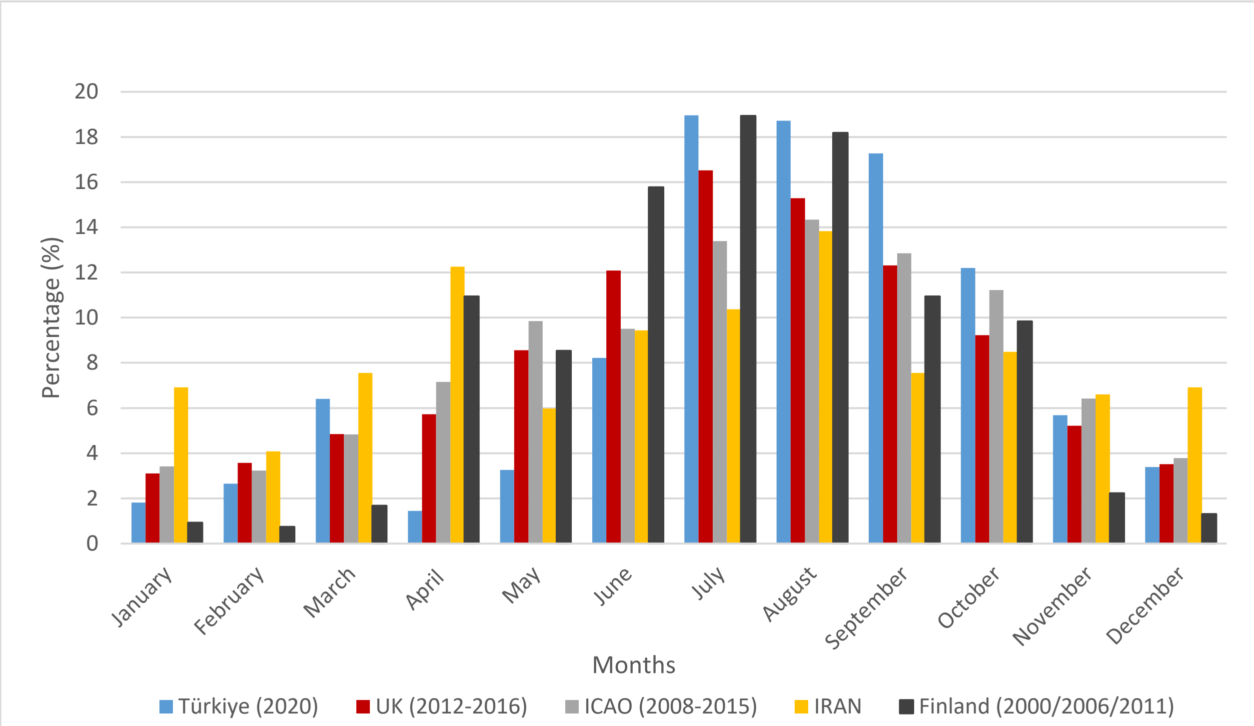


Figure 2. Bird strikes as a percentage by month

Figure 2 shows more bird strikes occur in summer. The number of flights and the greater density in the mobility of birds in these months are considered to be important reasons. As a matter of fact, in states such as Türkiye, where tourism takes an important role in the country's economy, there is a serious increase in the number of flights in the summer. In addition, people going to different countries for tourism often prefer air transportation due to the advantages such as speed, safety, and comfort provided by airline companies for their customers. As a result of this preference, the number of flights in the summer also increases.

Figure 2 shows the ICAO bird strike data by month between 2008 and 2015 separately. Currently, despite the fact that the number member states of ICAO is 193, there have been reports by only 91 states. Although there is no bird strike data for all states, according to the ICAO data, which collects data from different countries from different continents under one roof, one can understand that attention should be paid to bird strike events, especially in summer.

In Figures 3-6, bird strike data were shared according to the flight phase. A regular flight operation usually consists of take-off, climb, cruise, approach, and landing stages, respectively.

According to the flight phase for Türkiye between 2017 and 2018, one can observe that approximately 95-96% of the strikes occur during the take-off, approach, and landing phases. The high bird strike rates in the take-off and landing flight profiles near the airport show the importance of taking precautions around the airport. Figures 3 and 4 show that the case of a taxi in which the aircraft is located at the airport, parking position, and a cruise flight have relatively low strike rates. Factors such as the fact that the temperature and oxygen content is relatively low at the altitudes where today's commercial air transport aircraft fly reduce the likelihood of encountering a flock of birds at these altitudes. In this context, it is normal for the number of strikes to be so low on a cruise flight.

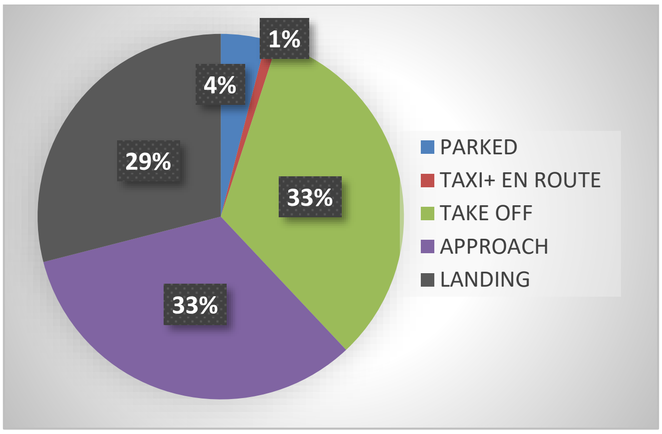


Figure 3. Bird strike by flight phase in Türkiye 2017

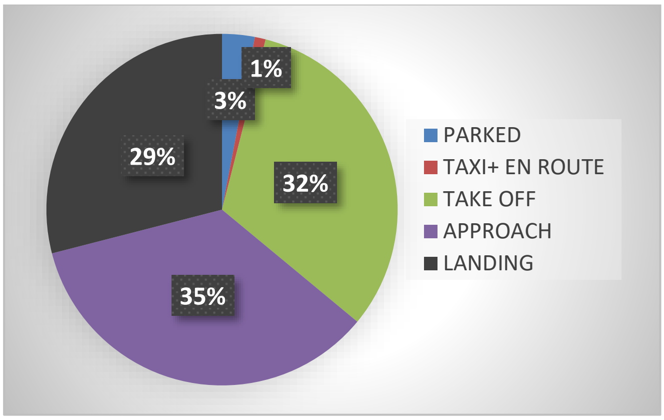


Figure 4. Bird strike by flight phase in Türkiye 2018

The bird strikes in Finland according to the flight stage in three different years show that the vast majority of the collisions occurred during the take-off, climb, approach, and landing stages where the flight altitude is low, which is parallel to the Türkiye's data. The approach stage has a considerable share of bird strikes, such as 46%, and this rate corresponds to the data of Türkiye, as well. However, it differs from the Turkish data by the fact that the cruise stage has an 8% rate. It is believed that the high output of data for the cruise stage is since helicopters, piston-engined, and turboprop aircraft, in which the cruising altitude is relatively lower than commercial passenger-carrying aircraft, are also included in the statistical data.

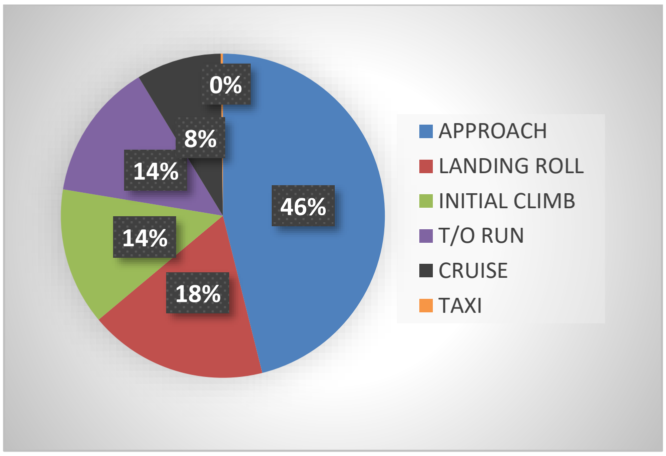


Figure 5. Bird strike by flight phase in Finland 2000/2006/2011

According to the ICAO data, the flight profile with the highest number of collisions is the approach stage with 35%, followed by the takeoff stage with 33% and the landing stage with 27%. In parallel with the data of other countries, it can be said in the ICAO data that these three flight stages account for a high percentage of all collisions.

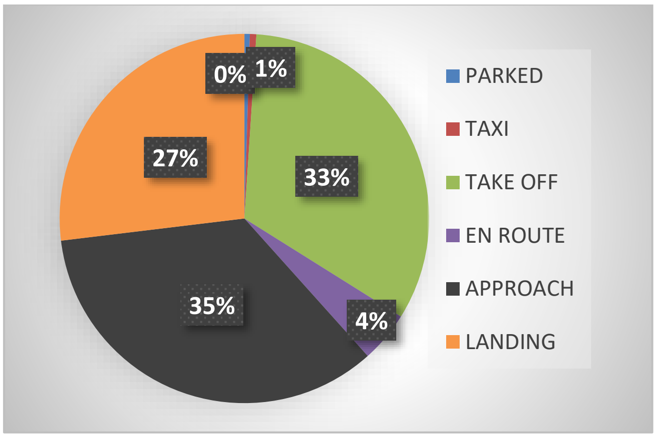


Figure 6. Bird strike by flight phase ICAO 2008-2015

Figure 7 shows the components damaged as a result of bird strikes. Only Iran and ICAO data are shared in Figure 7 because only data belonging to this country/authority can be accessed. When the specified figure is examined, it is seen that radome/nose and windshield are the two critical components exposed to collisions with 27% and 15% in the ICAO data. The presence of both aircraft sections at the front of the aircraft indicates that the collisions were mostly caused by oncoming birds. Again, according to ICAO data, engines were subjected to collisions by 14%. It is understandable for data to be high due to the high density of sucking air from aircraft engines. In the Iranian data, it can be again observed that aircraft engines have the largest share with 16%. The fact that a considerable percentage, such as 52%, is not known for Iran shows that reporting is not being applied very effectively.

The fact that bird strikes cause damage to aircraft components exposes airline companies to significant costs. In 2017, the cost of bird strike-induced maintenance in Türkiye was $33.08 million. For 2018, this value corresponds to a figure as high as 45.18 million dollars (Dogan, 2019). In addition to the maintenance costs, it is important to minimize the risks associated with bird strikes due to injuries to passengers and crew, plane accidents, cost increases caused by the inability of damaged aircraft to make scheduled flights, and customer dissatisfaction because of canceled flights.

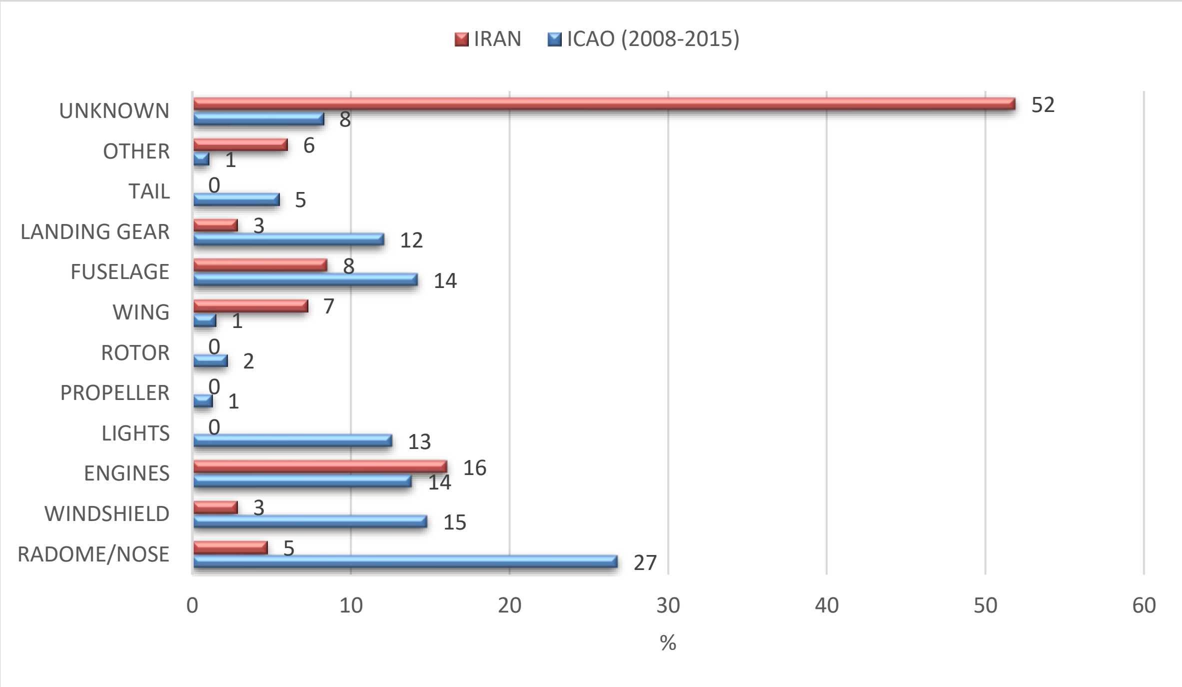


Figure 7. Aircraft parts damaged by bird strike

Within the scope of the study, bird strike percentages in different time periods were finally examined. As one can see in Figure 8, it is clear that bird strike rates are quite high during daytime, when the number of flights is greater. This is followed by nighttime with 24.56% (ICAO) and 17.68% (USA).

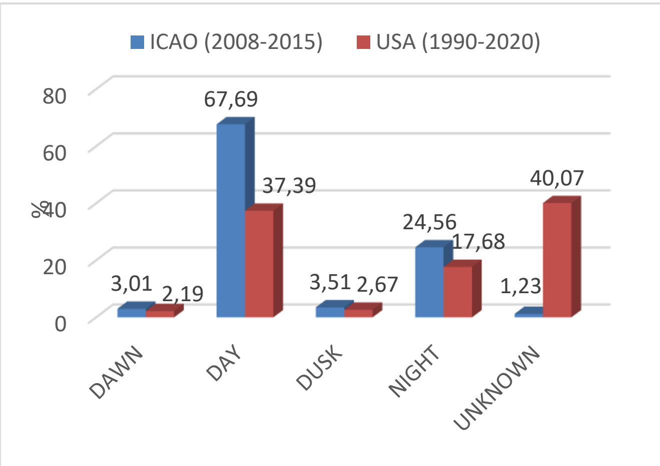


Figure 8. Bird strike by time

4. Discussion and Conclusions

Air transport connects continents, countries, regions with a unique global transport network, allowing people, cargo or mail to be relocated from place to place much faster than other modes of transport. In addition, it produces a tremendous amount of labor force directly or indirectly throughout the world. For these reasons, the air transport industry plays a very important role in increasing economic processes, social development and global prosperity throughout the world (ATAG, 2008; Wensveen, 2007). In order to obtain these benefits, air transport activities must be carried out safely. When this does not happen, unwanted results caused by safety matters may occur. As a result, accidents, incidents, injuries, or even deaths may occur (Gerede and Yaşar, 2017). Flight safety is extremely threatened when birds, which are often encountered in the sky where the aircraft perform their navigation, crash into aircraft, especially during the landing and take-off stages. When these collisions are explicitly exposed to the power group of the aircraft, the grip on the air becomes difficult, forcing aircraft into emergency landings, as occurred in the famous example Sully. In this regard, birds in some cases may present problems with the provision of the above-mentioned aviation safety. This study gathered statistical data on bird strike events from certain countries and Türkiye to examine and compare these data and offers a descriptive presentation for the readers.

The data shows that the bird strike rate on 10 000 flights has increased in countries such as Türkiye and America in recent years. On the basis of this, it was concluded that the share of increased air traffic and more effective reporting is high. In addition, although the precautions against bird strikes have been taken densely in recent years, the cost dimension of approximately $78.26 million in damage for Türkiye between 2017 and 2018 shows that more work should be done to minimize bird strike rates. Even though each of the countries under this study is in different geographies and has different bird species, there are similarities in the time periods, months, and flight phases where the bird strikes occur the most. This gives the idea that standard precautions can be taken to combat bird strikes to obtain a better safety report card in this matter.

When the data obtained from various sources are evaluated, it is understood that bird strikes are an important safety problem and a priority of risk management. As one can see through the events or cases, the responsibility falls on humanity since birds cannot take precautions against collisions. As a result, it is evident that compliance with the published and updated standards using experience is not an option but a must; otherwise, incidents/accidents that will cause material damage or loss of lives are inevitable. In addition, to minimize the damage caused by bird strikes that occurred in the aviation industry, one of the world's most organized and standardized industries, the national aviation authorities of the states must report the cases in an organized and systematic way. Another recommendation from this study is that data on bird strikes must be systematically collected by all countries' aviation authorities and reported to an international organization such as ICAO within specific time frames. Thus, it is thought that modeling via data analysis can guide professionals on a problem-solving path. Another situation that may make a significant contribution here will be the provision of bird strike committees or working groups established by some countries to be also found by other countries.

Today, it is observed that countries use various methods in combating bird strike. One of them is bird observation radars. Bird-watching radars are used to monitor birds. Hatay airport is the first airport in Turkiye to have a bird observation radar system (gokyuzuhaberci.com, 2011). 95% of the major airports in Spain use falcons, which are birds of prey, to prevent bird strikes. At Madrid's Barajas airport, falcons are trained to patrol its runways. There is a 'fleet' of 70 Peregrine falcons based at this airport (theolivepress.es, 2022). Advanced technology is used in the fight against birds in Canada. Edmonton International Airport is one of the first airport examples in the world to use robotic falcons to chase birds out of their flight paths and block nearby nesting sites (cbc.ca, 2017). In the legal regulations related to bird strike, there are issues related to how the designs of aircraft should be in case of a possible collision. For instance, the FAA, in its regulations on aircraft suitability, stated that the aircraft should be designed to ensure the ability of the aircraft to continuously safe flight and landing after a collision with an 8-pound bird (FAA, 1970).

Ethical approval
Not applicable.

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

References

Airbus. (2004). Flight Operations Briefing Notes. http://wildlifecenter.pr.erau.edu/flightOperations/airbus_flightop.pdf

Allan, J. R. (2000). The costs of bird strikes and bird strike prevention. Human Conflicts with Wildlife: Economic Considerations, 18, 147–153.

ATAG. (2008). Economic and Social Benefits of Air Transport.

Australian Transport Safety Bureau. (2019). Australian aviation wildlife strike statistics, 2008-2017.

CAA. (n.d.). Reported birdstrikes 2012-2016. https://www.caa.co.uk/media/ynyhgvh0/20170316-reported-birdstrikes-2012-2016.pdf

Cbc.ca (2017), Robotic falcons to scare away real birds at Edmonton airport, https://www.cbc.ca/news/canada/edmonton/edmonton-airport-robots-birds-falcons-1.4106703#:~:text=Edmonton/20International/20Airport/20will/20soon,paths/20and/20discourage/20nearby/20nesting.

Cleary, E. C., & Dickey., A. (2010). Guidebook for Addressing Aircraft/Wildlife Hazards at General Aviation Airports. In Guidebook for Addressing Aircraft/Wildlife Hazards at General Aviation Airports. Transportation Research Board.

Coban, R., & Bahar, İ. (2018). A Research on Wildlife Management in Aviation in Hamid Karzai International Airport (Kabul-Afghanistan). Journal of Aviation, 2(2), 87–104.

Dogan, M. O. (2019). Wildlife management in aerodromes and analysis, Master of Science Thesis. Eskisehir Osmangazi University.

Dolbeer, R. A., Wright, S. E., & Eschenfelder, P. E. (2005). Animal ambush at the airport: The need to broaden ICAO standards for bird strikes to include terrestrial wildlife. International Bird Strike Committee, 1, 102–113.

EASA. (2013). Bird strike, a European risk with local specificities. https://www.easa.europa.eu/sites/default/files/dfu/EGAST_GA6-bird-strikes-final.pdf

FAA. (1970). 14 CFR § 25.631 - Bird strike damage. https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/TAEgshT1&2-3151993.pdf

FAA. (2021). Wildlife Strikes to Civil Aircraft in the United States, 1990–2020.

General Directorate Of State Airports Authority. (2018). Havalimanları İşletme Hizmetleri Yönergesi. Doc 01. https://www.dhmi.gov.tr/Lists/KanunveYonetmelikler/Attachments/206/DHMI-Havalimanlari-Isletme-Hizmetleri-Yonergesi.pdf

Gerede, Ender; Yaşar, M. (2017). Evaluation of Safety Performance Indicators of Flight Training Organization in Turkey. International Journal of Eurasia Social Sciences, 8(29), 1174–1207.

