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The Experimental Study of Attitude Stabilization Control for Programmable Nano Quadcopter

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Abstract

Rotary-wing nano-quadcopters are unmanned technologies used for reconnaissance and surveillance operations in many areas, especially strategic missions such as security and military operations. The main problem for these devices, which reached a wide audience with the widespread use of civilian production, is stabilization. The most important parameter affecting the stable, effective and reliable flight of these UAVs in the air is PID elements. In this study, experimental studies are carried out in [x, y, z] coordinates using a programmable Nano-quadcopter Crazyflie 2.0 drone. In order to determine the relationship between stabilization and PID control parameters of these systems, each coordinate axis is analyzed statistically. As far as is known, there is no study in the literature regarding the performance of the PID parameters of the Crazyflie 2.0 drone. At the end of the analysis study with the SPSS program, it is determined that the related drone moves with a very high level of efficiency in the "z" axis and performs the task related to the high level of efficiency on the y-axis. It is also confirmed that the drone performs poorly in the stabilization movement on the "x" axis and as a result of the analysis study, the system becomes more stable by making the necessary adjustments in the "yaw_p" parameter. Thanks to the study, it is aimed to create a decision support system for the optimization of the PID control parameters of UAVs, which are used extensively in every sector.

1. Introduction

In recent years, unmanned aerial vehicle (UAV) also known as drone have become popular due to their relatively simple fabrication compared to other aircraft in the fields of robotics and control engineering (Ucar and Isleyen, 2019; Ucar and Isleyen, 2017; Kaya et al., 2017). Quadcopter, one of the unmanned aerial vehicles, is four-engine robot systems that is popular due to its simplicity, speed and wide application areas. It is used some applications such as delivery services, monitoring, mapping, military purposes, inspection of building and agricultural, etc. The scope of the quadcopter technology also changes over the years, as with every new technology. Due to its cost and reduced size, it now appeals to a wide audience, from researchers to hobbyists. However, manufacturers are seeking more autonomy, longer flight time, higher data processing capabilities and adaptability to changing environments. For this reason, there are many active researches and studies on the quadcopters. Studies on modeling, simulation and application of control algorithms are very important. Some research studies include the necessary automation techniques to control nonlinear dynamics.

Nanoquads are a new type of quadcopter with very low size and weight. Thus, it is made quadcopters an ideal platform for indoor use. In this study, a nano quadcopter named “Crazyflie 2.0” developed by Bitcraze company is used. It weighs 27 grams and has a length and width of 9.2 cm. For this reason, it is one of the preferred platforms for quadcopter researches recently.

In the literature, there are some articles and studies that give mathematical equations for modeling and control of UAVs and quadcopters. There are also theses that include both simulation and experimental studies for the development and testing of a mathematical model describing quadcopter dynamics. The open-source nano quadcopter named Crazyflie 2.0 is used to design the position and trajectory control algorithms as well as the system modeling of the nano quadcopter. Some of them also use the mathematical model for attitude, altitude and position controllers of the Crazyflie 2.0 (Zhou and Chen, 2021; Madhusudhan, 2016; Luis, 2016; Greiff, 2017; Murmu and Sharma, 2020).

Wang et al. (2020) have conducted a study including experimental and simulation results for the control of quadrotor systems. A new simple tracking control scheme with uncertain parameters in the dynamics have been presented in the study. This control scheme can be applied to parameters whose dynamics are unknown. It is also a useful study because it is a simple method that avoids complexity. Nguyen et al. (2020) has designed the tracking control for the multicopter. A two-layer hierarchical control scheme for trajectory tracking with mathematical equations has been examined. The simulation results have been compared with the experimental data. Oktay and Kose (2019) have modelled a quadrotor in MATLAB/Simulink with designed control system. They have used Proportional Integral Derivative (PID) control algorithm and mathematical model of longitudinal, lateral and vertical take-off and landing operations. In other study by authors (Kose and Oktay, 2019), they have used Newton Euler method for modeling of the quadrotor system. The PID control algorithm has been also performed in this study longitudinal and lateral flight. All quadrotor model with state space approach has been simulated in MATLAB/Simulink in their other study (Oktay and Kose, 2020). They have monitored differential morphing and PID algorithm for lateral flight performance.

Lambert et al. (2019) have implemented experimental and simulation study for Crazyflie quadrotor. They have used model-based reinforcement learning method for low level controls. On the other hand, Silano et al. (2018), have modeled the Crazyflie 2.0 nano-quadcopter in a physics-based simulation environment. The proposed simulation package has provided a quick understanding of the behavior of the flight control system by evaluating different indoor and outdoor scenarios at a near-realistic level. In another simulation study (Gong et al., 2020), PID control parameters and control scheme of Crazyflie 2.0 nano quadcopter have been examined. In another study used PID controller (Nithya and Rashmi, 2019), it has been aimed to develop and implement control algorithms for autonomous aircraft. Since the developed control algorithms could not be tested on a physical quadrotor, a simulation-based test study has been conducted for Crazyflie 2.0 quadcopter. A simple PID controller has been used to achieve position control and trajectory tracking.

Candan et al. (2018) have presented a fuzzy logic-based position control structure for the position control problems of the Crazyflie 2.0 nano quadcopter. Necessary models for Crazyflie 2.0 have created, simulation study has been carried out and experimentally tested. The advantages of the proposed Fuzzy PID controller over the classical PID controller in terms of performance and noise have been given with experimental results. In another study used Crazyflie 2.0 (Garcia et al., 2017), both simulation and experimental studies have been carried out for trajectory tracking of an autonomous nano quadrotor. Three methods, PID, LQR and MPC, have been used for the dynamic model of the quadrotor and their performances have been compared with flight tests. Budaciu et al. (2019) have also investigated the dynamic behavior of Crazyflie 2.0 nano quadcopter with mathematical modeling and experimental study. Dynamic behavior has been extensively evaluated to understand deviations in ideal and actual operating conditions. Neumann et al. (2019) have worked an experimental study with a swarm of nano-air robots using a Crazyflie 2.0 quadrocopter. With this robotic swarm consisting of nano unmanned aerial vehicles, they have implemented indoor air quality monitoring for occupational health and safety of workplaces. Test scenarios have optimized by developing algorithms in line with the objectives. In another experimental study (Giernacki et al., 2017) using the Crazyflie 2.0 nano quadrotor has been aimed to test and teach autonomous flights for control and robotics engineering. MATLAB/Simulink software has been used for the mathematical model and position control of Crazyflie 2.0 dynamics.

In this paper, the stabilization of Crazyflie 2.0 quadcopter in x, y and z coordinates is analyzed by associating it with PID parameters. Analysis results are evaluated by performing multiple regression analysis in SPSS statistical program and PID parameters affecting the axes are determined. As far as is known, there is no study in the literature on statistical analysis and performance attitude determination on the stabilization of the related quadcopter. The aim of this study is to ensure that the quadcopters, which are used extensively in every field, move more stably and use them more effectively. In the second part of the study, the definition of the problem and materials is made. In the third part, experimental studies are carried out on the quadcopter in real environment and in the last part, general evaluations about the study are made.

2. Material and Method

2.1. On-board Control Architecture

The autonomous flight of programmable quadcopters is directly related to the efficiency of their control software. When the PID control software on Crazyflie 2.0 nano quadcopters produced by Bitcraze is examined, it is seen that the control architecture given in Fig.1 is used.

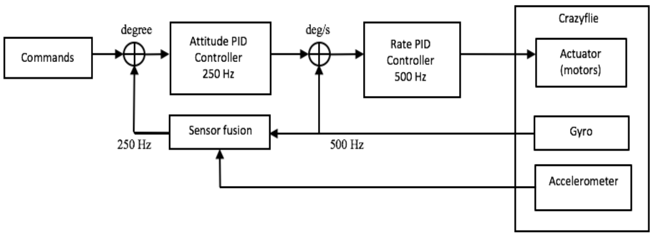

Figure 1. On-board control architecture, image courtesy of Bitcraze.

It appears that the control architecture given by the manufacturer is a two-stage PID control scheme. In this way, a control scheme given in stages can be analyzed by separating it into internal and external control loops. In the given diagram, it is understood that the outer loop regulates the inner loop, while the inner loop regulates the entire system. As a common rule in cascade systems, it is accepted that the inner loop should be organized faster than the outer loop. If the inner loop response is not as fast as it should be, or if the outer loop is faster than it should be, synchronization issues will arise between the two controllers. In applications this can be easily fixed by forcing the inner loop to be twice as fast as the outer loop as shown in the diagram (attitude controller running at 250Hz and speed controller running at 500Hz).

2.1.1. Inner Loop: Speed controllers

Speed control block inputs and outputs are shown in Fig. 2.

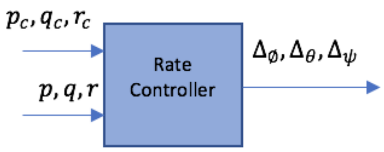

Figure 2. Speed control diagram

The purpose of this controller is to calculate the input variations of the motors at the equilibrium point to generate the required angular momentum with the state variables p, q, r in order to obtain p_c, q_c, r_c values. Therefore, three independent controllers are used. Roll Rate Proportional controller:

$$\Delta\phi\ (t) = K_{P,p}\ (p_c\ (t) - p\ (t)) \quad (1)$$

Using the given formula, the desired p_c value is calculated by the outer loop attitude controller. Pitch Rate Proportional controller:

$$\Delta_\theta\ (t) = K_{P,q}\ (q_c\ (t) - q\ (t)) \quad (2)$$

Similarly, the given equation is used to calculate the q_c value. Yaw Rate Proportional-Integral controller:

$$\Delta\psi(t) = K_{P,r}\,(rc\ (t) - r\ (t)) + K_{I,r} \int_0^t (rc\ (\tau) - r\ (\tau))\, d\tau \quad (3)$$

It is used to calculate the desired deviation (r_c) from the setpoint sent by an external system or specified by a teleoperation operator.

2.1.2. Outer Loop: Status check

In this Loop, the controller input and output values are as given in Fig. 3.

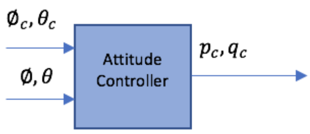

Figure 3. Attitude control diagram

This controller acts as the regulator of the speed controller by calculating the appropriate setpoints for the angular velocities around the X and Y axis to stabilize the quadrocopter in a particular desired angular position. The attitude controller takes the pitch and roll angles estimated from the sensor algorithm and compares them with external commands. The p_c *and* q_c, which are the desired angular velocities as output, are calculated with the following equations.

Roll Attitude Proportional-Integral controller: The desired (Pc) roll rate in the body frame is calculated using the control equation.

$$p_c\ (t) = K_{P,\phi}\,(\phi_c\ (t) - \phi\ (t)) + K_{I,\phi} \int_0^t (\phi c\ (\tau) - \phi\ (\tau))\, d\tau \quad (4)$$

Pitch Attitude Proportional-Integral controller: It works similarly to the Roll controller, using the corresponding variables.

$$q_c\ (t) = K_{P,\theta}\,(\theta_c\ (t) - \theta\ (t)) + K_{I,\theta} \int_0^t (\theta c\ (\tau) - \theta\ (\tau))\, d\tau \quad (5)$$

2.2. Off Board Position Controllers

A position controller is required to control the quadcopter by sending waypoints or trajectories through three-dimensional space. The workload of this controller can be divided into the following three different purposes.

1. Altitude controller to maintain position and thrust at a specified z altitude value as output data.
2. An x-y position controller with the required roll and pitch angles, whose output data will be edited by the on-board controller.
3. A yaw position controller that sends the required angular velocity to the on-board yaw velocity controller

As can be seen from the dynamic analysis of the quadcopter, the controllers of vertical, lateral, longitudinal and yaw movements can be adjusted independently of each other. This relatively simplifies the controller design task.

2.2.1. Altitude controller

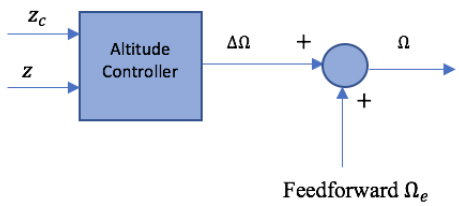

Figure 4. Block diagram of altitude controller

The altitude controller shown in Fig. 4 is a simple PID compensator whose input data comes from the orbital block for simulation and is the desired altitude for quadcopter dynamics. The controller equation that defines this PID is as follows.

$$\Delta\Omega\ (t) = K_{P,z}\,(zc\ (t) - z\ (t)) + K_{I,z} \int_0^t (zc\ (\tau) - z\ (\tau))\, d\tau + K_{D,z}\, \frac{d}{dt}(zc\ (t) - z\ (t)) \quad (6)$$

2.2.2. X-Y Position Controllers

The purpose of this controller is to regulate the on-board attitude controller by calculating the required roll and pitch angles to move the quadcopter between positions in X-Y plane. The block diagram in Fig.5 shows the inputs and outputs of this controller.

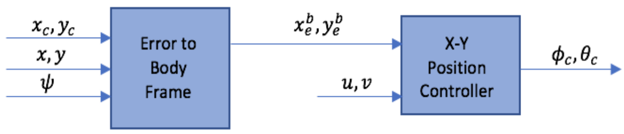

Figure 5. Block diagram of X-Y position controller

The first block given in Fig.5 calculates the error between the desired and actual X-Y position and performs the required rotation of the vehicle body with this error vector. This is done as follows:

$$\begin{bmatrix} x_e \\ y_e \end{bmatrix}^b = \begin{bmatrix} \cos(\psi) & \sin(\psi) \\ -\sin(\psi) & \cos(\psi) \end{bmatrix} \begin{bmatrix} x_e \\ y_e \end{bmatrix}^0 \quad (7)$$

when performing the calculations, the error in the body frame is defined as:

$$\begin{cases} x_e^b = x_e^0 \cos(\psi) + y_e^0 \sin(\psi) \\ y_e^b = -x_e^0 \sin(\psi) + y_e^0 \cos(\psi) \end{cases} \quad (8)$$

Then the error in the frame fixed to the body becomes the set point of the speed in the same frame. In this case, the larger the error, the faster the quadcopter must move to reach the desired point as soon as possible. Similarly, the smaller the error, the smaller the adjustment coefficient for the speed, as the quadcopter is closer to the desired point. Controllers satisfying the desired states use the equation given below.

X Position Proportional-Integral Controller:

$$\emptyset_c(t) = K_{P,x}\left(x_e^b(t) - u(t)\right) + K_{I,x}\int_0^t \left(x_e^b(\tau) - u(\tau)\right) d\tau \quad (9)$$

Y Position Proportional-Integral Controller:

$$\emptyset_c(t) = K_{P,y}\left(y_e^b(t) - v(t)\right) + K_{I,y}\int_0^t \left(y_e^b(\tau) - v(\tau)\right) d\tau \quad (10)$$

2.2.3 Yaw Position Controller

The block diagram showing the input and output data of the yaw position controller is given in Fig.6.

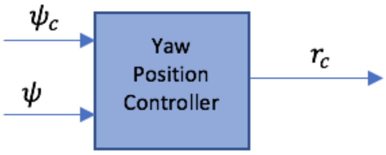

Figure 6. Block diagram of yaw position controller

The controller calculates the error between the desired deviation position and the actual position and sends it to a proportional controller whose output is the desired deviation rate regulated by the onboard speed controller. So, the action taken by the controller is given as:

$$\boldsymbol{r_c(t) = K_{P,\psi}\left(\psi_c(t) - \psi(t)\right)} \quad (11)$$

2.2.4 The Equations of Motion

Euler-Lagrangian formalism is used in the equations of motion of the CrazyFile Quadcopter 2.0. Considering quadcopter aerodynamic forces and moments, the equations of motion is derived and represented in Equations (12), (13), (14).

$$\ddot{\phi} = \frac{1}{Ixx}(Iyy - Izz) + Jr\,(W1 - W2 + W3 - W4) + lb\,(W_4^2 - W_2^2) \quad (12)$$

$$\ddot{\theta} = \frac{1}{Iyy}(Izz - Ixx) + Jr\,(W1 - W2 + W3 - W4) + lb\,(W_1^2 - W_3^2) \quad (13)$$

$$\ddot{\psi} == \frac{1}{Izz}(Ixx - Iyy) + (W_1^2 - W_2^2 + W_3^2 - W_4^2) \quad (14)$$

($\ddot{\phi}$, $\ddot{\theta}$, $\ddot{\psi}$) are the angular acceleration of quadcopter, (p, q, r) are the angular rates of roll, pitch and yaw angles, ($W1$, $W2$, $W3$, $W4$) are the angular rate of propellers, b is the thrust coefficient, d is the drag coefficient, l is length of the quadcopter from the center of gravity, (Ixx, Iyy, Izz) are the moment of inertia of x, y and z axis and Jz is the moment of inertia of motors.

2.3. Material Used in the Experiment Quadcopter

The physical characteristics of the Crazyflie 2.0 quadcopter used in the experimental studies is given in the Table 1 and the picture of the quadcopter is also given in Fig.7.

Table 1. Physical characteristics of the Crazyflie 2.0

Parameter	Description	Value	Unit
m_{quad}	Mass of the quadcopter alone	0.27	kg
m_{uwb}	Mass of the UWB module	0.04	kg
m_{vicon}	Mass of the VICON marker	0.02	kg
m	Total mass	0.33	kg
d	Arm length	39.73×10^{-3}	m
r	Rotor radius	23.1348×10^{-3}	m
I_{xx}	Principal moment of inertia around x axis	1.395×10^{-5}	$kgxm^2$
I_{yy}	Principal moment of inertia around y axis	1.436×10^{-5}	$kgxm^2$
I_{zz}	Principal moment of inertia around z axis	2.173×10^{-5}	$kgxm^2$
k_T	Non-dimensional thrust coefficient	0.2025	-
k_D	Non-dimensional torque coefficient	0.11	-

Figure 7. Crazyflie 2.0 quadcopter

2. Experimental Study

The experiment is carried out in a 3.5mx3.5mx3.5m closed environment free from disturbing factors indicated in Fig. 8. By using an autonomous flight software written in Python on the computer and a 2.4 GHz radio dongle, the quadcopter is raised to an altitude of 1m from the ground and it is requested to remain stable in the sent position for 50 seconds. Status information, instant position and altitude is recorded every second from the quadcopter. Then, the performance of the controller software is interpreted by converting the received data into graphics. Loco position node is used for area positioning and flow deck elements is used for altitude control. During the experimental study, the quadcopter and field positioner sensor images are given in Fig. 9.

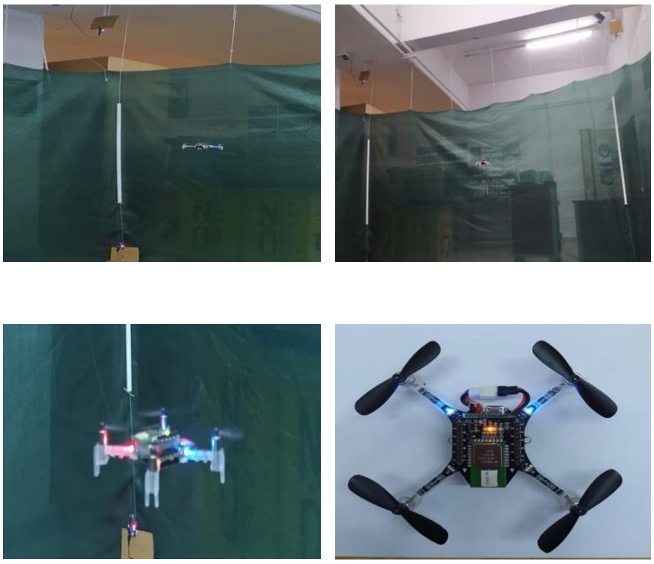

Figure 8. Experimental environment

In the studies, the quadcopters are moved on the [x, y, z] coordinates and the movement started from the [0,0,0] point and completed its movement at the [0,0,1] point. For each operation of the quadcopter, the data is analyzed by averaging the times in each second of hang in the air. In the analysis study, in addition to these data, 18 different PID control parameters affecting the flight are stored as specified, and based on these data, correlations between PID parameters and targeted coordinates are determined for the Crazyflie 2.0. quadcopter. Furthermore, using the developed software, the quadcopter coordinates and PID parameters per second are recorded in the system with the help of “Loco positioning deck” and “flow deck v2”. In line with this information, the instantaneous average [x, y, z] coordinates within 50 seconds are shown in Fig. 10.

Figure 9. Quadcopter and field positioner sensor images during the experiment

Planned and instant [x, y, z] coordinates of the quadcopter within 50 seconds are shown in Fig. 2. The planned coordinates are in the form of [0,0,1] and the distance of the quadcopter to these points every second is analyzed on the relevant figure. According to these results, we observe that the quadcopter moves with low deviations on the "z" axis, and these deviations increase moderately on the "y" axis. Looking at the movement of the drone on the "x" axis, it is determined that the deviations are higher compared to the "y" and "z" axis. The graphic regarding the deviation amounts is shown in Fig. 11.

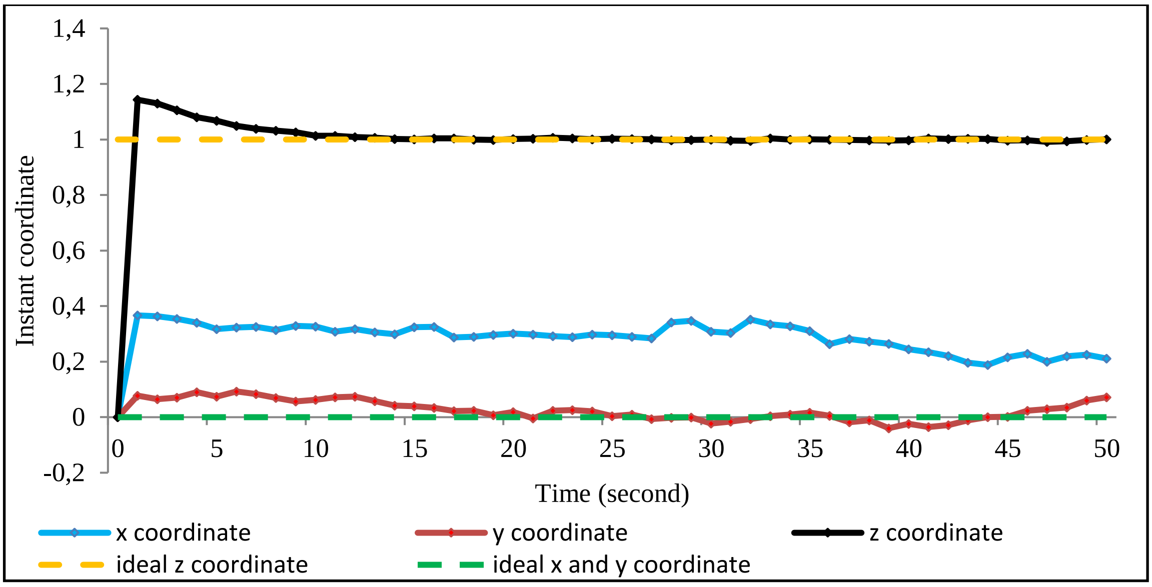

Figure 10. Instant x, y and z coordinates

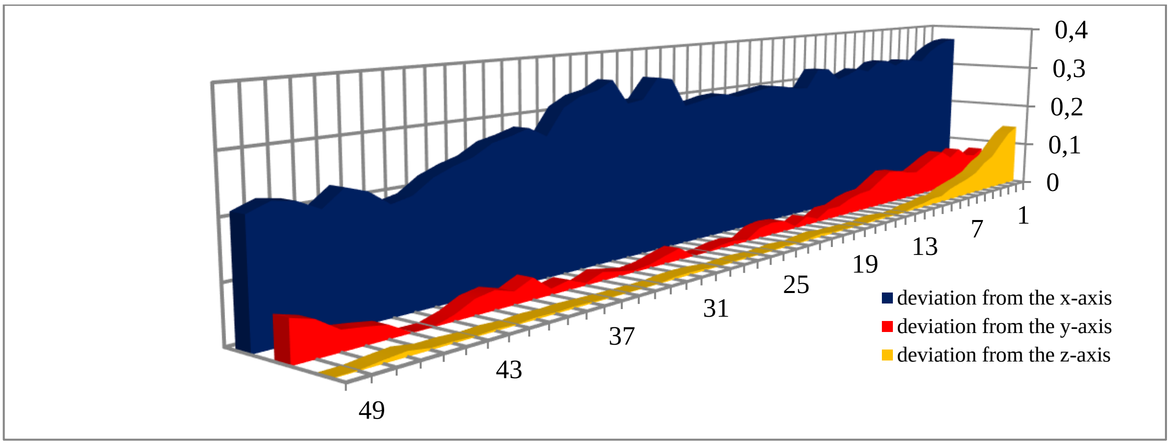

Figure 11. Deviations of the drone from the x, y and z axis during 50 seconds

In Fig. 11, the deviations of the experimental results from the ideal coordinates are expressed. Based on these results, it is understood that the deviation in the "x" axis is quite high and the quadcopter moves best and stable on the "z" axis. There are 18 different PID parameters that affect the relevant results and these parameters are expressed below.

- pitch_p
- pitch_i
- pitch_d
- roll_p
- roll_i
- roll_d
- yaw_p
- yaw_i
- yaw_d
- x_p
- x_i
- x_d
- y_p
- y_i
- y_d
- z_p
- z_i
- z_d

These parameters affect each axis stabilization and can affect each other. Multiple Regression Analysis is used to determine the effect of more than one independent variable on the dependent variable in statistics (Ucar and Isleyen, 2019; Ucar and Isleyen, 2020; Ucar et al., 2021). In this study, the effects of PID parameters on the stabilization of the axes are determined by using the related analysis method.

Multiple Regression Analysis is a statistical method used to determine the relationship of a dependent variable with more than one independent variable and the explanation rate of these independent variables for the relevant dependent variable (Statistics lecture notes, 2021). In the multiple linear regression model, the aim is to explain the total change in the dependent variable (response variable) using the independent variables (explanatory variables) (Kayaalp et al., 2015). The model created for Multiple Regression Analysis is expressed below.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon_i \quad (15)$$

β_0 in the model; It shows the fixed effect when all independent variables take the value 0. β_1; represents the partial effect of a one-unit change in independent variable X_1 on the dependent variable. β_2; It expresses the partial effect of a one-unit change in the independent variable X_2 on the dependent variable. βk; demonstrates the partial effect of a one-unit change in the independent variable X_k on the dependent variable (Statistics lecture notes, 2021). Analysis process is carried out in SPSS 15.0 program, analysis results are shown and interpreted in the tables below for "x", "y" and "z" axis.

Table 2. Multiple Regression Analysis – Descriptive Statistics Results

	Mean	Std. Deviation	N
x_coordinate	,2909	,04656	50
pitch_p	-,3833	2,62762	50
pitch_i	,0886	,25842	49
pitch_d	,0000	,00000	50
roll_p	,5262	2,30192	50
roll_i	,0549	,24456	50
roll_d	,0000	,00000	50
yaw_p	-,1937	3,34741	50
yaw_i	,0167	1,80139	50
yaw_d	,0753	,46143	49
x_p	-,0407	,28371	49
x_i	,0000	,00000	50
x_d	,0000	,00000	50
y_p	-,0008	,00791	50
y_i	,0000	,00000	50
y_d	,0000	,00000	50
z_p	-,0286	,06769	50
z_i	,0298	,06925	50
z_d	,0000	,00000	50

When Table 2 is examined, it has been determined that the quadcopter generally moves on 0,2909 point in x coordinate and deviations of ±0,04656 from these points for 50 seconds. In addition, the average values reached by the PID parameters along the x-axis are given in the table.

Table 3. SPSS model summary output for "x" axis PID parameter analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,746(a)	,557	,422	,03540

a Predictors: (Constant), z_i, roll_i, yaw_d, yaw_p, x_p, pitch_p, roll_p, pitch_i, yaw_i, y_p, z_p

In Table 3, there are 3 different statistical indicators, "R", "R Square" and "Adjusted R Square", which summarize the analysis work, and the information about them is given below.

The Multiple Indication Coefficient (R square - R^2) in Table 3 shows the ratio of independent variables to explain the dependent variable.

In multiple linear regression, the coefficient of determination is found by the ratio of the sum of squares of the regression to the sum of the overall squares. If all observations are on the regression line, $R^2=1$. In addition, if there is no linear relationship between the dependent and independent variable, $R^2=0$.

The coefficient of determination for multiple regression analysis with "k" independent variables is calculated with the following formula (Statistics lecture notes, 2021).

$$R^2 = \frac{\widehat{B_1}\ \sum y_i x_1 + \widehat{B_2}\ \sum y_i x_2 + \cdots + \widehat{B_k}\ \sum y_i x_k}{\sum y_i^2} \tag{16}$$

In addition, coefficient of determination for two independent variables is calculated with the following formula [26].

$$R^2 = \frac{SRS}{SGS} = \frac{\sum \widehat{y_i}^2}{\sum {y_i}^2} = \frac{\widehat{B_1}\ \sum y x_1 + \widehat{B_2}\ \sum y x_2}{\sum y_i^2} \tag{17}$$

In the above formula, it is defined as $x_1 = (X_1 - \overline{X_1})$, $x_2 = (X_2 - \overline{X_2})$ ve $y = (Y - \bar{Y})$. In addition, it stands for "SRS=Sum of Regression Squares" and "SGS=Sum of General Squares" [26].

In Table 3, the R^2 value is calculated as "0.557". When we look at the R Square value, the PID control parameters is explained the stabilization "x" at a medium level.

The Multiple Correlation Coefficient (R) value is a measure that shows how much of a relationship there is between the combination of independent variables and the dependent variable.

This value is equal to the square root of the coefficient of determination (Statistics lecture notes, 2021).

$$R = \sqrt{R^2} \tag{18}$$

In line with the above information, according to Table 3, the R value is calculated as 0,746. Accordingly, it is understood that there is a high degree of agreement between the model created and the observed model.

When unrelated independent variables are added to the regression equation, the multiple coefficients of determination is corrected to obtain the "corrected coefficient of determination R^2_{adj}" value. The adjusted coefficient of determination shows how well the model fits the population and is used when the number of explanatory variables is large. The adjusted coefficient of determination is calculated with the following formula (Statistics lecture notes, 2021).

$$R^2_{adj} = 1 - \frac{\frac{RKT}{(n-k)}}{\frac{GKT}{(n-1)}} \tag{19}$$

The "R^2_{adj}" value in Table 3 shows what percentage of the variance in the dependent variable is explained by the independent variables. Accordingly, 18 different PID values explain 42.2% of the variation in quadcopter stabilization.

Table 4. ANOVA table for "x" axis PID parameter analysis
ANOVA(b)

Model-1	Sum of Squares	df	Mean Square	F	Sig.
Regression	,057	11	,005	4,116	,001(a)
Residual	,045	36	,001		
Total	,102	47			

The results in Table 4 indicate whether the independent variables have a significant effect on explaining the dependent variables. Since the significance value is "0,001" here, it is understood that the relevant PID parameter values have a significant effect on explaining the "x" axis stabilization.

Table 5. Coefficients table for "x" axis PID parameter analysis
Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta	Zero-order	Partial	Part	Tolerance	VIF	B	Std. Error
1	**(Constant)**	,274	,007		40,383	**,000**					
	pitch_p	1,73E-005	,002	,001	,008	,994	-,010	,001	,001	,860	1,162
	pitch_i	,054	,033	,301	1,654	,107	,518	,266	,184	,371	2,693
	roll_p	,008	,004	,394	2,007	,052	,014	,317	,223	,320	3,129
	roll_i	,029	,033	,154	,879	,385	-,193	,145	,097	,400	2,499
	yaw_p	-,006	,002	-,397	-3,042	**,004**	-,280	-,452	-,337	,724	1,381
	yaw_i	,003	,004	,100	,583	,563	,458	,097	,065	,416	2,405
	yaw_d	,013	,013	,129	1,040	,305	,113	,171	,115	,796	1,256
	x_p	,010	,020	,058	,476	,637	-,089	,079	,053	,829	1,206
	y_p	2,927	1,249	,498	2,343	,025	,110	,364	,260	,273	3,666
	z_p	-,883	,782	-1,283	-1,129	,267	-,515	-,185	-,125	,010	105,082
	z_i	-,617	,734	-,918	-,840	,406	,498	-,139	-,093	,010	97,003

a Dependent Variable: x_coordinate

In Table 5, we see the individual relationship between the independent variables and the dependent variables. It is understood from these results that the "constant term" and "yaw_p" parameters should be present in the relevant Multiple Regression Analysis Model for the "x" axis. In addition, it is another result from the table that a one-unit increase in "yaw_p" causes a decrease of "-0,006" points on the "x" axis.

When the "Descriptive Statistics" analysis is performed for the "y" axis, it has been revealed that the drone generally moves at the "0,02490" point and can show deviations of "±0,036290" from this value. The model summary table for this axis is shown in Table 6.

Table 6. SPSS model summary output for "y" axis PID parameter analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,780(a)	,609	,489	,02594

a Predictors: (Constant), z_i, roll_i, yaw_d, yaw_p, x_p, pitch_p, roll_p, pitch_i, yaw_i, y_p, z_p

When Table 6 is examined, it is understood that the R value is 0,780 and the fit between the model created and the observed model is quite good. R Square value in Table 6; it states that the PID control parameters explain the stabilization results in the "y" axis at the medium-high level.

Table 7. ANOVA table for "y" axis PID parameter analysis
ANOVA(b)

Model-1	Sum of Squares	df	Mean Square	F	Sig.
Regression	,038	11	,003	5,090	,000(a)
Residual	,024	36	,001		
Total	,062	47			

Model-1	Sum of Squares	df	Mean Square	F	Sig.
Regression	,038	11	,003	5,090	,000(a)
Residual	,024	36	,001		
Total	,062	47			

a Predictors: (Constant), z_i, roll_i, yaw_d, yaw_p, x_p, pitch_p, roll_p, pitch_i, yaw_i, y_p, z_p
b Dependent Variable: y_coordinate

The results in Table 7 explain the significant "y" axis stabilization of the PID parameter values.

Table 8. Coefficiencts table for "y" axis PID parameter analysis
Coefficients(a)

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	Zero-order	Partial	Part	Tolerance	VIF	B	Std. Error
1	(Constant)	,020	,005		3,932	,000					
	pitch_p	,000	,002	-,036	-,320	,751	-,049	-,053	-,033	,860	1,162
	pitch_i	,038	,024	,267	1,562	,127	,591	,252	,163	,371	2,693
	roll_p	-,005	,003	-,322	-1,746	,089	-,265	-,279	-,182	,320	3,129
	roll_i	,015	,024	,103	,626	,535	-,068	,104	,065	,400	2,499
	yaw_p	-,001	,001	-,056	-,457	,650	,040	-,076	-,048	,724	1,381
	yaw_i	,004	,003	,214	1,323	,194	,635	,215	,138	,416	2,405
	yaw_d	-,005	,009	-,059	-,503	,618	-,061	-,084	-,052	,796	1,256
	x_p	-,001	,015	-,011	-,094	,925	-,200	-,016	-,010	,829	1,206
	y_p	-,115	,915	-,025	-,126	,901	,099	-,021	-,013	,273	3,666
	z_p	-1,138	,573	-2,123	-1,986	**,055**	-,604	-,314	-,207	,010	105,082
	z_i	-,968	,538	-1,847	-1,799	,080	,567	-,287	-,188	,010	97,003

a Dependent Variable: y_coordinate

From the results in Table 8, it is predicted that the "constant term" value in the relevant Multiple Regression Analysis Model for the "y" axis should only be in the model, in addition, the "z_p" value may affect the model compared to other values.

Finally, the "z" axis is obtained statistically. As a result of the analysis, when the mean value analysis is performed for the "z" axis according to "Descriptive Statistics", it is found that the drone generally moved at the "1,0143" point and could show deviations of "±0,03379" from this value. The model summary table for this axis is shown in Table 9.

Table 9. SPSS model summary output for "y" axis PID parameter analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1,000(a)	1,000	1,000	,00059

a Predictors: (Constant), z_i, roll_i, yaw_d, yaw_p, x_p, pitch_p, roll_p, pitch_i, yaw_i, y_p, z_p

From the results in Table 9, it is determined that the R value is 1, and the fit between the created model and the observed model is very high. The R Square value indicates that the PID control parameters "y" explains the stabilization at a very high level.

Table 10. ANOVA table for “z” axis PID parameter analysis
ANOVA(b)

Model-1	Sum of Squares	df	Mean Square	F	Sig.
Regression	,054	11	,005	13926,054	,000(a)
Residual	,000	36	,000		
Total	,054	47			

a Predictors: (Constant), z_i, roll_i, yaw_d, yaw_p, x_p, pitch_p, roll_p, pitch_i, yaw_i, y_p, z_p
b Dependent Variable: z_coordinate

The results in Table 10 explain the “z” axis stabilization with PID parameter values in a meaningful way.

From the results in Table 11, it is determined that the "z" axis should have "constant term" and "z_p" values in the Multiple Regression Analysis Model.

Based on all analysis results, it is determined that the "z" axis has a very stable flight and the "PID" parameters for this axis show high performance. It is determined that the stabilization in the “y” axis is at a medium to high level and the analysis data explains this performance in a meaningful way. As a result of the analyzes on the “x” axis, it is understood that the stabilization is low, the “PID” parameters have to be redefined here and the “yaw_p” parameter has a great importance in the multiple regression model.

Table 11. Coefficiencts table for “z” axis PID parameter analysis
Coefficients(a)

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.		Correlations		Collinearity Statistics	
Model-1	B	Std. Error	Beta	Zero-order	Partial	Part	Tolerance	VIF	B	Std. Error
(Constant)	1,000	,000		8813,136	**,000**					
pitch_p	4,01E-005	,000	,003	1,133	,265	-,116	,186	,003	,860	1,162
pitch_i	,000	,001	-,001	-,332	,742	,555	-,055	-,001	,371	2,693
roll_p	-2,33E-005	,000	-,002	-,351	,728	-,102	-,058	-,001	,320	3,129
roll_i	-6,14E-005	,001	,000	-,110	,913	-,017	-,018	,000	,400	2,499
yaw_p	6,10E-005	,000	,006	2,013	,052	,178	,318	,005	,724	1,381
yaw_i	-2,96E-005	,000	-,002	-,398	,693	,620	-,066	-,001	,416	2,405
yaw_d	-2,47E-005	,000	,000	-,118	,907	-,057	-,020	,000	,796	1,256
x_p	,000	,000	-,001	-,322	,749	-,227	-,054	-,001	,829	1,206
y_p	-,005	,021	-,001	-,256	,800	,088	-,043	-,001	,273	3,666
z_p	-,496	,013	-,993	-37,899	**,000**	-1,000	-,988	-,097	,010	105,082
z_i	,004	,012	,008	,327	,746	,991	,054	,001	,010	97,003

a Dependent Variable: z_coordinate

From the results in Table 11, it is determined that the "z" axis should have "constant term" and "z_p" values in the Multiple Regression Analysis Model.

Based on all analysis results, it is determined that the "z" axis has a very stable flight and the "PID" parameters for this axis show high performance. It is determined that the stabilization in the “y” axis is at a medium to high level and the analysis data explains this performance in a meaningful way. As a result of the analyzes on the “x” axis, it is understood that the stabilization is low, the “PID” parameters have to be redefined here and the “yaw_p” parameter has a great importance in the multiple regression model.

3. Results and Discussions

Unmanned Aerial Vehicles, which have many application areas, have been reduced to nano dimensions with the developing technology and have been equipped with high computing. These technological devices, called nano-quadcopters, have been used extensively in many sectors, especially in military operations, and with their programmable feature, they can respond quickly and effectively to the personal purposes of the users. It is very important for these systems to fly stably in terms of safety and efficiency. In this study, PID control parameters affecting the stable movement of rotary-wing nano quadcopters in the air have been analyzed statistically. Crazyflie 2.0 nano quadcopter has been taken into account in the analysis study and statistical analyzes have been performed with the average values obtained from 20 different flights.

As a result of the analysis study, it has been determined that the related drone moves quite stable in the z-axis and performs the task of staying in the air with high efficiency in the y-axis. In the "x" axis, it has been understood that the stabilization has quite bad and, in this context, the PID parameters has to be updated again. In addition to these, it has been determined from the analysis results that the parameter affecting the "x" axis with a high degree of importance is "yaw_p". Thanks to the methodology followed in the study, it is aimed to contribute to the more reliable and stable movement of the UAV systems. In addition, a decision support system is tried to be created before parameter optimization. In future studies, it is predicted that researchers will develop faster and more effective control algorithms by creating hybrid technologies.

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A Novel Biomimetic Wing Design and Optimizing Aerodynamic Performance

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Abstract

In this article, numerical and experimental analyzes were made by adding winglet and endless blade to the tip of the airfoil to improve the wind turbine blade performance. Similarly, the change in performance was investigated by making notches at different sizes and distances on the trailing edge of the wing structure, inspired by the creatures in nature. First of all, the designed wing structures were analyzed by numerical analysis as a fixed wing, and the lift and drag forces were examined and the aerodynamic performance parameters were examined. Then, the winglet, endless wing and trailing edge notch were mounted to the wing structure cast from a 3D printer, and the energy parameters produced by each design in the wind tunnel were examined. In curved wings, the stress values produced depending on the size of the endless wing structure added to the wing tip have changed and up to 15% aerodynamic performance improvement has been observed in the designed wing structure. In addition, the design was experimentally examined on conventional fixed blades, and up to 6% improvement was observed on fixed blades.

1. Introduction

Increasing world population and technological developments have brought along the increasing energy demand. These developments have accelerated the depletion cycle of non-renewable fossil fuels and have led human beings to seek new energy sources. With the steps taken to produce energy from renewable energy sources, sustainable energy has taken its place among the future energy plans of developed countries and has gained importance (Yilmaz & Kalkan, 2017). Scientists have done many studies in order to take the place of sustainable energy sources in our lives and to spread the use of renewable energy sources to all areas. In these studies, solar cells were developed to benefit from solar energy, and projects such as the use of wind turbines to benefit from wind energy were developed. Today, in order to form the basis of energy policies, it is necessary to diversify existing energy sources and make these sources available (Külekçi, 2009). All of the energy needed on earth comes from the sun, and an average of 2% of this energy is wind energy. The earth's atmosphere warms up at different rates as the sun's rays are absorbed at different rates by plants, water, soil and rocks. Variable pressure zones formed during this thermal exchange are the main driving force of air movement (Johnson, 1985). The heated air mass starts to move from high pressure points to low pressure points and as a result of this mass displacement, wind formation occurs (Kalmikov, 2017). The kinetic energy of the air mass that creates the winds and displaces due to the pressure difference is called wind energy. In other words, we can call the solar energy converted into kinetic energy as wind energy. The power of the winds increases with the cube of their speed, and their speed increases in proportion to the height (Özkaya et. al., 2019).

