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AIM AND SCOPE

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Structural and Fatigue Analysis of a UAV Wing

Metin Uzun[1*], Hasan Çınar[2], Abdullah Kocamer[3] and Sezer Çoban[4]

[1*]İskenderun Technical University, Department of Airframe and Powerplant Maintenance, 31200, İskenderun, Hatay, Türkiye. (metin.uzun@iste.edu.tr)
[2]İDepartment of Aeronautical Engineering, Faculty of Aeronautics and Astronautics, Necmettin Erbakan University, Konya, Türkiye.(hasan.cinar@erbakan.edu.tr)
[3]İskenderun Technical University, Department of Airframe and Powerplant Maintenance, 31200, İskenderun, Hatay, Türkiye. (abdullah.kocamer@iste.edu.tr)
[4]İskenderun Technical University, Department of Airframe and Powerplant Maintenance, 31200, İskenderun, Hatay, Türkiye. (sezer.coban@iste.edu.tr)

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Abstract

In this study, the structural and fatigue analyses of an unmanned aerial vehicle wing are investigated together. The spar, which is the main load carrier of the wing, and the ribs, which are the structural support parts that give the wing its aerodynamic shape, are analyzed using different numbers. Accordingly, 5 cases with different rip and spar numbers were examined with the finite element method. Additionally, aluminium and carbon epoxy materials were considered for the wing material in the simulations. The wall thickness for the wing is 0.5 mm and 1 mm, and the applied loads are 80 N, 150 N, and 250 N, respectively. As a result of these inputs, total deformation, maximum principal elastic strain, and fatigue analyses were performed.

1. Introduction

Structural and fatigue analysis of the aircraft wing is an important research topic in the aerospace industry. These analyses play a critical role in the safety, performance and durability of the aircraft. Aircraft wings have a particularly complex and delicate structure as they encounter aerodynamic effects and are subjected to large mechanical forces during flight (Kocamer et al, 2023).

Structural analysis is a detailed investigation process to evaluate the durability, strength, and overall performance of an aircraft wing. These analyses include factors such as material selection, geometry design, and manufacturing processes. Any structural weakness or defect in aircraft wings can seriously jeopardize the safety of the aircraft. Therefore, structural analyses are a critical stage in the design process. Fatigue analysis evaluates potential material fatigue under the repetitive loads and stresses to which the aircraft is subjected during its service life. This analysis plays an important role in determining the long-term durability and maintenance requirements of the aircraft. It also helps to identify in advance potential problems that may arise due to the use of the aircraft wing over time (Uzun et al, 2023).

The wing structure of the trainer aircraft, designed with Al-7075 and Kevlar, exhibits commendable stress and fatigue resistance, featuring a safety factor of 0.5 (Anil et al., 2017). CSIR_NAL's improved Fatigue Meter aids in the structural fatigue analysis of UAVs, reducing maintenance costs and prolonging service life (Nanda, 2013). Adjusting dynamic characteristics like natural frequencies, damping, and stiffness can enhance the fatigue life and damage tolerance of aerospace-grade composite materials (Anwar et al., 2017). Carbon fiber-reinforced polymer (CRFP) and glass fiber-reinforced polymer (GRFP) outperform Al alloy in aircraft wings, with GRFP showing superior fatigue life and noise reduction (Das & Roy, 2018). A study optimizing carrier-based UAV drawbar parameters through strain fatigue analysis reduces stress levels by 15.7% and increases drawbar life by 122% (Chen et al., 2021).

Conducting CFD analysis and employing structural optimization techniques to optimize a UAV wing structure results in significant weight reduction and an improved strength-to-weight ratio compared to the standard model (Sekar et al., 2020). The finite element model accurately simulates the structural performance of a composite wing for UAVs, featuring a tubercle design at the leading edge, and can predict failure modes at the seventh and eighth layers (Basri et al., 2021). The developed main wing for the HALE UAV reduces structural weight without compromising integrity, enhancing flight endurance without sacrificing safety (Park et al., 2018).

The wing structure of the newly configured UAV meets design requirements and is optimized for weight and stress analysis, paving the way for integrated aero-structural optimization and design (Shi, 2008). A study showcasing the effectiveness of ABAQUS in analyzing static strength and modal behavior of composite UAV wings underscores the importance of evaluating structural integrity and engineering feasibility (Liang-zhong, 2012). Recent research extensively explores structural and fatigue analysis of UAV wings. Johnson et al. (2018) comprehensively studied the impact of varying aerodynamic loads on UAV wing structural integrity, emphasizing the importance of understanding these loads for long-term durability. Smith and Brown (2019) conducted a detailed investigation into material aspects of UAV wing construction, stressing proper material selection for enhanced structural robustness. In the study Chinvorarat, S. (2021). in which Ansys software was used for analysis, it is stated that a light and cost-effective composite wing was created by balancing the amount and orientation of carbon fiber and glass fiber ply patterns. As a result of experimental tests, it has been shown that the optimal wing design is made to withstand maximum loads (positive and negative loads) and can carry these loads without structural collapse. It is stated that the experimental structural deformation and elastic stress are compatible with the finite element model and within an acceptable error range. In a study examining the strength and rigidity properties of the wing of an ultralight unmanned aerial vehicle Sullivan et al. (2009), the wing consists of foam core sandwich skins and various spars with varying laminate layer patterns. A non-geometric finite element model was developed and the static response of the wing under simulated whiffletree loading conditions was obtained by carefully matching the boundary conditions with the experimental setup. Stress and bending predictions obtained from finite element simulations were found to be in good agreement with experimental observations. Peruru et al. (2017) where the material to be used in this study was examined under a different condition and Ansys program was used for analysis, it was determined that carbon epoxy material had lower stress values than s2 glass and aluminium alloy 6061-T8 in static analyses. Additionally, Thompson et al. (2020) provided insights into advanced fatigue analysis techniques for UAV wings, highlighting the necessity of predicting and mitigating potential fatigue failures over the operational life cycle. These studies collectively deepen our understanding of UAV wing structural and fatigue analysis, offering valuable perspectives to enhance the reliability and performance of unmanned aerial systems.

2. Material and Methods

This study aims to examine the total deformation, Maximum principal elastic strain, and fatigue behaviors of a UAV wing (NACA2414) with different rib and spar numbers under different load conditions. In this context, simulation studies were carried out using the ANSYS Structural module. Figure 1 shows the working principle of the structural analysis format in the Ansys analysis program.

The unmanned aerial vehicle wing design has been obtained in a solid design with rib, spar and surface coating in order to prepare it to be strong enough to meet the mechanical loads that may occur during flight.

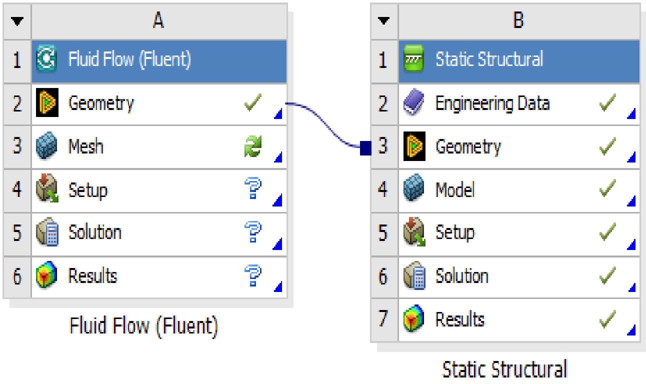


Figure 1. Ansys Static Structural

Mechanical loads acting on the aircraft, deformation in the wing structure, shear stress, compressive stress, as well as the number of ribs and spars to be selected, material preference, and material dimensions affect the life of the structural design. Since the number, material type and dimensions of the structural support parts used in the mechanical design will also affect the take-off weight of the aircraft, choosing the optimum values for the structural design in this study will help in the optimization study. For this reason, it will provide information about the material type, the number of ribs and spars, and the range in which the surface coating thickness can change under loads that may affect the aircraft throughout the flight. Figure 2 shows the mesh work images of the structurally designed wing design before it is sent to structural analysis. To prepare the wing solid design for static analysis, the smallest number of mesh elements was selected as 2 mm, the number of mesh elements was 347318 and the maximum value of mesh skewness was obtained as 0.6677.

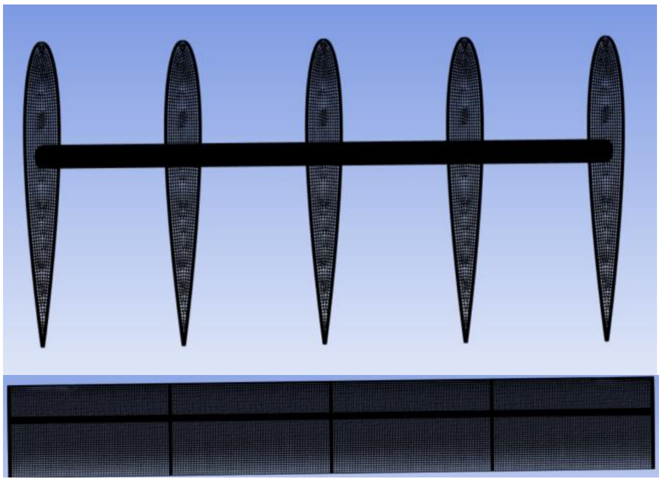


Figure 2. Mesh image of wing structural design

In this study, data is presented in table 1 to examine the static analyzes that will occur as a result of using different numbers of wing support equipment. Here, first of all, a total of 5 ribs and 1 spar, including the wing root and tip, were used for case 1. In Case 2, 3 ribs and 1 spar were used in the wing tip, wing root and wing mid-range. In Case 3, a total of 2 ribs and 1 spar were used at the wing root and wing tip. In Case 4, only 2 ribs were used at the wing root and wing tip, without the use of spar. Finally, in case 5, only 1 rib was used at the wing root.

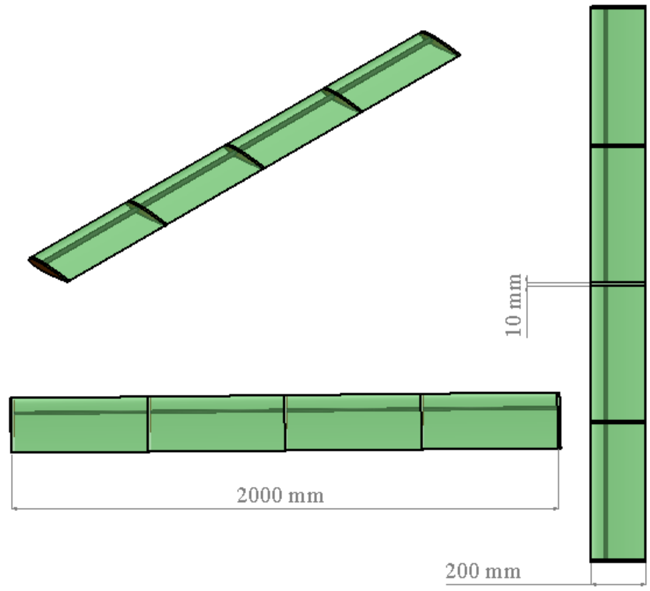


Figure 3. Geometric dimensions of the wing.

In the figure, 3D images of the analysis, structural support parts and dimensions of the wing geometry are given.

Table 1. Cases examined according to the number of ribs and spars.

	Number of ribs	Number of spars
Case 1	5	1
Case 2	3	1
Case 3	2	1
Case 4	2	-
Case 5	1	-

To evaluate the structural analysis of the wing, studies were carried out with different numbers of support equipment used, the support elements were made of aluminum and carbon materials, and the surface coating was made of only aluminum material. Another variable used in this study is the wall thickness of the surface coating material, which was analyzed at two different values: 0.5 mm and 1 mm. In this study, the static forces that will occur as a result of applying three different forces as 80N, 150N and 250N to our aircraft carrying force-producing wing designed with wing surface coating and support equipment are calculated.

3. Result and Discussion

Simulation results of total deformation, maximum principal elastic strain, and fatigue on the UAV wing are given in Tables 2-6 for cases 1-5, respectively. These simulations were performed for wing thicknesses of 0.5 mm and 1 mm and loads of 80 N, 150 N, and 250 N. In addition, aluminum and carbon were examined as wing materials. The yield strength for aluminum and carbon epoxy materials is 240 MPA and 300 MPA, respectively (Rumayshah et. Al (2018); Frulla and Cestino (2008)). Simulation results on the wing are given in Figures 2,3 and 4. In all cases, the wings that have carbon epoxy material have higher total deformation than aluminum material. In addition to the given tables, the maximum principal elastic strain, total deformation, and fatigue results for all cases are given in Figures 5, 6, and 7 respectively.

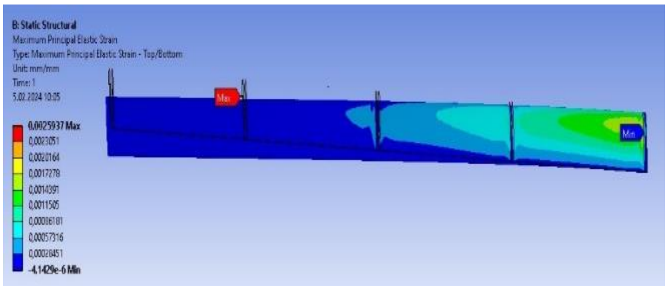


Figure 4. Maximum principal elastic strain on the wing

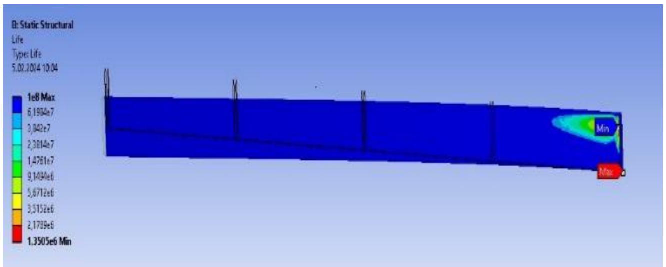


Figure 5. Fatigue on the wing

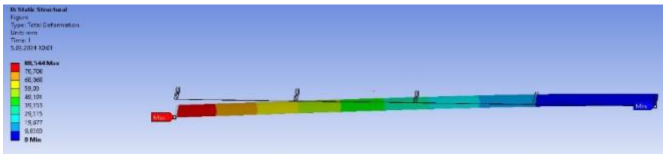


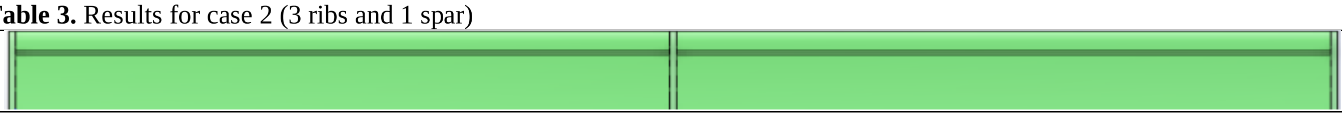
Figure 6. Total deformation on the wing

In table 2, static analysis results are given for the wing structure called case 1, where 5 ribs and 1 spar are used. Here, the different material information used for rib and spar is given in column 1, the thickness of the surface coating in column 2, and the values in N of the different forces applied to the wing surface in column 3. For 3 different input values, total deformation in the wing structure, Max. Principal elastic strain and fatigue values are given as output. When aluminum material is preferred instead of carbon material for rib and spar, which are wing support parts, total deformation and Max. It was observed that the principal elastic strain decreased, but the fatigue values increased in general, although not for every force value. The surface coating material was aluminum for the entire work. When the surface coating material thickness was preferred as 1 mm instead of 0.5 mm, the total wing weight increased, the total deformation decreased, and the value of the change in deformation increased as the applied force value increased. For example, in the case of 250 N applied force with 0.5 mm surface coating, the total deformation was 139 mm, while when the surface coating was selected as 1 mm, it decreased by 50% and was measured as 71 mm. The change in surface thickness also affected the fatigue value, increasing from 2.95E+05 cycle to 8.51E+07.

Table 2. Results for case 1 (5 ribs and 1 spar)

	Thickness (mm)	Load (N)	Total deformation (mm)	Max. principal elastic strain (mm)	Fatigue (cycle)
Carbon	0.5 mm	80	44.531	0.0047072	1.00E+08
		150	83.495	0.0088259	3.13E+07
		250	139.16	0.01471	2.95E+05
	1 mm	80	22.822	2.42E-03	1.00E+08
		150	42.791	4.54E-03	1.00E+08
		250	71.318	7.56E-03	8.51E+07
Aluminum	0.5 mm	80	38.664	3.75E-03	1.00E+08
		150	72.496	7.04E-03	6.52E+07
		250	120.83	1.17E-02	5.28E+05
	1 mm	80	21.147	1.75E-03	1.00E+08
		150	39.651	3.28E-03	1.00E+08
		250	66.084	5.46E-03	1.00E+08

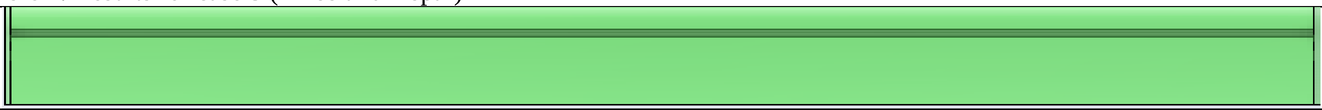
Table 3. Results for case 2 (3 ribs and 1 spar)



	Thickness (mm)	Load (N)	Total deformation (mm)	Max. principal elastic strain (mm)	Fatigue (cycle)
Carbon	0.5 mm	80	45.303	2.94E-03	1.00E+08
		150	84.943	5.51E-03	2.84E+07
		250	141.57	9.19E-03	2.74E+05
	1 mm	80	2.30E+01	1.39E-03	1.00E+08
		150	43.156	2.61E-03	1.00E+08
		250	71.927	4.35E-03	8.31E+07
Aluminum	0.5 mm	80	40.439	1.88E-03	1.00E+08
		150	75.823	3.52E-03	5.39E+07
		250	126.37	5.87E-03	4.41E+05
	1 mm	80	21.63	9.24E-04	1.00E+08
		150	40.556	1.73E-03	1.00E+08
		250	67.593	2.89E-03	1.00E+08

In table 3, static analysis values are given for the wing geometry, which we call case 2, consisting of the wing root, wing tip and 3 ribs and 1 spar located at the wing center. In the transition from case 1 to case 2 design for wing geometry, there is an increase in the total deformation value for all cases, although fatigue values are not affected for the entire study, there is a general decrease, Max. Principal elastic strain values showed differences. For example, when rib and spar carbon material and 250 N force was applied, the total deformation was 139 mm for case 1, while it was 141.57 mm for case 2. For the same input values, the fatigue value decreased from 2.95E+05 to 2.74E+05. It is clearly seen in Table 3 that decreasing the number of ribs in the wing design increases the deformation, albeit slightly, and reduces the fatigue value.

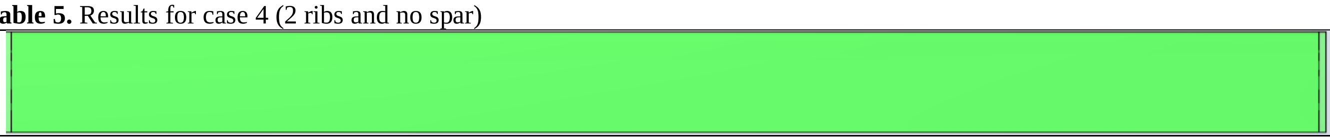
Table 4. Results for case 3 (2 ribs and 1 spar)



	Thickness (mm)	Load (N)	Total deformation (mm)	Max. principal elastic strain (mm)	Fatigue (cycle)
Carbon	0.5 mm	80	45.60746524	0.002855105	100000000
		150	85.51400257	0.005353322	27334157.93
		250	142.5233351	0.008922204	266719.7363
	1 mm	80	23.08689743	0.001243775	100000000
		150	43.28793053	0.002332079	100000000
		250	72.1465547	0.003886798	82198005.26
Aluminum	0.5 mm	80	41.10578463	0.001819731	100000000
		150	77.07334713	0.003411996	49114697.07
		250	128.455576	0.00568666	411815.5266
	1 mm	80	21.80096711	0.000776571	100000000
		150	40.87681357	0.001456071	100000000
		250	68.1280239	0.002426784	100000000

Table 4 shows the static analysis results for different input values for the geometry consisting of 2 ribs at the wing root and wing tip and 1 spar in wing design. Unlike case 2, 1 more rib located in the center of the wing was removed and the results were evaluated. The static analysis results that occurred when moving from case1 to case 2 were similar to those when moving from case2 to case3. When Table 3 is examined, the number of ribs was reduced by keeping the input values constant, and a partial increase in total deformation was observed for each analysis, along with a partial decrease in fatigue values.

Table 5. Results for case 4 (2 ribs and no spar)



	Thickness (mm)	**Load (N)**	**Total deformation (mm)**	**Max. principal elastic strain (mm)**	**Fatigue (cycle)**
Carbon	0.5 mm	80	46.16313289	0.002890485	100000000
		150	86.55587226	0.005419659	24490549.89
		250	144.2597846	0.009032764	245863.0446
	1 mm	80	23.22830823	0.001251567	100000000
		150	43.55307865	0.002346688	100000000
		250	72.58846441	0.003911146	79182346.31
Aluminum	0.5 mm	80	45.1608937	0.001997619	100000000
		150	84.67667616	0.003745535	21151120.64
		250	141.1277961	0.006242558	220547.8036
	1 mm	80	22.89032986	0.00081514	100000000
		150	42.91936968	0.001528387	100000000
		250	71.53228153	0.002547311	76089377.54

Table 5 shows the static analysis results for different input values for the geometry consisting of only 2 ribs at the wing root and wing tip. After the static analysis in Table 4, the spar, which is the longitudinal support piece, was also removed and its static effect was examined in this table. After the spar was removed, the total deformation created more difference as the applied force value increased. Especially when 250 N force was applied using carbon material with a wall thickness of 0.5 mm, approximately 2.5 mm more deformation was observed. Fatigue values remained constant at 80 N force application, but a decrease was observed in fatigue values at 150 and 250 N force applications. While spar was used in all studies until the case 4 study, spar was removed in this study and a decrease in fatigue value was observed for the first time for an aluminum material with 2 mm wall thickness. Therefore, it is clearly seen that spar is an important factor for structural support.

Table 6. Results for case 5 (1 ribs and no spar)

	Thickness (mm)	Load (N)	Total deformation (mm)	Max. principal elastic strain (mm)	Fatigue (cycle)
Carbon	0.5 mm	80	46.838563	0.001086038	100000000
		150	87.82230706	0.002036321	23475428
		250	146.3705041	0.003393868	238268.0057
	1 mm	80	23.31540189	0.000704117	100000000
		150	43.71637664	0.00132022	100000000
		250	72.860629	0.002200367	78361312.19
Aluminum	0.5 mm	80	46.42790796	0.001110006	100000000
		150	87.05232791	0.002081261	18841497.41
		250	145.0872157	0.003468769	202432.2108
	1 mm	80	23.09100956	0.000580818	100000000
		150	43.29564149	0.001089034	100000000
		250	72.15940249	0.001815056	73900939.52

In this study, there is only 1 structural rib at the wing root, which we call case 5 in table 6. After removing 1 rib at the wing tip, there was a decrease in the total deformation for the study, but no serious change was observed. However, when we look at the fatigue values, the structural strength decreased significantly, especially when 250 N force was applied.

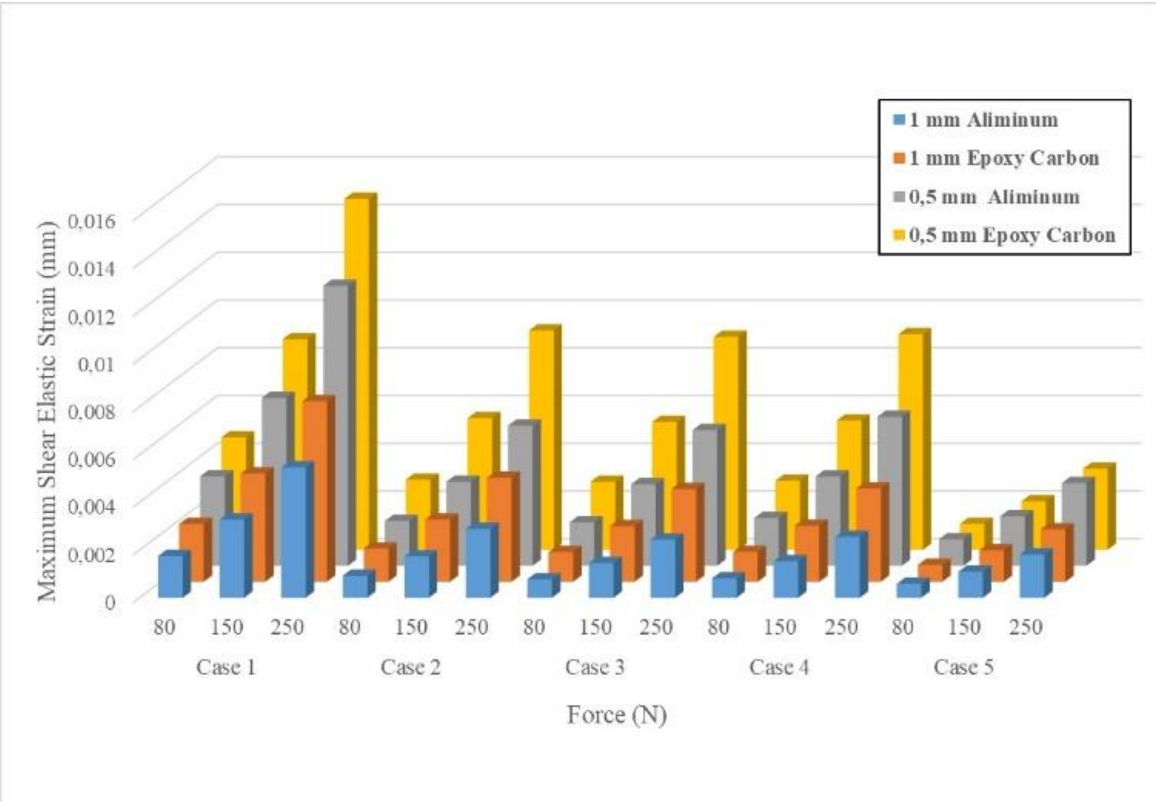


Figure 7. The results of the maximum principal elastic strain

In figure 7, the maximum shear elastic strain values for different input values are given graphically as a summary of all studies. In this chart, the horizontal axis shows the structural designs and applied force values we mentioned in Table 1, and the vertical axis shows the maximum shear elastic strain values for these input values.

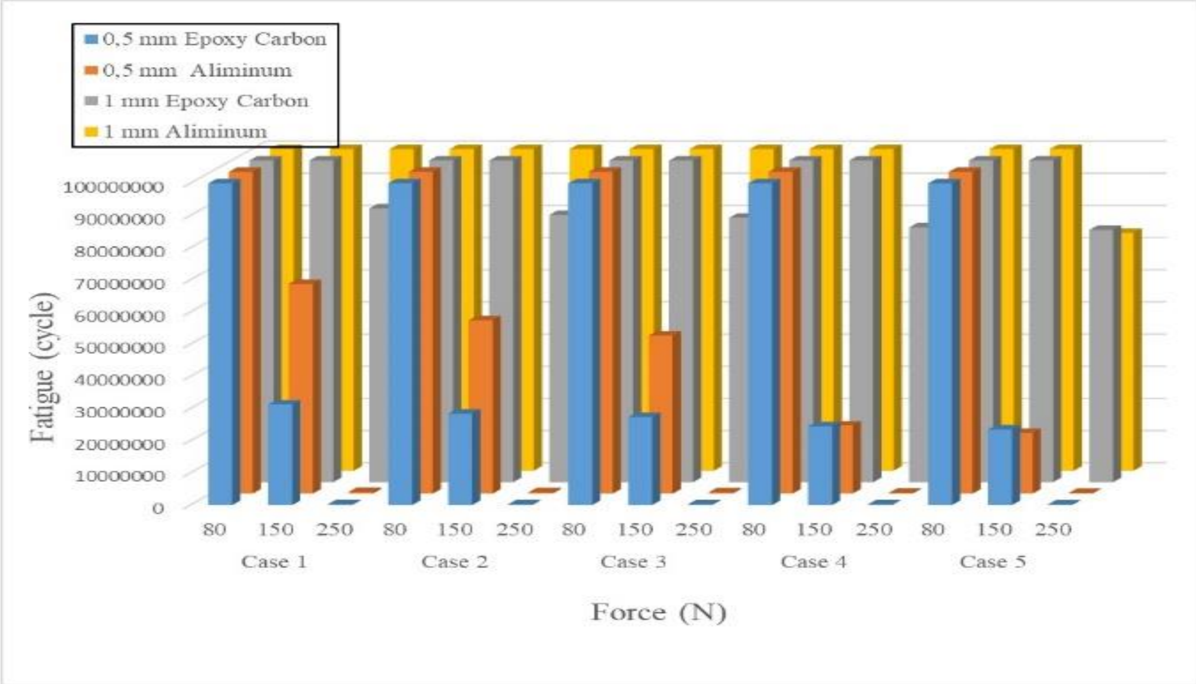


Figure 8. The results of fatigue

In figure 7, the fatigue values for different input values are given graphically as a summary of all studies. In this chart, the horizontal axis shows the structural designs and applied force values we mentioned in Table 1, and the vertical axis shows the fatigue values for these input values.

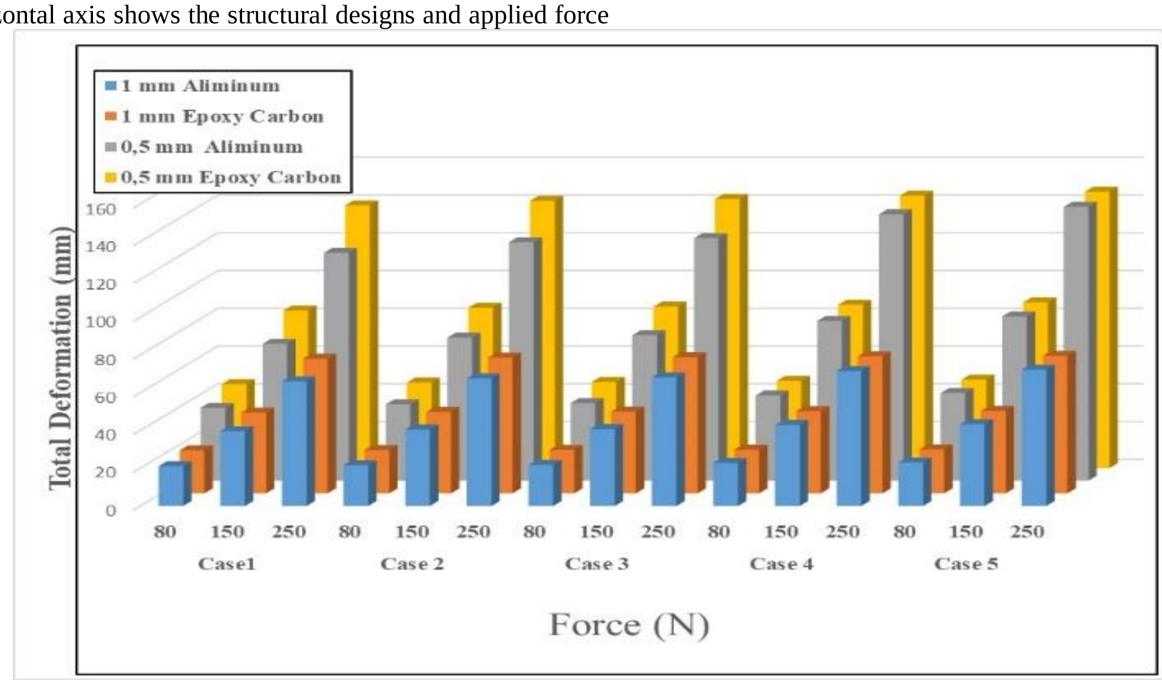


Figure 9. The results of total deformation

In figure 7, the total deformation values for different input values are given graphically as a summary of all studies. In this chart, the horizontal axis shows the structural designs and applied force values we mentioned in Table 1, and the vertical axis shows the total deformation values for these input values.