Gokyuzuhaberci.com. (2011). Antakya Havaalanı'na Kuş Radarı. https://www.gokyuzuhaberci.com/antakya-havaalani-na-kus-radari-14959.html

Hedayati, R., & Sadighi, M. (2015). Bird Strike: An Experimental, Theoretical and Numerical Investigation. In Bird Strike: An Experimental, Theoretical and Numerical Investigation. Woodhead Publishing.

Heimbs, S. (2011). Computational methods for bird strike simulations: A review. Computers and Structures, 89(23–24), 2093–2112.

ICAO. (2009). Safety management manual. Doc 9859 AN/474, 2nd edition.

ICAO. (2013). Safety management manual. Doc 9859 AN/474, 3rd edition.

Juračka, J., Chlebek, J., & Hodaň, V. (2021). Bird strike as a threat to aviation safety. Transportation Research Procedia, 281–291.

Metz, I. C., Ellerbroek, J., Mühlhausen, T., Kügler, D., & Hoekstra, J. M. (2020). The bird strike challenge. Aerospace, 7(3), 26.

Metz, I. C., Ellerbroek, J., Mühlhausen, T., Kügler, D., Kern, S., & Hoekstra, J. M. (2021). The efficacy of operational bird strike prevention. Aerospace, 8(1), 17.

Nikolajeff, J. P. (2014). Analysis of the Bird Strike Reports R e ceived by the Finnish Transport Safety Agency between the Years 2000 and 2011. https://pdfs.semanticscholar.org/f236/3a298799dbb112bf8543d165ad8f5425aab6.pdf?_ga=2.257457355.19

33108280.1593509326-2091356243.1582724361

Noyan, T. (2007). The analysis of environmental factors in aircraft accidents, Master's thesis. Ankara University.

SHGM. (2016). Havaalanlarında Yabani Hayvan Kontrolü Ve Azaltımı. https://web.shgm.gov.tr/documents/sivilhavacilik/files/pdf/kurumsal/yayinlar/Havaalanlarinda_Yabani_Hayvan_Kontrolu_ve_Azaltimi.pdf

SHGM. (2020). Emniyet Olaylari Yillik Bülteni. https://web.shgm.gov.tr/documents/sivilhavacilik/files/mevzuat/sektorel/bulten/2020/EOYB-2020.pdf

SKYbrary. (2022). Airport Bird Hazard Management. https://skybrary.aero/articles/airport-bird-hazard-management

Thorpe, J. (2009). Update on fatalities and destroyed civil aircraft due to bird strikes with appendix for 2008 & 2009. International Bird Strike Committee.

Theolivepress.es. (2022). Given the Bird: How Falcons are used to protect Spain's airports from the dangers of bird strikes. https://www.theolivepress.es/spain-news/2022/02/06/given-the-bird-how-falcons-are-used-to-protect-spains-airports-from-the-dangers-of-bird-strikes/#:~:text=Today/2C/209/25/20of/ 20the/20major,trained/20to/20patrol/20their/20runways

Ucer, Y. (2001). Kuş-Uçak Çarpışmalarının Önleme Usûl ve Yöntemleri. Hv.K.K. Uçuş ve Yer Emniyet Dergisi.

Wensveen, J. G. (2007). Air Transportation A Management Perspective, Sixth Edition. Ashgate Publishing Limited.

Wrigley, C. (2018). It's a bird! It's a plane! An aerial biopolitics for a multispecies sky. Environment and Planning E: Nature and Space, 1(4), 712–734.

Zadegan, S. ., & Rezaiefar, H. (2016). Aircraft and bird strikes in IR Iran. International Journal of Avian & Wildlife Biology, 1(1), 1–3.

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Bibliometric Analysis of Studies in the Field of Aviation Management in the Post-Deregulation Period

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Abstract

Aviation management is a broad field of science that encompasses all kinds of managerial and operational processes, generally in the safe transportation of passengers and cargo within the aviation industry. However, this branch of science, which is still very young in the history of science, acts as a catalyst in the economy by adding high added value to the world trade volume. This industry, which gained momentum with the liberalization period after 1980, has an ecosystem in which strong organizational structures can hold. With its key functions such as safety management, human resources management, marketing management, and financial management in terms of its scope, it needs a visionary perspective with a working area within the airport management network. From this point of view, understanding the development processes of the field in the literature and revealing its relationship with other variables will provide a systematic and holistic perspective to the related literature. For this purpose, the bibliometric analysis method was used in this study, which was conducted in the field of aviation management. The study covers a process, especially from the liberalization period to the present. The purpose of this study in the field of aviation management is to create a perspective on the aspects in which the field offers mobility, the development, quality, and quantity of the process. In this context; In this content; Studies in the field of aviation management were taken from WEB of Science (VOSviewer). Word cloud and keyword maps were created covering the distribution of the studies by years, the authors who contributed the most to the field, the institutions, and journals according to the number of publications, and the languages used in the publications. The contribution levels of the studies to the literature and the areas in which the subject interacts are explained.

1. Introduction

The aviation industry is very broad and is one of the most important components of the ever-rising service class of the global economy. It has become one of the most important components of both personal life and international trade with its fast, reliable, and short-term deliveries, technical developments, new business models in the aviation industry, and discounted ticket prices to consumers. International air travel is not only a major industry in its own right but also critically important as a component of the world's ever-expanding economy (Button & Taylor, 2000, p. 3). When we look at the aviation industry academically, the first studies that come to mind and are encountered are in the mechanical and technical characteristics of the industry. However, aviation has a multi-disciplinary service feature in a very wide area. The field of Aviation Management covers all of the core business functions. In addition, when viewed from the focus of management functions, team-based work has a deep structure where the field of organizational communication is very wide. In aviation, especially the focus on safety and profit motive should be evaluated in terms of management dilemma. The need for the maximum performance of every employee in the organization for safe operations also affects the quality of the service. In this respect, the field of aviation management in which you are evaluated; covers a wide spectrum such as human resource management, marketing management, technology management, and stand management. The fact that the industry is rapidly affected by many economic, sociological, political, and technological changes and its place in the world economic wheel creates a prediction about the diversity of studies and studies to be done in this field. However, this study, which was carried out to take this foreknowledge one step further, it was aimed to create an academic map of the studies made after the liberalization period, which was a turning point for the aviation industry. The importance of this study is to see what kind of a spectrum the studies carried out in the relevant industry is spread, and to create a perspective on which parts are missing and which gaps are filled. However, as the results of the study present a time perspective, it will also provide important information to see the development direction of the field. In the first part of the study, a general introduction was made. In the second part, general information about aviation management is given. In the third part, methodology and method information are given.

In the fourth part of the study, the findings are presented, and in the last part, the results are given.

2. Aviation Management

The air transport industry, which is defined as the transportation of passengers, cargo, or mail from one point to another by using an aircraft for a certain fee (ICAO, 2009), has some unique features. The most important feature that distinguishes air transport from other industries is that it provides faster and safer access to points that are difficult to reach, compared to its competitors (Canöz, 2018). Developments in the field of liberalization in recent years have led to the development and growth of the industry's infrastructure. Accordingly, it is a industry that continues to grow rapidly and has not yet reached saturation. Air transport industry has a highly advantageous position compared to other transportation models in terms of safety, security, comfort, speed, and quality, both in terms of passenger transportation and freight transportation. Especially with the deregulation in the USA in 1978, which means the removal of legal borders, air transport industry has become a competitive field. After these developments, airline companies started a new strategy called a hub and spoke (Oktal & Küçükönal, 2007). Air transport industry, which is an important social and economic resource for countries, has grown continuously despite negative activities such as war, economic crisis, and terrorism, and an annual increase of 4% to 5% has been observed (SHGM, Annual Report, 2012). One of the most important indicators of this is the world economic activity, which came to a halt during the covid-19 period. Although every field in the world came to a standstill with the relevant crisis, when the effect of the crisis began to fade in 2021, it showed the feature of being the most important industry that quickly returned to the limits it had come before the crisis. However, the aviation industry has such a wide range of features as cost management, human resources management, customer relationship management, and service production. The size of this organization requires several business models and serious management stability for these models to be sustainable. The field of aviation management has to ensure both profitability and safe operations within this stability. Because the most important feature that distinguishes this industry from other service management is that the smallest mistakes have dire consequences such as paying with human life. Therefore, the aviation industry has a structurally complex and spiral ecosystem. Airline companies in the aviation industry operate around the clock by adopting the concept of uninterrupted service. Airline companies, which have to serve all day long, work in shifts to increase the efficiency of the business and not overload the employees. This system increases the need for qualified employee employment (Karasu, 2007). This situation necessitates effective human resources management. Because several specialized workforces cannot be substituted in the industry. Training this workforce is time-consuming and costly. Another importance of human resources management in aviation management is related to safety management. In aviation, the sustainability of a company in terms of management depends on both economic profitability and safe operations. Approximately 75% of the accidents in aviation are due to the human factor (Xue ve Fu (2018). Therefore, safety management is considered an important field of study within aviation management. It is important in terms of customer relationship management that the human resource also has the feature of providing the service. As it is known, the determinant of service quality is the customer. At this point, marketing management also represents an important area in aviation management. Aviation management, when evaluated academically, has a wide scope such as risk management, airport management, ground handling management and airline management.

3. Methodology

Bibliometric analysis is a multidisciplinary mainstay that provides the opportunity to look at research from a broad perspective to improve the level of development of studies in the literature (Samiee & Chabowski, 2012;369). Bibliometrics is used to classify documents by quantitatively analyzing bibliographic data from scientific publications (Mao et al., 2015). Bibliometrics is a research method that includes the analysis of processes and features related to documents (Thelwall, 2008: 606). The purpose of bibliometric research; the development of the pace of the studies over time, the policies followed by the institutions where the publications are made, and the evaluation of the situation. Periodic examination of the countries in which bibliometric analysis is carried out provides the opportunity to understand the scientific infrastructure and the perspective of the field. This analysis also allows for different evaluations depending on the relevant field (Al, et al., 2012). Bibliographic analysis helps researchers discover the spread and impact of work in a particular field. At the same time, basically; It offers a perspective on measuring the effects on the formation of an individual, publication, or journal-based scientific field (Kraus et al., 2012). The bibliometric analysis includes statistical methods to identify qualitative and quantitative changes in a particular scientific research top to profile publications on the subject, and detect trends within a discipline (Rey-Martí et al., 2016: 1652). These methods, together with a systematic, transparent and reproducible review process, have the potential to improve the quality of the relevant science field (Zupic and Čater, 2014: 430). This method includes profiling, clustering, and visualization studies of publications (De Bakker et al., 2005); It gives information about mutual relations and the impact capacity of subjects, journals, authors, countries, and institutions (Krauskopf, 2018). In addition, examining the keywords in the relevant title is aimed to create a perspective on the transactional relationship readership with other areas and variables. The Web of Science Core Collection database was used in this analysis to obtain data. All bibliometric analyzes were performed via VOSviewer 1.6.16 software (Van Eck & Waltman, 2010), which is frequently used in bibliometric analyses. With VOSviewer, keywords defining the field, important themes, and band bibliographic match links between author and journals are visualized with network and density maps. Web of Science is recognized as the most comprehensive citation program for intensive data research work (et al, al 2018). For this reason, the VOSviewer analysis tool was used to map and visualize the data in the study. The number of publications, citation networks, authors, journals, countries, the scope of publication years, and the word cloud obtained from the studies have been visually transferred within the scope of this research.

4. Findings

The first data obtained as a result of the analysis was on the distribution of studies in this field by years. The data obtained are presented in figure 1. Looking at the transferred data, it is seen that the first publication in the post-liberalization period in the aviation industry was made in 1985. There appears to have been small numbers of progress over the next 10 years. However, it can be said that as of 2011, the orientation to the field of aviation management has started. After this year, it is seen that interest in the field has increased regularly, and the number has reached its highest level in 2020. The reason for seeing 1 publication in 2022 is that the research was conducted in the first month of this year.

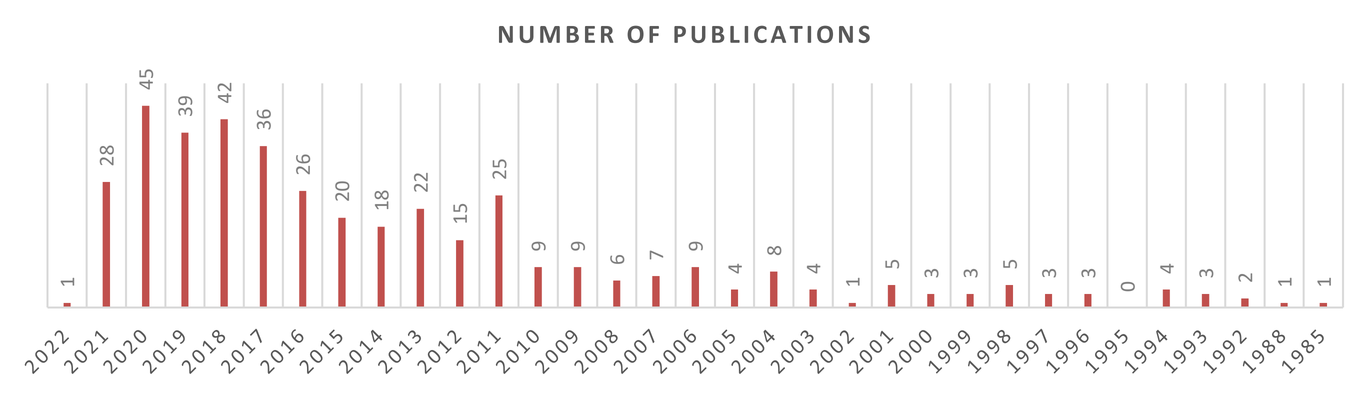

Figure 1. Distribution by years.

Table 1. Top countries

Country	Number of Publications	Percentage	Citations
USA	65	16.12%	926
Peoples R China	42	10.42%	245
Germany	34	8.43%	269
Spain	33	8.18%	343
Italy	31	7.69%	352
Türkiye	30	7.44%	148
Australia	23	5.70%	441
Poland	17	4.21%	25
England	16	3.97%	295
Brazil	14	3.47%	105
Canada	12	2.97%	237
Portugal	11	2.7%	110
Netherlands	9	2.23%	17
Taiwan	8	1.98%	78
New Zealand	7	1.73%	226
Greece	7	1.73%	37
Romania	5	1.24%	11
India	5	1.24%	22
France	5	1.24%	66
Switzerland	4	0.99%	38
Austria	4	0.99%	70
Malaysia	4	0.99%	70
Iranian	4	0.99%	8
Norway	4	0.99%	37
Singapore	4	0.99%	39
Belgium	3	0.74%	17
Colombia	3	0.74%	0
Saudi Arabia	3	0.74%	23
Pakistan	2	0.49%	0
Finland	2	0.49%	32
Denmark	2	0.49%	70
Israel	2	0.49%	53
South Africa	2	0.49%	5
Ireland	one	0.24%	3
Chile	one	0.24%	9
Croatia	one	0.24%	0
Indonesia	one	0.24%	13
Lithuania	one	0.24%	5
Russia	one	0.24%	one
Slovenia	one	0.24%	13
South Korea	one	0.24%	92
Thailand	one	0.24%	3
Wales	one	0.24%	6
Algeria	one	0.24%	one
Latvia	one	0.24%	5
Morocco	one	0.24%	one
Bosnia Herceg	one	0.24%	3
Cyprus	one	0.24%	one

Another point that was investigated as a result of the analysis was the extent to which countries contributed to this field. A total of 62 countries were found. It is seen in table 1 that the country that contributed the most to the field among the countries found was the USA with 65 publications. Afterward, the list continues with China with 42 publications, Germany with 34 publications, Spain with 33 publications, Italy with 31 publications, and Türkiye with 30 publications. Table 1 shows the most cited countries in the relevant field. It was created according to the citation values in the VOSviewer program. The USA ranks first with 65 publications and 926 citations. Australia is in 7th place in the publication ranking and is in second place with 441 citations. Italy is in the 3rd place with 352 citations, Spain is in the 4th place with 343 citations, and Italy is in the 5th place with 92 citations. On the other hand, England ranks 6th with 79 citations, despite being the country with the most publications.

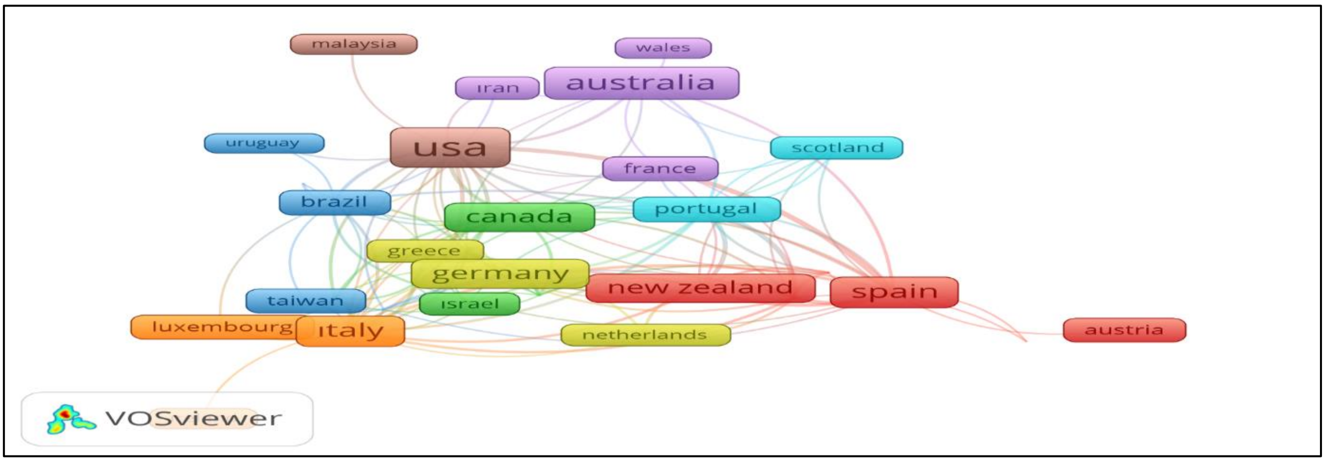

Figure 2. Citation of countries on VOSviewer

Another data obtained was on the authors who contributed the most to the field. Looking at the authors cited in table 2; Ayşe Küçük Yılmaz, Maria Freese, Jerrold Belant, and Travis Devault became the most published authors with 6 publications. The authors of countries such as Türkiye, the USA, and the Netherlands are registered as the publishers that contribute the most to the field.

Table 2. Top contributing authors

Author	Number of Publications	Country	Institute
Ayse Kucuk Yilmaz	6	Türkiye	Anadolu University
Maria Freese	6	Netherlands	Delft University of Technology
Jerrold L. Belant	6	USA	State University of New York
Travis L. Devault	6	USA	University of Georgia
James A Martin	5	USA	University of Iowa
Ender Gerede	4	Türkiye	Eskisehir Technical University
Guiming Wang	4	USA	Mississippi State University
Jose I. Castillo-Manzano	4	Spain	University of Seville
Paola DiMascio	4	Italy	Sapienza University Rome
Ian M. Humphreys	4	USA	University of Washington
Laura Moretti	4	Italy	Sapienza University Rome
Jacek Skorupski	4	Poland	Warsaw University of Technology

At this point, the country with the highest number of publications maintained its position in first place in the context of USA authors. In the following, writers from Italy, Spain, Türkiye, and, Poland drew attention. In table 3, the most published journals in the field are given. In this context, the Journal of Air Transport Management ranks first with 57 publications and 889 citations. After that, there was a big difference. Research in Transportation Business and Management ranked second with 10 publications. In the data in Table 3, the most cited journals are cited. From this point of view, although Tourism Management has published 4 publications, it has ranked second in the citation ranking. Another noteworthy journal is Transportation Research Part E-Logistics and Transportation Review, which ranked third with 170 citations.