Among the obstacles to global energy use forecasts and planned developments such as cost, farm area and technological constraints, the most important is the design of turbine blades, which are in contact with the wind and are the protagonists of electricity generation. Nature, which contains many problems and solutions, has been a source of inspiration for researchers and researchers have made new biomimetic designs for wind turbine blades with inspiration from nature. From sea creatures to birds, from the wings of winged insects to tree seeds and plant leaves, the designs of nature have been inspired and many studies have been presented on both new designs and design optimizations (Cognet *et. al.*, 2017).

Some of the most aerodynamically impressive bio-inspired works involve the flight of owls and seagulls. As a result of the researches, it has been determined that the wings of large owl species provide the ability to fly almost silently at frequencies above 1.6 kHz (Oerlemans. *et. al.*, 2009). Studies have shown that owls have this ability with a comb-like leading edge structure, trailing fringes and a soft and porous upper surface structure. This structure enables efficient use of air in terms of aerodynamics and high transport efficiency at low speeds (Jaworski & Peake, 2013). Teruaki Ikeda et al., inspired by bird wings that enable strong aerodynamic force generation and stable flight, have designed a biomimetic blade for small wind turbines. They used Computational Fluid Dynamics (CFD) to examine the aerodynamic properties of the bird-inspired curved wing morphology they developed and stated that their design had 8.1% better performance than a conventional wing. As a result of the positive results they found, they stated that the biomimetic blade design has an important and great potential for wind turbines and their design can provide an innovative, practical and effective method in wind turbine design for turbulent environments (Ikeda *et. al.*, 2018). Andrew Bodling et al. conducted a numerical research on the design of biomimetic blades to reduce noise in aircraft engines and wind turbines. Inspired by the feather structure of barn owls, the researchers modeled the wing geometry numerically and compared the aerodynamic and aeroacoustic performances with the traditional wing profile. They observed that trailing edge serrations originating from the owl wing structure reduce noise up to 1.8 dB at high frequencies. As a result of their simulations, they stated that the spacing of the serrations is an important design parameter (Bodling *et. al.*, 2017).

Ian A. Clark and colleagues conducted computational and experimental research for a new design inspired by the unique features of the wings of owls that use acoustic stealth during hunting for trailing edge noise control. Inspired by the feather structures on owl wings, the researchers placed the protrusions they developed towards the trailing edge on both the lower surface and the upper surface to prevent boundary layer turbulence. For their design, they tested more than 20 types by making aeroacoustic wind tunnel measurements and, thanks to the useful design they found, they observed a noise reduction of up to 10 dB in trailing edge noise, unlike conventional blades. In addition, they stated that the thickness, density, length and position of the processes to be applied in the design directly affect the effect of the process. The researchers, who obtained positive results in this application in terms of noise, also observed that this application did not have any harmful effects on the handling performance of the wing profile (Clark *et. al.,* 2017). Frank E. Fish and colleagues developed a bio-inspired wind turbine technology inspired by the fins of humpback whales. Using computational fluid dynamics, wing sections with cusps at 100 angles of attack compared to a tuberless section observed a 4.8% increase in lift, a 10.9% reduction in induced drag, and a 17.6% increase in lift/drag ratio. They also observed that the electricity production of wind turbines with tubercles increased at medium wind speeds. In addition, with this study, the working angle of the wings was increased from 11 degrees to 17 degrees (Fish *et. al.,* 2011).

Weichao shi et al. studied in detail the flow around turbines with and without biomimetic leading edge cusps. With the positive results obtained from the numerical studies, they applied the design to a scaled turbine model with different levels of cusps. It is stated that the hydrodynamic performance of the turbine can increase in the low-end speed ratio region without reducing the maximum power coefficient, which will allow the turbine to start at lower flow rates. The tubercles also help to limit the cavitation zone and thus reduce the noise level. With these advantages, a silent and fast-response turbine design is created (Shi *et. al.,* 2017). In his thesis, Garrett Wright examined a new design in which he applied the most effective and well-known humpback whale tubercles and owl wing structure of biomimetic design. The aim of the study is to combine the two designs to develop a hybrid design that simultaneously increases efficiency and reduces noise. After his research and testing on hybrid profiles, he found that while the noise reduction aspect of the design was successful, placing the tubercles on the trailing edge caused a decrease in overall efficiency (Wright, 2017).

In a study by H. Johari et al., the effects of leading edge protrusions on airfoil performance were investigated. They observed a decrease in lift and an increase in drag on protruding wings at angles of attack lower than the stopping angle of the basic wing structure. When the stall angle is exceeded, 50% greater lift than the basic wing design was observed. Another issue identified in the studies is that while the protrusions have a significant effect on the performance of the airfoils, the wavelength has little effect (Johari *et. al.,* 2007). On the other hand, plants, tree leaves and tree seeds, which are in constant interaction with the wind and are highly efficient in terms of aerodynamics, have also inspired researchers and many researches have been done in this field. Camilo Herrera and his colleagues designed a wind turbine blade inspired by the seed of a tree called "Triplaris Americana", also known as the ant tree, and presented a wind turbine design with a different design from traditional horizontal axis wind turbines with three blades. Computational fluid dynamics simulation was performed to estimate operational loads. The reason for choosing the selected seed in the study is the rotational movement it makes while falling from the tree. As a result of their experiments with more than 50 different seeds in the vertical wind tunnel they set up for the first stage of the study, they observed an angular velocity of around 1500 rpm and an average free fall velocity of 1.5 m/s. In the second stage, the structure of the wing was characterized from the cross-section of the seed and as a result of the experimental study, they reached a design that started to generate electricity at a wind speed of 2.5 m/s. This special geometry designed has shown that wind turbines have the potential to generate electricity in regions with very low wind speed (Herreraa *et. al.,* 2018). Yung-Jeh Chu and Wen-Tong Chong designed a biomimetic wind turbine inspired by the "Dryobalanops Aromatica" seed, also known as Borneo camphor. The designed biomimetic wind turbine provides a better self-starting and a good balance of yaw mechanism at low wind speeds thanks to its high torque (Chu & Chong, 2017). Cory seidel and colleagues have designed a bio-inspired vertical axis wind turbine from maple seeds and "Triplaris Samara" seeds. They observed that the seeds produced stable leading edge vortices (LEV) that increase the bearing force as they fall to the ground. It has also been shown that leading edge eddies near the root of the wing depend on the geometry of the wing, the Reynolds number, and the angle of attack. As a result, it has been observed that turbine blades inspired by maple seed show the ability to withstand stronger wind speeds (Seidel et. al., 2017).

In their study, Jeppe Johansen and Niels N. Sørensen described the numerical investigation of aerodynamics around a bladed wind turbine blade using Computational Fluid Dynamics (CFD). Five fin models with different twists and curvatures were examined. Of these, four are designated for the pressure side (upstream) and one for the suction side (downstream). As a result, it has been observed that adding a blade to the conventional wing increases the force distribution over approximately 14% of the wing, resulting in an increase of approximately 0.6% to 1.4% in power generated to wind speeds higher than 6 m/s. Curving the fin downstream further increased power output, but the effect of sweep and pitch angles was not taken into account in obtaining the results (Johansen & Sørensen, 2007).

With the dissolution of the complex structure of nature and the biomimetic designs made, the installation cost, turbine noise and low efficiency problems arising from the design, which hinder the progress of wind turbines as a disadvantage, will come to an end. The new biomimetic designs, which will be designed by improving the work done and inspired by nature, will enable many large and small scale turbines with high efficiency and widespread use, which can meet the installation, operation and recycling costs in a short time, become a part of our lives and export energy demand, even if they are not quiet, low cost. It will end the dependency.

Researchers have tried to reach the ideal wing design by observing nature-inspired wing designs in every area from aquatic creatures to birds, from insects with the ability to fly to plant seeds. Despite their size and weight among sea creatures, humpback whales have inspired researchers thanks to their superior hunting abilities and their unique morphological structures have been transferred to their wing designs. The tubercle protrusions on the fins of humpback whales provide an increase of about 18% in lift/drag force in their wing designs, while also allowing the wings to operate at high angles of attack. When the studies inspired by plant and tree seeds are examined, it is seen that the blade designs inspired by seeds enable the wind turbine blades to start working at low wind speeds such as 2.5 m/s. This provides the potential to generate electricity in regions with low wind speed. In addition, the most impressive biomimetic studies in terms of aerodynamics are those inspired by the wing designs of birds. While there is a significant reduction in the amount of noise and vibration, especially in the wing designs inspired by the owl wing, the use of the notched structure of the owl wing structure on the leading edge, unlike our thesis study, gave positive results in terms of aerodynamics. Nature, which contains many problems and solutions, will ensure that renewable energy sources, especially wind energy, become the energy of the future by removing the obstacles.

2. Biomimetic Wing Design and Aerodynamic Performance Analysis

In this study, the aerodynamic performance parameters of the wind turbine blade structure, which will be inspired by living things in nature, were examined as a fixed blade. Similarly, this study was carried out considering that if the aerodynamic parameter of a fixed blade is better, it will give better results when used in a wind turbine. The winglet, which significantly affects the fuel consumption and aerodynamic performance of aircraft, has also been a source of inspiration for us in this study. In addition, the wing tip vortex reducing endless wing, which is similar to the working logic of the winglet, is investigated in wind turbine blade design in this study. See in this (Uzun & Çoban, 2021). in the numerical analysis of the curved wing and winglet structure, it was observed that the aerodynamic performance improved with the change of the curvature percentage. In this study, the aerodynamic performance values were investigated numerically by adding the endless wing and the up and down curved shape of the wing in accordance with the wing structure. In this study was carried out at different speeds at a constant angle of attack, and flow images and aerodynamic parameters were given graphically.

2.1. Design parameters

Because of its overpowering in the wind turbine industry, it is very sensitive to changes in airfoil and design. In wind turbine blade design, turbine blade aerodynamics and wind load are important parameters. This section will shortly describe the main parameters that affect the performance of modern wind turbine blades. While designing the wing, drag and lift force, Betz limit, losses and wing element theory criteria should be considered.

In today's modern wind turbines, special airfoils are used to obtain ideal power from the blade. It is aimed to improve the carrying force in the airfoil structure. In these special profiles, two different curved blade structures are formed above and below a beam line. The fact that the upper curve has a more humped structure creates a pressure difference between the two surfaces and the tendency of the air in the high pressure area to move to the low pressure area creates the bearing force.

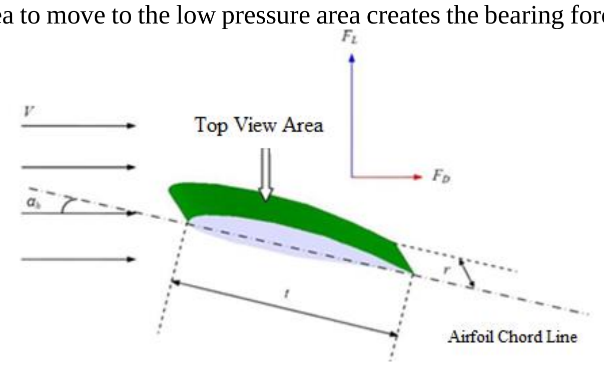


Figure 1. Forces acting on the airfoil

$$F_D = 1/2\ C_D\, \rho A V^2 \quad (2.1)$$
$$F_L = 1/2\ C_L\, \rho A V^2 \quad (2.2)$$

Here, C_L is the lift coefficient, and CD is the drag coefficient. C_L, C_D, C_L/C_D (ε) values are determined experimentally at certain Reynolds number and different angles of attack, and these values indicate the quality of the airfoil.

The dimensions of the wind turbine are considered to be directly related to the aerodynamic structure in order to obtain the best energy from the wind. No matter how good the installed turbine is, there is an upper limit to the energy that the system can obtain from the wind. According to the Betz limit, the energy that can be obtained from the wind in the ideal environment is theoretically 2/3 of the wind.

2.1.1. Tip speed ratio

The tip speed ratio is expressed as the relationship between the free flow speed and the wind turbine blade, and it has an important place in optimizing other parameters. (Schubel *et. al.,* 2012):

λ = Tip Speed Radio

Ω =Rotational Speed (rad/s)

r=Radius (2.3)

$$\lambda = \frac{\Omega r}{V_w} \qquad V_w = \text{Wind Velocity}$$

Optimizing wing tip speed depends on noise, torque force, aerodynamics and vibrations. Efficiency will tend to decrease with increasing noise, if the wing tip speed, which is taken into account together with other variables, increases, the efficiency of wind energy will increase (Gasch *et. al.,* 2002).

2.1.2. Wing plan shape and quantity

The ideal plan form of a HAWT rotor blade is defined using the BEM method by calculating the beam length according to the Betz limit, local air speeds, and blade lift. The simplest theory Based on the Betz optimization , several theories exist to calculate the optimum beam length varying in the complexity (Hau , 2006).range. For wings with six to nine tip velocity ratios using aerofoil sections with negligible drag and tip losses, Betz's momentum theory gives a good approximation [46]. In the case of low tip speeds, high friction aerofoil sections, and wing sections around the hub, this method can be considered inaccurate. In such cases, tracking and drag losses should be taken into account (Dominy *et. al.*, 2002). The Betz method gives the basic shape of the modern wind turbine blade (Figure 2). But in practice, more advanced optimization methods are often used.

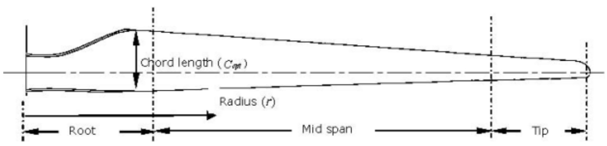


Figure 2. A typical wing plan and zone classification (Schubel *et. al.,* 2012)

Table 1. Optimum beam length

$C_{opt} = \frac{2\pi r}{n}\frac{8}{9C_L}\frac{U_{wd}}{\lambda V_r}$	r, radius (m) n, number of wing blades C_L, lift coefficient λ , local tip speed ratio V_r , local airspeed U, wind speed (m/s) U_{wd} , Designed wind speed C_{opt}, Optimum chord length
$V_r = \sqrt{V_r^2 + U^2}$	

Assuming that a reasonable lift coefficient is maintained, using a wing optimization method produces wing plans mainly dependent on the design tip speed ratio and the number of wings (Figure 3). Low tip speed ratios produce a rotor with a high stiffness ratio, which is the ratio of blade area to the area of the swept rotor. It is beneficial to reduce the strength area, as it leads to a reduction in material usage and thus production costs. However, problems are associated with high end speeds (Schubel *et. al.*, 2012).

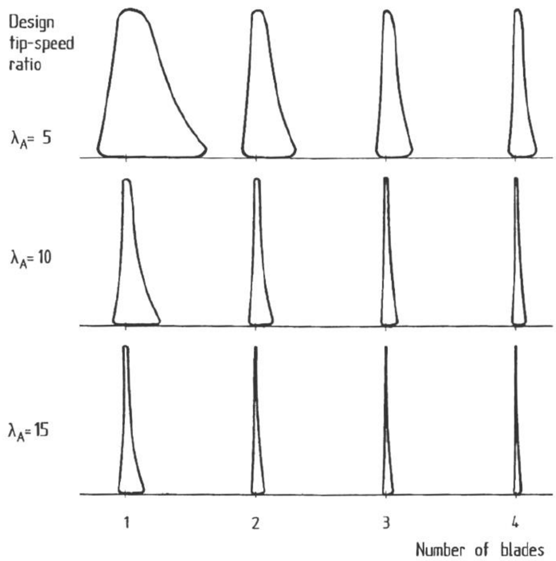


Figure 3. Optimum blade blade shape tip speed ratios and blade number for alternative design (Schubel *et. al.,* 2012)

2.2. Boundary conditions

The calculation area has been extended by 15 lengths (C) above and below the nose of the airfoil. Intercalarily, 20C was applied from the pressure outlet surface. The velocity input boundary condition was applied in the up and down directions at a speed of 13 m/s. Non-slip boundary condition is used on solid surfaces. Figure 4 shows all these setups for simulations.

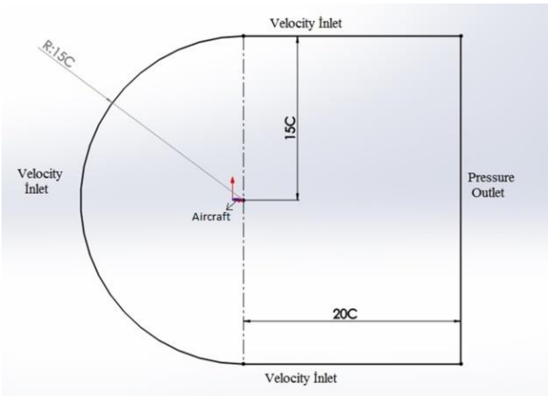


Figure 4. The dimensions and boundary conditions of the computational domain

Velocity components are defined for each angle of attack. The x component of velocity is calculated by x=13.cosα and the y component of velocity is defined by the formula y=13.sinα where α is the plane's angle of attack in degrees.

2.3. Grid Independency study

The grid used for the simulations is created with the CFD Mesh program and the mesh and all nose options are shown in Figure 5, the Patch Conforming / Sweeping method used. In order to eliminate mesh effects, the optimum number of mesh elements should be determined. Increasing the number of elements provides more accurate results, while using more elements increases the solving time. For this reason, network independence study was carried out with 100k, 200k, 400k, 800k, 1500k and 5000k elements. In Figure 5, the variation of the lift coefficient with different element numbers at 0 degree angle of attack is given. The lift coefficient value does not change much after 800k element count. In other words, it can be said that 2400k elements are sufficient for correct results.

In addition, the convergence criteria were chosen as 10-6. Approximately all analyzes were completed between 500-1000 iterations. Used computer with Intel(R) Xeon(R) CPU E5-1620-0 @ 3.60 GHz x64 bit and 8GB ram. The maximum analysis time for a simulation is 4 hours.

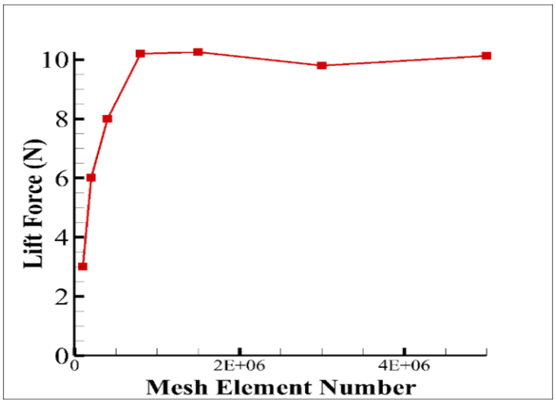


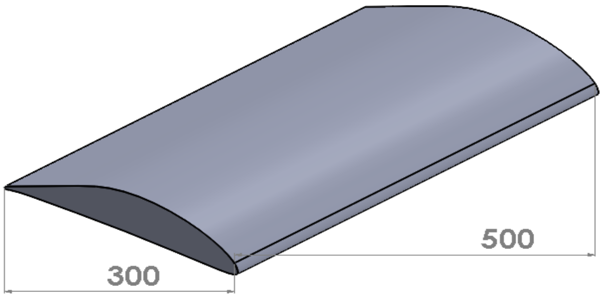
Figure 5. Variance of lift coefficient and number of elements

Table 2 gives the mesh properties of the our biomimetic wing design. Patch Conforming / Sweeping is selected as the mesh method and the smallest mesh element size is 1mm.

Table 2. Mesh properties

MESH PROPERTIES	
Minimum Element Size	0.0053056 m
Number of Elements	819427
Maximum Size	0.61847 m
Ortogonal Quality	0.19604
Skewness	0.80212
Growth Rate	1.115
Curvature Normal Angle	18°
Mesh Method	Patch Conforming / Sweeping

Figure 6 shows the dynamic pressure, velocity magnitude and pattline velocity analysis results of the fixed wing, respectively. The orthogonal quality gives an idea about mesh quality in wind blade and airfoil analysis. The range of 0.95-1.00 is excellent, 0.70-0.95 is very good, 0.20-0.69 is good, 0.10-0.20 is receivable, 0.001-0.10 is poor and finally 0- 0.001 is considered as inadmissible (Görgülü *et. al.,* 2021)



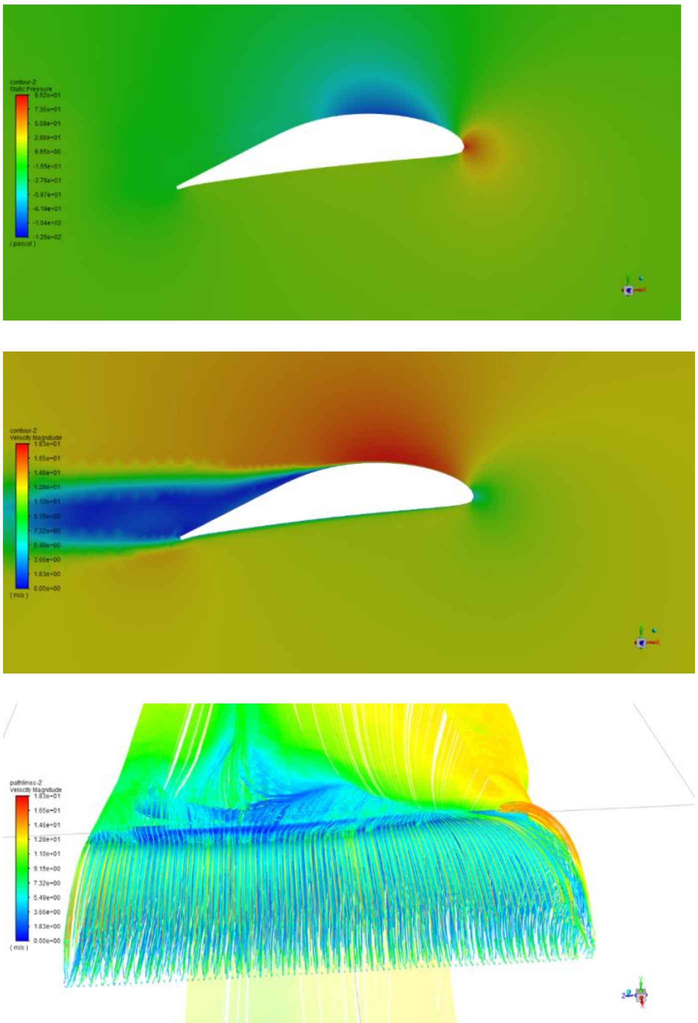
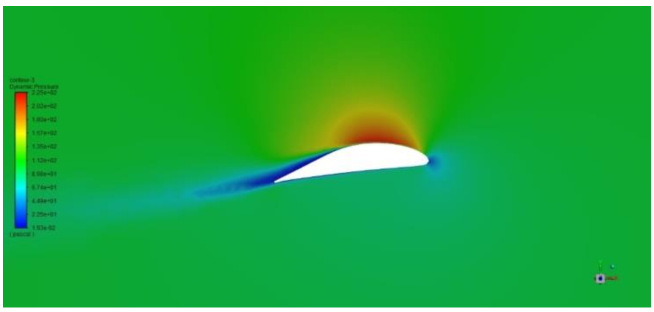


Figure 6. Fixed wing dynamic pressure, velocity magnitude and pattline velocity analysis

In figure 7, respectively, dynamic pressure, velocity magnitude and pattline velocity analysis results of the endless wing1 is given.



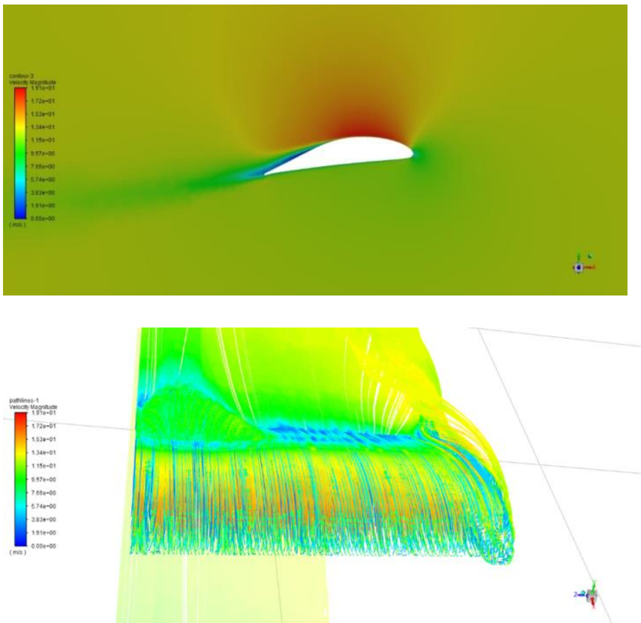
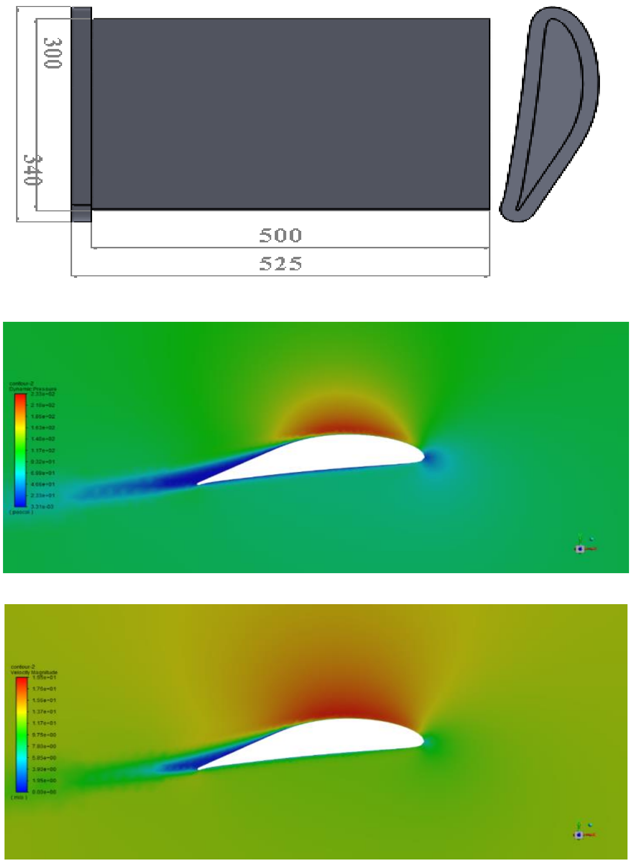


Figure 7. Endless wing1 dynamic pressure, velocity magnitude and pattline velocity analysis

Figure 8 shows the dynamic pressure, velocity magnitude and pattline velocity analysis results of the endless wing2, respectively.



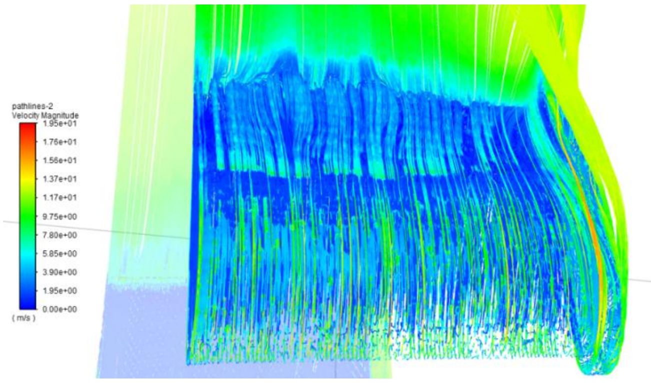


Figure 8. Endless wing 2 dynamic pressure, velocity magnitude and pattline velocity analysis

In figure 9, respectively, dynamic pressure, velocity magnitude and pattline velocity analysis results of the endless wing 3 is given.

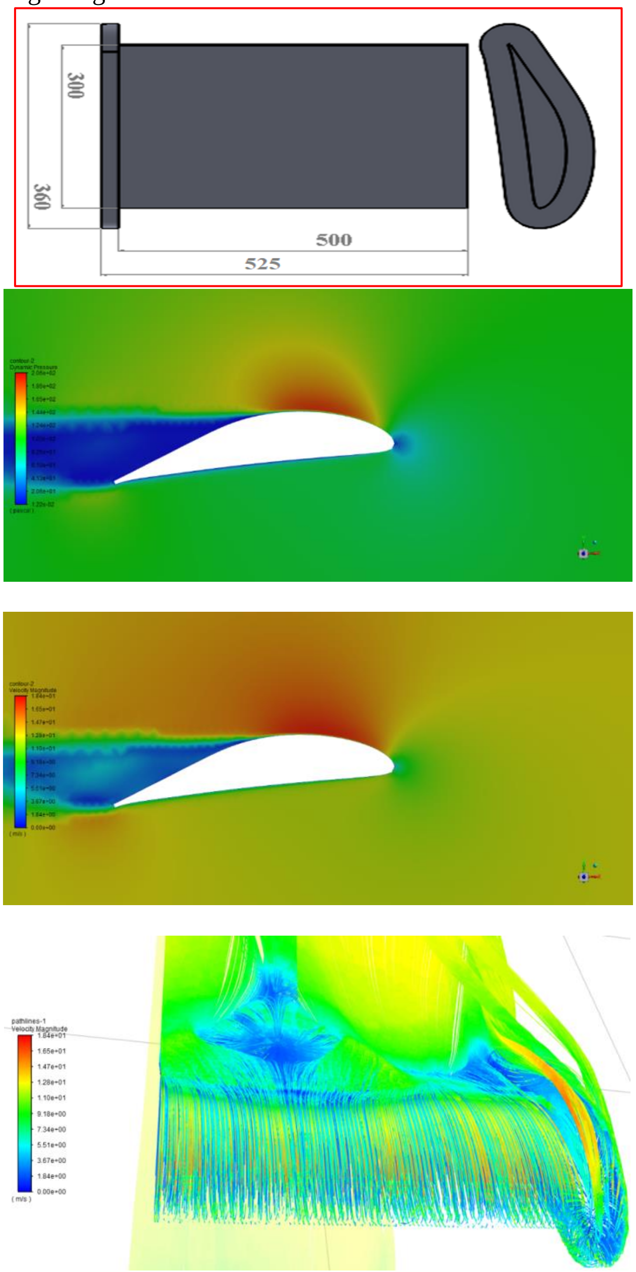


Figure 9. Endless wing 3 dynamic pressure, velocity magnitude and pattline velocity analysis

Figure 10 shows the dynamic pressure, velocity magnitude and pattline velocity analysis results of the curved down wing, respectively.

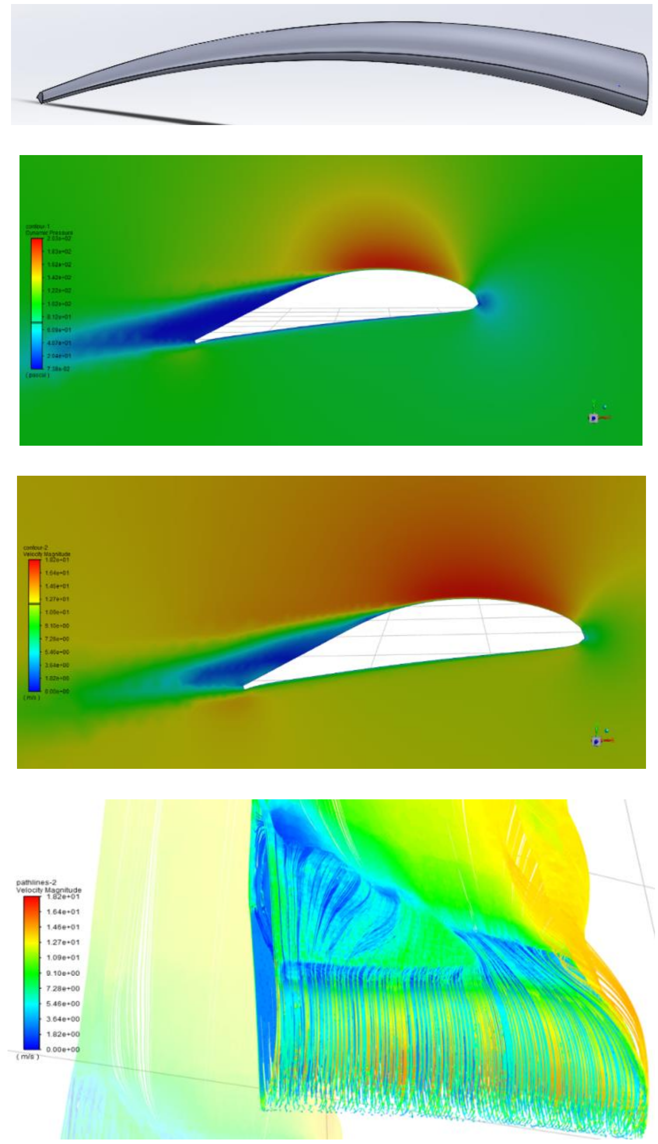
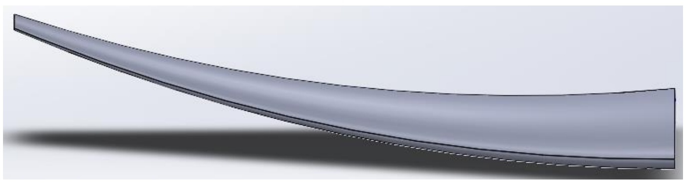


Figure 10. Curved down wing dynamic pressure, velocity magnitude and pattline velocity analysis

In figure 11, respectively, dynamic pressure, velocity magnitude and pattline velocity analysis results of the curved up is given.



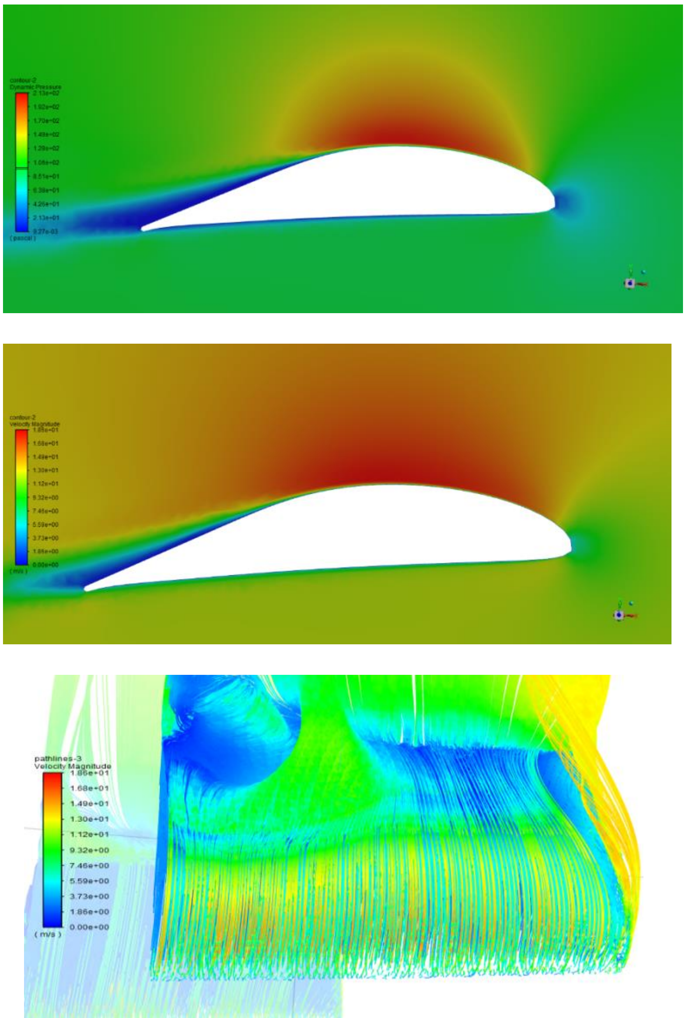


Figure 11. Curved up wing dynamic pressure, velocity magnitude and pattline velocity analysis

Detailed specifications of the designed wing profiles are given in Table 3.

Table 2. Detailed specifications of the designed wing profiles

	Angle of the wing tip	Radius(mm)
Winglet 1	70^0	5
Winglet 2	45^0	5
Winglet 3	30^0	5
	Notch width(mm)	Quantity(pcs)
Notched Leading Edge 1	2,5	4
Notched Leading Edge 2	2,5	6
Notched Leading Edge 3	2,5	14
	Endless wing length(mm)	Wing tip chord length(mm)
Curved Wing+ Endless Wing 1	12	8
Curved Wing+ Endless Wing 2	18	8
Curved Wing+ Endless Wing 3	27	8
Curved Wing+ Endless Wing 4	35	8

In Figure 12, the lift force values of the fixed wing and the curved wing are compared.

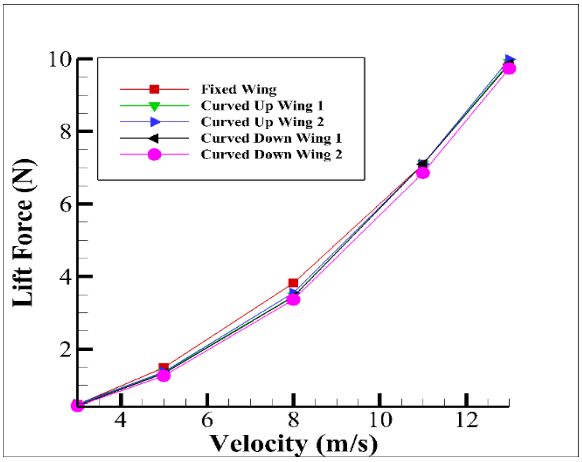


Figure 12. Lift force values fixed wing and curved wing

In Figure 13, the lift/drag force values of the fixed wing and the curved wing are compared.

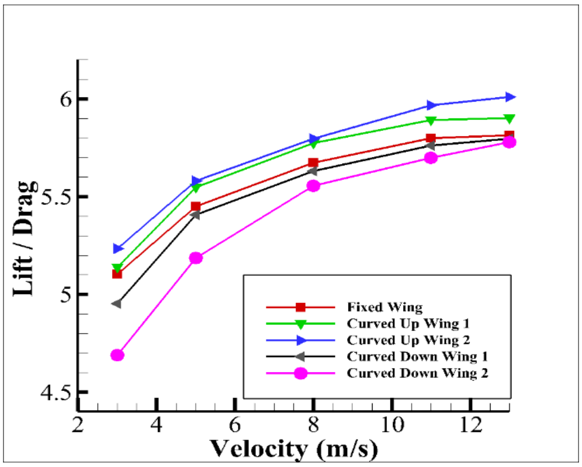


Figure 13. Lift/drag force values fixed wing and curved wing

In Figure 14, the drag force values of the fixed wing and the endless wings are compared.

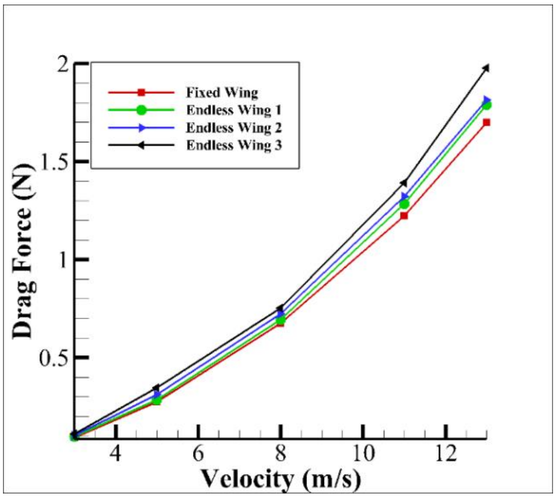


Figure 14. Drag force values fixed wing and endless wings.

In Figure 15, the lift values of the fixed wing and the endless wings are compared.

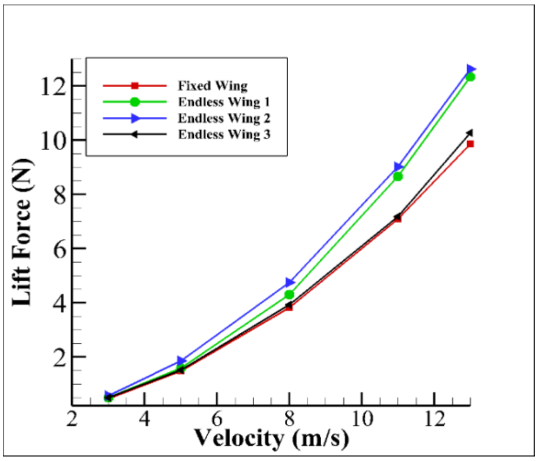


Figure 15. Lift force values fixed wing and endless wings.

In Figure 16, the lift/drag force values of the fixed wing and the endless wings are compared.

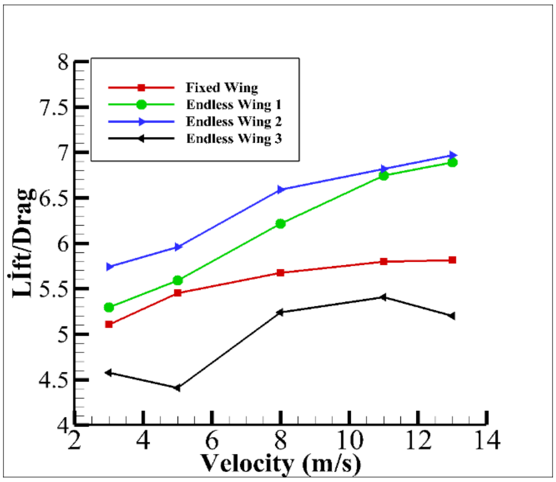


Figure 16. Lift/drag force values fixed wing and endless wings.

In this study, the flow analysis and aerodynamic parameters of fixed wing and variable sized fins mounted on the wing tip were compared. The endless wing structure was preferred from the same structure as the wing profile, but the variation in which size the infinite wing would give better results was examined by applying it. When the flow images are examined, while the flow disrupts the upper surface of the wing by forming a vortex due to the pressure difference from the tip of the fixed wing, this distortion is partially prevented when the endless wing structure is applied. However, when the size of the endless wing structure is increased, for example, for the endless wing 3, the increase in drag force has begun to affect the aerodynamic performance negatively. When the endless wing 1 and 2 structure is compared with the fixed wing, it is clear that the aerodynamic performance values improve when the graphs are examined, since the wing tip vortexes tend to decrease compared to the fixed wing. When the dynamic pressure images of the fixed wing and the endless wing are examined, it is clear that the pressure value naturally improves in terms of flow retention, as the upper part of the wing partially gets rid of the vortex. In Figure 16, the ratio of lift force to drag force, which is the aerodynamic performance values of fixed wing and endless wing operation, is given.