4. Conclusion

In this study, the structural behavior of a UAV wing with NACA 2414 airfoil was examined in 5 different cases depending on the number of ribs and spars. As wing materials, were considered carbon and aluminum, and simulation studies were conducted with the help of the ANSYS program under 80, 150, and 250 N loads and with 0.5 mm and 1 mm wing thickness. As a result, for these 5 cases, the total deformation, Maximum principal elastic strain and fatigue results are summarized in Table 2-6. According to these results, the maximum elastic strain among all cases was in case 1 for Epoxy carbon material with 0.5 mm wing thickness. The largest total deformation was for epoxy carbon material of 0.5 mm blade thickness in case 5 (for 250 N). In general, the life behavior of the aluminum material was better than that of the epoxy carbon material for all cases. In addition, it was observed that the total deformation and maximum principal elastic strain values decreased with increasing material thickness. This indicates that the structural strength increases with increasing material thickness and the material is subjected to less deformation. Another finding is that the deformation and elastic strain values of the material increase with increasing load. This shows that the material deforms more under higher loads and pushes its elastic limits more. As a result, it was determined that carbon and aluminium materials exhibit different behaviours under different thicknesses and loads. These findings should be taken into account in material selection and design processes in structural engineering applications. It is also recommended that future research should investigate and analyze these factors in more detail. In future work, the authors plan to carry out geometric optimization studies of the variable thickness wing for case 5 of this study.

Ethical approval

Not applicable.

Conflicts of Interest

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

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Aircraft Accident and Crash Images Processing with Machine Learning

Halil İbrahim Gümüş[1*], Ömer Osman Dursun[2]

[1*]Firat University, Aircraft Electrical and Electronics Department, Elazig, Türkiye. (ibrahimgumus23@outlook.com)
[2]Firat University, Department of Avionic, Elazig, Türkiye. (oodursun@firat.edu.tr)

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Abstract

The aviation industry is in constant need of innovations in terms of safety and operational efficiency. In this context, low-light image enhancement technologies play an important role in a numerous areas of disciplines, from night flights to accident and collision investigations. Machine learning, deep learning methods and traditional methods not only provide the aviation industry with an effective image processing and improvement capacity in low light conditions, but also reveal important information by analysing the data of low-light images of crashed and destroyed aircraft.

Within the scope of the study, traditional methods, deep learning method and machine learning are combined in order to enhance and process low-light ambient images of crashed and destroyed aircraft. By using Swish and Tanh activation functions together in the deep learning model, the performance of the neural networks used in the process of improving low-light environment images was improved and the image quality was increased. The enhanced images were evaluated and compared using PSNR and MSE as objective quality assessment measures. According to the PSNR and MSE criteria, the numerical results obtained from the image enhancement studies of the deep learning model were calculated as 29.85 and 100.44, respectively. The results introduce that the deep learning model provides better image enhancement than traditional methods. In conclusion, improvement of low-light image and processing is an important technological advancement in the aviation industry, enabling safer and more efficient operations. The successful of machine learning include deep learning and traditional methods shows that the aviation industry will achieve a safer and innovative structure in the future.

1. Introduction

The aviation industry continues its development on safer, effective and innovative flight systems with technological advances. In this context, the analysis of accident and crash images using machine learning can enable new developments in the aviation industry. Thanks to the enhancement of low-light ambient images obtained after aircraft accidents, it is an important source for analysing and investigating the causes of the event. Thanks to this, it can be used to improve the safety standards of the aviation industry, prevent similar incidents and improve flight systems.

Machine learning, an integral part of artificial intelligence, enables algorithms to acquire knowledge by analyzing large and complex datasets. By using machine learning, software applications can make result prediction more precise without the need for explicit programming. The basis of machine learning is to accept input data through algorithms and predict the output with the help of statistical analysis (Dhankar & Gupta, 2021).

Machine learning algorithms serve a crucial role in various domains. They are expert systems at classifying events, identifying relevant samples, making predictions, and even arriving at informed decisions. These algorithms can be employed individually or in combination to enhance accuracy when handling intricate and unpredictable data. (Karaburun, Arik Hatipoğlu & Konar, 2024).

Thanks to its ability to recognize objects, vehicles and people in the images, machine learning can determine the factors that caused the accident and their effects in detail. After the processing and enhancement of low-light ambient images obtained after the accident and breakdown, it provides a fast and precise analysis, allowing the evaluation of the condition of the aircraft involved in the accident and breakdown. This enables rescue teams to intervene more quickly and effectively at the scene.

Within the scope of the study, conventional methods and deep learning methods were used to enhance and analyze low-light ambient images of crashed aircraft. In this way, important features in the images are made clear and understandable. With traditional methods, basic corrections and filtering techniques were applied to the images to improve them. In the deep learning method developed on the basis of the knowledge and experience obtained, Convolutional Neural Networks (CNN) were used to reveal the important features in the images and to maximize the visual quality. Finally, the enhanced and restored versions of low-light environment images were processed using machine learning methods. In this way, it is aimed to enable the analysis of the damaged systems and the electronic, mechanical and structural parts of the aircraft in a short time after the accident and breakage of the aircraft.

1.1. Literature Review

In the study conducted by Perla et al., image enhancement can be performed quickly and effectively in images obtained under low-light conditions. In this study, the contrast-based fusion method was used, which overcomes the disadvantages of traditional methods and at the same time achieves more effective results (Perla & Dwaram, 2023).

Chen et al., use deep learning to enhance low-light images with text and numbers. In order for the enhancement of images to be effective, weighing feature maps are utilized together with a channel attention layer to increase the detail of images containing text and numbers (Chen et al., 2023).

Singh et al., utilized deep neural networks to improve image quality due to distortions in images acquired in low-light weather. The images acquired during the flight of the unmanned aerial vehicle include multi-resolution branches for a better understanding of different local and global context levels through various streams (Singh et al., 2022).

Zhang et al., proposed a deep learning method for self-supervised low-light image enhancement. In order to realize self-supervised learning, a constraint was added that the maximum channel of the reflection should be compatible with the maximum channel of the low-light image and the entropy should be maximized in the proposed model (Zhang et al., 2020).

Öztürk et al., explained the method obtained by using the transformation function, histogram expansion and histogram matching methods together, which are image enhancement techniques. Thanks to the Artificial Bee Colony Algorithm introduced in this study, images were improved by adjusting natural contrast and brightness (Öztürk & Öztürk, 2016).

Zhu et al., made improvements to the images using a multiple exposure fusion module used to solve high contrast and color problems to improve low-light images, and an edge enhancement module to improve the initial images using edge information (Zhu et al., 2020).

Tico et al., improved the images by using an image enhancement algorithm based on combining the visual information in two images taken with different exposure times under the same environmental conditions, taking advantage of the differences between the image distortions that affect both images (Tico & Pulli, 2009).

Park et al., proposed a learning-based low-light image enhancement algorithm, a histogram-based transform function estimation network that estimates transform functions using the histogram of an input image. This method was applied to low-light image enhancement using channel-wise intensity transform to obtain enhanced images (Park et al., 2022).

Liu et al., proposed an enhancement method for low-light Unmanned Aerial Vehicle images. This method aimed to increase global brightness and enhance local contrast. A brightness and chromaticity optimization process based on linear stretching was used to optimize the developed images (Liu et al., 2022).

Yu et al., introduced a new color constancy-based method to improve the visibility of low-light environment images, which involves applying a proper color constancy technique to the set of active pixels throughout the image (Yu & Liao, 2010).

2. Materials and Methods

Traditional methods, deep learning models and machine learning techniques play an important role in the analysis, enhancement and processing of low-light images of crashed and destroyed aircraft. These techniques are used to improve the quality of the images, to reveal important details and features, to improve contrast, to adjust brightness and to process the images.

Low light refers to environmental conditions that do not comply with general lighting standards (Perla & Dwaram, 2023). This situation can often lead to a decrease in image quality and distortion due to insufficient illumination or low illumination. The aim of low-light image enhancement is generally to increase the contrast of the image, improve the visual appearance and transform the image into a structure more suitable for human understanding or computer analysis, while at the same time reducing the noise in the images and obtaining the closest possible form to the original image (Öçer et al., 2022).

Image processing aims to obtain a more advanced image by performing the necessary operations on an image or to extract useful information from this image (Shen et al., 2017). Image enhancement refers to the operations performed to make an image that is useless or contains insufficient information for various reasons more visually or functionally usable. (Chen et al., 2023). A general mathematical expression of image enhancement can be written as in Equation 1, where $f(x, y)$ represents the original image, $g(x, y)$ represents the enhanced image, and the function a represents a particular enhancement process:

$$g(x, y) = a(f(x, y)). \quad (1)$$

With the integration of machine learning, traditional methods and deep learning models, by improving and processing low-light environment images, important details can be revealed and image quality can be improved and a clear and understandable image can be obtained. In this way, it provides an important visual contribution to better understand the causes of accidents and events. The analysis of low-light environment images allows for a more detailed examination of the events at the time of the accident. This helps rescue teams to intervene in a more effective and informed manner. In addition, the enhancement of the images can be used to evaluate post-accident events and improve safety standards in the aviation industry. The block diagram of the study is shown in Figure 1.

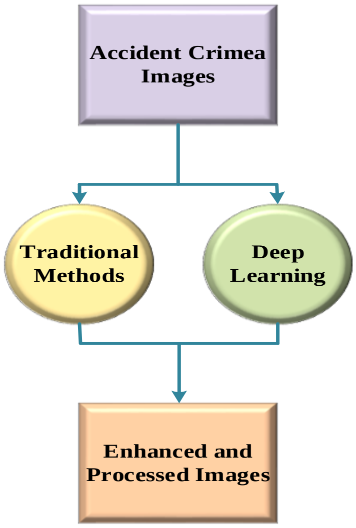

Figure 1. Block diagram of the study

2.1. Traditional Methods

Traditional methods are the most basic methods used for image enhancement. These methods are generally used to improve image quality or to emphasize certain features. In Google Colab application, Python programming language was used to enhance the images of crashed and destroyed aircraft.

2.1.1. Brightness Adjustment

It is used to increase or decrease the overall brightness levels of the image. Luminance refers to the amount of light a pixel reflects and is usually expressed as grayscale. This value is expressed in a range between 0 and 255, with 0 representing black (darkest tone) and 255 representing white (lightest tone) (Chen et al., 2023). In Figure 2, brightness adjustment was applied in order to better reveal the details of the image obtained in low light conditions of the crashed and destroyed aircraft.

Figure 2. Image with brightness adjustment applied

2.1.2. Contrast Adjustment

It gives more liveliness to the image by expanding or compressing the color ranges in the image. This method facilitates visual analysis by increasing the perceptibility of colors and can emphasize certain color tones (Chaney, 2013). Figure 3 shows the image of the crashed aircraft and the image with contrast adjustment applied.

Figure 3. Image with contrast adjustment applied

2.1.3. Thresholding Process

It is used to divide the image into black and white regions. By determining a certain threshold value, pixels larger or smaller than this value can be assigned to different colors. This method is used in various applications such as highlighting certain objects or features on the image, reducing noise, or adjusting the brightness contrast according to a certain threshold value (Gonzales & Woods, 2002). Figure 4 shows the original image of the crashed aircraft and the image with thresholding applied.

Figure 4. Image with thresholding applied

2.2. Deep Learning Method

Deep learning is a machine learning method designed to perform difficult-to-understand tasks. This method performs these tasks using artificial neural networks. It is a machine learning method used effectively in low-light image enhancement and object recognition systems. This methodology aims to improve image quality and gain the capacity to recognize objects by processing low-quality or low-light images through multi-layer artificial neural networks (Kayaalp & Süzen, 2018).

Artificial Neural Networks are known as machines equipped with a neural network consisting of thousands of artificial neurons or processing units that mimic the functioning of the human brain to perform certain tasks. These artificial neurons are brought together for the purpose of processing information and communicating, and they can work in interaction with each other to perform complex tasks. Artificial Neural Networks have the ability to learn patterns from data sets and are used especially in areas such as image recognition and image processing. In this way, significant successes are achieved in image enhancement and they play an effective role in applications such as sharpening low-resolution, noisy or damaged images (Haykin, 2009).

Convolutional Neural Networks (CNN), which stand out with their ability to recognize complex visual patterns by detecting different features, are an artificial neural network generally preferred in image analysis and enhancement applications. The filtered data sets obtained by CNN using large data sets in the training phase are prepared to process the input data in the inference phase. In the training phase, it is achieved by creating a feature matrix of the features extracted from the input data through convolution and pooling layers. It is possible that this feature matrix can be made more effective in recognizing complex visual patterns by increasing the learning capabilities of the network. In the inference phase, it is accurately determined which class the input image belongs to, with the information obtained during the training process. These operations, performed using full connection layers and activation functions, perform the correct classification using the operations learned by the network and ultimately complete the inference phase (Ahmadian et al., 2021).

The match between inputs and hidden layers in artificial neural networks is determined by activation functions. These functions take the data in the input layer, calculate the weighted sums of the neurons in the hidden layer, and then convert it into output. Activation functions play an important role in the learning process and information transmission of the neural network. Thanks to this process, the network has the capacity to learn complex relationships and patterns.

Within the scope of the study, Swish and Hyperbolic Tangent activation functions were used. Swish is an activation function discovered by Google in 2017. The Swish function is obtained by multiplying the input value by the sigmoid function and is generally preferred to the ReLU function because it is thought to have smoother gradients (Sharma, Sharma & Athaiya, 2017). The Swish function is expressed mathematically according to the formula in Equation 2.

$$swish(x) = x.sigmoid(x). \qquad (2)$$

In the given equation, the x value grows and as it gets closer to x regarding negative values, it provides a smoother and more continuous output approaching 0.

The hyperbolic tangent (tanh) activation function is an activation function used in many artificial neural network models. The Tanh function provides a symmetrical structure around the origin by compressing the input values in the range [-1, 1]. Symmetry around the origin makes the tanh function a preferred activation function in many applications (Sharma, Sharma & Athaiya, 2017). The hyperbolic tangent function is given mathematically in Equation 3.

$$tanh\,(x) = \frac{e^{2x}-1}{e^{2x}+1}. \qquad (3)$$

According to the mathematical expression given in Equation 3, the output values of the function vary between -1 and 1. The function value is zero at the origin (0,0) and approaches -1 or 1 as the input values increase or decrease. This feature allows us to obtain a symmetric distribution around the origin when using the tanh function. The Tanh activation function is often used in output layers, especially in classification problems.

Deep learning is also used in an important field such as improving and analyzing low-light images of crashed aircraft. This method performs an improvement process using learned representations to make low-quality or distorted images clearer, sharper and more meaningful. At the same time, processing crash images with machine learning makes a significant contribution to the process of understanding the causes and effects of accidents. Figure 5 shows a deep learning model applied to a low-light image of an aircraft that has suffered an accident and destruction.

Figure 5. Image with deep learning model applied

Machine learning is used to extract details from crash images, recognize objects, extract features and understand accident events. These techniques can help rescue teams respond quickly and effectively. Additionally, machine learning algorithms can provide important information about accident causes and effects by analyzing patterns in images. Deep learning and machine learning are helping to improve safety and better understand accident consequences in the aviation industry.

Enhancements to low-light images were conducted utilizing the Python programming language's Tensorflow library within the Google Colab environment. TensorFlow, an open-source software library created by Google, is designed for the execution of machine learning algorithms and deep learning applications. Its adaptable architecture empowers developers to execute computations across various platforms. TensorFlow boasts attributes such as remarkable computational efficiency, flexibility, robust portability, support for multiple languages, and optimized performance. (Kirac & Özbek, 2024).

The dataset has been specifically used for the purpose of enhancing low-light images. It comprises 80 images designated for training purposes and an additional 20 images allocated for testing. Within this dataset, each pair of images comprises a low-light input image alongside its corresponding well-exposed reference image. This setup facilitates the training and evaluation of algorithms aimed at enhancing images captured under low-light conditions, thereby offering a reliable benchmark for assessing the effectiveness of various image enhancement techniques.

In the deep learning method performed in the Google Colab environment using the Python programming language, this structure is a flat CNN consisting of a symmetric combination of seven layers. Each layer is in the 3x3 range and consists of 32 convolutional kernels with one step. After this stage, Swish is used as the activation function. In the last evolution layer, the generation of 24 parameters for 8 iterations using the Tanh activation system consists of a structure containing three curved parameter maps for three channels. Finally, the learning rate parameter for the deep learning model was set as 0.0001 and the process was carried out. The deep learning model is shown in Figure 6, and the hyperparameters and values used for this model are given in Table 1.

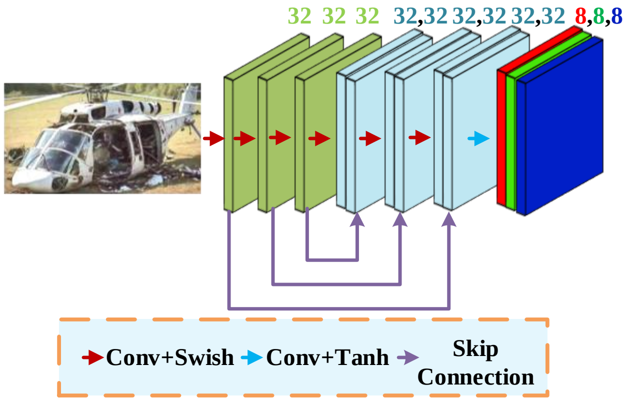

Figure 6. Deep learning architecture

Table 1. Hyperparameters and values used in the deep learning model

Hyperparameters	Value
Learning Rate	0.0001
Activation Function	Swish, Tanh
Epoch	100
Neural Network	CNN
Convolutional Layers	7
Size	3 × 3

2.3. Loss Functions

Loss functions play an important role in image enhancement. These functions are used to provide the closest approximation to the original of an image with corrupted or missing pixels. 5 loss functions were used in the deep learning model: Color Constancy, Exposure, Lighting Uniformity, Spatial Consistency and Total losses.

2.3.1. Color Constancy Loss

Color constancy loss is used to correct possible chromatic aberrations in enhanced images. With this loss function, it aims to obtain more accurate and realistic colors by increasing the color consistency in images.

2.3.2. Exposure Loss

Exposure loss is used to limit under- or over-exposed areas in images. This method aims to obtain a more balanced and visually better image by balancing the contrast.

2.3.3. Illumination Smoothness Loss

To preserve monotonicity relationships between neighboring pixels, illumination smoothness loss is added to each curve parameter map. This loss function ensures smooth and natural illumination of the image, making the transitions between pixels smooth and natural, thus preserving the details in the image.

2.3.4. Spatial Consistency Loss

Spatial consistency loss aims to increase the spatial coherence of the image by preserving the contrast of neighboring regions between the input image and the enhanced image. In this way, the details in the improved image are revealed more consistently.

2.3.4. Total Loss

It refers to the total loss occurring during Color Constancy, Exposure, Lighting Uniformity and Spatial Consistency losses. This total loss covers the differences between the original image and the processed image as a result of the processing, and is generally tried to be optimized to preserve or improve image quality.

2.4. Evaluation Criteria

These are metrics used in the fields of image enhancement and image processing to quantitatively evaluate the quality of an image. These metrics generally aim to measure the differences between a reference image and a damaged or enhanced image. Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) are the metrics used in image evaluation. MSE measures the similarity of the damaged image to the reference image by calculating the average of the error squares on a pixel basis. PSNR expresses the similarity of the damaged image to the reference image in the logarithmic scale of MSE.

2.4.1. Peak Signal-to-Noise Ratio (PSNR)

Peak Signal-to-Noise Ratio (PSNR) is a full-reference quality assessment metric used to measure and evaluate differences between a damaged image and a reference image. This metric expresses the similarity level between two images in logarithmic decibels. In this formula, the maximum pixel value is usually 255. MSE represents the Mean Square Error between the damaged and reference image. The mathematical calculation of the *PSNR* value is given in Equation 4.

$$PSNR = 10.log_{10}\left(\frac{Maximum\ Pixel\ Value^2}{Mean\ Square\ Error}\right). \quad (4)$$

PSNR quantitatively evaluates image quality by taking into account the ratio between signal and noise while determining the degree of similarity between two images. A higher PSNR value means lower MSE and better similarity. As the PSNR value increases, it indicates an image that is less damaged and has better image quality.

2.4.2. Mean Square Error (MSE)

It is a metric used to measure the differences between the reference and enhanced image. In particular, it is used to evaluate how similar one image is to another. MSE is expressed as the average square of the differences in pixel values between images. The mathematical expression of *MSE* is given in Equation 5. In this equation, N represents the total number of pixels, I_i represents the value of the i-th pixel in the original image, and K_i represents the value of the i-th pixel in the damaged image. The lower the value of MSE, the higher the similarity between two images.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(I_i - K_i)^2. \quad (5)$$

3. Result and Discussion

A methodology has been developed to measure the image processing techniques used in the field of aviation on the low-light ratios of aircraft exposed to accidents and crashes and to evaluate the obtained results objectively. This algorithm includes the processing of details and machine learning techniques, analysis and lens evaluation of the results obtained. Initially, different image enhancement techniques and machine learning methods are applied to aircraft with crash and refraction, low light ratios. These techniques are rated as performance ratio, such as increasing the brightness of images, contrast light, reducing noise, improving their performance and clarity. By operating low light environment rates with machine settings, it is possible to detect electronic, mechanical and durable damages of the aircraft more clearly and understandably by revealing important details and features in the images.

As a result of the operations performed on the low-light environment image of the aircraft that was subject to accident and breakage, it was observed that the deep learning model was more vivid, clear and perceptible than other computer monitoring. This highlights the superior properties of the deep learning model in relation to the view. Complex patterns of the deep learning model are learned more effectively, allowing important details in the images to be revealed more accurately. As a result, it appears that the deep learning model can be preserved more effectively in terms of visual quality and perceptibility.

The improvement and processing of images was carried out using the Python programming language in the Google Colab application. In this process, objective image quality evaluation such as mean square error (MSE) and Peak Signal-to-Noise Ratio (PSNR) were used to compare image processing methods.

Figure 7 shows the graph showing the test and verification values of color constancy loss. According to the color constancy loss graph, the training and validation values approached approximately 0.09 and 0.04, respectively. These values tend to be parallel to each other. In this way, the color constancy loss function minimizes color changes and brings it closer to the original image.

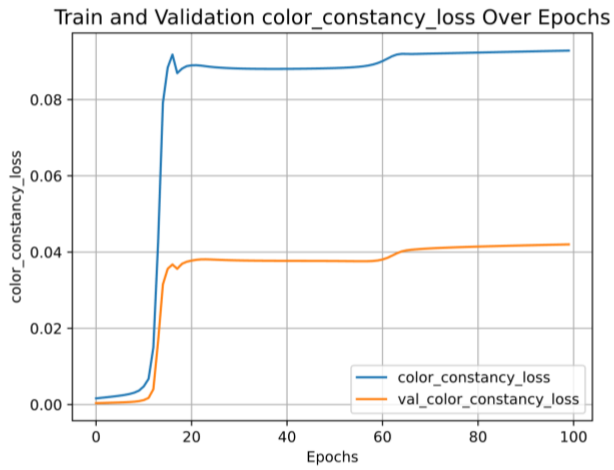

Figure 7. Training and validation plot of color constancy loss

Figure 8 shows the graph showing the test and verification values of exposure loss. According to the graph, training and validation values converge to 1 and 0.5, respectively. Training and verification values vary balancedly with each other. In this way, it provides a more balanced and accurate illumination of the images to be improved, thus revealing the details in the images better.

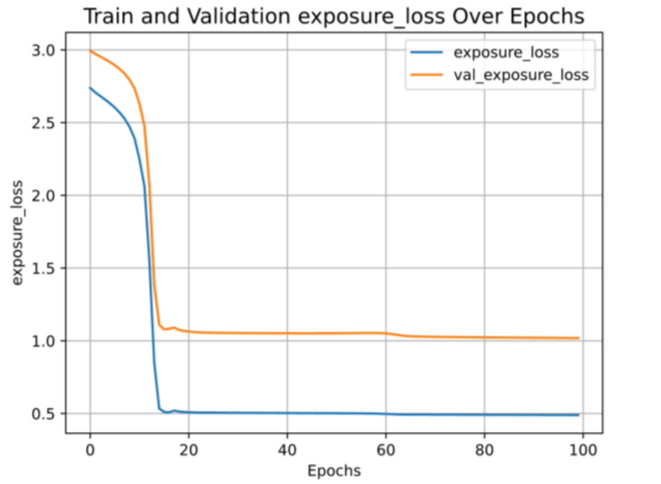

Figure 8. Training and validation plot of exposure loss

Figure 9 shows the graph showing the test and verification values of illumination uniformity loss. According to the illumination uniformity loss graph, training and validation values converge to 0.1. As a result of the convergence of training and validation values towards the same value, it makes the lighting more balanced in all regions of the images.

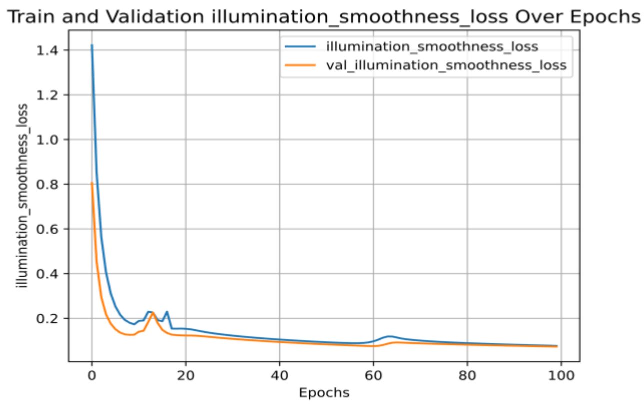

Figure 9. Training and validation plot of illumination smoothness loss

Figure 10 shows the spatial consistency loss graph showing the test and validation values. According to the graph, training and validation values converge to approximately 0.35 and 0.26, respectively. Data regarding training and validation values change in parallel with each other. In this way, the improved images are more balanced and more natural.

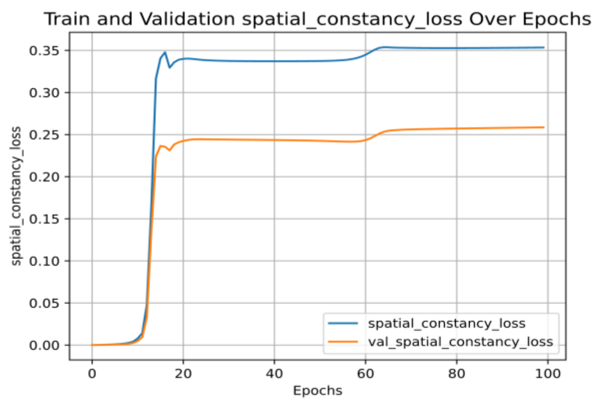

Figure 10. Training and validation plot of spatial consistency loss

Figure 11 shows the graph showing the test and verification values of the total loss. In the total loss graph, training and validation values converge to approximately 1 and 1.4, respectively. Training and validation values vary evenly. In this way, the total loss function minimizes the quality lost during image improvement and ensures that the image obtained as a result of the process is of the highest possible quality.

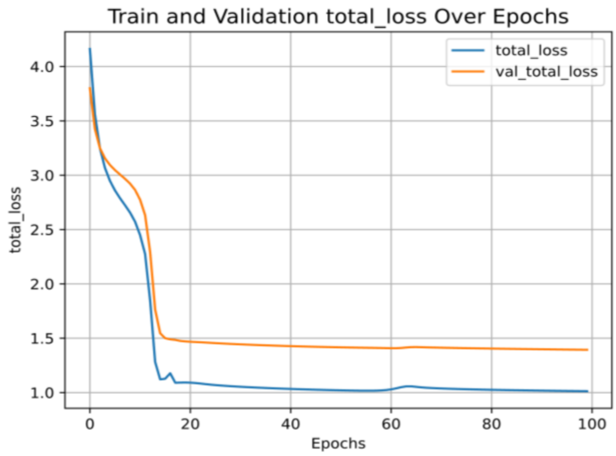

Figure 11. Training and validation graph of total loss

Numerical results of the evaluation made with image evaluation criteria are recorded in Table 2. These results were used to compare the effectiveness of different image enhancement techniques and machine learning algorithms and to determine the most suitable methods for enhancing images of crashed aircraft in the aviation industry.

Table 2. Image quality evaluation criteria

Methods	PSNR	MSE
Thresholding Adjustment	25.74	111.31
Brightness Adjustment	27.84	106.86
Contrast Adjustment	27.95	104.01
Deep Learning	29.85	100.44

As a result of the evaluation using image evaluation criteria, it was seen that the deep learning model was more successful than traditional methods. The PSNR values of the brightness adjustment and the deep learning model were calculated as 27.84 and 29.85, respectively. The high PSNR value obtained shows that the deep learning model improves image quality more effectively. In addition, the MSE values of the contrast adjustment and the deep learning model were obtained as 104.01 and 100.44, respectively. According to these results, it appears that the deep learning model is more successful. The decrease in the MSE value indicates that the model's predictions are closer to the real values and therefore the model improves more effectively.

This study aims to objectively evaluate the effectiveness of image enhancement techniques in the field of aviation on crashed aircraft and to reveal the potential of these techniques in security and analysis applications. In this way, it is aimed to detect electronic, mechanical and structural damages of aircraft more effectively and to increase the safety of the aviation industry.

5. Conclusion

This study aims to reveal the potential of the methods used in security and analysis applications by evaluating their effectiveness on low-light ambient images of crashed and crashed aircraft from an objective perspective. In this process, where machine learning algorithms are applied, image enhancement methodologies are used to determine the electronic, mechanical and structural damages of aircraft in more detail and precision. Finally, the findings demonstrate the effectiveness of the techniques used on crashed aircraft and can be used in aviation safety and analysis. This study may shed light on future research, aiding advances in image processing, image enhancement, and machine learning in the aviation industry.

Ethical approval

Not applicable.

Conflicts of Interest

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

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Redundancy in Automatic Flight Control System Design for A General Purpose Helicopter

Mutullah Eşer[1*], Berk Akın Yıldız[2], Umut Türe[3]

[1*]Ankara University, Department of Electrical and Electronics Engineering, Ankara, Türkiye. (eserm@ankara.edu.tr)
[2] Turkish Aerospace Industries, Department of Autopilot Systems, Ankara, Türkiye. (berkakin.yildiz@tai.com.tr)
[3] Turkish Aerospace Industries, Department of Autopilot Systems, Ankara, Türkiye. (umut.ture@tai.com.tr)

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Abstract

Redundancy is a popular concept among autopilot design engineers due to the importance of safety in aviation. The main goal of redundancy in autopilot design is to eliminate or minimize the loss of a system in case of single point failures. In this study, the designed autopilot flight control system with redundancy for a general purpose helicopter is presented, along with the simulator and flight test results of the design. The designed system combines the elements of direct and functional redundancy to achieve a full redundant system. The simulator tests were done in the flight control simulator in Turkish Aerospace Industries (TAI) in Ankara, and the flight tests were done with the general purpose helicopter over Ankara Mürted airspace. The results of these tests verify the proposed design, ensuring the safety of the flight under different failure scenarios.

1. Introduction

In aviation, safety is vital, achieved through redundancy to boost reliability. Redundancy can be achieved in many ways and in the scope of this study, the redundancy in AFCS (Automatic Flight Control System), which is one of the fundamental systems of an aircraft, is presented. The main purpose of the AFCS is to reduce the workload of the pilot, to increase the fuel efficiency during operations, and increase safety of flight, and today, almost every modern aircraft is equipped with an AFCS (Padfield, 2018). Although certain designs can be made to prepare for failures, some cannot be foreseen, nor can they be prevented, regardless of the quality of the equipment used in the autopilot system. Similarly, it is impossible to take into account every scenario that can happen before, during or after the flight. Therefore, having a replica of a system in the aircraft can prevent single points of failure from resulting in major or catastrophic failures. Where major failure causes significant reduction in the functional capabilities of the aircraft, and catastrophic failure resulting in the total loss of the aircraft.

A system having n number of sub-systems that can execute the tasks of the main system is called an n-redundancy system (Schafer et al., 2018). In order to predict the malfunctions and the faults that can occur, it is important to understand the behavior of all the subsystems with the help of Fault Tree Analysis (FTA). A malfunction does not only affect the system it has occurred in, contrarily, it tends to spread. For this reason, the relation between the component and the rest of the system is as important as the relation between the duplicate components when it comes to redundancy. In case of a failure, the autopilot algorithm should not jeopardize the safety of the system and should operate as robust as possible. Thus, the main goal of the redundancy in the autopilot system is to minimize the damage done and prevent the loss of a system in case of single point failure.

In general, redundancy in an aircraft can fundamentally be achieved in two ways. First, by designing a system having multiple elements all working simultaneously, where each element can operate the system by itself if necessary, and second, by having a standby equipment that can take over the tasks of the faulty one. This can also be done for different levels of equipment, where either the system itself or a component of it can be backed up (Downer, 2009).