Table 3. Distribution of the number of articles published by journals

Q. No.	Journal	Record	Citation
one	Journal of Air Transport Management	57	889
2	Research in Transportation Business and Management	10	117
3	Sustainability	7	13
4	Aircraft Engineering and Aerospace Technology	5	15
5	Transportation Research and Record	5	20
6	Tourism Management	4	242
7	Transportation Research Part E-Logistics And Transportation Review	4	170
8	European Journal of Transport and Infrastructure Research	4	13
9	Transport Policy	4	76
10	Aviation	4	7

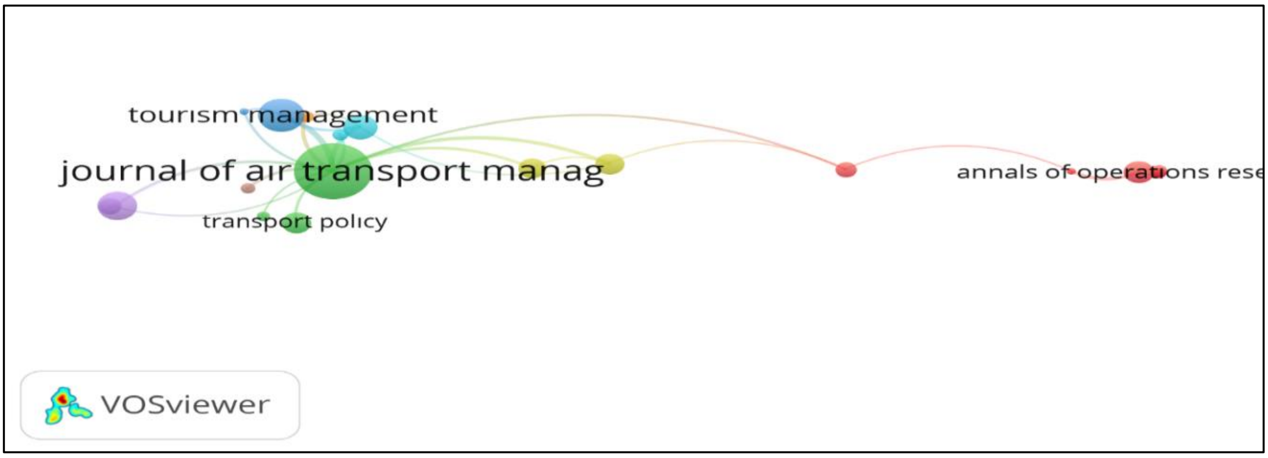

Figure 3. Citation of journals on VOSviewer

In table 4, institutions are listed according to the number of publications. Anadolu University and Helmholtz Association took first place here. Türkiye and Germany have been noteworthy countries at this point. It is seen that the USA, which is in first place in the citation order and the publication order, lags at this point. In figure 4, the most cited institutions are mapped. In this context, Waikato University formed the largest cluster with 188 citations. Then, British Columbia University ranked second with 178 citations. Anadolu University, which is in first place, fell behind in the citation ranking with 66 citations. In general, it is seen that there is an inverse proportionality between the number of publications and the number of citations.

Table 4. Distribution of documents by different institutions

Q. No.	Institution	Records	Percentage
one	Anadolu University	17	3,54%
2	Helmholtz Association	17	3,54%
3	German Aerospace Center Dlr	16	3.34%
4	Mississippi State University	7	1.46%
5	Hong Kong Polytech University	7	1.46%
6	University of British Columbia	5	1.05%
7	University Polytechnic Madrid	5	1.05%
8	University of Sydney	5	1.05%
9	NASA	5	1.05%
10	Embry Riddle Aeronaut University	5	1.05%
11th	Eskisehir Technic University	5	1.05%

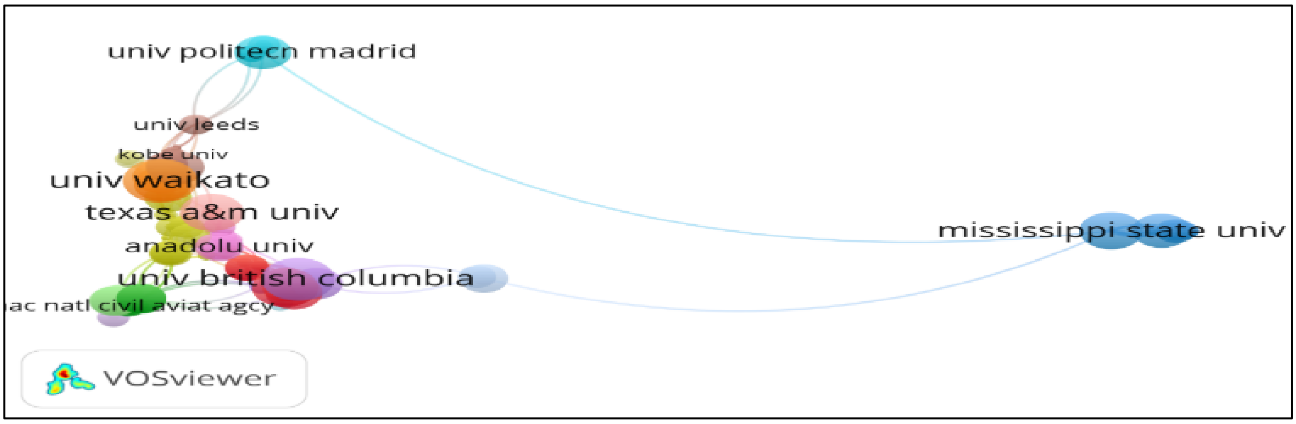

Figure 4. Citation of instituions on VOSviewer

In table 5, the language of the publications made as the last metric data was investigated. It was determined that 97.7% of the studies conducted were in English, and Spanish and Turkish were the languages that followed them. In Figure 5, the word cloud consisting of the titles of these publications is included. The feature of this transferred data is that it provides information about which words are the most repeated. Obtained in the word cloud made accordingly; It has been observed that studies related to sub-variables such as airport, airline, air transport, service quality, civil aviation, and risk management have been conducted.

Figure 5. Co-occurrence of author keywords on VOSviewer

Table 5. Distribution of Documents in various languages

Q. No.	Language	Records	Percentage
one	English	393	97.27%
2	Spanish	5	1.24%
3	Turkish	3	0.74%
4	Chinese	2	0.49%
5	Croatian	2	0.49%
6	French	one	0.24%
7	Italiy	one	0.24%

5. Conclusion

This study aims to provide new researchers a perspective on the developmental characteristics of studies in the field, related issues, leading authors and institutions, as well as a quantitative performance evaluation by looking at the metric features of the studies in the field of Aviation Management. These data will enable the researcher to make qualitative comments by transferring the quantitative metrics of journals, authors, countries, institutions, and citations. As a result of the analysis, it was on the distribution of studies in the field of aviation management by years. Looking at the transferred data, it is seen that the first publication in the post-liberalization period in the field of aviation management was made in 1985. There appears to have been small numbers of progress over the next 10 years. However, it can be said that as of 2011, the orientation to the field of aviation management has started. After this year, it is seen that interest in the field has increased regularly, and the number has reached its highest level in 2020. The reason for seeing 1 publication in 2022 is that the research was conducted in the first month of this year. According to the results of the research made based on countries, a total of 62 countries were found. It has been determined that the country that contributes the most to the field is the USA with 65 publications. When evaluated in terms of world aviation history, the fact that America is known as the base and initiator of aviation supports this conclusion. Afterward, this order was followed by China with 42 publications, Germany with 34 publications, Spain with 33 publications, Italy with 31 publications, and Türkiye with 30 publications. Of course, the most important academic development criterion in this ranking is not only the number of publications. In addition to the quantitative contribution of these publications to the literature, it is an important criterion to measure their qualitative strength. In this respect, another result of the research is given over the number of citations. According to the results of the research, the USA ranks first with 65 publications and 926 citations. It ranks 7th in the Australian publication ranking and second with 441 citations. While Italy ranks 3rd with 352 citations, Spain 4th with 343 citations, England ranks 5th despite being the country with the highest number of publications with 295 citations.

On the other hand, England ranks 6th with 79 citations, despite being the country with the most publications. At this point, it can be said that the quality of the publications, not the quantity, comes to the fore and contributes more to the literature. The number of publications and citations is very important in terms of literacy development in countries. However, at this point, it is also important to coresearchhe the authors. At this point, when we look at the authors who contributed the most to the field; Ayşe Küçük Yılmaz, Maria Freese, Jerrold Belant and Travis Devault became the most published authors with 6 publications. At this point, while the country with the highest number of publications is the USA in terms of authors, the authors from Türkiye Netherlands Italy, Spain Poland, which are lower in the number of publications, drew attention. At this point, the fact that the contribution to the relevant field in Türkiye is remarkable is considered important in terms of the contribution to the literature. Another criterion as important as countries and authors in the research is the journals in which they are published and the number of citations received by these journals. In this context, the Journal of Air Transport Management ranks first with 57 publications and 889 citations. After that, there was a big difference. Research in Transportation Business and Management ranked second with 10 publications. Although Tourism Management has published 4 publications, it ranked second in the citation ranking. Another noteworthy journal is Transportation Research Part E-Logistics and Transportation Review, which ranked third with 170 citations. Expert Systems with Applications, which was too far behind to enter the ranking table due to a large number of journals published in the field and the necessity of making a limitation in terms of the table, took place as the fourth most cited journal with 126 citations. This result is considered an important quality indicator in terms of the number of citations to the journal. One result of the research is to reveal the institutions in the countries where the publication is made. At this point, the aim is to point out an institution that has the qualifications to be considered as the authority in that country. In this respect, the most surprising result is that the USA, which is by far the leader in the number of publications, ranks 4th in the ranking of institutions. When the field literature is examined healthily, this is a normal result. Because the USA is the first and largest representative of the relevant field in the world, the number of institutions is very high. When we look at the institutions of other countries, the institutions that published the most were Anadolu University in TÜRKİYE and the Helmholtz Association in Germany. However, since the result that reveals the quality more deeply is related to the citation received by the institution, Waikato University formed the largest cluster with 188 citations. Then, British Columbia University ranked second with 178 citations. Anadolu University, which is in first place, fell behind in the citation ranking with 66 citations. In general, it is seen that there is an inverse proportionality between the number of publications and the number of citations. In addition, it was determined that 97.7% of the studies conducted were in English, and it was understood that Spanish and Turkish were the languages that followed them. In the word cloud pool where the titles of their research were examined, it was seen that studies related to sub-variables such as airport, airline, air transport, service quality, civil aviation, and risk management were conducted. For researchers who want to do research in this related field; He is experienced in human resources management, logistics management, financial management in aviation. Because it is a big budget with the progress of the place to be taken from the human in the information given to the focal points of the past researches.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Al, U. & Sezen, U. & Soydal, İ. (2012), Evaluation of Hacettepe University scientific publications by social network analysis method. Hacettepe University Journal of the Faculty of Letters, 29(1), 53-71.

Button, K., & Taylor, S. (2000). International air transportation and economic development. Journal of air transport management, 6 (4), 209-222.

De Bakker, FGA and Groenewegen, P. & Den Hond, F. (2005). A Bibliometric Analysis of 30 Years of Research and Theory on Corporate Social Responsibility and Corporate Social Performance. Business & Society, 44(3), 283–317.

Kraus, S., Filser, M., Eggers, F., Hills, GE, and Hultman, CM (2012). The Entrepreneurial Marketing Domain: A Citation and Co-Citation Analysis. Journal of Research in Marketing and Entrepreneurship, 14(1), 6-26.

Krauskopf, E. (2018). A bibliometric analysis of the journal of infection and public health: an electromagnetic actuator for biomedical application: a review. Polymers 12, 1–21.2008 2016. J. Infect. Public Health 11, 224 229.

Li, K. & Rollins, J. & Yan, E. (2018). Web of Science, 1997–2017 used in published research and review articles: a selective, dynamic, cross-domain, content-based analysis. Scientometrics 115, 1–20.

Mao, GZ & Zou, HY & Chen, GY & Du, HB & Zuo, J. (2015). Past, current, and future of MEMS technology. In: Thesis in Doctor of Philosophy. University Institute of biomass energy research: a bibliometric analysis. Renewable and Sustainable. Energy Lisbon. Rev. 52, 1823–1833.

Rey-Martí, A., Ribeiro-Soriano, D. & Palacios-Marqués, D., 2016. A bibliometric analysis of social entrepreneurship. Journal of Business Research, 69(5), pp.1651–1655.

Samiee, Saeed & Chabowski, Brian R (2012), Knowledge structure in international marketing: a multi-method bibliometric analysis, Journal of the Academy of Marketing Science, 40(2), 364-386.

SHGM, Annual Report, 2012, https://web.shgm.gov.tr/doc5/2012fr.pdf (Access: 10.08.2022).

Thelwall, M. (2008). Bibliometrics to webometrics. Journal of information science, 34(4), 605-621

Van Eck, NJ and Waltman, L. (2010). Software Survey: Vosviewer, A Computer Program for Bibliometric Mapping. Scientometrics, 84, 523–538.

Xue, Y. G. 2018. Modified Accident Analysis and İnvestigation Model For The General Aviation İndustry: Emphasizing On Human And Organizational Factors'' Journal Of Safety Research 67 :1–15

Župi˘c, I. and Cater, T. (2013). Bibliometric Methods in Management and Organization: A Review. ˇ SSRN Electron. J.18, 429–472.

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A Visualized Bibliometric Analysis of Mapping Research Trends Of Airline Business Models (ABMs) from 1985 to 2021

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Abstract

Deregulation and liberalization acts have contributed to the emergence of various airline business models (ABMs) in the airline industry by putting competition ahead. Influenced by catastrophic crises, increased competition, and changes in customer needs and expectations, airlines have had to innovate their business models or converge them with others over time. Thus, the topic of ABM has attracted tremendous scholarly attention. However, the extant literature lacks a visualized bibliometric study that investigates the evolution of ABM in depth. In this context, this paper employs a comprehensive visualized bibliometric analysis through CiteSpace software to present the evolution of the topic "airline business model" and its possible trends in the post Covid-19 era by benefiting 652 articles on ABMs published during the period from 1985 to 2021. The results reveal that studies on ABMs have increased especially over the past few years, and Journal of Air Transport Management is the leader outlet preferred by authors on this topic. In addition, although studies on low-cost carriers have an obvious dominance over studies on other ABMs, the results provide some evidence that studies on long-haul business models will increasingly continue in the future.

1. Introduction

The airline industry plays an important role in the economic growth and development of countries by facilitating integration into the global economy (The World Bank, 2021). An average of 12.5 million passengers and $18 billion worth of goods transported via 128,000 daily flights in 2019 can be expressed as proof of this situation. In addition, on an annual basis, 1478 commercial airlines carried 4.5 billion passengers via approximately 47 million scheduled flights (ATAG, 2020). Moreover, the fact that the airline industry employs approximately 88 million people worldwide, of which 11.3 million are directly in the aviation industry, clearly demonstrates its place in the global economy (ATAG, 2021).

Although the airline industry is one of the crucial industries that keep the global economy alive, it struggles with high fixed costs. The structure of the airline industry, which is easily affected by the crises, makes this struggle more difficult for the airlines. When looking at aviation history, it is seen that the concept of low cost has increased its impact on business models after the 1978 oil crisis, the 11/09 attack, and the 2008 crises in the airline industry which were dominated by traditional airlines. Thus, airlines head towards strategies that will keep their resilience strong in order to handle the crises successfully and accordingly strive to innovate their business models. On the other hand, recent changes in customer demands and needs, the intensity of competition in the markets served, corporate pressures, and the increasing appetite of airlines for successful business models are other factors that increase the pressure on business models. This causes convergence and hybridization on business models (Jiang, 2013; Corbo, 2017; Klophaus et al., 2012; Adiloğlu-Yalçınkaya and Besler, 2021).

The outbreaks experienced in the last 20 years are also among the above-mentioned crises that airlines have had to deal with. The outbreaks of SARS in 2003, bird flu in 2006, swine flu (H1N1) in 2009, MERS in 2012, and Ebola in 2014 have not seriously threatened the world economy but resulted in reduced demand for the airline industry in certain markets. The main reason is that air transport, which has gained great momentum since the beginning of the 2000s, increases the risk of spread of diseases by facilitating mobility with its characteristic of creating a bridge between travel points in a short time (Pereira and Mello, 2021; Brockmann and Helbing, 2013; Sun et al., 2020). The Covid-19 outbreak, which first appeared in Wuhan, China at the end of 2019, differentiated from previous epidemics and turned into a pandemic, not only affecting public health but also causing unprecedented damage to the global economy (Hou et al., 2021; Zhu et al., 2021). The measures employed to prevent the spread of the disease during the pandemic have considerably restricted mobility. Therefore, with the onset of the pandemic, the travel industry, and especially air transport, has experienced a very drastic decline (European Commission, 2020; Curley et al., 2020). With the peak of the crisis in April 2020, 90% of airline passenger traffic decreased (Jumar, 2020) and the airline industry experienced approximately 492 billion dollars loss in 2020. This figure accounts for about 60% of the airline industry's 2019 revenues. Moreover, future projections express that the return to 2019 figures will not occur before 2024 (Bouwer et al., 2021).

Considering the effects of the 9-11 terrorist attacks and the 2008 global financial crisis on aviation as the two major crises, the decline in passenger demand and its economic consequences due to the Covid-19 pandemic was recorded as the biggest blow to the aviation industry (Jumar, 2020). The pandemic has raised questions relating to how businesses worldwide will survive (Amankwah-Amoah et al., 2021). Consumer buying behavior (Mathurin et al., 2021) and the industry environment (Sheng et al., 2020) have been extensively reshaped during this period. All these developments create the impression that air transport will probably never be the same as before and will differ from the future scenarios presented in the current literature (Bauer et al., 2020). Bpharm (2020) also argues that a completely different world will be encountered post-Covid-19 and conceptualizes this period as the "post-Covid 19 era" or the "new normal". Song and Choi (2020) point out that such changes will lead to different demands and needs of passengers regarding the use of air transport.

Given the unprecedented challenges posed by the Covid-19 pandemic on the airline industry (Tuchen et al., 2020), strategic options for airlines include identifying the optimal structure of their networks and fleets, considering merger and integration opportunities, and restructuring their business models (Hsiu-Ying Kao et al., 2020). In this context, it is expected that the innovation in airline business models (ABMs) will be inevitable. Amankwah-Amoah et al. (2021) also argued that the way to successfully come through crises like Covid-19 depends on the ability of business models to innovate over time.

In the adventure of airline transportation that started with the traditional airlines, many different airlines have emerged that have adopted ABMs that meet different customer expectations and needs, such as full-service network carriers, low-cost carriers, and low-fare airlines. Therefore, possible innovative or revolutionary changes in the dimensions of ABMs (value proposition, customer, structure, value capture) would be seen as a normal expectation for the post-pandemic period. In this context, this study aims to shed light on past and possible trends in ABMs, with a comprehensive bibliometric analysis of the ABM literature by visualizing existing relationships and trends via CiteSpace software. In this context, the study seeks answers to the following research questions:

- What can we learn from the ABM literature for the future of the ABMs?
- What is the distribution of ABM studies by year?
- Which authors/institutions/journals/countries are prolific in terms of the ABM studies?
- Which clusters do the ABM studies gather around?
- Which studies come to the fore with a sudden burst at certain time intervals?
- What are the research trends regarding ABMs?

When the studies on ABMs are examined, it has not been encountered any study in the extension literature that retrospectively and comprehensively analyzes the evolution of the ABM. Current bibliometric studies on the airline industry research efficiency and effectiveness (Yakath Ali et al., 2021; See et al., 2022), airport capacity (Dixit and Jakhar, 2021), service quality (Bakır et al., 2022), air cargo transportation (Yıldız and Taşdemir), the future of air transportation through JATM literature (Tanrıverdi et al., 2020), and the relationship between air transport and ABM (Bergiante et al., 2015). Of these studies, the only one study focusing on ABMs, Bergiante et al. (2015) analyzed the relationship between air transportation and business model only descriptively and superficially by benefiting from the literature published between 1990-2012. In their study, Bergiante et al. (2015), presents limited results such as the distribution of ABM studies by years and productive authors/territories/countries in terms of ABM publications. The approach of this study also includes visual and quantitative analysis unlike Bergiante et al. (2015). In addition, this study focuses on a longer period (1985-2021) and provides clues to the post-crisis period by including the Covid-19 pandemic, which is the most catastrophic crisis experienced by the airline industry. The remaining parts of the study are as follows: Section 2 presents the data collection process based on the PRISMA approach. Section 3 mentions about the research methodology and other studies conducted using the relevant methodology. Section 4 presents publication and citation performance. Section 5 includes the results of graphical mapping analyses and while section 6 discusses the main results of the study. Last, section 7 contains some conclusions as well as limitations and suggestions for future studies.

2. The Bibliometric Data Collection Process

In this section, the data collection process is explained in steps. Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) was performed to increase the validity and reliability of the results in the data collection process of this study (Moher et al., 2009). Fig. 1. shows the PRISMA approach followed in the data collection process.