Here, it has been seen that the aerodynamic performance value of the fixed wing increases when the endless wing is added to the wing tip, and the design we call infinite wing 2 has the highest aerodynamic performance, and when the endless wing 3 dimension is changed, the performance value decreases due to the increase in drag force.

Similarly, inspired by the wing structure of the owl bird, the change of aerodynamic performance values was examined by giving an curved up and down from the middle part of the fixed wing. In figures 14 and 15, the solid design, aerodynamic parameters and flow analyzes of the curved up and down are given in detail. The flow separation bubble on the wing when the slope is given downwards in the wing structure and as a result, the losses in aerodynamic performance are clearly seen. When figure 16 is examined, it is seen that the lift divided by drag force values improve when the curve is upwards compared to the fixed wing, while the performance values decrease when the curve is downwards.

3. Wind Tunnel Analysis

It is used to test the aerodynamic properties of real or reduced-size parts and vehicles placed in the air tunnel (or wind tunnel) under controllable conditions. Different mechanisms are used according to the required speeds, as well as providing a smooth gas (or air) flow. Investigation of wind vortices formed around high-rise buildings, from air tunnels that used to be used only to control the aerodynamic forms of airframes, today both for the determination of the shape of projectiles and road-rail vehicles, as well as for the safe discharge of wind loads and gases of high-rise structures, bridges, power transmission lines and radar scanners. For this purpose, the experiments carried out to investigate how the snow falling in the regions where the highways are located can be counted. Experimental study of our wind turbine designs was carried out in the DNS brand T-490 model wind tunnel experiment set in the mechanical engineering inventory of Iskenderun Technical University.

Figure 17. T-490 wind tunnel

The T-490 air tunnel is designed to conduct experiments in the fields of aerodynamics and fluid mechanics. This air tunnel is an open air tunnel. In this type of air tunnels, air is taken from the atmosphere and given back to the atmosphere. The nozzle part controls the stable distribution of velocity in the closed measuring section.

3.1. Technical detail

Air velocity measurement, fan speed control, For airflow and aerodynamic experiments, large-scale intermediate channels, open type air tunnel, flow regulator, Transparent measuring section, Tunnel type axial fan, Drag and lift force with different apparatus, measurement, Blade model pressure distribution, Cylindrical pressure distribution.

3.2. Device dimensions

Device dimensions are A x B x H: 2500 x 670 x 1250 mm.

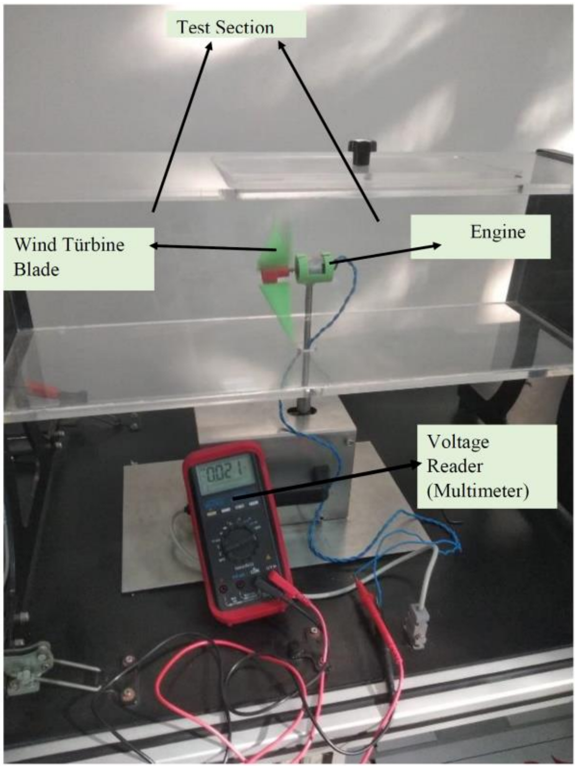
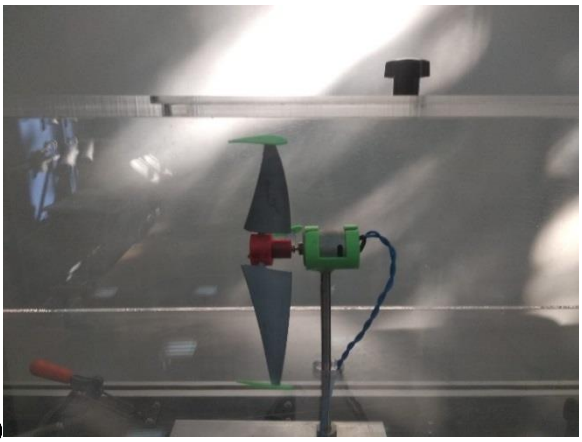
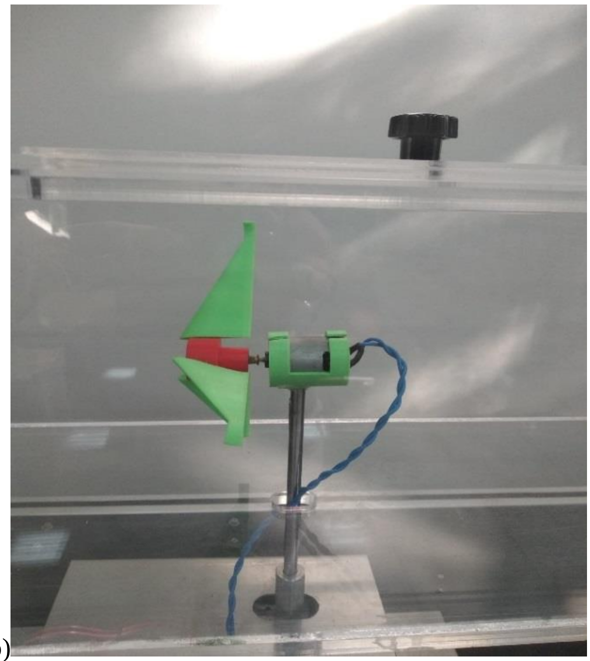


Figure 18. Wind turbine test system

In the previous sections, we talked a lot about the numerical analysis results and aerodynamic performance criteria of our wind turbine blade designs as fixed blades. In this section, it has been tried to determine the voltage values produced by the variables inspired by nature at different speeds and different connection angles with the help of an electric motor in the wind tunnel of the wind turbine blade designs experimentally. Here, the wind turbine hub, which is placed in the wind tunnel test flow region, the blade designs are mounted on the engine hub, and the cable connections of the engine are directly connected to the multimeter. When the wind tunnel is activated at different speeds, the flow rate information is obtained from the flow rate sensor in the diffuser area of our tunnel, and the multimeter gives us the generated power as voltage. The voltage values obtained were obtained by taking the test average of at least 3 minutes for each experiment. The aim of this study is to obtain a design that can produce higher power than different wind turbine blade designs.

a) 

b) 

c) 

Figure 19. View of wind tunnel from different angle

Therefore, the voltage value produced will give important information about learning which turbine blade design is more advantageous.

3.3. Endless blade effect in wind turbine design

In this section, inspired by the owl wing structure, the fixed wing structure is designed as curved wing and the power produced experimentally is measured when the endless wing structure is mounted on the wing tip. In figure 20, the dimensions of the endless wings placed on the curved wing tip are applied as variable and their size information is shown. Here, the meaning of the designs named endless wing1 or endless wing 2 and how they differ from the wing tip chord length are clearly given.

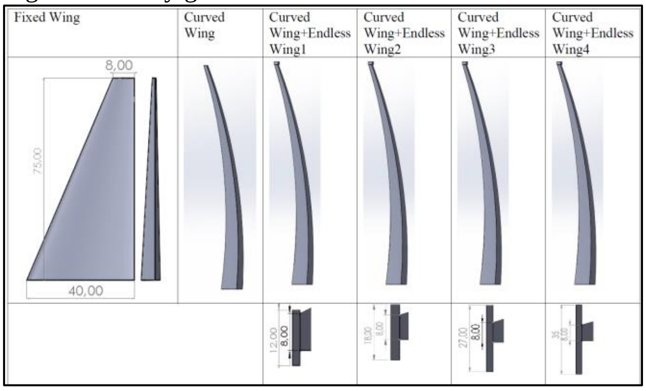
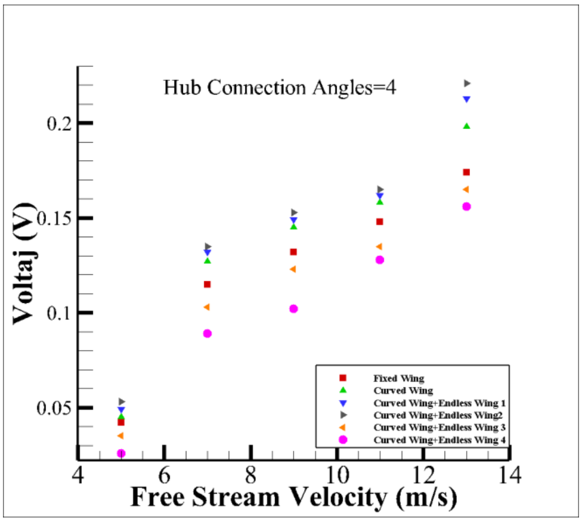
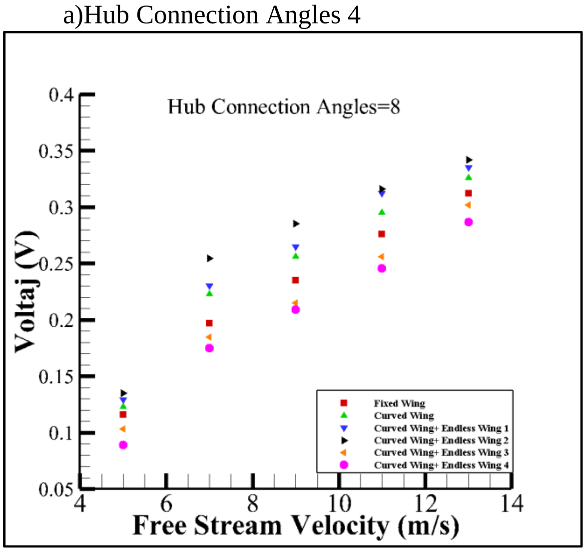


Figure 20. Endless blade designs

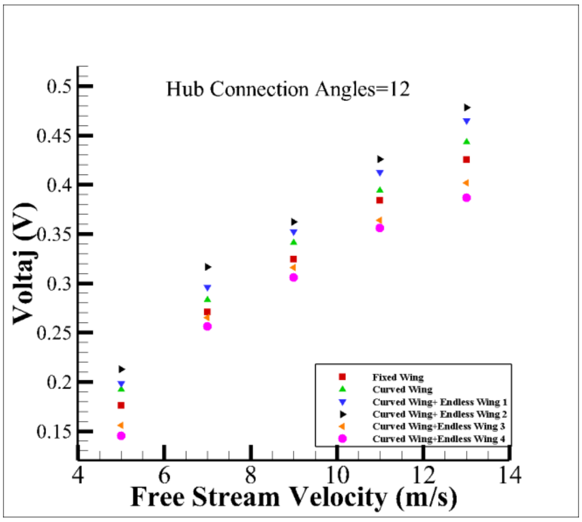
In the design named as Endless wing 1, while the wing tip is 8 mm, the mounted endless wing chord length is designed as 12 mm, and for the endless wing 4 it is designed as 35 mm. Here, the endless wing structure is obtained from the wing profile and enlarged at the same rate from all parts.



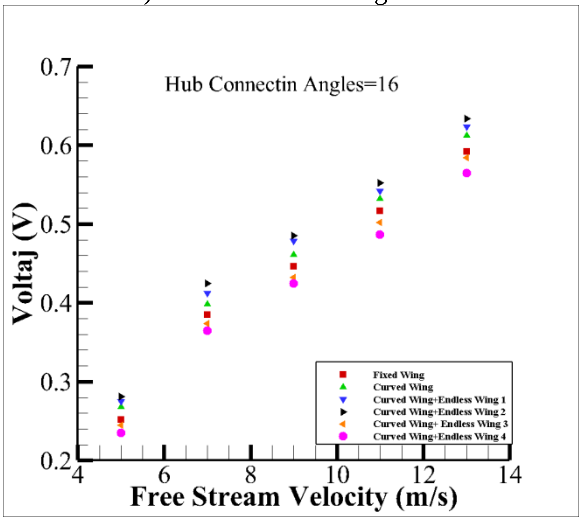
a)Hub Connection Angles 4



b) Hub Connection Angles 8



c) Hub Connection Angles 12



d) Hub Connection Angles 16

Figure 21. Voltage values of endless blade designs at different speeds

In figure 21, the voltage values obtained from the endless blade structures designed at different connection angles and different wind speeds are given. In figure 22, a visual about how the wind turbine blades are connected to the hub and how this hub is mounted with the engine is given.

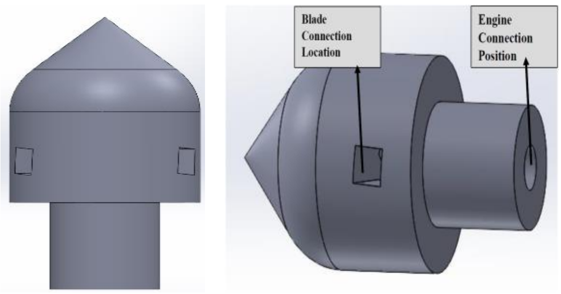


Figure 22. Blade hub connection

The measurements taken here were carried out at different hub connection angles, so different hubs were produced with different hub connection angles. Changing the hub connection angle corresponds to the angle of attack in the fixed wing system, but in systems such as power generation with the propeller, it creates a similar operation to the pitch angle. In Figure 21, 4 different graphs are given in these graphs. In these graphs, the information about how the endless wing structure that we add to the wing tip will be beneficial as a wind turbine according to different flow velocity values at different hub connection angles is presented. When the graphs given comparing the fixed wing and the endless wing are examined, the voltage value increased when the endless wing is placed on the wing tip, but the voltage value started to decrease because the increase in the endless wing chord length after a certain value produces extra drag force. hub connection angles were applied between 4-16 degrees, and when working with connection angles higher than 16 degrees, voltage generation decreased due to airfoil stall. In section 2, the results of constant flow analysis and flow visuals of designs with endless blades are also given, and it has been observed that the blade tip vortexes decrease when endless blades are applied. Based on this, it was thought that the endless blade application would be beneficial in wind turbine blade design. When the results were examined, it was seen that the voltage values produced were improved when the endless blade application was made in the right dimensions.

3.4. Winglet blade effect in wind turbine design

In this section, a wind turbine blade design has been made by adding a winglet to the fixed blade tip, and the voltage value produced by the designs defined as winglet 1, winglet 2 and winglet 3 has been measured. In the design called winglet 1, the fixed wing length and width were kept constant, and the design was obtained with the same airfoil structure as the wing profile, making an angle of 70 degrees with the vertical to the wing tip.

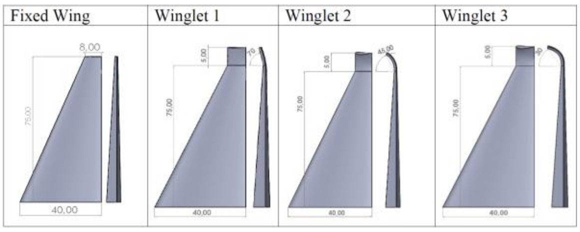
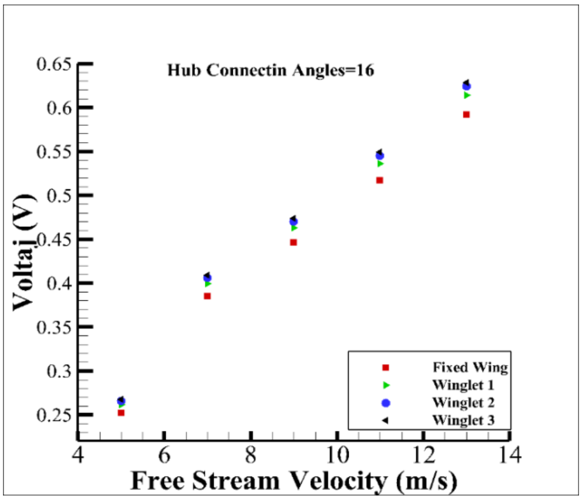


Figure 23. Designs with winglet mounted on the wind turbine blade tip

In the designs called winglet 2 and winglet 3, the fixed wing and the length and width are the same, and the angles they make with the vertical are 45 and 30 degrees, respectively. It is clear that aerodynamic performance values improve when a winglet is mounted on the wing tip of an unmanned aerial vehicle [20]. For this reason, it is significant that adding a winglet to the end of the wind turbine blade will also contribute to the electrical energy produced.



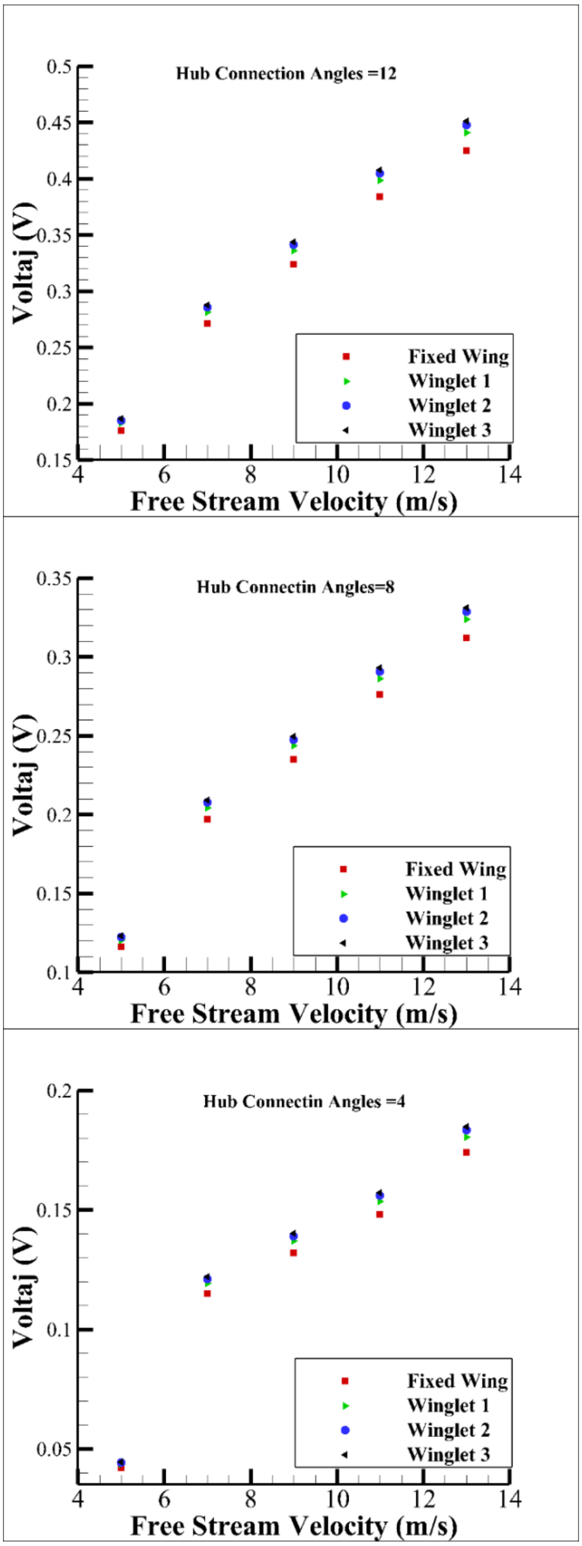


Figure 24. Voltage values of winglet blade designs at different speeds

In figure 24, the comparison of the voltage values obtained at different flow rates of the designs named winglet 1, winglet 2 and winglet 3 at different hub angles with the fixed blade is given. The winglet wing structure placed on the tip of the wing structure improves the flight performance of the aircraft, as it helps to reduce the tip vortices. Similarly, when the winglet usage in the wind turbine blade structure is examined, the generated voltage value has increased. The use of winglets increases the number of revolutions in the same environment as the wind turbine produces less drag force in the blade structure compared to the fixed blade. Free stream flow velocity values were preferred between 3-13 m/s. Since wind energy generally causes a decrease in efficiency above 13 m/s, and 3 m/s is the most inefficient of our designs to start power generation.

3.5. Notched leading edge blade effect in wind turbine design

When the trailing edges of the owl's wing structure or the wing structure of other similar birds were examined, it was observed that there were gaps between their feathers. There are designs in different technological fields inspired by nature. Especially in the aircraft engine exhaust part, it is clear that the logic of this actually reduces the noise level in the hunting mechanism, so it can be preferred in areas where noise and vibration reduction is desired. In this study, the study was carried out with the thought that it would be useful to produce the wind turbine blade design inspired by this.

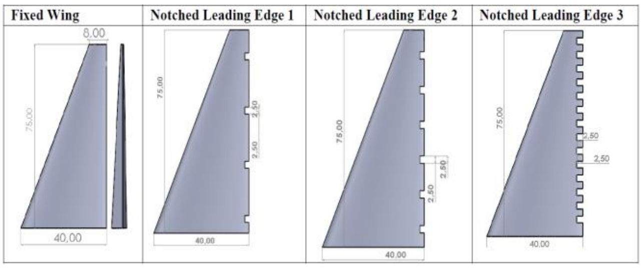
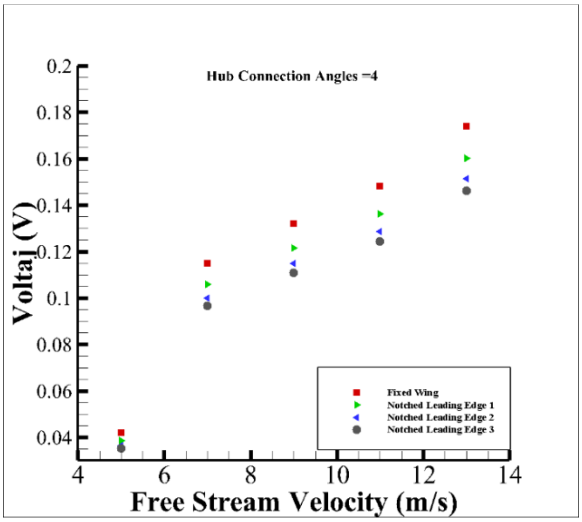


Figure 25. Designs with Notched Leading Edge mounted on the wind turbine blade tip

In figure 25, it is clearly shown in what size and how often the notched leading edge wing structure is added to the trailing edge with different designs in the fixed wing design.



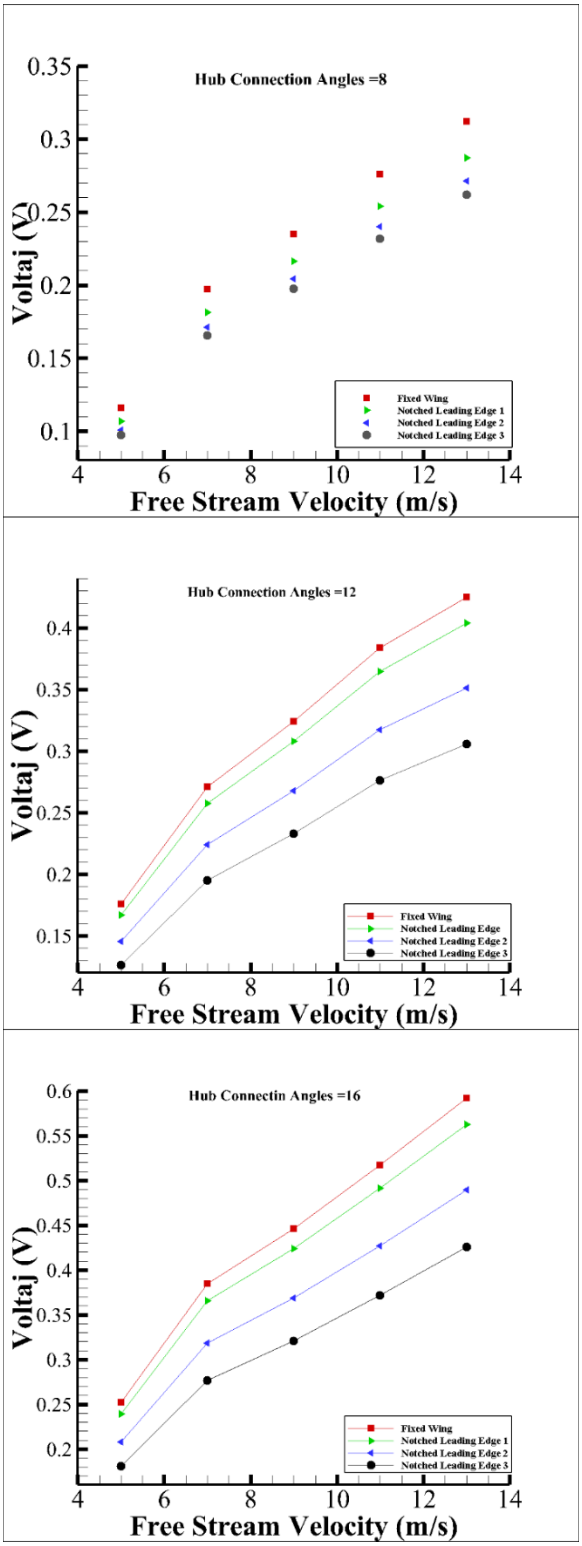


Figure 26. Voltage Values of Notched Leading Edge Blade Designs At Different Speeds

In figure 26, the comparison of the voltage values obtained at different flow rates of the designs named Notched Leading edge 1, Notched Leading edge 2 and Notched Leading edge 3 at different hub angles with the fixed blade is given. When the velocity and voltage changes of the notched leading edge wing designs compared with the fixed wing are examined, the presence of leading edge wing on the trailing edge or the increase in its frequency increase the cause the flow separation and turbulence to increase. Therefore, as a result of the notched leading edge blade application, the efficiency decreases and the voltage value produced decreases. However, it should be examined whether there is any improvement in vibration or noise and if there is an increase in efficiency in wind energy as a result of this effect.

4. Conclusion

In this study, it has been tried to maximize the efficiency of wind energy with a new design inspired by nature in the blade design of the wind turbine. First of all, the curved wing shape in the wing structure of the owl bird during flight attracted our attention. In the previous study, it was seen that the curved blade structure was beneficial in the efficiency of the wind turbine compared to the fixed blade, and together with these, the endless blade was integrated into the tip of the curved blade structure and tested in the wind tunnel. Variations in the voltage value produced depending on the size of the endless wing structure added at the wing tip were observed. An improvement of up to 15% was observed in the designs we named as curved wing1 and curved wing 2. Similarly, in the designs we named curved wing 3 and curved wing 4, when the endless wing size was enlarged, the opposite effect was observed, that is, a voltage drop of up to 12% was observed as the drag force increased too much. In section 3.4, the comparison of the fixed wing and the fixed wing structure with the winglet structure placed at the tip is given, and it is explained how the use of the winglet and the change of the winglet angle affect the voltage generation. An improvement of about 6% in the voltage values produced by the use of winglet in the fixed wing structure was obtained at different speeds and different hub angles. In section 3.5, a comparison of the voltage value produced by the notched leading edge and the use of fixed blade design as a wind turbine is given. When notched leading edge is applied to the trailing edge of the wing structure, it causes the flow to be disrupted and the vortexes to increase at the trailing edge. There is definitely a reason why there is this feature in living things in nature, but there is no benefit in terms of voltage or energy production when it is used in wind turbine blade structure. When the generated voltage values are examined, it is observed that the energy value produced has decreased by 30% with the increase in the number of notched leading edges.

Ethical approval

Not applicable.

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Investigation of Visual Disappearance by Intelligent Illumination of Exterior Surfaces of Unmanned Aerial Vehicles

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Abstract

Nowadays the elimination of the visual trace is very important, especially for the low altitude unmanned ait vehicles (UAVs) to protect from their enemy targets. For UAVs, which are widely used in both civil aviation and military fields, the issues of being undetected by visual and auditory and radar are have critical importance. For this reason, visual trace destruction has been taken into consideration at this work.

For this purpose, the design of the UAV with the intelligent illumination system and disappearance technology in the desired environment has been discussed. For this purpose, a UAV with a weight of 2,5 kg, a wingspan of 1,3 m, a length of 1 m, with a brushless electric motor, mid-range, medium-height, and moderately hovering features has been produced. Lighting system equipment is placed on the fuselage, wing and tail structure of the UAV. Flight tests were carried out by installing the appropriate lighting system in order to give the UAV the ability to disappear.

In the application study on the examination of the disappearance of UAV's by intelligent illumination of the outer surfaces, the design of the Intelligent illumination system and the application of the outer surface lighting were carried out.

1. Introduction

Today's technological developments have increased the studies on UAVs and made UAVs a popular engineering application field. UAVs have performed the observation and analysis of many military and civil applications and situations in daily life quickly and safely with meteorology, aerial mine detection, digital mapping, electronic warfare, rescue, aerial photography and video graphics, traffic surveillance, small package transport, scientific research, etc. (Austin, 2010; Konar, 2019; Konar et al., 2020; Kekec et al., 2020; Yildirim Dalkiran et al., 2021; Kekeç et al, 2021).

In the process of observation and inspection of UAVs, the invisibility feature has a great contribution to the UAV in terms of camouflage. UAVs designed for special missions also have made great contributions to users thanks to visual invisibility. In order to occur the concept of visual invisibility in UAVs, there should be occurred a contrast between the surface of the UAV and the background (sky) below the contrast threshold that the naked eye can detect.

It is known that when this contrast threshold occurs, the most suitable conditions for UAV visual disappearance are provided.

Unmanned Air Vehicle (UAV) is a kind of plane in which there is no pilot or any living being to control the vehicle, but there have only suitable equipments for the function such as a camera, laser scanning machine or GNSS. The management of plane is provided by remotely or automatically controlling. Due to the military, civil (hobby and commercial) and scientific uses UAVs are becoming more and more widespread. There has clear insights in today's life that UAVs will gain a big role in our future. Among the main reasons for these interests are the wide range of uses for civil-purposes UAVs as well as, it can be included the high accuracy, time and cost savings (Konar, 2020; Traub et al. 2021; Gur et al. 2009; Avanzini et al. 2013; Chang et al. 2015; Chamaidi, 2006; Igaw, 1999; Hsu, 2015; Koçkanat, 2020; Koçkanat et al. 2015)

The first studies on giving visual disappearance feature to the UAV date back to 1943. In the Second World War, the United States Army have started the Yehudi Project (Barrett et al., 2005; Chamaidi, 2006).

Today, the loss of visual trace is of great importance, especially for small UAVs that fly at low altitudes, so that they cannot be detected by their targets.

There are some studies about sky luminance and visual disappearance feature in the literature (Barrett et al., 2005; Macheret et al., 2011; Chamaidi, 2006). However, there are very few studies on bringing this feature to the UAV.

A study examining human vision has been conducted by Wu et al. in 2009 (Bo-Wen, 2009). In this study, image recognition based on the classification of human vision has been based and human eye modelling has been emphasized. In the studied models, the Optical Transfer Function (OTF) curve has been used as the evaluation-recognition capability and the optimum recognition model most suitable for human eye physiology has been summarized. However, they stated that their studies continue to create a more suitable model because there are a number of aspects to handle such as age, brain, vision process, CCD/CMOS sensitivity, display characteristics, human night vision etc.

In another study in 2015, Hsu et al., have designed a thin dielectric meta-surface using the reflection pattern of a flat surface (Hsu, 2015). By equating the angle of reflection to the angle of incidence, it has been stated that the observer sees a flat ground instead of a dispersed surface, with a gradual meta-surface design. Extremely low wavelength dielectric resonators have been used for the meta-surface and the phase value required to achieve concealment has been calculated.

The methods which are used in the second part of the application study on the investigation of visual disappearance by intelligent illumination of exterior surfaces of unmanned aerial vehicles have been discussed. In the third part, the design of smart lighting system and the illumination of exterior lighting are given. In the last section, the results are given.

2. Method and Procedure

In this part, visual disappearance technology, and analysis of invisibility in different conditions, theoretical infrastructure for invisibility, design of UAV and mechanism design for invisibility have been discussed.

2.1. Disappearance Technology

Today, the removal of visual trace can be achieved efficiently with the following technology-method: When cover of UAV which is luminous with electricity is brightened enough to create a level of contrast between the sky as the background and the UAV surface, which is the main surface, below the contrast level that can be perceived by the human eye, the relevant UAV will not be detected by the naked eye by the target on the ground (Igawa, 1999). In this way, invisibility will be ensured. In the figure 1, it has been presented the reduction and elimination of visual detection of a UAV with illumination at different altitudes (Hambling, 2020; Barrett, et al., 2005; Macheret et al., 2011). Visibility decreases with illumination at 5 m altitude, while at 300 m, invisibility has been fully achieved.

Figure 1. Visual detection analysis

2.2. Theoretical Background for Invisibility

Invisibility can be ensured when a contrast occurs between the surface of the UAV and the background (sky) below the contrast threshold that the naked eye can detect. This contrast threshold depends on the sky luminance and the eye's viewing angle of the UAV. Luminance refers to the intensity of light emitted in a certain direction from the unit area of the surface. Because of the intensity of light does not depend on the distance between the observer and the point whose luminance is calculated, luminance is also independent of the distance in between. Although brightness is an objective magnitude which is based on subjective evaluations by observers. Brightness largely both depends on the luminance of the surface, and also on the overall luminance distribution in the field of view, called adaptation luminance (such as the gray square on a white background appearing darker than on a black background, although they have the same luminance).

The correlation expressing the contrast threshold, sky luminance, and the eye's viewing angle of the UAV has been presented in Figure 2. (Barrett,R et al., 2005; Macheret et al., 2011). In Figure 2, the x-axis represents the sky luminance in foot-lambert units on a logarithmic scale, and the y-axis represents the contrast threshold perceived by the naked eye on a logarithmic scale. In this way, the object viewing angle of 5 different eyes has been handled in terms of arc minutes. These are 3.6, 9.68, 18.2, 55.2 and 121.0 arc minutes. In order to better understand the above shape and relations, it has been briefly summarized in Equation 1, which expresses the concept of luminance necessary for contrast and invisibility. The contrast can be found with the following formula (Equation 1):

$$C = \frac{L - L_B}{L_B} \tag{1}$$

In 1 in equation L; the luminance level of the object, L_B the luminance level of the background, and C; represents the level of contrast between the object and the background.

Luminace required to achieve contrast invisibility can be found by the following formula Equation 2. (Bo-Wen, 2009; Macheret et al., 2011; et al., 2011; Gordon, 1964; Blackwell, 1964). The lighting system on the UAV will create luminance at this level and it will be invisible to the eye.

$$L_0^* = L_B\left(1 - C_t\, e^{aH\frac{m}{m_0}}\right) \tag{2}$$

In Equation 2 (Macheret et al., 2011) a; damping coefficient, m; mass density of air in kg/m^3 at the level of the object, m_0; is the mass density of the air in kg/ m^3 at the zenith point. C_t; contrast threshold perceived by the naked eye, H; is the atmospheric altitude setting.

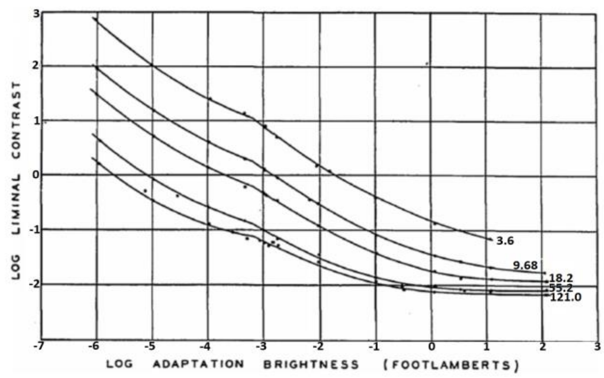

Figure 2. The amount of contrast required for invisibility in different sky luminance and the eye’s different viewing angles

2.3. Analysis of Invisibility in Different Conditions

In Figure 3 (Macheret et al., 2011), the variation of the threshold light power required for invisibility at different times of the day with altitude and area has been given (for 10.30 in the morning and at sunset). When viewed with this graphic, an object must be almost the same with the sky luminance to disappear (Bo-Wen, 2009).

2.4. Design of the UAV

At this part, first of all, the data of the UAV, which is planned to be produced, and the technical drawings of the UAV have been handled (Coban et al., 2018). In addition, the inertia matrix terms have been determined along with the positions of the luminance strip panels. The inertia matrices of the fuselage, wing and tail, which have luminance strip panels, have been found, and the parametric variation of the inertia matrix has been determined by the Parallel Axis Theorem (Oktay et al., 2016, Coban et al., 2018). Finally, a few basic assumptions used for the power assembly and have been passed in the manufacturing phase. The planned UAV will weigh 2.5, have a NACA 2415 profile with a width of 1.3 m, a length of 1 m, an electric motor, mid-range, mid-altitude flying, and moderately hovering. The presentation of the UAV is given in Figure 4.

2.5. Mechanism Design for Invisibility

Smart lighting system which is designed by detecting the sky luminance and the light dependent sensor will be given as an input to the control card. An external ground station control input will be added to the smart lighting system control card for any malfunction in the light dependent sensor. These two inputs will be processed on the smart lighting system control card and information will be sent to the luminance strip panel. Thus, the UAV, which will have the same luminance level with the sky, will be provided invisible.

The first control of the mechanism will be done on the ground. At the stage of ground controls, the sensitivity test of the mechanism to be measured with a lux-meter will be carried out. Then, the device tests will be carried out during the flight, and the UAV will be provided invisible (Figure 5).

The control chart of the mechanism to be used for invisibility is given in Figure 6. According to this scheme, an Arduino-based main control card will be used in the project works.

Arduino-based main control board will be programmed depending on 4 basic inputs: light dependent sensor input information, ground station lighting input, ground station selection control and ground station lighting active/passive control. The light dependent sensor input information will be obtained with the light dependent sensor, which offers a linear output between 0 and 2.3 volts at its output, depending on the sky luminance.

Thus, the sky luminance will be measured. The ground station luminance information will form the input where the amount of luminance can be adjusted manually by the ground station. The sky luminance information sent by the ground station will be received via the receiver on the aircraft. Another function of this input is that it allows the aircraft to be manually controlled against any malfunction that may occur in the light dependent sensor. With the ground station selection control input of the main control card, it will be possible to select whether the light dependent sensor or ground control input will be used to adjust the luminance. The last input information of the main control card (ground station lighting active/passive control) will be used to activate the lighting system. In terms of flight safety, the active and passive lighting system will be made by the ground station. Again, the control card will automatically deactivate the lighting system in case of disconnection from the ground station.

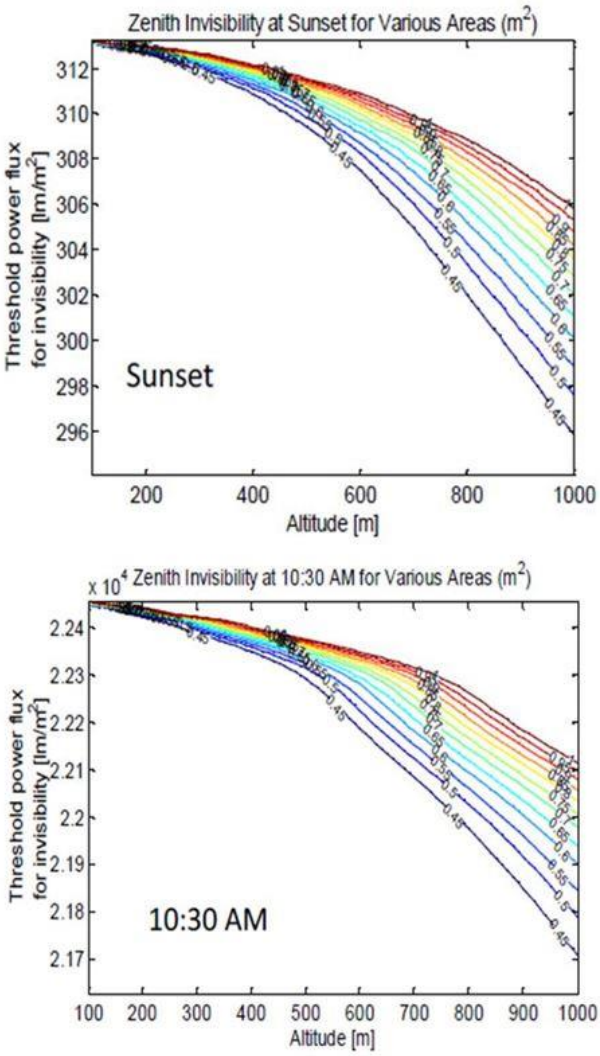

Figure 3. The variation of the threshold light power required for invisibility at different times of the day with altitude and area

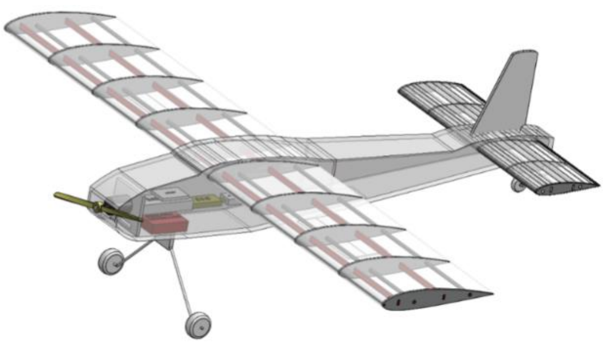

Figure 4. Demonstration of UAV

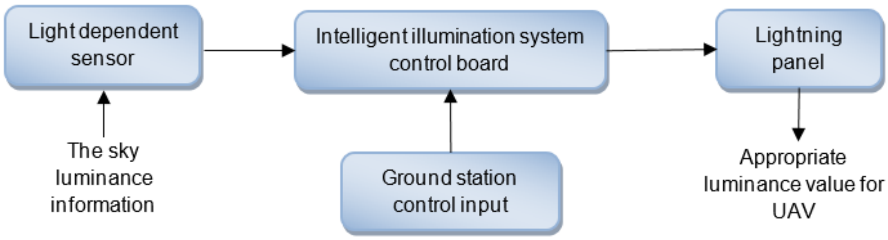

Figure 5. The mechanism used for the invisibility

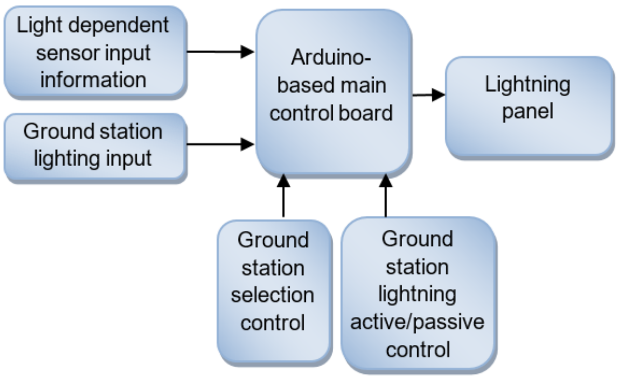

Figure 6. The working scheme of the mechanism used for invisibility

3. The Practice Phase

3.1. Circuit Diagram and Working Principle

The circuit diagram created for the smart lighting system is given in Figure 7. 555 integrated circuit is used as an astable multivibrator in this study. The capacitor C2 in the circuit is connected to the trigger (pin number 7) of the integrated circuit and is charged through the LDR in the circuit. This charge time varies depending on the RC time constant, where the "R" resistor is the LDR internal resistance. This resistance change causes the charging time of the capacitor C2 to change and as a result, the output frequency to change. Since the change of the output frequency will also change the time that the BD664 transistor connected to the output remains on per unit time, the power transferred per unit time on the load will change. Since the internal resistance of the LDR changes depending on the light change on it, it will show low internal resistance in cases where it receives a high amount of light, accordingly the output frequency will increase and the power transferred to the load will be high. On the contrary, when it receives low amount of light, it will show high internal resistance, accordingly the output frequency will decrease and the power transferred to the load will be low. In summary, the led lighting, this is used as a load in the circuit, will shine brightly under high light and dim under low light.