In this study, the work done on the hardware, also known as direct, and software, also known as functional, redundancy of AFCS in a utility helicopter is presented. The developed redundancy system has been tested and verified with different malfunction scenarios in HIL (Hardware in the Loop) laboratory tests and in flight tests. The first benefit of the proposed design is maintaining the functionality of the system in case of a malfunction by being an aggregate of several subsystems, and increasing safety by disengaging the autopilot upon detecting that the system can no longer function properly due to a critical fault. The second benefit is being a system where both direct and functional redundancy is utilized.

2. Automatic Flight Control System

Aircrafts have 6 degrees of freedom and each require a form of control during flight. This control can be done by a computer, just like it can be done by a human. Automatic Flight Control System (AFCS) is a system of hydraulic, mechanical and electrical components that can control the aircraft under certain circumstances (Padfield, 2018). AFCS has three main components: sensors, computers and actuators, which can be seen in Figure 1. Sensors are used to measure the relevant parameters and transmit the necessary information to the computer. Computers, which may contain electronic, mechanical or other forms of processing, convert the information coming from the sensors into the signals which are fed to the system output devices (Newman, 1994). The actuator converts the computer signals into a form which will result in the necessary helicopter control movement.

In our system, the AFCS is a conventional four axis limited authority flight control system with conventionally configured cyclic, collective and tail rotor pedal flight controls provided for pilot interface. AFCS architecture is based on two Flight Control Computers (FCC) and their peripherals which provide Fail/Safe operation. The system gives full control authority to the pilot, regardless whether the autopilot is engaged or disengaged. This in turn means that in case the autopilot is engaged and the pilot controls (cyclic, collective and pedals) are controlled by the autopilot, the pilot can still override these controls and suspend the autopilot commands by moving the controls manually.

In aircrafts, such AFCSs employ feedback control to increase the stability of the aircraft, reduce pilot workload, reduce the effect of transients such as gust, and increase flight comfort (Newman, 1994).

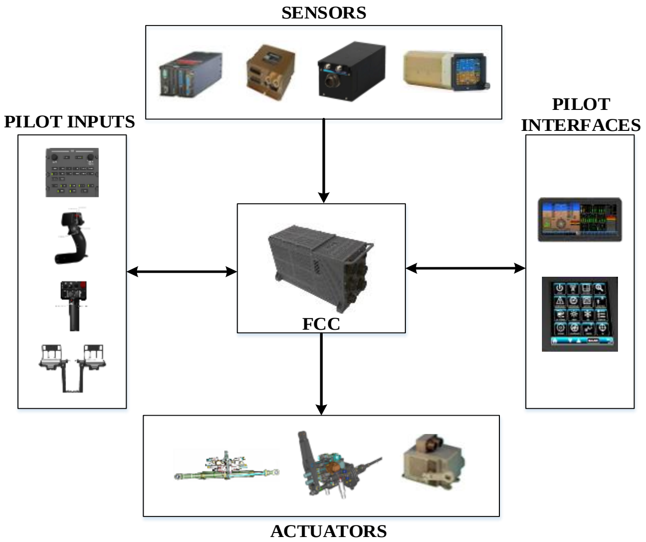


Figure 1. AFCS interface

The AFCS has two main modes, SAS and ATT, and several upper modes such as IAS (Indicated Airspeed Hold) and HDG (Heading Hold). FCC receives mode selections from flight control panel.

The SAS (Stability Augmentation System) improves the handling characteristics of the helicopter by damping the effects of the short-term external aircraft disturbances on pitch, roll and yaw.

The ATT (Attitude Hold) provides long-term attitude retention and stabilization for hands-off flying. The pilot can override the AFCS ATT mode at any time by taking over the controls manually.

The upper modes enable the pilot to focus on other tasks rather than keeping the helicopter at a certain altitude, speed, orientation etc. during flight and can only be engaged from ATT. The details about the designed AFCS architecture is given in section 3.1.

3. Redundancy in AFCS Design

The safety-critical systems in aircrafts have to comply with certain safety and architectural standards, and aircrafts with several of these systems are where redundancy is the most prominent. For this reason, redundancy is a popular concept among AFCS algorithm design and system engineers.

In this section, a brief summary of the works done in literature on this topic is given, and afterwards the steps in redundancy in AFCS design is mentioned.

Ahlström et. al. (2002) performed simulations on different fault handling strategies for distributed flight control systems. JAS 39 Gripen is used as a platform for the simulations. The redundancy for the system is realized by having a separate controller each control surface, for a total of 7 actuator nodes, each receiving data from all the sensor nodes, which are also duplicated. To handle the communication between the nodes, a scheduled communication system is implemented where each node can send message only in their predetermined assigned cycle, which prevents the nodes from sending values outside of their cycle in case of a failure. The three methods discussed are transferring the context of a non-faulty actuator node to the faulty one, letting the fault go through and be handled by the actuator nodes fulfilling replica determinism, and there being no recovery action, letting the disturbed context be corrected by subsequent sensor inputs and approach the non-faulty actuator nodes. The first two methods generated faulty output for only one operation cycle after which they were corrected by the mentioned strategies and give the same results as the non-faulty ones, however they can experience consensus problems. The latter method does not suffer from such problems but also perform worse, always having a small amount of error.

Amato et. al. (2006) proposed nonlinear observer based functional redundancy algorithm for detecting and isolating sensor faults on aircraft. The proposed algorithm decides to isolate the faulty signal if a fault has occurred.

Zhi-hong et. al. (2006) designed a dual-redundancy electrical and mechanical actuator system for improving safety of aircraft. Mechanical redundancy reduces two mechanical outputs into one without using conventional controllers. This way, the controller design is simplified, along with increasing the stability and the reliability of the system in case of a malfunction.

Schafer et. al. (2018) proposed a mixed-integer linear programming model to design the redundancy in an aircraft's door control system. This is a network system and has k-redundancy for the functions.

The main goal in designing an AFCS with redundancy is to keep the systems functioning properly and to not endanger the flight upon the malfunction of a system component. Usually, the design in made by expecting the system to fail in a way that is foreseen or predicted, however, there can be unexpected failures that make the design process harder.

The terms used commonly in designing autopilot systems with redundancy elements are summarized below:

Redundancy: The provision of additional or duplicate systems, equipment, etc. that function in case an operating part or system fails, as in a spacecraft. In other words, the existence of more than one means for accomplishing a given function. Each means of accomplishing the function need not necessarily be identical (Li & Shi, 2020).

Redundancy Management: The portion of the system logic and control (hardware or software) that detects and isolates failures in a fault-tolerant system; and reconfigures the system after the failure is detected and isolated so as to maintain the same or a reduced level of operation.

Active Redundancy: A type of redundancy whereby all redundant items are operating simultaneously, rather than being activated when needed.

Standby Redundancy: A type of redundancy whereby the alternative means of performing the function is inoperative until needed, and is activated upon failure of the primary means of performing the function.

Fail Operational: A design feature that enables a system to continue to operate despite the malfunction or failure of one or more components.

Fail Passive: Refers to the quality whereby the failed device or system ceases to create any active output.

Fail-Safe: Refers to the quality whereby the control device or system ceases to function, but the conditions or consequences resulting from the failure are not hazardous and do not preclude continued safe flight. The condition following failure may be completely passive, or it may involve driving to a predetermined non-active condition.

Failure: Describes the state of having failed. In dealing with fault-tolerant flight control systems, a failure occurs when a device within the system fails to function within prescribed limits without regard to the cause of the failure. Thus a failure may be: (a) any loss of function of any element within the control system; (b) loss of supply power to the system; (c) erroneous hardover conditions or loss of control intelligence at the signal input; or (d) any out-of-tolerance condition that exceeds normal operating limits.

Lane: An independent computational unit which includes processor and input-output capability inside a Flight Control Computer.

Redundancy increases the number of elements in both the software and hardware, which can result in unexpected interactions between the components. This result in a system that is more difficult and complex, to design and to understand (Zolghadri, 2000). Therefore, the autopilot should be designed keeping in mind these interactions, and necessary measures should be taken to prevent undesired responses stemming from the complexity. This results in additional designs in algorithm level to handle the redundant systems, such as the communication delay between the two FCCs, or the malfunction of a sensor.

In autopilot systems, there are two components to redundancy: direct and functional. To have an autopilot system with redundancy to work as expected, these two concepts must be designed to be in compliance with each other. If these do not comply with each other, the error risk increases in the system (Amato et al., 2006).

Direct redundancy is the replication of the physical systems such as FCCs, sensors, actuators, wiring, busses, and these components working in parallel with their counterparts. This way, if a component malfunctions, it can be detected and isolated from the system. However, functionality is not lost and the system keeps working as there is a back-up component. Therefore, the advantages of direct redundancy can said to be the isolation of the malfunction, and safety (Li & Shi, 2020). The disadvantage stems from the necessity for additional physical components, which result in bigger physical space requirement, higher cost, heavier overall component mass, additional wiring and increased system complexity.

Functional redundancy are the special algorithms that determine whether the system functions properly or not, and also make the logic decision enable correct operation. These algorithms are responsible of several critical tasks such as deciding on which of the redundant sensor data to use, making sure the FCCs are in the same state, checking whether the actuators have similar displacements as they should be receiving similar commands from the FCCs and so on.

3.1. Direct redundancy design

Direct redundancy in AFCS is physically having the duplicate of critical systems such as FCC, sensor, wiring and actuator. This hardware redundancy requires the presence of one or more sub-systems or equipment in the design. Direct redundancy can be implemented in two ways: hot (active) and cold (standby).

In standby redundancy, the redundant element is activated only in case of a failure in the main unit by means of a switching and the standby unit is often not energized until operation. Active redundancy requires that both main and redundant units to be operational during the whole mission period. In Figure 2, schematic Reliability Block Diagram presentations of two units (A and B) which are non-redundant, active redundant and standby redundant are given respectively.

According to the results from Fault Tree Analysis, the systems that should have direct redundancy are determined. These systems are processing units, both inside the FCCs and between them, sensors, AFCS related electrical power systems, control panels and actuators.

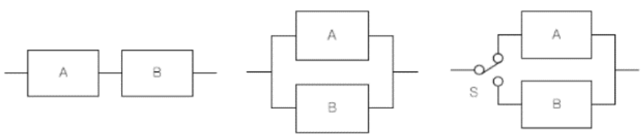


Figure 2. Types of direct redundancy

The designed AFCS system has two channels. Each channel consists of an FCC and a series actuator for each main rotor actuator, MRA, and tail rotor actuator, TRA.

Each FCC has dissimilar processors with different real-time operating systems. In each FCC, there are two independent CPU and IO modules and these CPU-IO pairs are called a lane. Both FCC lanes shall provide the same processing at the same time in order to ensure that both lanes provide the same outputs in absence of hardware failures or common mode failures. The check mechanism to make sure that both lanes generate the same outputs is given as a flowchart in Figure 3.

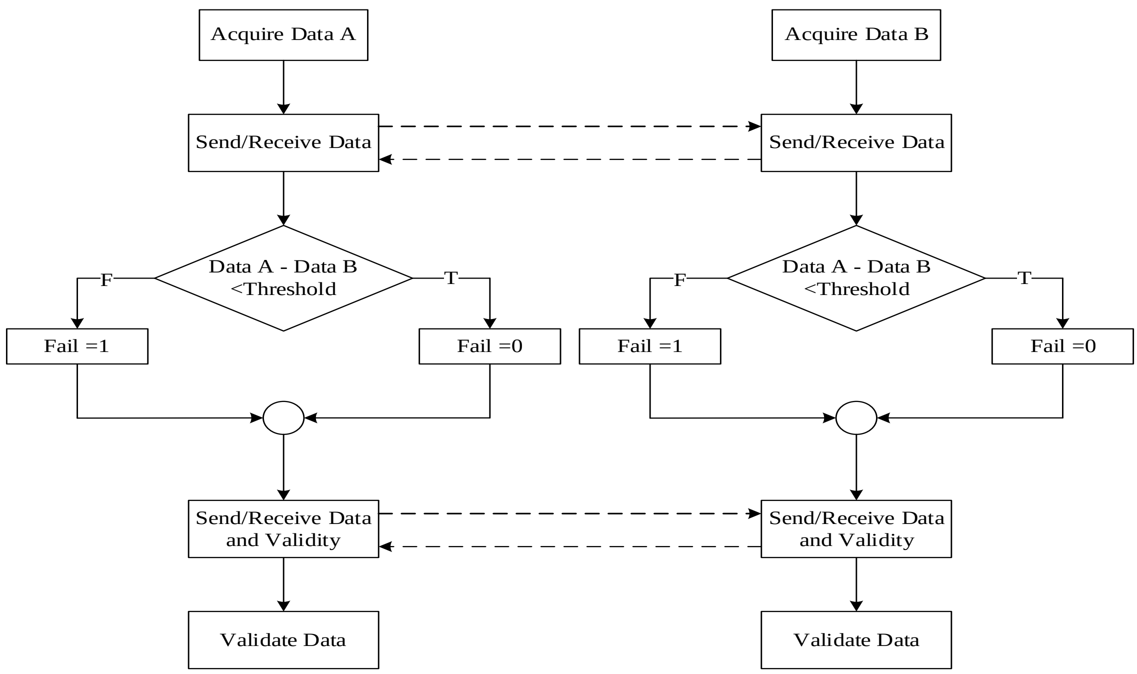


Figure 3. Lane check algorithm

The communication between these lanes is called LDL (Lane Data Link) which shares the input information and the control commands between them. The LDL is implemented from two serial "Point to Point Ethernet Busses" with transformer isolation and galvanic isolation to prevent the cascade of any failures within the one lane coupling into the other lane via the LDL. Data transferred across the link is monitored using "Cyclic Redundancy Checks" and ethernet protocol checks to detect for data bus and data transfer errors. The LDL Interface provides the capability to read the data of the other lane from the LDL RX buffer and to write the data to be sent to the other lane to the LDL TX buffer.

The communication between the FCCs where the mode information, CLAW (Control Law) commands, references and such are shared are maintained by the FDL (FCC Data Link). In case of FDL failure, the system cannot operate with dual FCC redundancy, but the helicopter can still fly with single FCC and autopilot. The FDL and LDL architectures are shown in Figure 4.

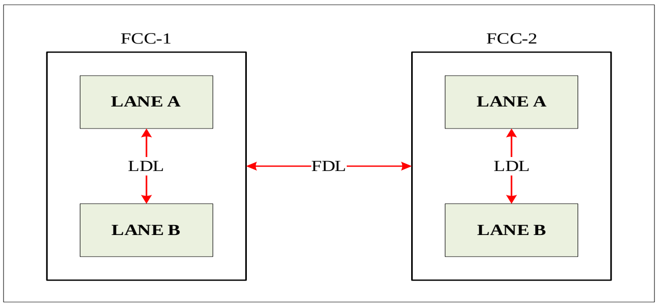


Figure 4. Communication architecture of AFCS

AFCS shall use redundant sensors, EGI (Embedded Global Positioning System Inertial Navigation System), ESIS (Electronic Standby Instrument System), ADU (Air Data Unit), RADALT (Radar Altimeter), for core functions. The backup sources the sensor data can be received from are given in the Table 1.

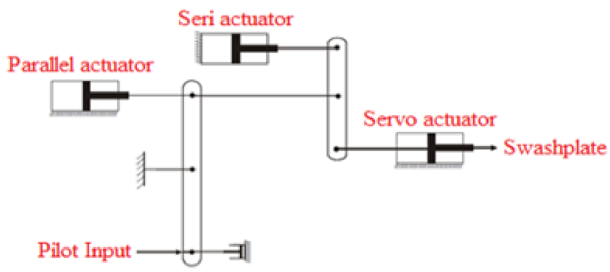
Table 1. AFCS sensor redundancy

Equipment	Backup sources
EGI1	EGI2, ESIS
EGI2	EGI1, ESIS
ESIS	EGI1, EGI2
ADU1	ADU2, ESIS
ADU2	ADU1, ESIS
RADALT	-

Both of the FCCs are connected to all the sensors to have data availability in case a bus fails. Within Channel-1, the EGI-1 is the primary source for basic data and EGI-2 is the redundant source for integrity validation of basic data, similarly, within Channel-2, the EGI-2 is the primary source for basic data and EGI-1 is the redundant source for integrity validation of basic data. EGI1 and EGI2 sensors are used as primary sensors whereas ESIS is used as an arbiter sensor in the event that the sensor values differ from each other. The validity of the sensor data that is sent to the FCCs and their logical controls are done in Sensor Selection module, which provides functional redundancy. In normal operating conditions, both of the FCCs function actively, receiving data from sensors and sending commands. The power busses that supply the FCCs are also duplicated. Both FCCs have primary and secondary power grids. The details are given in section 3.2.

The series actuators that work in series with the pilot commands and execute the generated AFCS command are also duplicated in each axis. Each Main Rotor Actuator (MRA) and Tail Rotor Actuator (TRA) has two independent SCAS actuators which are integrated on their own chassis to provide the full redundant actuator system. Two FCCs control SCAS actuators with Active/Active mechanism and control Trim actuators with Active/Standby mechanism. In Active-Active mechanism, each FCC is active and drives its own actuators on the MRAs and TRA. In case of one FCC failure, other FCC continues to drive its own actuators. When it comes to trim actuators, there are four trim actuators, one for each axis, and these are controlled by the trim master FCC, decided by the algorithms in each FCC. In Active/Standby mechanism, the FCCs communicate to each other to decide who will drive the Trim Actuator. One FCC becomes the master drives the actuator, while the other waits in Stand-By. In case of any failure in driving (master) FCC, stand-by FCC takes over the control. The way the series and the trim actuators are connected to each other and to the system are given in the Figure 5.

Figure 5. Actuator structure



Additionally, the hardware redundant AFCS system architectural design is given in Figure 7.

The abbreviations used in the figure are: AHRS (Attitude and Heading Reference System), ADC (Air Data Computer), Radalt (Radar Altimeter), ESIS (Electronic Standby Instrument System), DCU (Data Concentrator Unit), IMD (Integrated Modular Display), and MRA (Main Rotor Actuator). Since the scope of the study is the design of a system with redundancy, the details of the components are not given.

3.2. Functional redundancy design

Functional redundancy means the use of logic and mathematical relations to ensure redundancy in the system.

The designed AFCS algorithm of the general purpose helicopter being worked on consists of 3 main parts which are System Govern, Logic and CLAW (Control Law), which is shown in Figure 6. A brief summary of these algorithms is given below, explaining their overall functionality, followed by the logical and mathematical modifications made on them for functional redundancy.

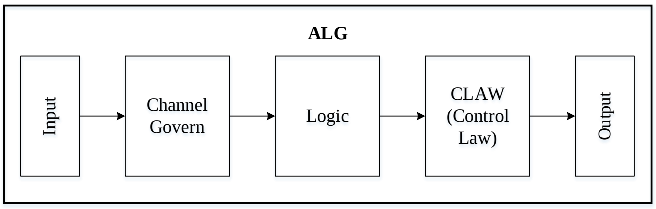


Figure 6. Algorithm layout

System govern: Manages system level algorithms. It allows or prevents the engagement of the autopilot by checking if all the necessary systems, such as the actuators and the busses, are working correctly and as expected. It also helps handle the information coming from the opposite FCC and decides which of the systems should be chosen as master for the upper modes.

Logic: Collects information from the sensors, pilot inputs and flight management system to determine which autopilot mode should be engaged and which reference values should be followed. Logic also handles the transition between the modes that can arise from speed transitions or pilot changing modes. These transitions are crucial for both safety and comfort of flight, they should be smooth and handled correctly. Therefore, the design should be approached with utmost care and the logic should be analyzed in terms of both safety and performance thoroughly. The following points should be considered in Logic design:

- Engagement conditions, determining when should a mode be engaged.
- Disengagement conditions, determining when should a mode be disengaged, or how can the pilot disengage a mode.
- Reference management, determining how the pilot can change the reference values, whether it be an attitude or upper mode reference such as airspeed.
- Limit values, determining the minimum and the maximum references considering the abilities and the limitations of the helicopter.

CLAW: Algorithms that calculate the commands that should be sent to the actuators to achieve the desired helicopter references. There are certain aspects of the control law algorithms that become more complicated with redundancy, increasing in complexity as the number of redundant systems increase. The commands should be handled in such a way that the CLAW algorithms in each FCC is guaranteed to generate similar commands, so that if one fails, there is no significant change in command to affect the helicopter. These transitions should be as smooth as possible as to not discomfort the pilot or to not strain the hydraulics of the actuator.

Basically, system govern determines the state of the systems, deciding whether the FCC is capable of controlling and letting, or preventing, the autopilot to engage. Logic on the other hand determines the state of the autopilot. It decides on which mode should be engaged, which functions should be active and feeds this information to CLAW. CLAW takes this information and, along with the input from sensors, does the necessary calculations to determine the necessary command to maneuver the helicopter or hold the attitude, whichever the pilot desires.

The redundancy starts at System govern module. The algorithm checks if both FCCs are suitable for operation and decides between one channel and two channel modes. This decision is made by ensuring the following conditions are met:

- Both channels are powered up;
- The FDL working correctly;
- Both channels are synchronized;
- Both channels are operating with the same software and parameters.

In two channel mode, the FCCs communicate with each other through FDL with a transport delay taken into account in the design. The algorithms that use the information from the other FCC execute few cycles after the main logic to handle this delay, which are called second phase logic.

The Logic module has the sensor selection, second phase logic, reference management, command management and FD (Flight Director) mastership algorithms for redundancy and redundancy management.

Starting from the input, to ensure that the correct data is used in the control law calculations, a sensor selection algorithm is used. Designed architecture include dual navigation sensors and these sensors will feed flight displays, AFCS and other subsystems if required. Sensor selection algorithm used to find best usable/healthy source between multiple sensors.

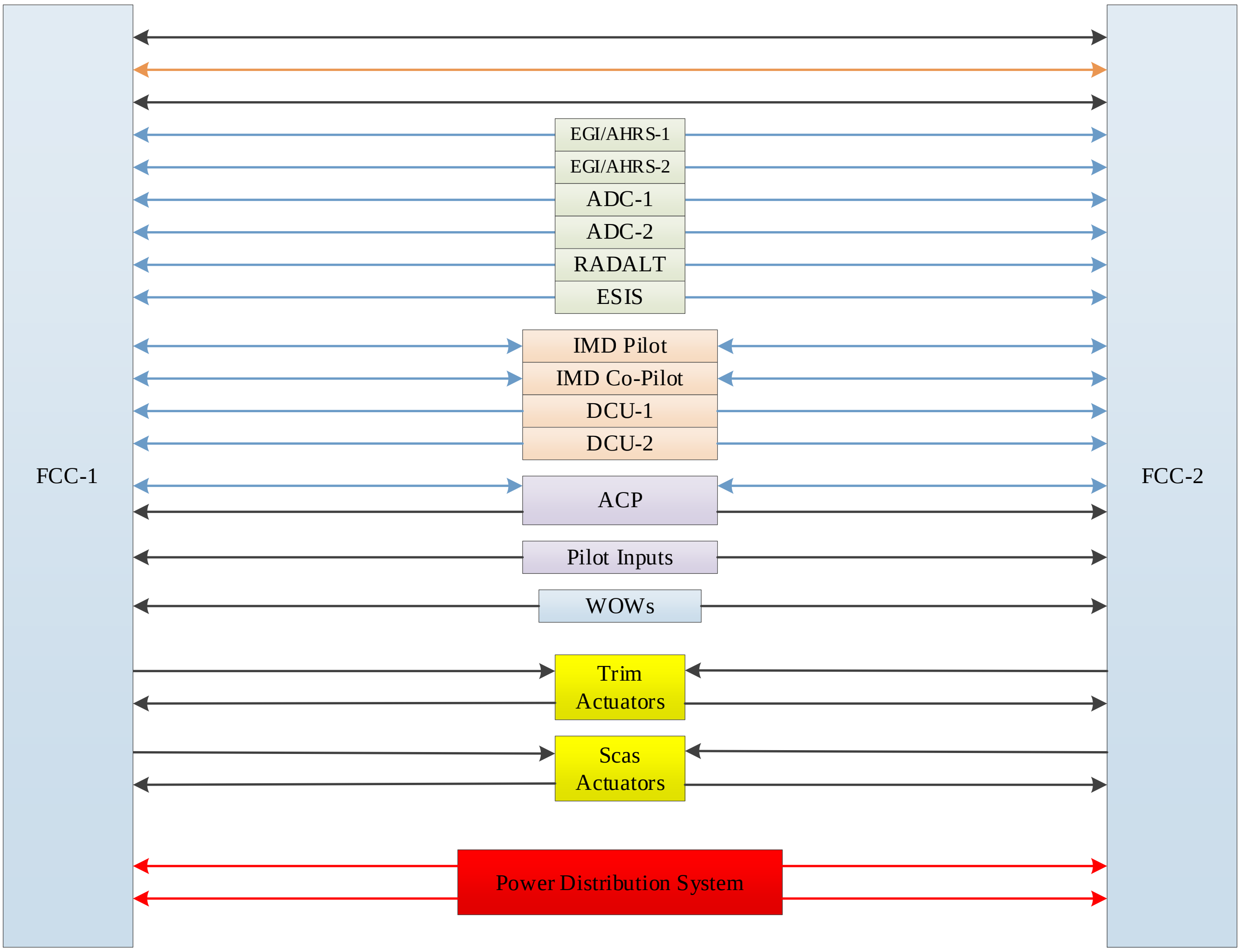


Figure 7. Hardware redundant AFCS system architecture

The Sensor Monitor and Selection unit operates independently from the state of the channel and it continuously gets the computed information to the potential user. The flow chart of the attitude source selection in the AFCS is given in Figure 8.

The AFCS provides the monitor function to determine the usability of attitude parameters fed by the two primary sensors EGI1 and EGI2 to support the selection of the source for the AFCS basic control functions. This algorithm compares the data from the dual redundant AHRS equipment and calculates the deviation of the data between the sensors. Difference is calculated by taking the difference between the sensors.

$$difference = |\text{sensorX} - \text{sensorY}| \quad (1)$$

where, sensorX/sensorY pair refers to EGI1/EGI2, EGI1 /ESIS, and EGI2 / ESIS.

If the difference is less than a pre-determined threshold value, each FCC uses their assigned sensor's value e.g. FCC1 uses AHRS1 pitch angle value, FCC2 uses AHRS2 pitch angle value. However, if the difference exceeds the threshold, the electronic standby instrument system, ESIS, is used as an arbiter, as without another sensor, it wouldn't be possible to determine which of the sensors give the correct data. The sensor which gives a closer value to the arbiter is deemed as the correct value, and the data is sent to both FCCs. If neither value is within a certain range of ESIS, the sensors enter a fail state instead of sending wrong values.

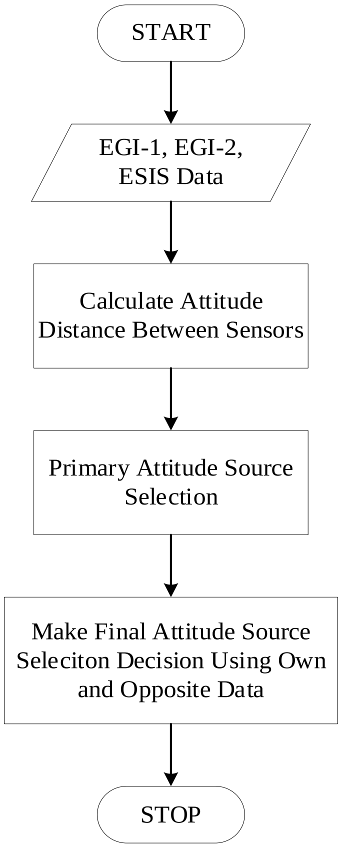


Figure 8. Attitude source selection flowchart

One of the sub-logics in second phase is a logic that compares the own reference values of both FCCs and averages them to obtain final reference (Equation 2). The own reference refers to the reference value computed before the second phase logic in each FCC separately. Afterwards this common reference value is used to calculate the error and multiplied with gain to calculate similar commands (Equation 3-4). However, because the sensor data can differ within a certain range of each other, the integrator commands could deviate between the two FCCs over time, despite the references being the same. To prevent this, the integrator data is sent between the computers and are equalized. Additionally, to ensure that the FCCs share the same states and generate similar commands, upon engaging the autopilot, if the other autopilot is already engaged, the filter states of the engaged autopilot is sent to and used as initial condition by the previously disengaged FCC. Otherwise, the filter outputs wouldn't match and different commands would be observed.

$$final\_reference = (\text{own\_FCC1\_ref} + \text{own\_FCC2\_ref})/2 \tag{2}$$

$$FCC1\_cmd = (\text{final\_reference} - \text{FCC1\_sensor}) \times \text{gain} \tag{3}$$

$$FCC2\_cmd = (\text{final\_reference} - \text{FCC2\_sensor}) \times \text{gain} \tag{4}$$

The status information and the decisions of the FCCs are also sent between them using FDL. By comparing the "health" of the FCCs, the more suitable one is chosen as the master to drive the trim resolver, as there is only one. Even so, the trim commands are compared to each other and averaged before being driven by the master. This way, even if one FCC loses communication with the trim actuators due to software or even hardware fault, the other FCC will take over the mastership and continue normal operation. By looking at a wider range of criteria, the healthier FCC is chosen as flight director, FD, master. Being FD master means that, despite the upper mode commands still being calculated by both FCCs, the final commands sent belong to the master FCC, as it is the healthier, and more reliable one. The FD master FCC still uses the information from the other FCC similar to basic mode operation, but solely uses its own sensor and forces its own FD command in the axis the upper mode is engaged. In case of a failure or degradation, the mastership is taken over by the other FCC and because the calculations are done on both FCCs regardless of the mastership, this transition is smooth and no severe command change is observed.

4. Test Results

The tests results were gathered both from simulator flights and flight tests. The flight tests were done with the Turkish Light Utility Helicopter GÖKBEY over Ankara Mürted airspace and the simulator flights were done in the System Integration Laboratory in Turkish Aerospace Industries, TAI, with Hardware-In-The-Loop tests. The simulator shown in Figure 9 has a physical replica of the helicopter cockpit along with the FCCs, displays, control panel and the trim actuators whereas the series actuators and the sensors are emulated.

Several tests were done to show different aspects and responses of the algorithm in terms of redundancy. In the first test case both FCCs are in Attitude mode. As seen in Figure 10, FCC1 is disengaged in simulator environment and re-engaged while changing only the heading reference and the response of FCC2 is observed. At t = 2287s, the FCC1 autopilot is disengaged manually, which can also happen due to a malfunction in flight, and the own reference value is directly taken as the current sensor value for FCC1. However, the final reference value does not change, as FCC2 now acts as master and forces its reference to FCC1. Upon re-engagement, the own reference of FCC1 is initialized to the existing reference value, which belongs to FCC2. This way, during both transitions, no change in the autopilot commands is observed as both FCCs make their own calculations and the disengagement does not affect the existing command, an example of hot (active) direct redundancy. Similarly, the newly engaged autopilot takes the existing values of the already active autopilot, this way the calculations converge and become similar, as desired and expected, much faster. Therefore, the transition is smooth and happens without any discomfort to the pilot and does not endanger the safety of flight.

Figure 9. TAI flight simulator

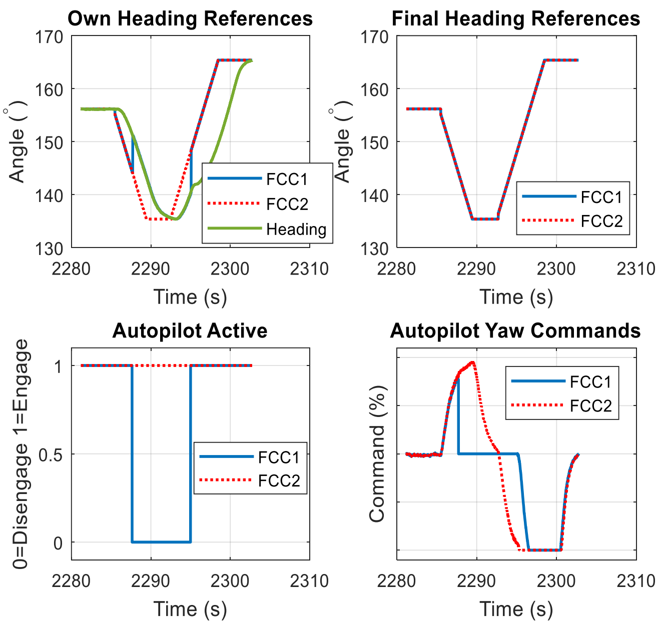


Figure 10. Reference management test

In the second test case, the FCC1 autopilot is disengaged during an agile maneuver where the autopilot generates high commands. The disengagement happens at t = 2373s, at which point the commands of FCC1 are forced to 0, as an extra safety precaution since it cannot move the actuators anyway. The FCC2 commands are not affected by this disengagement, as seen in Figure 11. Even though the FCCs communicate with each other and use information from one another, they can still operate independently an as standalone in case of failure. This way, as seen here, the malfunction of one does not affect the other. The rates are also examined as the rate of change in angular rates, angular acceleration, is felt as a force by the pilots. This change is expected to be minimal as to be smooth and not discomfort the pilot. In Figure12, it can be seen that there is little no significant change in rates when one of the autopilots disengage.