2.1. Identifying keywords and initial search

In the first stage of the data collection process, keywords related to the ABM were determined. Then, Science Citation Index Expanded (SCI-Expanded), Social Science Citation Index (SSCI), and Emerging Sources Citation Index (ESCI) were selected among the Web of Science (WoS) Core Collection Editions. Afterward, a search was made through the specified keywords (“airline business model” or “traditional airlines” or “full-service airlines” OR “flag carriers” OR “legacy airlines” OR “low-cost airlines” OR “low-fare airlines” OR “no-frills airlines” OR “budget airlines” OR “long-haul low-cost” OR “charter airlines” OR “hybrid airlines”) and 1078 records were identified. Since all keywords were searched together, duplicates were automatically excluded. WoS removes duplicates by searching these keywords together with "or". The data collection was conducted on May 21, 2021. This study does not include studies published after this date.

2.2. Screening the initial search results

In the second stage, the studies that are suitable for the exclusion criteria (“book and book chapters”, “conference proceedings” and “non-English studies”) were removed from the 1078 records by switching to the “analyze results” page from the WoS result screen. After the application of the criteria, the number of studies decreased from 1078 to 958. 958 studies were recorded by transferring them to a marked list on the WoS web page called the "airline business model" created by the authors for further review.

2.3. Assessment of full bibliometric information for eligibility and inclusion

The "Marked list" section in WoS allows the researchers to review the listed studies at different times and facilitates the assessment for the eligibility process, preventing inappropriate studies from being overlooked. After the screening phase, the remaining 958 studies were carefully examined in terms of compliance with the ABM topic. 307 studies were eliminated in the eligibility assessment stage and 652 studies were suitable for visualized bibliometric analysis. The dataset of 652 studies consists of author name, publication date, publication name, citation number, keywords, and digital object identification (DOI) for each study. Finally, a dataset of 652 studies was imported as plaintext from WoS for analysis via the CiteSpace 5.8.R3 software.

3. Research Methodology

This study aims to present the existing relationships and trends, and also new trends in the ABM topic with a comprehensive and systematic visualized bibliometric analysis. The bibliometric analysis method is expressed as the quantitative analysis of bibliometric data on a field, journal, or subject. Bibliometric analysis outlines large amounts of bibliometric data to present the state of intellectual knowledge structure and new trends in a topic or field of research (Donthu et al., 2021). Fig. 2 shows that the number of bibliometric studies has increased significantly over the past few years. The main reason behind this development is that advances in information technologies and statistics facilitate the data collection process (Cancino et al., 2017).

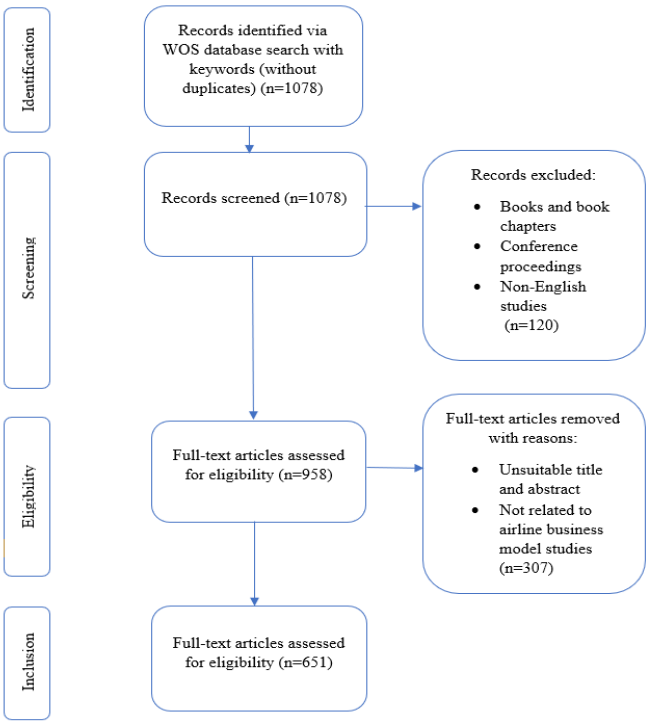

Figure 1. PRISMA approach diagram for data collection process

The extant literature contains numerous studies employing bibliometric analysis in different ways. Some of these studies reveal the development of a particular field of science (Demir et al., 2020; Mulet-Forteza et al., 2019). Some of the other studies may focus on the development of one journal in a particular field (Merigó et al., 2019; Donthu et al., 2021) or more than one journal (Modak et al., 2019; Koc and Boz, 2014). On the other hand, there are some studies on prolific scholars (Kivipelto, 2011), institutional contributors (Jogaratnam et al., 2005), and contributing countries (Chanbour et al., 2021; Ramkumar et al., 2020) in the literature.

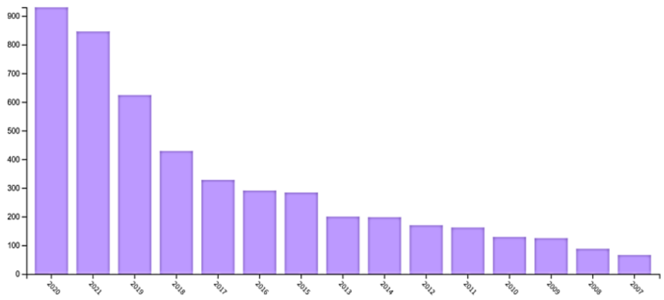

Figure 2. Distribution of ABM studies published between 1985-2021 by years (most to least)

Moreover, the literature also includes many examples of studies on-trend topics in various scientific fields such as machine learning (Su et al., 2021), eco-tourism (Khanra et al., 2021), blockchain (Guo et al., 2021), occupational health (Bautista-Bernal et al., 2021), safety culture (van Nunen et al., 2018), shipping finance (Alexandridis et al., 2018; Jiang et al., 2020), carbon emissions (Tian et al., 2018), social innovation (Foroudi et al., 2021), sustainability in a business (Ferreira et al., 2021), entrepreneurship and crisis (Xu et al., 2021), corporate social responsibility (Ji et al., 2020), high-speed railway (Chen and Liu, 2020).

This study analyzes 652 studies on the ABM published between 1985-2021 comprehensively and bibliometrically in a visual way. Research data were derived from the Core Collection Database of Web of Science (WoS). The WoS database contains the journals with the highest impact factor compared to different databases such as Scholar and Scopus. This reveals that the journals included in WoS are the most influential and therefore the most important. WoS also has a long history and is the most used database by bibliometric studies (Mongeon and Paul-Hus, 2016).

The study carries out publication performance analyses including total publications, citation analysis, and contributing authors/institutions/countries/journals, and graphical science mapping analyses including document co-citation, collaboration networks (authors, institutions, and countries), co-word analysis, and burst detection. Publication performance analysis reveals the distribution of studies on the ABM by years and academic journals, the most cited studies, the most productive authors, institutions, and countries. Document co-citation analysis, which assesses the relevance of documents based on how frequently they are cited together is used since it facilitates the identification of independent clusters and foundational themes (Belussi et al., 2019), while collaboration analysis is used for determining the network relationships of authors, institutions, and countries that contribute to the ABM literature. Finally, the word analysis is used to determine current and future trends in the ABMs

(Donthu et al., 2021), burst detection analysis, on the other hand, is used to reveal keywords, authors, institutions, and countries that stand out by exceeding a certain threshold in a limited time frame (Guzeller and Celiker, 2019).

Bibliometric and visualization studies in the literature use visual analysis software such as CiteSpace, VOSviewer, R Bibliometrix, BibExel, and HistCite, each of which has different prominent features. In this study, CiteSpace (5.8.R3) which is one of the visualization-based bibliometric analysis software is utilized since it offers unique and in-depth analysis possibilities such as burst detection (Li et al., 2017).

4. Publication and citation performance of ABM literature

In this section, the ABM literature is evaluated in terms of publication and citation performance. The figures regarding the number of publications and citations show that the number of publications has been generally increasing over the 20 years, although there are some minor breaks. At this point, Fig. 3 shows that the number of publications exceeded 50 (58) in 2015 for the first time, and then, the same publication number was reached again in 2016 and 2020, respectively. It is noteworthy that the increase in ABM studies immediately after the world economic crisis in 2008, MERS in 2012, Ebola in 2014, and Covid-19 pandemic in 2019, hindered the development of the airline industry and caused the airlines to deal with financial troubles. Here, of course, the strategic responses of airlines to the relevant crises by innovating their business models or converging them with different business models to cope with costs and explore different revenue paths may play a role. The annual total number of citations and the average number of citations per publication are also almost proportional to the course of the annual number of publications. However, this ratio had a decreasing effect on the number of citations per publication in years such as 2011 and 2015, when the number of publications increased more than the number of citations.

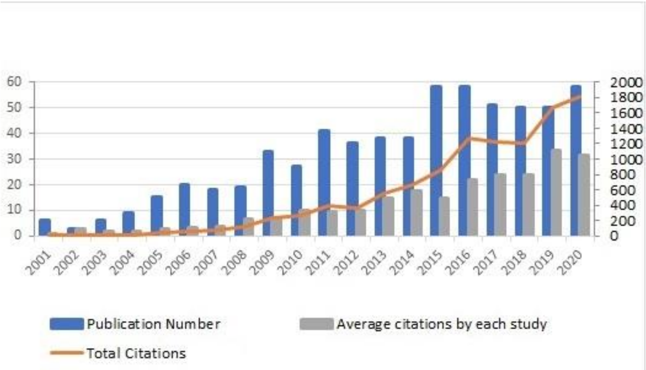

Figure 3. Publication and citation performance of ABM literature by years

After examining the publication and citation performance of the ABM literature, going a little deeper and looking at the publications focus on which ABMs, provides us with a foresight to understand how the interest of researchers and the course of the airline industry has changed during this period. Fig. 4 shows that research on pure Low-cost Carriers (LCCs) has gained significant upward momentum over two decades, albeit with some minor shake-ups. Considering only the year 2020, we can say that the research on LCCs is almost one and a half times the sum of the studies on traditional airlines and Full-service Carriers (FSCs). Undoubtedly, low-cost carriers, which have increased in number since the beginning of the 2000s, after the deregulation and liberalization movements were accepted in America and Europe, have a large share in the formation of this situation.

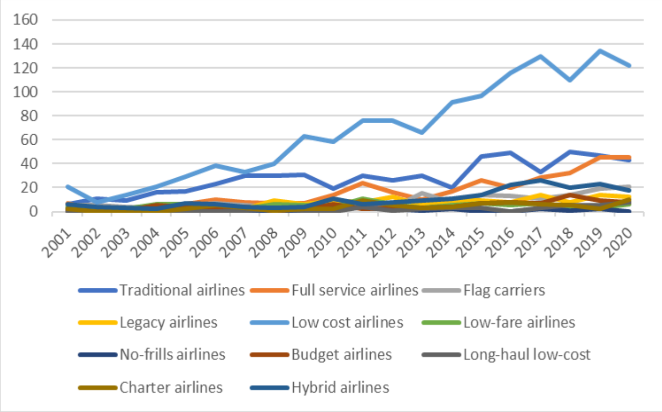

Figure 4. Distribution of the number of publications by years in terms of ABMs

The number of citations is frequently used as an evaluation criterion that shows the impact of the studies in a certain field (Belussia et al., 2019). For example, the most cited articles on the topic of the ABM researched within the scope of this study are important factors that reveals the studies on which the topic is shaped. The number of citations also reveals the impact of research and journals. In this context, Table 1 lists the most influential articles in the ABM literature in terms of the citation number. The most cited study on the ABM is the study of Escobar-Rodriguez et al. (2014) called “Online purchasing tickets for low-cost carriers: An application of the unified theory of acceptance and use of technology (UTAUT) model” (189 citations). According to the total number of citations, the study of O'Connell and Williams called "Passengers' perceptions of low-cost airlines and full-service carriers: A case study involving Ryanair, Aer Lingus, Air Asia, and Malaysia airlines" is the second while the study of Dobruszkes and Frederic called "An analysis of European low-cost airlines and their networks” ranks third. In addition, the figure for the annual average number of citations indicates that six studies were cited 10 or more times. Escobar-Rodriguez et al. (2014) is also the most cited study on average, while Leong et al. (2015) are the second and Akamavi et al. (2015) is the third.

In the adventure of airline transportation that started with traditional airlines, the literature shows that different ABMs meeting different customer expectations and needs such as network carrier business model, low-cost business model, and even ultra-long-haul (ULH) business model were researched. In this context, Table 1 also points out that the most shining ABM is the low-cost business model and its derivatives (16 studies among 20).

Table 1: Top 20 most cited studies in the ABM literature

Rank	Publication Title	Author(s)	Year	TC	AC/EY
1	Online purchasing tickets for low-cost carriers: An application of the unified theory of acceptance and use of technology (UTAUT) model	Escobar-Rodriguez, T.; Carvajal-Trujillo, E.	2014	189	23.63
2	Passengers' perceptions of low-cost airlines and full-service carriers: A case study involving Ryanair, Aer Lingus, Air Asia, and Malaysia airlines	O'Connell, JF; Williams, G	2005	184	10.82
3	An analysis of European low-cost airlines and their networks	Dobruszkes, Frederic	2006	167	10.44
4	The impact of low-cost carriers on airport and route competition	Dresner, M; Lin, JSC; Windle, R	1994	154	5.92
5	The impact of strategic management and fleet planning on airline efficiency - A random-effects Tobit model based on DEA efficiency scores	Merkert, Rico; Hensher, David A.	2011	137	12.45
6	Air transport and tourism - Perspectives and challenges for destinations, airlines, and governments	Bieger, T; Wittmer, A	2006	129	8.06
7	Competition between network carriers and low-cost carriers - retreat battle or breakthrough to a new level of efficiency?	Franke, M	2004	126	7
8	Service quality, satisfaction, and behavioral intentions: A study of low-cost airline carriers in Thailand	Saha, Gour C.; Theingi	2009	123	9.46
9	How do the demands for airport services differ between full-service carriers and low-cost carriers?	Barrett, SD	2003	122	6.78
10	Competitive advantage of low-cost carriers: some implications for airports	Gillen, D; Lall, A	2004	122	6.78
11	High-speed rail and air transport competition in Western Europe: A supply-oriented perspective	Dobruszkes, Frederic	2011	107	9.73
12	Airline performance in the new market context: A comparative productivity and efficiency analysis	Barbot, Cristina; Costa, Alvaro; Sochirca, Elena	2008	103	7.36
13	Customer satisfaction using low-cost carriers	Kim, Yu Kyoung; Lee, Hyung Ryong	2011	96	873
14	Where next for low-cost airlines? A spatial and temporal comparative study.	Francis, Graham; Humphreys, Ian; Ison, Stephen; Aicken, Michelle	2006	95	594
15	An SEM-artificial-neural-network analysis of the relationships between SERVPERF, customer satisfaction and loyalty among low-cost and full-service airline	Leong, Lai-Ying; Hew, Teck-Soon; Lee, Voon-Hsien; Ooi, Keng-Boon	2015	94	1343
16	Airport-airline interaction: the impact of low-cost carriers on two European airports	Francis, G; Fidato, A; Humphreys, I	2003	92	484
17	Airports' perspectives on the growth of low-cost airlines and the remodeling of the airport-airline relationship	Francis, G; Humphreys, I; Ison, S	2004	90	5
18	Key determinants of passenger loyalty in the low-cost airline business	Akamavi, Raphael K.; Mohamed, Elsayed; Pellmann, Katharina; Xu, Yue	2015	89	1271
19	Low-cost airlines in Europe: Reconciling liberalization and sustainability	Graham, Brian; Shaw, Jon	2008	89	636
20	The geography of European low-cost airline networks: a contemporary analysis	Dobruszkes, Frederic	2013	86	956

Notes: TC =Total Citations, and AC/EY =Average citations per year.

Considering the institutions and countries contributing to the ABM literature, we can say that 652 studies analyzed within the scope of the study were carried out in 67 countries. Table 2 presents a ranking of the ten most productive (by the total number of publications) countries and institutions that have contributed to the field of the "airline business model". According to the table, the most productive institution is Cranfield University (n=30), while the most productive country is the USA (n=102). England (n=96), Spain (n=73), Australia (n=50) and Germany (n= 42) follow the USA in terms of country publications while University of Bergamo (n=20), University of British Columbia (n=18) and Loughborough University (n=15) follows Cranfield University (n=30) in terms of institution publications.

Table 2: Top 10 countries and institutions contributing to the ABM literature

Institution	Total Publication	Total Citation	Average Citation	Country	Total Publication	Total Citation	Average Citation
Cranfield University	30	925	31.77	**USA**	102	1667	17.55
University of Bergamo	20	264	14.75	**England**	96	2701	30.43
University of British Columbia	20	625	33.5	**Spain**	73	1104	16.41
Loughborough University	18	582	33.33	**Australia**	50	923	20.18
University of Barcelona	15	230	16.2	**Germany**	42	539	13.74
Massachusetts Institute of Technology MIT	12	300	25.42	**Italy**	42	652	17.1
Embry Riddle Aeronautical University	11	47	4.91	**Peoples R China**	36	548	16.69
Griffith University	11	133	12.64	**Taiwan**	33	425	13.52
Hong Kong Polytechnic University	11	216	20.36	**South Korea**	31	343	11.68
University of Sydney	11	362	34.64	**Canada**	28	918	34.68

A total of 652 studies on the ABM retrieved from the web of science database were written by 1111 different authors. Table 3 presents the authors who contributed the most (in terms of the number of publications) to the ABM literature. When we look at the publication numbers of the authors in the table. we can easily say that the most contribution was provided by Redondi (n=17). Redondi is followed by Malighetti (n=15). Fu (n=13) and Fageda (n=12). When we look at the table in terms of the number of citations. the author ranking changes. Accordingly. the most prolific author is Dobruszkes with 10 studies and 539 citations. It is followed by Fu with 303 citations and O'Connell with 298 citations. Lastly. Fig. 5 graphically presents the total number of publications and citations of the authors

Table 3: Top 10 authors contributing to the ABM literature

Author	Total Publication	Total Citation	Average Citation
Redondi R	17	245	16.18
Malighetti P	15	235	17.6
Fu Xw	13	303	27.31
Fageda X	12	187	16.67
Castillo-Manzanoji	10	85	9.6
Dobruszkes F	10	539	55.4
O'connell Jf	10	298	29.8
Lopez-Valpuesta L	9	78	9.89
Paleari S	9	190	22
Lei Z	8	207	27

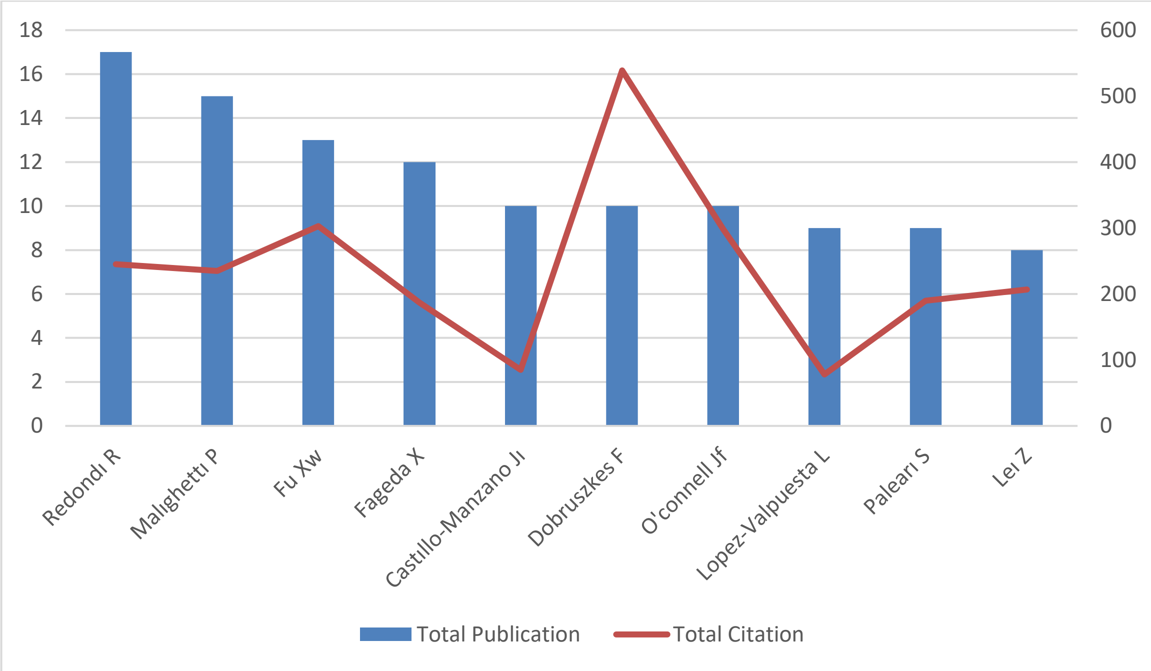

Figure. 5. Top authors contributing to the ABM literature

652 ABM studies included in the analysis were published in 198 different journals. This is due to the multidisciplinary character of the ABM topic. Table 4 shows the top 10 academic journals in which the most studies on ABM were published. These ten journals have more than half of the total number of articles with 353 articles published on the topic. The Journal of Air Transport Management is by far the leading journal on this topic with 191 studies published. Other key journals in the field are the Journal of Transport Geography and Transportation Research Part A Policy and Practice. with 30 and 28 publications. respectively. Additionally. Table 4 provides additional information in terms of the number of citations and the h-index. Journal of Air Transport Management is also the most-cited journal on this topic (total citation=6781) in terms of the total citation number. Tourism Management (total citation=919) and Journal of Transport Geography (total citation=831) are followed.