In Figure 8 the frequency value of the circuit in low light and in Figure 9 the frequency values of the circuit in high light are presented. In addition, before the printed circuit stage of the circuit, the circuit diagram has been tested on the board.

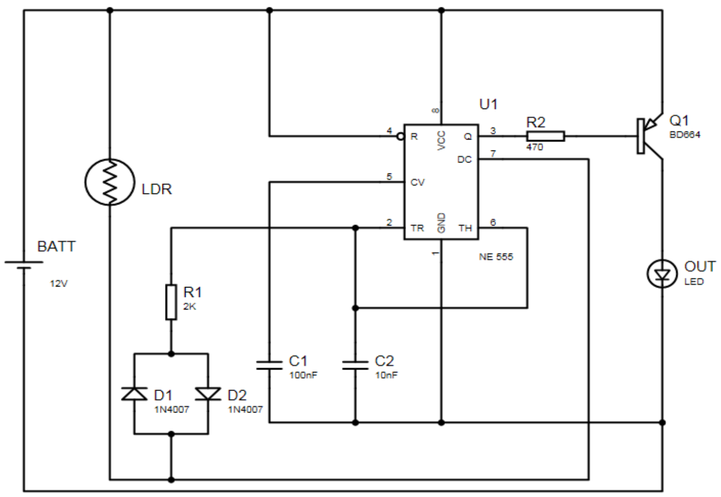

Figure 7. Circuit diagram

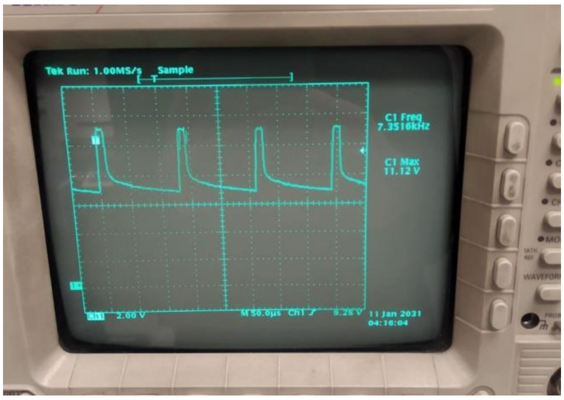

Figure 8. Frequency value of the circuit in low light conditions

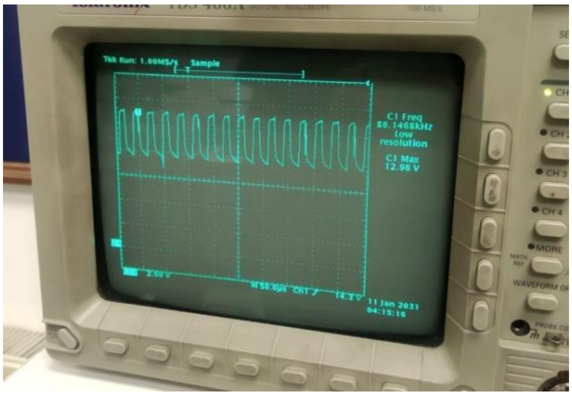

Figure 9. Frequency value of the circuit at high light conditions

3.2. Pre-flight Tests

It is of great importance to conduct ground tests before the flight. The most important of these is weight weighing. After weight weighing, the weight of the UAV must be covered by the propulsion system. If there is no enough propulsion system or the weight of the UAV is more than the calculated before, it will cause to the UAV not be able to fly. Therefore, the relationship between the Weight propulsion systems needs to be adjusted correctly. In Figure 10, the measurement of the gravitational force obtained from the propulsion system of the UAV is given.

The installation of the smart lighting system on the UAV is given in Figure 11 and Figure 12. As can be seen in the figure, the operating test at maximum brightness has been carried out in the UAV workshop environment. It has been checked whether the test time is sufficient for a 20-minute flight. The maximum brightness test has been carried out by using the manual input of the smart lighting system, that is, by giving it from the remote control. In this process, the change between the maximum and minimum levels has been observed by increasing and decreasing the brightness level from the dimmer channel of the controller. During this change, the smart lighting system circuit has worked well. After manual control, sensor control, which is smart lighting control, has been passed. It has been checked whether the smart lighting system works or not, taking into consideration of the sensor and the sky luminance. The representation of the sensor used is given in Figure 13. In Figure 14, the display of the brightness measurement of the UAV is given.

The brightness test of the smart lighting system installed on the UAV has been performed indoors, and the brightness level has been measured with luxmeter. In this measurement, it has been observed that luminance was obtained at the daylight level. After these tests, the flight test has been started.

Figure 10. Propulsion test of the UAV

Figure 11. Display of UAV's lighting

Figure 12. Illuminated UAV display

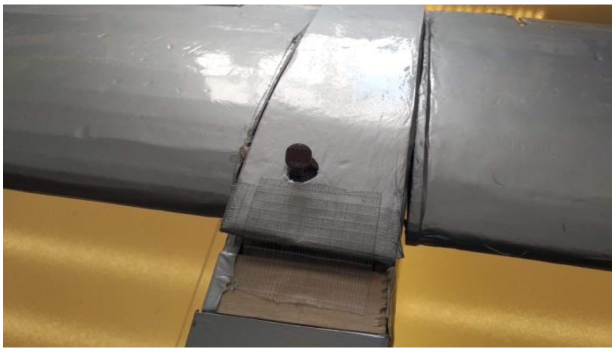

Figure 13. The representation of the external surface sensor on UAV

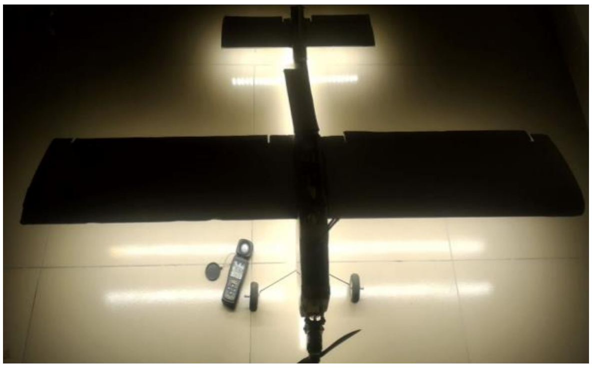

Figure 14. Display of the brightness measurement of the UAV

3.3. Flight phase

After the tests such as weight, accuracy test and balance, which was made in the atelier environment, UAV has started the flight phase. The flight phase consists of two phases. From the first stage, flights have been made without smart lighting system and the necessity of trim and balance settings have been checked. After these settings, a stable UAV is set.

The second flight stages are the flights with the smart lighting system. At this stage, first of all, stability has been taken into consideration, and after a stable UAV has been formed, the smart lighting system has been put into use in order to get visual disappearance feature.

A view from the first flight tests of the UAV is given in Figure 15. Take-off and flight views of the UAV are given in Figure 16 and Figure 17.

Figure 15. The view of the UAV in flight tests

Figure 16. Take-off view of the UAV

Figure 17. Aerial view of the UAV

3.4. The Disappearance of the UAV

With the completion of all ground and flight tests, the smart lighting system has been put into use. This stage, which has been carried out on the Talas Municipality Model Airplane Runway, has been tested in clear weather conditions. First of all, this test has been carried out in a short time, and it has been tried to avoid accident crashes of the UAV. Accidents have been experienced in the long-term trial. In the light of the findings related to the study, it has been observed that the visual disappearance changes depending on its location relative to the ground. It is obvious that visual disappearance obtained from different perspectives will be different. As a result of the study, it has been concluded that the UAV visually disappeared at an altitude of 300 meters in the view given in Figure 18.

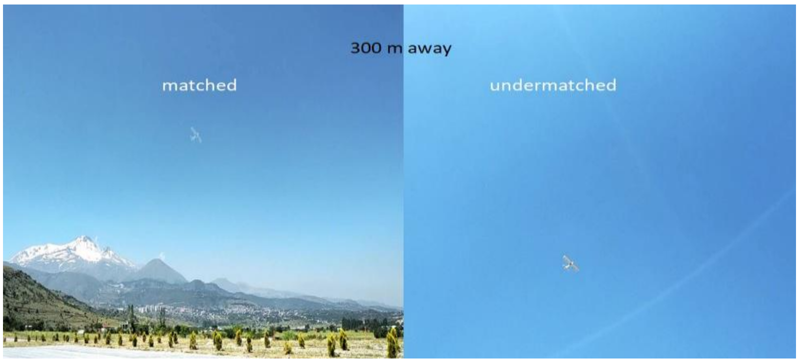

Figure 18. Comparison of UAV disappearance in mid-air

4. Results

In this study, UAV which has an electric brushless motor, 2,5 kg weight, 1.3 meter wingspan, 1 meter longitudinal length has been produced. The design and production stages of the UAV are explained. UAV electronic components used after production have been introduced. With the completion of the UAV, flight tests have been made.

In the study, the sky luminance has been detected by the light dependent sensor and given as an input to the designed smart lighting system control card. Also, a second ground station control input has been added for control at the ground station. These two inputs have been processed on the smart lighting system control card and the LED lighting level has been adjusted. The first control of the apparatus has been made on the ground in a dark environment, using a luxmeter. Then, the setup set up during the flight has been tested.

After successful flight tests, the designed smart lighting system has been installed on the UAV. Flights have been carried out with the smart lighting system. Visual disappearance has been observed with the activation of the smart lighting system in flights.

Ethical approval

Not applicable.

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The Effect of Social Media Activities on Consumers' Attitudes and Behaviour in Aviation Sector

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Abstract

The decline of ticket prices to reasonable levels, the increase of airports and the change in the perception of geographical distance have also increased interest in the airline passenger transportation sector. Therefore, it's important to determine the attitudes and behaviors of passengers as consumers for all segments of the sector. In this study, the effect of social media on consumer behavior and attitudes of passengers in air passenger transportation, whose role in consumer behavior has been shown by different studies in recent years, has been examined with an experimental study. The findings of the study show that there are significant differences in consumer attitudes and behaviors of those who are exposed to social media content compared to those who are not. Also, attitudes and perceptions of the consumers may change according to gender and age. It's hoped that the results will contribute to marketing practitioners in the industry and expand the social media literature.

1. Introduction

Mankind has always thought of flying throughout history and has made progress in this framework. From the first flight to this day, the air passenger transportation sector has entered into a continuous development in stages and continues to develop today. Despite the lockdown period due to Covid-19 pandemic, spend on air transport increased from 384 in 2020 to 487 billion dollars in 2021 according to the expected 2021 statistics (IATA 2021 End-year report). Parallel to the development of the industry, it is important for businesses to adopt the suitable marketing strategies in order to raise awareness, keep customer satisfaction levels at the desired level, and meet the expectations of their customers more than competing companies in order to create brand loyalty. One of the strategies that has developed in this process and is frequently used today is marketing strategies through social media.

On social media platforms where people share content such as information, videos, pictures, news, brands are advertised, promoted, videos and pictures are published, information about brand activities is given, and most importantly, comments are received from customers. Social media has become an important factor that affects purchasing behaviors positively or negatively (Constantinides and Stango, 2011: 9). It has been revealed that the purchasing behavior of consumers is mostly affected by social networks (İşlek, 2012: 141). In the air transportation sector, which is becoming more and more important every day, it is important to reveal the purchasing preferences and intentions of the passengers, as a customer, and the attitudes of the sector players towards their content on social media in such a social media age.

However, there is a gap in the literature regarding the effect of social media activities of airline passenger transport companies on consumers' attitudes and perceptions towards airline companies. Based on this gap and the importance of the situation, in this research, it is aimed to reach meaningful findings about the relations between purchasing preferences as well as perceptions of the consumers and social media contents and marketing activities of companies by examining passenger behaviors as a consumer within the scope of the airline transportation sector in the social media era.

2. Literature Review

2.1. Turning social media into a marketing tool

Since its existence, human beings have constantly felt the need to socialize in relation to the desire to make themselves accepted by the society and to be a part of a society. Communication, which is the most important component of the need for socialization, has been exposed to various changes throughout history. Nowadays, in parallel with the development of computer and telecommunication technology, communication has also been subject to a digital transformation (Onat and Alikılıç, 2008). In this point, It is useful to look at how the Internet has entered our lives. The

US and Soviet Russia sides, who did not want to lose the ongoing cold war in the 1950s, had to develop different military technologies. Communication is also at a very important point from a military point of view, and the US side, which understands that it is important to develop a communication system that will not be damaged in a nuclear attack and will not collapse when a single point is eliminated, has developed such a communication network. This new model proposed by Paul Baran creates a network system that is not tied to a specific point, where each unit transfers information to another unit. This network system that allows computers to communicate with each other is ARPANET, and this system, which was originally developed for military service, is considered its ancestor on the internet. With this system, it became possible to establish a connection between computers with the introduction of the "world wide web" (www) by Tim Barners Lee at CERN in 1989. As a result of all these developments, the network structure has become global and suitable for commercial activities (Başlar, 2013).

With the continuous development in internet technologies, a platform called "Web 2.0" has been adopted, in which two-way communication is established, where content prepared by someone else is not only read but also users contribute to the content (Askeroğlu, 2010). Web 2.0 brought with it social media. This concept has started to become a tool where individuals spend their time to chat, have fun, access information easily and follow the agenda (Solmaz et al., 2013). Social media are platforms where people can share things and discuss issues regardless of time and place (Vural and Bat, 2010), where individuals can communicate using internet technologies, create and share their own content (Semiz and Bora, www.stb.org.tr). Over time, businesses understand the power of social media and social media has become a platform where businesses can communicate with their customers and carry out marketing activities.

Social media marketing is marketing efforts made through social media platforms in order to increase the brand value of a product or to sell it (Alan et al., 2018: 495) or the promotion of products and sales activities of businesses using social media tools (Barefoot and Szabo, 2010: 13). Today, using social media tools is no longer a luxury. From the point of view of businesses, social media tools offer the opportunity to save both time and money (Barutçu and Tomaş, 2013: 6-20). According to Nair (2011: 47), businesses with social media marketing; It aims to design new product designs together with customers and potential customers, to follow the market and customers, to monitor customers' ideas, to gather vendors and all other partners in the value chain and to be in constant dialogue, to use the social network as a messaging platform and to serve customers in this way. The benefits of social media marketing for businesses are that it is costless or very low cost, that it is possible to communicate with customers, so that the products that the customer wants can be produced, and that the products at hand can be controlled more effectively (Sarıyer and Ceylan, 2018: 373).

2.2. Social media advertising

When social media platforms are examined in terms of the advertising sector, it is seen that marketing efforts shared on social media reach a large consumer mass effectively and cheaper in a short time (Özdemir and Doğanay, 2019: 301). In Çağlıyan's study (2016, 54-55), it has been observed that social media advertisements have a significant effect on the purchasing behavior of consumers. The language, style, content, visuals used in social media advertisements play a major role in customers' perceptions and attitudes towards brands and companies (Akkaya, 2013: 107). Businesses generally aim to make customers want to buy and sell their products with social media advertisements (Akkaya, 2013: 61). What businesses need to advertise on social media platforms such as Facebook, Instagram and Twitter are comments, likes and followers. In addition, follower customers will quickly reach the ads of the businesses and will be informed about the campaigns and prices on the pages they follow before other customers.

The most important feature of social media ads is the dissemination feature. With this feature, users can share advertisements and information of businesses. Products with the expected performance are self-advertised on social media platforms (Kazançoğlu et al., 2012: 161). Another advantage is that social media ads have a high level of interaction. Thanks to this feature, businesses can learn the thoughts of their customers. Thanks to its flexibility feature, if a change is to be made on the advertisement, this change can be made in a very short time. At the same time, while social media ads do not get caught by geographical or seasonal barriers, their costs are very low. In addition to all these, another feature of social media ads is that they can appeal to everyone from a certain age group (Canlı, 2015: 29). As can be seen, social media advertisements can reach all customers of businesses simultaneously with very low costs. At the same time, due to its low cost, it can be used by every business from very large businesses to small businesses.

2.3. Consumer behaviour in social media

Today, social media platforms are one of the most important factors affecting the consumer behaviour. According to the study of Erdemir (2017: 13), individuals actively use social media and prefer it to traditional media tools. Especially in the recent years, most individuals have started to shop on social media. Consumers influence each other's thoughts in these channels, comments made below the products in these platforms are read by the other users and are affected by these comments (Say, 2015: 66). According to Olgun (2015, 502-504), consumers have become stronger today and consumers who actively use social media can easily reach comments about the products they want and can be affected by these comments. In the same research, it was found out that the majority of the participants did research about the product before buying a product and considered the comments about the product. İşlek (2012, 141-144) similarly stated that users generally read comments written by other users and that consumers are most influenced by social networks in their purchasing behavior. He also observed that before buying a product or service, users search for these products on social media and find the comments generally reliable. In a study conducted by Çağlıyan et al. (2016, 54-55) on students, it was seen that the participants examined a product on social media and took into account the comments before purchasing it. Özcan and Akıncı (2017, 151-152) stated in their study that businesses have responsibilities to respond to consumers, and social media provides a great advantage for this in today's conditions. In the research, it has been seen that consumers examine the product they will buy on social media beforehand, and the recommendations of people they know before are effective in purchasing products and services. Again, it was seen that users who were not satisfied with these products they purchased shared their thoughts on social media and did not recommend this product.

A different reflection of consumer behavior is consumer participation. The concept of consumer participation is mentioned in the literature as a more comprehensive form of relational marketing. This concept describes the centralization of consumers, brand or business, i.e. the behavior of consumers to share their experiences together (Buran and Koçak, 2019). This concept also includes participation between potential consumers and all other stakeholders. The main purpose of the concept of consumer participation is information sharing. At the present time the continuous development of technology has made it easier for consumers to receive and share information. This is important for consumer participation (Önder and Çakıroğlu, 2021).

2.4. Social media activities of air passenger companies in Turkey

To give an example from social media advertising applications; Domestic flight tickets were given as gifts to the first 15 people and one of their friends, who participated in the "Gift Air Ticket from Onur Air" campaign, which was special for the opening of Onur Air's Facebook address and collected the most points. In addition, Onur Air gave one-way domestic flight tickets to every 500 people participating in the campaign, giving 110 gift tickets in total. The number of people participating in the campaign was 40000. Onur Air also started a "second ticket free" campaign for Valentine's Day and the application form was arranged to remain open only on Valentine's Day. With this campaign on Facebook, the corporate Facebook page was actively used, the number of followers was increased and rival businesses flying to the same destinations were prevented (www.facebook.com/onurair).

Table 1. Research on Consumer Behavior in Social Networks in The Airline Industry

Study Name	Author	Date	Conclusion	Reference
A Revıew On Electronıc Word-Of-Mouth (Ewom) In Airline Sector	Kocak, B.	2017	In the literature review conducted in line with eWOM researches on air transport, it was seen that these studies are very few. There is an undergraduate and a master's thesis on the subject in the scanned databases.	Kocak, B. (2017)
The Leverage Effect of Social Media: How Turkish Civil Aviation Industry Use Social Media Power?	Kara, T	2016	According to the results of the study, it is seen that domestic airline companies that carry passengers do not use social media applications actively and efficiently. The most commonly used platforms are Facebook and Twitter. According to the data obtained from the study, domestic airline companies do not use any of the social trade practices. Foreign airlines offer their users the opportunity to book and sell tickets through their Facebook accounts, while domestic airlines direct their users who want to buy tickets to their web pages.	Kara, T. (2016)
Socıal Medıa Marketing In Covid-19 Process In Turkey: Pegasus And Bim Sample	Coşkun, E. and Sener, B. C.	2020	As a result of the overall evaluation of the research findings, the aviation sector is the sector most affected by the COVID-19 pandemic, so covid19 related posts are frequently included in the pegasus airlines brand's posts in a way that coincides with social media marketing. In this process, it can be said that pegasus airlines brand carries out successful social media marketing activities	Coşkun, E. and Sener, B. C. (2020)

Anadolu Jet also made similar marketing efforts. The online game "Flight Control Center", commissioned by Anadolu Jet to Publicis Modem, attracted great attention, and users won airplane models, tickets and various gifts thanks to this game (www.facebook.com/anadolujet). Another recent social media campaign was launched with the slogan "You will be happy for yourself". In this campaign published on Pegasus Airlines' social media sites, the two names that are written the most on Facebook, Twitter and Instagram will be the winners of the campaign. The names selected here must also be a member of "Pegasus Bol Bol" in order to benefit from the discounts. With this campaign, Pegasus Airlines highlighted its social media accounts and directed its users to its mobile application (facebook.com/pegasus).

According to 2018 SocialBrands data, THY is stated as the company that uses social media most effectively. It is seen that Turkish Airlines constantly improves its website, advertises on platforms that may be relevant, and actively uses Facebook, Instagram, Youtube, Twitter and LinkedIn accounts. In the study on Twitter usage of THY, Anadolu Jet and Pegasus companies, THY was evaluated as the airline company that uses Twitter most actively, the number of tweets handled in the competition / survey category was found to be higher than the others, followed by tweets seeking complaint / information (Atalık et al., 2014). In a study comparing THY with different foreign airline companies, it was stated that the platform that brands attach the least importance to for social media marketing is Youtube, and Twitter is the most accurate and most effective platform, followed by Facebook and Instagram (Büyükçelikok, 2018). In the same study, it was stated that THY uses Facebook and Twitter effectively for marketing, and THY is one of the companies that ensure effective use of Youtube.

Atalık and Kocak examined the advertising policies of some airlines from Turkey in their study. Airlines often used some unique figures. One of the companies has talked about compassion, children, price. Another firm uses love, on time performance and an authoritative image. It aims to increase ticket sales with such figures (Atalik and Kocak, 2015).

3. Materials and Methods

In this study, in which the effect of social media activities in the airline passenger transport sector on consumer attitudes and behaviors was investigated, experimental method with static group comparison design was employed to collect data. Participants were selected to the experimental and control groups non-randomly and the participants in the experimental group were initially shown a booklet containing the social media (Instagram, YouTube, Facebook and Twitter) content of Turkish Airlines.

The research part of the study was carried out at Çanakkale Airport, which is affiliated to the General Directorate of State Airports Authority. The study was carried out on the passengers who use Çanakkale Airport for departure. Within the scope of the research, the survey was conducted with 200 participants at Çanakkale Airport and a booklet consisting of THY social media contents was shown to 100 participants before the survey, and 100 other participants took the survey without seeing this booklet. This number provides the requirement of at least 100 observed variables for each group which Wang and Wang (2012) points.

The questionnaire consisting of different sections and totally 40 items was given to the participants, and the answers were subjected to frequency analysis, t-test and ANOVA to find answers to the research questions and developed hypotheses. Apart from this, open-ended questions were included in the questionnaire that the participants could easily answer and that they could share their comments with the sector, company and company's social media activities. One section in the questionnaire includes the items to reveal the comparison between the experimental and control groups statistically. In the questionnaire form, the studies of Alhidari et al. (2015), O'Cass (2004), Pollay and Mittal (1993), İşlek (2012) and Akkaya (2013) were used to measure the attitude towards social media advertisements and measuring the general attitude. The reliable and persuasive features used in the evaluation of the attitude towards social media advertisements were taken from MacKenzie and Lutz (1989) and the informative and entertaining features were taken from Ducoffe (1996), and these four features were frequently used in related studies. Apart from these, the interesting feature used by Mitchell and Olson (1981) and Shimp (1981) was added to the scale as it was deemed appropriate to be included in the questions. Likert-type questions were asked on a five-point Likert scale (1=Strongly disagree; 2=Disagree; 3=Neither agree nor disagree; 4=Agree; 5=Strongly agree).

The hypotheses developed to reveal the difference between the experimental group and the control group are as follows:

H1: Participants who are exposed to the company's social media activities think that social media activities affect their purchasing behavior significantly more than those who are not.

H2: Participants who are exposed to the company's social media activities are determined to buy flight tickets from Turkish Airlines significantly more than those who are not.

H3: Participants who are exposed to the company's social media activities have positive attitudes towards the company's social media advertisements significantly more than those who are not.

H4: Participants who are exposed to the company's social media activities have a general positive attitude towards Turkish Airlines significantly more than those who are not.

These hypotheses which compare two groups were tested with t-test. In addition, the same variables were tested according to gender and age. These hypotheses are shown below:

H5a: The perceptions of the effect of Turkish Airlines's social media activities on purchasing behavior significantly change according to the gender.

H5b: Determination of buying flight tickets from Turkish Airlines significantly change according to the gender.

H5c: The general attitudes towards Turkish Airlines change according to the gender.

These hypotheses about gender were tested with t-test too. There are the last group of hypotheses about age in which there are more than two groups so ANOVA was employed to test the hypotheses. These hypotheses are shown below:

H6a: The perceptions of the effect of Turkish Airlines's social media activities on purchasing behavior significantly change according to the age.

H6b: Determination of buying flight tickets from Turkish Airlines significantly change according to the age.

H6c: The general attitudes towards Turkish Airlines change according to the age.

4. Analyses and Findings

The data obtained from the questionnaires were analyzed through the SPSS 22 program. During data collection, efforts were made not to differentiate the experimental and control

groups in terms of age, gender, education level, occupational group, marital status and income status of the participants. The results show that there is not much difference between the two groups in terms of age (between 25-45; nearly %60 for control and %67 for experiment group), gender (%44 and %45 female for control and experimental groups), education level (%89 of the control group and %76 of the experimental group have at least undergraduate degree), occupation (%76 of the control group and %67 of the experimental group are private or public sector employees), marital status (%67 of the control group and %61 of the experimental group are married), income (%71 of the control group and %68 of the experimental group have income between 1000 TL and 10.000 TL. per month).

Initially, t-tests were performed to analyze the hypotheses which were developed to analyze the differences between control and experimental groups. As a result of the t-test conducted to compare the perceptions of the effect of Turkish Airlines's social media activities on purchasing behavior, it was found that the perceptions of the two groups of participants were not statistically different from each other (p = 0,235; α = 0.05). H1 was not supported.

According to the t-test result, in which the control and experimental groups were compared regarding their determination about buying flight tickets from Turkish Airlines, the experimental group was found significantly more determined from the control group (p = 0,048; α = 0.05). H2 was supported.

As a result of the t-test conducted to compare the general attitudes of the control and experimental groups towards Turkish Airlines, it was found that the attitudes of the two groups of participants were statistically significantly different from each other (p = 0.032; α = 0.05). It is seen that the scores of the experimental group participants were higher. H3 was supported. All these t-test results are shown in Table 2.

Table 2. T-test results for the comparison of control and experimental groups for the first three hypotheses

H_1	N	**Mean**	SD	t	df	**p**
Control	100	**3,3100**	1,26886	-1,190	198	**0,235**
Exper.	100	**3,5300**	1,34431			
H_2	N	**Mean**	SD	t	df	**p**
Control	100	**2,3900**	1,49000	-1,952	198	**0,048**
Exper.	100	**2,8200**	1,62294			
H_3	N	**Mean**	SD	t	df	**p**
Control	100	**4,0100**	0,89234	-2,163	198	**0,032**
Exper.	100	**4,2600**	0,73333			

As a result of the t-test performed to compare the perceptions of the control and experimental groups towards social media advertisements of Turkish Airlines, it was found that the perceptions of the two groups of participants were statistically different from each other (Fun: p = 0,003; Reliable: p = 0,006; Informative: p = 0,023; Convincing: p = 0,022; Interesting p = 0,001 α = 0.05). When the means are examined, it is seen that the scores of the experimental group participants are higher than the means of the control group for all five dimensions. H4 was supported. The results of this t-test are shown at Table 3.

Table 3. T-test results for the comparison of control and experimental groups for the fourth hypothesis

H_4	Group	N	Mean	SD	t	df	p
Fun	Control	81	3,4198	1,32159	-3,019	149,821	0,003
	Exper.	92	3,9674	1,02122			
Reliable	Control	81	3,3210	1,09347	-2,778	171	0,006
	Exper.	92	3,7717	1,03884			
Informative	Control	81	3,3951	1,22146	-2,299	151,217	0,023
	Exper.	92	3,7826	1,00345			
Convincing	Control	81	3,3210	1,09347	-2,308	154,45	0,022
	Exper.	92	3,6739	0,89084			
Interesting	Control	81	3,6049	1,28140	-3,507	147,990	0,001
	Exper.	92	4,2174	0,97017			

Secondly, perceptions and attitudes towards Turkish Airlines generally and the social media activities of the brand were compared regarding to gender and age. As a result of the t-test performed to compare the perceptions of the effect of Turkish Airline’s social media activities on purchasing behavior according to the gender, it was found that the perceptions of the two groups of participants were not statistically different from each other (p= 0,186, p= 0,420; α= 0.05). H5a was not supported. The results are represented at Table 4.

Table 4. T-test results comparing the perceptions of the effect of Turkish Airline’s social media activities on purchasing behavior according to the gender

Control Group	N	**Mean**	SD	t	df	**p**
Female	44	**3,5000**	1,13096	1,333	98	**0,186**
Male	56	**3,1607**	1,35883			
Exper. Group	N	**Mean**	SD	t	df	**p**
Female	45	**3,8222**	1,07215	2,062	96.390	**0,42**
Male	55	**3,2909**	1,49905			

According to the t-test result, in which the female and male participants for both control and experimental groups were compared regarding their determination on buying flight tickets from Turkish Airlines show that there’s no significant difference between male and female participants in both groups (p= 0,805, p= 0,105; α= 0.05). H5b was not supported. The results are shown at Table 5.

Table 5. T-test results regarding the determination on buying flight tickets from Turkish Airlines according to the gender

Control Group	N	**Mean**	SD	t	df	**p**
Female	44	**2,4318**	1,57595	0,248	98	**0,805**
Male	56	**2,3571**	1,43246			
Exper. Group	N	**Mean**	SD	t	df	**p**
Female	45	**3,1111**	1,51090	1,636	98	**0,105**
Male	55	**2,5818**	1,68535			

As a result of the t-test conducted to analyze the general attitudes of female and male participants towards Turkish Airlines for both control and experimental groups show that there is no significant difference between male and female participants for both two groups (p= 0,186, p= 0,420; α= 0.05). So. H5c was not supported. The results are on the Table 6.

Table 6. T-test results regarding consumers' general attitudes towards Turkish Airlines according to the gender

Control Group	N	**Mean**	SD	t	df	**p**
Female	44	**3,9545**	0,80564	-0,548	98	**0,585**
Male	56	**4,0536**	0,96143			
Experim. Group	N	**Mean**	SD	t	df	**p**
Female	45	**4,3333**	0,79772	0,904	98	**0,368**
Male	55	**4,2000**	0,67769			

In the last section, perceptions and attitudes towards Turkish Airlines generally and the social media activities of the brand were analyzed regarding to the age. Age groups in the study are numbered as 18-24 (1), 25-31 (2), 32-38 (3), 39-45 (4), 46-52 (5), 53-59 (6), 60 years and older (7) group. One-way analysis of variance (ANOVA) is used in cases where the class variable constitutes more than two subgroups (Sipahi et al., 2008: 117). Firstly, perceptions of the effect of Turkish Airlines's social media activities on purchasing behavior according to the age groups are analyzed. As the first step of ANOVA, Levene Statistic results were analyzed. Below, test of homogeneity of variances for the control group is presented at the left side (Table 7).

Table 7. The results of ANOVA regarding perceptions of the effect of Turkish Airlines's social media activities on purchasing behavior according to the age groups for the control group

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
4,382	5	94	0,001

Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	3,936	5	38,702	,006
Brown-Forsythe	3,458	5	71,375	,007

a. Asymptotically F distributed

Levene test results were examined and it was seen that the variances of the groups were not equal (p: 0.001 < 0.05). In this case, Welch and Brown-Forsythe tests are performed (Sipahi et al., 2008: 133) which are shown at the Table 6, right side. Welch and Brown-Forsythe tests results are found significant (Welch p: 0,006; Brown-Forsythe p: 0,007) so Post Hoc test was performed. According to the results, there is a significant difference between Group 1 and Group 2; Group 1 and Group 6. Means of the groups are 2,37; 3,58 and 4,22 for the Group 1, Group 2 and Group 6 respectively. H6a was supported for the control group.

The same hypothesis was tested for the experimental group too. Levene Statistic results are shown at the Table 8.

Table 8. The results of ANOVA regarding perceptions of the effect of Turkish Airlines's social media activities on purchasing behavior according to the age groups for the experimental group

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
,533	5	94	,751

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10,160	5	2,032	1,132	,349
Within Groups	168,750	94	1,795		
Total	178,910	99			

Levene Statistic results show that homogeneity of variances was accepted so ANOVA results are examined (Table 8) The results show that there is no significant difference among the age groups for the experimental group. For this reason, H_{6a} was not supported for the experimental group.

Then, the determination of the participants to buy flight tickets from Turkish Airlines regarding the age group was examined. Table 8 shows firstly Levene Statistic results.

Table 9. The results of ANOVA regarding the determination of the participants to buy flight tickets from Turkish Airlines according to the age groups for the control group

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
4,758	5	94	,001

Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	2,101	5	37,450	,087
Brown-Forsythe	1,802	5	65,440	,125

a. Asymptotically F distributed.

According to the results, homogeneity of variances was not accepted so Welch and Brown-Forsythe tests were performed. The results which are shown at Table 10, at the down side reveal that there is no significant difference among the groups. So, H6b was not supported for the control group.

The test was performed for the experimental group for the same hypothesis. Levene Statistic results are shown at Table 10, at the up side.

Table 10. The results of ANOVA regarding the determination of the participants to buy flight tickets from Turkish Airlines according to the age groups for the experimental group

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
0,878	5	94	0,499

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8,002	5	1,6	0,595	0,704
Within Groups	252,758	94	2,689		
Total	260,76	99			

Since the homogeneity of variances is accepted (0,499 > 0,05), ANOVA test results were examined. The results show that there is no significant difference among age groups (0,704 >0,05). For this reason, H_{6b} was not supported for the experimental group too.

Lastly, general attitudes of female and male participants towards Turkish Airlines regarding their age groups were examined. Levene Statistic shows that homogeneity of variances was accepted (0,837>0,05). Then, ANOVA tests result were examined (Table 11, down side).

Table 11. The results of ANOVA regarding the general attitudes of participants towards Turkish Airlines according to the age groups for the control group

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
0,415	5	94	0,837

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10,215	5	2,043	2,792	0,021
Within Groups	68,775	94	0,732		
Total	78,99	99			

ANOVA results show that there is a significant difference among age groups (0,021<0,05). Post Hoc test was performed and a significant difference was found Group 1 and Group 5 (Means; 3,56 and 4,47, respectively). H_{6c} was supported for the control group. Then, ANOVA was performed for the experimental group. The results are presented at the Table 12.

Table 12. The results of ANOVA regarding the general attitudes of participants towards Turkish Airlines according to the age groups for the experimental group

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
0,371	6	93	0,895

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1,633	6	0,272	0,49	0,814
Within Groups	51,607	93	0,555		
Total	53,24	99			

Levene Statistic shows that homogeneity of variances was accepted (0,895>0,05). Then, ANOVA was performed and the results reveal that there is no significant difference among groups (0,814>0,05). H_{6c} was not supported for the experimental group.

5. Conclusion

Social media, which enters our lives more and more every day, is used for many different purposes. Businesses have also kept up with the development of social media and started to use social media as a marketing tool in order to gain a competitive advantage against other businesses in the competitive world. In this context, the air passenger transportation sector has started to use social media frequently. The fact that this sector is a service sector and serving more and more people every day has increased the importance of the sector. It is seen that they communicate various marketing messages to the passengers through social media and carry out their marketing strategies through these platforms. The fact that companies present their marketing strategies with less cost and less time loss through social media platforms, and that the customer can access these activities faster and from anywhere, has made social media marketing more popular in the air passenger transportation sector.

In this context, in this research conducted in the air passenger transportation sector to examine consumer behavior in the era of social media, it is aimed to examine the perceptions of passengers, as consumers, about the activities of airline companies in social media and the content created in general, and their perceptions of Turkish Airlines' social media content in particular.

The results show that a significant difference was found between the two groups regarding the perception of social media advertisements. It was revealed that the group who examined Booklet found social media ads more entertaining, reliable, informative, believable and interesting. It was concluded that the detection of significant differences in all dimensions of social media advertisements positively affects the perception of social media advertisements of consumers who are exposed to social media content related to the company.

It has been observed that the mean scores of female participants are higher than the male participants in terms of general attitude towards THY, determination to buy THY flight tickets, and perception of the effect of social media content on purchasing. However, the difference between the two groups was not statistically significant. It is considered important by marketing practitioners that women's means are higher. On the other hand, it is an important result of the study that the mean of the older participants is high in terms of the perception of the effect of social media content on purchasing, and the mean of the young people in the 18-24 age group is very low compared to the others. This situation experienced in the control group was not experienced in the experimental group. This created an idea that the attitudes of the young people who saw the booklet shifted to a more positive way. In addition, it was revealed that the mean of the 18-24 age group was low in terms of the attitudes towards THY in the control group. The fact that such a situation was not encountered in the experimental group made the researchers think that the attitudes of the young people who saw the booklet changed positively.

It is a limitation that this study was carried out only at Çanakkale Airport, with people who purchased a flight ticket from Turkish Airlines. It can give different results when done with people who have bought plane tickets from various airline companies in different places. For this reason, those who will work on the subject from now on can be included in the study at different airports or virtual, and attitudes towards various airline companies can be collected and compared. After that, another suggestion for those who want to work on similar subjects with the experimental method is to use stronger experimental designs, which consist of controlled and randomly assigned groups.

It is thought that the findings of this study will contribute to marketing science and marketing practitioners. It is hoped that it will provide useful results to media managers in terms of the way consumers perceive the content of airline companies in the age of social media and the effect of social media on their purchasing preferences and attitudes, both academic researchers and companies in the airline passenger transport sector, in particular, marketing practitioners of Turkish Airlines, and especially the social media that has been given importance recently.

Ethical approval

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Analysis of Cost Structures and Cost Control Strategies of Airlines: An Empirical Study on A Hypothetical Airline Company

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Abstract

In the context of controlling costs in the airline industry, this study aims to determine empirically until which available seat mile (ASM) an airline should continue its activities based on an analysis of the costs and revenues incurred relating to these ASM. The study is based on a hypothetical company and the data used indicated that the company has reached profitability between certain efficiency levels (ASM). The results also showed that the airline can still continue its activities at efficiency levels where it is making a loss but only in situations where its total income exceeds its total variable costs (creating positive added value). In the study, it is pointed out that companies in the airline industry, which are under the pressure of intense competition and uncontrollable factors, can still survive and maintain their competitive power through the cost control methods they can apply.

1. Introduction

To be successful and efficient, airline companies must control costs and monitor the behavior of these costs in their operations. Therefore, the emergence of Low Cost Carriers (LCC) in recent times has become a major threat to traditional network airlines due to their intense cost control strategies and cheap ticket prices. These Low Cost Carriers can enjoy certain cost advantages because of their lower input costs efficient product design (Franke, 2004), which enable them to compete, based on price. Costs obviously become an important part of airlines strategy especially in times of global crises (Hatty and Hollmeier, 2003; Diaconu, 2013; Zuidberg, 2014).

The ultimate reason for companies' existence is to provide value to their shareholders and, for this reason, there is an ever-growing competitive environment surrounding the airline companies to maximize their shareholder wealth and increase their profitability. To increase profitability, companies must focus either on increasing their revenues or on decreasing their costs. Hence, a cost control strategy is inescapable unless they have significant market power. This is one of the reasons LCCs outperform legacy carriers in many markets; it is their low-cost nature. Airlines with a high level of productivity will be able to enjoy cost advantages obtained from efficiently utilizing their aircrafts, focusing on the time taken for aircraft preparation, and optimizing the number of employees per Available Seat Mile (ASM) (Smith and Wilson, 1995; Alamdari and Fagan, 2005; Daraban, 2012).

Declining revenues and high costs caused many airlines to go bankrupt in the 2000s. Operating in a highly competitive environment have often made raising prices difficult, thus making cost control the only real solution to profitability. Many airlines around the world have managed to make a progress in reducing non-fuel unit costs after 2001 (Oum and Yu, 1998). On the other hand, in order to manage their fuel costs they have started implementing various hedging strategies (Lim and Hong, 2014). While airlines can control some of the costs associated with the level of service they provide, they cannot always directly control many others, such as fuel price, labor costs, airfares, landing fees and air navigation fees.