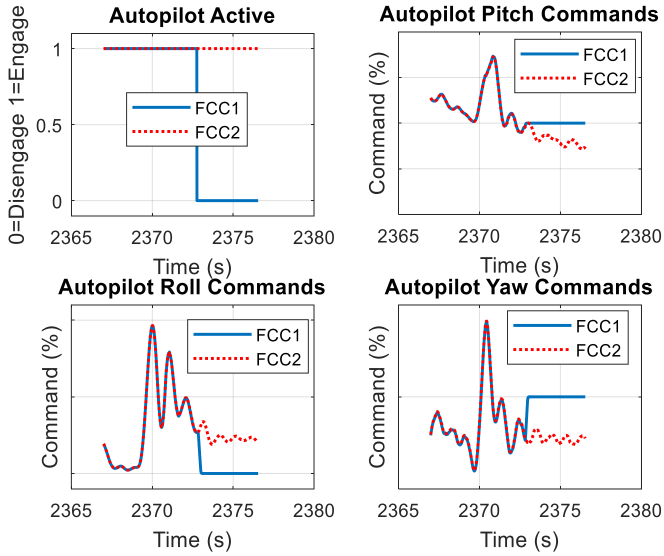


Figure 11. Command change during disengage

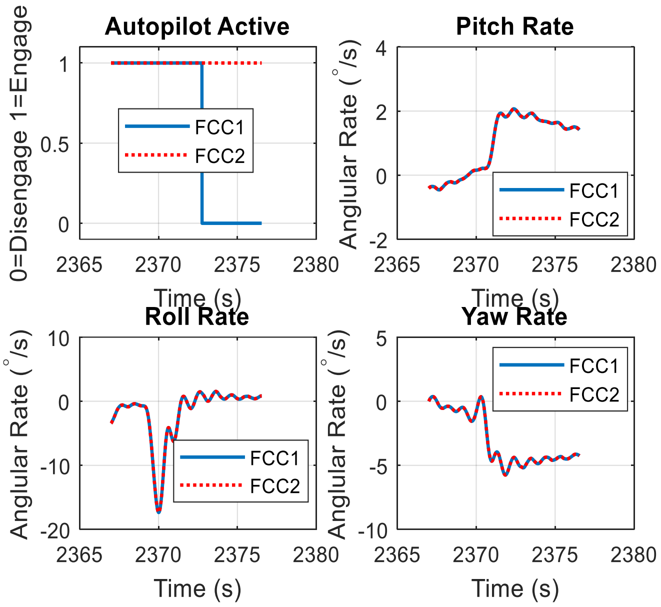


Figure 12. Rates during disengage

In the third test case, FD mastership transition test is made in the simulator. Initially, the IAS upper mode is engaged and FCC1 is FD master. Its commands are being sent to the actuators to control pitch to hold the desired airspeed. FCC2 is also doing its own calculations and sending commands to its own series actuators, however, because it is not the master, the command it sends is overridden by FCC1. This is done to ensure that the healthier FCC sends the upper mode commands, which is where the upper modes differ from SAS and ATT, since upper modes require more parameters from sensors. The mastership transition is made at t = 2577s, where FCC2 becomes the master after only a few operational cycles. At that instance, the FCC1 commands are forced to zero, its reference equated to current airspeed, and FCC2 now sends its own calculated commands to the actuators. Because it was constantly running its calculations, the command change and pitch rate change is almost nonexistent during the transition, which can be seen in Figure 13.

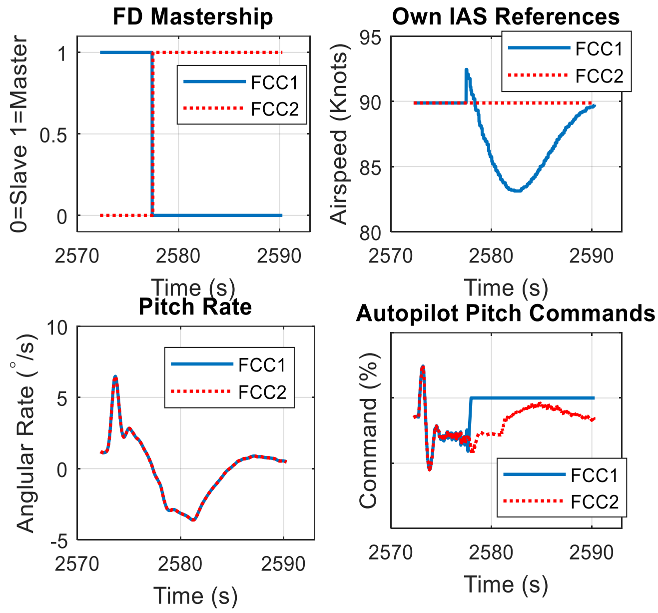


Figure 13. FD mastership transition

In the fourth test case, trim mastership transition is made in the simulator. Initially, FCC1 is the trim master. Despite both FCCs calculating the command to be sent to the trim actuator,

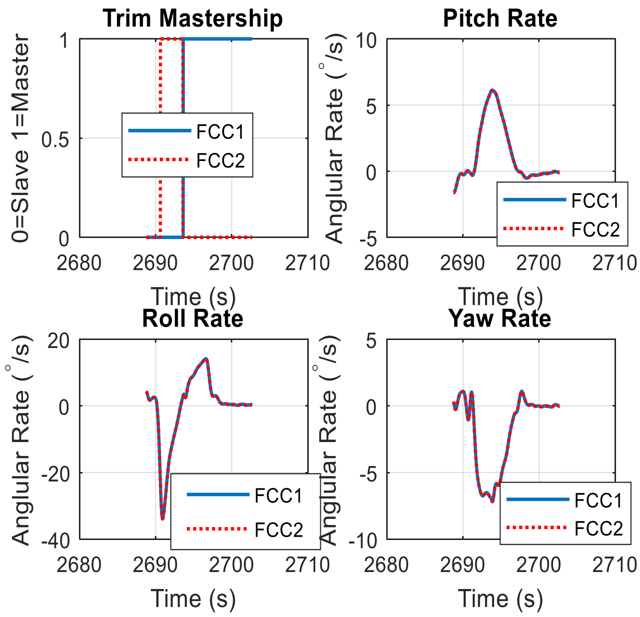


Figure 14. Trim mastership transition

FCC1 is the one that controls the actuator and since there is only one, unlike the series actuator where each actuator has its own actuator. At t = 2693s, the communication between the trim resolver and FCC1 is cut, which triggers a series of responses that transfer the trim mastership to FCC2 in a matter of few operational cycles. During this, the rates are examined, which as expected show no change in pitch and yaw, and only a slight change in roll rate at the transition instance, but does not change its overall behavior, as seen in Figure 14. It can be seen that the transition happens smooth with little to no disturbance. Additionally, Figure 15 shows the trim actuators position during fourth test case.

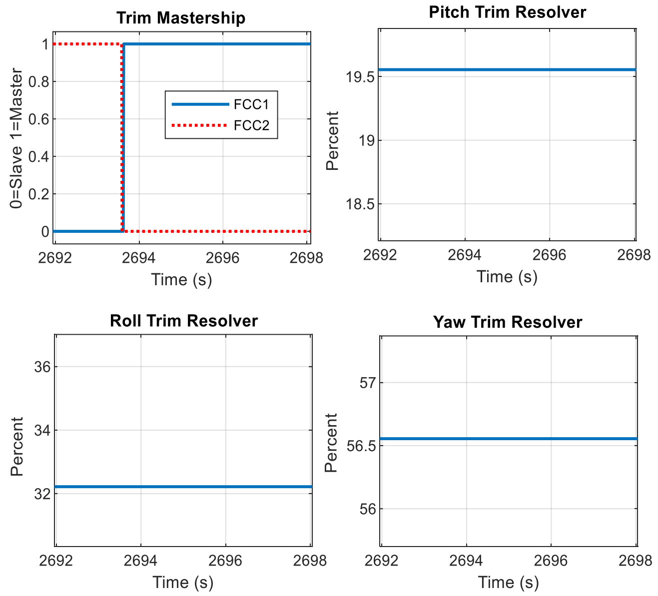


Figure 15. Trim actuator positions

In the fifth test case, the sensor redundancy is tested is simulator. Normally, FCC1 uses attitude data from EGI1, and in this case, the link between the sensor and FCC is cut at t = 2855s, at which point FCC1 starts to use the opposite side sensor, which is EGI2, as seen in Figure 16. During this, no loss of functionality occurs and both FCCs continue their operation as normal. At t = 2862s, the link between FCC1 and EGI2 is cut too, leaving FCC1 with no access to attitude data. The algorithm starts an internal clock and triggers sensor unavailable signal after some time. Once sensor unavail is triggered, FCC1 holds to last valid attitude data as its angles and no longer generates command. Both of these transitions happen without any disturbance as expected since FCC2 continues its normal operation and is not affected by the malfunction in FCC1. At t = 2910s, the links are restored and FCC1 return to its normal operations, receiving attitude data from the sensors. This transition also does not cause any disturbance in the system, to test that the FCC1 correctly receives the data and functions properly a small pilot input is given. From this test, it is seen that the loss of a sensor during flight does not cause a major effect and the flight can safely be continued thanks to redundancy of the sensors.

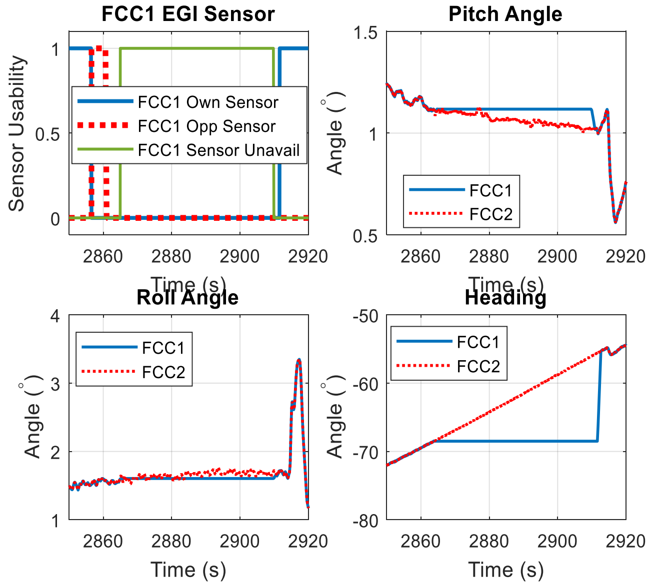


Figure 16. Sensor loss test

In the last test case, the second phase reference management is tested in flight. In Figure 17, it is seen that the EGI1 sensor of FCC1 and the EGI2 sensor of FCC2 give slightly different pitch angle data and therefore the references of these two FCCs are different, which would normally result in the two algorithms trying to hold the helicopter in two different pitch angles. However, these references are sent between the FCCs by the FDL and are used in second phase algorithm, taking the average of these two signals, to create final reference which is the same for both FCCs. This is a method of handling the sensor redundancy in the design, if left unattended, this case would decrease the overall performance of the helicopter and can lead to oscillatory behavior.

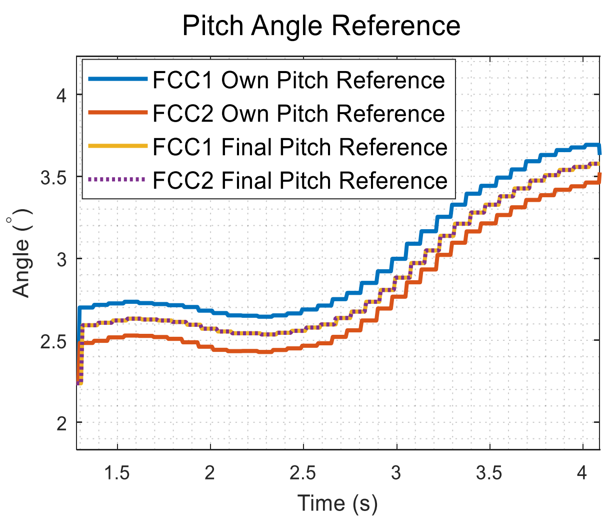


Figure 17. Reference averaging

5. Conclusion

The simulation and flight test results validate the proposed direct and functional redundancy design and meet the expected results. In case of a failure in the systems considered critical for the helicopter, the safety of the flight remains intact and the redundant subsystems can resume normal operation. Some of these cases include sensor failure, autopilot malfunction or mechanical failure such as trim failure, which are all tested and validated in the scope of this study. Additionally, several algorithms that are implemented to handle the dual FCC operation and its drawbacks are mentioned such as the second phase logic and mastership management. Despite the platform used in this study being a limited authority system, such measures are taken to ensure safety, which can further be improved in fly-by-wire flight control systems.

Ethical approval

Not applicable.

Conflicts of Interest

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

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The Mediation Role of Impression Management in The Effect of Job Security Perception on Task Performance: A Study on Airport Employees

Yeşim Kurt[*1], **İbrahim Rençber**[2]

[1*] Balıkesir University Edremit School of Civil Aviation, Department of Aviation Management, 10300, Balıkesir, Türkiye. (yesim.kurt@balikesir.edu.tr)
[2] Independent Researcher, Doctor of Management and Organization, 26005, Eskisehir, Türkiye. (ibrahimrencber35@gmail.com)

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Abstract

This study aims to reveal the relationship between the job security perceptions and task performances of airport employees and whether impression management has a mediating role in this relationship. The sample of the study consists of employees working at airports in Turkey. The data of the research were collected by online survey method using convenience sampling method between 5-17 October 2022. The IBM SPSS 25 and AMOS 24 statistical programs were used to analyze the data from 278 employees using structural equation modeling methods. According to the results of the analysis, it was determined that the perception of job security had a positive effect on job performance and a negative effect on impression management tactics. According to another important result of the research, there was a negative relationship between impression management and task performance. Finally, impression management did not mediate the relationship between job security perception and task performance.

This article was presented as a paper at the congress named "Karadeniz 13th International Conference on Social Sciences

1. Introduction

Recent developments in the global economy have included the business world in an uncertain process where competition has become more intense, costs have increased and productivity has become more important than ever. Mergers, downsizing, acquisitions, and economic crises in the business world in this uncertainty have made the threats to job security chronic. In this process, businesses' approaches to job security have been transformed, and life-long employment has been replaced by short-term or project-based working styles (Kraja, 2015, p. 19). On the other hand, in this process, not only businesses but also employees' perceptions of job security began to change, and a period full of anxiety began for employees where job security could not be felt (Fried et al., 2003, p. 787; De Witte, 2005; Probst et al., 2019, p. 306).

Today, while millions of employees feel this anxiety, the importance of job security has begun to increase, and this issue has become the focus of attention not only in the business world but also of academics from different disciplines (Ma et al., 2016, p. 123; Fried et al., 2003, p. 787). Numerous studies have been conducted examining the causes of job security or job insecurity, and its individual or organizational effects (Pilipiec, 2020; De Witte et al., 2016; Jiang & Lavaysse, 2018; Huang et al. 2012; Shoss, 2017; Huang, 2013). Performance is one of the important issues that are examined together with job security in the literature. Psychological contract theory and social change theory are the basic foundations used to explain the relationship between employees' perceptions of job security and their performance. Supporting the claims of these theories, according to the studies on this relationship, the level of perception of job security shapes performance in the workplace (Lu et al., 2017; Cheng and Chan, 2008; Huang, 2013, p. 2; Piccoli et al., 2021; Probst et al., 2019, p. 309; Piccoli et al., 2017, p. 1510).

Another important variable for employees who perceive a threat to their job security is impression management (IM). Employees' awareness of impression management strategies is also extremely important in managing this process (Huang, 2013, p. 2; Chawla, 2021; Ispas et al., 2014; Uziel, 2010; Kang et al., 2012, p. 316). According to the stress theory, employees who feel threatened with job security aim to reduce threats to job security by creating positive impressions on their performance (Folkman, et al., 1986; Putri & Purba, 2018, p. 273). Research on this subject also reveals an inverse relationship between job security and impression management (Kang, Gold, & Kim, 2012; Probst, Jiang, & Bohle, 2019).

In light of the above-mentioned theories and research, there are relationships between impression management, job security, and task performance (Agina et al., 2017, p. 221;

Chawla, 2021, p. 2). For the advancement of a field, it is important not only to say that there is a relationship but also to explain how this relationship is (Hayes, 2012, p.1). In this context, the role of impression management in the relationship between job security and job performance becomes an important research question (Probst et al., 2019, p. 307). Although there are few studies in the literature focusing on the relationships between impression management, job security, and job performance (Probst et al., 2019; Andriana & Purba, 2018; Huang, 2013, Kang et al., 2012), the relationship between these three important variables remains unclear in the aviation literature. protects. To eliminate this deficiency, it is aimed to reveal the effect of job security perceptions of airport employees on their job performance and whether there is a mediating role of impression management in this relationship if any. For this purpose, first of all, the conceptual framework related to job security, job performance, and impression management is given. Then, hypotheses between the variables were formed and tested with structural equation modeling. Finally, the findings were discussed and conclusions and recommendations were presented.

2. Literature Review

2.1. Job security perception

Job security can be defined as the protection of the employee against job loss. According to another definition, this concept is how safe and protected a person feels in the face of the fact that he unintentionally loses his job (Kraja, 2015, p. 20). While the environments in which employees feel safe about their jobs to create positive results for both the individual and the business, the opposite leads to job insecurity. In other words, job security and job insecurity perceived by individuals are closely related concepts. Perception of job insecurity refers to a situation where employees feel anxious about the continuity of their jobs, threat perception, and continuity, contrary to job security. Therefore, job security refers to a relaxing process about the future, while job insecurity refers to an anxious process about the future of work (Erlinghagen, 2008; De Witte, 2005; Purba & Muhammad, 2020).

Individuals' concerns about what they will experience in the future with their jobs or whether they will be able to maintain their positions are exacerbated in times of uncertainty when the economy is going badly. In such periods, workplaces closing and increasing mass layoffs negatively affect employees' perceptions of job security. Certain segments feel less job security and higher job insecurity outside of crisis periods. Job insecurity is higher among those working in part-time or seasonal jobs, recruits, and low-educational workers. In addition, the management style and communication style in the workplace also affect this perception (Schaufeli & VanYperen, 1992; Storseth, 2006; Kraja, 2015, p. 20).

Times when perceived job security is negative, that is, when job insecurity is felt intensely, can have individual and organizational consequences. Previous research has shown that low levels of job security (i.e., high job insecurity) harm employees' psychological well-being and work behavior (Loi, et al., 2011, p. 670). In environments where employees feel job insecurity, individual job satisfaction, organizational their commitment and organizational trust levels decrease. At the same time, in this process, while the physical and mental health of the employees is damaged, work-related low performance may also be experienced and even the intention to leave the job may occur in the employees (Clark, 2005; Sverke et al., 2002; Rosenblatt & Ruvio, 1996).

2.2. Task performance

Performance is related to the relationship between what the employee should do and what he/she does in the organizational environment. This relationship, which shows the job performance of the employee, is divided into two groups. These are task and contextual performance. Task performance is the degree to which an employee performs his or her basic duties. The effort made by the employee to complete processes related to job descriptions is the subject of task performance. These efforts refer to activities related to the basic technical processes by which the product or service is produced. The fact that employees perform the tasks expected of them by using their technical knowledge, skills, and experience is related to task performance (Borman & Motowidlo, 1997; Van Scotter & Motowidlo, 1996). In other words, in task performance, employees contribute to the technical core of the organization by performing the activities expected of them according to their job descriptions. Contextual performance is different from technical performance. Accordingly, employees voluntarily undertake responsibilities that are not required by their job descriptions, perform in extra roles, and shape the organizational and social environment (Borman & Motowidlo, 1997; Motowidlo & Van Scotter, 1994; Onur & Yürür, 2011).

The success of an organization in achieving its goals is related to the performance of its employees. Therefore, it is important to investigate which factors affect performance. Many factors affecting the performance of employees in the organization have been the subject of many studies. It has been revealed that concepts such as organizational support, organizational justice, respect for employees, transparency, rewards, clear and clear job descriptions, fair performance evaluation and promotion systems, training and motivation, and adopted common values have an impact on both the task and contextual performance of the employees (Orçanlı et al., 2019, p. 80).

2.3. Impression management

Impression management can be defined as the conscious or unconscious activities of individuals to influence others and to manage their perceptions (Leary, 2019; Jones & Pittman 1982). With these activities, individuals aim to create and manage the image they want about themselves in the eyes of others (Bozeman & Kacmar, 1997; Ralston & Kirkwood, 1999, p. 192). By managing impressions, individuals may benefit from rewards or avoid punishments at work, while seeking to be noticed by the environment, to be accepted, and to gain legitimacy and status (Elsbach & Sutton, 1992; Higgins et al., 2003). Impression management is a relationship with both social life and business life. Studies reveal that the impression method is associated with many organizational variables such as performance, job security, and leader-member interaction (Kang et al., 2012; Abbas et al., 2019; Agina et al., 2017).

There are various impression method tactics used by individuals in the impression management process. Various classifications have been made for these tactics by different researchers. (Bozeman & Kacmar, 1997; Jones and Pittman 1982; Chen, & Fang 2008). Despite this diversity, these tactics are divided into two groups and framed as assertive and defensive strategies (Crane & Crane, 2002; Tedeschi & Melburg, 1984; Schütz, 1998). Assertive strategies are about acting proactively and asking for more about impressions. In other words, the individual makes efforts to create positive impressions about himself/herself now and in the future. The most widely accepted assertive tactics in the literature are "ingratiation", "self-promotion", "exemplification", " supplication" and "intimidation" (Bolino & Turnley, 1999; Jones & Pittman, 1982; Crane and Crane, 2002). Defensive strategies are carried out to reactively manage negative situations and the threats that arise against these situations (Accra Jaja, 2003, p. 84). In essence, the individual avoids being evaluated negatively in the face of threat, does not want his image to be damaged, and develops tactics for this (Palmer et al., 2001, p. 35). These tactics are also used by employees in the business environment for purposes such as correcting the damaged image and preventing career damage. Justifications and apologizing are the two main methods of this tactic (Gardner & Martinko, 1988, p. 327).

3. Hypothesis Development

3.1. The relationship between job security perception and task performance

Job security is a situation related to how secure employees feel about the continuity of their jobs. Since it is a subject based on perception, it carries subjectivity, so there may be differences in the perception of job security felt between people who do the same job in the same organization (Cheng & Chan, 2008; Loi, et al., 2011, p. 670). When this perception is negative, that is, when employees feel low job security, they face various negative consequences. One of these results is related to the employees' ability to fulfill their responsibilities, that is, their performance levels. According to this, the degree of fulfillment of responsibilities of employees who do not feel job security decreases and there is a decrease in their job performance. On the contrary, it can be said that employees who feel high job security will have a higher level of fulfillment of their duties, that is, their job performance. Various theories are used in the literature to explain this relationship (Demerouti et al., 2001; Hobfoll, 2001; Loi, et al., 2011, p. 670; De Cuyper et.al., 2020).

Psychological contract theory focuses on the debtor-creditor relationship in the relations between employees and employers, that is, the obligations of the parties to each other. This theory, which includes two different types of contracts, transactional (short-term, clear-frame) and relational (long-term, trust-based), is also effective in explaining the relationship between performance and job security. Accordingly, the perception of long-term job security can be considered a symbol of the relational contract (Lester et al., 2002; De Meuse et al., 2001). As trust increases, the relational contract becomes stronger and the employee's performance is shaped accordingly. Otherwise, there is a breach of contract and the employee can punish this with his/her performance (Kraimer et al., 2005, p. 390-391; Vander Elst et al., 2016; Probst et al., 2019, p. 309).

Social exchange theory also focuses on exchanges between employees and employers. Employees who create safe conditions their employers reward their employers with higher performance by being motivated (Staufenbiel & König, 2010; Ma et al., 2016, p. 124). In other words, employees increase their performance in the face of certain organizational incentives. For this reason, employers should maintain their incentives as a requirement of social change. Job security is one of these incentives (Lu et al., 2017, p. 3). Employees fulfill their duties at a higher level as a requirement of the equal exchange principle in return for job security (Lu et al., 2017, p. 8; Probst et al., 2019, p. 309; Piccoli, 2017, p. 1510). In light of all these theories, the following hypothesis was developed in this study regarding the relationship between job security perception and task performance:

H1: The perception of job security has a positive effect on job performance.

3.2. The relationship between job security perception and impression management

It is known that uncertain situations in the business world pose a threat to employees' perception of job security. In such situations, managing employees' impressions becomes a more strategic tool for job security. “Who can be fired in cases of uncertainty?” For the employee who asks the question himself, motivation is created to get away from this threat. Impression management becomes an important agenda of this motivation (Huang, 2013, p. 4; Kang et al., 2012, p. 316).

Along with the ability to monitor themselves, employees develop proactive strategies to create impressions that will increase their job security (Huang, 2013, Putri & Purba, 2018, p. 272). This goal-oriented behavior of employees can be self-focused or top management-oriented. Top management, which is the target of impression management tactics, has a direct say in deciding who stays in the organization in case of significant organizational change such as downsizing, layoffs, and restructuring. Therefore, the impression management process used to create the desired image in senior management can have critical consequences for employees. In summary, it is reasonable for employees to use impression management to avoid the perceived threat of potential job loss, and to use these tactics as a preventive measure to pursue their careers (Probst et al., 2019, p. 310; Andriana & Purba, 2018, p. 22; Purba & Muhammad, 2020, p. 82).

One of the theories explaining this relationship between job security and impression management is problem-focused coping based on Transactional Stress Theory. Here, the individual evaluates the situation he lives in and determines its importance for himself. If the importance is great, it is perceived as a threat and stress arises. When job insecurity creates a threat that needs to be dealt with, impression management is used as a tool to overcome this threat (Putri & Purba, 2018, p. 272-273; Folkman, et al., 1986). The theory of conservation of resources also supports that employees can develop proactive strategies when they perceive a threat to an important resource such as job security (Hobfoll, 2001, p. 351). Accordingly, when there is uncertainty about the job security of the employees, various impression management tactics can be applied to cope with the uncertainty (De Cuyper et al., 2014; Huang et al., 2013; Ghosh, 2017; Kang et al., 2012, p. 317). Employees turn to impression management tactics to ensure and maintain high job security. In other words, if employees have a high perception of job security, they will not develop behaviors to create impressions that will affect their supervisors or employers. Studies have also found results supporting this negative relationship between job security and impression management (Kang et al., 2012; Probst et al., 2019). Based on all these discussions, the following hypothesis was established in the research:

H2: The perception of job security has a negative effect on impression management.

3.3. The relationship between impression management and task performance

Managing impressions in the workplace is based on intentions such as being accepted by the business community, being loved, and being noticed and appreciated by managers. Various awards await the employees who gain this legitimacy by managing their impressions. One of them is to get positive results from performance evaluations (Leary, 2019; Higgins, et al., 2003; Rajasekharan, & Rajasekharan, 2020, p. 85; Kurt, 2022). Studies demonstrating that those who implement manager-leader-oriented impression management tactics receive higher grades from performance evaluations support this claim (Bolino et al., 2008; Chawla, 2021, p. 3; Wayne & Ferris, 1990).

An employee's ability to effectively manage tactics such as ingratiation, self-promotion, or exemplification, which are among the impression management tactics, is also related to his/her task performance (Jones & Pittman, 1982; Crane & Crane, 2002; Bozeman & Kacmar, 1997; Chawla, 2021, p. 2). In other words, it can be expected that the employee manages the impressions on the one hand and performs consistently with them on the other (Agina et al., 2017, p. 221). For this reason, there is a relationship between impression management behaviors and the performances of the employees. However, there are various arguments regarding the direction of this relationship.

For example, the relationship between impression management strategies and task performance is unclear in employees who naturally have high job performance and high-performance efficiency without the aim of impression management. In other words, it can be said that employees who spontaneously get high marks in performance evaluations due to their professional work and are aware of their productivity may not need to manage their impressions. In this case, it can be argued that a positive relationship may not be established between task performance and impression management. According to another basis, employees who use ingratiation tactics may feel less responsible for fulfilling their task performance in an environment where they think they are loved by senior management and teammates and therefore feel safe. As a result of being loved by everyone, they may be able to avoid responsibility, and they may show the belief that they will not face punishment or sanctions. The supplication tactic may also contribute to explaining this inverse relationship. An increase in the performance of employees who present themselves as incompetent and in need of help cannot be expected. One of the important features of this tactic is that it alleviates the workload of individuals for a certain period (Kurt, 2022, p. 3-4). In these cases, there may be a negative relationship between impression management and task performance. According to a study to support these discussions, the effect of impression management on job performance is low (Ispas et al., 2014, p. 48). According to some researchers, the positive effect of impression management on task performance depends on certain occupational groups, job types, and objective criteria. According to researchers (Uziel, 2010; Viswesvaran et al., 2001), there may be a positive relationship between IM and performance in jobs that do not require technical competence but instead require competence in interpersonal relations. Otherwise, in cases where a job requires technical skills and expertise, there is no relationship between IM behaviors and the performances of professionals who perform the job.

Considering airport employees for this research, there is important expertise due to the nature of the industry. Although interpersonal communication skills are necessary for airport employees, the airport system cannot continue uninterrupted without technical knowledge and skills in aviation. In summary, technical knowledge and skills are inevitable for these employees. Based on this discussion, the following hypothesis was established in this part of the research:

H3: Impression management has a negative effect on task performance.

3.4. The relationship between job security perception, impression management, and task performance

As researchers have sought to examine potential mediating mechanisms that explain the relationship between job insecurity and task performance, impression management has come up consistent with what is discussed here. As Hayes (2012, p.1) points out, for the advancement of a field, it is important not only to say that a relationship exists, but also to explain how this relationship came to be. In this context, the role of impression management in the relationship between job security and performance becomes an important question (Probst et al., 2019, p. 307). It is known that impression management is one of the strategies used to protect the current business (Huang et al., 2013; Kang et al., 2012). Positive perceptions of the employee's performance are also supported by impression management tactics. In other words, the employee's perception of high job security is possible when he/she fulfills his/her job performance and demonstrates that he/she fulfills this to his/her superiors with impression management strategies. It is possible to provide job security and career advancement for employees who strive to create opportunities to improve current conditions (Probst et al., 2019, p. 308; Huang, 2013; Piccoli et al., 2021). In other words, while employees show high performance for the perception of high job security, they also promote their qualifications, show that they are exemplary employees, and may strive to be loved more (De Cuyper et al., 2014; p. 2-3; Rajasekharan & Rajasekharan, 2020, p. 856).

For all these reasons, the emergence of more task performance is consistent with the increased perception of job security; In this process, impression management tactics are expected to play an active role in the relationship between job security and job performance. There are also various studies supporting this mediation relationship (Probst et al., 2019; Staufenbiel & König, 2010). In light of these discussions, the following hypothesis was formed in this study:

H4: Impression management has a mediating effect on the relationship between job security perception and job performance.

Figure 1 depicts the model created following the research hypotheses. According to the model, perception of job security is the independent variable, task performance is the dependent variable, and impression management is the mediator variable.

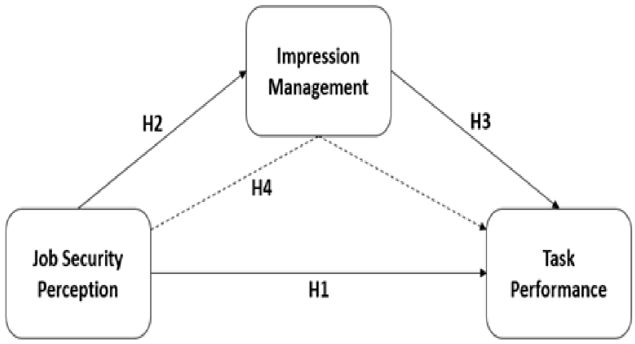

Figure 1. Research Model

4. Method

4.1. Procedures and sample

The sample of the research consists of the employees of airports operating in the aviation industry. These companies have undertaken the operation of many airports in Turkey. These are General Directorate of State Airports Authority, Istanbul Grand Airport, TAV Airport, Airport Management & Aeronautical Industries Inc. Companies have an important place in airport operations with their knowledge, highly qualified human resources, and advanced technology. The data of the research were collected with an online questionnaire prepared on Google Forms using the convenience sampling method between October 05-17, 2022. That questionnaire was sent to the individuals via LinkedIn which is a professional business network and social networking platform aimed at people in the business world to communicate and exchange information with others. In the questionnaire, the purpose of the research was explained and it was stated that it was voluntary and no personal information was requested. A total of 278 responses were returned. There were no missing data due to the online data collection.