Table 4. Top journals contributing to the literature ABM

Journal	Total Publication	Total Citation	Average Citation	h-index
Journal of Air Transport Management	191	6.781	25.32	52
Journal of Transport Geography	30	831	30.1	17
Transportation Research Part A: Policy and Practice	28	577	21.14	11
Transportation Research Part E: Logistics and Transportation Review	21	577	28.19	14
Tourism Management	18	919	52.72	14
Transport Policy	16	294	18.94	8
Aviation Week Space Technology	15	5	0.36	1
Journal Of Transport Economics and Policy	12	379	32.25	9
Research In Transportation Business and Management	11	85	7.91	6
Transportation Research Record	11	30	2.82	3

5. Graphical mapping analyses

In this section. the intellectual knowledge of the ABM is presented by visual maps in order to deepen the descriptive bibliometric results given in the previous section. In this direction. document co-citation analysis. co-authorship analysis on authors and author affiliations (institutions. countries). and co-word analysis are carried out respectively.

5.1. Document co-citation

In this section. firstly. a co-citation analysis of 652 studies was carried out to reveal the main research topics and the clusters around these research topics in the ABM literature. Fig.7 presents the intellectual structure of the extant ABM literature. which includes 15 co-citation clusters from different topics. The most co-cited studies that form the background of the ABM literature are respectively "The evolving low-cost business model: Network implications of fare bundling and connecting flights in Europe" by Fageda et al. (2015) with 32 citations. "Low-cost carriers going hybrid: Evidence from Europe" by Klophaus et al. (2012) with 28 citations and "The geography of European low-cost airline networks: a contemporary analysis" by Dobruszkes (2013) with 27 citations.

Each color in Fig. 6 represents a cluster and a key topic in the ABM literature. Studies gathered around the same color are studies that contribute to the development of the same topic. This also shows us that the ABM literature is shaped by different topics. These clusters are labeled with the index terms of the studies that cite the studies they contain. Table 5 shows the 6 largest topic clusters in the ABM literature. Here. the largest cluster (#0) is labeled “airport traffic” and has 117 members. The average year of publication of the studies in this cluster is determined as 2003. The mean silhouette value of the #0 cluster is calculated as 0.886. This shows that the studies in the cluster are very compatible with each other and represent the cluster well. The mean silhouette value is a measurement that shows how similar and compatible an object is to its cluster compared to other clusters. As this value gets closer to +1. we can say that the studies in that cluster match well with the cluster and the fit is good. and as it gets closer to -1. there is a problem in matching and coherence (Rousseeuw. 1987). The log-likelihood ratio (LLR) value in this table also evaluates the goodness of fit of each cluster by comparing the probability that the same keyword is found in different clusters. while TF-IDF is often employed to measure the importance of a term in a document (Zhao et al.. 2020; Chen and Xiao. 2016).

Cluster #1 emerged as the second-largest cluster and is labeled as a “long-haul low-cost network”. There are 75 members of this cluster. and the average publication date of the documents included here is 2016. The mean silhouette value of the #1 cluster was determined as 0.851. Cluster #2. in the third row. with 73 members. is labeled as “pricing strategies”. The average publication date of the 73 documents covered by #2 was determined as 2011. The mean silhouette value of this cluster is 0.865. Cluster #3. labeled as the “Entry pattern”. is the fourth largest cluster with its' 70 members. The cluster. whose average publication date is 2014. has a mean silhouette value of 0.764. “UK airport” (#4) is ranked fifth out of 6 clusters. While the average publication years of the studies in the cluster with 67 members were 2009. the mean silhouette value was calculated as 0.932. “Construal level theory” takes the last place among the 6 largest clusters offered by CiteSpace software.

The study also performs burst analysis. which revealed the studies that were cited many times in a certain period. Table 6 indicates the 10 studies with the highest burst rating out of 25 citation bursts found by the CiteSpace software. Accordingly. the most effective study is Doganis (2001). which is in cluster #0 with a value of 9.86. Doganis (2001) received this value due to the citations he received in the three years between 2003 and 2006. The second most effective burst is de Wit (2012) in cluster #4 with a value of 9.40. De Witt (2012) has this value with the citations it received between 2015 and 2017. three years after it was published. The study. which ranks third in terms of burst value. is Fu (2015). which stood out with the citations it received between 2017-2021 with a value of 8.88 and was included in cluster #3.

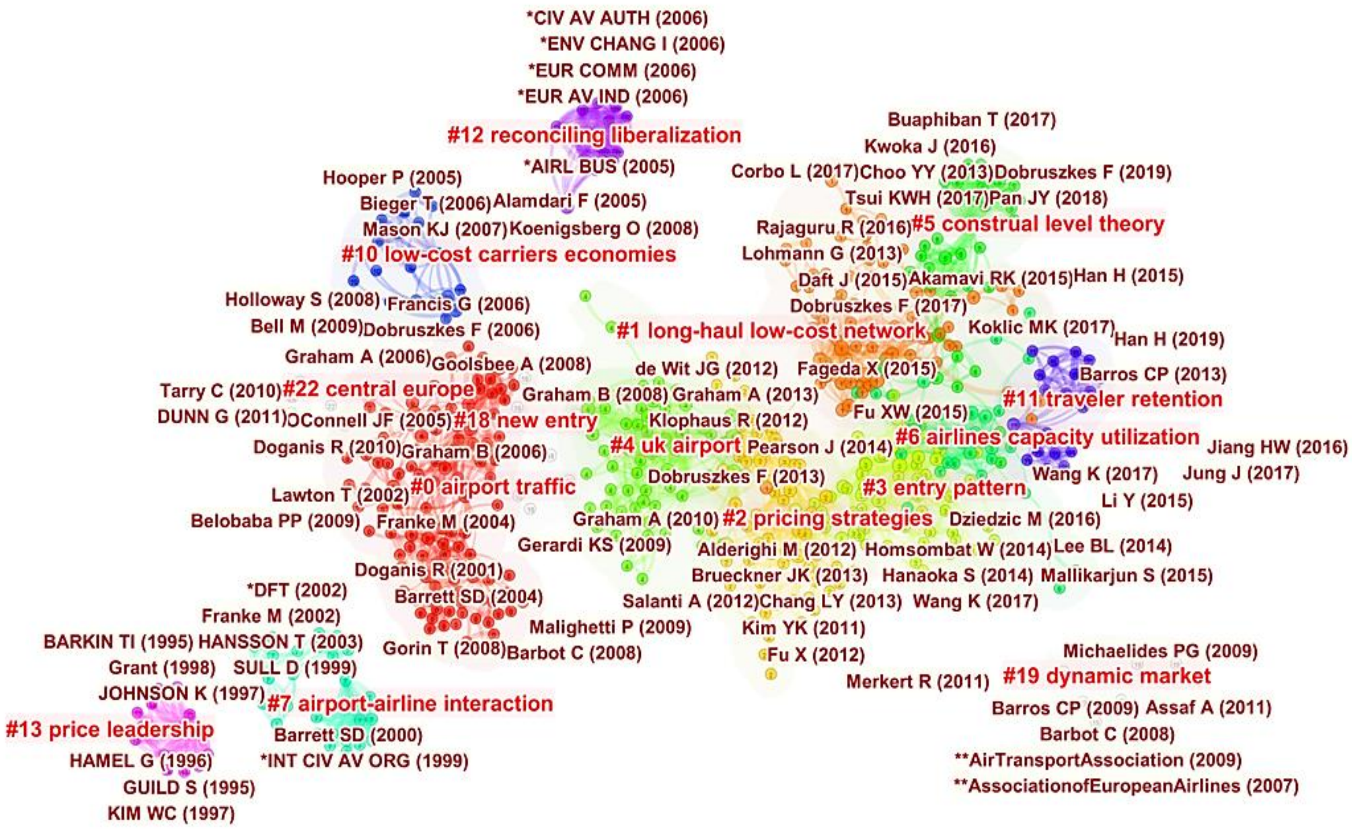

Figure 6. Document co-citation of ABM literature

Table 5: Topic clusters in line with document co-citation analysis

Cluster-ID	Size	Mean Silhouette	Label (TF-IDF)	Label (LLR)	Average Year
0	117	0.886	Low-Cost Carriers	Airport Traffic (109.15. 1.0E-4)	2003
1	75	0.851	Low-Cost Carriers	Long-Haul Low-Cost Network (80.99. 1.0E-4)	2016
2	73	0.865	Low-Cost Carriers	Pricing Strategies (143.14. 1.0E-4)	2011
3	70	0.764	China	Entry Pattern (95.53. 1.0E-4)	2014
4	67	0.932	Low-Cost Carriers	Uk Airport (85.15. 1.0E-4)	2009
5	41	0.919	Airline Selection	Construal Level Theory (70.75. 1.0E-4)	2016

Table 6: Top 10 documents out of 25 with citation burst

Rank	Bursts	References	Cluster ID	Begin	End	1985 - 2021
1	9.86	Doganis R. 2001. AIRLINE BUSINESS 21. 0. 0	0	2003	2006	
2	9.40	de Wit JG. 2012. J AIR TRANSP MANAG. 21. 17	4	2015	2017	
3	8.88	Fu XW. 2015. TRANSPORT RES A-POL. 79. 3	3	2017	2021	
4	8.69	Klophaus R. 2012. J AIR TRANSP MANAG. 23. 54	4	2014	2017	
5	8.61	Francis G. 2006. J TRANSP GEOGR. 14. 83	10	2008	2011	
6	8.39	Fageda X. 2015. J AIR TRANSP MANAG. 42. 289	1	2016	2021	
7	8.13	Dobruszkes F. 2017. J AIR TRANSP MANAG. 59. 50	1	2017	2021	
8	8.05	Dobruszkes F. 2013. J TRANSP GEOGR. 28. 75	4	2014	2018	
9	8.03	Franke M. 2004. J AIR TRANSP MANAG. 10. 15	0	2006	2009	
10	7.74	Graham A. 2013. TOURISM MANAGE. 36. 66	4	2014	2018	

5.2. Author collaborations

Fig. 7 visualizes the collaborative network between authors contributing to the ABM literature. Different colors in the figure represent different networks/clusters. In addition. the closeness of the authors shown in the figure indicates the degree of network collaboration relationship between authors. Accordingly. there are 3 different author collaboration clusters in the ABM literature. Renato Redondi is located at the center of the red cluster. In addition. most of the authors who constitute this cluster is from the University of Bergamo (Renato Redondi. Paolo Malighetti. and Stefano Paleari). While John O'Connell is at the center of the cluster seen in green. we can express that this cluster is UK-based and shaped by researchers from Cranfield University. Finally. at the center of the cluster. which is visualized in pink. is Anming Zhang. a senior author in the field. and this cluster originates from China. As a result. we can say that spatial proximity and citizenship have a significant impact on academic collaborations. and these concepts are important catalysts in the formation of author collaboration clusters over time.

5.3. Institution and country collaboration networks

Fig. 8 and Fig. 9 show institution and country collaboration networks that shape the ABM literature. Fig. 8 consists of three different clusters in parallel with the author's collaboration network. As mentioned before. the closeness of the names of the institutions in the figure reveals the level of collaboration between them. The UK institutions (Cranfield University and the University of Loughborough) are at the center of the network cluster in red. and these institutions carry out their academic cooperation on ABM with institutions in Australia. Although the green cluster in the network highlights the collaborations of institutions from different countries (Hong Kong. Canada. and the UK). we can see that Chinese researchers from these different institutions are behind those institutional collaborations here when we make a deeper analysis by benefiting from the author collaboration network. Finally. it is possible to say that two institutions in Italy stand out in the pink cluster. However. it should be noted that the institutions here are different from the institutions of the authors in the red cluster in the author collaboration network. One of the key factors that should be noted for institution clusters is also that former institutions of authors are significantly important in the formation of the institution clusters. In other words. the fact that changing institutions by authors over time and collaborating with authors from their former institutions constitute an important part of the institutional collaboration clusters. The country collaboration network in Fig.10 refers to the collaborations between the countries where the authors' institutions are located. Accordingly. countries such as the USA. England. Spain. Australia. and Italy at the center of the country collaboration network are prominent in the network.

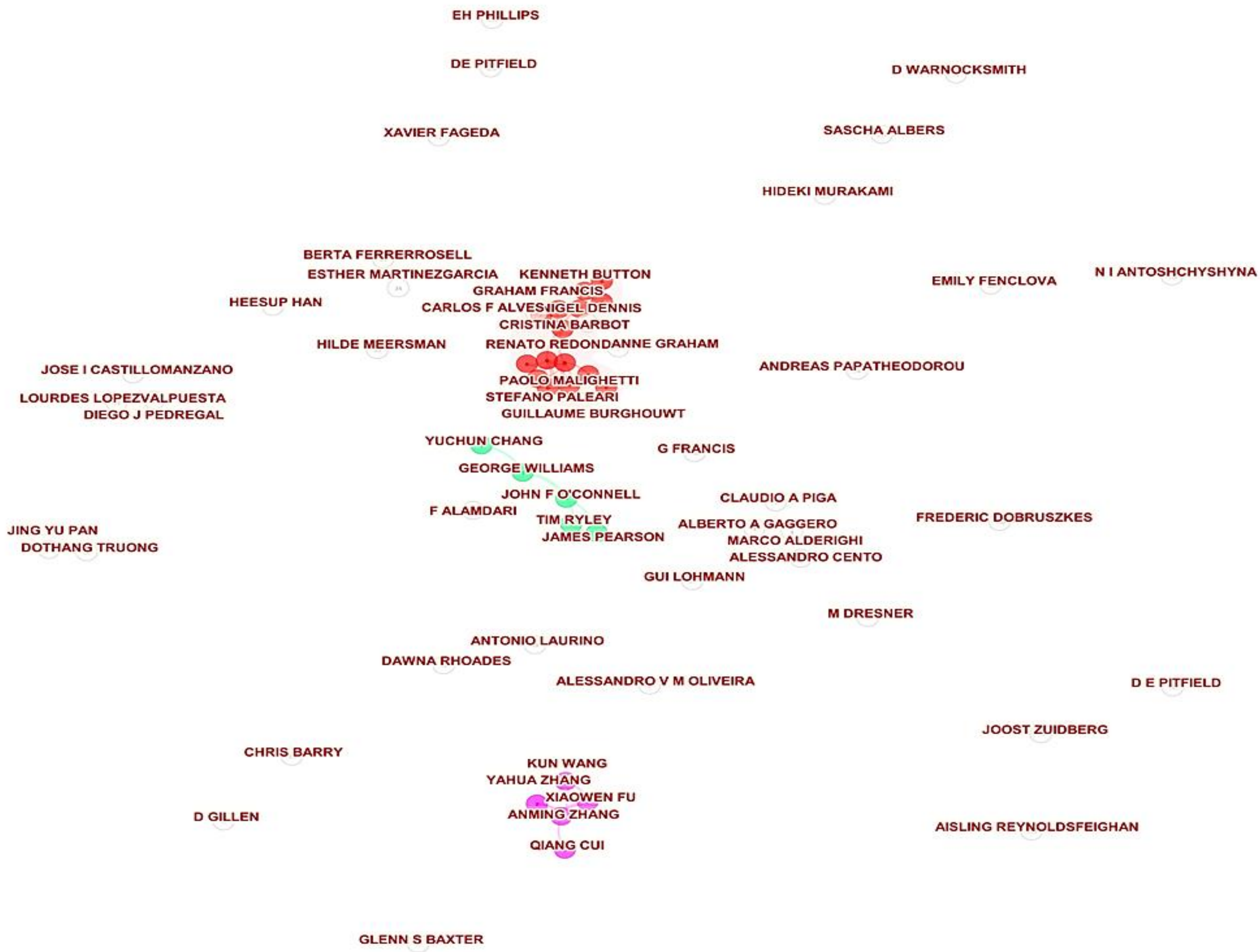

Figure. 7. Author collaboration network

5.4. Co-word analysis

Co-word analysis reveals the interests of a particular field through the keywords used by the authors for indexing documents (Tanrıverdi et al.. 2020). Accordingly. while Fig. 10 presents the visualization of co-word analysis of 652 studies in our sample. Table 7 shows the frequencies of the studies subject to analysis. Also. Table 8 demonstrates the results for bursts detected with the CiteSpace software. When we look at Fig. 10. we can see that the important keywords for the ABM literature are in the center and with larger fonts compared to the others. The word frequencies given in Table 7 also confirm this. Here. the study performs two different word frequency analyses to reveal the prominent words recently. While the first column of Table 7 gives the result for all studies between January 1985 and March 2021 (652 publications). the second column of the table includes the results of word frequency analysis for 58 studies published between January 2020 and March 2021 by referencing the emergence of the Covid-19 pandemic. Accordingly. the first column of Table 7. highlights the most essential keywords of the ABM literature as “airline (n:106)". “Impact (n:101)". “Competition (n:81)". “Model (n:76)". "Carrier (n:70)" respectively. It is possible to say that these words are among the most used keywords in ABM studies examining different business models. The right column of Table 7. reflecting the analysis results of studies published after the pandemic. almost completely parallels the words in the left column reflecting the analysis results of all studies. In addition. the concept of “low-cost carrier” on the during-Covid-19 period side of the table is three steps above the left side of the table. Moreover. there has been a noticeable increase in the frequency of the word "strategy". We can express the reason leading this as the fact that the importance of the low-cost concept has increased with the occurrence of Covid-19. and the airlines have focused on recovery and tried to produce strategies for their economic sustainability. However. although at least one year has passed since the onset of the pandemic and soon special issues have been published on the Covid-19 pandemic in the leading transport journals (e.g., Journal of Air Transport Management SI: Air Transport Covid-19). words such as “Covid”. “Covid-19”. "Coronavirus". "Pandemic". "Outbreak". "recovery" and "crisis" were surprisingly not seen in the list of the most used keywords. We can express the main reason behind this as the studies published on the pandemic are not yet at the expected level despite the elapsed time. or that these words are not included in the keywords of the studies published by their authors.

Citation burst results do not give the recent trend but give the prominent words in a certain period in the past and present. While 7 words with citation burst are observed within the calculations made by CiteSpace software. the words with the strongest burst value are low-cost airline (Burst strength = 4.96). low-cost airline (Burst strength = 4.71). China (Burst strength = 4.3). Burst values provide clues about the effectiveness levels of the related words in the years in which they were effective. Although the years (1997-2012) in which it was most effective are over. we can say that the low-cost business model still continues to be a hot topic as the business model on which the most studies have been published in the ABM literature so far (see Fig. 4). In addition. we can say that the effects of words such as “China”. “Growth” and “High-speed rail”. which have gained citation burst value with their influence in the ABM literature in recent years. will continue for a while. As a remarkable result. we must mention the long-haul low-cost (LHLCC) business model. is a new ABM here. Fig. 4 indicates that the studies on this business model have been increasing recently. Moreover. the gathering of studies on LHLCC around the label of "long-haul low-cost network" (see Table 5) shows that researchers' interest in studies on LHLCC has increased. and therefore, studies on LHLCC have increased. The ongoing debate over the LCCs' competitiveness with FSCs in long-haul markets and their sustainability will continue to be a hot topic in the ABM literature until airlines adopting the LHLCC business model are completely eliminated.