Having understood the importance of cost control in the airline sector, just like in any other industry, in this study, first, the concepts related to cost in the airline sector will be evaluated. Then, the costs incurred in the sector will be classified and the techniques and strategies applied to control these costs will be analyzed and discussed based on a case study.

2. Cost Concepts and Cost Classification in the Airline Industry

There are certain start-up costs that are required to start the business. Startup costs are the expenses that investors make from the start up until the business becomes operational. For example, to become operational, all businesses must obtain the necessary licenses and other types of permits required to operate a business legally in a particular country and/or city. In addition, manufacturing companies should have facilities, necessary machinery, tools and equipment, and hence will require large amounts of funds prior to fully operationalize. This point to the fact that different industries will have different set-up costs to consider in their start-up phases.

In highly regulated industries such as the airline industry, required permits such as Air Operator Certification (AOC) can take significant time and need high level of funds. Besides these requirements, there is also the procurement of the aircraft, obtaining the rights for landing as well as finding suitable office area, establishing a solid IT infrastructure and providing the necessary employee trainings. In all this long process, the airline company will be exposed to huge costs and will have spent millions of dollars until their first flight. Therefore, substantial initial capital is required to finance an airline's start-up costs. These capital requirements will also be a barrier to entry into the airline industry.

Sunk cost, which also exists in the airline industry, is a type of cost that is generally neglected and not taken into account for future business decisions. These are costs that companies have already made but yet have not recovered it (Stiglitz et al., 1987). In the airline industry, it emerges as the company managers' inability to make efficient use of their aircrafts, especially where large investments are required to utilize them. For example, despite being a newer aircraft, Boeing 737 NG type aircrafts were replaced with Boeing 737 MAX due to their lack of good fuel usage and economically higher fuel costs. In this situation, investments previously made in 737 NG type aircraft will not have had any effect on the decision to purchase Boeing 737 MAXs.

It is not correct to look at airline costs in terms of just sunk costs. Companies in the airline sector provide many different services including passenger and freight transport services as well as complementary services such as maintenance and repair, catering and ground services. Managing the cost structure in the airline industry not only increases the profitability of the company, but also allows airlines to better provide these mentioned services to their customers. All of these services are associated with two main costs: fixed costs and variable costs. Costs arising from an aircraft purchase, airport gate usage agreements, airport terminal leases, buildings, equipment and other lease agreements are examples of fixed costs within the airline industry whereas fuel and labor expenses are examples of variable costs. An airline's total cost per unit is measured by the total cost per available seat mile/kilometer (CASM or CASK), which takes into account both fixed and variable costs. CASM is also expressed in terms of operating costs, which assists in the evaluation of the true average cost related to flying an aircraft. However, it ignores the non-operating expenses in its calculation (Tsoukalas et al., 2008; Köse, 2020).

The costs of airline resources can also be divided into two: operating and non-operating costs. Operating costs of airlines include both variable and fixed costs such as; aircraft, fuel, and maintenance expenses together with expenses relating to employees, and landing fees. These costs are all incurred by making air transport services available for both passengers and freight handlers. In other words, all relate to the core business of the company. Non- operating costs, on the other hand, are different. They do not relate directly to the core business of the airline but are necessary to run it, such as interest expenses (Uslu and Cavcar, 2002). The classification of operating costs is given in Table 1 below.

Table 1. Airline Operations Costs

Operating Costs	
Direct Operating Costs	**Indirect Operating Costs**
Flight crew	Marketing expenses
Aircraft fuel and oil	Ground and equipment costs
Airport fees (landing fees, cost per ton of landing aircraft)	Depreciation, insurance, and maintenance
Navigation fees	Management and sales services
Direct maintenance (labor and materials)	Booking and sales
Depreciation/lease/insurance (flight equipment)	Advertisement, promotions
	General services (passenger, aircraft, traffic services)
Non-Operating Costs	
Interest obligations	
Losses due to affiliated companies	
Losses associated with the decommissioning of aircraft	

(Source: Vasigh et al., 2015).

Direct operating costs, shown in Table 1, represent the type of costs within the airline sector that can be directly linked to a given production level. Examples to such costs often include block hour, airplane mile, or available seat mile (ASM). For an airline, there are two major costs that can be referred to as a direct operating cost, these are, fuel and labor costs. Indirect operating costs, such as workforce training costs, sales expenses, and management costs, are all costs that are essential for the operation of an airline, but they are not linked to the operation of an airline directly, they exist for support purposes (Alpaslan, 2010). Because they do not directly operations, these are the first cost elements a manager usually focuses on to reduce the overall operating costs.

Costs can also be non-operations related. These include expenses arising from activities not related to the delivery of air transport services. Typically, it relates to the company's financial structure and is the result of the airline's financial strategy. Interest expense is the most common non-operating cost in the airline industry, reflecting the large debt loads that airlines usually carry. Interest expenses incurred to finance operations such as aircraft purchases are considered non-operating costs as they are not directly related to an airline's operations. Other non-operating costs for airlines include any loss from the sale of aircraft, losses from investment positions, and other non-aviation expenses.

2. Cost Control Strategies in Airline Companies

Airline companies can reduce their costs with the control strategies and measures they take on the basis of each of the operational cost elements they are exposed to. The elements with the highest rate among these cost elements are fuel, personnel and labor costs. It is very difficult to reduce these two important factors as it is beyond the direct control of airline companies. For this reason, financial managers of enterprises mostly focus on cost elements other than these two (Vasigh et al., 2010). For this purpose, cost control strategies of airline companies can be examined under the following headings (Chang and Shao, 2011; Vasigh et al., 2015):

- Optimizing route flight plans and using alternative airports,
- Encouraging employees to propose cost control strategies;
- Implementing fuel price hedging strategies,
- Reducing personnel expenses, including laying off some of the employees,
- Improving aircraft engine performance for aircraft fuel savings,
- Optimizing aircraft fleet management;
- Reducing fuel costs by improving flight speeds,
- Reducing the dead weight of an aircraft,
- Removing intermediary commissions in ticket sales,
- Eliminate aircraft departure delays,
- Removing free water and sandwiches on board,
- Replacing old planes,
- To schedule reasonable flight times for the flight crew,
- Reducing the size of the toilets on the plane to make room for four more seats in the economy class.

Some of the above-mentioned operating costs are fixed, some are variable, and some are both fixed and variable. Existence of these costs affects the cost reduction strategies of airlines. Airlines will need to overcome many barriers and situational factors if they are to implement such cost reduction strategies. An important barrier is the legal issue relating to the strategies to be implemented. Any attempts made on changing the existing operations must be made in accordance with safety regulations, labor law, and environmental issues, as well as noise restrictions and other legal requirements. Second, any attempt to reduce labor costs may require extensive and difficult negotiations with labor unions. Another potential barrier to cost control is the structure of the airline market. Some of the efforts made on restructuring, such as surcharges, baggage charges and service cuts, may be feasible only if the majority of other airlines comply. The meaning is that, before making a decision about its customer-sensitive standards, an airline needs to analyze its competitors and their expected reactions.

4. Literature Review

There are very few studies in literature that focus on the costs related to airline companies and their cost control strategies. Most studies on airline cost performance are seen to focus on the unit costs and how they differ from one company to another. It is also seen that especially the cost per Available Seat Mile (CASM) is used as a variable under these unit costs. CASM can be expressed as an airline's operating expense over its already generated available seat miles (ASMs). In contrast, available seat miles are calculated as the number of available seats flown by the airline times the distance flown by the aircraft. A study by Tsoukalas et al. (2008) examined the unit costs between Network Legacy Carriers (NLC) and LCC airlines with the focus of CASM, and as a result, they revealed that unit costs, excluding fuel and transportation related expenses and especially labor unit costs, approached towards each other among both groups.

In addition, it is seen in the literature that the focal points of airline companies regarding the cost performance have changed in time. Especially with the deregulation in airline markets, researchers started to examine the effects of market efficiency and costs. Just after the US domestic airline market deregulation, Meyer et al. (1981) conducted studies on airline efficiency and unit costs, while Jordan (1982) focused on Canadian airlines and did a comprehensive study on its cost and productivity performance. Baltagi et al. (1995) examined cost changes such as technical change, economies of scale, density and input prices of US airlines between these periods, using datasets covering both pre- and post-deregulation. Regarding the subject, Caves et al. (1987) compared the cost structures of airline companies in order to examine the effects of deregulation, Morrel and Taneja (1979) focused on efficiency, and researchers such as Doganis (1985) and Pryke (1987) mentioned the unit cost differences between airline companies in America and Europe.

An inevitable result of deregulation has been the mergers and acquisitions (M&A) of airline companies in order to survive in this competitive environment. Through M&A's the aim for these companies was to gain a better place within the market while trying to achieve economies of scope and scale at the same time (Nolan et al., 2014). This has made it possible for them to grow much faster when compared to their rivals. In general, M&As became a survival method for companies within the competitive aviation market (Merkert and Morrell, 2012). A study to determine the reasons for mergers and to examine their effects on the systematic risks of the companies that bid in the airline market was conducted by Evripidou (2012) where it was expressed that the reasons for mergers fell under three different headings: cost-effectiveness, economies of scale and market power. Merkert and Morrell (2012) also stated in their study that mergers and acquisitions reduce costs and this can be counted as one of their advantages. Goh and Yong (2006) focused on the strategic collaborations between airline companies in their study, and as a result for the study, they revealed that code-sharing collaborations affect the cost structure of the company. According to the results, strategic cooperation for these companies causes their costs to decrease. In addition, another finding obtained in the study was that having large partners and being in a positive cooperation with them had a greater effect on the costs of airlines. The effects of airline strategic alliances on airline companies have been examined by other researchers, and these effects were generally stated as on welfare and competition, traffic demand, airfare, partner selection, outputs and profitability.

Just as the emergence of collaborations, acquisitions and mergers, deregulation in airline markets has also led to the establishment of low-cost carriers (Kumar, 2012). This has attracted researchers' interest and number of studies on LLCs is seen to be increasing. It is stated in literature that these low cost rivals create a significant competitive pressure (Tretheway, 2004) especially on traditional network carriers and invalidate the cost recovery strategies created by these large airline companies. Tretheway (2004) who has revealed the disruptions in the business models of large airline companies and emphasized that these airlines no longer have an income to cover their traditional base costs conducted a supporting study. Franke (2004), on the other hand, stated that factors such as the decrease in the number of cabin crew, crew efficiency, higher utilization of aircraft, low ground handling fees due to the lack of main airport usage, and high average aircraft sizes were effective in low-cost carriers' more affordable flights. In addition, O'Connell (2007) stated that when compared to network carriers, low-cost carriers can reduce costs by 50% and simultaneously provide close to 80% of the service offered by network carriers. As a result of all these studies, the importance of cost structures and strategies in the airline sector becomes clearer. Hofer et al. (2008) has dealt with these similar issues in terms of price premiums. The price premium is defined as the price increases that occur when market dominance and density is achieved at the airport and on the routes. The results of studies show that low-cost carriers do not actually receive price premiums, and at the same time, other network carriers do not receive high premiums during their existence in the market.

5. A Hypothetical Case Study

5.1. Purpose and scope of the study

In the context of controlling costs in the airline industry, this study aims to determine empirically until which available seat mile (ASM) should an airline continue its activities based on an analysis of the costs and revenues incurred relating to these ASM of a hypothetical airline company.

This study is based on an airline that has adopted the low-cost carrier (LCC) business model, which has and still is playing an important part in the dramatic expansion of the aviation industry. Although providing affordable, cheap tickets is the main characteristic of this model, LCC's have many business and operational practices that helps to reduce their costs. Some of the cost saving practices assumed in the model, which affects their available seat miles (ASM), passenger revenue per usable seat mile (RPM), and total costs, involves using secondary airports, utilizing limited number of aircraft types, not offering any additional promotions, and trying to keep cost of labor as low as possible.

5.2. Method

In the study, the analysis will be made using the cost-volume-profit figures based on the data obtained from the aviation sector.

5.3. Analysis and Findings

The cost of producing available seat mile (ASM) for an airline depends on the types of adjustments it can make to the quantities of the various resources it uses (labor, fuel, etc.). These amounts tend to change often, especially in the short run. However, it requires more time for other sources to adapt to this change. For example, buying new aircraft or building new hangars can only be changed in a significant time frame. Sometimes focusing on the short term may not be enough for an airline to change its capacity, as the overall capacity is fixed and the period may be too short to change it. However, an airline can change its available seat miles in the short term, to an extent, through better use of its labor and an efficient time management and hence, affect its capacity. Since the airline is adding resources to a capacity that is fixed, together with its ASMs, its production may increase at an incremental rate for a time up to a point where the ASMs rate of increase will start to slow down until final capacity is reached. The principle behind this is referred to as the Law of Diminishing Returns, which is shown quantitatively in Table 2.

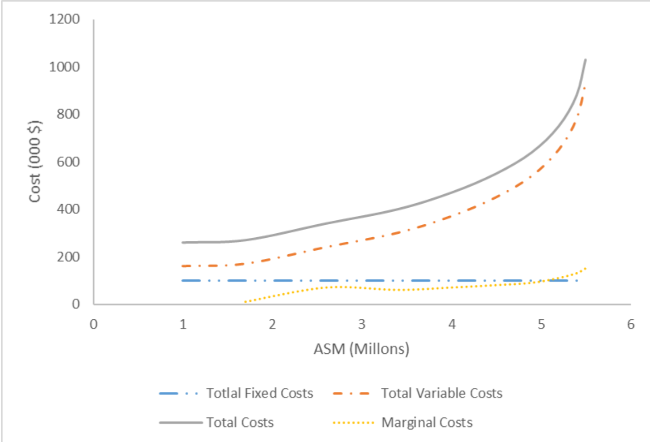

Figure 1. Total Cost, Total Fixed Cost, Total Variable Cost, Marginal Cost and ASM (Hypothetical Data)

According to the values in Table 2, it can be seen that there is an increasing trend in the rate of ASMs until it reaches the) value 2.6 million from which the rate of increase slows down. The third column of the table points to the total variable costs that are related to each level of available seat miles flown and shows that they are not constant. From 1.7 million ASMs to 2.6 ASMs there is a decreasing trend in the increase in total variable costs. However, afterwards this trend changes and the increase in variable costs will take place at an increasing rate, due to the Law of Diminishing Returns. The last column shows the total costs (sum of both fixed and variable costs) at each level of the ASMs. Figure 1 graphically shows the relationship between Total Cost, Total Fixed Cost, Total Variable Cost, Marginal Cost and ASM.

Table 2. Total Fixed Costs, Total Variable Costs, and Total Costs for an Airline for the Period (000)

Available Seat Miles (ASM)	Total Fixed Costs ($)	Total Variable Costs	Total Costs	Marginal Cost
1	100	160	260	-
1,7	100	170	270	10
2,6	100	240	340	70
3,4	100	300	400	60
4	100	370	470	70
4,5	100	450	550	80
4,9	100	540	640	90
5,2	100	650	750	110
5,4	100	780	880	130
5,5	100	930	1030	150

According to the concept of passenger revenue per usable seat mile (RPM), it is assumed that fee-paying passengers will

Table 4. An Airline's Profit-Maximizing Output Over a Period (Hypothetical Data)

ASM (Mil.)	Price ($)	RPM (Mil.)	Total Revenue (000 $)	Total Fixed Costs (000 $)	Total Variable Costs (000 $)	Total Costs (000 $)	Load Factor (%)	Profit or Loss (000 $)
1	*0,265*	*0.800*	*212*	*100*	*160*	*260*	*80*	*-4,8*
1,7	**0,260**	**1.275**	**331,5**	**100**	**170**	**270**	**75**	**+61,5**
2,6	**0,255**	**1.820**	**464,1**	**100**	**240**	**340**	**70**	**+124,1**
3,4	**0,250**	**2.210**	**552,5**	**100**	**300**	**400**	**65**	**+152,5**
4	**0,245**	**2.400**	**588**	**100**	**370**	**470**	**60**	**+118,0**
4,5	**0,240**	**2.475**	**594**	**100**	**450**	**550**	**55**	**+44,0**
4,9	*0,235*	*2.500*	*587,5*	*100*	*540*	*640*	*51*	*-52,5*
5,2	0,230	2.515	578,5	100	650	750	48	-171,5
5,4	0,225	2.520	567	100	780	880	47	-313,0
5,5	0,220	2.522	554,8	100	930	1030	46	-475,2

fill not all ASMs produced by the airline. This means that revenue cannot always be generated per available seat mile created. This parameter is expressed as a percentage and the higher it is, the more efficient the airline will be. The Load factor is obtained by dividing the passenger revenue per usable seat mile by the Available Seat Mile. The assumption is that the load factors shown in Table 3 are related to the ASMs and RPMs shown previously. A reduction in the available seat miles will lead to an increase in load factors as the airline can choose to reduce flights and routes with the lowest load factors and profits.

Table 3. Passenger Load Factor for an Airline at a Certain Time Period (Hypothetical Data)

Available Seat Miles (ASM)	Revenue per Usable Seat Mile (RPM)	Load Factor (%)
1	0.800	80
1,7	1.275	75
2,6	1.820	70
3,4	2.210	65
4	2.400	60
4,5	2.475	55
4,9	2.500	51
5,2	2.515	48
5,4	2.520	47
5,5	2.522	46

In practice, load factors above 75% and below 55% are not realistic, although a balance between flights with low and high load needs to be established. The level of ASMs at which the airline can minimize losses or maximize profits can be established if values of prices, RPMs, total revenues, total costs and load factors are provided beforehand.

Table-4 shows the hypothetical cost-volume-profit data of an airline that implements the Low Cost Carrier (LCC) business model. In the table, ASM shows the number of seat miles supplied in a given period, and RPM shows the revenue per mile filled by passengers from the seats supplied during that period. The load factor (LF), obtained by dividing RPM by ASM, represents the airline's occupancy rate, or the rate at which it uses the capacity created.

If, in this scenario, the initially supplied seat miles are taken as 1 million, and the demand showed that 800,000 of these were to be filled by paid passengers, with the price per mile (yield) of $0.265 the total revenue becomes $212.000 ($0.265 x 800.000). Given that the total cost (total variable costs plus total fixed costs) incurred at this level is $260,000, the company will make a loss because the total cost is higher than the total revenue in 1 million ASM. When the company raises the level of ASM it created from 1 million to 1.7 million (supply increases), demand will be expected to increase as well, yet generally at a lower rate.

When the demand is taken as 1,275,000, the occupancy rate can drop from 80% to 75%, and the yield per mile can drop to $0.260. In this case, the total revenue will become $331.500 ($0.260 x 1.275.000), total costs will be $270.000 and the airline can then be seen to make a profit at this level ($331.500-$270.00=$61.500).

However, there is a point where after this level, as ASM increases, demand and revenue per mile and occupancy will decrease, yet the total revenue will still be higher than the total costs. Based on the data, the company will reach maximum profitability when ASM is 3.4 million with $0.250 as the yield per mile; making RPM 2,210,000 with 65% occupancy rate. After this level, as the ASM level increases, the demand, occupancy rate, price per mile (yield), and profitability will decrease. When ASM rises to 4.9 million, the load factor will drop to 51%, the yield per mile will drop to $0.235, and the total revenue will still be below the total cost, and the company will start to make a loss. If the company is unable to increase RPM or LF beyond this point, the company's losses will increase as the price per mile (yield) also increases due to increased competition and reductions in response to further price reductions.

In this case, it is considered that it would be rational for the company to keep its activities at the level of 1.7-4.9 million ASM.

The calculations provided in Table 4 give an indication of how variables such as ASM, LF, Total Costs, Total Revenue, and price relate to one another. When LCC companies want to pursue different strategies they can be able to utilize these variables. For example, for deciding to pursue a profit maximizing strategy, 3.4 million ASMs should be produced. However, if the airline's concern is more on retaining market share, then by increasing its scheduled flights and reducing its load factors to 55% system-wide, it could still make a profit of $44,000. At output levels beyond 4.5 million ASMs, traffic generated will not be enough to offset costs and, therefore, passengers will not further respond to price reductions.

In Figure 2, the relationship between total revenue and total cost and ASM is presented graphically. This airline's profits are maximized at the production level where total costs fall below the total revenue at the maximum point. However, in case where RPMs that are provided in Figure 2 does not take place, both demand and revenues will fall in all of the price levels. If price are in a range that is not flexible (i.e., passengers are not responding to further price reductions), the airline's only option will then be to reduce capacity (reduce ASMs). In doing so, it is hoped to reduce variable and total costs, improve load factors, and maintain profitability.
However, it would be rational for the airline company to continue its activities at these levels, as the total revenue generated at 1 Million and 4.9 Million ASM levels, despite the airline's loss, contributes to some of the fixed costs after covering the variable costs.

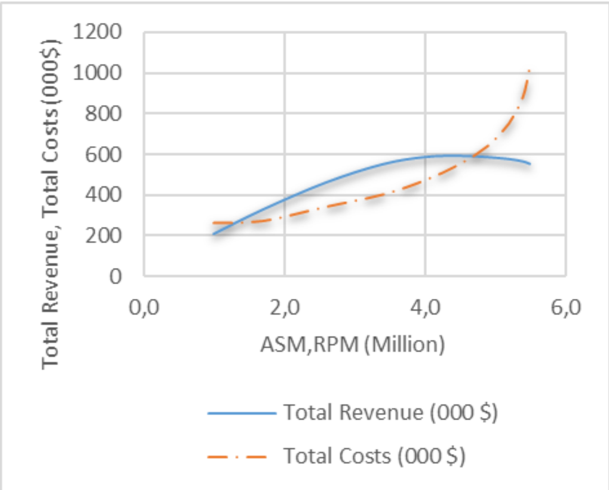

Figure 2. Relationship Between Total Revenue, Total Cost, and ASM (Hypothetical Data)

6. Conclusion

Today, despite the uncontrollable systematic global factors such as financial crises, competition, national and international regulations, terrorist incidents, increase in oil prices, epidemics, climate and environment, cost control has become an important aspect for airline companies that aim to increase their company value by increasing profits and creating positive free cash flows. For this reason, airline companies are trying to minimize their costs and protect themselves from the risk of bankruptcy with strategies such as introducing "Low Cost Carriers ", and forming mergers and alliances among various airline companies.

Especially low-cost airline companies have managed to control their costs with some operative and strategic measures and methods. For example, in order to minimize their costs, Pegasus Airlines, a low-cost airline carrier has stopped serving sandwiches and water in the cabin, increased the number of seats by reducing the distance between seats, and received support from the cabin crew for preparing the plan for its next flight in order to avoid penalties for violating flight departure times. At the same time, in order to increase their income, Pegasus airlines have taken measures such as in-cabin food and beverage sales, and charging extra fees for selecting seats and checking in additional luggage.

Airline companies all over the world have been adversely affected by the Corona Virus (Covid-19) pandemic for the past two years. Whether they are LCC or Network Legacy Carriers, airline companies are trying to reduce their losses from this pandemic. For example, American Airlines, a legacy carrier company, achieved a cost reduction of $1.3 billion by applying various cost reduction strategies after its loss of $8.9 billion in 2020 (https://thepointsguy.com/news/american-airlines-cost-cutting-2020-loss/, accessed 29.10.2021).

Unlike other sectors, businesses in the airline industry have to be exposed to a very high amount of fixed costs in order to carry out their activities, and this requires the economic and rational use of their aircraft, as it is their main fixed asset. In the airline sector, again unlike other sectors, the efficiency volume in passenger transport is generally expressed in seat miles supplied, passenger income per seat mile, and income per ton in cargo transportation parameters. Based on the activity volumes specified in this study, between which activity volumes it would be rational for a hypothetical airline company to continue its main activities was investigated. In these determined activity volumes it will be rational for the company to continue its activities if the total revenue is generally higher than the costs. In situations where the costs are higher than the revenues, if the variable costs can be covered with the revenues on hand, that is, if the contribution margin is positive, then again the company can continue its activities.

In addition, costing and cost control can be done in a more rational and realistic way by differentiating general production expenses according to the services provided by applying activity-based costing instead of distributing the general production expenses equally to the seats flown by using the traditional costing system in airline companies that provide different classes of flight services.

Strategic alliances established between airline companies, which have become widespread today, will rationalize and reduce the costs of these airline companies due to the synergy they create. For example, the three major strategic alliances currently in existence globally, Star Alliance, SkyTeam and OneWorld, account for 61% of worldwide sales and provide cost savings and consistent service to their customers (https://www.sia-partners.com/en/news-and publications/from-our-experts/partnerships-between-airlines-strategy-win-asian-market, accessed 30.10.2021)

As policy implications, it is evaluated that an airline company can increase its profitability and free cash flow by controlling and reducing its costs, and as a result, it can maximize the market value of its stocks and company value. This will provide a greater return for its investors and hence, will make the company an attractive investment opportunity.

Within the scope of the new works to be done, it is considered that the issue of capital structure and cost in airline companies can be an advanced research topic following this study. In terms of cost control, airline companies should apply new methods and approaches under the pressure of emerging and increasing costs. They should use and develop their creativity. Along with these methods and approaches, it is recommended that they also increase customer satisfaction and service quality, and thus contribute to the airline industry in which they serve, nationally and internationally.

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Impact of the COVID-19 Pandemic on the Mental States of Airline Pilots in Turkey

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Abstract

Mental state of airline pilots is of paramount importance with regard to flight safety. The coronavirus (COVID-19) pandemic exposes individuals to psychological stressors, depression, and anxiety which are detrimental to the performance of airline pilots. While some research has been carried out on the psychological effect of COVID-19 pandemic among various groups including students, healthcare workers, and general public, no research has been found that explored the psychological impact of the COVID-19 outbreak among airline pilots to the best of authors' knowledge. With these consideration in mind, the aim of this study is set out to examine the impact of the COVID-19 pandemic on airline pilots' mental state. A cross-sectional study was designed. A 50-items questionnaire was administrated online. The questionnaire included demographic items, 18 items regarding psychological states of participants, and the Depression Anxiety Stress Scale-21 Scale (DASS-21). The response rate was 40%. It was found that 63.2% (N=127) of the participants had various levels of depression, 57.2% (N=115) had anxiety, and 76.6% (N=154) were stressed. Results showed that 44.3% of the participants had contact with COVID-19 suspected/ diagnosed patients. The findings of this study may help airlines and aviation authorities to take preventive and protective psychological measures against COVID-19 outbreak and can improve aviation safety.

1. Introduction

On 11th March, 2020, the outbreak of the novel coronavirus (COVID-19) was declared as a global pandemic by the World Health Organization (Cucinotta & Vanelli, 2020). As of 24th February, 2022, the number of confirmed COVID-19 cases were more than 426 million and there were over 5 million confirmed deaths worldwide (WHO, 2022). People's livelihoods, their health, and the economy has been adversely affected by the COVID-19 outbreak (WHO, 2021). This outbreak has had a devastating effect on public mental health as well (Xiong et al., 2020)·(Giorgi et al., 2020).

The pandemic has also had a significant impact on airline industry in the World (Dube et al., 2021)(Amankwah-amoah et al., 2021). The airline industry faces several challenges including closure of the borders, strict control measures, mandatory lockdowns, isolation periods and resulting economic crisis (Dube et al., 2021). As a result, employees in aviation industry have experienced job or income losses which are highly likely to result in mental outcomes among aviation industry workers (Grout & Leggat, 2021). Furthermore, many airlines completely stopped their operations and filed for bankruptcy (Czerny et al., 2021). Numerous studies have attempted to explain the impact of the COVID-19 pandemic on the aviation industry (HEİETS & XİE, 2021)(ICAO, 2021).

The health of pilots is an essential element in performing safety-related duties (Kilic & Soran, 2020) (Kilic, 2021b). Previous studies reported that adverse mental state of pilots gave rise to near-misses, incidents, and accidents (Kilic, 2019)·(Kilic, 2020)·(Havle & Kilic, 2019). Therefore, the mental state of aircrew is of paramount importance regarding safety in aviation (Kilic, 2021a) (Kilic & Ucler, 2019).

Investigating the impact of COVID-19 outbreak on mental state of individuals is a topic of growing relevance. There is a large volume of published studies describing the impact of the pandemic on medical care workers (Yas et al., 2020), students (Collins, 2021), and general population (Giorgi et al., 2020). Prior studies have noted that the COVID-19 gave rise to depression, stress and anxiety among healthcare workers (Yas et al., 2020). However, no previous study has investigated the effect of the COVID-19 pandemic on the mental state of airline pilots to the best of authors' knowledge.

2. Methods

2.1. Subjects

The survey participants were primarily identified from airline companies operating in Turkey. The questionnaire was sent online to 500 airline pilots from 4 different airline companies. Of the intended population, 201 pilots (40.2%) were reached. Participation to survey was anonymous and all responses were collected electronically. Informed consent was obtained prior to start of the survey.

2.2. Questionnaire

Based on the reported two questionnaire (Yas et al., 2020)·(Verma & Mishra, 2020), we developed the survey consisting of three parts: 1) demographics (e.g., age, gender, marital status, ranking, type of flying aircraft, total flying experience, comorbidities, and whether they had contact with COVID-19 suspected or diagnosed person (11 questions); 2) psychological state of the person regarding the COVID-19 pandemic (18 questions); 3) the Depression Anxiety Stress-21 scale (21 questions). Questions in the second part of the survey were to be answered on a 5-point Likert-type scale (1. Strongly Disagree – 5. Strongly Agree. Questions of the DASS-21 scale were to be answered on a 4-point Likert-type scale (1. Never – 4. Always) (Appendix A1).

2.3. Statistical Analysis

Descriptive statistical methods (frequency, percentage, and standard deviation) were carried out. We performed Alpha test to analyze the reliability of the survey questionnaire and factor analysis to investigate the consistency. The Cronbach's alpha coefficient of 18 expressions (2^{nd} part of the survey) used to determine was found to be 0.85. Furthermore, the Cronbach's alpha coefficient of the DASS-21 scale was found to be 0.93. Regression analysis and Spearman correlation analysis were performed to test the degree of association between variables. To test collected data, Mann-Whitney U and Kruskal-Wallis H tests were used. A significance level of $P<0.05$ and a 95% confidence interval were used for the interpretation of the results. The statistical analyses were carried out by using the SPSS (the Statistical Package for the Social Sciences) for Windows 25.0

3. Results

The majority (93.5%, N=188) of the respondents were male. Among the participants, there were 125 (62.2%) commander, 34 (16.9%) first officer and 42 (20.9%) senior first officer (cruise relief pilot). The majority (75.6%, N= 152) of the participants were married and 68.7% (N=138) had children. Almost one quarter of the respondents (22.4%, N= 45) had elderly or high-risk individuals among the family or they lived with those. Almost half of the participants (44.3%, N= 89) reported that they got in contact with a COVID-19 suspected person. A minority of the respondents (2.5%, N=5) received psychological support during the pandemic period. Of all participants (2.5%, N=5) requested psychological support. Among participants, 6% (N=12) had comorbidities.

Based on the results, it was found that of all participants, 63.2% had various levels of depression, 57.2% had anxiety, and 76.6% had stress. It was found that request for psychological support was associated with psychological state of the person regarding the COVID-19 pandemic ($p=0,01$). Furthermore, the findings indicated that demographic items (e.g., age, gender, marital status, type of aircraft, flying experience, additional diseases, and contact with a COVID-19 suspected/diagnosed person) did not demonstrate a positive and statistically significant correlation with negative impact of the COVID-19 pandemic (e.g., depression, anxiety, and stress) ($p>0,05$). Table-1.

The findings showed that 63.2% of the respondents had various levels of depression. The frequency of mild depression was 13.4%, moderate depression was 40.8%, and severe depression was 9%. Based on the results, it was detected that 57.2% of the participants had various levels of anxiety, which were moderate anxiety at 27.9%, severe anxiety at 18.4%, and extreme severe anxiety at 10.9%. The results revealed that 76.6% of participants had various levels of stress. The frequency of moderate stress was 22.9%, severe stress was 18.4%, and extremely severe depression was 35.3%.

Furthermore, the results, as shown in Table 2, showed that there was a positive correlation between the levels of depression, anxiety and stress of participants and the negative impact of the COVID-19 pandemic. The negative impact of the pandemic was measured by evaluating the results of the 18 expressions in the second part of the survey.

Based on the findings, it has been found that pilots who received psychological support during the pandemic period showed depression, anxiety and stress at various levels. Participants living with their elderly or high-risk individuals had various levels of stress.

Based on the results of factor analysis, it was found that the scale of the second part of the survey has one subscale. The KMO value was found to be 0.56.

4. Discussion

This study set out to examine the impact of the COVID-19 pandemic on mental state of airline pilots. To the best of authors' knowledge, this is the first study investigating the effect of the COVID-19 outbreak on the psychological status of airline pilots. In this work, we created 18 expressions to determine the psychological effect of the COVID-19 pandemic. It was found that 18 expressions were significantly associated with depression, anxiety and stress levels of participants. It appears that the COVID-19 outbreak had a negative psychological impact on airline pilots. The most important finding was that more than half of the participants had stress, anxiety and depression at various level. Contrary to expectations, this study did not find a significant difference between long-haul pilots and short-haul pilots in levels of stress, anxiety, and depression.

A number of limitations need to be considered. First, the study group was composed of airline pilots, most of them male (93.5%). Second, participants flying long-haul aircraft were occasionally exposed to strict quarantine measures abroad which might have additional negative psychological impacts. Therefore, the findings might not be generalizable to general population. Further research might explore the negative psychological impacts of COVID-19 outbreak on student pilots and cabin crews.

The COVID-19 pandemic has created significant challenges for employees (e.g., pilots, cabin crews, and ground staff) and organizations (airlines, flight training organizations, and local and international aviation authorities).

Table 1. Factors associated with depression, anxiety, and stress at any level

Properties		Depression	p	Anxiety	p	Stress	p
Gender	Male	13.50±5.15	0.06	11.94±5.77	0.08	29.96±11.63	0.05
	Female	10.15±4.95		8.00±1.68		22.31±7.51	
Age	20-30	12.00±6.23	0.15	12.14±6.78	0.19	28.36±12.44	0.10
	31-40	13.42±5.46		11.82±6.10		29.00±11.76	
	41-50	12.14±4.69		10.34±4.15		27.17±10.00	
	51 and older	14.64±4.80		12.78±6.05		32.78±12.13	
Marital Status	Married	13.53±5.15	0.22	11.74±5.47	0.28	30.07±11.23	0.18
	Single	12.51±5.27		11.49±6.34		27.59±12.45	
Do you have children?	Yes	13.33±5.03	0.43	11.83±5.60	0.37	29.77±11.74	0.28
	No	13.19±5.55		11.37±5.88		28.79±11,2	
Which position do you hold?	Commander	13.09±5.11	0.19	11.36±5.47	0.25	29.23±11.76	0.32
	First Officer	12.85±5.22		11.53±5.59		29±10.9	
	Senior Officer	14.21±5.4		12.76±6.33		30.52±11.66	
How long have you been flying? (Total Flight experience)	less than 5	13.36±6.28	0,11	11.57±6.99	0.35	28.14±11.30	0.30
	6-10 years	13.59±5.39		12.49±6.18		30.22±12.02	
	11-15 years	11.75±.,91		10.20±4,30		25.00±10.19	
	16-20 years	12.14±5.84		10.0±4.240		26.64±10.16	
	More than 21	13.58±4.84		11.72±5.54		30.57±11.66	
What type aircraft do you fly? (Current Type Rating)	Long Haul	13.41±5.14	0.32	11.78±5.77	0.39	29.72±11.73	0.38
	Short Haul	12.96±5.36		11.43±5.46		28.79±11.15	
Do you have any comorbidities	Yes	13.58±4.01	0.34	13.67±6.47	0.11	30.92±13.45	0.36
	No	13.26±5.26		11.56±5.62		29.37±11.46	
Do you have elderly or high-risk individuals among the	Yes	13.71±5.5	0.27	13.44±6.13	0.14	33.73±11.40	0.07
	No	13.16±5.11		11.17±5.46		28.23±11.34	
Have you ever got in contact with a COVID-19 suspected	Yes	13.65±4.92	0.22	12.07±5.81	0.28	31.53±11.16	0.25
	No	12.99±5.40		11,38±5.58		27.82±11.64	
Have you ever received psychological support during the pandemic	Not Requesting	13.06±5.09	0.01*	11,35±5,37	0.01*	28.87±11.38	0.01*
	Requesting	15.60±5.86		15.80±7.95		39.00±10.42	
	Received	19.60±4.93		20.20±7.82		42.60±7.96	

Table 2. The association between the impact of the COVID-19 and the DASS-21 results

		Depression	Anxiety	Stress
The negative mental impact of the COVID-19 on airline pilots	r	0.316*	0.397*	0.453*
	p	0.01	0.01	0.01

*0,01 statistically significant

5. Conclusion

In summary, we were able to demonstrate conclusively that COVID-19 outbreak had a negative impact on the mental status of airline pilots. The current findings add to a growing body of literature on the negative impact of the COVID-19 pandemic. Airlines should implement preventive strategies against the negative psychological impact of the COVID-19 in addition to anti-contagion measures Our work towards investigating the negative impact of the COVID-19 outbreak on ab-initio pilots is in progress in our research group.

Appendix
Survey

Part-1. Demographic Factors

1. Gender
   a. Female
   b. Male
2. Age
   a. 21-30
   b. 31-40
   c. 41-50
   d. 51 and older
3. Marital Status
   a. married
   b. unmarried
4. Do you have children?
   a. Yes
   b. No
5. Which position do you hold?
   a. First officer
   b. Senior first officer
   c. Commander
6. How long have you been flying? (Total Flight experience)
   a. Less than 5
   b. 6-10 years
   c. 11-25 years
   d. 16-20 years
   e. More than 21 years
7. What type aircraft do you fly ? (Current Type Rating)
   Short-haul (e.g. Boeing 737 and Airbus 320)
   Long-haul (e.g. Boeing 777, 787, 747, and Airbus 330, 340, 350, 380)
8. Do you have any comorbidities?
   a. Yes
   b. No
9. Do you have elderly or high-risk individuals among the family or do you live with those?
   a. Yes
   b. No
10. Have you ever got in contact with a COVID-19 suspected person?
    a. Yes
    b. No
11. Have you ever received psychological support during the pandemic period?
    a. Received
    b. Requesting
    c. Not requesting

Part-2 Situations related to the COVID-19 Pandemic

12. Worried about being infected
13. Thinking I already got the infection
14. Worried about my/my family’s other problem
15. Afraid of spreading the infection to my family or others.
16. Afraid of my parents being infected.
17. Thinking the virus spread cannot be controlled.
18. Don’t feel safe myself.
19. Feeling my life is under threat
20. Feeling I lost control of my life.
21. Feeling stressed because of the increased in my workload
22. Afraid of flying to countries where confirmed COVID cases have rapidly increased.
23. Afraid of doing my job
24. Thinking there is not enough equipment (e.g., disinfection kit and protecting mask) in training aircraft to prevent contamination and to be protected.
25. Thinking I have been excluded by my relatives and other people because of my job
26. Afraid of being isolated or restricting my activities
27. Thinking if I get an infection, I will suffer financially
28. Thinking I have a lack of information about preventing the epidemic and protecting myself.
29. News/ TV/ social media increases my stress level.

    Questions in the second part of the survey were to be answered on a 5-point Likert-type scale (1. Strongly Disagree – 5. Strongly Agree.

Part-3 DASS-21 scale

30. I found it hard to wind down during the past week
31. I was aware of dryness of my mouth during the past week
32. I couldn't seem to experience any positive feeling at all during the past week
33. I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion) during the past week
34. I found it difficult to work up the initiative to do things during the past week
35. I tended to over-react to situations during the past week
36. I experienced trembling (e.g., in the hands) during the past week
37. I felt that I was using a lot of nervous energy during the past week
38. I was worried about situations in which I might panic and make a fool of myself during the past week
39. I felt that I had nothing to look forward to during the past week
40. I found myself getting agitated during the past week
41. I found it difficult to relax during the past week
42. I felt down-hearted and blue during the past week
43. I was intolerant of anything that kept me from getting on with what I was doing during the past week
44. I felt I was close to panic during the past week
45. I was unable to become enthusiastic about anything during the past week
46. I felt I wasn't worth much as a person during the past week
47. I felt that I was rather touchy during the past week

48. I was aware of the action of my heart in the absence of physical exertion (e.g., sense of heart rate increase, heart missing a beat) during the past week
49. I felt scared without any good reason during the past week
50. I felt that life was meaningless during the past week

Questions of the DASS-21 scale were to be answered on a 4-point Likert-type scale (1. Never – 4. Always)

Ethical approval

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The Relationship between Gender and Emotional Labor: A Research on Flight Attendants

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Abstract

One of the most important values to be given importance by the businesses has been the human factor. The human factor is affected by both the physical and emotional characteristics of the individuals. The businesses inspect the human factor carefully because whether individuals are affected positively or negatively will also affect the businesses positively or negatively. In this study, the rates of emotional labor of the flight attendants as employees of airlines were analyzed according to gender differences. The analysis shows that there is not a significant relationship between the gender and the emotional labor. Nevertheless, it is observed that females have higher level of emotional labor compared to males.

This article was produced from the author's doctoral thesis.

1. Introduction

Human factor is one of the most essential values in the operational success of the businesses. Today, it is important for the businesses to attach importance to the emotional characteristics of individuals as much as their physical characteristics so that the sustainability of the businesses is ensured. On the other hand, emotional labor is the display of desired emotions by the employees within the communication of businesses with their customers and whether the customers feel these emotions positively or negatively. It will be beneficial for all the employees, customers, suppliers and the managers of the business that the businesses managers call attention and attach importance to emotional labor for the management and shaping of the employees' emotions and employ accordingly. For the businesses to achieve their objectives and reach their goals, the employees are expected to make an effort on the concept of emotional labor.

Emotional labor provides various advantages for the business if managed properly by the managers. The positive outcomes of emotional labor include many issues such as the increase in the motivation of the employees, achievement of business objectives, increased customer satisfaction, high level of work performance and strong organizational commitment. Nonetheless, the negative outcomes of emotional labor for the business can be counted as burnout syndrome, work-family conflict, tendency to quit, psychological and physiological disorders, role conflict and alienation. Every business and business manager who have the desire to be successful and continue their existence has to use emotional labor in a positive way (Barutçugil, 2003).