Table 1. Demographic Characteristics

Characteristics	Frequency	Percentage	Characteristics	Frequency	Percentage
Gender			Marital Status		
Female	205	77.9	Married	133	50.6
Male	57	21.7	Single	129	49.0
No Statement	1	0.4	No Statement	1	0.4
Age			Education		
18-26 years old	51	19.4	High school	21	8.0
27-34 years old	102	38.8	Associate degree	54	20.5
35-42 years old	68	25.8	Bachelor degree	138	52.5
43-49 years old	30	11.4	Post graduate degree	49	18.6
50-57 years old	9	3.4	No Statement	1	0.4
58 years old and more	1	0.4	Montly wage (Turkish Lira)		
No Statement	2	0.8	5000-10000	61	23.2
Tenure			11000-15000	90	34.2
1-5 years	169	64.2	16000-20000	4	15.2
6-10 years	46	17.5	21000-25000	17	6.5
11-15 years	17	6.5	26000-30000	6	2.3
16-20 years	17	6.5	31000 and more	31	11.8
21-25 years	8	3.0	No Statement	18	6.8
26 years and more	2	0.8			
No Statement	4	1.5			

Table 1 shows the demographic characteristics of the participants. The majority part of the participants was female (77.9%) compared to 21.7% of male. Married participants were 50.6%, and single participants were 49.0%. In terms of tenure in the company, the majority of participants were 1-5 years (64.2%), and 6-10 years (17.5%). They have a high school degree (8%), associate degree (20.5%), bachelor's degree (42.1%), and postgraduate degree (18.6%). The monthly income of the majority of respondents was between 11000₺–15000₺ (34.2%).

4.2. Scales

The questionnaire consisted of four parts: demographic information, job security perception scale, task performance scale, and impression management scale. A 5-point (1: Strongly Disagree, 5: Strongly Agree) Likert scale was used to answer all questions. A pilot study was conducted on 76 individuals before the final data collection.

Job security perception scale (JSPS): Individuals' perception of job security was measured with the JSPS developed by Geçdoğan Yılmaz (2020). The JSPS consists of six statements (Ex.: I have sufficient job security) under one dimension. In the scale development study, exploratory factor analysis was used to determine the construct validity of the scale and the explained variance was 71.49%. Also, in that study the Cronbach's Alpha reliability coefficient of the scale was reported as 0.91. In the present study, Cronbach's Alpha reliability coefficient of the JSPS was 0.91.

Task performance scale (TPS): The TPS developed by Goodman and Svyantek (1999) was used to measure task performance. The scale consists of 9 statements (Ex.: I fulfill all the requirements of my job) under one dimension. The Turkish adaptation of the scale was made by Bağcı (2014). In the adaptation study, the scale was subjected to exploratory factor analysis for construct validity and it was determined that the resulting factors (factor load values between 0.570 and 0.804) matched the original structure. In the adaptation study, Cronbach's Alpha reliability coefficient of the scale was determined as 0.88. In another study by Şahin and Kanbur (2022), the reliability coefficient was reported as 0.90. In the present study, Cronbach's Alpha reliability coefficient of the TPS was 0.83.

Impression management scale (IMS): The IMS developed by Bolino and Turnley (1999) was used to measure the impression management variable. The Turkish adaptation of the scale was made by Basım, Tatar, and Şahin (2006). In the adaptation study, the IMS consisted of a 5-factor structure which was named supplication (Ex.: Pretend to not understand something that you do understand), self-promotion and ingratiation (Ex.: Make people aware of your accomplishments), exemplification (Ex.: Arrive at work early to look dedicated), intimidation (Ex.: Threaten a coworker), and job chauvinism (Ex.: Have showdowns with coworker or supervisors). Data were collected from two different samples and factor analysis was applied within the scope of the construct validity of the scale and it was determined that the resulting factors overlapped with the original structure. The Cronbach's Alpha reliability coefficient of the entire scale was determined as 0.82 in the adaptation study. In another study where the scale was used, the general reliability coefficient was reported as 0.80. In the present study, Cronbach's Alpha reliability coefficient of the entire IMS was 0.73

4.3. Data analysis

The Statistical Package for Social Sciences (SPSS) version 25 was used to analyze descriptive statistics, reliability ratings, and correlations. AMOS Statistical Package version 24 was used to examine the hypotheses using structural equation modeling (SEM) (Arbuckle, 2016). Confirmatory factor analysis (CFA) was used in AMOS to validate the suggested measurement model with data. The model goodness of fit was evaluated based on the following values: Chi-square/degree of freedom ($x2/df < 5$), root mean square error of approximation (RMSEA < 0.08), standardized root means square residual (SRMR < 0.08), goodness of fit index (GFI > 0.85), comparative fit index (CFI > 0.90), incremental fit index (IFI > 0.90) (Hair et al., 2014; Schermelleh-Engel et al., 2003). For the convergent validity of the construct, the average variance extracted (AVE > 0.50) and composite reliability (CR > 0.70) were calculated also (Fornell & Larcker, 1981). For the mediation, a bootstrapping analysis with 500 resamples and 95% bias-corrected confidence intervals was performed (Hayes, 2009)

5. Results

5.1. Preliminary analysis

The normality of the distribution was evaluated using the skewness and kurtosis values. After the outliers were removed from the data, the skewness values (ranging from -1.256 to 0.608) and the kurtosis values (ranging from -0.155 to 1.351) were acceptable (Kline, 2016).

The JSPS, TPS, and IMS were subjected to CFA one by one, and their construct validities were verified with the collected data. In this validation process, items with factor loadings producing high modification coefficients and cross-loading tendencies were excluded from the analysis. Each factor was represented with at least three items. Factor loadings above 0.455 were acceptable because the sample size was higher than 150 respondents (Kline, 2016; Hair, Black, Babin, and Anderson, 2014). Firstly, CFA was used to test the validity of the JSPS's one-factor structure. As a consequence of the analysis, it was decided to make modifications between items e4 and e5. The goodness-of-fit indices suggested that the scale was validated. Factor loadings ranged from 0.694 to 0.896. Later, the validity of the one-factor structure of the TPS was tested with CFA. As a result of the analysis, it was decided to remove one item (TP6) from the scale and to make modifications between items e1 and e2. The goodness-of-fit indices indicated that the one-factor task performance scale was validated. Factor loadings ranged from 0.455 to 0.807. Finally, the validity of the second level five-factor structure of the IMS was tested with CFA. As a result of the analysis, the second-order three-factor structure of the scale was confirmed by the data of supplication (SUP1-5), exemplification (EXE1-4), and self-promotion and ingratiation (SPI 1, 2, 4, 5, 7). The goodness-of-fit indices indicated that the second-order three-factor impression management scale was validated. Factor loadings ranged from 0.659 to 0.906. Table 2 presents the CFA results.

Table 2. CFA Results of Scales

Scales	x^2(CMIN)	df	x^2/df	RMSEA	SRMR	GFI	CFI	IFI
Job security perception	15.545	8	1.94	0.06	0.02	0.98	0.99	0.99
Task performance	33.113	19	1.74	0.05	0.04	0.97	0.98	0.98
Impression management	150.800	72	2.09	0.07	0.06	0.93	0.91	0.91

N=263, $p < 0.05$

Harman's single-factor test was applied to evaluate the common method variance. There was no problem with common method bias in this data since the total variance extracted by one factor is 18.630% and it was less than the recommended threshold of 50% (Podsakoff et al., 2003).

Table 3. Descriptive Statistics

Scales	Mean	SD	α	CR	AVE	1	2
1. Job security perception	3.88	1.01	0.909	0.91	0.63		
2. Task performance	4.61	0.42	0.826	0.86	0.44	0.145*	
3. Impression management	1.92	0.46	0.726	0.86	0.67	-0.144*	-0.159**

N=263

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 3 indicates the means, standard deviations, Cronbach's α, CR, AVE, and correlations of the research variables. A bivariate correlation analysis was used to analyze the relationship between the variables. As expected, job security perception was positively correlated with task performance ($r = 0.145$, $p < 0.05$). Job security perception was negatively correlated with impression management ($r = -0.144$, $p < 0.05$). Impression management also showed a negative correlation with task performance ($r = -0.159$, $p < 0.01$). The CR values ranged from 0.86 to 0.91. The AVE values ranged from 0.44 to 0.67. If AVE is less than 0.50, the convergent validity is still acceptable if CR is higher than 0.60. Therefore, these findings implied that the measurement model showed convergent validity (Lam, 2012; Fornell and Larcker, 1981; Hair et al., 2014).

5.2. Hypotheses testing

The purpose of this study is to ascertain whether job security perception positively influences task performance (H1), whether job security perception negatively influences impression management (H2), whether impression management has a negative effect on task performance (H3), and whether impression management mediates the relationship between job security perception and task performance (H4). The structural models with the latent variable were employed to test these hypotheses.

Firstly, a structural model in which job security perception and task performance were established to examine H1. The goodness-of-fit indices indicated that the structural model fit the data well ($x2$ [74, N = 263] = 136.544, $p < 0.001$, $x2/df = 1.845$, RMSEA = 0.06, SRMR = 0.04, GFI = 0.93, CFI = 0.97, IFI = 0.97). The analysis results are shown in Table 4. According to these results, job security perception was a positive effect on task performance ($\beta = 0.17$, $p < 0.05$). Job security perception explained 3% of the variance in task performance. These results showed that H1 was supported.

Table 4. The Results of the Structural Model

Interdependent variables	Dependent variables	
	Task performance	Impression management
	β	β
Job security perception (H_1, H_2)	0.17*	-0.16*
R^2	0.03	0.03
Impression management (H_3)	-0.30**	-
R^2	0.09	-
Job security perception —> Impression management —> Task performance (H_4)		
Indirect effect, β = 0.108, 95% CI = (0.000, 0.149)		

N= 263, ** $p < 0.01$, * $p < 0.05$, Standardized beta coefficients are reported. R^2 indicates the variance described. CI: Confidence Interval. Values in parentheses are lower and upper confidence intervals. Bootstrap samples = 500.

Secondly, a structural model in which job security perception and impression management were established to examine H2. The goodness-of-fit indices indicated that the structural model fit the data well ($x2$ [163, N = 263] = 291.335, $p < 0.001$, $x2/df = 1.845$, RMSEA = 0.06, SRMR = 0.07, GFI = 0.90, CFI = 0.93, IFI = 0.94). The analysis results are shown in Table 4. According to these results, job security perception was a negative effect on impression management ($\beta = -0.16$, $p < 0.05$). Job security perception explained 3% of the variance in impression management. These results showed that H2 was supported.

Thirdly, a structural model in which impression management and task performance were established to examine H3. The goodness-of-fit indices indicated that the structural model fit the data well ($x2$ [202, N = 263] = 320.881, $p < 0.001$, $x2/df = 1.589$, RMSEA = 0.06, SRMR = 0.08, GFI = 0.90, CFI = 0.93, IFI = 0.93). The analysis results are shown in Table 4. According to these results, impression management was a negative effect on task performance ($\beta = -0.30$, $p < 0.01$). Impression management explained 9% of the variance in task performance. These results showed that H3 was supported.

A bootstrap analysis with 500 resamples was performed to determine whether impression management plays a mediating role in the effect of job security perception on task performance. According to the bootstrap analysis, the indirect effect of job security perception on task performance through impression management was not statistically significant ($\beta = 0.11$, 95% CI [0.000, 0.149], $p = 0.071$), because the confidence intervals included the value zero. These findings showed that impression management did not act as a mediator between job security perception and task performance (Table 4). In this case, Hypothesis 4 was not supported.

Figure 2 demonstrates the findings of structural path analysis. Although the coefficients among job security perception, impression management, and task performance were significant, the indirect effect of job security perception on task performance through impression management was not statistically significant.

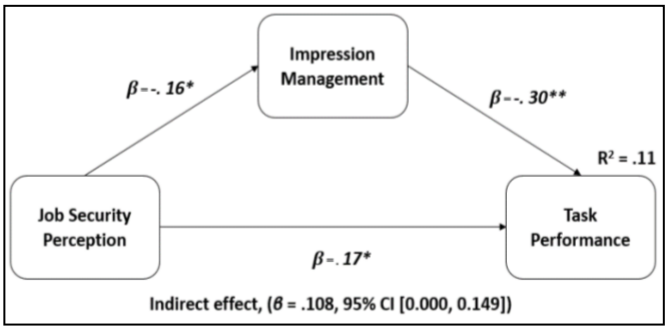

Figure 2. The Results of Structural Path Analysis

6. Discussion and Conclusion

This research aimed to examine the effect of job security perceptions of airport employees on their task performance, and whether there was a mediating role of impression management in this relationship. The hypotheses created for the research were tested. The results of the research partially supported the proposed hypotheses.

According to the structural model developed to test the first hypothesis of the study, job security perception was found to be positively related to task performance. Accordingly, individuals who perceive a high level of job security tend to fulfill their job duties at a higher level. In other words, the task performance of individuals who perceive a low level of job security will be lower than other individuals. One reason for this result may be that airport employees do not feel the stress and anxiety that arise when low job security is perceived, so they do not use impression management tactics, which is a coping method. Some studies conducted in the literature support the results of the relationship between job security perception and task performance (Lu et al., 2017; Probst et al., 2019).

The structural model's findings, which were used to test the second hypothesis, showed that job security perception negatively affects impression management. In other words, individuals who perceive job security do not exhibit behaviors aimed at influencing their supervisors' or colleagues' perceptions of themselves. When impression management is used as a coping mechanism, it is expected that there will be a positive correlation with job insecurity, so when there is high job security, employees are expected to use impression management tactics less. Some studies conducted in the literature also support the results of the relationship between job security perception and impression management (Kang et al., 2012; Probst et al., 2019).

The structural model developed to evaluate the third hypothesis of the study revealed the negative impact of impression management on task performance. Individuals who use impression management tactics such as self-promotion, ingratiation, supplication, and exemplification have a lower level of task performance. One possible explanation for the negative association is that impression management practices are not tolerated in the aviation culture in general. Because the aviation industry, where human life is very important, requires high technical skills and expertise, individuals are expected to perform their duties and responsibilities fully. Therefore, employees who perform their duties do not need to exhibit their impression management behaviors. These findings are consistent with previous research on these variables (Abbas, Raja, Anjum & Bouckenooghe, 2019; Agina, Mohammed & Omar, 2017; Viswesvaran, Ones & Hough, 2001).

Finally, a structural equation modeling was developed to test the entire research model. Contrary to expected, impression management did not play a mediating role in the effect of job security perception on task performance. It has been revealed that individuals who feel high job security do not apply the techniques of impression management in fulfilling their duties. According to this result, it can be said that the high job security perceptions of the employees in the aviation sector are positively reflected in their job performance, therefore, they do not need impression management practices to influence their superiors or colleagues.

7. Implications

When the literature is examined, there are very few studies that examine these three variables together. In the aviation literature, however, no study has been encountered that explains these relationships. The present study extends prior research on job security perception and task performance by integrating impression management as a mediator of a structural model. The results from this empirical research fill gaps in the organizational behavior, human resources, and strategic management literature by indicating the relationships among the research variables. In the study, it has been revealed that the perception of job security has a positive effect on task performance, the perception of job security has a negative effect on impression management, and impression management has a negative effect on task performance. On the other hand, it has been determined that impression management does not have a mediating role in the relationship between job security perception and task performance.

It is considered that this result between job security perception expressing a relaxing process about the future, and task performance that increases the effectiveness and efficiency of the individual and organization, make a major contribution to the literature on organizational behavior and human resource management. In addition, the negative relationship of impression management, which individuals use to influence others, with job security perception and task performance will also contribute to the relevant literature.

These results are anticipated to enhance human resources departments' efforts to improve employees' productivity and effectiveness to build a sustainable competitive advantage. Putting more emphasis on human resources management policies, which eliminate the concerns of employees about job security, contributes to the success of the organization by enhancing the task performance of individuals.

8. Limitations and Directions for Future Research

There are some limitations to this study. First, the research data was gathered from three aviation companies in Türkiye. As a result, the findings cannot be generalizable to other organizations, industries, or countries. Future research could be conducted in different companies or sectors.

Second, this study examined the relationships among job security perception, task performance, and impression management in a theoretical framework. The results mostly supported the theory and extended the results of previous research. The associations among job security perception, task performance, and impression management were significant statistically. But impression management did not act as a mediator in the relationship between job security perception and task performance. In future studies, variables such as organizational commitment or leader-member exchange can be added to the model to better understand the relationships between these variables.

Finally, the study relied on self-reported data. Because the study is based on data from a single source, the findings may be influenced by common source variance (Podsakoff et al., 2003). To control method biases, the questionnaire instructed the respondents that there was no right or incorrect response and that their responses wouldn't be shared with anyone. The participants were instructed to give answers that as closely as possible mirrored the truth. Also, the Harman single-factor analysis revealed that no common method variance existed. Future research should be designed to be longitudinal, with data from management collected to detect causal links.

Ethical approval

In this study, ethics committee permission was obtained from Kırklareli University Scientific Research and Publication Ethics Committee on October 4, 2022 (E-35523585-302.99-61627).

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Do We Scapegoat The Pandemic? Investigating The Changes in Satisfaction Drivers of Air Passengers With DWLS-SEM

Ferhat İnce[1*], Özlem Atalık[2]

[1*] Eskisehir Technical University, Aviation Management Department, Eskisehir, Türkiye. (ferhatince@eskisehir.edu.tr)
[1] Eskisehir Technical University, Aviation Management Department, Eskisehir, Türkiye. (oatalik@eskisehir.edu.tr)

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Abstract

This paper aims to investigate whether there is an alteration in the drivers of air passenger satisfaction before and after COVID-19. We conducted the multigroup structural equation modelling with the diagonally weighted least squares estimation method as the variables are categorical. Lastly, we performed ANOVA to spot if there is a change in the drivers of passenger satisfaction between before and after the pandemic. The results suggest all service attributes have a significant impact on satisfaction in the pre-COVID-19 era. Even if it seems that in-flight entertainment and in-flight WiFi are not as influential as before in the post-pandemic, ANOVA results revealed the difference between the pre-pandemic and the new-normal period was not statistically significant. Accordingly, airlines should not ignore the need to improve service attributes, called premium services, and holistically improve service design. In addition, after value for money, the most important attribute for passengers is ground handling. Hence, speeding up the boarding process would return carriers in the form of more satisfied customers. To the best of our knowledge, this is the first paper employing Multigroup DWLS SEM to focus on changes in determinants of air passenger satisfaction in a holistic approach, focusing on pandemic periods.

1. Introduction

The airline industry has a dynamic structure and has experienced numerous transformations (Bakır et al., 2020). One of the most contemporary changes is deregulation. The Airline Deregulation Act, approved by the US Congress on October 24, 1978, (Goetz & Vowles, 2009), made markets competitive. Since competition solely based on price is not sustainable (Chang & Yeh, 2002), airlines compete for customers by offering high-quality services. A company's ability to keep its customers happy affects its competitive advantage by maintaining travelers' loyalty, which leads to a larger market share and increased profitability (Gazi et al., 2024). Delivering high-quality service to travelers is challenging and impacts an airline company's long-term success (Perçin, 2018). In this sense, airline companies are obliged to understand the requests and needs of customers (Aksoy et al., 2003). Airlines, for sure, measure passenger perception, yet sometimes they have inadequate information regarding what they truly want (Chen & Chang, 2005; Chou et al., 2011). In other words, they sometimes might have marketing myopia (Opengart et al., 2018).

The COVID-19 pandemic has posed challenges for the aviation industry since numerous nations admit domestic and international air transport connections can contribute to the spread of epidemics (Zhang et al., 2020). Apart from the economic and psychological damage rooted in COVID-19 (Choi, 2021; Imroz et al., 2023; Pappachan, 2023; Sulu et al., 2021), pronounced as a pandemic in March 2020, it changed travelers' behavior, expectations, and perceptions in terms of both airports and airlines (Lamb et al., 2020; Lin et al., 2023; Lin & Zhang, 2021; Samanci et al., 2021; Yalcin Kavus et al., 2022; Zhang et al., 2021). International Air Transport Association (IATA) stated that passengers prioritize convenience more than ever before, and therefore, digitalization and biometrics are consequential in the post-COVID-19 era (IATA, 2022). Passenger behavior is subject to continuous change due to various reasons. It has been established that navigational searches of airline customers related to flight tickets vary significantly, even within hourly periods, as reported by Koçak (2020). In another example, focusing on tweets sent to 6 Turkish air carriers, Koçak and Atalık (2019) emphasized that the theme of food and beverages lessened, and flight convenience peaked during Ramadan. Pereira et al. (2023) adopted a sentiment procedure to analyze 9745 reviews and revealed that the most crucial driver of passenger satisfaction is staff behavior in the post-COVID-19 period. Similarly, Bakır et al. (2022) conducted analyses of multiple regression and necessary conditions and demonstrated that staff is the most significant determinant of passenger satisfaction. Therefore, staff service is not just a service attribute that has attained prominence after the pandemic. Furthermore, Kim et al. (2024) utilized sentiment analysis and topic modeling to investigate the shift in passenger perception based on 12,522 reviews of 50 airlines. They revealed that the most significant SERVQUAL dimension in the pre-COVID-19 was reliability, while after the pandemic, it was responsiveness. Due to changes in airline schedules and an increase in refund requests during the pandemic, these findings remain consistent. Even if COVID-19 is the most influential crisis in recent years, the relatively recent studies (Biswakarma & Gnawali, 2021; Çallı & Çallı, 2023; Hassan & Salem, 2022; Sulu et al., 2021) do not propose a holistic view. To the best of our knowledge, there is no study with a holistic approach to evaluating the alteration of passenger satisfaction in the context of full-service carriers. Accordingly, this paper aims to fill this gap by investigating the variance of passenger satisfaction of worldwide full-service carriers pre and post-pandemic. Moreover, the airline service quality papers utilize several methodologies, such as PLS-SEM (Farooq et al., 2018), logistic regression (Sari & Sener, 2022), multi-criteria decision-making (Gupta, 2018), sentiment analysis (Badanik et al., 2023), and so on. On the other hand, it is the first paper employing Multigroup DWLS SEM to evaluate the passenger satisfaction of full-service carriers with a holistic perspective, to the best of our knowledge.

The rest of the paper is structured as follows. Section 2 presents the background and hypotheses. Section 3 proposes the research framework and methodology. Section 4 summarizes the findings, and Section 5 discusses the results, delivers managerial implications, states limitations, and offers suggestions for forthcoming studies.

2. Background and Hypotheses

2.1. Background

Service quality is a term expressing the meeting level of services to customers' expectations (Namukasa, 2013). When it comes to the airline industry, it is not wrong to say that service quality means offering adequate frequent routes with perfect standards. It is a fundamental factor that affects the passengers' purchasing decision (Anderson & Zeithaml, 1984). Customer satisfaction, a key dimension of airline performance (Chow, 2014), is achieved when customers purchase a product or service that meets or exceeds their needs and expectations (Jiang & Zhang, 2016). So, it is a post-decision since it is based on experiences. By providing top-notch services, airlines ensure that their customers are satisfied with their experience and are more likely to return. This not only enhances the company's brand image but also increases passengers repurchase intent (Hu et al., 2009; Law et al., 2022). In addition, airlines attempt to improve customer engagement using figurative language in their social media posts (Koçak et al., 2024).

For service organizations, it is vital to comprehend and quantify customer expectations due to financial and resource constraints. By identifying any gaps in service quality from the customer's point of view, managers can decide on cost-effective ways to bridge those gaps. Given the limited resources available, managers must prioritize the most critical gaps to allocate their resources efficiently. This decision is crucial in ensuring optimal utilization of the available resources (Geraldine & David, 2013). That's why there are numerous studies on airline service quality and passenger satisfaction (Atalık et al., 2019; Babbar & Koufteros, 2008; Badanik et al., 2023; Ban & Kim, 2019; Cunningham et al., 2004; Huang, 2023; Jeong et al., 2023; Kassir, 2024; Leon & Dixon, 2023; Liou et al., 2011; Özden et al., 2023; Park et al., 2019; Ravishankar & Christopher, 2023; Samosir et al., 2024; Song et al., 2024; Suki, 2014; Sultan & Simpson, 2000; Tiernan et al., 2008; Tsaur et al., 2002; Wang et al., 2011).

2.2. Hypotheses proposed

Value for money is a trade-off that specifies what benefits the customer receives in exchange for what they consent to give up (Zeithaml, 1988). It is a guiding measurement that assists air carriers in determining marketing strategies, customer satisfaction, and pricing (Dike et al., 2023). Mason (2001) stated that value for money is an exceptionally significant factor for both low-cost and network carriers. In addition, (Rajaguru, 2016) noted that value for money is essential for low-cost carriers to accomplish customer satisfaction, and the success of full-service carriers relies on both customer satisfaction and value for money. Accordingly, airlines offering services with more value for money than their opponents might attain a competitive advantage (Brochado et al., 2019). Hence, we propose the hypothesis as follows:

H1: Value for money positively affects passenger satisfaction.

Ground service is a part of the chain of services offered in air transportation (Chen & Chang, 2005). The service quality assessment concentrates on two main elements: in-flight service quality (also expressed as on-board service quality) and ground service quality (Alkhatib & Migdadi, 2018). Increasing the quality level of ground services yields customer satisfaction (Ban & Kim, 2019). Hence, we propose the hypothesis as follows:

H2: Ground services positively affect passenger satisfaction.

Ergonomics gained attention with the instantaneous development of the aviation industry (Fan et al., 2022). An empirical study focusing on business passengers revealed that seat comfort has the highest influence on value for money (Atalık et al., 2019). Airlines should prioritize seat comfort to improve service quality (Lippitt et al., 2023; Tahanisaz & Shokuhyar, 2020). Hence, we propose the hypothesis as follows:

H3: Seat comfort positively affects passenger satisfaction.

Cabin staff should be polite, genial, friendly, willing to solve travelers' problems, and have satisfactory language mastery (Suki, 2014). Cleanliness, cabin interior, and experienced cabin crew with vocational competency offering high-quality service contribute to increasing the satisfaction of passengers (Atalay et al., 2019; Kim & Park, 2017; Namukasa, 2013). Hence, we propose the hypothesis as follows:

H4: Cabin staff service positively affects passenger satisfaction.

The food and beverage services are an inflight service that is one of the most influential factors affecting the perceived quality of passengers (Šebjan et al., 2017). It is especially vital for premium passengers, and the quality of this service is one of the common words in online reviews (Koçak & Atalık, 2019; Korfiatis et al., 2019). High-quality food and beverage service at a reasonable price increases customer satisfaction and loyalty by improving the value of money, especially for full-service carriers (An & Noh, 2009). Hence, we propose the hypothesis as follows:

H5: Food and beverages positively affect passenger satisfaction.

Misopoulos et al. (2014), analyzing 67,953 tweets shared by four airline companies, stressed that high-quality inflight entertainment results in positive sentiments of customers toward the airlines. Siering et al. (2018) stated that inflight entertainment is essential, especially for full-service carriers since both the business model of low-cost carriers and the passengers preferring low-cost carriers do not focus on this service generally. It is a considerable distinguishing service in passengers' decision to choose an airline (Lim & Lee, 2020). Hence, we propose the hypothesis as follows:

H6: Inflight entertainment positively affects passenger satisfaction.

In recent times, many airlines have provided in-flight WiFi services to enhance their revenue streams (Ismail & Jiang, 2019). It is another service attribute associated with the full-service carriers. (Lippitt et al., 2023) stated that airline managers proposing in-flight WiFi can attract passengers. Hence, this service might gain new customers for the company (Byun & Lee, 2016). This service is correlated with passenger satisfaction (Hong et al., 2023), provided that its connection and speed have to be at least acceptable (Gao et al., 2021). Hence, we propose the hypothesis as follows:

H7: Inflight WiFi positively affects passenger satisfaction.

Accordingly, the hypothesis development is illustrated in Figure 1.

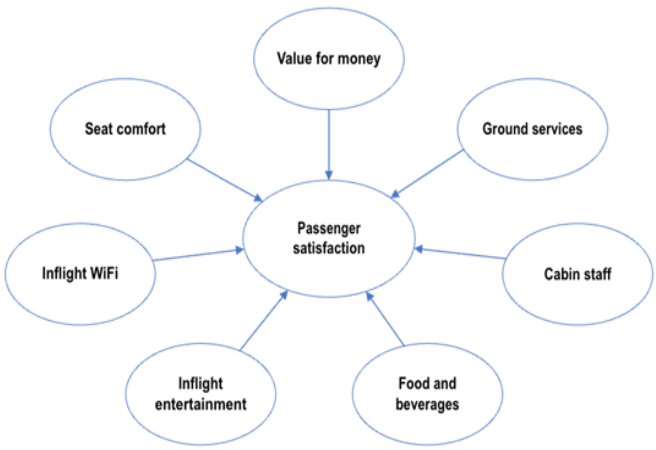

Figure 1. Hypothesis development.

3. Research Flow and Methodology

3.1. Research flow

The rapid development of digitalization brings forward user-generated content (UGC). UGC, which can be visual or text-based, refers to the ability of regular people to freely share their thoughts and feelings on any topic rather than professionals (Naab & Sehl, 2017). There are various UGC platforms, such as Instagram, X (Twitter), Facebook, YouTube, TripAdvisor, Snapchat, Skytrax, and Yelp (Flecha-Ortíz et al., 2021; Garner & Kim, 2022; A. J. Kim & Johnson, 2016; Rauchfleisch et al., 2017; Roma & Aloini, 2019; Samir et al., 2023; Smith et al., 2023). This paper utilizes Skytrax as a database. Skytrax, established in 1989, is a leading organization in rating airlines, airports, and lounges (Skytrax, 2022). In addition, it is accepted as a reliable source providing UGC regarding the services mentioned above (Kwon et al., 2021). Furthermore, Skytrax is widely utilized as a database in satisfaction and service quality studies (Anitsal et al., 2019; Bin Taliah & Zervopoulos, 2023; Pholsook et al., 2024; Shadiyar et al., 2020). Figure 2 depicts an airline review shared in Skytrax.

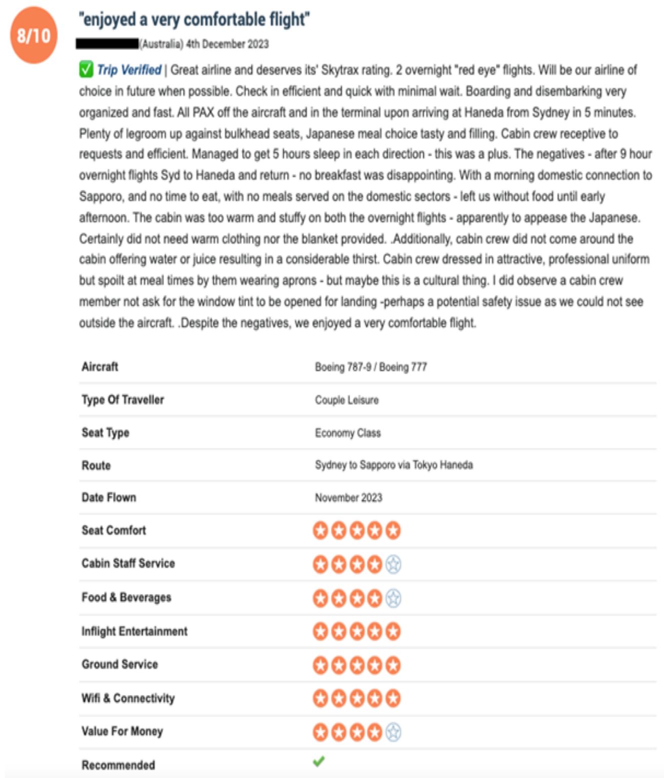

Figure 2. Review example.