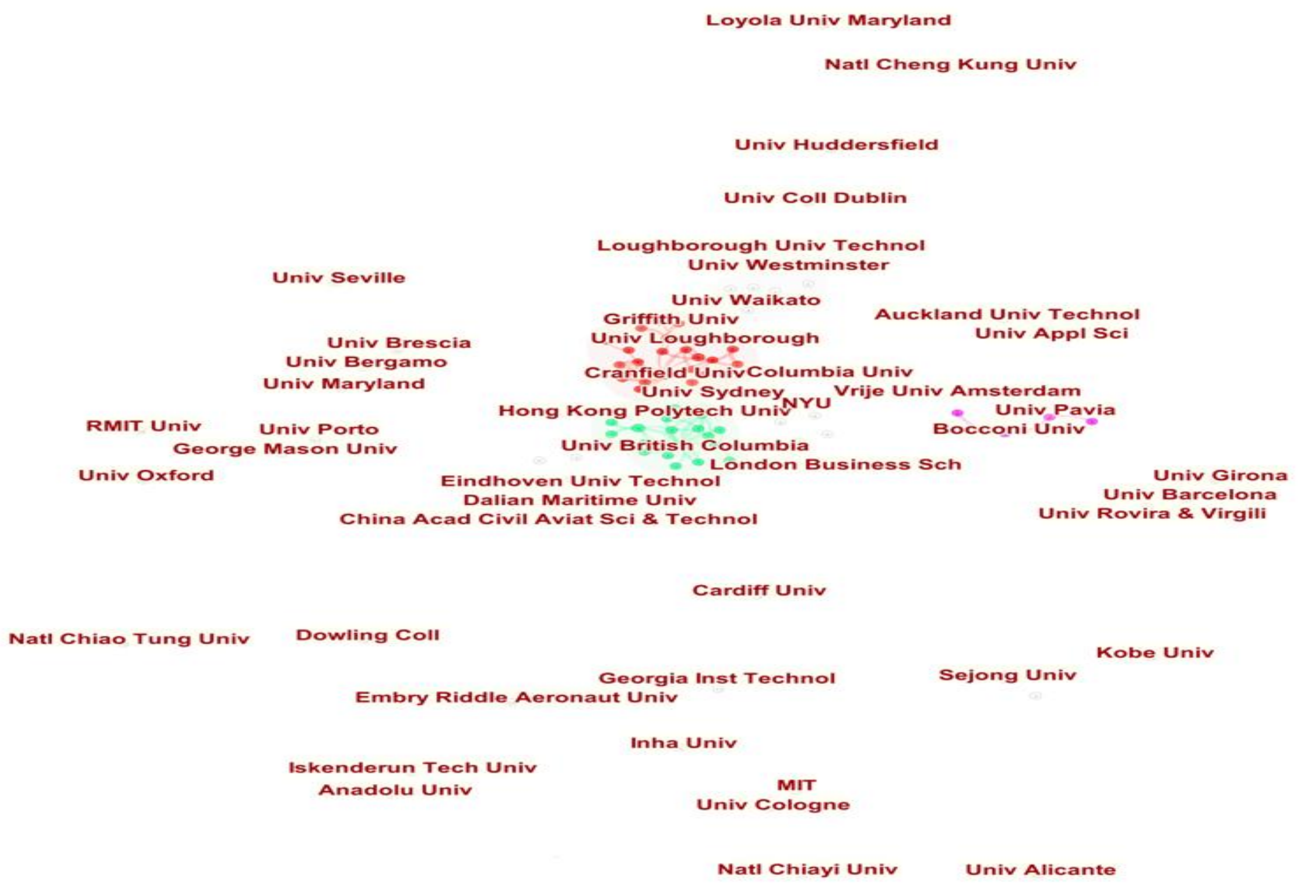

Figure 8. Institution collaboration network

6. Discussion and new trends of ABMs

Regarding the results of the study. it is possible to mention some overlaps and differences with the literature. First. Bergiante et al. (2015). which examines the relationship between air transport and business model in the literature. reveals that England. the USA. and Taiwan are the research centers for ABM studies. The results of this study are similar to the previous result by one difference (Spain instead of Taiwan). LCCs represent one of the main dynamics of the airline industry. especially since the early 2000s. Capacity. congestion. and competition have become the leading concepts of the airline industry as LCCs' activities increase (Dixit and Jakhar. 2021). Accordingly. the fact that the cluster with the highest number of members is “airport traffic” (LLR) under the label of “low-cost carriers (TFIDF)” (the average year of publication of the studies in the cluster is 2003). is an important proof of that. In recent years. LCCs seem as a rival to FSCs in long-haul markets. In this sense. one of the remarkable clusters that emerged as a result of the cluster analysis in our study is the "long-haul low-cost network" (LLR) under the low-cost carrier (TFIDF) label as a result of the increase in studies on LHLCCs (average publication year is 2016). This is a significant indicator that LCCs are taking the competition to a different level as a natural consequence of the LCC storm that has taken the industry by storm. In a study carried out by Tanrıverdi et al. (2020) in the leading journal of air transport. the Journal of Air Transport Management. the fact that the "low-cost carrier" is the largest cluster. seriously reveals the effectiveness of LCCs in the last 20 years. The literature also argues that the competitive environment created by low-cost airlines has a positive impact on the services and prices of airlines (Tanrıverdi and Küçük Yılmaz. 2021). In this direction. it is possible to say that the issue of “pricing strategies (LLR)”. which emerged as the third-largest cluster (average publication year 2011) under the label of “low-cost carrier (TFIDF)” in our study. is still among the issues that the airlines think about the most (Avogadro et al.. 2021; Wang et al.. 2018). On the other hand. ensuring efficiency and productivity has become the main agenda for airlines that desire to increase their load factor by achieving more demand at reasonable prices in the industry where costs can hardly be met (Yakath Ali et al.. 2021). The most cited studies in the ABM literature also reveal the quest for efficiency and productivity by airlines adopting different business models in a fiercely competitive environment (Merkert and Hensher. 2011; Franke. 2004; Barbot et al.. 2008). One of the results of our study that is similar to the literature is the results of the word analysis revealed by Tanrıverdi et al. (2020). Both studies overlap in terms of prominent words such as “airline”. “model”. “airport”. “impact” and “service quality”. This shows the consistency of the results of this study with the literature and means that the words mentioned are also significant words for ABM. However. we can interpret the prominence words "strategy" and "high-speed train" unlike the literature in studies published post-Covid-19 as follows. First. airlines are in quest of exit/survival/recovery/mitigation strategies from the Covid-19 crisis. Second. especially in short and medium-haul markets. the competition between high-speed rail and LCCs has increased in the recent period since high-speed rail is more dominant than LCCs in terms of frequency and cost. As a result. we can state that these two factors among the most critical factors for the future of ABMs will play an important role in the shaping of ABMs for the period post-Covid-19.

When the key findings obtained at the end of the study are considered holistically. we can say that LCCs have established a competitive advantage over FSCs in short and medium-haul markets and they have started to focus on long-haul markets. In this direction. despite some unsuccessful initiatives at different times from the past to the present. LHLCCs have come to the fore again over 15 years. Albers et al. (2020). in their study. state that there are 31 LHLCC initiatives from the past to the present. and there were 18 active LHLCCs in the light of the pre-pandemic data. In addition. some airlines are planning to start operations. Norwegian. Cebu Pacific. and Azul Airlines are some of the active and leading LHLCCs. However. the recent popularity of LCCs in long-haul markets has pushed FSCs to seek the ULH non-stop markets as a new business model. Another major factor causing this situation is the recent activity of Bosporus-Gulf hubs. Bosporus-Gulf hubs such as Doha. Abu Dhabi. Dubai. and Istanbul have allowed intercontinental air transport to increase through their location and rise in recent years. Thus. the FSCs. which were adversely affected by the new competitive environment. found the solution by clinging to the ULH business model in response to this situation. New aircraft developed by aircraft manufacturers with a commercially viable payload and fuel efficiency stands out as an important advantage in terms of the applicability of the ULH business model (Grimme et al.. 2020). Bauer et al. (2020) also underline that ULH routes can be a lifeline for airlines. especially in the period after the Covid-19 pandemic. Modeling and scenario analyses carried out by the authors underline that this new ABM will outperform other ABMs and create a serious competitive advantage. The possible benefits of the ULH business model are also listed as follows: Simultaneous higher load factors (seat) and yields. high network flexibility and ability to bypass densely populated central airports. and unique health benefits achieved by eliminating transfer times and fatigue.

Figure. 9. Country collaboration network

Figure 10. Co-word analysis

Table 7: The 20 most frequently used words in the ABM literature

1985 January-2021 March		2020 January-2021 March (During Covid-19)	
Frequency	**Word**	**Frequency**	**Word**
106	Airline	22	Impact
101	Impact	15	Airline
81	Competition	10	Low-Cost Carrier
76	Model	9	Carrier
70	Carrier	8	Competition
63	Low-Cost Carrier	8	Airport
60	Airport	7	Loyalty
46	Entry	7	Choice
42	Performance	7	Service Quality
39	Industry	6	Market
39	Market	5	Air Transport
33	Demand	5	Strategy
28	Network	5	Intention
25	Choice	5	Model
24	Low-Cost Airline	5	High Speed Rail
24	Service	4	Determinant
21	Determinant	4	Quality
20	Behavior	4	Perception
20	Service Quality	4	Travel
20	Travel	4	Moderating Role

Table 8: Top 7 keyword with the strongest citation bursts

Rank	Keywords	Year	Strength	Begin	End	1985 - 2021
1	Low-Cost Airline	1985	4.96	1997	2012	
2	Low-Cost Airline	1985	4.71	2011	2012	
3	China	1985	4.3	2017	2021	
4	Growth	1985	4.15	2017	2019	
5	High Speed Rail	1985	3.93	2018	2021	
6	Airport	1985	3.88	2006	2009	
7	Density	1985	3.7	2001	2012	

7. Conclusions. Limitations. and Future Studies

The deregulation in 1978 and the subsequent liberalization process resulted in the entry of different business models from traditional airlines into the airline industry (Mrázová and Kazda. 2021). This study reveals the current trend and relationships in the ABMs literature with the bibliometric analysis of the studies published on the ABM between 1985-2021. The study also explores the clues about the future of ABMs post-Covid-19 by employing word analysis of studies published post-Covid-19. To do this. 652 studies related to the topic were included in the bibliometric analysis as a result of the examination and extraction of 1078 studies in terms of title. keywords. and abstract. retrieved ed in the search made on WoS using 12 keywords. Thus. the study investigated: 1) the most cited studies on the ABM. 2) the most prolific authors. 3) the clustering and grouping of the ABM literature under some themes. and 4) the past and future trends in the ABM through burst and word analyzes (for the post-Covid-19 era).

ABMs have attracted the attention of researchers. especially since 2010. and it is possible to say that this trend has reached a higher level in 2018-2020. We can express that the first factor to be mentioned here is the 2008 economic crisis. which was experienced just before 2010. and its reflection on ABMs through increasing costs. Second. we can explain the increase in the number of publications in recent years as the change in the needs and expectations of customers due to the advancement in technology and the effects of the Covid-19 catastrophic crisis. which is much more than the previous crises. In addition. studies on low-cost carriers are quite dominant compared to other ABMs. Moreover. we can say that the most notable event which occurred in this process is the emergence of LHLCCs. which peeked into the long-haul markets of traditional airlines. As a result of the convergence between the LCC business model and the FSC business model. the studies on the LHLCC business model have also tended to increase and a cluster on LHLCC has arisen in the ABM literature. Such developments. which are threatening to FSCs. have resulted in FSCs turning towards the ULH business model with the help of technological advances. We can say that FSCs will adapt to the ULH business model. which is the response of FSCs to LCC competition before long.

While the study also sheds light on the collaborations based on authors. countries. and institutions in the ABM literature. On the other hand. the USA. and England based on country. Cranfield University. the University of Bergamo. and the University of British Columbia based on institutions. and the Journal of Air Transport Management which is the flagship in the field of air transport. based on journal contribute to the literature at most. In addition. "airport traffic". "long-haul low-cost network" and "pricing strategies" are among the prominent topics in the ABM literature. Moreover. it is expected that research on "long-haul low-cost network". which has emerged relatively recently among others. will increase gradually. In addition. while Redondı R is the leader in the ABM literature in terms of publication performance. Dobruszkes. F. holds the leadership by far in terms of publication efficiency. with more citations to his fewer studies than Redondı. R. And the last. when we focus on the keywords used. we can see that the studies published post the Covid-19 pandemic did not differ much from the words used in the studies published before the pandemic. However. the word "strategy" is relatively prominent. and we can say that this is due to the research conducted on airlines' recovery and mitigation strategies. At this point. when considering that there are relatively few studies on the pandemic. we can express the reason as the ongoing publishing processes of studies on the pandemic in journals and expect an increase in terms of publication numbers on the pandemic near future.

The negative effects of the Covid-19 pandemic on the airline industry. as the most serious crisis experienced by the industry. are. of course. undeniable fact. The bankruptcy of some airlines or filing for bankruptcy protection of others (for example. LATAM. Alitalia. Atlas Global). regardless of size. can be expressed as proof of this. Thus. in the next period. airlines are expected to take actions to increase their resilience against more harmful crises and innovate their ABMs. considering the experience, they have gained from the current pandemic. To give an example. it is known that Covid-19 has increased people's tendencies toward technology. In this direction. although it is not among the results of the study. we can predict that this condition and the digital transformation trend that started before the Covid-19 pandemic will deeply affect the ABMs adopted by airlines in terms of their sustainability. In other words. airlines are required to innovate their business models in order to meet the demands and needs of their customers in the new digital world post the pandemic.

This study. which deals with the ABM literature comprehensively. bibliometrically. and visually. is expected to make a significant contribution to the literature. as it reveals the past and future trends of the ABM literature. However. the study also has some limitations. First of all. the documents examined in the study cover the years between 1985 and 2021. These documents are limited to articles published in journals indexed in the ESCI. SCI-E. and SSCI in the Web of Science database. In the following years. it would be appropriate to repeat this study by considering different criteria and conditions to reveal the development of the ABM literature. Secondly. the study focuses on ABM. one of the key topics of air transport. Conducting bibliometric studies focusing on different key topics of air transportation in the future will provide important insights on related topics to air transportation readers who closely follow the development of the topics. Finally. the study uses CiteSpace (5.8.R3). one of the visualization-based bibliometric analysis software. Possible bibliometric studies can be carried out using the up-to-date versions of the CiteSpace software at the time of analysis and the up-to-date analysis tools added to the software. In addition. studies can be carried out using the Bibliometrix library through the R programming language on the R Studio or using the VOSviewer.

Ethical approval

Not applicable.

Conflicts of Interest

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

References

Adiloğlu-Yalçınkaya. L.. & Besler. S. (2021). Institutional factors influencing business models: The case of Turkish Airlines. Journal of Air Transport Management. 91.

Akamavi. R.K.. Mohamed. E.. Pellmann. K.. Xu. Y. (2015). Key determinants of passenger loyalty in the low-cost airline business. Tour. Manag. 46 (0). 528-545

Albers. S.. Daft. J.. Stabenow. S.. & Rundshagen. V. (2020). The long-haul low-cost airline business model: A disruptive innovation perspective. Journal of Air Transport Management. 89.

Alexandridis. G.. Kavussanos. M. G.. Kim. C. Y.. Tsouknidis. D. A.. & Visvikis. I. D. (2018). A survey of shipping finance research: Setting the future research agenda. Transportation Research Part E: Logistics and Transportation Review. 115. 164–212.

Amankwah-Amoah. J.. Khan. Z.. & Osabutey. E. L. (2021). COVID-19 and business renewal: Lessons and insights from the global airline industry. International Business Review. 1-10.

ATAG. (2020). Global Fact Sheet Septemper 2020. Air Transport Action Group.

ATAG. (2021. 04 06). Facts figures. Air Transport Action Group: https://www.atag.org/facts-figures.html

Avogadro. N.. Malighetti. P.. Redondi. R.. & Salanti. A. (2021). A tale of airline competition: When full-service carriers undercut low-cost carriers fares. Journal of Air Transport Management. 92.

Bakır. M.. Akan. Ş.. Özdemir. E.. & Atalık. Ö. (2022). A bibliometric analysis of airport service quality. Journal of Air Transport Management. 104.

Barbot. C.. Costa. Á.. & Sochirca. E. (2008). Airlines performance in the new market context: A comparative productivity and efficiency analysis. Journal of Air Transport Management. 14(5). 270–274.

Barrett. S. D. (2004). How do the demands for airport services differ between full-service carriers and low-cost carriers? Journal of air transport management. 10(1). 33-39.

Bauer. L. B.. Bloch. D.. & Merkert. R. (2020). Ultra Long-Haul: An emerging business model accelerated by COVID-19. Journal of Air Transport Management. 89.

Bautista-Bernal. I.. Quintana-García. C.. & Marchante-Lara. M. (2021). Research trends in occupational health and social responsibility: A bibliometric analysis. Safety Science. 137.

Belussi. F.. Orsi. L.. & Savarese. M. (2019). Mapping Business Model Research: A Document Bibliometric Analysis. Scandinavian Journal of Management. 35(3).

Bergiante. N. C. R.. Santos. M. P. S.. & Espírito Santo. R. A. (2015). Bibliometric study of the relationship between business model and air transport. Scientometrics. 105(2). 941–958.

Bieger. T.. & Wittmer. A. (2006). Air transport and tourism—Perspectives and challenges for destinations. airlines and governments. Journal of air transport management. 12(1). 40-46.

Bouwer. J.. Saxon. S.. & Wittkamp. N. (2021). Back to the future? Airline sector poised for change post-COVID-19. In McKinsey (Vol. 22). Retrieved from https://blog.sodipress.com/wp-content/uploads/ 2021/08/back-to-the-future-airline-sector-poised-for-change-post-covid-19_vf.pdf% 0Ahttps:// www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/ back -to-the-future-airline-sector-poised-

Bpharm. G. M. (2020). A Lens on the Post-COVID-19 “New Normal” for Imaging Departments. Journal of Medical Imaging and Radiation Sciences. 361-363.

Brockmann. D.. & Helbing. D. (2013). The hidden geometry of complex. network-driven contagion phenomena. Science.

Cancino. C.. Merigó. J. M.. Coronado. F.. Dessouky. Y.. & Dessouky. M. (2017). Forty years of Computers & Industrial Engineering: A bibliometric analysis. Computers and Industrial Engineering. 113. 614–629.

Chanbour. H.. El Masri. J.. Bsat. S.. Bsat. A.. Jiblawi. A.. & Sunna. T. (2021). A Bibliometric Analysis of Neurosurgery Research Productivity in Arab Countries Between 2005 and 2019. World Neurosurgery. 154. e313–e319.

Chen. G.. & Xiao. L. (2016). Selecting publication keywords for domain analysis in bibliometrics: A comparison of three methods. Journal of Informetrics.

Chen. X.. & Liu. Y. (2020). Visualization analysis of high-speed railway research based on CiteSpace. Transport Policy. 85. 1–17.

Corbo. L. (2017). In search of business model configurations that work: Lessons from the hybridization of Air Berlin and JetBlue. Journal of Air Transport Management. 64. 139–150.

Curley. A.. Dichter. A.. Krishnan. V.. Riedel. R.. & Saxon. S. (2020). Coronavirus: Airlines brace for severe turbulence. McKinsey & Company.

Demir. E.. Yaşar. E.. Özkoçak. V.. & Yıldırım. E. (2020). The evolution of the field of legal medicine: A holistic investigation of global outputs with bibliometric analysis. Journal of Forensic and Legal Medicine. 69.

Dixit. A.. & Jakhar. S. K. (2021). Airport capacity management: A review and bibliometric analysis. Journal of Air Transport Management. 91.

Dobruszkes. F. (2006). An analysis of European low-cost airlines and their networks. Journal of Transport Geography. 14(4). 249-264.

Dobruszkes. F. (2011). High-speed rail and air transport competition in Western Europe: A supply-oriented perspective. Transport policy. 18(6). 870-879.

Dobruszkes. F. (2013). The geography of European low-cost airline networks: a contemporary analysis. J. Transp. Geogr. 28. 75–88.

Donthu. N.. Kumar. S.. Mukherjee. D.. Pandey. N.. & Lim. W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research. 133. 285–296.

Donthu. N.. Kumar. S.. Pandey. N.. & Gupta. P. (2021). Forty years of the International Journal of Information Management: A bibliometric analysis. International Journal of Information Management. 57.

Dresner. M.. Lin. J. S. C.. & Windle. R. (2017). The impact of low-cost carriers on airport and route competition. In Low Cost Carriers (pp. 241-260). Routledge.

European Commission. . (2020). Future of Transport: Update on the economic impacts of COVID-19. The European Commission's science and knowledge service.

Escobar-Rodríguez. T.. & Carvajal-Trujillo. E. (2014). Online purchasing tickets for low cost carriers: An application of the unified theory of acceptance and use of technology (UTAUT) model. Tourism Management. 43. 70-88.