2. Literature Review

2.1. The Scope and Definition of Emotional Labor

The changes in the feelings of an individual during a psychological assessment and managed by nerve endings of the brain are called emotion. In the process of emotional change, people will have many differences. The emotional changes are caused by the effect of human soul and brain and outside observers can sense these changes in the body language, facial expressions and skin color. The word "emotion" in English corresponds to emotions, that is, it is used to express the emotions outside the body (Keskin et al., 2013).

The emotions can be considered a natural part of human experience. They are reflected in the thoughts and words through previous experiences. The essential means of thought and talk is the sentence suggested through the words. The language communication expressed through emotions in daily life does not always reflect the real emotions of people. Therefore, sometimes the emotions can reveal the emotions of people or expected emotions or the emotions of people affected by the expectations. The mission of the corporate governance is to manage emotions according to corporate objectives (Vainik, 2002).

The emotions directly or indirectly affect the human behaviors cognitively, socially and physiologically. Thus, it can be useful for emotions to be managed in order to make operational activities more effective (Lord et al., 2002).

Emotional labor is the expression of desired emotions in the process of service delivery. The employees reflect their emotions and services in their works. The other field reflecting the emotions can be defined as the services provided to the customers. The emotions that the employees feel and experience during work may not always be as expected. Accordingly, emotional labor varies in accordance with the communication activity between the colleagues and their motivations (Güngör, 2009).

For the benefit of the company, directing and controlling the emotions of the employees can help corporate objectives to be achieved (Oktuğ, 2013).

Emotional labor can be defined as the management and shaping of the emotions throughout their careers while working professionally. Therefore, the employees are required to manage their social cognitions as well in the process of social labor. Emotional labor is a behavior that is observable regarding the service quality provided by the employees and defined as the effects of the employees' emotions on their job (Grandey, 2000).

The employees must not express their emotions the way they want in their daily lives. The people who think that their emotions are under control can be more disposed to exhibit behaviors that do not violate social norms rather than their own emotions. Individuals earning a certain amount of salary can be more disposed to control their emotions to get works done. Emotional labor is also defined as a form of reflecting emotions in accordance with the requirements of the job and exhibiting behaviors appropriate to objectives of the business (Köse and Oral, 2011).

Considering the positive and negative outcomes of emotional labor on people and organization, it has positive effects on motivation, improvement of business objectives, customer satisfaction, work performance and organizational commitment. Nevertheless, it has negative effects on the level of burnout, work-family conflict, tendency to quit, psychological-physiological disorders, role conflicts and alienation (Büyükbeşe and Aslan, 2019).

2.2. Gradual Development of Emotional Labor

The fundamentals of emotional labor concept date back a long time and have approximately 40 years of research field. Even though emotional labor concept which was introduced by Hochschild (1983) for the first time is about the regulation of emotions, it is defined within the scope of code of conduct performed by the individuals in the organization, that is workplace, as a part of their job and its scope has been renewed and expanded by many researchers until today.

As known to be introduced by Hochschild (1983) for the first time, emotional labor has been defined as the service provider's regulation of the forms of emotions that can be observed by the service receiver based on the ways of expression that the organization considers appropriate. Just like an actor who cries, gets angry, laughs and displays the characteristics of a character in spite of not being so, the service providers try to exhibit the emotions and behaviors required within the work environment even though they do not comply with their personality or current emotions (Hochschild, 1979; 1983).

While introducing emotional labor concept, similar with the social skills learnt through collaboration in the Zone of Proximal Development concept by Vygotsky (1980), Hochschild (1983) stated that there are certain rules in the display of behaviors, the emotions that need to be shown in certain conditions are learnt within the social environment in which the person is and can depend on the settings and the conditions. However, when the emotions that is to be felt in a certain condition is not the same with what the person actually feels, the person tries to resolve this inconsistency by regulating his/her emotions and behaviors, that is, using his/her thoughts (cognitive), and changing the physical indications caused by the emotions (physical) or the facial expressions (control of mimics and gestures). From this expression and the definition of emotional labor, it can be inferred that the factors such as the existence of display rules in organizations (i.e., in some shops, the salesperson does not sit at all), the relationship between the service provider and receiver (i.e., the interaction between the doctor and the patient while explaining the test results) and the inconsistency between the service provider's emotions and behaviors in accordance with the organization rules and the actual emotions and behaviors (i.e., the hotel receptionist welcomes a client with a smile even though s/he does not feel so) (Hochschild 1979; 1983).

Finally, Hochschild (1983) expresses that regardless of the actual emotion felt in a certain condition in the workplace, the individual uses the surface acting subdimension of emotional labor while displaying the expression of the emotion which is to be felt in that condition, and that when the individual regulates both his/her emotions and their expressions in accordance with the display rules in the same condition, s/he uses deep acting subdimension of emotional labor.

It can be said even by just looking at the definition part that Morris and Feldman (1996) handle the concept of emotional labor more comprehensively. According to this approach, emotional labor is comprised of 4 dimensions: the frequency of emotion display subdimension that considers the frequency of communication with the employees and service receivers and expresses that the increase in the frequency results in individuals exerting more effort; attentiveness subdimension expressing for how long and how severe the display rules will be in the interactions with the service receivers and that the duration of and increase in emotion display cause the individuals to exert more effort; variety of emotions subdimension expressing the types of positive, neutral or negative emotion display, respectively, to enhance the relationships with the service receivers, to transfer the authority to the service receiver and to control the service receiver, and that the increase in the variety requires more planning, effort and control; and lastly, emotional dissonance subdimension expressing the inconsistency between the emotion to be displayed and the emotion that is felt, and that an increase in this inconsistency results in individuals exerting more effort.

Throughout the years, Grandey (2000) defines the emotional labor concept the definitions and scope of which have been developed by various researchers, as the individual's regulation of his/her emotions and display of emotions to reach the objectives set by the organization and actually reveals the common aspect of the definitions mentioned from the very beginning.

By aiming to assert the research conducted until his time as a unifying model, Grandey (2000) has based his model upon Emotion Regulation Theory. Accordingly, the antecedent focused emotion regulation based on changing the interpretation of the condition causing the emotion felt and the reaction focused emotion regulation based on changing the display of the emotion felt were used to explain emotional labor concept (Grandey, 2000).

Distraction method (i.e., when a salesperson is scolded by a customer in vain, s/he can think of his/her happy memories by saying "You are right" and distract himself/herself from anger) and cognitive change method (i.e., every time a customer says something negative, the salesperson infers that "S/he is an angry person I guess" and exclude himself/herself) is included in the antecedent oriented emotion regulation and these methods are associated with emotional labor deep acting method according to Grandey (2000).

In the reaction (response) focused emotion regulation method, the person changes the display of his/her emotions (i.e., the doctor who is nervous about a critical surgery controls his/her facial expressions and betrays no emotion) to show reactions appropriate to the situation instead of changing his/her emotions regarding a situation and this method is associated with surface action dimension of emotional labor according to Grandey (2000).

Grandey (2000) who generally includes emotion regulation model in emotional labor states that it is necessary to consider 3 main factors (situational signs and emotional events, the process of emotion regulation and emotional labor, long-term outcomes of emotional labor) and additional factors such as individual and corporate factors, and that emotional labor has a complex structure.

2.3. Relationship between Emotional Labor and Gender

There have been many studies conducted on the relationship between emotional labor and gender. In a study carried out in 1993, gender factor was observed between the relationships of work-family conflict and work-family role. It was concluded that females had more tendency towards emotion management under the conditions of both home and work compared to males (Savaşkan and Göktaş Kulualp, 2019). In the study by Dursunova and Geylan in 2020, it was presented that females experienced more emotional labor than males. As a result, a significant relationship between gender orientation and emotional labor (Dursunova and Geylan, 2021).

3. Method

3.1. Limitations

As the results of this study can vary according to the current sample, the findings are limited to the sample and must be tested with different sample groups. The results obtained from the research may vary over time. Therefore, the results must be evaluated considering the time period. The scales used can vary according to the perception of applied sampling.

3.1. Universe and Sampling

The flight attendants working at airline companies constitutes the universe of the research. The sample includes participants from different airline companies and representing the universe. The sample in this study was determined through "quota sampling" as a nonrandom sampling method. In order to apply quota sampling, it must be determined according to which characteristics the information to be collected will be evaluated. Besides, the sample representing the universe must be in accordance with the current distribution (İslamoğlu and Almacık, 2014, p.190). The data obtained from 650 individuals working at airline companies through surveys were evaluated. The survey was distributed to the flight attendants and 385 of them were taken back. The rate of return is 59.23%.

3.3. Method of Analysis

At the beginning of the research, reliability analyses were conducted and Cronbach alpha values were detected. Cronbach alpha coefficient shows the internal consistency of the survey. Alpha coefficient is evaluated according to the intervals below (Kalaycı, 2008):

1. The scale is "not reliable" if $< a < 0.40$
2. The scale is "less reliable" if $0.40 < a < 0.60$
3. The scale is "rather reliable" if $0.60 < a < 0.80$
4. The scale is "very reliable" if $0.80 < a < 1.00$.

Questions regarding demographic information were included in the first part of the survey, while questions for emotional labor scale were included in the second part. 5-point Likert scale was used in the scales (1-Strongly Disagree/5-Strongly Agree). Emotional Labor Scale was generated by Diefendorff et al. (2005) by adapting some items and improving some other items of emotional labor scales by Grandey (2003) and Kruml and Geddes (2000). Turkish adaptation and the analyses of reliability and validity were conducted by Basım and Beğenirbaş (2012). The scale consists of 3 dimensions as surface acting, deep acting and natural (sincere) emotions. In the scale, surface acting is evaluated through 6 items, while deep acting is evaluated through 4 and natural emotions through 3 items. The scale includes items such as "I act like I feel good when I am with the passengers" and "I make an effort to feel the emotions that I need to display in real life". Cronbach alpha reliability value of three-factor emotional labor scale was found to be 0.813 (rather reliable).

As a result of factor analysis for Emotional Labor Scale, 3 factors were validated. Total variance explained is 53.347%. Considering the scale factors, it was found that the "surface acting" factor had a share of 12.732%, the "deep acting" factor 11,358%, and the "natural emotions" factor 10.889% of the explained variance. The test result of Kaiser Meyer Olkin (KMO) sample suitability was 0.857. Cronbach alpha reliability values for emotional labor dimensions were found to be 0.889 for surface acting factor, 0.861 for deep acting factor and 0.803 for natural feelings factor.

Data obtained were analyzed on SPSS 22 program and the mean, frequency and percentage distributions of the answers were calculated and the results were exhibited both in table and in written. T Test was conducted while hypotheses were tested. As a result of the analysis, Ho was rejected if the p value was lower than alpha value 0.05. If the p value was higher than alpha value 0.05, it was stated that there was a significant relationship between the two variables.

For normality, normal probability plot where the observed and expected values of data in distribution was shown on a chart and also Kolmogorov-Smirnov values which is a normality test were analyzed. It was observed that the values were gathered on or around a line in the probability plots and that the Kolmogorov-Smirnov test values were at $p<0.05$ significance level and all data were normally distributed.

3.4. Hypotheses

In the study, whether there was a relationship between gender and emotional labor were evaluated and this hypothesis was put forward:

Ho: Emotional Labor does not vary by gender.

H1: Emotional Labor varies by gender.

4. Findings

In this section, survey results applied during research process are given. Gender data, mean of answers for survey questions, mean of answers according to gender and T Test results are given both in table and in written.

3.4. Gender Data

From the demographic characteristics of survey, it is observed that there are 235 female participants and 150 male participants. Because it is known that women prefer this profession more than men, this difference can be acceptable

Table 1. Gender Data

Gender	Number	Percentage	Cumulative Percentage
Female	235	61.0	61.0
Male	150	39.0	100.0
Overall	385	100.0	-

Table 2. Emotional Labor Items

Questions	N	Min.	Max.	Avg.	S. D.
I act like I feel good when I am with the passengers	385	1	5	2.6831	1.44639
It feels like I wear a mask to display the emotions my job requires.	385	1	5	2.9922	1.38159
When I am with passengers, I put extra effort as if I am in a show.	385	1	5	2.9299	1.37983
I act to deal with passengers appropriately.	385	1	5	3.0571	1.31571
I act like I feel the emotions that I do not feel while working.	385	1	5	3.1455	1.36536
When I am with passengers, I display emotions different than I actually feel.	385	1	5	2.9143	1.26468
I make an effort to actually feel the emotions I need to display.	385	1	5	2.3844	1.13549
I do my best to feel the emotions I have to display to the passengers.	385	1	5	2.2597	1.13425
I make a great effort to feel the emotions that I have to display to the passengers.	385	1	5	2.4519	1.13807
I try to really experience the emotions that I have to display to the passengers.	385	1	5	2.2831	1.08029
The emotions I display to the passengers arise spontaneously.	385	1	5	3.6545	1.11226
The emotions I display to the passengers are sincere.	385	1	5	3.9740	0.98391
The emotions I display to the passengers are the same as those I felt at that moment.	385	1	5	3.7039	1.14365
Overall Mean	-	-	-	2.9564	-

In the survey results, while 1 means that emotional labor is low, 5 means it is high. As a result, the answers that the participants gave show that overall mean of emotional labor analysis is 2.9564

Table 3. Mean by Gender.

	Group Mean				
	Gender	**N**	**Avg.**	**S. D.**	**Avg. Std. Error**
DE_Mean	Female	235	3.0085	.65413	.04267
	Male	149	2.8720	.72064	.05904

From the answers of females or males to emotional labor questions, it is observed that females have a mean rate of 3.0085, while males have 2.8720. Accordingly, it can be inferred that women have more emotional labor than men.

Table 4. T Test

		Levene Test for the Equality of Variances		T test						
									95% conf. interval	
		F	Sig.	t	df	Sig. (2-tails)	Mean difference	S. D.	Lower Bound	Upper Bound
DE_Mean	Assumption of Equal Variances	3.747	.054	1.916	382	.056	.13654	.07128	-.00361	.27670
	Assumption of Unequal Variances			1.874	292.530	.062	.13654	.07284	-.00682	.27991

As a result of T Test, Ho cannot be rejected because sig. value in Table 4 is higher than alpha value 0.05. In accordance with this sample, no significant relationship between gender and emotional labor could be found.

5. Conclusion

This study aimed to show whether there was a difference between the genders of flight attendants working at airlines and emotional labor.

It is important for the emotional labor to be measured in aviation which is within service sector in terms of aviation safety and the future of the companies. Data of 385 participants in total were evaluated in the study. The number of female flight attendants was 235 and male flight attendants was 150 in this evaluation. Because women prefer this profession more than men, this difference can be acceptable.

The analysis of the answers to survey questions shows that the mean of 365 flight attendants' emotional labor is 2.9564. From this mean, it is observed that the mean of emotional labor is generally low. Nevertheless, except for the overall mean, the mean of emotional labor for women is 3.0085 while for men 2.8720 based on gender mean. This shows that women are in emotional labor more than men.

Considering whether there is a significant relationship between gender and emotional labor factor, no significant relationship was found. However, it must be remembered that this result is limited to the sample of this study and can vary in other studies.

To summarize in general, there is not a significant relationship between the gender and the level of emotional labor to be experienced in accordance with this sample. Nevertheless, it is observed that women slightly have a higher level of emotional labor mean than men.

In the forthcoming periods, new analyses can be made through a more comprehensive study with flight attendants working domestically and abroad from different control variables. Except for the flying aviators, studies can be conducted with the aviation personnel working at the ground operations or administrative departments and the emotional labor results of employees from different fields can be obtained. New studies especially in the service sector where emotional labor is intensely experiences and in the aviation sector where the circulation rate is much higher than the other sectors on a sectoral basis or in other sectors can provide important and valuable results.

As a suggestion to the airline companies, it is thought that this kind of studies can be helpful for the department of human resources to obtain important information in the process of employment. There is a system called Crew Resource Management (CRM) which is important in terms of aviation safety in the aviation industry as a sector where the human factor is intense and errors can never be allowed. CRM is always used in the trainings of all cabin crews and in their career. The main goal of CRM is to keep the human factor at the lowest level in this operation by minimizing errors with the coordinated and appropriate risk management of the entire crew in order to carry out the flight operation to be performed in a safe and effective way, and thus to prevent possible accidents or incidents (Terzioğlu, 2010). Since CRM is essential for the aviation safety, flight attendants are essential for CRM. Therefore, the airlines must elect the appropriate persons in terms of CRM. Additionally, as the flight attendants are always with the passengers, they are the ambassadors of the airlines in a way. This is why the emotional labor behaviors of the flight attendants are highly important and this cannot be ignored by the airline companies. In this sense, the airline companies must establish a professional and corporate human resources department, create human resources for the corporate culture, determine various stages for the employment process and make evaluations through personality tests and psychological interviews. Otherwise, the probability of moral and material damage in short- and long-term especially in the aviation sector will be inevitable.

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A Review of Financial Performance of Aircraft Leasing Companies

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Abstract

The Covid-19 pandemic has caused many industries, especially the air transport industry, to experience a crisis. It is important to analyze the change in the financial performance of global aircraft leasing companies, one of the most important stakeholders of the airline industry during this crisis period. Therefore, this study aims to analyze the financial performance of global aircraft leasing companies in the period from Q1 2018 to Q4 2020. In the study, we analyzed the financial data of 6 global aircraft leasing companies using the CRITIC-based CODAS method. Our findings indicate that some aircraft leasing companies have been ahead of the competition due to the Covid-19 pandemic, while others have fallen behind in the financial performance rankings. Therefore, our results prove that aircraft leasing companies are affected by the covid-19 pandemic. Our analysis on a sectoral basis indicates the relationship between the debt repayment capacity of airlines and the performance of leasing companies.

1. Introduction

One of the most important stakeholders in the air transport industry is leasing companies. Leasing companies are vital to the success of airlines, which do not have enough funding resources to purchase aircraft. These companies make a significant contribution to the growth of the sector by entering into various long-or short-term contracts with airlines.

But the Covid-19 pandemic has significantly affected all sectors, especially the airline industry. Due to Covid-19, revenue passenger-kilometres (RPK) in the aviation industry has fallen by 66% year-on-year (IATA, 2021) while the total number of passengers has declined by 60% (ICAO, 2021). Therefore, leasing companies are significantly affected by shrinking demand in the airline industry. In this context, it is observed that airlines that have experienced financial difficulties or bankruptcy have delayed or failed to meet their obligations to leasing companies (Caslin and O'brien, 2020). This has caused leasing companies, which are already in a difficult situation due to shrinking demand, to have difficulties collecting receivables and increase their financial risks.

It is important to examine the performance of global aircraft leasing companies that face various risks due to the crisis experienced by the air transport industry during the Covid-19 period. This is because some of the decisions taken by global aircraft leasing companies give them a competitive advantage. Decisions taken by firms in times of crisis can increase their financial risk, as well as allow them to move well ahead of the competition when the crisis is over. In this study, we analysed the performance of global aircraft leasing companies from the pre-Covid-19 pandemic period to 2020. Our main goal is to determine the financial position of leasing companies that are vital stakeholders in the air transport industry. Several studies are examining the air transport industry in the Covid-19 period in the literature (Abate et al., 2020; Bauer et al.,2020; Dube et al., 2021; Gössling, 2020; Nabboush and Alnimer, 2020; Pereira and Soares 2021; Serrano and Kazda, 2020). However, we have not come across any study on the financial performance of global aircraft leasing companies. Therefore, we expect this study to benefit decision-makers and investors in the industry both by filling the gap in the literature and by revealing the performance of global aircraft leasing companies.

2. Literature Review

In the literature, there are numerous studies on the performance of leasing companies. As the number of aircraft leasing companies is limited, studies on these companies are few. Therefore, studies on general leasing companies were examined. As the study covers the period of the pandemic, which has deeply affected aviation and other service industries, studies that measure financial performance during crises are initially examined. The use of multi-criteria decision-making methods in measuring financial performance provides a flexible structure since it is for finding the best option out of many options. Rates used in performance measurement are operating income, cash flows, the difference between book value and market value, and accumulated earnings and profits. The literature consists of four parts. The first part deals with studies on the financial performance of companies, the following part examines studies on leasing companies, studies using the CODAS method are examined in the third part, and studies on Covid-19 are reviewed in the last part.

Temizel et al. (2016) analyzed the financial performance ranking of 34 out of 50 companies of the Corporate Governance Index using the TOPSIS method. The results show that the financial performance of companies varied over the years analysed the relationship between firm financial performance and corporate social responsibility in Borsa Istanbul 100 index companies. They showed that there was a significant relationship between corporate social responsibility and company size. However, they did not find any significant relationship between financial performance and corporate social responsibility. Gumus et.al (2019) used SWARA and ARAS methods to evaluate the financial performances of the companies operating in the construction sector in Borsa İstanbul (BİST). They concluded that the current and cash ratios have the highest weight and the equity transfer rate has the lowest weight from the rates used in the decision-making method. Akcakanat (2018) evaluated the provinces based in the TR-61 region using multi-criteria decision-making methods based on the province with the EDAS method. The resulting criterion weights were calculated separately using the EDAS method and the calculation with two different criteria weights was found to be the same. Karakaya (2020) measured the performance of participation banks in Turkey based on the CAMELS system. The order of the main criteria based on their weights was determined as capital, earnings, asset quality, liquidity, management quality, and sensitivity. The highest weighted criteria were found to be the equity profitability ratio. Orcun (2019) evaluated the financial performances of the companies included in the Borsa İstanbul Electricity Index (XELKT) by the WASPAS method. According to the result of the study, companies declaring low profits, providing other variables of companies that are similar, were found to be the most successful companies. Sariay and Bagci (2019) examined the effect of asset consumption on financial performance by using the DEA method. They found that asset consumption increased financial performance. Ulutas and Karakoy (2020) measured the financial performance of a cargo company using CRITIC and ROV methods. They concluded that CRITIC and ROV methods are successfully applied in performance measurement. Tayyar et.al. (2018) analysed the performance of insurance companies using the Reference Ideal Method (RIM). They determined that RIM is a suitable method for performance evaluation according to financial ratios. On the other hand, decision-makers should be cautious when determining the ideal range. In addition to these studies, some studies examine performance in various dimensions in the airline industry (Tayyar et al., 2018; Borochin, 2020; Chen et al., 2021; Eufrasio et al., 2021; Gudiel Pineda et al., 2018; Huang et al., 2020; Renold et al., 2019).

Examining studies on financial performance measurement, models are capable of measuring the financial performance of companies. Moreover, it has been revealed that profitability is the most important performance indicator, and meeting liabilities and asset quality are also effective in the success of the company. The following section examines studies on leasing companies. Alam et.al. (2011) classified the leasing companies based on financial ratios. According to the result of the study, the ranking of leasing companies changed depending on different factors. Kiraci and Bakir (2019) evaluated the performance of airlines using CRITIC and EDAS methods. They concluded that the method they used was successful in measuring the impact of the crisis on firms. Dalfard et.al (2012) applied data envelopment analysis (DEA) models for the efficiency assessment and ranking of leasing companies. They found that both the CCR and BCC models were not suitable for ranking leasing companies. Ashgar and Afza (2013) calculated the profit efficiency, technical efficiency, and cost efficiency of modaraba and leasing companies in Pakistan with the help of the parametric Stochastic Frontier Approach (SFA). They concluded that leasing firms technically performed better than mudaraba firms, but mudaraba firms performed better in terms of cost management. Gurol (2018) calculated the financial ratios of financial leasing, factoring and financing companies, and these ratios were analyzed by the TOPSIS analysis method. Gurol found that financial leasing and factoring companies showed similar financial performance, but profitability rates fell despite the increase in the number of customers in 2016. Ceyhan and Demirci (2017) examined the performance of leasing companies using the MULTIMOORA method. They found that the MULTIMOORA method gave successful results for firms in different sectors. Kiraci and Asker (2019) examined the performance of aircraft leasing companies using the Entropy-based Topsis method and emphasized that the method was successful in measuring performance. Schmit (2004) examined the credit risk of leasing companies with the Basel II criteria and found that the risk levels of leasing firms varied depending on the assets they leased. Amanollahi (2016) examined external factors affecting the credit risk of leasing companies. He concluded that the external factors were the size of leasing, foreign exchange, ownership interest rate, inflation, and Gross Domestic Product (GDP). In addition to these studies, studies have also been conducted to examine the impact of aircraft leasing companies or airlines' leasing policies on the industry in various dimensions (Bazargan and Hartman, 2012; Bourjade et al., 2017; W. T. Chen et al., 2018; Gavazza, 2010; Kuhle et al., 2021; Oum et al., 2000).

Examining studies on CODAS, Tus and Adali (2018) emphasized that CODAS was successful in personnel ranking by using the CODAS method together with the CRITIC and PSI methods. Peng and Garg (2018) found that the method had great power to determine the most appropriate alternative and was successful in preventing parameter selection problems in emergency decision-making problems. Yalcin and Pehlivan (2019) presented a methodology that integrates the fuzzy CODAS (COmbinative Distance-based Assessment) method with the fuzzy envelope of HFLTs according to CLEs to figure out a personnel selection problem. They found that the presented methodology was efficient and stable for solving personnel selection problems in a hesitant fuzzy environment. Deveci et.al. (2020) stated that the method of selecting alternatives to renewable energy sources in Turkey has some drawbacks such as not always providing reasonable results as in other multi-criteria decision-making methods. Badi and Kridish (2020) used a new COmbinative Distance-based ASsessment (CODAS) method to solve MCDM problems for a steelmaking company in Libya. The results indicated that the proposed method was effectively able to choose the best supplier out of the six alternative suppliers. Katranci and Kundakci (2020) assessed the most suitable ten cryptocurrency alternatives by using the Fuzzy CODAS (COmbinative Distance-based ASsessment) method. As a result of the study, the most suitable cryptocurrency alternative was determined for the investors.

Zheng and Ahang (2021) investigated the effect of the COVID-19 on the financial efficiency of microfinance institutions (MFIs). They found that the pandemic-induced impact decreased the financial efficiency of MFIs. Chen and Yeh (2021) examined the reaction of sectors to the global financial crisis and Covid-19 and found that firms were affected by the 2008 financial crisis and pandemic, but the monetary expansion policies announced by the US Federal Central Bank relatively prevented firms from affecting badly. Ichsan et.al. (2021) have examined the determinants of the performance of Islamic banks during the Covid-19 period and found that Islamic banks in Indonesia have been impacted by the pandemic due to suspension. Colenda et al. (2020) applied stress tests to health institutions during the pandemic. They found that health institutions were unprepared for the crisis, but they took lessons from the crisis. Folger-Laronde et.al. (2020) determined that sustainability performance did not affect the performance of firms during the crisis period by examining the financial performance of publicly-traded companies in the Covid-19 period. Rababah et.al. (2020) analysed the financial performance of publicly traded firms in China during the pandemic and found that there were very serious decreases in revenues, and the tourism and travel sectors were the most severely affected by the outbreak. Demirgüç-Kunt et al. (2020) examined the performance of the banking sector during the pandemic period. They determined that public banks with high liquidity were relatively more resistant to the crisis and that the impact of the crisis on the sector would be felt more in the medium long term. Khan et.al. (2021) identified the influence of entrepreneur traits on Small and Medium-Sized Enterprises' performance during COVID-19. They concluded that the age of SMEs and the educational background of the entrepreneur affected the resilience of firms to the crisis. Recently, many studies have been conducted in which the effect of the Covid-19 pandemic on the airline industry has been studied in various dimensions dimensions (Amankwah-Amoah et al., 2021; Belhadi et al., 2021; Brown and Kline, 2020; Carter et al., 2021; Dube et al., 2021b; Maneenop and Kotcharin, 2020; Pereira and Soares de Mello, 2021b; Piccinelli et al., 2021; Sobieralski, 2020). However, we have not come across any study in which the financial performance of global aircraft leasing companies has been studied, taking into account the Covid-19 pandemic. Therefore, we expect that this study will contribute to the literature both in terms of revealing the effect of the Covid-19 pandemic on global aircraft leasing companies and in terms of monitoring the recent performance of global aircraft leasing companies.

3. Method

3.1. Critic Method

Weights of the criteria are impacted as much by characteristics of the criteria as from the subjective point of view of the decision-maker (Kazan and Özdemir, 2014, s. 209). To eliminate subjective point of view of the decision-maker, many methods based on objective weighting have been developed. One of the most commonly used methods is the CRITIC method. The objective weights calculation is built as follows (Diakoulaki, Mavrotas, and Papayannakis, 1995, p. 764-765; Cakir and Rivet, 2013, p. 451):

Step 1: Creation of decision matrix

The matrix indicates the performance of different alternatives according to different criteria.

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

In Equation 1, m denotes alternatives and n denotes the criteria.

Step 2: The decision matrix is normalized through the following equation.

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

Here; x_j^{min} means the lowest value of the j criterion, and x_j^{max} means the highest value according to the j criterion

Step 3: While deciding the criteria weights, both the standard deviation of the criterion and its correlation between other criteria are included.

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)(r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 \sum_{i=1}^{m}(r_{ik} - \bar{r}_k)^2}} \quad (3)$$

Pearson correlation coefficient was used in equation (3). In cases where the number of alternatives is low, Spearman sequence correlation coefficients, which are non-parametric tests, are used.

Step 4: Calculation of the amount of information (cj)
This method covers the intensity of the contrast and the conflict in the structure of the decision making problem. For this purpose, standard deviations of normalized decision matrix column values are used.

$$c_j = \sigma_j \sum_{k=1}^{n}(1 - \rho_{jk}) \quad (4)$$

It can be said that this method gives a higher weight to the criterion which has a high standard deviation and low correlation with other criteria. The namely higher value of Cj indicates that a greater amount of information is obtained from the given criterion so the relative significance of the criterion for the decision-making problem is higher.

Step 5: Obtaining criterion weights
In the last step, criterion weights are obtained with the help of equation (5).

$$w_j = c_j / \sum_{k=1}^{n} c_k \quad (5)$$

3.2. Codas Method

The COmbinative Distance-based ASsessment (CODAS) is another new MCDM method, developed by Ghorabaee et.al. (Dahooei et al, 2018, s. 176; Peng and Garg, 2018, s. 440). In the Codas method, in the process of determining the performance of alternatives for decision problems, the distance of decision problems from the negative-ideal solution is taken as a basis. The distance to the negative ideal solution (NIS) is divided into Euclidean (Euclidean) and Manhattan (Taxicab) distances (Badi, et al., 2018, p. 4; Yeni and Özçelik, 2019, P. 440). Euclidean distance is generally used as the primary criterion in the comparison stage of alternatives. But the taxicab distance approach, which is considered a secondary criterion, is applied if the Euclidean distances of the compared alternatives are equal; (Keshavarz et al., 2016, p. 28; Mathew and Sahu, 2018, p. 140; Bolturk and Kahraman, 2018, p. 2; Deveci, et al., 2020, p. 2)

The CODAS utilizes the Euclidean distance as the primary measure of assessment. If the Euclidean distances of two alternatives are very close to each other, the Taxicab distance is utilized to contrast them. The degree of closeness of Euclidean distances is determined by a threshold parameter. The Euclidean and Taxicab distances are measures for 1^2-norm norm and 1^1-norm indifference spaces, respectively (Peng and Garg, 2018, s. 440; Bakır and Alptekin, 2018, s. 1341).

The application stages of the CODAS method are given below (Keshavarz et al., 2016, p. 29; Bolturk and Kahraman, 2018, p. 4; Ulutas, 2020, P. 1642; Kiracı and Bakır, 2020, P. 89);

Step 1: Construct the decision-making matrix (X), shown as follows:

$$X = [x_{jk}]_{nxm} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (6)$$

Where xij ($xij \geq 0$) indicates the performance value of ith alternative on jth criterion ($i \in \{1,2, \ldots, n\}$ and $j \in \{1,2, \ldots, m\}$).In the decision matrix, there are performance values that the alternative "j" shows on the criterion "k".

Step 2: Calculate the normalized decision matrix.

$$n_{ij} = \begin{cases} \dfrac{x_{jk}}{max_j x_{jk}} & if\ k \in N_b \\ \dfrac{min_j x_{jk}}{x_{jk}} & if\ k \in N_c \end{cases} \quad (7)$$

where Nb and Nc indicate the sets of benefit and cost criteria, respectively.

Step 3: Calculation of weighted normalized decision matrix; after determining the weighting coefficients (wj) of the criteria to be evaluated, the weighting process is applied to the decision matrix. This process takes place by multiplying the weight coefficients (wj) with the elements in the columns in the decision matrix with the normalization process. The said transaction is carried out through equation (8).

$$r_{kj} = w_j n_j \quad (8)$$

Step 4: Determine the negative-ideal solution (point) as follows:

$$ns = [ns_j]_{1xm} \qquad ns_j = min_k r_{kj} \quad (9)$$

At this stage, it is considered that the alternative located at the furthest distance from the negative ideal solution point in terms of all criteria is the optimal alternative.

Step 5: Calculate the Euclidean and Taxicab distances of alternatives from the negative-ideal solution, shown as follows:

$$E_i = \sqrt{\sum_{j=1}^{m} (r_{kj} - ns_j)^2} \quad (10)$$

$$T_i = \sum_{j=1}^{m} |r_{kj} - ns_j| \quad (11)$$

Step 6: Form the relative assessment matrix, shown as follows; The comparative evaluation matrix is arranged employing equation (12) by comparing the values of each alternative according to the Euclidean and Taxicab distances to other alternative values.

$$R_a = [h_{ik}]_{nxn}$$
$$h_{ik} = (E_i - E_k) + \big(\psi(E_i - E_k) \times (T_i - T_k)\big) \quad (12)$$

ψ indicates a threshold function to recognize the equality of the Euclidean distances of two alternatives and is defined as follows. The value in question is calculated through equality (13).

$$\psi(x) = \begin{cases} 1 & if\ |x| \geq \tau \\ 0 & if\ |x| < \tau \end{cases} \quad (13)$$

The value of τ shown in Equation (13) is an indicator created by the decision-maker. It is suggested that this indicator be valued between 0.01 and 0.05. Accordingly, if the difference between the Euclidean distances of the values of the two alternatives compared is less than the τ value, the comparison is performed based on the taxicab distance of these alternatives.

Step 7: Calculate the assessment score of each alternative, shown as follows:

$$H_{ik} = \sum_{k=1}^{n} h_{ik} \quad (14)$$

4. Application and Findings

In this study, the financial performance of 6 aircraft leasing companies for the period from Q1 2018 to Q4 2020 was examined by the CRITIC-based CODAS method. From this point of view, firstly, the CRITIC method was used, and then the CODAS method was conducted. Within the scope of the research, ten financial performance indicators, which are among the most commonly used indicators in the literature, were used. Data on performance indicators were obtained from the Thomson Reuters DataStream database. Financial performance indicators of aircraft leasing businesses are given in Table 1.

Table 1 Financial Performance Indicators and Codes Used in the Study

Financial Performance Indicators	Code
Current Assets / Short-Term Liabilities	C1
Total Debt / Total Assets	C2
Total debt / Shareholder's Equity	C3
Shareholder's Equity / Total Assets	C4
Long-Term Liabilities/ Total Assets	C5
Net Sales / Shareholder's Equity	C6
EBIT / Total Assets	C7
EBIT / Shareholder's Equity	C8
Operating Profit / Shareholder's Equity	C9
Operating Profit / Total Assets	C10

Table 1 includes financial performance indicators and codes for these indicators. Codes for financial indicators will be used in the tables in the later parts of the study.

In this part of the research, the CRITIC method was used during the weighting process of variables belonging to aircraft leasing companies. The CRITIC method is a method that can be used in cases where subjective weighting approach reflecting the values and judgments of decision-makers is insufficient and therefore the resulting judgments are uncertain [85].

As part of the research, due to the use of quarterly data for the period 2018-2020, the criterion weights for each quarter were taken from the decision matrix and the application process was performed and repeated for each period. However, as an example, the application process was carried out using only the first quarter data of 2018.

At the first stage of the CRITIC method, the decision matrix is produced. The decision matrix in Table 2 was produced with the help of equation (1). The decision matrix is composed of 6 aircraft leasing companies (alternative) and 10 criteria (indicator).

4.1. CRITIC Method Application

Table 2 Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
AERCAP	1.16	0.80	3.91	0.20	0.73	0.13	0.01	0.07	0.06	0.01
GE	1.81	0.80	3.89	0.20	0.58	0.38	0.00	0.02	-0.02	-0.00
AIR LEASE	0.44	0.62	2.34	0.27	0.70	6.21	0.01	0.05	0.05	0.01
ORIX	14.18	0.36	1.54	0.24	2.18	0.11	0.01	0.03	0.02	0.00
FLY	14.43	0.73	4.74	0.15	0.84	5.84	0.01	0.08	0.07	0.01
SMBC	0.97	0.04	0.35	0.11	0.04	0.03	0.00	0.04	0.08	0.01

After the decision matrix is produced in the CRITIC method, the normalization process is applied to the decision matrix through equality (2). The normalization process is a set of processes in which the maximum and minimum values of each criterion are determined and the equation is applied through these alternative values. The decision matrix obtained through the normalization process is given in Table 3.

Table 3 Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
AERCAP	0.05	0.00	0.19	0.61	0.68	0.02	0.99	0.76	0.74	0.86
GE	0.10	0.00	0.19	0.62	0.75	0.06	0.05	0.00	0.00	0.00
AIR LEASE	0.00	0.23	0.55	1.00	0.69	1.00	1.00	0.51	0.71	1.00
ORIX	0.98	0.57	0.73	0.81	0.00	0.01	0.28	0.09	0.38	0.48
FLY	1.00	0.09	0.00	0.30	0.63	0.94	0.86	1.00	0.85	0.84
SMBC	0.04	1.00	1.00	0.00	1.00	0.00	0.00	0.25	1.00	0.69

As seen in Table 4, not only the normalization process was applied, but also the standard deviation (σ_j) value used in calculating the amount of information (c_j) was obtained. After the normalization process, correlation analysis was applied, which revealed the strength and direction of the relationship between the criteria. Correlation analysis is given in Table 4.

Table 4 The Correlation Coefficients Between The criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	1.00	0.01	-0.19	-0.03	-0.72	0.19	0.04	0.20	-0.04	-0.02
C2	0.01	1.00	0.93	-0.47	0.05	-0.32	-0.57	-0.40	0.41	0.07
C3	-0.19	0.93	1.00	-0.15	-0.01	-0.35	-0.52	-0.56	0.25	0.05
C4	-0.03	-0.47	-0.15	1.00	-0.55	0.23	0.41	-0.15	-0.50	0.02
C5	-0.72	0.05	-0.01	-0.55	1.00	0.09	-0.05	0.17	0.38	0.12
C6	0.19	-0.32	-0.35	0.23	0.09	1.00	0.66	0.60	0.31	0.57
C7	0.04	-0.57	-0.52	0.41	-0.05	0.66	1.00	0.83	0.38	0.77
C8	0.20	-0.40	-0.56	-0.15	0.17	0.60	0.83	1.00	0.64	0.75
C9	-0.04	0.41	0.25	-0.50	0.38	0.31	0.38	0.64	1.00	0.85
C10	-0.02	0.07	0.05	0.02	0.12	0.57	0.77	0.75	0.85	1.00

After the correlation analysis application, the amount of information and the criterion weights were calculated. In this respect, the amount of information for each criterion (c_j) was calculated with the help of equation (4). During the calculation of the amount of information, the standard deviation of the values shown in Table 4 was taken and the process was carried out. In the next step, with the help of equation (5), the criterion weights were obtained by dividing the (c_j) value of each criterion by the sum of the (c_j) value of all criteria. Information values (c_j) and criterion weights (w_j) related to these criteria are shown in table 5

Table 5 Criterion Weights for Q1 2018

Std. Dev	0.490	0.400	0.380	0.360	0.330	0.490	0.470	0.390	0.360	0.360
Cj	4.670	3.690	3.640	3.660	3.160	3.450	3.330	2.720	2.300	2.100
W.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	0.1427	0.1127	0.1112	0.1119	0.0967	0.1053	0.1018	0.0832	0.0702	0.0643

Within the scope of the research, the criterion weights for the Q1 2018 period have been determined so far. Criteria weights for other periods other than Q1 2018 period are shown in Table 6.

Table 6 Criteria Weights (2018 Q1-2020 Q4)

Period/Criterion	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Q1 2018	0.143	0.113	0.111	0.112	0.097	0.105	0.102	0.083	0.070	0.064
Q2 2018	0.095	0.117	0.120	0.107	0.086	0.100	0.086	0.114	0.095	0.080
Q3 2018	0.144	0.103	0.085	0.121	0.141	0.146	0.066	0.065	0.066	0.065
Q4 2018	0.102	0.131	0.128	0.121	0.108	0.102	0.090	0.075	0.074	0.070
Q1 2019	0.134	0.121	0.119	0.102	0.090	0.098	0.075	0.077	0.092	0.093
Q2 2019	0.099	0.140	0.130	0.130	0.119	0.097	0.077	0.070	0.071	0.067
Q3 2019	0.126	0.122	0.079	0.116	0.145	0.134	0.072	0.064	0.072	0.070
Q4 2019	0.105	0.144	0.106	0.125	0.128	0.085	0.071	0.101	0.073	0.062
Q1 2020	0.126	0.119	0.112	0.114	0.084	0.114	0.083	0.086	0.084	0.077
Q2 2020	0.149	0.118	0.077	0.118	0.129	0.134	0.075	0.065	0.069	0.067
Q3 2020	0.151	0.092	0.070	0.128	0.116	0.109	0.077	0.082	0.084	0.091
Q4 2020	0.142	0.088	0.078	0.121	0.079	0.120	0.090	0.086	0.093	0.104

Due to the fact that the weighting of the relevant criteria covers more than one period, the change of weights according to periods is shown in Figure 1.