The reviews include recommendations (yes or no), service attributes, traveler's type (business, family, couple, and solo), and nationality. Figure 3 represents the research flow. Initially, we examined Skytrax to determine the decision-making units. Skytrax shows 150 full-service carriers for ten regions. Second, we researched the number of reviews belonging to all operators by region and proceeded with the top five carriers. It is noteworthy to remember that Russia, CIS & Central Asia region has four air carriers. Third, we scraped all reviews regardless of date by employing the Chrome extension of Web Scraper. The raw dataset consists of 49 airlines with 42934 reviews. Fourth, we arrange the period as pre-pandemic and post-pandemic. The reviews until December 31, 2019, are considered the pre-pandemic period, and those beginning from January 1, 2022, are considered the post-pandemic period. Fifth, we cleaned up the reviews with missing values and noticed that the post-pandemic period has 44 airlines. Therefore, we excluded the four carriers (Air Caraibes, Air Moldova, Belavia Belarusian Airlines, Cayman Airways, and South African Airways) from the pre-pandemic period. Accordingly, the final dataset has 44 airlines with 13635 reviews. The 44 relevant airlines are presented in the Appendix. Sixth, following (Dike et al., 2023), we divided the variables into two clusters: displeased (scores of 1-3) and pleased (scores of 4-5) for service attributes, and unsatisfied (scores of 1-6) and satisfied (scores of 7-10) for overall satisfaction. Ultimately, we binarized all groups: displeased and unsatisfied as 0 (reference level), pleased and satisfied as 1. The underlying reason for binarizing values is that the DWLS estimation method works with categorical variables. Dichotomous variables are preferred instead of polychotomous to ease the interpretation of the findings.

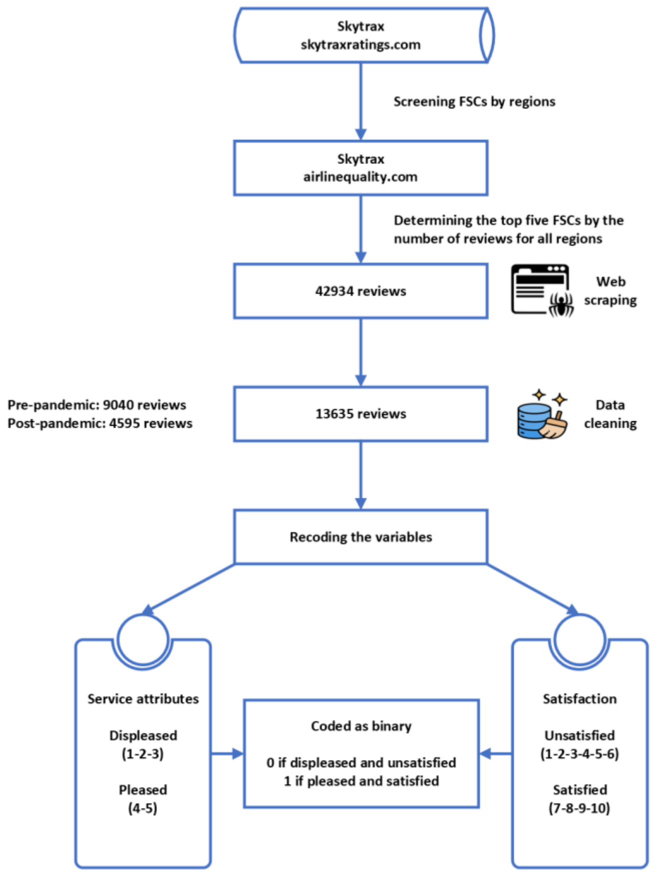

Figure 3. Research flow**.**

3.1. Methodology

This study employs structural equation modeling (SEM). SEM, which has a confirmatory procedure, allows academics to concurrently estimate and model complicated associations among multivariate endogenous and exogenous variables (Byrne, 2016; Hair et al., 2022). There are some assumptions of SEM. First, researchers should have adequate sample size (N). As a rule of thumb, N should at least be ten times the number of variables (Tanaka, 1987). There is, however, no consensus regarding this issue. Academics have proposed several rules about sufficient N, such as 50 observations for each variable or at least 100 (Muthén & Muthén, 2002). Shi et al. (2019) stated that RMSEA (Root Mean-Square Error of Approximation), TLI (Tucker-Lewis Index), and CFI (Comparative Fit Index) might worsen if the N is low. On the other hand, (Shi et al., 2018) stressed that the observed variable number (x) is the most significant driver of the model's size effect and proposed that a high number of x (e.g., equal to or higher than 60) causes Type I errors, even if the higher N (e.g., 2000). Therefore, the authors suggested that the N should be at least equal to or higher than χ^2 (chi-square). Additionally, data should have a normality distribution (Kline, 2023). Moreover, the theoretical background regarding the analysis is necessary.

Besides the assumptions, goodness-of-fit indices must be presented. Although there is no consensus on which goodness-of-fit indices should be reported (Marcoulides et al., 2020), RMSEA and CFI are widely reported global fit measurements (Lai & Green, 2016). As incremental fit indices, CFI and TLI values should be greater than 0.90 or 0.95. The absolute fit indices, RMSEA and SRMR (Standardized Root Mean-Square Residual) should be lower or equal to 0.05 (J. Wang & Wang, 2020; Whittaker & Schumacker, 2022). Besides, χ^2 is also reported in studies, yet it should be noted that it produces unreliable values when N is large (Y. Fan et al., 2016).

The maximum likelihood (ML) is the most common estimation method in SEM and is utilized for continuous variables (J. Wang & Wang, 2020). On the other hand, the DWLS (diagonally weighted least squares) estimation method is recommended when studying categorical data with less than five categories (Kline, 2023). Additionally, (Whittaker & Schumacker, 2022) suggested that categorical endogenous variables should have less than four categories. DWLS produces estimates with fewer standard errors, has fewer restrictive assumptions than ML, yields more accurate results even with small samples than WLS (weighted least squares), and is not as sensitive to normality distribution as ML (Josephy et al., 2016; Koğar & Yilmaz Koğar, 2015; Mîndrilă, 2010). In accordance with the purpose of the paper, we utilized Multigroup SEM with the DWLS estimation procedure. Moreover, we conducted ANOVA to specify whether a statistically significant difference exists regarding passenger satisfaction between the pre-pandemic and post-pandemic periods. The analyses are conducted by Lavaan package in R (Rosseel, 2012). The normality and collinearity check is conducted by jamovi (The jamovi project, 2023).

4. Results

This section provides the determinants of satisfaction derived from the DWLS estimation method. The values of skewness, kurtosis, Variance Inflation Factor (VIF), and tolerance are presented in Table 1. Accordingly, the data has a normal distribution since the skewness and kurtosis are lower than 2 and 7, respectively (Finney & DiStefano, 2013). In addition, there is no multicollinearity risk since the VIF < 5 and tolerance > 0.2 (Bagheri et al., 2012; Handoyo et al., 2023).

Table 1. Normality and collinearity check

Predictors	Skewness	Kurtosis	VIF	Tolerance
Seat comfort	0.805	-1.35	2.58	0.39
Cabin staff	0.521	-1.73	2.34	0.43
Food and beverages	0.956	-1.09	2.56	0.39
Inflight entertainment	0.708	-1.50	2.38	0.42
Ground services	0.924	-1.15	2.32	0.43
Inflight WiFi	1.21	-0.533	1.88	0.53
Value for money	0.980	-1.04	3.11	0.32

In order to spot the alteration in passenger satisfaction between COVID-19 periods, we proposed two models: the free model (i.e., no equal constraint of intercepts) and the strict model (i.e., equal constraint of intercepts). The results of relevant models are displayed in Table 2. Instead of χ^2, we report Bentler's CFI, which yields more accurate results since it is a standardized index for N (Bentler, 1990). Based on the goodness-of-fit indices, it is clear that the model is fit (CFI= 1.000; TLI= 1.000; RMSEA= 0.000; SRMR= 0.000). The results of the free model indicate that all service attributes have a statistically significant impact on overall passenger satisfaction in the pre-pandemic era, in line with the literature (Atalay et al., 2019; Ban & Kim, 2019; Brochado et al., 2019; Hong et al., 2023; Šebjan et al., 2017; Siering et al., 2018; Tahanisaz & Shokuhyar, 2020). Value for money, stressed by

Rajaguru (2016) as an indispensable factor for airlines to survive, has the highest impact, based on the coefficients. It is followed by ground services with 0.933 coefficients. Disruptions in the ground services or lack of staff could also lead to delays in the flight (Pamplona & Alves, 2020).

Table 2. Results of the free and strict model

Model	Period	Predictors	Estimate	Std. error	p
FREE MODEL	Pre-pandemic	Seat comfort	0.581	0.059	0.000
		Cabin staff	0.897	0.061	0.000
		Food and beverages	0.449	0.063	0.000
		Inflight entertainment	0.345	0.062	0.000
		Ground services	0.933	0.057	0.000
		Inflight WiFi	0.151	0.063	0.015
		Value for money	1.618	0.058	0.000
	Post-pandemic	Seat comfort	0.645	0.106	0.000
		Cabin staff	0.666	0.105	0.000
		Food and beverages	0.445	0.112	0.000
		Inflight entertainment	0.205	0.114	0.071
		Ground services	1.013	0.100	0.000
		Inflight WiFi	0.180	0.116	0.122
		Value for money	1.688	0.107	0.000
STRICT MODEL	Pre-pandemic	Seat comfort	0.590	0.051	0.000
		Cabin staff	0.828	0.053	0.000
		Food and beverages	0.443	0.054	0.000
		Inflight entertainment	0.309	0.054	0.000
		Ground services	0.944	0.049	0.000
		Inflight WiFi	0.157	0.055	0.004
		Value for money	1.619	0.053	0.000
	Post-pandemic	Seat comfort	0.590	0.051	0.000
		Cabin staff	0.828	0.053	0.000
		Food and beverages	0.443	0.054	0.000
		Inflight entertainment	0.309	0.054	0.000
		Ground services	0.944	0.049	0.000
		Inflight WiFi	0.157	0.055	0.004
		Value for money	1.619	0.053	0.000

Delays, bringing additional costs, influence customer satisfaction adversely (Song et al., 2024; Wesonga et al., 2014). Air travelers also attach importance to seat comfort and cabin staff services, as stressed by Tansitpong (2020). Consistent with (Chatterjee & Mandal, 2020), inflight entertainment and food & beverages are significant drivers of satisfaction, whereas not as much as cabin staff and seat comfort. Even if inflight WiFi services have gained prominence over the years because of digitalization (Suprapto & Oetama, 2023), the results revealed that it has a significant but the lowest impact on satisfaction. The underlying reason for this issue might be the unstable connection or insufficient speed, which disappoints passengers, as stressed by Gao et al. (2021). In brief, the order of importance of service attributes is value for money, ground services, cabin staff, seat comfort, food & beverages, inflight entertainment, and inflight WiFi. This ranking has not changed in the new-normal period, based on the findings belonging to the post-pandemic era of the free model. However, it seems there are some changes. To illustrate, the coefficients of value for money, ground services, and seat comfort boosted, while that of cabin staff and food & beverages diminished. On the other hand, inflight WiFi has no statistically significant effect on satisfaction. Besides, inflight entertainment is still statistically significant, yet at the significance level of 10% rather than 5%. The results of ANOVA revealed that the difference between passenger satisfaction between the eras of pre-pandemic and post-pandemic is not statistically significant, stochastic ($\chi^2(7) = 6.677, p: 0.435$).

5. Discussion and Conclusion

5.1. Synopsis of findings

The success of any firm relies on its ability to understand customers' perceived quality of goods or services. Failure to comprehend customer expectations can lead to severe consequences, such as reduced profitability and customer dissatisfaction (Bakır et al., 2019). As a demand-driven industry, aviation is experiencing rapid growth (Gürçam, 2022). Accordingly, air carriers are looking for new ways to maximize their lifespan in an intensely competitive environment. To this end, they strive to develop service designs that exceed or at least meet the passenger expectations for both retaining current customers and attracting new ones (Lucini et al., 2020; Park et al., 2019).

The results presented in Table 2 indicate that all predictors are significant determinants of passenger satisfaction. So, all hypotheses are supported by the aggregated model. Thus, our findings are consistent with the literature (An & Noh, 2009; Atalık et al., 2019; Hong et al., 2023; Kim & Park, 2017; Siering et al., 2018). It is an anticipated consequence that passengers prioritize value for money as the primary driver of satisfaction, in line with Rajaguru (2016). Value for money is also a pivotal driver of the recommendation intention of passengers, regardless of the business model (Fu, 2023), and also contributes to the brand image of airlines (Baumeister et al., 2022). IATA (2022) stressed that 65% of passengers grumbled about complex processes and recommended the dissemination of digital technology to speed up travel. On the other hand, inflight WiFi has the lowest impact on satisfaction in the pre-pandemic period and is not a powerful driver of satisfaction in the post-pandemic. The underlying reason for this finding might be the increasing concerns regarding hygiene and safety (Afaq et al., 2023; Bakır et al., 2022; Ma et al., 2022). Even if COVID-19 restricts social life, passengers do not compromise on the perceived quality of primary service attributes (such as seat comfort, cabin staff, food and beverage, ground services, and value for money). The sentiment and topic modeling procedure adopted by Srinivas & Ramachandiran (2023) revealed that cabin and ground staff is the largest topic (40%) in passenger reviews for the period August 2017-September 2019. Similar research conducted by Sulu et al. (2021) revealed that staff is one of the most important themes during the pandemic. In accordance, our results point out cabin and ground staff services remain a compulsory attribute for passengers after the pandemic.

On the other hand, the results of ANOVA suggest that the difference between pre-pandemic and post-pandemic is not statistically significant. This finding should not be misapprehended. What we want to stress here is to emphasize that the pandemic is the cause of any behavioral change of any passenger, even without conducting a comparative analysis. This study does not assert that there is no difference in the facets influencing any traveler's purchasing behavior after the pandemic. However, the results of this study, which was designed with a holistic approach by collecting data from airlines in each region and questioning whether there is a statistical difference in the determinants of satisfaction between the periods, do not hesitate to point out that the pandemic has been scapegoated in terms of passenger satisfaction.

5.2. Managerial Implications

The aviation industry has quite a dynamic structure. The air carriers have realized that competition based on price does not necessarily bring a competitive advantage. Accordingly, airlines are continuously competing with each other in terms of attracting more and more passengers. Airlines, , need to know which service attributes passengers value most and which ones have room for improvement. In this context, the concept of user-generated content (UGC), which has gained importance with the rapid development of technology in eliminating marketing myopia, stands out (Halliday, 2016; Vollrath & Villegas, 2022). Social media applications, various blogs, and countless forums where consumers share their experiences influence potential customers' purchasing decisions to such an extent that influencing customers has shifted from companies to consumers (Mendes-Filho et al., 2018; O'Hern & Kahle, 2013). In other words, UGC is a free marketing service for companies through word of mouth (Albuquerque et al., 2012; Bronstein & Aharony, 2009).

This study utilizes UGC, an indispensable source for businesses to spot the aspects that require improvement and puts forward that passengers did not consider two service attributes, in-flight entertainment, and WiFi, as much in the post-pandemic period as in the pre-pandemic period. Based on these findings, it should not be assumed that people do not value premium services such as in-flight entertainment and WiFi as much after the pandemic period when social life came to a standstill. ANOVA results reveal that the difference between the two periods is stochastic (i.e., random). Even if the value for money is still the highest contributor to satisfaction, it is crucial to remember that price without service quality is not enough to increase repurchase intention and customer loyalty (Chonsalasin et al., 2022; Mikulić et al., 2017; Vlachos & Lin, 2014). Therefore, airlines should persist in enhancing all service attributes. In addition, based on the regression coefficients of service attributes, ground handling is the second-best determinant of customer satisfaction. Although it is not emphasized as much as other service attributes in airline service quality literature, this finding is consistent with Ban & Kim (2019), who stated that ground handling quality improves customer satisfaction. Passengers might hold airline companies responsible for delays, even if they are not caused by the carrier. Minimizing the disruptions in the ground handling process or working with ground handling companies that have proven their service quality may return to the airline company as increased passenger satisfaction.

5.3. Limitations and future research suggestions

As with all articles, this paper has some limitations. First, the dataset consists of full-service carriers from different regions. In this sense, following Punel et al. (2019), investigating whether there are cross-cultural differences in passenger satisfaction through the lens of comparative periods in future studies can provide beneficial information to the airline industry and raise new research questions. In addition, we chose Skytrax as the database, which is easy to scrape thanks to its static link structure. On the other hand, the number of reviews on Skytrax is lower than on TripAdvisor. If possible, researchers can choose TripAdvisor, which has a much higher number of reviews but has a dynamic link structure, and bring to light the gray areas that this study cannot illuminate. Besides, it is also noteworthy to remember that satisfaction is a complex phenomenon because of the dynamic structure of the industry and the subjective nature of people, and therefore, this paper asserts that more studies related to the scope are required. Moreover, comparing the results obtained from different methodologies that have not been employed before might yield methodological advancement. Lastly, academics can adopt a similar procedure for comparing airline business models, customer types, or cabin classes without losing the context of the pandemic eras.

Ethical approval

Not applicable.

Conflicts of Interest

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

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Appendix

Table A.1. Regions and airlines

Region	Airline
Africa	Ethiopian Airlines Royal Air Maroc Egyptair Kenya Airways
Asia	Thai Airways Singapore Airlines Air India Cathay Pacific Airways Malaysia Airlines
Australia/Pacific	Qantas Airways Air New Zealand Virgin Australia Air Tahiti Nui Fiji Airways
Central America & Caribbean	Bahamasair Caribbean Airlines Copa Airlines
China	China Southern Airlines Hainan Airlines Air China China Eastern Airlines Xiamen Airlines
Europe	Lufthansa Turkish Airlines British Airways KLM Royal Dutch Airlines TAP Portugal
Middle East	Emirates Etihad Airways Oman Air Qatar Airways Saudi Arabian Airlines
North America	Delta Air Lines Air Canada American Airlines JetBlue Airways United Airlines
Russia, CIS & Central Asia	Air Astana Azerbaijan Airlines
South America	Azul Brazilian Airlines Boliviana de Aviación Aerolineas Argentinas LATAM Airlines Avianca

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Passenger Service Quality Perceptions to Star Alliance Airlines

Fatma Selin Sak[1*]

[1*]Giresun University, Aviation Management Department, Giresun, Türkiye. (selin.sak@giresun.edu.tr)

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Abstract

Through performance measurement, airline operators can conduct situation assessments and evaluate the contributions of decisions to performance beforehand. Evaluating performance based on the perceived service quality by airline passengers has become crucial for airlines to understand and improve their services in order to achieve success in competition by meeting passengers' desires and expectations. This study aims to examine the perception of customer service quality among airline operators in the Star Alliance, the largest alliance worldwide based on 2023 data, using multi-criteria decision-making (MCDM) methods known as Entropy and MARCOS, with Tripadvisor data as a basis. Firstly, criteria weights were obtained using the Entropy method, and then airline operators were evaluated and ranked based on service quality using the MARCOS method. The study revealed that the most significant evaluation criterion was the in-flight entertainment systems (Wi-Fi, TV, movies), and Singapore Airlines exhibited the best service quality performance.

1. Introduction

The success of service quality is measured by the ability of the business and its personnel to consistently meet customer expectations. Particularly for service businesses, the importance of service quality is explained by its status as a key factor in the consumer's purchasing decision process (Wahyuni & Praninta, 2021). In order to better understand customers' experiences with services, businesses need to identify certain tangible factors (Ghotbabadi, Feiz, & Baharun, 2015). Airline service quality refers to passengers' subjective perceptions regarding the efficiency and benefit of the services provided by the service provider airline operator (Li, Wu, Han, & Li, 2022).

According to Namukasa (2013), airline service quality influencing customer satisfaction and loyalty is measured in pre-flight, in-flight, and post-flight phases. Factors affecting pre-flight service quality include the reliability of the airline website, discount offers, flight cancellations, baggage allowance, and responsiveness to emergencies. In-flight services entail quality factors such as safety perceptions, seat comfort, meal quality, in-flight entertainment services, language skills, and the courtesy of the flight crew. Post-flight service perception revolves around quality factors such as the speed of baggage delivery and retrieval (Namukasa, 2013). In contrast, Chen and Chang (2005) categorize airline services that influence customers' quality perceptions into ground services and in-flight services. Ground services encompass information gathering, reservations and ticket purchasing, airport check-in, and post-flight services, while in-flight services encompass all services provided during the flight (Chen & Chang, 2005).

However, defining and measuring the quality of airline service is challenging due to the heterogeneous, intangible, and inseparable nature of services (Chang & Yeh, 2002). Nevertheless, various conceptual and empirical studies have been conducted to explain this phenomenon. In the literature, studies on airline service quality have been conducted across different carriers (low-cost, full-service, regional) (Baker, 2013; Truitt & Ray Haynes, 1994), in different contexts (customer loyalty, satisfaction, value co-creation, corporate image, etc.) (Ostrowski, O'Brien, & Gordon, 1993; Namukasa, 2013; Chung & Tan, 2022; Yanginlar & Tuna, 2020), with different service providers (airlines, airports, cargo, etc.) (Youngo, Cunningham, & Lee, 1994; Özden & Celik, 2021; Özdağoğlu, Işıldak, & Keleş, 2022), and using various methods (quantitative, qualitative, multi-criteria decision-making) (Bakır & Atalık, 2021; Tali & Karaduman, 2021).

When the aforementioned studies were examined, no study was found in which Entropy and Marcos method were used together in measuring airline service quality in recent years. In the Entropy method, more reliable results are provided since objective weighting is made in accordance with the purpose of the study. In the Marcos method, which is a newer and flexible method, it is possible to evaluate many alternatives together without turning into complexity. The fact that there are 26 alternatives in the study shows the purpose of using this method.

In this context, this study aims to examine the perception of customer service quality among airline operators in the Star Alliance, which has the highest membership worldwide, based on 2023 data, using multi-criteria decision-making (MCDM) methods known as Entropy and MARCOS, with Tripadvisor data as a basis. In the study, 26 airline operators were evaluated as alternatives, and the criteria considered in the evaluation were determined based on Tripadvisor website criteria. Accordingly, the following sections will first address the phenomenon of service quality, followed by a literature review. Subsequently, the method used in the study will be described, and the results obtained using this method will be shared. Finally, the discussion section will present the conclusions reached in the study.

2. Literature Review

The SERVQUAL model, developed by Parasuraman et al. (1985), is widely used in the literature to measure customer perceptions of the quality of services provided by businesses. The SERVQUAL model consists of five general dimensions. (1) Tangibles; the appearance of physical facilities, equipment, and personnel. (2) Reliability; the ability to deliver the promised service reliably and accurately. (3) Responsiveness; the willingness to help customers and provide prompt service. (4) Assurance; the ability of employees to instill confidence and trust through their knowledge and courtesy. (5) Empathy; the provision of attentive and personalized attention to customers by the firm (Parasuraman, Zeithaml, & Berry, 1985).

In addition, the Airline Service Quality (AIRQUAL) model developed for airline operators is considered a significant factor for all service providers in the airline industry. Derived from the SERVQUAL service quality model, it was developed by Bari et al. (2001) as a tool to assess customer satisfaction with the services provided to them during service encounters (Badrillah, Shuib, & Nasir, 2023).

A comprehensive model based on five different dimensions has been proposed for evaluating airline service quality using AIRQUAL dimensions (Bari et al., 2001):

(1) Tangible services of airlines - Physical environment elements demonstrating in-flight features such as design, catering, and cleanliness.

(2) Tangible services at the terminal - Facilities provided for customers at the airport, including restrooms, luggage carts, and shops.

(3) Personnel - Encompasses all staff members dealing with customer service at the terminal, whether exhibiting good or uncooperative behavior towards customers.

(4) Empathy - A business policy applied to make customers feel safe and protected while using the services of the airline operator.

(5) Image - This factor involves offering tickets at low prices and maintaining the reputation of the operation to attract customers to use the services. Consequently, customers believe that the services provided by the operation will always be consistent.

The satisfaction of passengers is achieved through the quality and consistency provided by airline operators in each service component. Consequently, the relationship between airlines and passengers becomes more harmonious, influencing repeat purchase intentions, increasing passenger loyalty, generating word-of-mouth recommendations, establishing corporate reputation, and ultimately boosting the airline's profit. It can be observed that the continuous improvement of quality is not an extra cost but rather an investment made to increase profits (Rady, 2018).

One of the studies that extensively considers airline service quality, focusing on a wide range of criteria, is the work of Eboli, Bellizzi, and Mazzulla (2022). In their study, the authors compiled airline services affecting quality from all studies measuring airline service quality in the literature. Accordingly, they identified 24 factors: flight booking, seat selection, airline website, check-in process, flight frequency and scheduling, waiting lounges, boarding operations, punctuality, airline staff/cabin crew, cabin announcements, seat comfort/space availability, acoustic comfort inside the cabin, thermal comfort inside the cabin, air quality inside the cabin, cabin cleanliness, restroom facilities, safety and security measures, food and beverage services, entertainment options, in-flight internet/phone services, baggage handling and delivery, frequent flyer programs, and pricing (Eboli, Bellizzi, & Mazzulla , 2022).

When examining recent studies measuring service quality in airline operations, it is observed that various MCDM methods have been employed (Table 1).

Table 1. Studies on Service Quality in Airline Companies with MCDM Methods

Author(s)	Methods
(Gupta, 2018)	Best Worst Method (BWM) and VIKOR
(Bakır & Atalık, 2018)	Entropi and ARAS
(Perçin, 2018)	Fuzzy DEMATEL, Fuzzy ANP and Fuzzy VIKOR
(Pineda, Liou, Hsu, & Chuang, 2018)	DANP and VIKOR
(Badi & Abdulshahed, 2019)	FUCOM and AHP
(Fu, 2019)	AHP, ARAS, Multi-Choice Goal Programming
(Öztürk & Onurlubaş, 2019)	AHP and TOPSIS
(Büyüközkan, Havle, & Feyzioğlu, 2020)	Interval-Valued Intuitionistic Fuzzy AHP (IVIF-AHP)
(Altınkurt & Merdivenci, 2020)	EDAS
(Bakır & Atalık, 2021)	Fuzzy AHP and Fuzzy Marcos
(Gedik & Bayram, 2022)	Entropi and Aras
(Kavus, Tas, Ayyildiz, & Taskin, 2022)	BWM and IVN-AHP
(Awadh, 2023)	AHP

In studies conducted using multi-criteria decision-making techniques (Table 1), the scarcity of research on airline service quality is notable. Among these studies, no research focusing on passenger evaluations covering all airline operators belonging to the Star Alliance has been encountered. In this context, the aim of the study is to determine the importance levels of service quality factors based on passenger evaluations for the 26 airline operators belonging to the Star Alliance.

3. Materials and Methods

In the study, the Entropy method, known as an objective weighting method, was employed for the process of weighting criteria to determine their importance levels. Additionally, the MARCOS method was utilized to obtain rankings of decision alternatives.

3.1. The entropy method

Entropy was first introduced to the literature through its adaptation to information theory by Shannon (1948). In decision-making problems with multiple criteria, various subjective and objective decision-making techniques exist for calculating the weights of criteria. Among these, although

Analytic Hierarchy Process (AHP) is one of the most preferred methods, it has been subject to some criticisms due to its reliance on subjective criteria, which can lead to biased results. On the other hand, the Entropy method provides more reliable results as it performs objective weighting (Arslan, Durak, & Özdemir, 2021). As seen in some studies in the literature, the Entropy method is applied by following the five steps outlined below. (Kehribar, Karademir, & Evci, 2021; Özgüner & Özgüner, 2020; Bağcı & Caba, 2018; Akçakanat, Eren, Aksoy, & Ömürbek, 2017).

Step 1: *Formation of the Decision Matrix*

In the first step of the Entropy method, there is a decision matrix formed using equality (1).

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

Step 2: *Performing the Normalization Process*

In this step of the Entropy method, the decision matrix is normalized to a common unit. In this process, criteria are normalized using equality (2) without distinguishing between benefit and cost functions.

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{j} a_{ij}} \quad (2)$$

Here;

i= alternatives
j= criteria
$r_{ij=}$ *normalized values*
x_{ij}*= the benefit values of alternative i for criterion j*

After the normalization process, the matrix $R = [r_{ij}]_{mxn}$ is obtained.

Step 3: *Calculation of Entropy Values* (e_j) *for Criteria*

In this step, the entropy values for criteria are calculated using equality (3).

$$e_j = -k \sum_{j=1}^{n} r_{ij}.\ln(r_j) \qquad (i = 1,2,3,\ldots,m \; ve \; j = 1,2,3,\ldots,n) \quad (3)$$

k= entropy coefficient $\{(\ln(n))^{-1}\}$
r_{ij}*= normalized values*
$e_{j=}$ *entropy value*

In this notation, e_j represents the entropy value of criterion j. and it lies between $0 \leq e_j \leq 1$.

Step 4: *Calculation of Differentiation Degree of Information* (d_j)

$$d_j = 1 - e_j \qquad (i = 1,2,3,\ldots m \; ve \; j = 1,2,3,\ldots,n) \quad (4)$$

In this step, the calculated d_j values being high indicate that there is a high degree of contrast, or in other words, significant differentiation, among the alternative values for the criteria.

Step 5: *Calculation of Criterion Weights* (w_j)

In this final step of the method, entropy weights are obtained for each criterion.

$$w_j = {}^{1-e_j}\!\Big/_{\sum_{i=1}^{n}(1-e_j)} \quad (5)$$

In this case, $w_1 + w_2 + w_3 + \cdots + w_n = 1$ equality for holds.

3.2. The Measurement of Alternatives and Ranking According to Compromise Solution (MARCOS) method

After determining the weight values of criteria, the MARCOS method is employed to obtain the rankings of alternatives. MARCOS method is one of the preferred methods for ranking decision alternatives, as indicated by Stević et al. (2020). The method is based on establishing the relationship between alternatives and reference values (ideal and anti-ideal alternatives) to rank the performances of alternatives. For the defined relationships, firstly, the benefit functions of alternatives are determined, and a ranking is made according to the ideal (AI)-anti-ideal (AAI) solutions. Decision preferences are defined based on benefit functions. Benefit functions express the position of an alternative relative to the ideal and anti-ideal solutions. At this point, the best alternative is the one closest to the ideal and farthest from the anti-ideal reference point (Stević, Pamučar, Puška, & Chatterjee, 2020).

The implementation of the MARCOS method occurs in six stages (Stević, Pamučar, Puška, & Chatterjee, 2020):

Step 1: Establish an initial decision matrix

The values taken by *m* alternatives according to *n* criteria in the decision problem are represented in the decision matrix shown in Equality (7).

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & \ldots & C_n \end{matrix} \\ \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \ldots & x_{mn} \end{bmatrix} \end{matrix}$$

Step 2: The ideal *(AI)* and anti-ideal *(AAI)* solutions of the alternatives are calculated, and an extended matrix is constructed using the values of these solutions. In this step, each of the alternatives is evaluated for each of the criteria, and the optimal and anti-optimal solutions of this alternative are calculated for these criteria. This step is performed according to the following equations.

$$AAI = \min_j x_{ij} \;\; if \;\; j \in B \;\; and \;\; AAI = \max_j x_{ij} \;\; if \;\; j \in C \quad (7)$$

$$AI = \max_j x_{ij} \;\; if \;\; j \in B \;\; and \;\; AAI = \min_j x_{ij} \;\; if \;\; j \in C \quad (8)$$

Where B stands for the criteria to be maximized, and C stands for the criteria to be minimized.

Step 3. The normalization of the extended initial matrix *(X)*. Normalization is performed by using the following equations

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \; if \; j \in C \qquad (9)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \; if \; j \in B \qquad (10)$$

Where the elements x_{ij} and x_{ai} represent the elements of the initial decision matrix.

Step 4. The determination of a weighted matrix. Aggravation is performed by multiplying normalized matrix values by corresponding weights

$$v_{ij} = n_{ij} \times w_j \qquad (11)$$

Step 5. The calculation of the utility degree of the alternatives *Ki*. The utility degree is determined by applying the following equations:

$$K_i^- = \frac{S_i}{S_{aai}} \qquad (12)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \qquad (13)$$

Where S_i ($i=1,2,..,m$) represents the sum of the elements of a weighted matrix *V*, equation:

$$S_i = \sum_{i=1}^{n} v_{ij} \qquad (14)$$

Step 6. The formation of the utility function of the alternatives $f(K_i)$. The utility function is calculated by using the following equation:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \qquad (15)$$

Where $f(K_i^-)$ is the utility function versus the anti-ideal solution, while $f(K_i^+)$ is the utility function versus the ideal solution. The utility functions are calculated using the following equations:

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \qquad (16)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \qquad (17)$$

As a result, alternatives are ranked. A rank is formed based on the final value of the utility function. The alternative should have the most significant value of the utility function.