Ferreira. J. J.. Fernandes. C. I.. Schiavone. F.. & Mahto. R. V. (2021). Sustainability in family business – A bibliometric study and a research agenda. Technological Forecasting and Social Change. 173.

Foroudi. P.. Akarsu. T. N.. Marvi. R.. & Balakrishnan. J. (2021). Intellectual evolution of social innovation: A bibliometric analysis and avenues for future research trends. Industrial Marketing Management. 93. 446–465.

Francis. G. et al. (2003). Airport–airline interaction: the impact of low-cost carriers on two European airports. Journal of Air Transport Management 9. 267–273.

Francis. G.. Humphreys. I. M.. & Ison. S. G. (2004). Airports' perspectives on the growth of low-cost airlines and the remodelling of the airport-airline relationship. Tourism Management. 25. 507–514.

Francis. G.. Humphreys. I.. Ison. S.. Aiken. M. (2006). Where next for low cost airlines? A spatial and temporal comparative study. Journal of Transport Geography 14 (2). 83–94.

Franke. M. (2004). Competition between network carriers and low-cost carriers - Retreat battle or breakthrough to a new level of efficiency? Journal of Air Transport Management. 10(1). 15–21.

Gillen. D.. & Lall. A. (2004). Competitive advantage of low-cost carriers: some implications for airports. Journal of Air Transport Management. 10(1). 41-50.

Graham. B.. Shaw. J.. 2008. Low-cost airlines in Europe: reconciling liberalization and sustainability. Geoforum 39 (3). 1439–1451.

Grimme. W.. Bingemer. S.. & Maertens. S. (2020). An analysis of the prospects of ultra-long-haul airline operations using passenger demand data. Transportation Research Procedia. 51. 208–216.

Guo. Y. M.. Huang. Z. L.. Guo. J.. Guo. X. R.. Li. H.. Liu. M. Y.. Nkeli. M. J. (2021). A bibliometric analysis and visualization of blockchain. Future Generation Computer Systems. 116. 316–332.

Guzeller. C. O.. & Celiker. N. (2019). Bibliometrical analysis of Asia Pacific Journal of Tourism Research. Asia Pacific Journal of Tourism Research. 24(1). 108–120.

Hou. M.. Wang. K.. & Yang. H. (2021). Hub airport slot Re-allocation and subsidy policy to speed up air traffic recovery amid COVID-19 pandemic --- case on the Chinese airline market. Journal of Air Transport Management. 1-13.

Hsiu-Ying Kao. G.. Wang. S. W.. & Farquhar. J. D. (2020). Modeling Airline Crisis Management Capability: Brand attitude. brand credibility and intention. Journal of Air Transport Management. 89.

Ji. Y. G.. Tao. W.. & Rim. H. (2020). Mapping corporate social responsibility research in communication: A network and bibliometric analysis. Public Relations Review. 46(5).

Jiang. C.. Bhat. C. R.. & Lam. W. H. K. (2020). A bibliometric overview of Transportation Research Part B: Methodological in the past forty years (1979–2019). Transportation Research Part B: Methodological. 138. 268–291.

Jiang. H. (2013). Service quality of low-cost long-haul airlines – The case of Jetstar Airways and AirAsia X. Journal of Air Transport Management. 26. 20–24.

Jogaratnam. G.. Chon. K.. McCleary. K.. Mena. M.. & Yoo. J. (2005). An analysis of institutional contributors to three major academic tourism journals: 1992-2001. Tourism Management. 26(5). 641–648.

Jumar. U. (2020). Annual review 2020. In at - Automatisierungstechnik (Vol. 68).

Khanra. S.. Dhir. A.. Kaur. P.. & Mäntymäki. M. (2021). Bibliometric analysis and literature review of ecotourism: Toward sustainable development. Tourism Management Perspectives. 37.

Kim. Y. K.. & Lee. H. R. (2011). Customer satisfaction using low cost carriers. Tourism management. 32(2). 235-243.

Kivipelto. M. (2011). World's most prolific researcher in Alzheimer's disease: Professor Bengt Winblad. European Geriatric Medicine.

Klophaus. R.. Conrady. R.. & Fichert. F. (2012). Low cost carriers going hybrid: Evidence from Europe. Journal of Air Transport Management. 23. 54–58.

Koc. E.. & Boz. H. (2014). Triangulation in tourism research: A bibliometric study of top three tourism journals. Tourism Management Perspectives. 12. 9–14.

Leong. L.Y.. Hew. T.S.. Lee. V.H.. Ooi. K.B. (2015). An SEM-artificial-neural-network analysis of the relationships between SERVPERF. customer satisfaction and loyalty among low-cost and full-service airline. Expert Syst. Appl. 42. 6620e6634.

Li. X.. Ma. E.. & Qu. H. (2017). Knowledge mapping of hospitality research − A visual analysis using CiteSpace. International Journal of Hospitality Management. 60. 77–93.

Mathurin. P.. Aliaj. O.. & Fontanella-Khan. J. (2020). Pandemic triggers wave of billion-dollar US bankruptcies. Retrieved from https://www.ft.com/content/277dc354-a870-4160-9117-b5b0dece5360

Merigó. J. M.. Miranda. J.. Modak. N. M.. Boustras. G.. & de la Sotta. C. (2019). Forty years of Safety Science: A bibliometric overview. Safety Science. 115. 66–88.

Merkert. R.. & Hensher. D. A. (2011). The impact of strategic management and fleet planning on airline efficiency - a random effects tobit model based on dea efficiency scores. Transportation Research Part A: Policy and Practice. 45(7). 686–695.

Modak. N. M.. Merigó. J. M.. Weber. R.. Manzor. F.. & Ortúzar. J. de D. (2019). Fifty years of Transportation Research journals: A bibliometric overview. Transportation Research Part A: Policy and Practice. 120. 188–223.

Moher. D.. Liberati. A.. Tetzlaff. J.. & Altman. D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ (Online). Vol. 339. pp. 332–336.

Mongeon. P.. & Paul-Hus. A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics. 106(1). 213–228.

Mrázová. M.. & Kazda. A. (2021). The direction of airlines business models - up or down? (Post Covid-19 crisis - case study). INCAS Bulletin. 13(1). 263–274.

Mulet-Forteza. C.. Genovart-Balaguer. J.. Mauleon-Mendez. E.. & Merigó. J. M. (2019). A bibliometric research in the tourism. leisure and hospitality fields. Journal of Business Research.

O'Connell. J. F.. & Williams. G. (2005). Passengers' perceptions of low cost airlines and full service carriers: A case study involving Ryanair. Aer Lingus. Air Asia and Malaysia Airlines. Journal of air transport management. 11(4). 259-272.

Pereira. D. da S.. & Soares de Mello. J. C. C. B. (2021). Efficiency evaluation of Brazilian airlines operations considering the Covid-19 outbreak. Journal of Air Transport Management. 91.

Ramkumar. S.. Kartheeswaran. S.. Kesavan. M. B.. Lavakumar. V.. Elanjiyam. G.. Thamaraiselvi. G.. & Priya. B. S. (2020). A bibliometric study on soft computing techniques and applications in top most populated asian countries. Materials Today: Proceedings. 37(Part 2). 2938–2946.

Rousseeuw. P. J. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. Journal of Computational and Applied Mathematics. 20(C). 53–65.

Saha. G. C. (2009). Service quality. satisfaction. and behavioural intentions: A study of low-cost airline carriers in Thailand. Managing Service Quality: An International Journal.

See. K. F.. Ülkü. T.. Forsyth. P.. & Niemeier. H. M. (2022). Twenty years of airport efficiency and productivity studies: A machine learning bibliometric analysis. Research in Transportation Business and Management.

Sheng. J.. Amankwah-Amoah. J.. Khan. Z.. & Wang. X. (2020). COVID-19 Pandemic in the New Era of Big Data Analytics: Methodological Innovations and Future Research Directions. British Journal of Management.

Song. K.-H.. & Choi. S. (2020). A Study on the Behavioral Change of Passengers on Sustainable Air Transport after COVID-19. Sustainability. 1-18.

Su. M.. Peng. H.. & Li. S. (2021). A visualized bibliometric analysis of mapping research trends of machine learning in engineering (MLE). Expert Systems with Applications. 186.

Tanrıverdi. G.. Bakır. M.. & Merkert. R. (2020). What can we learn from the JATM literature for the future of aviation post Covid-19? - A bibliometric and visualization analysis. Journal of Air Transport Management. 89.

Tanrıverdi. G.. & Küçük Yılmaz. A. (2021). The Transformation of Strategic Airline Alliances and Airline Joint Ventures: Where Are They Headıng? Independent Journal of Management & Production. 12(1).

Tian. X.. Geng. Y.. Zhong. S.. Wilson. J.. Gao. C.. Chen. W.. Hao. H. (2018). A bibliometric analysis on trends and characters of carbon emissions from transport sector. Transportation Research Part D: Transport and Environment.

Tuchen. S.. Arora. M.. & Blessing. L. (2020). COVID-19. Airport user experience unpacked: Conceptualizing its potential in the face of. Journal of Air Transport Management. 89-99.

van Nunen. K.. Li. J.. Reniers. G.. & Ponnet. K. (2018). Bibliometric analysis of safety culture research. Safety Science. Vol. 108. pp. 248–258.

Wang. K.. Zhang. A.. & Zhang. Y. (2018). Key determinants of airline pricing and air travel demand in China and India: Policy. ownership. and LCC competition. Transport Policy. 63. 80–89.

WorldBank. (2021). Air Transport. Understanding Poverty Transport. Retrieved from https://www.worldbank.org/en/topic/transport/brief/air transport

Xu. Z.. Wang. X.. Wang. X.. & Skare. M. (2021). A comprehensive bibliometric analysis of entrepreneurship and crisis literature published from 1984 to 2020. Journal of Business Research. 135. 304–318.

Yakath Ali. N. S.. Yu. C.. & See. K. F. (2021). Four decades of airline productivity and efficiency studies: A review and bibliometric analysis. Journal of Air Transport Management. 96.

Yıldız. R.. & Taşdemir. M. (2021). Bibliometric analysis on air cargo transportation for two decades. Journal of Aviation. 5(2). 230-240.

Zhao. X.. Ke. Y.. Zuo. J.. Xiong. W.. & Wu. P. (2020). Evaluation of sustainable transport research in 2000–2019. Journal of Cleaner Production.

Zhu. C.. Wu. J.. Liu. M.. Wang. L.. Li. D.. & Kouvelas. A. (2021). Recovery preparedness of global air transport influenced by COVID-19 pandemic: Policy intervention analysis. Transport Policy. 106. 54–63.

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A Critical Assessment of The Public Service Obligations (PSO) in European Air Routes

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Abstract

The deregulation of air transport created the need to safeguard an acceptable level of air connectivity between urban centres and remote European regions. To this end, several protection schemes have been developed around the world, including the imposition of Public Service Obligations (PSOs) in a few European air routes. Thirty years after the establishment of PSOs in Europe, the debate over their efficiency and effectiveness is still active. This paper offers an overview of the European PSO program along with a review of the academic literature exploring the main issues that accompany the PSO scheme. The main findings that call for consideration from both scholars and policymakers are the need to strengthen the competition in these non-commercially attracting routes, the necessity for central network design and coordination and the requirement for transparency and open dissemination of information regarding the PSO routes.

1. Introduction

Since 1944 when Chicago Convention set the operational and legal frame of civil aviation, international air transportation was strictly regulated via bilateral Air Service Agreements (ASAs). The liberalization of air transportation started in the U.S. with the Airline Deregulation Act in 1978. Europe followed in 1987 with three liberalization packages evolving into a single aviation market formally established within the EU in 1997. The deregulation of the aviation market was accompanied by intensified airline competition, improved efficiency, enhanced service quality and market growth (Calzada & Fageda, 2014). On the other hand, the removal of protectionist restrictions exposed national flag carriers to competition forcing them to adjust their operation to the new, commercial terms. Liberalization led airlines to shrink their service network and focus only on profitable routes, leaving regional services underdeveloped (Di Francesco & Pagliari, 2012). To mitigate regional traffic loses, Essential Air Services (EAS) program was launched in the USA in 1978 and similar schemes were applied in Australia, Canada and India (Merkert & Williams, 2013), while EU introduced Public Service Obligations (PSO) in air routes in 1992. Thirty years later the debate over the effectiveness of the PSO scheme is still active, with researchers questioning the ever-growing numbers of PSO routes and trying to benchmark their efficiency across countries and/or airlines, using mainly operational and financial criteria (Costa et al. 2021).

This paper firstly offers an overview of the policies engaged by governments around the world to enhance air connectivity in remote regions[1] and then focuses on the European PSO scheme, by analyzing the available data about all PSO routes operating in Europe and discussing the recent debate over the selected policies. The aim of this paper is to critically evaluate the effectiveness of the PSO scheme after three decades of operation and to make suggestions about its improvement in face of the ominous future of the European aviation due to challenges posed by the covid-19 pandemic and the rising fuel prices that forebode one more crisis.

[1] There are similar but not identical definitions of "remote" regions in the literature. Dijkstra & Poelman (2008) suggest that a region is considered remote if less than half its population can drive to the centre of a city of at least 50,000 inhabitants within 45 minutes. According to OECD (2011), a region is considered to be remote if at least 50% of its population needs to drive 60 minutes or more to reach a populated centre with more than 50,000 inhabitants. European Commission advices that remoteness and isolation of a region should be assessed with regard to the territory of the Member State, its administrative, business, education and medical centres, but also with regard to the territory and such centres of other Member States with which it shares a border (C 194/01, 2017).

2. Air Connectivity Policies Across The World

To avoid the apparent isolation of remote areas that are not commercially appealing, a heterogeneous set of policies have been implemented around the world, which can be grouped into the following four categories (Fageda et al, 2018): 1) route-based policies, 2) passenger-based policies 3) airline-based policies and 4) airport-based policies.

In the first case (route-based policies), which is the most widely used, states have the right to impose Public Service Obligations on specific airlines, when the air transport services offered are not sufficient in terms of frequency, seats offered and pricing if designed only on free market terms and profitability criteria (Williams & Pagliari, 2004; Williams, 2010).

In such cases, states can hold open tenders for the assignment of the specific PSO routes to the lowest bidders by placing in the tenders' binding conditions regarding the frequency and timetable of the routes, the capacity and types of aircraft, as well as the amount of fares. In the event that no carrier expresses interest, additional restrictions may be imposed make specific routes more attractive, such as an exclusive right of operation for a period of 4-5 years and financial compensation of the carrier that will take over the route (Fageda et al, 2018).

Typical examples of protected PSO routes are those connecting large urban centers in a country to small islands or the latter to each other. In such cases sea transport is the only available connection, but it is accompanied by long journey times, low frequencies and very often, high ticket prices. At the same time, demand from the local market is very low and unable to attract a commercial airline, even though air connectivity is vital for access to health and education facilities, tourism development, commercial activity, economic development and connectivity to a regional or national urban center (Merkert & O'Fee, 2013).

In the second case (passenger-based policies), discounts are granted to residents of remote areas or a single price for air fares. For example, Spain has instituted a 50% discount on airline ticket prices for all permanent residents of the Canary and Balearic Islands. Similarly, residents of the Scottish Highlands and Islands enjoy a 40% discount (Calzada & Fageda, 2014). Portugal has a single reduced ticket price for residents of the Azores traveling by air to Madeira (Fageda et al, 2018). Recently (2019), the Greek state implemented the Transport Equivalent measure for air transport as well, returning a part of the ticket cost to the permanent residents of the island regions (GTP, 2019). It must be noted that route-based policies may be combined with passenger-based policies and air connectivity may be achieved not only by airplanes but with other types of aircraft, too. For example, Spanish PSOs coexist with a scheme of passenger-based policies and the remote region of Ceuta is connected with the Spanish mainland via helicopter flights from the local heliport (Poulaki et al., 2020).

In the third case (airline-based policies), air service to remote areas is provided by state-owned airlines. Such cases are observed in Algeria (Air Algerie), Argentina (Aerolineas Argentinas), Egypt (EgyptAir), Ethiopia (Ethiopian Airlines), Indonesia (Garuda Indonesia), Pakistan (PIA), and Russia (Aeroflot). The main problem with this model is that no efficiency incentives are provided. Competition is distorted and governments usually have weak control over the efficient implementation of the state aid granted (Fageda et al, 2018).

The fourth case (airport-based policies) is divided into two separate schemes: a) incentives for air carriers to launch new routes to remote destinations and b) financial incentives for airports in remote areas to continue their operation (Fageda et al, 2018). Incentives to airlines can take the form of discounts on airport charges, subsidies, guarantees for commercial development of the specific routes and promotional actions to increase demand (Fageda et al, 2018). In the second case, remote area airports, which are usually small in size and state-owned, are financially supported by the central or local government. The Government of Canada for example subsidizes 13 remote airports through the Airports Capital Assistance Program (ACAP) (Fageda et al, 2018).

The policies described above can be applied in combination by each country to enhance the connectivity of remote areas.

The USA started to implement the program Essential Air Services (EAS) in 1978 and similar schemes were later implemented by Australia (the program Remote Air Services Subsidy-RASS) (Merkert & Williams, 2013). Subsequently, the European Commission implemented a series of measures to strengthen economic and social cohesion and balance uneven distribution of mobility opportunities between European regions. These measures include travel subsidies for permanent residents and/or the establishment of PSO routes in regional or developing areas, so as to ensure the viability of non-commercial airlines deemed essential to the economic and social development of the specific areas, at the lowest possible cost for taxpayers (ICAO, 2003).

India operates a slightly modified air rights allocation model, whereby more commercial airlines "subsidize" less commercial ones. According to this program called Route Dispersal Guidelines (RDGs), airlines are classified into three categories: Category I includes air connections between one of the cities of Bombay, Calcutta and Delhi, each other or to another major city. Category II includes connections involving airports of North East India, cities of Jammu, Kashmir, Andaman Lakshadweep and Nicobar Islands. Category III includes all other destinations. Under the RDG programme, any airline operating between Category I airports is obliged to also serve Category II and III airlines.

3. Public Service Obligations in Europe

European Commission put into force a set of measures to ensure economic and social cohesion and to prevent mobility discrepancies among diverse European regions. These measures include subsidies to residents and/or the imposition of Public Service Obligations of peripheral or development regions to allow survival of thin routes which are considered vital for the economic and social development of this region, at the lowest cost possible to the taxpayer (ICAO, 2003). In the first case, discounts are offered on the market fares or a flat rate on the ticket prices. In the second case, the member states have the right to impose PSOs on specific routes where adequate provision of air services in terms of regularity of service, capacity and pricing is not possible if carriers are solely taking their own commercial consideration into account (Williams, 2005) and to activate an open tendering procedure regulating the frequencies, capacity, flight schedules, fares and aircraft types. The PSO route is assigned to the air carrier that claims the lowest or no subsidy for a period of 4-5 years.

3.1. PSO legislation

Public Service Obligations were established in Europe in 1992 with Council Regulation 2408/1992 (EEC, 1992), which permitted the EU Member States and two European Free Trade Association (EFTA) countries (Iceland, Norway) to impose a

PSO and award financial compensation in respect of specific scheduled air services. Regulation 2408/1992 was reformed with Regulation (EC) No 1008/2008 of the European Parliament and the Council of 24 September of 2008, on common rules for the operation of air services in the Community (EC, 2008). Article 16 describes the general principles for Public Service Obligations: "A Member State, following consultations with the other Member States concerned and after having informed the Commission, the airports concerned and air carriers operating on the route, may impose a Public Service Obligation in respect of scheduled air services between an airport in the Community and an airport serving a peripheral or development region in its territory or on a thin route to any airport on its territory any such route being considered vital for the economic and social development of the region which the airport serves. That obligation shall be imposed only to the extent necessary to ensure on that route the minimum provision of scheduled air services satisfying fixed standards of continuity, regularity, pricing or minimum capacity, which air carriers would not assume if they were solely considering their commercial interest."

Additionally, article 17 of the Regulation (EC) No 1008/2008 describes the public tender procedure for Public Service Obligation and article 18 sets the PSO examination requirements that may be asked by the European Commission.

3.2. Overview of PSO routes across Europe

The Member States have a large degree of autonomy regarding the characterization of a specific route as a PSO and about the regulatory authority which may be a national government department (e.g. Spain, Greece, Croatia, Ireland, Lithuania, Estonia and Sweden) or a regional authority, (e.g. Finland and the Czech Republic) or a combination of both (e.g. in Italy and Portugal) or even at the community level, as is the case in France and Great Britain (Bråthen & Eriksen, 2018; Martínez Raya & González-Sánchez, 2020).