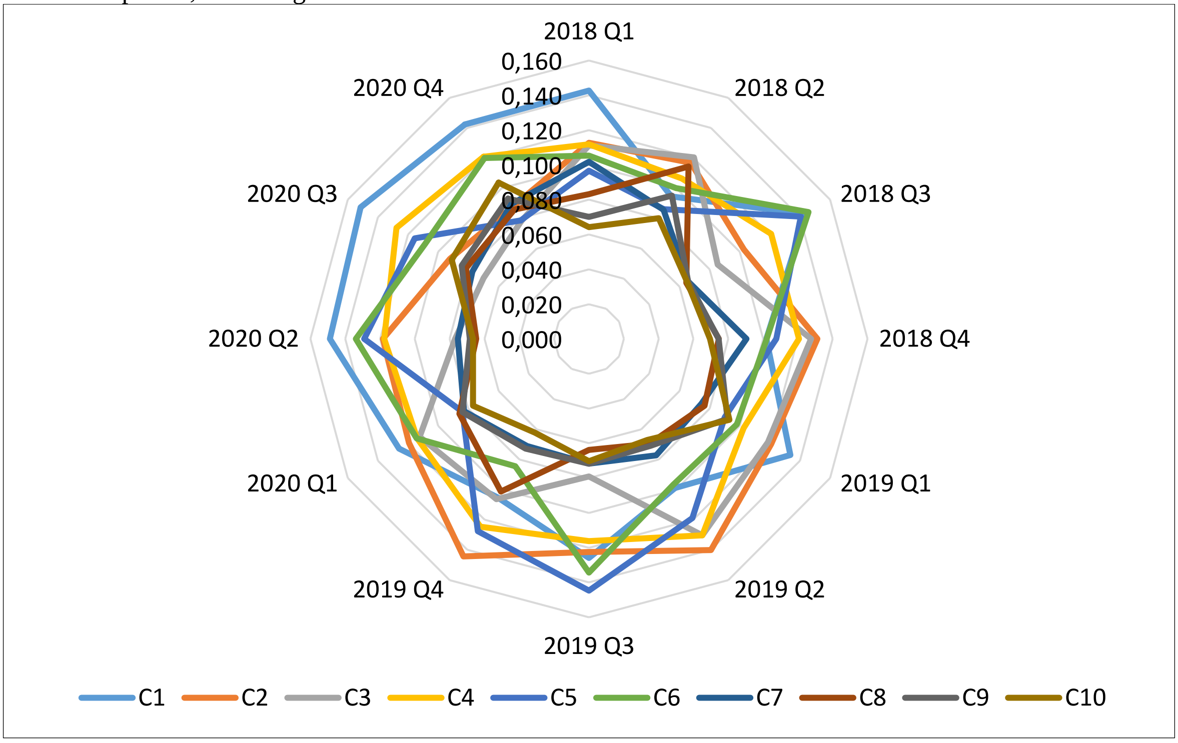

Figure 1. Change in Significance of Performance Criteria in Q1 2018 – Q4 2020 Period

4.2. CODAS Application

In this study, the financial performance of aircraft leasing companies in the Covid-19 period was examined using the CODAS method. CRITIC method was used in weighting the criteria. As in other multi-criteria decision-making methods, firstly, the decision matrix is constructed with the help of equation (6) in the CODAS method. The initial decision matrix for financial indicators is included in Table 7.

Table 7 Initial Decision Matrix (Q1 2018)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
AERCAP	1,160	0,796	3,914	0,204	0,727	0,130	0,014	0,067	0,055	0,011
GE	1,810	0,796	3,893	0,204	0,581	0,380	0,004	0,021	-0,016	-0,003
AIR LEASE	0,440	0,620	2,339	0,265	0,696	6,210	0,014	0,052	0,052	0,014
ORIX	14,185	0,362	1,541	0,235	2,177	0,106	0,007	0,027	0,020	0,005
FLY	14,430	0,725	4,744	0,153	0,838	5,840	0,012	0,081	0,065	0,011
SMBC	0,967	0,037	0,350	0,106	0,037	0,027	0,004	0,036	0,080	0,008

After the decision matrix was formed, the normalization process was applied to the decision matrix utilizing equation (7) in the second stage of the analysis. The normalization process is GIVEN in Table 8.

Table 8 Normalized Decision Matrix (Q1 2018)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
AERCAP	0,080	0,046	0,089	0,768	0,051	0,021	0,990	0,825	0,695	0,824
GE	0,125	0,047	0,090	0,771	0,064	0,061	0,318	0,264	-0,196	-0,234
AIR LEASE	0,030	0,060	0,150	1,000	0,053	1,000	1,000	0,640	0,647	1,000
ORIX	0,983	0,102	0,227	0,887	0,017	0,017	0,480	0,332	0,255	0,364
FLY	1,000	0,051	0,074	0,577	0,044	0,940	0,902	1,000	0,815	0,804
SMBC	0,067	1,000	1,000	0,400	1,000	0,004	0,279	0,446	1,000	0,619

In the third stage of the analysis, the weights of the criteria are included in the calculation process. In this direction, the weighting procedure is shown in equation (8) was performed using the criterion weights found through the CRITIC method. In the fourth stage of the analysis, negative ideal solution points of the criteria were determined utilizing equality (9). In other words, the smallest value was determined by calculating the weighted normalized Matrix values of the column in which the criterion is located in terms of each criterion. In the fifth stage, the Euclidean and taxicab distance values of the alternatives were determined with the help of equality (10-11). The weighted normalized matrix obtained, the distance values from the negative-ideal solution, and the distance values of Ei (Euclidean) and Ti (Taxicab) are given in Table 9

Table 9 The Weighted Normalized Decision Matrix and Distance Values From the Negative-Ideal Solution (Q1 2018)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Ei	Ti
AERCAP	0,011	0,005	0,010	0,086	0,005	0,002	0,101	0,069	0,049	0,053	0,133	0,305
GE	0,018	0,005	0,010	0,086	0,006	0,006	0,032	0,022	-0,014	-0,015	0,045	0,071
AIR LEASE	0,004	0,007	0,017	0,112	0,005	0,105	0,102	0,053	0,045	0,064	0,178	0,429
ORIX	0,140	0,012	0,025	0,099	0,002	0,002	0,049	0,028	0,018	0,023	0,157	0,311
FLY	0,143	0,006	0,008	0,065	0,004	0,099	0,092	0,083	0,057	0,052	0,216	0,522
SMBC	0,010	0,113	0,111	0,045	0,097	0,000	0,028	0,037	0,070	0,040	0,204	0,465
NIS	0,004	0,005	0,008	0,045	0,002	0,000	0,028	0,022	-0,014	-0,015		

After the calculation of Ei (Euclidean) and Ti (Taxicab) distance values, each alternative was evaluated according to the other alternatives by using these distance values and a relative evaluation matrix was formed. Equality (12) was used to create a relative evaluation matrix. In the calculation phase, the value of ψ in Equation (12) was used. The value of ψ was determined as 0.02, as in many studies in the literature (Badi, et al., 2018; Mathew and Sahu, 2018; Boltürk and Kahraman, 2018; Kiracı and Bakır, 2020). The comparative evaluation matrix is given in Table 10.

Table 10 Comparative Evaluation Matrix (Q1 2018)

	AERCAP	GE	AIR LEASE	ORIX	FLY	SMBC	H	Rank
AERCAP	0,000	0,322	-0,169	-0,031	-0,300	-0,231	-0,4085	5
GE	-0,322	0,000	-0,491	-0,353	-0,622	-0,552	-2,3399	6
AIR LEASE	0,169	0,491	0,000	0,138	-0,131	-0,062	0,6056	3
ORIX	0,031	0,353	-0,138	0,000	-0,269	-0,200	-0,2246	4
FLY	0,300	0,622	0,131	0,269	0,000	0,012	1,3348	1
SMBC	0,231	0,552	0,062	0,200	-0,012	0,000	1,0326	2

At the last stage of the analysis, the evaluation score for each decision alternative was calculated by means of equation (14). H_i value was obtained by summing the values in the related lines for each alternative. The ranking of the decision alternatives was obtained by ordering the H_i values in descending order.

According to the results of the analysis, the aircraft leasing company with the best performance for the Q1 2018 period was FLY, while the aircraft leasing company with the worst performance was GE.

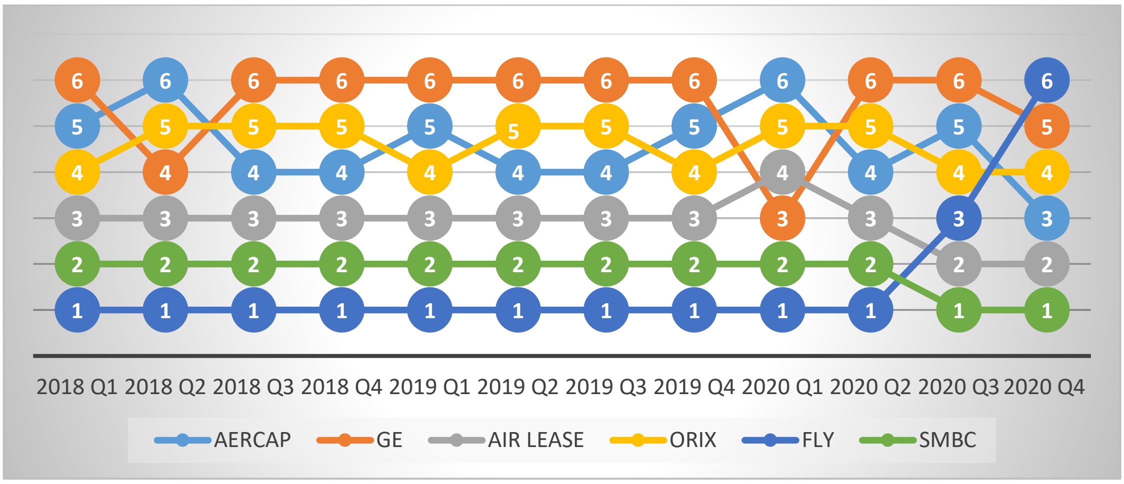

Figure 2. Performance of Aircraft Leasing Companies In Q1 2018 – Q4 2020

Figure 2[1] depicts the change in the financial performance of aircraft leasing companies in the period Q1 2018 - Q4 2020. FLY leasing was the best performer until the beginning of the pandemic. However, its performance has decreased after the pandemic. This company ranked first until Q2 2020 period. But it dropped back to sixth place in Q4 2020 period. The pandemic affected SMBC less than others. The financial performance of AIR LEASE decreased with the beginning of the pandemic. However, it has improved slightly in comparison to the beginning of the pandemic. The financial performances of other companies did not change significantly.

5. Discussion and Conclusion

The airline industry is facing one of the most significant crises in its history. Due to Covid-19, all industry stakeholders, especially airlines, have experienced financial difficulties. Global aircraft leasing companies, which interact closely with airlines, have also been significantly affected by this crisis. In particular, the difficulties experienced by airlines in meeting their obligations and the contraction in the airline leasing market have increased the likelihood that these companies will experience financial difficulties or bankruptcy. Managerial and tactical decisions implemented in this process significantly have affected the survival and/or competitive performance of firms. Therefore, while some global aircraft leasing companies came out of the crisis stronger, some of them got into difficulties. In this study, we aim to determine the financial performances of global aircraft leasing companies from the pre-Covid-19 period to the end of 2020.

To determine the financial performance of global aircraft leasing companies, financial performance indicators were determined at the first stage. Ten financial performance indicators were determined through a thorough literature review. These indicators are frequently used in the literature to measure the financial performance of firms in terms of cash flow, debt level, and (Abban and Hasan, 2021; Elyasiani and Jia, 2019; García-Ramos and Díaz, 2020; Lahouel et al., 2021; Ma et al., 2019; Martí-Ballester, 2021; D. Wang et al., 2021).. Therefore, we used these indicators to determine the financial performance of global aircraft leasing companies ambidextrously.

In multi-criteria decision-making, it is important to correctly determine the criteria weights. Determining criterion weights

[1] The details of air leasing companies' score and rankings in the period between 2018 Q1 - 2020 Q4 is in the appendix.

with deviations may cause performance analysis results to be biased. In this study, we used the CRITIC method to determine the weights of financial performance criteria. The CRITIC method is one of the methods based on objective weighting (Diakoulaki et al., 1995). In addition, we made the weight calculations separately for each period we examined in the study (Q1 2018 – Q4 2020). It is observed that there are changes in the importance levels depending on the Covid-19 pandemic in the criterion weights.

In the study, we applied the CRITIC-based CODAS method to reveal the financial performance of global aircraft leasing companies. We examined the financial performance of six global aircraft leasing companies for the Q1 2018 - Q4 2020 periods. The findings indicate significant changes in the financial performance of global aircraft leasing companies occurred due to the Covid-19 pandemic. The results of the study show that SCMB rose to first place. In contrast, FLY, the best performer until Q2 2020, dropped back to last place. The findings indicate that Air LEASE and AerCap aircraft leasing companies improved their financial performance compared to the pre-Covid-19 period, while there was no significant change in the financial performance of ORIX and GE. Another interesting finding in the study is that GE aircraft leasing has improved its financial performance indicators in the Q1 2020 period, but they have deteriorated in a short period.

There are several reasons why some aircraft Leasing companies have lower performance than their peers in performance analysis results. First of all, the B737 MAX aircraft two fatal crashes on October 2018 and March 2019 negatively affected aircraft leasing companies that had more B737 MAX in their fleet. Because after the two fatal crashes, Boeing 737 MAX type airplanes were grounded worldwide between March 2019 and December 2020. Secondly, many airlines have experienced financial distress due to Covid-19. Due to Covid-19, approximately 90% of airlines unable to make lease payments and had to request a rental deferral (Charters, 2020; CMS, 2020). Therefore, the Covid-19 performance of aircraft leasing companies is closely related to the risk of airlines experiencing financial distress or bankruptcy. That is why some aircraft leasing companies performed lower than others during the Covid-19 process. There may be many reasons for the performance change in question, but we think that further studies might focus on this case.

Ethical approval

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The Relationship Between Attitudes of Students Studying in Aviation Departments Towards Distance Education and Their Commitment to University During COVID 19 Epidemic Period

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Abstract

This study aims to investigate the relationship between university students' attitudes towards distance education and their university commitment in aviation departments/programs, where practical (applied) courses are vital in addition to theoretical courses, in the distance education which is compulsory during the pandemic process caused by COVID 19. Within the scope of the research, 282 participant students enrolled in the Civil Air Transport Management and Civil Aviation and Cabin Services program of the 2-year Vocational Schools of the foundation universities in Istanbul, and the Aviation Management and Pilotage Departments of the 4-year aviation departments could be reached. The questionnaire administered to the participants consists of 3 parts. The first part comprises questions regarding the demographic characteristics of the participants. The second part, includes survey questions including the "Attitude Scale towards Distance Education Applied during the Epidemic Period" and the third part include "Student Commitment in Higher Education Scale". In order to analyze the data obtained from this survey, SPSS 25.0 statistical package program is employed. According to the findings of the research; 51% of the change in student commitment in higher education was explained by the attitude towards distance education offered during the COVID 19 pandemic. Significant differences are found between the attitudes towards distance education and student commitment according to the department types and grade levels of the students. It has been observed that student commitment increases as the scores of satisfaction with the opportunities offered by the university in distance education, communication and access in distance education, and comparison scores of distance education and face-to-face education increase.

1. Introduction

Since the beginning of the 20th century, the civil aviation sector has been one of the most rapidly developing sectors in the world and is inextricably linked to technology. The aviation industry has a complex structure that includes many systems. This structure requires experienced and qualified staff with appropriate technical expertise to maintain and improve this structure. To satisfy the need for qualified personnel, an education system with international standards is required (Durali and Özdamar, 2021).

The aviation sector, which has grown with great momentum in tandem with the globalization and technological advancements and steadily expanding its share in passenger and freight transportation around the world (Çoban, 2019), is an integral aspect of modern life in an age where safety and time are continually gaining value. Air transportation, which is the fastest and most reliable type of transportation plays a vital role in our lives.

With the global expansion of the aviation sector, civil aviation operations in our country are gaining momentum day by day. The increased demand for aviation sector allows private airline companies to increase. With the growth of private airline firms, there is a greater awareness of the significance of awareness of education in the civil aviation sector in order to train qualified personnel. To fulfill demand, there has been considerable increase in both the number and quality of higher education institutions that provide this education (Kiracı et al., 2013). To put it another way, the fast expansion of the aviation sector has resulted in the quick establishment of aviation departments and programs at universities (Gülaçtı, 2019). With the acceleration of the growth in the civil aviation sector, businesses in the aviation sector will be able to meet graduates of universities that provide education in the relevant field for the human resources they need, as well as people who receive training from the courses that have been opened (Karaağaçoğlu, 2015).

A multi-faceted cooperation protocol has been signed between the Directorate General of Civil Aviation (SHGM) and the Presidency of Council of Higher Education (YÖK), covering all fields in civil aviation, opening relevant departments and programs at universities, determining curricula, and conducting sector analysis studies. In accordance with the advancements at Turkish civil aviation, it is intended that civil aviation trainings would be expanded in higher education institutions in order to fulfill the growing need for qualified human resources in the aviation sector and to ensure the sustainable development of civil aviation. As a result, the number of universities and vocational schools offering training in fields like as piloting, aircraft maintenance technician, cabin and ground handling services has increased significantly (SHGM, 2012).

In our country, there are 4-year piloting aviation management departments and 2-year civil air transportation management, aircraft technology and operator programs that accept students based on the results of the Student Selection and Placement Center (ÖSYM) exam placement results on civil aviation (ÖSYM, 2021).

With the COVID 19 pandemic that broke out in Wuhan, China in 2019, impacting the entire world, some changes in the education system were required. In this circumstance, there is a need to develop and implement new education models that cover education and training procedures. The computer and internet-based distance education application in education is the most important of these applications. Distance education is a type of education system that allows students to participate in education without the having to be physically present in the same place with their instructors (Johnson and Aragon, 2003).

This study aims to examine the relationship between the attitudes of students, who have been studying in higher education, especially in programs with practical curricula such as the Civil Aviation Transportation Management program and Civil Aviation Cabin Services program in 2-year Vocational Schools and Aviation Management Department and Pilotage Department in 4-year aviation departments towards distance education applied in their universities and their commitment to the university during the COVID 19 Epidemic Period.

2. Conceptual Framework

2.1. Distance Education

Distance education, which has taken its place in education with the opportunities provided by communication and information technologies to humanity, it is the maintain of educational activities without any physical effect through communication tools such as computers, mobile phones, tablets and televisions (Clark, 2020).

According to research on distance education, it is noted that there are positive and negative aspects of distance education. Distance education is known to have a different learning environment design compared to the classical education model (Traxler, 2018).

The COVID 19 outbreak first broke out in Wuhan, China in November 2019 and spread rapidly, and eventually was declared a “pandemic” by the World Health Organization (WHO) on March 11, 2020 (WHO, 2020). At the meeting held by the YÖK on March 13, 2020, it was decided to suspend education in universities in our country for a period of 3 weeks as of March 16, 2020. It has been agreed that starting of March 23, 2020, educational activities would be carried out remotely at institutions with distance education infrastructure (YÖK, 2020).

Many academic studies on the attitudes of students and teachers in the education sector, which is one of the sectors most affected by the distance education process have been undertaken. Altun-Ekiz (2020) conducted a study on participants consisting of students from the school of physical education and sports and he was found that the disadvantages of distance education are more than the advantages during the pandemic process.

According to the survey results of a study conducted by Altuntaş-Yılmaz (2020) on 265 students on distance education; it was concluded that especially practical (applied) courses should be developed or that alternative methods would be beneficial.

According to Kürtüncü and Aylin (2020), the group that has the most problems due to the fact that practiced courses and internships are held in clinics during the COVID 19 process are students who are educated in the nursing department. In the study, it was seen that fact that the conduct of the courses and the exams were in the form of distance education caused anxiety in the students.

Erzen and Ceylan (2020) say that being able to teach courses effectively online is related to being competent in information technologies. It is seen that it is an advantage to be impartial and to conclude quickly in the evaluation of the exams.

In the research conducted by Bayram et al. (2019), it was concluded that university students agree on problems such as the inadequate infrastructure for distance education and the inability to obtain the expected efficiency from distance education, especially in practical courses. According to the study, it can be said that there is a statistically significant difference between men and women in distance education courses, and that women believe that distance education courses are more advantageous than face-to-face courses compared to male participants.

2.2. University Commitment

The concept of organizational commitment is associated with the behavior and attitudes of employees towards their work. Organizational commitment is defined as the loyalty (fidelity) of the employees to their work and the identification with their job (Bayyurt and Kılıç, 2017). The concept of commitment at the organizational level refers to working people, the concept of commitment in educational institutions, on the other hand, refers to students. This is because, in the education sector; satisfaction, belonging and quality studies in the educational institution are handled by the students who are directly affected by these processes (Strauss and Volkwein, 2004).

If students have a negative perception and attitude towards technology, as well as fear of technology in students, these situations should be eliminated and the present negative perception should be rectified, since this is thought to affect students’ commitment to university (Günüç, 2013).

The fact that failure to organize educational environments in accordance with student’s wishes and needs, as well as lack of proper integration of technology and education platforms, results in problems such as decreasing the attractiveness of educational institutions, increasing student absenteeism, and increasing indifference to learning (Yazzie-Mintz, 2010). In this sense, the quality of service should be enhanced in order for students to strengthen their ties with the university and to identify themselves with the university where they are studying (Ismanova, 2019).

Some research suggests that the quality of higher education service and trust perceived by students affect students’ commitment to higher education (Hennig-Thurau et al., 2001). Rojas-Méndez et al. (2009) concluded that student satisfaction is the most important factor directly affecting student commitment and other premises have only indirect effects on student commitment.

Student commitment (Osman et al., 2019), considered as students' willingness to maintain their engagement with the university, is critical for universities to survive (Demir et al., 2021). As a result, higher education institutions that benefit from the technological development in a way that does not make the students suffer and face-to-face education, by carrying out a successful process in the distance education system during the pandemic period, particularly in departments and programs where applied practical courses predominate, are institutions that have turned the situation in the sector where competition is intense into an opportunity.

3. Data Collection Tools and Analysis of Data

3.1. Data Collection Tools

The survey consists of three parts. In the first part, the first part include personal information form consisting of 4 questions about the socio-demographic characteristics of the students. The second part has "Attitude Scale towards Distance Education Applied during the Epidemic Period" and third part contain a "Student Commitment in Higher Education Scale".

- Personal Information Form: The first part contains questions such as gender, age, student's department/program type, student's class.

- "Attitude Scale towards Distance Education Applied during the Epidemic Period": In the second part, "Attitude towards Distance Education Applied during the Epidemic Period" consisting of five sub-dimensions and 21 questions developed by Arslan (2021) to measure the attitudes of the participants towards distance education at their universities during the epidemic period. Sub-dimensions of the scale defined as Satisfaction with the Facilities Provided by the University in Distance Education (SFPUDE), Attitude towards Faculty Members in Distance Education (AFMDE), Attitude towards Online Exams (ATOE), Communication and Access in Distance Education (CADE), Comparison of Distance Education and Face-to-face Education (CDEFE).

- "Student Commitment Scale in Higher Education": Third part includes "Student Commitment Scale in Higher Education" developed by Çınkır et al. (2021), which consists of 14 questions and one dimension, in order to determine the level of commitment of students towards the university.

3.2. Analysis of Data

Within the scope of the research, skewness and kurtosis coefficients were used to determine the distribution of scores obtained from the attitude towards distance education and student commitment in higher education scales offered during the COVID 19 epidemic period. If the skewness and kurtosis coefficients are in the range of ±1, it indicates that the scores have a normal distribution (Büyüköztürk, 2007). The skewness and kurtosis coefficients obtained as a result of the calculations showed that their scores had a normal distribution (Table 1). Considering this result, parametric analysis techniques were used.

Table 1. Skewness and Kurtosis Coefficients

Variables	Skewness		Kurtosis	
	z	SH	z	SH
SFPUDE	-0.69	0.15	0.26	0.29
AFMDE	-0.25	0.15	0.55	0.29
ATOE	0.92	0.15	0.79	0.29
CADE	-0.19	0.15	0.13	0.29
CDEFE	-0.10	0.15	-0.86	0.29
ASTDE Total Score	-0.87	0.15	0.75	0.29
Student commitment in higher education	-0.69	0.15	0.32	0.29

(ASTDE)= Attitude Scale towards Distance Education Offered During the COVID 19 Epidemic Period

Since the data satisfied the assumption of normal distribution, Pearson correlation coefficients were calculated and the relationships between the attitude towards distance education offered during the COVID 19 epidemic and student commitment scores in higher education were calculated. Multiple linear regression analysis was performed to determine the predictive effect of the attitude components towards distance education presented during the COVID 19 epidemic period on the attitude towards distance education. The existence of a multicollinearity problem between the independent variables was investigated before to performing the regression analysis by computing the variance increase factor (VIF) values. If VIF <10, it indicates that there is no multicollinearity problem (Çokluk et al., 2010). Because the calculated VIF value was found range between 1.10 and 2.64, it was concluded that there was no multicollinearity between the independent variables. The Durbin-Watson coefficient was used to examine the assumption of independence of errors. The fact that this coefficient should be between (>1.5 and <2.5) shows that the assumption of independence of errors is met (Kalaycı, 2017). As a result of the analysis, the Durbin-Watson coefficient was found to be 2.02. The coefficients obtained showed that the relevant assumption was satisfied.

Independent groups t-test was used to compare the attitudes towards distance education and student commitment in higher education offered during the COVID 19 epidemic period by gender, and one-way analysis of variance was used to compare by the age, department/program type and grade level. In order to make more accurate comparisons, some of the groups which have small number of participants were combined and included in the analysis. The confidence interval for the analyses was set at 95%. Analyzes were carried out using the SPSS 25.0 statistical package program.

4. Findings

Information about Participants

When Table 2 is examined, it is seen that 44% of the participants are male and 56% are female. The majority of the participants are in the 18-20 (50%) and 21-24 (40.8%) age groups. 75.9% of the participants are vocational school students and 57.1% of them are studying in the first year. Vocational School students refer to the students studying in the Civil Air Transportation Management and Civil Aviation and Cabin Services Program.

Table 2. Distribution of Participants by Diagnostic Characteristics

		f	%
Your gender	Man	124	44.0
	Woman	158	56.0
Your age	18-20	141	50.0
	21-24	115	40.8
	25-30	14	5.0
	31 and over	12	4.3
Your Department/Program	Aviation Management	38	13.5
	Civil Air Transport Management- Civil Aviation and Cabin Services	214	75.9
	Pilotage	30	10.6
Your class	1st Class	84	29.8
	2nd Class	161	57.1
	3rd Class	2	0.7
	4th Class	35	12.4

Table 3. Descriptive Values of the Scores Obtained from the Attitudes towards Distance Education and Student Commitment Scales in Higher Education Presented During the COVID- 19 Epidemic Period

Variables	N	min.	Max.	Mean	ss
SFPUDE	282	6	30	22.18	5.63
AFMDE	282	4	20	16.12	3.32
ATOE	282	4	20	12.11	2.21
CADE	282	4	20	16.01	3.42
CDEFE	282	3	15	9.46	3.44
ASTDE Total Score	282	21	105	75.89	12.55
Student commitment in higher education	282	14	70	51.51	13.46

When Table 3 is examined, it is found that the mean scores of satisfaction with the opportunities offered by the university in distance education, attitude towards faculty members in distance education, attitude towards online exams, communication and access in distance education, comparison of distance education and face-to-face education, ASTDE total score and student commitment in higher education score averages were calculated as 22.18(Ss=5.63), 16.12 (Ss=3.32), 12.11 (Ss=2.21), 16.01 (Ss=3.42), 9.46 (Ss=3.44), 75.89 (Ss=12.55) and 51.51 (Ss=13.46) respectively. According to the results obtained, it was found that the students participating in the research had a high level of positive attitudes towards distance education and student commitment in higher education during the COVID 19 epidemic period.

Table 4. Attitudes towards Distance Education and Student Commitment Scores in Higher Education Presented During the COVID 19 Epidemic Period by Gender, Standard Deviations and Independent Samples t-Test Results

Variables	Your gender	N	Mean	ss	t(280)	p
SFPUDE	Woman	158	22.47	5.23	0.98	0.33
	Man	124	21.81	6.11		
AFMDE	Woman	158	16.35	2.99	1.34	0.18
	Man	124	15.82	3.68		
ATOE	Woman	158	11.92	1.93	-1.68	0.09
	Man	124	12.36	2.51		
CADE	Woman	158	16.10	3.29	0.52	0.60
	Man	124	15.89	3.59		
CDEFE	Woman	158	9.27	3.33	-1.04	0.30
	Man	124	9.70	3,57		
ASTDE Total Score	Woman	158	76.12	11.60	0.35	0.72
	Man	124	75.59	13.72		
Student commitment in higher education	Woman	158	51.28	13.83	-0.32	0.75
	Man	124	51.80	13.01		

When Table 4 is examined, it is understood that the mean scores of satisfactions with the opportunities offered by the university in distance education, attitude towards faculty members in distance education, attitude towards online exams, communication and access in distance education, comparison of distance education and face-to-face education and ASTDE total score and student commitment in higher education do not differ significantly by gender ($p>0.05$). It was observed that the positive attitudes of women and men towards distance education and student commitment in higher education were similar.

Table 5. Attitudes towards Distance Education and Student Commitment Scores in Higher Education, Standard Deviations and Independent Samples t-Test Results by Age Groups during the COVID- 19 Epidemic Period

Variables	Age group	N	Mean	ss	t(280)	p
SFPUDE	18-20	141	22.54	5.17	1.06	0.29
	21 and over	141	21.83	6.05		
AFMDE	18-20	141	16.54	2.91	1.13	0.03
	21 and over	141	15.70	3.64		
ATOE	18-20	141	12.21	2.22	0.75	0.45
	21 and over	141	12.01	2.21		
CADE	18-20	141	16.24	3.10	1.15	0.25
	21 and over	141	15.77	3.71		
CDEFE	18-20	141	9.62	3.48	0.76	0.45
	21 and over	115	9.30	3.40		
ASTDE Total Score	18-20	141	77.15	11.16	1.69	0.09
	21 and over	115	74.62	13.74		
Student commitment in higher education	18-20	141	52.43	12.14	1.16	0.25
	21 and over	115	50.58	14.64		

When Table 5 is examined, the results showed that the mean scores of satisfactions with the opportunities offered by the university in distance education, attitude towards online exams, communication and access in distance education, comparison of distance education and face-to-face education and ASTDE total score and student commitment in higher education does not show significant difference according to age groups ($p>0.05$).

However, the mean scores of attitudes towards faculty members in distance education according to age groups show significant difference (p<0,05). The average score of the participants in the 18-20 age group towards the faculty members in distance education is significantly higher than the average score of the participants in the 21 and over age group.

Table 6. Attitudes Towards Distance Education and Student Commitment Scores in Higher Education, Standard Deviations and Independent Samples t-Test Results in the COVID 19 Epidemic Period by Department/Program Type

Variables	School	N	Mean	ss	t(280)	p
SFPUDE	Vocational School	214	22.65	5.35	2.48	0.01
	Pilotage and Avi. Man.	68	20.72	6.25		
AFMDE	Vocational School	214	16.35	3.28	2.08	0.04
	Pilotage and Avi. Man.	68	15.40	3.36		
ATOE	Vocational School	214	12.02	2.11	-1.21	0.23
	Pilotage and Avi. Man.	68	12.40	2.51		
CADE	Vocational School	214	16.19	3.34	1.57	0.12
	Pilotage and Avi. Man.	68	15.44	3.65		
CDEFE	Vocational School	214	9.66	3.38	1.72	0.09
	Pilotage and Avi. Man.	68	8.84	3.56		
ASTDE Total Score	Vocational School	214	76.87	11.72	2.35	0.02
	Pilotage and Avi. Man.	68	72.79	14.54		
Student commitment in higher education	Vocational School	214	53.15	12.45	3.72	0.00
	Pilotage and Avi. Man.	68	46.34	15.20		

When Table 6 is examined, the results showed that the mean scores of satisfaction with the opportunities offered by the university in distance education, attitude towards faculty members in distance education, attitude towards online exams, comparison of distance education and face-to-face education and ASTDE total score and student commitment in higher education show significant difference according to the department/program type (p<0.05). The mean scores of attitude towards online exams, communication and access in distance education, comparison of distance education and face-to-face education does not show significant difference according to the department/ program type (p>0.05).

Table 7. Attitudes towards Distance Education and Student Commitment Scores in Higher Education, Standard Deviations and ANOVA Results Presented During the COVID 19 Epidemic According to Grade Level

Variables	Class	N	Mean	ss	F(2;279)	p	Post Hoc (Scheffe)
SFPUDE	1st class [a]	84	21.87	5.52	7.15	0.00	a>c, b>c,
	2nd class [b]	161	23.02	5.45			
	3rd and 4th Class [c]	37	19.27	5.76			
AFMDE	1st class [a]	84	15.92	3,51	5.79	0.00	a>c, b>c,
	2nd class [b]	161	16.58	3.24			
	3rd and 4th Class [c]	37	14.59	2.71			
ATOE	1st Class	84	12.57	2.77	2.60	0.08	-
	2nd Class	161	11.91	2.00			
	3rd and 4th Class	37	11.97	1.42			
CADE	1st class a	84	16.14	3.05	3.30	0.04	a>c, b>c,
	2nd Class b	161	16.24	3,52			
	3rd and 4th Class c	37	14.68	3,54			
CDEFE	1st class a	84	11.23	3.37	17.90	0.00	a>b, a>c,
	2nd Class b	161	8.79	3.16			
	3rd and 4th Grade c	37	8.38	3.36			
ASTDE Total Score	1st class a	84	77.73	13.49	7.16	0.00	a>c, b>c,
	2nd Class b	161	76.53	12.02			
	3rd and 4th Class c	37	68.89	10.42			
Student commitment in higher education	1st class a	84	54.80	12.41	12.78	0.00	a>c, b>c,
	2nd Class b	161	51.97	12.88			
	3rd and 4th Class c	37	42.03	14.24			

When Table 7 is examined, it is found that the mean scores of satisfaction with the opportunities offered by the university in distance education, attitude towards faculty members in distance education, attitude towards online exams, communication and access in distance education, comparison of distance education and face-to-face education and ASTDE total score and student commitment in higher education differ significantly by the class level (p<0.05). According to results of Scheffe test, the mean scores of first and second class students' satisfaction with the opportunities offered by the university in distance education, attitude towards faculty members in distance education, communication and access in distance education, ASTDE total score and student commitment in higher education were significantly higher than the mean scores of 3rd & 4th class students. The mean score of first-year students comparing distance education and face-to-face education was found to be significantly higher than the average score of second, third and fourth class students.

Table 8. Pearson Correlation Coefficients of the Relationship between Attitudes towards Distance Education and Student Commitment Scores in Higher Education during the COVID 19 Epidemic Period

Variables	1.	2.	3.	4.	5.	6.	7.
1. UEÜSİM	1						
2. AFMDE	,710**	1					
3. ATOE	,168**	,212**	1				
4. UEİE	,721**	,731**	,224**	1			
5. CDEFE	0,012	-0,028	,285**	0,029	1		
6. CUTO Total Score	,866**	,812**	,447**	,837**	,330**	1	
7. Student Commitment in higher education	,626**	,468**	,219**	,537**	,325**	,678**	1

**p<0.01; N=282

When Table 8 is examined, it is found that there are low and moderate positive correlations between the scores of student commitment higher education and UEÜSİM (r=0.626; p<0,01), attitude towards Faculty Members in Distance Education (r=0.468; p<0,01), Attitude towards Online Exams (r=0.219; p <0.01), Communication and Access in Distance Education (r=0.537; p<0,01), Comparison of Distance Education and Face-to-Face Education (r=0,325; p<0,01), and ASTDE Total Score (r=0.678; p<0.01).

Table 9. Results of Regression Analysis Performed to Determine the Predictive Effect of Attitudes towards Distance Education Presented During the COVID 19 Epidemic Period on Student Commitment in Higher Education

Variable	B	SH	β	t	p
(Fixed)	2.39	3.99		0.60	0.55
SFPUDE	1.20	0.16	0.50	7.60	0.00
AFMDE	-0.01	0.28	0.00	-0.05	0.96
ATOE	0.06	0.28	0.01	0.22	0.83
CADE	0.65	0.27	0.17	2.40	0.02
CDEFE	1.22	0.17	0.31	7.00	0.00
R=0,711	R^2=0.506		F(5;276)=56.43		*p*<0.01

Dependent variable = student commitment in higher education

When Table 9 is examined, it is found that the created regression equation is statistically significant (R=0.711; F(5;276)=56.43; p<0.01). 51% of the change in student commitment in higher education was explained by the attitude towards distance education offered during the COVID-19 pandemic. When the significance values of the standardized beta coefficients are examined, it is found that the variables UEÜSİM (β=0.50; p<0.01), communication and access in distance education (β=0.17; p<0.01) and comparison of distance education and face-to-face education (β=0.31; p<0.01) predict student commitment positively. As the scores of satisfaction with the opportunities offered by the university in distance education, communication and access in distance education, and comparison of distance education and face-to-face education increase, student commitment also increases.

5. Conclusion and Recommendations

This study investigates the relationship and impact between the attitudes of aviation-related department and program students towards distance education applied during the COVID-19 pandemic period in higher education and university commitment where the importance of practical courses in the curriculum is stressed. Of the 282 questionnaires answered on a voluntary basis, 214 are consisted of university students from the 2-year Civil Air Transport Management and Civil Aviation and Cabin Services programs, 38 from the 4-year aviation management departments, and 30 from the department of Pilotage.

According to the study's finding, there is no significant difference between students' attitudes towards distance education and student commitment by gender and age groups. The attitudes of the students in the Civil Air Transport Management and Civil Aviation and Cabin Services programs and the students enrolled in the Aviation Management department towards distance education, as well as satisfaction with the opportunities offered by the university in distance education, attitude towards faculty members in distance education, attitude towards online exams, communication and access in distance education, and student commitment in higher education consisting of the sub-factors of the scale are significantly higher than students studying in the pilotage department. From this; it can be concluded that pilotage students have higher expectations as a result of the higher tuition fees paid to the university due to the department in which they are enrolled

On the other hand, according to the class level, the general attitudes of first and second year students towards distance education, as well as satisfaction with the facilities offered by the university in distance education, attitude towards faculty members in distance education, communication and access in distance education and student commitment in higher education, which are the sub-factors of the scale, are significantly higher than those of 3rd and 4^{th} year students. This may be because 1st and 2^{nd} class students are not as familiar with face-to-face education as 3rd and 4th class students.

It is found that there are low and moderate positive relations between students' general attitudes towards distance education and satisfaction with the facilities offered by the university in distance education, attitude towards faculty members in distance education, communication and access in distance education, comparison of distance and face-to-face education in higher education, and student commitment in higher education which are the sub-factors of the scale.

Students' general attitudes towards distance education and satisfaction with the opportunities offered by the university in distance education, the variables of communication and access in distance education, and comparison of distance education and face-to-face education, which are the one of the sub-factors of the scale, positively predict student commitment.

It is thought that this study will contribute to the literature because there is no previous study on the process in universities in distance education in aviation departments, where practices courses are important, where the transition from face-to-face education to distance education in higher education institutions due to the onset of the pandemic process and the rapid spread of the COVID-19 virus all over the world. Despite the fact that higher education institutions have made a transition to face-to-face education again, some universities have decided to continue with the blended education model and some courses in the form of distance education. It is believed that it will be beneficial for science if researchers conducting studies to measure the attitudes and perceptions of students in different faculties and departments, where the practices should be made.

Ethical Approval

Ethical Approval The survey study was carried out with the approval number 2022/02 of Istanbul Aydın University Ethics Commission.

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Important Issues in Unmanned Aerial Vehicle User Education and Training

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Abstract

Unmanned aerial vehicles (UAVs) are aircraft that can be controlled remotely or autonomously without a pilot on the platform deck, with the help of Auto-Pilot and software-controlled flight plans. Unmanned aerial vehicles (UAVs) are a component of the Unmanned Aerial System (UAS). For this reason, those who program the mission pattern of these vehicles in advance, use them by remote command with or without sight, how to act in the face of possible developments during the mission, and who know the UAV technology and working principles well in this context, if the connection with the unmanned aerial vehicle (UAV) is lost, The training of the pilots, who enter the necessary information into the system as a command, in order to complete their mission and return safely to the starting point or to a different place, is very important. A professional and qualified UAV pilot/operator should possess five key characteristics, including professional dedication, sense of duty, self-control, enthusiasm for work, logicalness, and rationality. While preparing personality tests for pilot candidates, it should be based on measuring five main personality areas (neuroticism, extraversion, openness, agreeableness and conscientiousness). In the last 20 years in Turkey, the number and kinds of UAVs used especially in the field of security has been constantly increasing, and the number of national and domestic projects is increasing at a level that can compete with their counterparts in the world. Armed unmanned aerial vehicles (Armed UAV) are used extensively in domestic and international security operations, especially in internal security operations, contributing significantly to the success of the operation and reducing casualties and risks. For that reason, this research is focused on UAV pilots education and training as key personnel of UAV and try to bring front important issues of training period.

1. Introduction

Unmanned aerial vehicles (UAVs) are aircraft that can be controlled remotely or autonomously without a pilot on the platform deck, with the help of Auto-Pilot and software-controlled flight plans. Unmanned aerial vehicles (UAVs) are a component of the Unmanned Air System (UAS). In UAV, it basically includes a control system on the ground and the communication system between the two. UAVs can be operated autonomously in various situations, or they can be operated autonomously by remote control by a pilot, by computers at a fixed location or by piloting an autonomous robot (Figure 1) (Ateş, Düzgün, 2020).

Figure 1. Unmanned Aerial Vehicle (UAV)

Since the UAV pilot/operator manipulates the UAV with the data link on the remote control and sometimes works at the control station, which is hundreds or even thousands of kilometers away, the importance of the system in command is quite high. The more autonomous the vehicle, the more important the need for the operator. In addition, the mission becomes more difficult if the mission duration is too long and the atmospheric conditions are complex. Also, compared to a manned aircraft pilot, being at a remote ground control station has the disadvantages of collecting mission-related information in a timely manner, with the same quality and quantity. In other words, the UAV pilot who has lost contact with the vehicle cannot receive direct feedback from the flight environment such as vision, sound and kinetic emotion, weather conditions (Ateş, Düzgün, 2020).

The UAV pilot can transmit commands to the UAV via radio link or satellite link. As the drone pilot feels isolated, it is more difficult to access information, get feedback and make quick decisions as in conventional aircraft. Considering the wide variety of UAVs, the importance of UAV piloting is increasing (Williams, 2004).

For this reason, those who program the mission pattern of these vehicles in advance, use them by remote command with or without sight, how to act in the face of possible developments during the mission, and who know the UAV technology and working principles well in this context, if the connection with the unmanned aerial vehicle (UAV) is lost, It is very important to train the pilots, who enter the necessary information into the system as a command beforehand, in order to complete their mission and return safely to the starting point or to a different place (Best, 2013).