4. Result and Discussion

4.1. Data collection and definition of variables

Tripadvisor is the world's largest and most widely used online travel guidance company. Travelers seeking to go from one place to another turn to Tripadvisor to discover what mode of transportation to use, where to stay, what activities to engage in, and even what food to enjoy based on the reviews provided by individuals on the platform. Airlines providing travel services are also featured within the platform. Travelers share their experiences, rating them based on the criteria provided by Tripadvisor, and they can also leave comments for other travelers (potential/actual). The rating system ranges from 1 to 5. Travelers can evaluate their experience as follows: 1=very poor, 2=poor, 3=neither good nor bad, 4=good, and 5=excellent.

In order for these evaluations to be conducted, Tripadvisor has determined the criteria that define the quality of airline services as legroom, seat comfort, in-flight entertainment (Wi-Fi, TV, movies), onboard experience, customer service, value for money, cleanliness, check-in and boarding, food and beverage. Table 2 displays the criteria and codes used in this study.

Table 2. Criteria and Criteria Codes Used in the Study

Criteria Codes	Criteria
LR	Legroom
SC	Seat Comfort
IFE	In-flight entertainment
OBE	Onboard experience
CS	Customer service
VM	Value for money
CL	Cleanliness
CHB	Check-in and boarding
FB	Food and beverage

In the study, the calculation of alternative scores related to the criteria was approached using the Entropy method, and importance coefficients were calculated. Subsequently, the MARCOS method was employed to obtain rankings of the alternatives.

4.2. Obtaining importance coefficients with the entropy method

Step 1: Obtaining the Decision Matrix

In the study, the importance coefficients of the criteria were obtained using the Entropy method. The decision matrix is presented in Table 3.

Table 3. Decision Matrix for Airlines

AIRLINES	LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
THY	3.500	3.500	4.000	4.000	4.000	4.000	4.000	4.000	4.000
UNITED	3.500	3.000	3.000	3.000	3.500	3.000	3.500	3.500	3.000
AEGEAN	3.500	4.000	2.500	4.000	4.000	4.000	4.500	4.000	4.000
AIR CANADA	3.500	3.500	3.500	3.000	3.500	3.000	3.500	3.500	3.000
AIR CHINA	3.000	3.000	2.500	3.000	3.000	3.500	3.500	3.500	3.000
AIR INDIA	3.500	3.500	2.500	3.000	3.000	3.500	3.000	3.500	3.000
AIR NEW ZEALAND	4.000	4.000	4.000	4.000	4.500	4.000	4.500	4.500	4.000
ALL NIPPON AIRWAYS	4.000	4.000	4.000	4.000	4.500	4.000	4.500	4.000	4.000
ASIANA AIRLINES	4.000	4.000	3.500	4.000	4.000	4.000	4.000	4.000	4.000
AUSTRIAN	3.500	3.500	3.000	3.500	4.000	3.500	4.000	4.000	3.500
AVIANCA	3.500	3.500	4.000	3.500	4.000	3.500	4.000	4.000	3.500
BRUSSELS AIRLINES	3.500	3.500	2.500	3.000	3.500	3.500	4.000	3.500	3.000
COPA AIRLINES	3.500	3.500	3.500	3.500	4.000	3.500	4.000	4.000	3.500
CROATIA AIRLINES	3.500	3.500	2.000	3.500	3.500	3.500	4.000	3.500	3.000
EGYPTAIR	3.500	3.500	2.500	3.000	3.500	3.500	3.500	3.500	3.000
ETHIOPIAN	3.500	3.500	3.000	3.000	3.500	3.500	3.500	3.500	3.500
EVA AIR	4.000	4.000	4.000	4.000	4.500	4.000	4.500	4.500	4.000
LOT POLISH AIRLINES	3.500	3.500	2.500	3.000	3.500	3.500	4.000	3.500	3.000
LUFTHANSA	3.500	3.500	3.500	3.500	4.000	3.500	4.000	4.000	3.500
SAS	3.500	3.500	2.500	3.500	3.500	3.500	4.000	4.000	3.000
SHENZHEN AIRLINES	3.500	3.500	2.500	3.000	3.500	3.500	3.500	3.500	3.000
SINGAPORE AIRLINES	4.000	4.000	4.500	4.000	4.500	4.000	4.500	4.500	4.000
SOUTH AFRICAN	3.500	3.500	3.000	3.000	3.500	3.500	4.000	3.500	3.500
SWISS	3.500	3.500	3.500	3.500	4.000	3.500	4.000	4.000	3.500
AIR PORTUGAL	3.000	3.000	2.500	3.000	3.500	3.000	3.500	3.500	3.000
THAI	4.000	4.000	3.500	4.000	4.000	4.000	4.000	4.000	4.000

Step 2: The normalized decision matrix was obtained

In this step, the values for each criterion were normalized using Equation (2). By dividing the criteria by the sum of the respective columns, normalized values were obtained. These values are presented in Table 4.

Table 4. Normalized Decision Matrix

AIRLINES	LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
THY	0.038	0.038	0.049	0.045	0.041	0.043	0.039	0.040	0.045
UNITED	0.038	0.032	0.037	0.034	0.036	0.032	0.034	0.035	0.034
AEGEAN	0.038	0.043	0.030	0.045	0.041	0.043	0.044	0.040	0.045
AIR CANADA	0.038	0.038	0.043	0.034	0.036	0.032	0.034	0.035	0.034
AIR CHINA	0.032	0.032	0.030	0.034	0.030	0.037	0.034	0.035	0.034
AIR INDIA	0.038	0.038	0.030	0.034	0.030	0.037	0.029	0.035	0.034
AIR NEW ZEALAND	0.043	0.043	0.049	0.045	0.046	0.043	0.044	0.045	0.045
ALL NIPPON AIRWAYS	0.043	0.043	0.049	0.045	0.046	0.043	0.044	0.040	0.045
ASIANA AIRLINES	0.043	0.043	0.043	0.045	0.041	0.043	0.039	0.040	0.045
AUSTRIAN	0.038	0.038	0.037	0.039	0.041	0.037	0.039	0.040	0.039
AVIANCA	0.038	0.038	0.049	0.039	0.041	0.037	0.039	0.040	0.039
BRUSSELS AIRLINES	0.038	0.038	0.030	0.034	0.036	0.037	0.039	0.035	0.034
COPA AIRLINES	0.038	0.038	0.043	0.039	0.041	0.037	0.039	0.040	0.039
CROATIA AIRLINES	0.038	0.038	0.024	0.039	0.036	0.037	0.039	0.035	0.034
EGYPTAIR	0.038	0.038	0.030	0.034	0.036	0.037	0.034	0.035	0.034
ETHIOPIAN	0.038	0.038	0.037	0.034	0.036	0.037	0.034	0.035	0.039
EVA AIR	0.043	0.043	0.049	0.045	0.046	0.043	0.044	0.045	0.045
LOT POLISH AIRLINES	0.038	0.038	0.030	0.034	0.036	0.037	0.039	0.035	0.034
LUFTHANSA	0.038	0.038	0.043	0.039	0.041	0.037	0.039	0.040	0.039
SAS	0.038	0.038	0.030	0.039	0.036	0.037	0.039	0.040	0.034
SHENZHEN AIRLINES	0.038	0.038	0.030	0.034	0.036	0.037	0.034	0.035	0.034
SINGAPORE AIRLINES	0.043	0.043	0.055	0.045	0.046	0.043	0.044	0.045	0.045
SOUTH AFRICAN	0.038	0.038	0.037	0.034	0.036	0.037	0.039	0.035	0.039
SWISS	0.038	0.038	0.043	0.039	0.041	0.037	0.039	0.040	0.039
AIR PORTUGAL	0.032	0.032	0.030	0.034	0.036	0.032	0.034	0.035	0.034
THAI	0.043	0.043	0.043	0.045	0.041	0.043	0.039	0.040	0.045

Step 3: Calculation of Entropy Values for Criteria

For this step, first, the normalized values (r_{ij}) shown in Table 4 were multiplied by their natural logarithms (ln (r_{ij})). Then, the sum of the obtained r_{ij} and ln (r_{ij}) values was calculated to obtain the entropy values e_j using equation (3).

The value "k" in Equation (3) represents the entropy coefficient, which is the logarithmic form of the number of alternatives in the decision matrix. For example, considering that this study involves 26 decision alternatives, the value of "n" is assumed to be 26. Hence, using the formula $k=(ln\ (n))^{-1}$, we calculate $k=\frac{1}{\ln(26)}=0{,}3069$. All obtained e_j values in this step are presented in Table 5.

Table 5. The Values of e_j for Each Criterion

LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
0.999	0.999	0.993	0.998	0.998	0.999	0.999	0.999	0.998

Step 4: The Calculation of the Differentiation Degree of Information

The entropy values e_j for the criteria shown in Table 5 have been subtracted from 1 using Equation (4), and the d_j values have been calculated (Table 6).

Table 6. The d_j values related to the criteria

LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
0.001	0.001	0.007	0.002	0.002	0.001	0.001	0.001	0.002

Step 5: Calculation of Entropy Criterion Weights

In the final step, the entropy weights for the criteria were obtained using equation (5), and the results are presented in Table 7. The sum of the weight values for the 9 criteria was found to be 1. Accordingly, it was observed that the most important evaluation criterion is the in-flight entertainment systems (Wi-Fi, TV, movies) with a weight of 0.355.

Table 7. Entropy Criterion Weight Values

LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
0.045	0.057	0.355	0.121	0.099	0.061	0.079	0.062	0.121

The criterion weights obtained in Table 7 will be considered as criterion weights in the subsequent step using the MARCOS method.

4.3. Application of the MARCOS (Measurement Alternatives and Ranking according to Compromise Solution) method

The creation of a multi-criteria model consists of nine criteria and twenty-six alternatives. This represents a group decision-making process, akin to the initial matrix in the MARCOS method (as in determining the importance of criteria). The estimations of decision-makers are aggregated using geometric mean to obtain an initial decision-making matrix. Using Equations (7) and (8), an expanded initial decision-making matrix is obtained, as shown in Table 8. The anti-ideal solution (AAI) represents the worst features, i.e., the highest values of their criteria, while minimum values for all other criteria of the benefit type are part of the AAI solution. The ideal solution (AI) is the opposite of the anti-ideal.

Table 8. An Extended Decision-Making Matrix

AIRLINES	LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
AAI	3.000	3.000	2.000	3.000	3.000	3.000	3.000	3.500	3.000
THY	3.500	3.500	4.000	4.000	4.000	4.000	4.000	4.000	4.000
UNITED	3.500	3.000	3.000	3.000	3.500	3.000	3.500	3.500	3.000
AEGEAN	3.500	4.000	2.500	4.000	4.000	4.000	4.500	4.000	4.000
AIR CANADA	3.500	3.500	3.500	3.000	3.500	3.000	3.500	3.500	3.000
AIR CHINA	3.000	3.000	2.500	3.000	3.000	3.500	3.500	3.500	3.000
AIR INDIA	3.500	3.500	2.500	3.000	3.000	3.500	3.000	3.500	3.000
AIR NEW ZEALAND	4.000	4.000	4.000	4.000	4.500	4.000	4.500	4.500	4.000
ALL NIPPON AIRWAYS	4.000	4.000	4.000	4.000	4.500	4.000	4.500	4.000	4.000
ASIANA AIRLINES	4.000	4.000	3.500	4.000	4.000	4.000	4.000	4.000	4.000
AUSTRIAN	3.500	3.500	3.000	3.500	4.000	3.500	4.000	4.000	3.500
AVIANCA	3.500	3.500	4.000	3.500	4.000	3.500	4.000	4.000	3.500
BRUSSELS AIRLINES	3.500	3.500	2.500	3.000	3.500	3.500	4.000	3.500	3.000
COPA AIRLINES	3.500	3.500	3.500	3.500	4.000	3.500	4.000	4.000	3.500
CROATIA AIRLINES	3.500	3.500	2.000	3.500	3.500	3.500	4.000	3.500	3.000
EGYPTAIR	3.500	3.500	2.500	3.000	3.500	3.500	3.500	3.500	3.000
ETHIOPIAN	3.500	3.500	3.000	3.000	3.500	3.500	3.500	3.500	3.500
EVA AIR	4.000	4.000	4.000	4.000	4.500	4.000	4.500	4.500	4.000
LOT POLISH AIRLINES	3.500	3.500	2.500	3.000	3.500	3.500	4.000	3.500	3.000
LUFTHANSA	3.500	3.500	3.500	3.500	4.000	3.500	4.000	4.000	3.500
SAS	3.500	3.500	2.500	3.500	3.500	3.500	4.000	4.000	3.000
SHENZHEN AIRLINES	3.500	3.500	2.500	3.000	3.500	3.500	3.500	3.500	3.000
SINGAPORE AIRLINES	4.000	4.000	4.500	4.000	4.500	4.000	4.500	4.500	4.000
SOUTH AFRICAN	3.500	3.500	3.000	3.000	3.500	3.500	4.000	3.500	3.500
SWISS	3.500	3.500	3.500	3.500	4.000	3.500	4.000	4.000	3.500
AIR PORTUGAL	3.000	3.000	2.500	3.000	3.500	3.000	3.500	3.500	3.000
THAI	4.000	4.000	3.500	4.000	4.000	4.000	4.000	4.000	4.000
AI	4.000	4.000	4.500	4.000	4.500	4.000	4.500	4.500	4.000

The normalized decision matrix created using Equations (9) and (10) for airline companies is presented in Table 9.

Table 9. Normalized Matrix

AIRLINES	LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
AAI	0.750	0.750	0.444	0.750	0.667	0.750	0.667	0.778	0.750
THY	0.875	0.875	0.889	1.000	0.889	1.000	0.889	0.889	1.000
UNITED	0.875	0.750	0.667	0.750	0.778	0.750	0.778	0.778	0.750
AEGEAN	0.875	1.000	0.556	1.000	0.889	1.000	1.000	0.889	1.000
AIR CANADA	0.875	0.875	0.778	0.750	0.778	0.750	0.778	0.778	0.750
AIR CHINA	0.750	0.750	0.556	0.750	0.667	0.875	0.778	0.778	0.750
AIR INDIA	0.875	0.875	0.556	0.750	0.667	0.875	0.667	0.778	0.750
AIR NEW ZEALAND	1.000	1.000	0.889	1.000	1.000	1.000	1.000	1.000	1.000
ALL NIPPON AIRWAYS	1.000	1.000	0.889	1.000	1.000	1.000	1.000	0.889	1.000
ASIANA AIRLINES	1.000	1.000	0.778	1.000	0.889	1.000	0.889	0.889	1.000
AUSTRIAN	0.875	0.875	0.667	0.875	0.889	0.875	0.889	0.889	0.875
AVIANCA	0.875	0.875	0.889	0.875	0.889	0.875	0.889	0.889	0.875
BRUSSELS AIRLINES	0.875	0.875	0.556	0.750	0.778	0.875	0.889	0.778	0.750
COPA AIRLINES	0.875	0.875	0.778	0.875	0.889	0.875	0.889	0.889	0.875
CROATIA AIRLINES	0.875	0.875	0.444	0.875	0.778	0.875	0.889	0.778	0.750
EGYPTAIR	0.875	0.875	0.556	0.750	0.778	0.875	0.778	0.778	0.750
ETHIOPIAN	0.875	0.875	0.667	0.750	0.778	0.875	0.778	0.778	0.875
EVA AIR	1.000	1.000	0.889	1.000	1.000	1.000	1.000	1.000	1.000
LOT POLISH AIRLINES	0.875	0.875	0.556	0.750	0.778	0.875	0.889	0.778	0.750
LUFTHANSA	0.875	0.875	0.778	0.875	0.889	0.875	0.889	0.889	0.875
SAS	0.875	0.875	0.556	0.875	0.778	0.875	0.889	0.889	0.750
SHENZHEN AIRLINES	0.875	0.875	0.556	0.750	0.778	0.875	0.778	0.778	0.750
SINGAPORE AIRLINES	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SOUTH AFRICAN	0.875	0.875	0.667	0.750	0.778	0.875	0.889	0.778	0.875
SWISS	0.875	0.875	0.778	0.875	0.889	0.875	0.889	0.889	0.875
AIR PORTUGAL	0.750	0.750	0.556	0.750	0.778	0.750	0.778	0.778	0.750
THAI	1.000	1.000	0.778	1.000	0.889	1.000	0.889	0.889	1.000
AI	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

The next step is to weight the normalized matrix by multiplying all its values with the values of the criteria using Equation (11). The weighted normalized matrix is shown in Table 10.

Table 10. The Weighted Normalized Matrix

AIRLINES	LR	SC	IFE	OBE	CS	VM	CL	CHB	FB
AAI	0.034	0.043	0.158	0.091	0.066	0.046	0.052	0.048	0.091
THY	0.039	0.050	0.315	0.121	0.088	0.061	0.070	0.055	0.121
UNITED	0.039	0.043	0.236	0.091	0.077	0.046	0.061	0.048	0.091
AEGEAN	0.039	0.057	0.197	0.121	0.088	0.061	0.079	0.055	0.121
AIR CANADA	0.039	0.050	0.276	0.091	0.077	0.046	0.061	0.048	0.091
AIR CHINA	0.034	0.043	0.197	0.091	0.066	0.053	0.061	0.048	0.091
AIR INDIA	0.039	0.050	0.197	0.091	0.066	0.053	0.052	0.048	0.091
AIR NEW ZEALAND	0.045	0.057	0.315	0.121	0.099	0.061	0.079	0.062	0.121
ALL NIPPON AIRWAYS	0.045	0.057	0.315	0.121	0.099	0.061	0.079	0.055	0.121
ASIANA AIRLINES	0.045	0.057	0.276	0.121	0.088	0.061	0.070	0.055	0.121
AUSTRIAN	0.039	0.050	0.236	0.106	0.088	0.053	0.070	0.055	0.106
AVIANCA	0.039	0.050	0.315	0.106	0.088	0.053	0.070	0.055	0.106
BRUSSELS AIRLINES	0.039	0.050	0.197	0.091	0.077	0.053	0.070	0.048	0.091
COPA AIRLINES	0.039	0.050	0.276	0.106	0.088	0.053	0.070	0.055	0.106
CROATIA AIRLINES	0.039	0.050	0.158	0.106	0.077	0.053	0.070	0.048	0.091
EGYPTAIR	0.039	0.050	0.197	0.091	0.077	0.053	0.061	0.048	0.091
ETHIOPIAN	0.039	0.050	0.236	0.091	0.077	0.053	0.061	0.048	0.106
EVA AIR	0.045	0.057	0.315	0.121	0.099	0.061	0.079	0.062	0.121
LOT POLISH AIRLINES	0.039	0.050	0.197	0.091	0.077	0.053	0.070	0.048	0.091
LUFTHANSA	0.039	0.050	0.276	0.106	0.088	0.053	0.070	0.055	0.106
SAS	0.039	0.050	0.197	0.106	0.077	0.053	0.070	0.055	0.091
SHENZHEN AIRLINES	0.039	0.050	0.197	0.091	0.077	0.053	0.061	0.048	0.091
SINGAPORE AIRLINES	0.045	0.057	0.355	0.121	0.099	0.061	0.079	0.062	0.121
SOUTH AFRICAN	0.039	0.050	0.236	0.091	0.077	0.053	0.070	0.048	0.106
SWISS	0.039	0.050	0.276	0.106	0.088	0.053	0.070	0.055	0.106
AIR PORTUGAL	0.034	0.043	0.197	0.091	0.077	0.046	0.061	0.048	0.091
THAI	0.045	0.057	0.276	0.121	0.088	0.061	0.070	0.055	0.121
AI	0.045	0.057	0.355	0.121	0.099	0.061	0.079	0.062	0.121

Equations (12), (13), and (14) are utilized to perform the necessary calculations for the final step. The last step involves determining the utility function using Equations (15), (16), and (17), and creating a ranking accordingly. The best alternative is selected based on the most significant utility function value. When considering all relevant criteria, Table 11 reveals the best airline company. Accordingly, Singapore Airlines emerges as the best airline, while Air China has the lowest value in the ranking according to the utility function.

Table 11. Ranking of Alternatives According to the Utility Function

AIRLINES	Si	Ki-	Ki+	f(K-)	f(K+)	f(Ki)	Rank
AAI	0.629						
THY	0.921	1.466	0.921	0.386	0.614	0.741	5
UNITED	0.733	1.166	0.733	0.386	0.614	0.590	18
AEGEAN	0.819	1.303	0.819	0.386	0.614	0.659	12
AIR CANADA	0.779	1.240	0.779	0.386	0.614	0.627	14
AIR CHINA	0.684	1.089	0.684	0.386	0.614	0.551	26
AIR INDIA	0.688	1.095	0.688	0.386	0.614	0.554	24
AIR NEW ZEALAND	0.961	1.528	0.961	0.386	0.614	0.773	2
ALL NIPPON AIRWAYS	0.954	1.517	0.954	0.386	0.614	0.767	4
ASIANA AIRLINES	0.895	1.423	0.895	0.386	0.614	0.720	6
AUSTRIAN	0.804	1.280	0.804	0.386	0.614	0.647	13
AVIANCA	0.883	1.405	0.883	0.386	0.614	0.711	8
BRUSSELS AIRLINES	0.717	1.140	0.717	0.386	0.614	0.577	19
COPA AIRLINES	0.844	1.342	0.844	0.386	0.614	0.679	9
CROATIA AIRLINES	0.693	1.102	0.693	0.386	0.614	0.557	23
EGYPTAIR	0.708	1.126	0.708	0.386	0.614	0.570	21
ETHIOPIAN	0.763	1.213	0.763	0.386	0.614	0.614	16
EVA AIR	0.961	1.528	0.961	0.386	0.614	0.773	3
LOT POLISH AIRLINES	0.717	1.140	0.717	0.386	0.614	0.577	19
LUFTHANSA	0.844	1.342	0.844	0.386	0.614	0.679	9
SAS	0.739	1.175	0.739	0.386	0.614	0.595	17
SHENZHEN AIRLINES	0.708	1.126	0.708	0.386	0.614	0.570	21
SINGAPORE AIRLINES	1.000	1.591	1.000	0.386	0.614	0.805	1
SOUTH AFRICAN	0.771	1.227	0.771	0.386	0.614	0.621	15
SWISS	0.844	1.342	0.844	0.386	0.614	0.679	9
AIR PORTUGAL	0.688	1.094	0.688	0.386	0.614	0.553	25
THAI	0.895	1.423	0.895	0.386	0.614	0.720	6
AI	1.000						

5. Discussion

The airline transportation system, considering the diversity of services and facilities offered, is quite complex. High service quality positively influences customer satisfaction and consequently their loyalty. Loyal customers tend to have stronger intentions for repeat purchases. Therefore, in today's competitive market, businesses need to measure customers' perception of service quality to deliver better service (Ghotbabadi, Feiz, & Baharun, 2015). According to Bari et al. (2001), the key factor for success is to maintain high levels of service quality and sustain this level. Failures result in service dissatisfaction. Accordingly, based on data from 2023, this study aims to examine the perception of service quality among airlines operating under the Star Alliance, the world's largest airline alliance, using multi-criteria decision-making (MCDM) methods known as Entropy and MARCOS. For this purpose, data on quality from TripAdvisor were collected for 26 airline companies under the Star Alliance umbrella. Subsequently, these airlines were ranked based on quality data using the Entropy and MARCOS methods. The criteria analyzed include legroom, seat comfort, in-flight entertainment, onboard experience, customer service, value for money, cleanliness, check-in and boarding, and food and beverage.

Upon initial analysis, it was determined that according to the weighting process conducted with the Entropy method, the most important evaluation criterion is the in-flight entertainment systems (Wi-Fi, TV, movies) (0.355), followed by the in-flight experience (0.121) and the quality of food and beverages (0.121), which are equally important. In-flight communication systems are particularly important for full cost carrier airlines offering different segments such as first and business class, especially in the application of smart cabins (Jin & Kim, 2022). Similar studies conducted from past to present have also highlighted the role of in-flight entertainment in influencing passengers' perceptions of service quality (Alamdari, 1999; Francis, Dennis, Ison, & Humphreys, 2007; Liu , 2007; Atalık, Bakır, & Akan, 2019; John, 2022; Li, Jing, & Zhu , 2024).It is believed that the presence of series, movies, etc., in the in-flight entertainment systems with subtitles in the languages of the countries flown to, and the presence of programs specific to the country's own culture, will result in positive experiences for customers during the flight. Additionally, including alternatives from the cuisines of the countries in the catering services is expected to increase the perception of service quality among customers from those countries. Furthermore, customer service (0.099), cleanliness (0.079), check-in and boarding (0.062), value for money (0.061), seat comfort (0.057), and legroom (0.045) criteria follow in descending order. It can be said that legroom and seat comfort emerged as the least important criteria for passengers participating in the scoring process. Curtis, Rhoades & Waguespack (2012) examined satisfaction with service quality in airlines and found that seat comfort and legroom were related to the frequency of flying. Frequent flyers are more affected by these features, whereas occasional flyers may be less influenced by them. Considering that this study is based on TripAdvisor data from passengers who have flown at least once, a similar situation is likely. That is, since most of the passengers rating the service are not frequent flyers, they may place less importance on in-flight seat comfort and legroom.

Subsequently, based on the results of the MARCOS method, the airlines with the best performance were determined using the relevant criteria. Among the 26 airlines examined, Singapore Airlines was found to exhibit the best performance. This finding aligns closely with Skytrax[1] user evaluations in 2023, where Singapore Airlines was selected as the world's best airline, reflecting the similarity of the study's results. Following Singapore Airlines, Air New Zealand ranked second and Eva Air ranked third. It is noteworthy that Turkish Airlines ranked fifth, representing Turkey. Turkish Airlines' position can be attributed to its reputation as one of the airlines with the best catering services globally, which has contributed to its high standing in terms of quality perception. Additionally, in the APEX[2] passenger assessment in 2023, Turkish Airlines was awarded for the best in-flight entertainment and the best food and beverage services.

In conclusion, since one of the member airline companies of Star Alliance is Turkish Airlines operating in Turkey, it is thought that the results of the study will contribute to national theory and practice as well as being an international indicator. However, there are some limitations with this contribution. The primary constraint was that the study evaluated 26 airline companies that are members of Star Alliance, the world's largest alliance. Airlines belonging to other alliances such as Oneworld and SkyTeam were not included in the study. Furthermore, the data analyzed only reflected the evaluations of airline users on Tripadvisor, and only 9 evaluation criteria were considered in the study, which constituted additional limitations. Despite these constraints, the study is expected to contribute to the literature by analyzing the service quality of relevant airline companies using integrated methods and serve as a guiding reference for future research. It is anticipated that future studies with broader samples, the inclusion or utilization of different MCDM methods, will lead to significant progress in the literature.

Ethical approval

Not applicable.

Conflicts of Interest

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

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[1] Skytrax established in 1989, the international air transport rating organisation, based in London, UK.

[2] The Airline Passenger Experience Association

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The Mediating Role of Turnover Intention in The Relationship Between Job Insecurity and Compulsory Citizenship Behavior: A Research in The Aviation Industry

Tuba Bayar[1*], Daimi Koçak[2]

[1*]Samsun University, Aviation Management Department, Samsun, Türkiye (tuba.bayar@samsun.edu.tr)
[2] Erzincan Binali Yıldırım University, Aviation Management Department, Erzincan, Türkiye (dkocak@erzincan.edu.tr)

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Abstract

In this study, we proposed and tested a mediation model that examines turnover intentions as the mediators in the relationship between job insecurity and compulsory citizenship behavior. Data were collected from 213 employees of one private airline company and one private ground handling company located in İstanbul, Turkey. The results showed that job insecurity was positively related to compulsory citizenship behavior. Furthermore, turnover intention mediated the relationship between job insecurity and compulsory citizenship behavior. The implications, limitations, and future research directions are also discussed.

This paper has been derived from the master's thesis completed at Erzincan Binali Yıldırım University Institute of Social Sciences, Aviation Management Master Program

1. Introduction

In the rapidly globalizing business world influenced by economic, social, and technological developments, organizations are facing intense competition. While in traditional times, processes, organizational structures, and outputs were considered sufficient for organizational success, it is now understood that employees play a significant role in increasing organizations' efficiency, achieving competitive advantage, and sustaining it. As a result of employees being seen in such a crucial position for organizations, the expectations of organizations from their employees have also changed. Organizations have started to require employees to take on responsibilities beyond their formal role descriptions without relying on an official reward system. Researchers have observed that behaviors initially undertaken voluntarily by employees have gradually been implemented as if they were their own responsibilities, and employees have felt pressured to carry them out compulsorily over time. Furthermore, it has been observed that, contrary to the positive outcomes generated when organizational citizenship behavior is voluntarily performed, negative outcomes are produced in organizations when these behaviors are carried out compulsorily (Chen & Gao, 2020). Therefore, understanding the antecedents that contribute to the emergence of compulsory citizenship behavior (CCB) is crucial for organizations to establish more efficient management.

Business life constitutes a large part of individuals' lives. Thus, the attitudes and behaviors of employees who spend a considerable part of their lives in the workplace are highly significant for organizations. In this context, one of the issues to be examined is the concept of job insecurity. Job insecurity is an expression of employees' concerns about the possible loss of their current job or their worries about the future of their job (Rosenblatt & Ruvio, 1996; Sverke et al., 2002). The level of job insecurity perceived by individuals varies depending on organizational cultures, environmental factors, family structures, demographic characteristics, and personality structures (Kinnunen et al., 1999). Additionally, high self-esteem, employability, life satisfaction, perceptions of organizational justice, and the support provided by organizations have a negative impact on job insecurity perceptions (Adekiya, 2018; Blackmore & Kuntz, 2011; Çalışkan & Özkoç, 2020; Piccoli & De Witte, 2015). Individuals who are concerned about job security exhibit various negative behavioral and psychological reactions. These reactions include job dissatisfaction, low organizational commitment, experiencing high levels of stress, feeling burnout, considering leaving the job, and being physically present at work while mentally absent (Davy et al., 1991; Dığın

& Ünsar, 2010; Greenhalgh & Rosenblatt, 1984). Therefore, the existence of individuals with these attitudes and behaviors negatively affects the performance and efficiency of organizations in the long term.

Another factor that affects the performance and efficiency of employees in their jobs is turnover intention. This intention encompasses the idea of employees leaving their current jobs and seeking alternative employment (Tett & Meyer, 1993). Turnover intention is due to environmental factors such as unemployment, employability, and economic conditions; organizational factors such as salary, career advancement, organizational culture, and manager behavior; and individual factors such as age, education, experience, and ability (Cotton & Tuttle, 1986). Turnover intention requires a process. As a result of this process, individuals either leave their jobs if there are alternative opportunities or continue to work in their current positions due to their life circumstances. Both events have negative outcomes for organizations. In the absence of alternative opportunities, employees who do not leave the organization cannot perform as efficiently and effectively as before. Therefore, in the study, the concepts of job insecurity and turnover intention, which are considered important determinants of employees' display of extra behaviors expected by organizations, were addressed.

When considering the structural characteristics of the aviation sector, which constitutes the research field of study, it is a sector that requires high capital and labor. The aviation sector, which serves as a good example of open systems, is a service sector affected by many economic, technological, social, and political factors. In recent years, competition in the sector has been increasing every day, driven by rapid developments in the field of transportation. Under these conditions, for the success of organizations, it is important not only to keep up with developments in the sector but also to have qualified and trained human resources. Working in a sector with time pressure, a continuous 24/7 shift system, the potential for serious consequences of errors, a fragile structure, and constant risks, the negative attitudes and behaviors displayed by employees need to be addressed. In this context, this study examined the impact of job insecurity perceptions of aviation sector employees on CCB and the mediating role of turnover intention in this impact.

2. Theoretical Background and Hypotheses

2.1 Job insecurity and CCB

The rapidly increasing competition in the business world has made it necessary for organizations to be dynamic and sustainable in an intensely competitive environment. Organizations that want to gain a competitive advantage ask their employees, who are an important resource for them, to exhibit organizational citizenship behavior that is not determined by formal reward systems and is on a voluntary basis. According to social exchange theory, long-term and quality relationships between managers and employees are linked to the activities that individuals exhibit after mutually performing cost-benefit analysis (Cropanzano & Mitchell, 2005). Based on social exchange theory, the norm of reciprocity generates obligations towards the other party if they have previously engaged in a behavior that will benefit the recipient (Blau, 1964). For example, Ng and Feldman (2011) found that employees who were satisfied with their jobs were more likely to suggest improvements in response to positive treatment within their work relationships. In addition, although individuals do not know exactly how much contribution their organization will make to them at the beginning, they expect that their contribution to their organization will be reciprocated over time (Altunel, 2009). When employees perceive that this expectation is not fulfilled in accordance with the norm of reciprocity or that actions are taken in a way that will harm the exchange relationship, they reduce the frequency of organizational citizenship behavior (Robinson & Morrison, 1995). Therefore, employees who do not receive the benefits they expect from their organizations compulsorily exhibit this voluntary organizational citizenship behavior (Vigoda-Gadot, 2006).