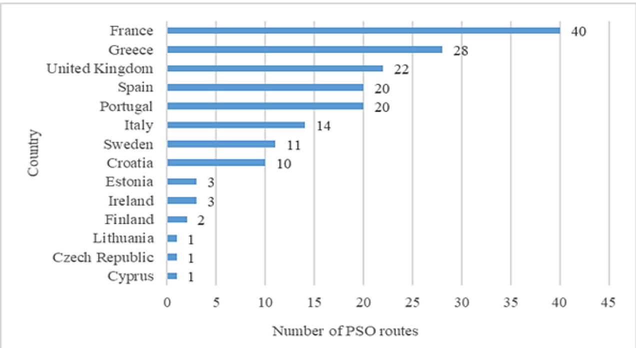

Figure 1. Number of PSO routes across European countries

As a consequence, a large degree of heterogeneity in PSO practices is witnessed across Europe (Figure 1 and Tables 1 and 2). According to the latest (as of 18.9.2019) PSO inventory table published by the European Commission (EC, 2019) there are 176 PSO routes in Europe dispersed over 14 countries. Some countries (e.g., France, Greece, United Kingdom, Spain, Portugal) make extensive use of the PSO policies, while others (e.g., Cyprus, Czech Republic, Lithuania) are more restricted (Figure 1). There are also countries such as Austria, the Netherlands, etc. that do not make use of the PSO program, possibly because of adequate connectivity through surface transport; however, the overall number of PSO routes continues to grow over the years (Merkert & O'Fee, 2013).

Table 1. Characteristics of the European PSO routes

Number of Months of operation per year	Number of PSO routes	Percentage
2	2	1.14%
3	1	0.57%
6	2	1.14%
7	4	2.27%
9	1	0.57%
10,5	1	0.57%
11	3	1.70%
12	159	90.34%
no data	3	1.70%
Sum	*176*	*100.00%*
Number of airlines operating the route		
0	5	2.84%
1	143	81.25%
2	9	5.11%
3	5	2.84%
4	8	4.55%
no data	6	3.41%
Sum	*176*	*100.00%*
PSO justification (More than one may be applicable on the same		
Peripheral route	142	39.89%
Development route	114	32.02%
Thin route	100	28.09%
Open PSO or Restricted to one carrier		
Open PSO	39	22.16%
Restricted PSO	135	76.70%
no data	2	1.14%
Sum	*176*	*100.00%*
Type of PSO route		
within member-state	173	98.30%
cross-border	3	1.70%
Sum	*176*	*100.00%*
Economic		
Yes	133	75.57%
No	41	23.30%
no data	2	1.14%
Sum	*176*	*100.00%*
Preferential fares for residents (Yes/No)		
Yes	63	35.80%
No	113	64.20%
Sum	176	100.00%
Additional discounts for residents? (Yes/No)		0.00%
Yes	28	15.91%
No	148	84.09%
Sum	*176*	*100.00%*
EU air carrier from another Member State		
Yes	21	11.93%
No	146	82.95%
Max fare € (Yes/No)		
Yes	126	71.59%
No	50	28.41%
Sum	*176*	*100.00%*

As seen in Table 1, most routes justified as PSO are Peripheral routes, but they may also be Development or Thin routes, or their combinations. The first two types of PSO routes connect peripheral or development regions with urban centers. A *peripheral* region is typically a remote region or one that is difficult to reach from the capital and other major cities of a Member State. A *development* region is economically lagging, as measured by factors such as per capita GDP or unemployment rate. Typically, this condition would be met by less developed regions within the context of EU regional policy (where the GDP per capita is less than 75% of the EU average). The qualification as a development region may also be based on a comparison with the national gross domestic product or unemployment rate of the Member State in question, given that the respective situations of regions within the same Member State may vary substantially (C 194/01, 2017). Regarding the *thin* routes, the Regulation 1008/2008 does not define a quantitative criterion for evaluating the "thinness" of a route due to the varying circumstances that may exist in different Member States. On the other hand, based on the Commission's experience in a large number of PSO cases, it appears safe to say that a route with more than 100,000 annual passengers cannot normally be considered a thin route within the meaning of the Regulation (C 194/01, 2017).

The PSO routes are usually operated all year round, but in some cases, they are contracted only on a seasonal basis. When operations on a route exhibit a strong seasonal pattern, air carriers are likely to concentrate capacity during periods of high demand and significantly reduce capacity during other periods on certain routes. In such cases, PSO obligations may be imposed in low-demand seasons to maintain a minimum level of service during those times of the year when the supply of air services tends to be very low (C 194/01, 2017).

About ¾ of the PSO routes are compensated, with the average compensation per passenger (pax) on 124,97€ (Table 2).

Table 2. Statistics of the European PSO routes

Load Factor (pax/actual seats)	**Percentage**
min	2.06%
max	347.92%
average	85.54%
min	2.06%
PSO passengers in 2017 (or 2016)	**Number of passengers**
min	65
max	1.226.762
average	95.534
Minimum number of annual seats	**Number of**
min	1.152
max	1.100.000
average	98.704
Compensation per passenger	**Euros (€)**
min	4.39
max	1.076.80
average	124.97

While the average minimum number of annual seats required by the PSO was 98.704, it wasn't fully covered by the actual passenger volume (95.534 pax). Diverse types of aircrafts operate in PSO routes, with an average load factor of 85,54%. The fares are regulated with a price-cap in most of the cases (71,5%) but preferential fares or additional discounts for the residents are not widely adopted.

4. PSO Literature Review

The air PSO literature focuses primarily on theoretical dimensions of the public service delivery program.

Reynolds-Feighan's (1995) study provides a detailed, critical review of the early years of the European PSO program in comparison with the equivalent EAS program in the United States, concluding that there is an apparent gap at the central European level in terms of the uniform definition of the standards for the inclusion of a line in the PSO regime, which results in an uneven distribution of European resources between the member states. In addition, cabotage restrictions prevent the system from operating in a more efficient and flexible manner. All the above factors, acting in combination, do not allow the overall development of European aviation.

Williams & Pagliari (2004) produced a comparative survey of the implementation of the PSO program among European states, spotting large heterogeneities and discontinuities regarding the extent of PSO line coverage networks, minimum service levels, award criteria and financial oversight of the program by regulatory authorities. They proposed that the management and financing of all PSO lines should be taken at a central European level.

Merkert & O'Fee (2013) focused their study on regulatory authorities that impose Public Service Obligations and limitations, with the aim of highlighting best practices among those already in use at the European level. The conclusion of their research was that there is generally a lack of clarity and completeness in PSO contracts and that local authorities should have more freedom and autonomy in establishing the criteria for the provision of the public service to better serve local specificities. They also suggest aligning objectives between airlines, airports and regulators as well as enhancing the transparency of the framework in place with more open dissemination of information across Europe.

A second body of literature deals with demand and competition issues in the PSO routes.

Calzada Fageda (2014) studied the implementation of alternative aviation PSO policies in five European countries over an eight-year period (2002-2010). Their results show that the implementation of discount schemes had the potential to increase air demand in the island regions and possibly enhance competition and increase the number of connections. On the other hand, the imposition of a public service led to a reduction in competition, while the effects on flight numbers varied from case to case, depending on the state restrictions imposed.

Similarly, Socorro & Betancof (2020), studying the ticket subsidy scheme applicable to permanent residents of the Canary Islands, concluded that, if this line operates under a monopoly regime, the monopoly will try to compensate as much as possible the subsidizing residents by increasing the ticket price and burdening non-resident passengers. In order to mitigate this undesired effect, competition should be promoted and one possible way to do this is to increase the resident discount to make it profitable for other airlines to enter. With competition, the undesirable effects of subsidizing residents only are mitigated, such a policy, however, requires significant public expenditure and should be implemented after a prior cost-benefit analysis.

In addition, the study by Alvarez-Albelo et al (2020) has found that the application of passenger-based policies discriminates between permanent residents of remote areas (who are entitled to discounts on ticket prices) and visitors, who are charged higher fares. This phenomenon, according to the authors, can act as a deterrent for the development of tourism in these areas which are very often islands, pushing those interested to choose alternative destinations with lower access costs.

Another category is econometric PSO studies that focus on price and overall efficiency issues.

The research team of Abreu et al (2018) made an empirical assessment of the evolution of the PSO program in Spain. In particular, they studied the PSO lines connecting the Canary Islands, finding that a schedule reform made in 2006 that relaxed restrictions on ticket prices while increasing required frequencies had a strong positive impact on passenger traffic volumes. However, the next reorganization of the program, implemented in 2011, placing exclusive exploitation on the PSO lines, did not have the same results.

Di Francesco & Pagliari (2012) dealt with fare prices and their research findings proved that a possible removal of PSO restrictions from the airline connecting the island of Sardinia with the Italian mainland would lead to an increase in ticket prices and to a change in the mix of travelers, with an increase in tourists and a decrease in the group of Visiting Friends and Relatives (VFRs) passengers. In addition, it could lead to wide variations in the frequency of services, occupancy rates and capacity offered.

Fageda et al (2017) conducted an empirical assessment of the effects of the European PSO program on fare prices, in islands of five European countries. The research found that there are large differences in the amount of fares offered and that the PSO program has generally not succeeded in reducing the ticket prices paid by islanders for their air transport. In addition, airfares were more expensive on lines that offered subsidies only to permanent residents, especially when a price cap was set instead of a discount rate.

Merkert & Williams (2013), applied the DEA method in order to estimate the technical and economic efficiency of 18 European airlines operating PSO routes, and to identify the factors that contribute to this efficiency. The results of the study showed that the ownership status of the companies has no impact on their efficiency. Conversely, the number of PSO contracts an airline has a positive effect on profitability, and as time approaches for these contracts to expire, profitability decreases.

Bråthen & Eriksen (2018) developed a method to measure the overall level of service (Level of Service, LOS) on Norwegian PSO lines. The study concluded that relaxing PSO restrictions would lead to increased fares and a reduction in the level of service offered.

There are also some studies about intermodality, exploring the possibilities of combining the air routes with other modes of transport.

Angelopoulos et al. (2013) noticed the growing number of Greek PSO routes, the lack of well-defined criteria for the eligibility of any air route as PSO, the high compensation costs and the lack of any provision for network design that would increase the efficiency and the coordination both between air routes and between air and maritime transport. Few studies (Sambracos, 2001; Rigas, 2009) have examined the modal choice between ferry and air transportation concluding that there is complementarity and limited competition between the two modes since they serve separate market segments with different income status and travelling preferences. More specifically, it seems that ferry passengers are more cost-sensitive, while air-passengers are more time-sensitive.

5. Discussion and suggestions about the air PSO program

The efficiency and the effectiveness of the PSO policies has replenished the interest of researchers lately, particularly due to the recent economic and health crisis that call for reexamination of the public funds and spending allocation. The proper planning and implementation of the PSO program can bring substantial benefits to the national economy, as Smyth et al. (2012) determined for the Scottish Route Development Fund (RFD). In addition, the study by Wu et al (2020), argues that these programs also bring about significant development of local economies, mainly by allowing the entry of tourist flow in remote areas and also establishes the positive correlation of these programs to strengthen the connectivity of remote areas, with a range of social welfare indicators, such as standard of living and social cohesion, allowing the inhabitants of remote areas access to critical social infrastructures, such as health, trade, education and public administration. In the same study, however, reservations are expressed regarding the environmental impact of increasing aviation and tourist activity in isolated areas Wu et al (2020).

On the other side, studies of Merkert & O'Fee (2013), Fageda et al. (2017), Calzada & Fageda, (2014); Socorro & Betancof, (2020); Abreu et al, (2018) have recognized serious distortions in the PSO program across Europe, mainly limited competition and inefficiency of the price regulation, partly due to the failure of the bidding process to attract low-cost airlines that could offer lower fares. There is an apparent need to strengthen the competition in these non-commercially attracting routes. This could be done by increasing the discount given to passengers, to make it profitable for other airlines to enter in this specific route (Alvarez-Albelo et al, 2020). Calzada & Fageda, (2014) suggest that the alternative way of granting fare discounts is preferable to the imposition of a PSO regime because it enhances demand and acts as an incentive for new carriers to enter the market. However, the complete removal of the PSO designation from certain lines would lead to higher fares, greater price fluctuations depending on the departure date and greater fluctuations in demand during the year (Di Francesco & Pagliari, 2012). Additional caution is needed to avoid unfair price treatment between local habitats and visitors.

Furthermore, there is no unanimity in the literature regarding the overall efficiency of the PSO program. Efficiency studies focus primarily on ticket prices and passenger volumes (Di Francesco & Pagliari, 2012; Abreu et al, 2018; Fageda et al, 2017), as well as on airlines' profitability (Merkert & Williams, 2013). In an overall assessment of the effectiveness of implemented policies to enhance remote areas, Fageda et al (2019) found that these policies generally achieve the expected results in terms of ensuring affordable prices and high levels of frequencies on protected routes, compared with the commercial ones. However, the results display geographic heterogeneity. For example, the resident fare subsidy scheme has resulted in similar charges for protected and non-protected area routes in France, Portugal, Sweden and Great Britain, lower charges in Norway and higher charges in Greece. Nonetheless, the quality of services offered has attracted little attention (Bråthen & Eriksen, 2018) and needs further research.

Further research is also needed on the central network design and coordination both between air routes and between air and maritime transport, as highlighted by Sambracos, 2001, Rigas, 2009 and Angelopoulos et al. (2013). Additional issues that call for further consideration is the inclusion of passengers and other stakeholders (i.e., local communities, airports)' views in the PSO planning that is currently dominated solely by regulatory authorities and airlines (Bråthen & Eriksen, 2018). It is also suggested that the central role of EU should be enforced to guarantee that the application of PSO program from the member states serve the objectives of the EC Regulation 1008/2008.

Finally, the issue of transparency and the need for more open dissemination of information across Europe is also emphasized in the literature (Merkert & O'Fee, 2013). It is characteristic that, although the European Commission provides current data about the calls for tenders in every Member state on its official webpage (transport.ec.europa.eu), the list of the PSO routes (PSO inventory table) has not been updated since 18/9/2019, something that does not serve the need for transparency and disclosure about the implementation of the PSO scheme from each Member State. With remote European areas hit hard by lockdowns and mobility restrictions imposed during the covid-19 pandemic, air connectivity remains a top priority and relevant data should be available to the public.

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Conflicts of Interest

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

References

Abreu, J., Fageda, X., & Jiménez, J. L. (2018). An empirical evaluation of changes in Public Service Obligations in Spain. Journal of Air Transport Management, 67, 1-10.

Álvarez-Albelo, C. D., Hernández-Martín, R., & Padrón-Fumero, N. (2020). The effects on tourism of airfare subsidies for residents: The key role of packaging strategies. Journal of Air Transport Management, 84, 101772.

Angelopoulos, J., Chlomoudis, C., Christofas, P., & Papadimitriou, S. (2013). Cost assessment of sea and air transport PSO services: The case of Greece. International Journal of Maritime, Trade and Economic Issues, 1(2), 3-49.

Bråthen, S., & Eriksen, K. S. (2018). Regional aviation and the PSO system–Level of Service and social efficiency. Journal of Air Transport Management, 69, 248-256.

C 194/01 (2017). Interpretative guidelines on Regulation (EC) No 1008/2008 of the European Parliament and of the Council — Public Service Obligations (PSO). European Commission.

Calzada, J., & Fageda, X. (2014). Competition and public service obligations in European aviation markets. Transportation Research Part A: Policy and Practice, 70, 104-116.

Costa, J., Alves, T., Andrade, A. R., & Kalakou, S. (2021). Assessing efficiency in public service obligations in European air transport using Data Envelopment Analysis. Case Studies on Transport Policy, 9(4), 1783-1809.

Di Francesco, A., & Pagliari, R. (2012). The potential impact of removing public service obligation regulations on air fares between the Italian Mainland and the island of Sardinia. Journal of Transport Geography, 24, 332-339.

Dijkstra L. and Poelman H. (2008). Remote Rural Regions: How the proximity to a city influences the performance of rural regions, Regional Focus N°1/2008, EU - DG REGIO, Brussels.

EC (2008). Regulation. No 1008/2008 of the European Parliament and of the Council of 24 September 2008 on Common Rules for the Operation of Air Services in the Community (recast). Commission of the European Communities, Brussels, Belgium. /https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX %3A32008R1008

EC (2019). PSO inventory table. European Commission https://ec.europa.eu/transport/sites/transport/files/pso_inventory_table.pdf

EEC (1992), Regulation No 2408/1992 of the European Parliament and of the Council on access for Community air carriers to intra-Community air routes, Council of the European Communities, Brussels, Belgium. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31992R240 8

ERA (2016). Public Service Obligation (PSO) routes in Europe. European Regions Airline Association. United Kingdom. https://www.eraa.org/system/files/170105_pb_pso_brochure_2016.pdf

Fageda, X., Jiménez, J. L., & Fageda et al., Valido, J. (2017). An empirical evaluation of the effects of European public policies on island airfares. Transportation Research Part A: Policy and Practice, 106, 288-299.

Fageda, X., Suárez-Alemán, A., Serebrisky, T., & Fioravanti, R. (2018). Air connectivity in remote regions: A comprehensive review of existing transport policies worldwide. Journal of Air Transport Management, 66, 65-75.

Fageda, X., Suárez-Alemán, A., Serebrisky, T., & Fioravanti, R. (2019). Air transport connectivity of remote regions: the impacts of public policies. Regional Studies 53:8, 1161-1169.

Fu, X., Oum, T. H., & Zhang, A. (2010). Air transport liberalization and its impacts on airline competition and air passenger traffic. Transportation Journal, 49(4), 24. https://www.jstor.org/stable/40904912

GTP (2019). Greek Island Residents Can Now Claim Air Transport Discounts. Greek Travel Pages.https://news.gtp.gr/2019/05/21/greek-island-residents-can-now-claim-air-transport-discounts/

ICAO (2003). European Experience of air transport liberalization. International Civil Aviation Organization. Montreal, Canada. https://www.icao.int/sustainability/casestudies/statesreplies/europeliberalization_en.pdf

Martínez Raya, A., & González-Sánchez, V. M. (2020). Tender Management Relating to Imposition of Public Service Obligations on Scheduled Air Routes: An Approach Involving Digital Transformation of Procurement Procedures in Spain. Sustainability, 12(13), 5322.

Merkert, R., & O'Fee, B. (2013). Efficient procurement of public air services—Lessons learned from European transport authorities' perspectives. Transport Policy, 29, 118-125.

Merkert, R., & Williams, G. (2013). Determinants of European PSO airline efficiency–Evidence from a semi-

parametric approach. Journal of Air Transport Management, 29, 11-16.
OECD (2011). OECD regional typology. Directorate for Public Governance and Territorial Development.
Poulaki, I., Papatheodorou, A., Panagiotopoulos, A., & Liasidou, S. (2022). Exclave accessibility and cross-border travel: the pene-exclave of Ceuta, Spain. Tourism Geographies, 24(1), 152-176.
Reynolds-Feighan, A. (1995). European air transport public service obligations: a periodic review. Fiscal Studies, 16(1), 58-74. https://www.jstor.org/stable/24437967
Rigas, K. (2009). Boat or airplane? Passengers' perceptions of transport services to islands. The example of the Greek domestic leisure market. Journal of Transport Geography, 17(5), 396-401.
Sambracos, E. (2001, December). Air-sea transport: competitiveness or complementarity in the Greek insular market. In Proceedings "International conference on Air Transport and Airports evolution in the 21st Century" (pp. 3-4).
Smyth, A., Christodoulou, G., Dennis, N., Marwan, A. A., & Campbell, J. (2012). Is air transport a necessity for social inclusion and economic development? Journal of Air Transport Management, 22, 53-59.
Socorro, M. P., & Betancor, O. (2020). Air transport subsidies for resident passengers: The unexpected effects on competition. Research in Transportation Economics, 79,100772.
Williams, G., & Pagliari, R. (2004). A comparative analysis of the application and use of public service obligations in air transport within the EU. Transport Policy, 11(1), 55-66.
Williams, G., (2010). European experience of public service obligations. In: Williams, G., Bråthen, S. (Eds.), Air Transport Provision in Remoter Regions. Ashgate Publishing, UK.
Wu, H., Tsui, K. W. H., Ngo, T., & Lin, Y. H. (2020). Impacts of aviation subsidies on regional wellbeing: Systematic review, meta-analysis and future research directions. Transport Policy 99, 215-239.

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