With the rapid development of technology, UAVs can be used for intelligence, attack and etc. as an auxiliary force to the air force that can perform operations such as surveillance, reconnaissance, electronics. was used for the purposes. UAVs were initially used for "boring, dirty or dangerous" missions for humans. Although the use of UAVs generally occurs in military activities, depending on the developing technology and needs, it can be used continuously in commercial activities, scientific studies, security services, logistics, cargo transportation and large warehouses, entertainment sector, agricultural field, meteorology, firefighting, fishing, aerial photography. It continues to be used in infrastructure inspections, smuggling and other application areas that are necessary and difficult to access (Wang, Ying, 2018).

2. Materials and Methods

This research is “descriptive”. The main purpose of this research is to give important information, which obtained from different sources and feedback reports about UAV pilot education and training. The data collecting methodology is a “literature review”. The data are collected from national and international aviation literature, feedback reports from UAV courses institutions and General Directorate of Civil Aviation (GDCA) of Turkey, interview with UAV pilot trainers, and from the congress conclusion reports of World UAV Federation. Collected data are grouped as “theme-based”. Descriptive analysis’ techniques are used to analyses collected data, then, reached findings and comments, and conclusions made based on those comments.

3. Discussion

Several factors must be considered for UAV pilot/operator qualification as the operation is conducted based on current airworthiness regulations and the interaction between the pilot and the system. These are technical information about UAV and its components, the degree of professionalism and quality of education received, meeting medical needs, level of evaluation of psychological state and events, duration of user experience and coordination ability (FBEACAS, 2016).

First of all, it is necessary pilot to know the technology, additional equipment, working concept of the UAV, the principles of interaction in the external environment and different meteorological conditions, what and how to do in accordance with the conditions and especially command a high-tech system (Ateş, Düzgün, 2020).

The UAV pilot must have basic knowledge about main components, which are vital for every safe flight. Knowing the main components of a UAV will give pilot extra confidence while using it and it will also helpful for maintenance and inspection of a vehicle. If the pilot has knowledge any flight problems, each UAV component may assist greatly in finding the underlying cause of any flying issues. This one is the best ways to become a highly skilled and successful UAV pilot.

The main components and sub-systems of UAV are; brushless motors, propellers, flight controller (FC), electronic speed controller (EFC), power distribution board (PDB), camera, gimbal, LiPo battery, frame and boom (F), GPS module, R/C receptor (RX), video transmitter (VTX), first person view (FPV), and landing gear (Figure 2) (Uddin, 2020).

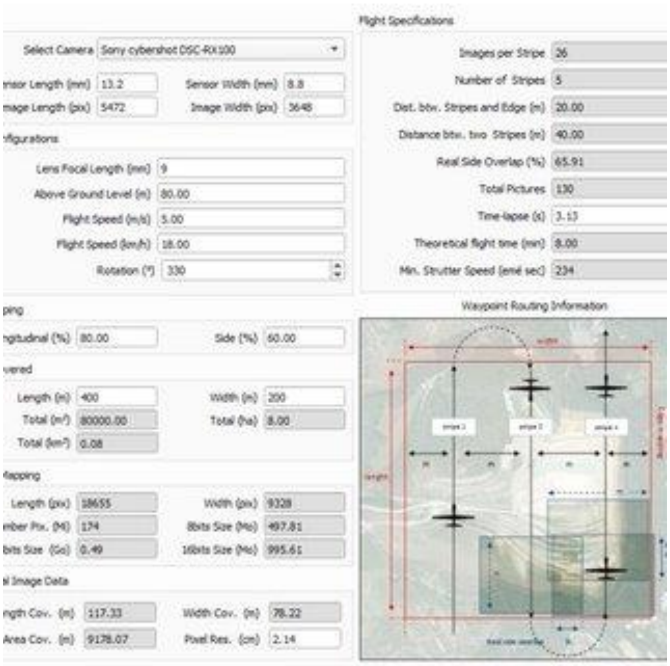
Figure 2. Main Components and Systems of UAV

Brushless motors provide neutralization of the turning force produced by the rotating propellers. UAV have two clockwise motors and two counter clockwise motors. That is simply due to Newton’s 3rd Law, which refers that every action/movement has an equal, and opposite reaction. Latest versions of UAVs use a brushless electric motor, which is more efficient, more reliable, and quieter than a brushed motor.

One of the most important parts of the UAV is the propellers. These rotating blades are the blades of the system, the part that creates the airflow that lifts the machine into the air. UAV propellers come in many different shapes and sizes and all serve the same general purpose, but the flight characteristics of each can differ significantly (Become A Drone Pilot, 2020). UAV has two different kind of propellers, each one for each motor direction. Each propeller rotating to push the air down on the airfoil surface resulting in a difference of pressure, so this making the vehicle airborne.

Figure 3. 4-Propeller UAV With Camera

The UAV flight controller takes in inputs from the Global Positioning System (GPS) module, from the sensors, and from the remote controller unit. Then processes it into information that is given out to the electronic speed controllers (ESC) to control the motors. This part of UAV hence known as the brain of the vehicle. The pilot gives the flight safety parameters via flight controller (Figure 4 and 5).



Source: FAA, 2016

Figure 4. Flight Safety Parameters of UAV

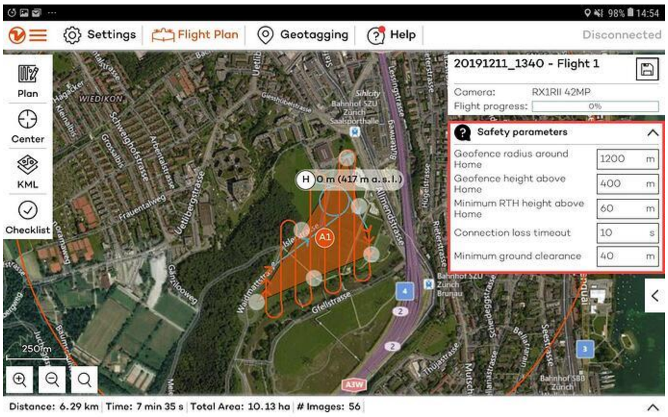


Figure 5. Flight Safety Parameters Entering Via Flight Controller.

The electronic speed controllers (ESC) are connected to the power distribution board (generally the battery) and the flight controller of UAV. As the ESCs receive signals from the flight controller, it changes the amount of power given to each of the motors.

The power distribution board (PDB) is like the motherboard of a computer, the place where all the UAV's electrical components connect and uses power from the battery.

The camera captures video feed, allowing for real-time, first person view (FPV) flight. Gimbal is the mechanical piece that enables movement and stabilization of the camera.

LiPo battery stands for lithium-ion polymer battery, which is a rechargeable battery of lithium-ion technology using a polymer electrolyte instead of the more common liquid electrolyte

Frame is that plastic catching which holds everything together. In many UAVs, the boom is part of the main body.

The GPS module often combines receiver and magnetometer to provide latitude, longitude, elevation, and compass heading from a single device. Without GPS, UAV would have very limited usage. Some military UAVs are GPS-independence to provide security of a flight and keep away from outside effects.

R/C receptor (RX) is the sensor receiving signals from remote controller. Remote controller (TX) provides the link between the pilot and UAV. It looks very similar to toy remote controllers, with the big difference that this has more way buttons and it is significantly more sensible.

Video transmitter (VTX) connects to the camera to transmit video to the first person view goggles or monitor. First person view (FPV) goggles or screens are the devices used by pilots to observe the live video feeds being transmitted from UAV.

UAVs which carry payload comes with a fixed landing gear like helicopter mounted directly to the body. However, the UAVs have retractable landing gear thus allowing a full 360-degree view when in flight. UAVs which have no hanging payload omits landing gear but if it flies in areas where there is long grass, rocks or dusts then either carry a big landing mat or it can be leg height extenders.

The sensor is very important technology in today's world. This part is also important for UAV. A sensor is a device, module, machine, or subsystem to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. In UAV, position and movement sensors give information about its location. Exteroceptive sensors deal with external information such as distance measurements, while exproprioceptive ones correlate internal and external condition. Non-cooperative sensors are able to detect targets autonomously so they are used for separation assurance and collision avoidance. Degrees of freedom (DOF) refers to both the amount and quality of sensors on board: DOF implies 3-axis gyroscopes and accelerometers. The types of sensors are light, sound, heat, chemical, magnetic, and image (Figure 6) (Uddin, 2020).

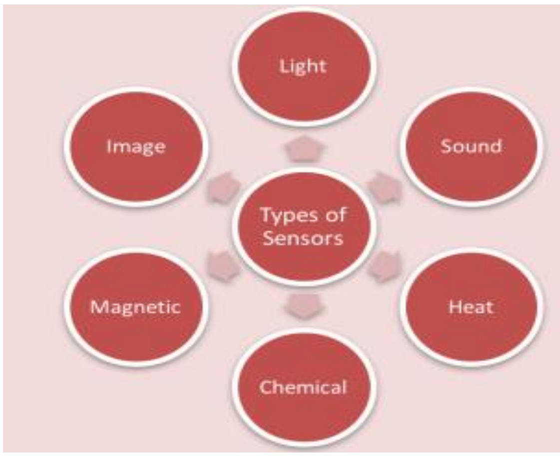


Figure 6. Types of Sensors

Another important issue for pilot to know the meteorology and weather conditions.

The stability of an air mass refers its weather characteristics. When one type of air mass overlies another one, air conditions change with altitude. The characteristics of typical an unstable and a stable air mass can be seen on Table 1 (Uddin, 2020).

Table 1. Air Conditions for UAV Operation

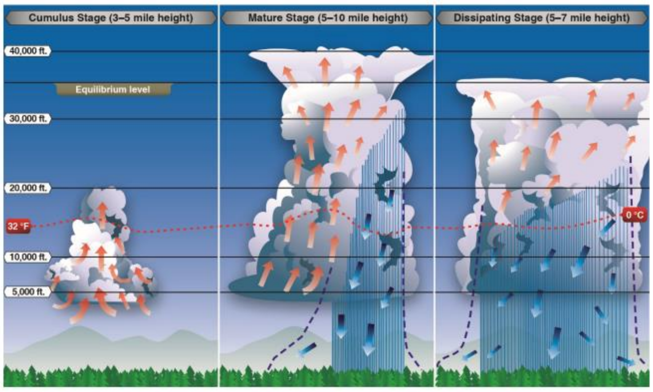
Unstable Air	Stable Air
Cumuliform clouds	Stratiform clouds and fog
Showery precipitation	Continuous precipitation
Rough air (Turbuance)	Smooth air
Good visibility (except in blowing obsructions)	Fair too poor visibility in haze and smoke

Source: Uddin (2020)

To increase the temperature of a substance cause decreases its density. Vice versa, to decrease the temperature of the air cause to increase the density. So, the density of the air varies inversely with air temperature. This condition is true only at a constant air pressure. Both air temperature and air pressure decrease with altitude and have conflicting effects upon density in the atmosphere. However, a rapid drop in air pressure, as altitude increases, usually has a dominating effect. Hence, pilots can expect the air density to decrease with altitude.

Before starting, needs to check temperature, wind, fog and cloudiness, and keep in mind that if the temperature falls below the freezing point, this may have a negative effect on the batteries. In temperatures below the freezing point, pilot will need detailed knowledge of the batteries; make sure pilot is familiar with how batteries are affected. Also, make sure to keep them heated before start. At freezing temperatures and humid air, ice may build up on the propellers, dramatically increasing the risk for crash. Keeping in mind, that wind speed often increases with altitude (FAA, 2016).

The most dangerous air condition for UAV operation is thunderstorm. Downdrafts characterize the dissipating stage of the thunderstorm cell can be seen in Figure 7 and the storm dies rapidly. Whenever rain has stopped and downdrafts have abated the dissipating stage can be completed. When all cells of the thunderstorm have completed at this stage, only harmless cloud of UAV operation remains.



Source: FAA, 2016

Figure 7. Altitude and Cloud Conditions for UAV Operation

In aviation, situational awareness (SA) is often discussed. Situational awareness refers to the pilot being in control of the entire situation – the flight, the UAV, the surroundings, the airspace, etc. The pilot must be able to understand what happens during the flight and what may affect it: other pilots, weather conditions, the UAV's and the remote pilot's limitations. The better the situational awareness, the safer the flight.

Another important issue for UAV pilot is to know how actually UAV flies. Directional control the most popular UAVs available today are multi-rotors. They keep UAV stability by varying the speeds of each propeller. Directional control in an UAV is succeeded via changing the angle of attack of the propellers, the same as a chopper. However, this change in attack is accomplished by slowing some of the rotors (FAA, 2016).

There are two vital sensors, which are required to be able to make it smooth flight for movements of a multi-rotor UAV. The accelerometer detects linear movement, which means to move in a straight line, and the gyroscope detects rotational movement, which means to move around a line.

To be able to control of UAV remotely, UAV pilot must have capability to communicate with it wirelessly. Radio waves are an invisible form of wave on the electromagnetic spectrum. To work radio to work, UAV pilot must have a transmitter and receiver to send and to get the messages. Important point is transmitter and receiver need to be tuned to the same frequency. Most UAVs today are Wi-Fi enabled, so that they can broadcast video to a computer, tablet PC, or smartphones. Some UAVs also use Wi-Fi for remote control through a tablet PC or other mobile applications.

The GPS is mainly used to communicate location back to a mobile application. The GPS also can be used for pre-programming of the routes. Once programmed, if the UAV loose communication, it is possible to fly in sequence to each of the GPS locations identified in advance by the pilot.

Another issue for UAV pilot is considering the environment. Many areas and airspaces are closed, either during certain periods or constantly. Pilot may be able to unlock some of them with an app or via air traffic control towers, while some of them will always stay closed. It is important that pilot is very familiar with the environment and the route in order for the flight to be as safe as possible. Pilot should not forget to notify people nearby that the flight will happen.

UAV always flies within pilot's visual line of sight. One concept that pilot may come across when flying UAV is visual line of sight (VLOS). In addition to being able to see UAV while flying, keeping the UAV within pilot's visual line of sight means that pilot must also keep a safe distance to people, animals, buildings, vehicles and other aircraft. It is never allowed to fly higher than 120 meters.

UAV pilot should follow some procedures during the flight operation. First one is compass calibration. Pilot should always follow the manufacturer's instructions for compass calibration in the drone's manual. If no chance to access to the manual and it is needed to calibrate the compass, it can be followed the generic instructions. First think is removing watches and other metal objects from clothing and body and turning on the radio transmitter. Second step is placing the UAV outdoors on a metal-free surface and switching the power on. Until waiting at least six satellites are visible in the app or on the radio transmitters display, to start calibration in the app (if applicable) or via the radio transmitter. After then, it should be put the radio transmitter aside, standing behind the UAV with the camera facing away from pilot, then lifting the UAV and holding it with straight arms. After this, pilot makes a complete clockwise rotation in about 5–7 seconds and "tip"s the UAV forward so that the camera points straight down towards the ground. At the last step, completing a new rotation at the same pace as before and putting the UAV down and ensure that the calibration is completed.

After the compass calibration, it must be controlled radio transmitter and UAV batteries be charged fully, any frequency interferences that affect video and receiver, the photo and video equipment mounted correctly, the take-off position secured, airspace restrictions. After that starting the radio transmitter first, starting the camera system, control sticks in neutral position, and control the direct remote identification system work properly (FAA, 2016).

During flight, pilot must keep fingers on the radio transmitter at all times. UAV shouldn't fly higher than 120 metres above the ground (in uncontrolled airspace) and keeping the UAV within pilot's visual line of sight (Figure 8).

Figure 8. UAV Pilot and Mobil Flight Controller

To rise to optimal altitude to reduce risks and noise. Avoiding flying over people, animals, electrical wiring, buildings, and no disturbing ongoing rescue operations. Moreover, immediately landing the UAV if a helicopter or other low flying aircraft is approaching.

For landing, it should be checked the landing area for obstacles or any other hazards and landing the UAV at a safe distance from obstacles and people. Then switch the UAV off.

After the flight, if needed, pilot should inform the air traffic control tower that flight is completed. To switch off the camera and any other equipment. Carrying out an ocular examination: looking for damage and abnormal wear and tear, removing the batteries, recharge and store them in a safe place.

A professional and qualified UAV pilot/operator should have five important key characteristics, including professional dedication, self-control, sense of mission, logicalness, rationality, and enthusiasm for work. To prepare personality tests, pilot candidates should be measured in five main personality areas (agreeableness, extraversion, neuroticism, conscientiousness, and openness) (Wang, Ying, 2018).

If problems are seen in these issues and are not promptly resolved, they may have a significant impact on mental health condition, mission success, and flight safety to a certain extent. Therefore, during the selection tests of the pilot/operator of the UAV, in the evaluation of the psychological state of the pilot candidates; it is necessary to take into account various factors such as a sense of cooperation, emotional stability, high level of conscientiousness, flexibility, responsibility, self-confidence, and achievement orientation (Barnes, Matz, 1998).

The UAV pilot must successfully complete the special training required to be able to control the vehicle by working in an isolated environment to some extent and to ensure the safety of the vehicle. For small UAVs, experience may be less as the operator works in the visual field of view, but for larger UAVs, especially those used in the military or public services, it is important for pilots to have advanced experience for mission success and flight safety (Figure 9) (Chappelle, Swearengen, Goodman, Thompson, 2014).

Figure 9. Military UAV Pilot and Flight Control Ground Station

UAV pilots have to know the legislation regarding the use of UAVs, the issues to be applied for a successful operation, and the procedures to be applied for a safe flight during both training and post-training use. It is important that both the physical and psychological state of the UAV pilot meet the flight requirements (Lewis, E. Forster, Whinnery, Webster, 2014).

Comparing with manned aircraft pilot, there is no much physical limitation for UAV pilot and requires lesser operating skills (Ateş, Düzgün, 2020).

UAV is controlled by an expert team including the pilot, data link operator, mission planner, payload operator, and other personnel. This requires more attention to responsibility and while preparing training program. The training of UAV pilots, which have different technological features and are designed for very different tasks, can also be unique. All of this determines that the content and method of UAV pilot training needs to be carefully evaluated on a case-by-case basis (Department of Defense, 2011).

Like manned aircraft pilot training, the UAV pilot needs more training. There are two downsides to relying on UAS program. First one is risk. In manned aircraft, in dangerous situations, the pilot has the opportunity to take some measures to reduce the risk. Conversely, if malfunction occurs during the UAV flight, the most serious consequence will be collision or fall damage. The second is the increasing cost as complexity increases, especially for large UAVs. It will cost more to use real UAVs for each training subject, the need for maintenance, additional safety measures and more crew assistance will be needed. At the same time, wear or damage may occur due to missing controls and misuse, which can increase training, maintenance and operating costs (Wang, Ying, 2018).

The human factor draws attention in accidents that occur during the use of UAVs. Issues related to the human factor consist of four parts. First, from the perspective of the drone pilot, the main impact of the human factor on the task should reveal the limitation of the team in cognitive processes such as situation awareness, attention, decision-making, vision, workload, auditory, and attitude (Ateş, Düzgün, 2020).

Second, the instructor in terms of design and operation; it should be offered ergonomic effects on UAV operation, such as display system, the human- control system, machine interface, and indoor environment in the ground command center. Examining the human error concept major UAV accident research reports and combining them with their experience, the trainer will be able to analyze how human error affects the operation and propose recommendations and evaluation criteria to prevent human error. Instructor and program developers mainly; should be concerned with analyzing human factor issues that will affect flight safety and operational efficiency, such as situational awareness, human-machine function distribution, and workload (Department of Defense, 2013).

With the inclusion of the human factor in the program, the UAV pilot will be able to demonstrate the importance of the human factor in operations that will reduce disruptions or accidents in UAV operation and increase the safety, reliability and efficiency of the UAV (Uncrewed Aircraft Systems, 2019).

The control of the legal regulations regarding UAVs in Turkey and their implementation, the control of the registration, permit and license procedures of the UAVs used with pilot training and pilots are under the responsibility of the General Directorate of Civil Aviation (GDCA) of the Ministry of Transport, Maritime Affairs and Communications. With the Unmanned Aerial Vehicle Systems Instruction (SHT-UAV) published by GDCA, the procedures and principles of the operations of UAVs in the allocated airspace, relevant organizations and systems, institutions, organizations and businesses that will operate these systems, personnel to be assigned in these organizations, UAV pilots, Procedures and principles regarding air traffic control services to be provided to UAV flight crews and UAVs have been determined (Ateş, Düzgün, 2020).

Within the scope of this instruction; UAVs with a take-off weight of more than 4 kg and a maximum speed of more than 50 km/h, as well as a flight altitude of 100 meters or more from the ground surface, are included. Model airplanes and UAVs produced for indoor use are out of the scope of this instruction (GDCA, 2016).

UAV flights can be performed within the scope of the permission given by DGCA and under the control of a pilot. UAVs that do not require pilot control and can only operate autonomously cannot be used for civilian purposes (Ateş, Düzgün, 2020).

UAV pilots; having additional training from the training institutions and organizations authorized by the DGCA on the use of UAV systems, together with the theoretical training of the relevant Private Pilot License (PPL), successfully completing the UAV pilot training program of the said education institution and being successful in the proficiency check to be made by the DGCA required. UAV Pilot Licenses are issued by the DGCA for a period of 3 years, and if the pilot is re-qualified at the end of this period, the pilot license is renewed (GDCA, 2016).

4. Conclusion

Technological developments in UAVs continue at a dizzying pace, and competition continues at the global level. Since the development and application areas of the UAV have expanded rapidly in recent years, other UAVs, UAVs designed for special missions, manned aircraft, unmanned land vehicles and unmanned underwater vehicles with which it has to work together and act in coordination for the success of the given mission. He has the opportunity to cooperate more with its agents. The UAV pilot needs to be familiar with not only undesirable aircraft conditions and atmospheric conditions, but also the operating procedures of other vehicles, but also must complete systematic training cooperation before the mission is accomplished.

According to statistics and accident investigation reports, the two main factors affecting safety are psychological health and human error. However, there is limited research on UAV pilot training. For this reason, detailed studies on psychological health and human factors are required in UAV pilot training.

All these studies should be reviewed by professional aviation psychologists and included in the training programs and the courses should be determined according to the task characteristics, age and current mental health status.

Considering these factors, UAV pilot training; It should include at the beginning theoretical training, after then simulator training, small UAV operation, and special training that must include almost all training topics, which can reduce the risks and costs of training, to increase productivity, and reduce unwanted damage because of human errors.

As much as UAV technologies improved, military and civil aviation and some other sectors will rely more on UAV. For the drone pilot, the future looks more intense and promising than ever before. Until the safety levels on the UAV reach the levels equivalent to that of manned aircraft, UAV pilots will not be replaced. Now UAV engineers and researchers will provide more contributions to UAV pilot qualification and training program, which may increase the flight safety level and promote the development and application of UAV technologies.

The development of the UAV control system will reduce the workload of the UAV pilot in the future and have more ability in competence. Further research and continuous improvement will contribute to improving UAV pilot qualification and training. In connection with the rapid development and wide application of the UAV, the UAV pilot will play an important role in future aviation.

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Application of an ANFIS to Estimate Kansai International Airport's International Air Passenger Demand

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Abstract

This study presents an Adaptive Network Based Inference System (ANFIS) model to forecast international passenger demand at Osaka's Kansai International Airport. The study covered the period 1994 to 2018. The study used nine determinants of air travel demand and three dummy variables as input variables. The results reveal that the model successfully forecasts Kansai International Airport's international passenger demand. The coefficient of determination (R^2) was high, being around 0.9776%. The overall MAPE of Kansai International Airport's international air passenger demand model was 7.40%.

1. Introduction

Air passenger transport demand forecasting is one of the most important determinants of airport planning, design, and operations (Karlaftis et al., 1996). Passenger demand forecasts are regarded as an important parameter for aviation planners and airport authorities (Sohag & Rokonuzzaman, 2016; Wadud, 2014) as future passenger demand forecasting could be the most critical factor in the development of airports as well as airline networks (Karlaftis, 2010). Indeed, forecasting air passenger demand is regarded as a critical aspect of formulating appropriate operation plans for airport operations (Kim & Shin, 2016). The forecasting of passenger demand is a key requirement for the daily management of an airport (Zheng, Lei & Wang, 2018). Errors in forecasting can be very costly for an airport. This is because the underestimation in passenger demand may result in increased congestion, delay, and inadequate airport facilities. Conversely, the overestimation of passenger demand may also present serious economic problems for airport authorities. Accordingly, it is essential for airport planners to develop reliable forecasting models (Karlaftis et al., 1996). as highly accurate and reliable airport passenger demand forecasts are regarded as imperative for policymaking and planning by airport managers (Tsui, & Balli, 2015). Passenger demand forecasts form for the basis of airport planning (Cook & Billig, 2017). Forecasting air travel demand helps and airport to reduce its risk profile (Adeniran, Kanyio & Owoeye, 2018). Furthermore, the forecasting of future air transport demand is particularly critical in airport master plans (Andreoni & Postorino, 2006).

The aim of this paper is to develop and empirically evaluate for the first time an adaptive neuro-fuzzy inference system (ANFIS) model for estimating Osaka's Kansai International Airport international passenger demand. Kansai International Airport commenced operations in September 1994 (Dempsey & O'Connor, 1997; Morikawa, Tabata & Emura, 2007; Ohta, 1999). Kansai International Airport is a major air transport hub and is Japan's third busiest airport. A secondary reason for focusing on Kansai International Airport in the study was the ready availability of the enplaned passenger datasets that covers the period from the commencement of operations in 1994 to 2018.

2. Materials and Methods

2.1 Variables selection and data normalization for the adaptive neuro fuzzy inference system (ANFIS) modelling

Nine determinants of passenger air travel demand were included as input parameters in the adaptive neuro fuzzy inference system ANFIS) modelling. These included world GDP, world real air fares, world oil prices, world population size, outbound flights from Kansai International Airport, Japan's unemployment, Japan's tourism expenditure, the annual exchange rate between the Japanese yen and United States dollar and Japan's real interest rates, which are among the most important drivers of air passenger travel demand.

There were three dummy variables included in the ANFIS modelling. The first dummy variable accounted for the downturn in passenger demand following the impact of the 9/11 terrorist attacks on air travel demand (Chi & Baek, 2013; Dileep & Kurien, 2022). The second dummy variable, the impact of SARS in Japan in 2003, which had an impact on Japanese travel patterns (Cooper, 2005). The third dummy variable modeled the impact of the 2008 global financial crisis (GFC) on Kansai International Airport international air travel demand, as air travel demand was negatively impacted by the GFC (Pearce, 2012; Piccioni, Stolfa & Musso, 2022; Wong et al., 2019).

Before training the data in the adaptive neuro fuzzy inference system (ANFIS), it is important to normalize the raw data into patterns. The normalization of the data ensures that the adaptive neuro fuzzy inference system (ANFIS) will be trained effectively and this will also prevent any variable skewing the results (Papageorgiou,et al., 2020; Srisaeng, Baxter & Wild, 2015). In this study, each variable was normalized to [0, 1] prior to the forecasting model being applied (Narang, Kumar & Verma, 2017; Papageorgiou,et al., 2020; Srisaeng &, Baxter, 2021). The data collected for the study were normalized using the following equation:

$$x_{norm} = \frac{x - x_{min}}{x_{max} - x_{min}} \qquad (1)$$

2.2. Adaptive neuro fuzzy inference system (ANFIS)

The ANFIS is comprised of a fuzzy inference system (FIS) and an artificial neural network (ANN) (Papageorgiou,et al., 2020; Pigatto, & Balbinot, 2018; Ravi et al., 2008). Three types of data are used in ANFIS modelling. These are the training, checking, and testing data sets. The training set is used to build the model. In the following steps, test and control sets are used to generalize and validate ANFIS models (Mardani et al., 2018).

The training set is used to build the model. In the following steps, test and control sets are used to generalize and validate ANFIS models.

The Takagi-Sugeno fuzzy model inference system was used in this study (Adewuyi, 2013; Chaudhari & Patil, 2014; Khosravanian et al., 2016). The Takagi-Sugeno Model was originally developed in 1985, and it consists of four principal elements of membership functions, internal functions, rules, and the subsequent outputs (Zounemat-Kermani & Scholz, 2013). To present the study's adaptive neuro-fuzzy inference system (ANFIS) structure, the two fuzzy if-then rules based on the first order Takagi-Sugeno Model are considered (Bagheri, Peyhani & Akbari, 2014; Srisaeng &, Baxter, 2021; Übeyli et al., 2010).

Rule1: If a_1 is MF_{A1} and a_2 is MF_{A2} then b is MF_B
Rule2: If a_1 is MF_{A1} and a_2 is MF_{A2} then b = $f(a_1, a_2)$

Where MF_{A1} and MF_{A2} denote two input membership functions, respectively; MF_B denotes the membership function of the output; and $f(a_1, a_2)$ is a function of the two inputs (Alhumade & Rezk, 2022, p. 4).

Alhumade and Rezk (2022) have noted that "the Sugeno-type fuzzy inference system is recommended in modelling applications". Once each rule has produced its output, they are subsequently combined to generate one final fuzzy equation. Following this, it is defuzzified to generate its corresponding crisp value. The defuzzification method is chosen according to type of rules. The Wavg, weighted average, is suggested in the modelling using Takagi- Sugeno inference system (Srisaeng & Baxter, 2021). For a given input example x the output y of the whole system can be summed up by the weighted average Wtaver method as shown in equation 2 below:

$$y(x) = \frac{\sum_{i=1}^{n} w_i . y_i(x)}{\sum_{i=1}^{n} w_i} \qquad (2)$$

Where w_i and y_i are the rule i 's weight and output, respectively; and n is the amount of rules (Alhumade & Rezk, 2022, p. 4)..

The ANFIS system is comprised of five different adaptive layers. The study's adaptive neuro fuzzy inference system (ANFIS) architecture is presented in Figure 1. As previously noted, the fuzzy rules were configured based upon the Takagi-Sugeno fuzzy model and the adaptive neuro fuzzy inference system (ANFIS) with a back-propagation algorithm that was used for error correction (Cho et al., 20120; Srisaeng, Baxter & Wild, 2015; Takagi & Sugeno, 1985).

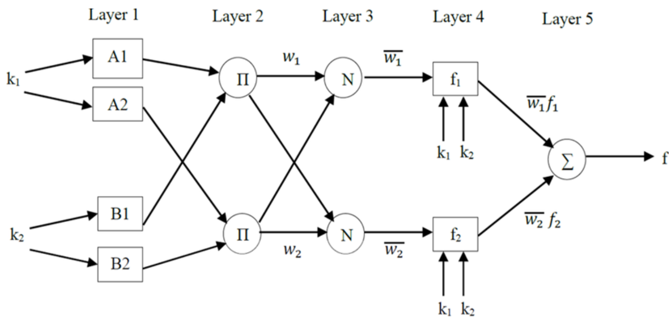

Figure 1. The adaptive neuro-fuzzy inference system architecture

In this study, the total number of data used to produce the ANFIS model was 25. The data was split as follows: 80% of the overall data was used to successfully train the ANFIS model. Five data were then used for verifying and testing the robustness of the proposed ANFIS model (Srisaeng & Baxter, 2021; Yetilmezsoy, Fingas & Fieldhouse, 2011). Hence, in this study, 20 training, 3 validating, and 2 test data points were used in the ANFIS modelling.

In this study, the Linear membership functions and the Gaussian membership were selected. From the crisp input, the artificial neural network passes data utilizing the membership functions. The algorithm of the hybrid learning was employed during the training stage (Srisaeng & Baxter, 2021; Srisaeng, Baxter & Wild, 2015). The training was conducted using 400 epochs. Following the guidance of Savkovic et al. (2019), "during the model training, new rules and forms of membership functions were constantly generated to produce the output with the smallest error". Once the ANFIS model's error rate was deemed acceptable, the model was subsequently tested. The final model was accepted once the relative errors of training and testing fell below 10% (Srisaeng & Baxter, 2021; Srisaeng, Baxter & Wild, 2015). Each combination of the model parameter with a varying number of epochs was tested to avoid possible overfitting of the ANFIS model. (Efendigil, Önüt & Kahraman, 2009; Srisaeng & Baxter, 2021; Srisaeng, Baxter & Wild, 2015).

The process of Takagi-Sugeno ANFIS network setup was developed with 18 Gaussian membership type functions. The adaptive neuro fuzzy inference system (ANFIS) model developed in this study used the hybrid learning algorithm (Srisaeng & Baxter, 2021; Srisaeng, Baxter & Wild, 2015). Figure 2 depicts the study's ANFIS architecture.

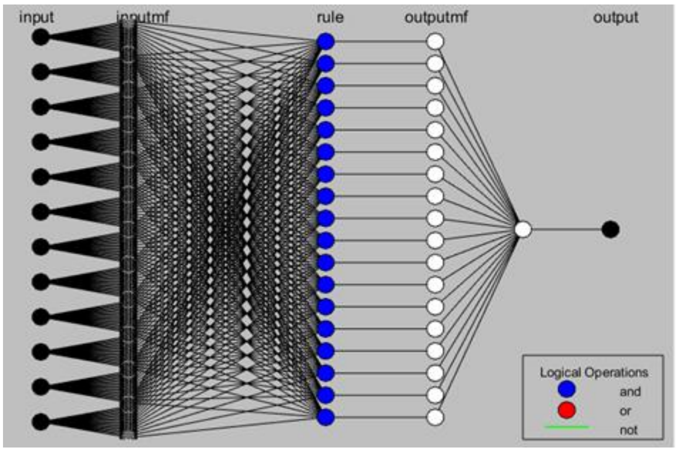

Figure 2. Optimal ANFIS model architecture for forecasting Kansai International Airport international passenger demand.

3. Results

The final structure of Kansai International Airport international airline passenger ANFIS forecasting system is presented in Figure 3.

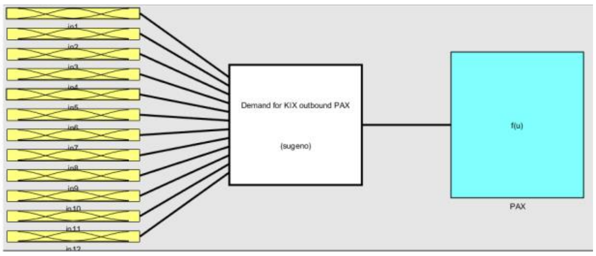

Figure 3. The structure of Kansai International Airport international airline passenger ANFIS forecasting system

The ANFIS model was trained by the Matlab R2020a software that used various possible combinations of the subtractive clustering parameters. These parameters included range of influence (ROI), squash factor (SF), accept ratio (AR), and reject ratio (RR). The developed ANFIS model was operated until the best scenerios were achieved depended on the lowest value of RMSE. The training process was concluded whenever the maximum epoch number was found, or the training error target was accomplished (Srisaeng & Baxter, 2021; Srisaeng, Baxter & Wild, 2015). In this study, the RMSE became assured after running two epochs of training data. The ultimate convergence values were 0.0000002127.

Upon the conclusion of the training phase, the ANFIS model for predicting Kansai International Airport's international air passenger was tested and validated by choosing five points of data, which are different from the other 20 points utilized for the training stage (Srisaeng & Baxter, 2021; Srisaeng, Baxter & Wild, 2015). Each validation data point was fed into the adaptive neuro fuzzy inference system (ANFIS) system and then Kansai International Airport's forecasted international passenger values were calculated and matched to the actual values.

A comparison between the actual and predicted of the ANFIS Kansai International Airport's international passengers' model for the ANFIS training are presented in Figure 4. Figure 4 shows that the ANFIS system is well-trained to forecast Kansai International Airport international enplaned air passengers.

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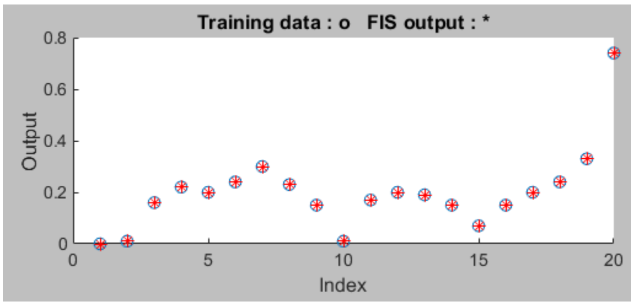

Figure 4. Kansai International Airport's actual and predicted international air passenger values

Figure 5 presents the surface graphs obtained from ANFIS. These graphs show the variation of the output according to two different parameters (X and Y axes). (Hamed, Sadkhan & and Hameed, 2018; Patil et al., 2011; Raihana et al., 2017).

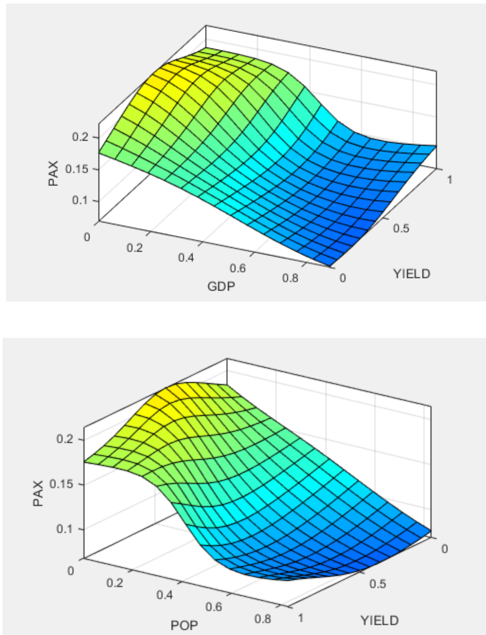

Figure 5. Obtained surfaces in the ANFIS model: Kansai International Airport's international passengers versus world GDP, world international passenger yields, and world population.

The performance index of training, testing, validation and general data of the international air passenger ANFIS model of Kansai International Airport was calculated as shown in Table 1. Table 1 shows that the ANFIS model has a very satisfactory predictive capability. The ANFIS model shows that the mean absolute error (MAE), mean absolute percent error (MAPE), mean square error (MSE), and root mean square error (RMSE) are very low for training, testing, validation, and general datasets.

Table 1. The training, validating, testing, and overall data set performance indexes of the ANFIS model

Performance Index	Training Data	Validating Data	Testing Data	Overall Data
MAE	$2.06x10^{-3}$	$4.32x10^{-2}$	$1.52x10^{-1}$	$1.89x10^{-2}$
MAPE	2.96%	31.43%	15.78%	7.40%
MSE	$5.77x10^{-6}$	$3.19x10^{-3}$	$2.40x10^{-2}$	$2.31x10^{-3}$
RMSE	$2.40x10^{-3}$	$5.65x10^{-2}$	$1.55x10^{-1}$	$4.81x10^{-2}$

The regression between the overall predicted and actual value of Kansai International Airport's international passengers are shown in Figure 6. The coefficient of determination (R^2) is high, being around 0.9776.

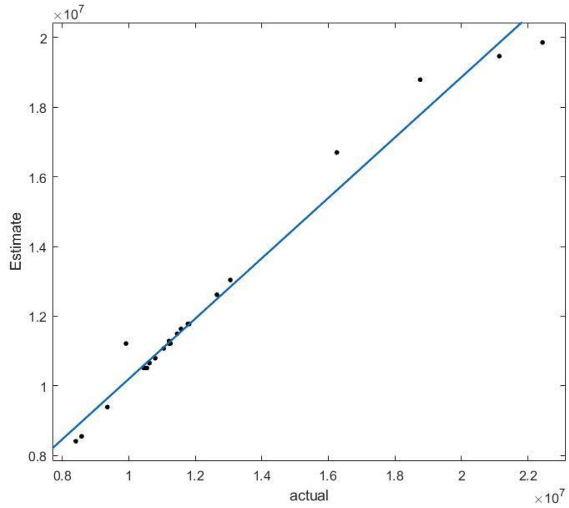

Figure 6. The regression of predicted and actual values of the ANFIS model for estimating Kansai International Airport international passenger demand

The actual and forecasted values of Kansai International Airport's international air passenger demand model are plotted in Figure 7. Figure 7 clearly illustrates the very good fit of the ANFIS to the actual data, exhibiting the high estimation precision of the Kansai International Airport international passenger demand ANFIS model.

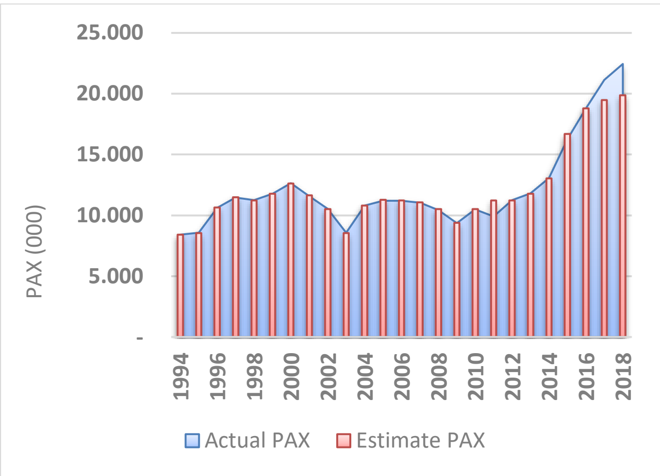

Figure 7. A comparison of Kansai International Airport actual and forecasted international passengers: 1994-2018. Legend: PAX = Passengers

4. Conclusion

This study has presented an adaptive neuro-fuzzy inference system (ANFIS) that has successfully predicted Kansai International Airport's international air passenger demand. The study used nine determinants of air travel demand and three dummy variables as input variables. The results reveal that the model successfully forecasts Kansai International Airport's international passenger demand. The coefficient of determination (R2) was high, being around 0.9776%. The results show that the average absolute percent error (MAPE) for the overall data set of the international air passenger demand model of Kansai International Airport is 7.40%. The proposed adaptive neuro-fuzzy inference system (ANFIS) structure provided very encouraging results for the successful forecasting of an airport's international air passenger demand. Airports as require highly accurate passenger forecasts, as these underpin key decisions on the very capital-intensive infrastructure and facilities that will be required to handle the predicted growth in passenger demand.

A key component of an airport's passenger throughput are passengers connecting through the airport. Thus, should connecting passenger become available, then possible future research could consider the application of an adaptive neuro-fuzzy inference system (ANFIS) for forecasting future connecting passenger traffic at an airport.

Ethical approval

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