Individuals perceive secure employment as an important part of the psychological contract and as a benefit that their organizations will provide them. For this reason, employees will try to exhibit organizational citizenship behavior under pressure and out of necessity in organizational environments where they do not feel psychologically safe (Vigoda-Gadot, 2006). According to Lam et al. (2015), employees are less likely to participate in organizational citizenship behavior when job security is inadequate. This is because they do not feel obliged to reciprocate by going the extra mile for the organization. Job insecurity can be particularly detrimental to employees' contribution to the organization if they feel uncertain about maintaining the desired continuity in their work situation. When examining job insecurity models, it has been found that perceiving job insecurity can lead to reduced extra effort (Greenhalgh & Rosenblatt, 1984), job dissatisfaction (Debus et al., 2012), and decreased commitment to the organization (Probst, 2002). In addition, studies have shown that there is a negative relationship between organizational commitment and CCB. In this context, individuals with low organizational commitment perform extra behaviors outside their role definitions as a necessity for the benefit of the organization (Peng & Zhao, 2012; Şeşen et al., 2014).

When job insecurity is adapted to the scope of social exchange theory, it becomes better understood why job insecurity should increase CCB. When a business does not adequately ensure the job security of its employees and fails to fulfill its obligations towards them, its employees will respond negatively to them. Employees who do not feel safe in their organizations will not most likely display behaviors outside their job descriptions that will be beneficial for the organization. Considering social exchange theory and job insecurity models, the following hypothesis is put forward:

Hypothesis 1: Job insecurity will be positively related to CCB

2.2 The Mediating Role of Turnover Intention

The turnover intention is defined as an employee's conscious contemplation of terminating their employment soon (Mobley, 1982; Long et al., 2012). Factors such as organizational commitment (Steers, 1977), burnout (Faiz, 2019; Yıldırım et al., 2014), work overload (Çelik & Çıra, 2013; Jones et al., 2007), stress (Barak et al., 2001), role ambiguity and salary (Cotton & Tuttle, 1986), organizational identification (Polat & Meydan, 2010), job autonomy (Kim & Stoner, 2008), and organizational justice (Ulutaş, 2018) are influential in the emergence of employees' turnover intention in their positions. While many employees within organizations may have turnover intention, not all individuals proceed to terminate their positions. Various reasons underlie this circumstance, such as economic constraints, familial reasons, the failure to obtain a new job, unemployment rates, and the country's economic situation (Başar & Varoğlu, 2016; Cotton & Tuttle, 1986). Individuals intending turnover but unable to do so manifest their reactions toward their organizations differently. Among these reactions might be reluctance to perform extra-role behaviors as requested. Signs of decreased interest in their tasks, contributing less to the organization, and reluctance to take on additional responsibilities beyond their role are examples of these behaviors (Wang et al., 2017). Indeed, Yieng et al. (2019) confirm through their research a strong association between turnover intention and CCB.

Social Exchange Theory relies on individuals' confidence that their actions will result in expected reciprocation. Employees who do not feel secure within their organizations tend to feel more vulnerable to negative emotions compared to other employees, thus experiencing higher levels of stress. Perceiving higher levels of stress in their work environments negatively affects their commitment to the organization, subsequently increasing their turnover intention, signifying a negative state (Dığın & Ünsar, 2010; Dekker & Schaufeli, 1995). Additionally, studies on CCB indicate that stress, low organizational commitment, and employee job dissatisfaction are prevailing antecedents influencing employees' decisions to exhibit CCB (Kerse et al., 2019; Koçak, 2018; Vigoda-Gadot, 2006; Zhao et al., 2014; He et al., 2017). Therefore, when the boundaries of individuals' formal responsibilities concerning their organizations and jobs are extended toward displaying informal behaviors, individuals are likely to perform these behaviors under various pressures.

This study anticipates that the mediating role of turnover intention will serve as a reciprocity mechanism in explaining the effects of job insecurity on CCB. Considering Social Exchange Theory and previous research, it is hypothesized that employees' turnover intention could be caused by CCB, thus potentially mediating the impact of job insecurity perceptions on CCB. This assumption is based on the idea that, due to perceptions of job insecurity, not all employees who want to leave their job may be able to do so. Therefore, the second hypothesis of the research was developed as follows:

Hypothesis 2: Turnover intention mediates the relationship between job insecurity and CCB.

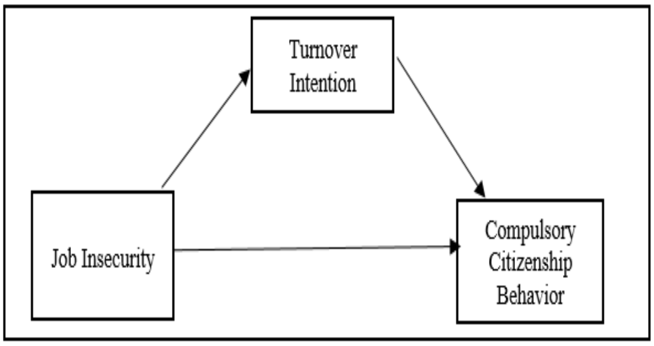

Figure 1. The Proposed Mediation Model

3. Method

3.1 Sample and Procedure

The population of the research consists of white-collar employees working in the aviation sector, including one airline and one ground handling service company in Istanbul, Turkey. In selecting the sample from the population, the simple random sampling method was employed, ensuring an equal chance of participation for each participant. To collect research data, participants were sent surveys via email. 70.4% of the employees who answered the survey were male participants. When the employees were examined in terms of their working period in their institution, it was determined that 43.2 percent of them had worked for one to five years, 21.1 percent for less than one year, 19.2 percent for more than ten years, and 16.4 percent for six to nine years.

3.2 Measures

All measurements were in Turkish and followed the translation-back translation process (Brislin, 1980). The participants completed the measures using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

Job Insecurity Scale: In the study, the four-item "Job Insecurity Scale" developed by Cuyper et al. (2010) and modified into Turkish by Seçer (2011) was used to measure the participants' perceptions of job insecurity. The scale consists of one dimension. An example item is “I feel insecure about the future of my job.”.

Turnover Intention Scale: The study employed a four-item turnover intention scale, originally developed by Rosin and Korabik (1991) and later modified into Turkish by Tanrıöver (2005). The scale consists of one dimension. An example item is “Lately, I've been thinking about leaving my job more often."

Compulsory Citizenship Behavior Scale: A five-item scale developed by Vigoda-Gadot (2007) and adapted into Turkish by Sürücü et al. (2020) was used to measure the CCB of employees. The scale consists of one dimension. An example item is “Managers where I work pressure their employees to do extra activities outside of their official duties."

4. Findings

4.1 Normality Analysis

A normality analysis is performed on the data distribution to determine which analysis methods will be used to test the data obtained because of the research. The research data distribution was analyzed using skewness and kurtosis values. Table 1 shows the results of the analysis conducted to determine the distribution of research data. When the data in the table was examined, the data showed a normal distribution because the skewness and kurtosis values of the research variables were between +1.5 and -1.5 (Gürbüz & Şahin, 2018). Therefore, when conducting additional analyses on the research data, parametric tests ought to be employed.

Table 1. Results of Normality Analysis

Scales	Skewness	Kurtosis
Job insecurity	0.24	-0.63
Turnover intention	0.57	0.42
CCB	0.33	-0.81

4.2 Multicollinearity analysis

The Variance Inflation Factor (VIF) and Tolerance Values were computed to assess the multicollinearity situation between the study's independent variables. The results are displayed in Table 2.

Table 2. VIF and Tolerance Values

Scales	VIF	Tolerance
Job insecurity	1.22	0.81
Turnover intention	1.17	0.85

A tolerance value of more than 0.1 and a VIF value of less than 10 are required to prevent multicollinearity (Albayrak, 2005). Examining the analysis results reveals that our independent variables' VIF values are 1.22 and 1.17, and our tolerance values are 0.81 and 0.85. Thus, it was determined that there was no multicollinearity problem.

4.3 Reliability Analyses of the Scales

Reliability analysis is used to determine whether the measurement tool is consistent with scientific research. Table 3 shows the Cronbach Alpha coefficients obtained from the analysis performed to determine the reliability of the scales.

Table 3. Reliability Analysis Results of Scales

Scales	Cronbach Alpha
Job insecurity	0.80
Turnover intention	0.93
CCB	0.86

As shown in Table 3, the job insecurity scale coefficient was 0.80, the turnover intention scale coefficient was 0.93, and the CCB scale coefficient was 0.86. Results indicated that all scales had reliability levels that exceeded the acceptable threshold (0.70) (Tavakol & Dennick, 2011).

4.4 Exploratory Factor Analysis

In this study, we used Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity to determine whether the data was suitable for factor analysis. Table 4 presents the findings from the analyses. The KMO value above 0.60 and significant Bartlett's Test of Sphericity at $p \leq 0.05$ suggest that the data is suitable for factor analysis (Williams et al., 2010). As shown in Table 4, the results confirmed that the KMO values of the variables (job insecurity = 0.75, turnover intention = 0.80, and CCB = 0.82) and the Bartlett Test of Sphericity ($p < 0.01$) were significant. In addition, the explained variance amount of job insecurity (65%), turnover intention (84%), and CCB (64%) scales are above the acceptable value of 50% (Gürbüz & Şahin, 2018). As a result of the analysis, it was determined that the research sample was sufficient, the data related to the scale was suitable for factor analysis, and the scales had a one-dimensional structure.

Table 4. Explanatory Factor Analysis Results

Scales	Eigenvalue	Total Variance Explained	KMO	Bartlett's Test	*p*
Job insecurity	2.61	65.44	0.75	358.27	0.00
Turnover intention	3.39	84.95	0.80	861.87	0.00
CCB	3.24	64.86	0.82	485.99	0.00

4.5 Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was conducted to establish the discriminant validity of the study variables prior to testing the research hypotheses. Results showed that the three-factor model of job insecurity, turnover intention, and CCB fit the data better when compared with alternative models (CMIN/DF = 1.28; RMSEA = 0.03; SRMR = 0.05; CFI = 0.99; GFI = 0.95). The results provided support for the discriminant validity of the three constructs in the current study.

The scales' convergent and discriminant validity were assessed using the Average Variance Extracted (AVE) and Composite Reliability (CR) values. CR values and AVE values need to be respectively higher than 0.50 and 0.70 to ensure validity (Yaşlıoğlu, 2017).

Table 5. AVE and CR Values

Scales	AVE	CR
Job insecurity	0.54	0.82
Turnover intention	0.78	0.93
CCB	0.57	0.86

The data in the Table 5 show that the values are in appropriate ranges, the scales used in the model represent the factors well, and these factors are valid.

4.6 Descriptive Statistics

Means, standard deviations, and correlations are reported in Table 6. As shown here, job insecurity was significantly related to turnover intention ($r = 0.36$, $p < 0.01$), and CCB ($r = 0.33$, $p < 0.01$). Turnover intention had a significant correlation with CCB ($r = 0.48$, $p < 0.01$)

Table 6. Means, Standard Deviations, and Intercorrelations for Variables

Scales	M	SD	1	2	3	4	5	6
1. Gender	-	-	-					
2. Age	2.14	0.81	0.10	-				
3. Organizational Tenure	2.34	1.01	0.60	0.62**	-			
4. Job insecurity	2.32	0.87	-0.11	-0.12	-0.11	-		
5. Turnover intention	2.68	1.16	-0.05	-0.09	-0.02	0.36**	-	
6. CCB	2.81	0.95	-0.01	-0.07	-0.03	0.33**	0.48**	-

Note: N = 213; ** $p < 0.01$; CCB: Compulsory Citizenship Behavior

4.7 Hypotheses Testing

Structural Equation Modeling (SEM) testing was conducted using the AMOS statistical program to analyze the relationships between job insecurity, turnover intention and CCB variables. The causal relationship between the variables was examined and the results are given in Table 7.

As seen in the table, job insecurity had a positive direct relationship with CCB ($\beta = 0.22$; $p < 0.01$). Thus, Hypothesis 1 was supported.

Hypothesis 2 suggested that turnover intention will mediate the influence of job insecurity on CCB. A bootstrap test was performed to determine the significance of the mediation effect between the dependent and independent variables. The results showed that the indirect effect of job insecurity on CCB through turnover intention ($\beta = 0.13$, $p < 0.01$), and this effect was different from zero (0.07, 0.19). Taken together, the results provided support for Hypothesis 2 that turnover intention mediate the relationship between job insecurity and CCB.

Table 7. Regression Analysis Results Regarding Hypotheses

Predictor variables	TI			
	B	**S.E.**	**t**	**p**
Job insecurity	0.35**	0.09	4.80	0.00
	CCB			
	B	**S.E.**	**t**	**p**
TI	0.38**	0.06	4.87	0.00
Direct Effect of JI	0.22**	0.06	2.99	0.00
Total Effect of JI	0.36**	0.07	5.09	0.00
	B	**S.E.**	**LLCI%95**	**ULCI%95**
Indirect effect of JI on CCB via TI	0.13**	0.05	0.07	0.19

Note: N=432; Bootstrap sample size = 5.000. LL: Lower Limit; CI: Confidence Interval; UL: Upper Limit; JI: Job Insecurity; TI: Turnover Intention; CCB: Compulsory Citizenship Behavior

5. Discussion

The findings of this study indicated that job insecurity positively and significantly related to CCB. Furthermore, turnover intention mediated the relationship between job insecurity and CCB. In other words, job insecurity appears to have an indirect effect on CCB through turnover intention.

Thus, the findings of the research supported the hypotheses that job insecurity positively relates to CCB, and that this relationship is mediated by turnover intention. The theoretical and practical implications of these findings are discussed in the following.

5.1 Theoretical and Practical Implications

Researchers have found that organizational citizenship behavior has a positive effect on organizational performance (Organ, 1988). For this reason, managers' demands for their employees to exhibit more organizational citizenship behavior have increased. However, Vigoda-Gadot (2006; 2007) observed in his studies that the pressure exerted by managers to fulfill these requests caused employees to perform these behaviors reluctantly. CCB, expressed as the dark side of organizational citizenship behavior appears as a new concept that has been studied in the literature for the last 20 years. Although there are not yet sufficient studies on this concept in the literature, researchers have generally focused on the results of CCB (Abukhait et al., 2023; Lin & Chi, 2022; Vigoda-Gadot, 2007; Zhao et al., 2014). In addition, job insecurity, turnover intention, and CCB variables have not yet been examined together in the field of organizational behavior, and this study will be the first study in the aviation industry to study these three variables together. In this way, our study enriches scientific knowledge about how job insecurity may affect employee behavior. Additionally, the research results will contribute to the literature by expanding the current knowledge of the antecedents of CCB.

The research results will raise awareness about CCB among managers, decision-makers, and employees of businesses in the aviation sector. Since the study includes premises that may be effective in the formation of CCB, it will serve as a resource for managers to develop policies and practices that prevent the formation of this behavior. Due to its structure, the aviation industry is a fragile sector where competition is intense, businesses want to maintain a competitive advantage, and it can be significantly affected by environmental factors. In addition, since it is a sector, whose product is service, the human factor is one of the most important resources for businesses. In this regard, some suggestions can be made to managers, considering the structural characteristics of the aviation sector.

Researchers have found that CCB is generally associated with attitudes and behaviors such as organizational silence, less job performance and organizational commitment, more burnout, and work stress (He et al., 2018; Liu et al., 2019; Peng & Zhao, 2012; Pinder & Harlos, 2001). Research findings revealed that employees' perceptions of job insecurity are effective in their display of CCB. For this reason, it is emphasized that managers should ensure that their employees feel safe in their jobs to prevent CCB from occurring. In this context, practices that ensure the permanent employment of employees and support their participation in decision-making processes should be implemented in a way that prevents employees from worrying about the security of their current jobs and experiencing uncertainty. If there are negative environmental factors that positively affect employees' perceptions of job insecurity, preparations should be made for effective crisis management so that employees do not worry about the future of their jobs. Furthermore, providing training and development opportunities for employees, implementing fair labor practices, and making improvements in the use of union rights will reduce the perception of job insecurity (De Witte, 2017; Ouyang et al., 2015).

Another finding of the research is that turnover intention mediates the relationship between employees' job insecurity and CCB. Although it is of great importance to recruit well-educated, talented, and knowledgeable employees, keeping them at the same efficiency and effectiveness in their businesses in the long term requires a high level of effort from qualified management. For this reason, it may be an appropriate human resource management strategy to consider employees' thoughts of continuing in their current jobs to decrease the rate of CCB during the period when job insecurity exists. Organizations should put forward practices that will reduce employees' turnover intention by improving their careers and economic opportunities. In addition, to prevent employees' turnover intention for their jobs and perceptions of job insecurity, policies that increase positive organizational behaviors such as organizational commitment, organizational trust, organizational support, organizational justice, and job satisfaction need to be adopted. However, since the needs and culture of each organization are different, to decide which strategy will be most appropriate, employees should be interacted with, and intra-organizational dynamics should be considered. CCB, which constitutes the dependent variable of the research, is a hidden threat to organizations and causes many negative behaviors that will reduce the efficiency of the organization. For this reason, preventing the elements that may be effective in the formation of CCB in advance will positively affect the functioning within the organization. Research findings show the importance of employees feeling insecure about their jobs and their turnover intention. Implementing practices that will make employees feel safe in their jobs will also increase employees' desire to continue in their current jobs; thus, the tension and negative effects of CCB in organizations will significantly decrease. For this reason, human resources units of organizations should be informed on this issue, and necessary training should be provided. In addition, organizations should develop an organizational culture in which their employees adopt the goals and objectives of their organizations as if they were their own, so that they do not feel obliged to do so.

5.2 Limitations and Recommendations

In addition to its theoretical and practical contributions, research also has some limitations. The first of these is that the causality between variables cannot be adequately explained due to the cross-sectional nature of the data. For this reason, in future studies, sufficient information can be obtained about the causal relationship between variables by collecting data with longitudinal and experimental designs.

The second limitation is that although the CFA results in the study proved that the distinguishing feature between the variables is valid, the survey data collected from the participants in a single time may have caused common method bias (Podsakoff et al., 2003). For this reason, future studies can collect data on CCB, job insecurity, and turnover intention from participants at different time periods to reduce common method bias. Thirdly, it is important to note that the sample size of the study is limited to employees within the aviation sector. Therefore, the results reflect only employees in this sector. The research can be repeated for different sectors in future studies to make the results we obtained more generalizable. Lastly, while conducting the research, only the attitudes and behaviors of the employees were examined. For this reason, different leadership types that have a significant impact on employees' attitudes and behaviors can be analyzed by including them in the research model, or different research models can be examined to understand the antecedents of CCB.

Ethical approval

Approved by the Ethics committee, with the decision of Erzincan Binali Yıldırım University Ethics Commission, dd 22.11.2022, no 11/05.

Conflicts of Interest

The authors declare that they have no conflicts of interest with regard to the publication of this paper.

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Fatigue Among Cabin Crew and Work-Life Balance: A Qualitative Study in the Turkish Context

Seçil Ulufer Kansoy[1*], Özge Erduran Tekin[2]

[1*]Kırklareli University, Lüleburgaz Faculty of Aeronautics and Astronautics, Department of Aviation Management, Kırklareli, Türkiye. (seciluluferkansoy@klu.edu.tr)
[2] National Defense University, Air Force Academy, Department of Humanities and Social Sciences, İstanbul, Türkiye. (oerduran@hho.msu.edu.tr)

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Abstract

In the context of literature review, it can be observed that information regarding the fatigue levels of cabin crew generally relies on quantitative data obtained from the flight crew. Considering that cabin crew members also have their own personal lives, it is believed that managing work fatigue and achieving work-life balance are crucial for them to sustain their lives in a healthy manner. However, it is rarely investigated in the literature what the views of cabin crew members are regarding fatigue and what strategies can be employed to reduce fatigue. Therefore, in order to better understand the causes and consequences of cabin crew fatigue, participants' experiences related to fatigue and how fatigue affects work-life balance were examined through semi-structured interviews using phenomenological analysis. Twenty cabin crew employees participated in the study. The analysis revealed three main themes titled "*Perception of fatigue in cabin crew members*, *The impact of fatigue on work-life balance* and *Strategies for coping with fatigue*" along with eight sub-themes that elucidate these themes. Based on the findings, recommendations are provided at the individual and organizational levels to reduce fatigue in cabin crew members, ensure work-life balance, and enhance productivity.

1. Introduction

Especially after the pandemic, significant changes in workload have occurred in many sectors, initiating a new period of adaptation. The aviation industry is one of those sectors. Considering the reduced number of employees and increased workload following the pandemic, one of the best ways to learn about the reasons for fatigue among cabin crews and what can be done to reduce fatigue and establish work-life balance is to thoroughly examine the perspectives of the cabin crew based on their experiences. Cabin crew members are an integral part of ensuring passenger comfort and cabin and passenger safety in commercial flights. However, working in a sector that operates 7/24 presents its own set of challenges for the cabin crew (Berg et al., 2019). Existing studies indicate that the causes of fatigue among cabin crew generally stem from irregular work schedules, long duty hours, circadian rhythm disruptions, sleep deprivation, and high workload (Avers et al., 2011; MacDonald et al., 2003; Nesthus et al., 2007). Particularly due to the physical demands involved in performing tasks related to cabin duties, these individuals significantly differ from the flight crew (Berg et al., 2019). As a result of demanding working conditions, cabin crew members often experience sleep disorders, depression, and fatigue (McNeely et al., 2014). Considering that fatigue can potentially affect the performance and personal lives of cabin crew members, investigating the causes of their fatigue is crucial not only for ensuring work-life balance but also for preventing any safety issues. Initial research on fatigue was conducted in the industrial field, and the effects of fatigue on productivity were discussed (Noy et al., 2011). Studies related to fatigue primarily focused on identifying pilot fatigue during World War II, although there is limited research specifically addressing aviation fatigue and sleepiness, with a predominant focus on pilots (Wen et al., 2021). Fatigue is defined as a state of increased physical and mental weakness accompanying a decrease in alertness (Nelson, 1997). When individuals do not get sufficient rest, increased fatigue can hinder their ability to perform at the desired level (Gander, 2011).

Considering that a significant portion of individuals' day is spent at the workplace and considerable time is dedicated to work, it can be argued that work and family life can greatly influence each other (Carlson and Grzywacz, 2008). It is important for individuals to strike a balance between the demands of their work and their personal lives in order to continue their lives in a positive manner (Lockwood, 2003). Employees may experience stress due to the roles they assume in both their work and family lives, and this stress can lead to a decrease in their performance (Greenhaus et al.,2003). Studies have shown that the nature of the profession, working hours, and working conditions play a significant role in individuals' ability to achieve work-life balance (Crooker et al., 2002; Pichler, 2009). Given that cabin crews have demanding work conditions, resulting in increased physical fatigue and psychological stress, which can lead to more errors (Kim et al., 2022), it is believed that cabin crew members may struggle to establish work-life balance due to work fatigue.The aim of this study is to examine the factors causing fatigue among cabin crew, how it affects their lives, and to identify possible solutions from their own perspectives based on their fatigue experiences, in order to contribute to the existing literature.

1.1. Literature review

Work-life balance

Work-life balance has gained significant attention in organizational behavior and human resource management research. The concept of work-life balance refers to the equilibrium individuals seek between their work-related commitments and personal lives (Greenhaus and Allen, 2011). This literature review aims to explore the antecedents and outcomes of work-life balance and the strategies used to facilitate it in the workplace. Several factors influence work-life balance. Individual-level factors such as personal values, coping strategies, and individual differences in managing work and personal roles play a significant role (Kalliath and Brough, 2008). Moreover, socio-cultural factors, such as societal norms and gender roles, shape individuals' perceptions and experiences of work-life balance (Byron, 2005). Work-life balance has various individual and organizational outcomes. At the individual level, it is associated with increased job satisfaction (Clark, 2000), stress and burnout (Grzywacz and Carlson, 2007), improved physical and mental health (Hill et al., 2001). Organizational outcomes include increased employee engagement (Bakker and Demerouti, 2017), higher organizational commitment (Allen et al., 2000), improved productivity (Beauregard and Henry, 2009), and reduced turnover intentions (Allen et al., 2000). Organizations adopt various strategies and interventions to promote work-life balance. Flexible work arrangements, such as telecommuting and compressed workweek, have gained popularity (Gajendran & Harrison, 2007). Family-friendly policies, including parental leave and on-site childcare facilities, contribute to work-life balance (Kossek et al., 2006). Individual-level strategies, such as effective time management and boundary management techniques, are also essential for achieving work-life balance (Nippert-Eng, 1996). Work-life balance is crucial for both individuals and organizations. It requires attention to individual, organizational, and socio-cultural factors to create an environment that supports work-life balance. By understanding the antecedents, outcomes, and strategies related to work-life balance, organizations can implement practices that enhance employee well-being and organizational effectiveness. Fatigue among cabin crew members is a critical issue within the aviation industry. The demanding nature of their work, irregular schedules, and long duty hours expose cabin crew members to various factors that contribute to fatigue. This literature review aims to explore the causes and consequences of fatigue among cabin crew, as well as the strategies and interventions employed to mitigate its impact and ensure the well-being and safety of cabin crew members.

Fatigue among Cabin Crew

Fatigue among cabin crew can be attributed to several factors. Irregular work schedules, including early morning or overnight flights, disrupt the circadian rhythm and reduce the quality and quantity of sleep (Avers et al., 2011). Long duty hours, time zone changes, and extended periods of wakefulness further contribute to fatigue (MacDonald et al., 2003). Additionally, the physical demands of cabin crew duties, such as lifting heavy objects and prolonged standing, can exacerbate fatigue (Berg et al., 2020). Furthermore, high workload, multiple flight segments, and unpredictable operational conditions also play a role in cabin crew fatigue (Nesthus et al., 2007).

Fatigue among cabin crew members can have significant consequences on both individual and organizational levels. Fatigue impairs cognitive functioning, attention, and decision-making abilities, which can compromise safety during critical tasks (Nesthus et al., 2007). It also increases the risk of accidents, errors, and incidents during flight operations (McNeely et al., 2014). Moreover, cabin crew members experiencing fatigue are more susceptible to physical and mental health issues, such as sleep disorders, depression, and burnout (McNeely et al., 2014). Fatigue-related impairments can also impact job satisfaction, work engagement, and overall well-being of cabin crew members (Berg et al., 2020).

Various strategies and interventions have been implemented to manage and mitigate fatigue among cabin crew. These include regulatory measures such as flight time limitations, rest requirements, and duty time restrictions imposed by aviation authorities (Federal Aviation Administration, 2022). Fatigue risk management systems (FRMS) have been implemented by airlines to proactively manage and mitigate fatigue risks (Caldwell et al., 2009). Additionally, fatigue awareness and management training programs are provided to enhance cabin crew's understanding of fatigue, its effects, and strategies for its mitigation (Rosekind et al., 1995). Sleep and fatigue education, rest facilities onboard, and supportive organizational cultures that prioritize fatigue management also contribute to addressing cabin crew fatigue (Berg et al., 2019). Fatigue among cabin crew is a major concern in the aviation industry. The complex interaction of various factors contributes to fatigue, which can have adverse impacts on the safety, well-being and performance of cabin crew members. By understanding the causes and consequences of fatigue and implementing appropriate strategies and interventions, aviation psychology can reduce the risks associated with cabin crew fatigue and ensure the safety and well-being of both cabin crew members and passengers. In this context, the aim of this study is to examine the relationship between cabin crew fatigue and work-life balance through phenomenological analysis. The sub-objectives of the study are as follows:

-What are the themes that explain the fatigue experiences of cabin crew?

-What are the themes explaining cabin crew's work-life experiences?

-What are the themes explaining cabin crew's experiences of the relationship between fatigue and work-life balance?

2. Materials and Methods

In this study, interpretative phenomenological analysis, a research approach within the phenomenological tradition, was employed. Interpretative phenomenological analysis is a method that aims to explore how individuals ascribe meaning to various life experiences and how they perceive and interpret them (Smith et al., 2009). It focuses on how individuals subjectively experience and perceive events, how they go through the process, and how they make sense of it (Larkin et al., 2006).

The Population and Sample of this Research

In qualitative research, purposive sampling is frequently used to select individuals who can provide detailed information about the phenomenon under investigation. The aim is to identify individuals who have experienced the phenomenon or concept of interest accurately (Creswell and Clark, 2015). When selecting interviewees, the researcher establishes certain criteria within the framework of the research objective. Criteria such as being cabin crew personnel, having at least five years of active experience in the profession, and volunteering to participate in the study were determined. This approach aimed to create a homogeneous study group to observe similarities and differences and obtain detailed information about the phenomenon. As a second criterion, diversity was sought by considering characteristics such as gender, marital status, having children, and receiving psychological support in order to obtain more in-depth data. The study was announced to cabin crew employees, and data were collected through snowball sampling. In snowball sampling, a connection is established with one unit from the population. Then, with the help of that person, contact is made with another person, and the process continues, expanding the sample in a chain-like manner. In this context, the study was conducted with 20 participants. The number of participants in the study is consistent with the average number recommended for phenomenological research (Creswell, 2012). The demographic characteristics of the participants comprising the study group are presented in Table 1.

Table 1. Demographic information of the study group

Participant	Age	Gender	Marital status	Having children or not	Job description	Professional experience	Psychological support
K1	32	Female	Married	No	Cabin attendant	9 years	Not receiving
K2	34	Male	Married	No	Cabin attendant	12 years	Not receiving
K3	34	Female	Single	No	Cabin attendant	10 years	Receiving
K4	30	Male	Married	Yes	Cabin attendant	8 years	Not receiving
K5	42	Female	Married	Yes	Cabin chief	22 years	Not receiving
K6	40	Male	Married	Yes	Cabin chief	19 years	Not receiving
K7	38	Female	Married	No	Cabin chief	11 years	Not receiving
K8	41	Male	Single	No	Cabin chief	20 years	Not receiving
K9	38	Female	Married	Yes	Cabin chief	12 years	Not receiving
K10	26	Male	Single	No	Cabin attendant	6 years	Receiving
K11	43	Male	Married	No	Cabin chief	18 years	Not receiving
K12	27	Female	Single	No	Cabin attendant	7 years	Not receiving
K13	35	Male	Single	No	Cabin chief	11 years	Not receiving
K14	34	Female	Married	No	Cabin attendant	10 years	Receiving
K15	33	Female	Married	No	Cabin chief	8 years	Not receiving
K16	29	Male	Single	No	Cabin attendant	7 years	Not receiving
K17	39	Female	Single	No	Cabin attendant	15 years	Not receiving
K18	41	Male	Married	Yes	Cabin chief	14 years	Receiving
K19	42	Female	Single	No	Cabin attendant	12 years	Not receiving
K20	40	Female	Married	Yes	Cabin chief	14 years	Not receiving

As shown in Table 1, the ages of the participants range from 26 to 43. Ten participants are female, and ten participants are male. Twelve participants are married, while eight participants are single, and six participants have children. Ten participants work as cabin crew members, while the other ten serve as cabin managers. The participants' professional experience ranges from 6 to 22 years. Four participants receive psychological support, while sixteen participants do not receive psychological support.

The Data Collection Method of the Research

A semi-structured interview technique was employed as the data collection tool in this study. While preparing the interview questions, a comprehensive review of phenomenological research was conducted to ensure that the questions provide detailed information about the intended situations. The prepared interview questions were sent to six academic experts in the field, and they were revised based on their suggestions. The revised interview questions were worked on by conducting pilot interviews with three volunteer participants and finalized. Sample question items are presented below:

-Can you introduce yourself? (age, marital status, job description, work experience, working hours, parenthood, receiving psychological support)

-Do you experience moments when you feel tired due to your profession?

-How does your profession affect your experience of fatigue?

-How does fatigue affect your job performance?

-How does work-related fatigue impact your personal life?

-What would be necessary for reducing your fatigue related to work?

-In your opinion, what can be done to decrease occupational fatigue?

-What is necessary for achieving a balance between your personal and work life?

The Research Model

The data analysis of the qualitative data employed the steps of Smith and Osborn's Interpretative Phenomenological Analysis. Given the inherent nature of this analysis method, the researcher's process is dynamic (Creswell, 2012). Following a detailed reading of the data, codes were generated and compiled into a list. Subsequently, these codes were reorganized into themes through a more analytical and theoretical framework. The themes and sub-themes were summarized in tabular form. The analysis of the interviews was performed using the MAXQDA 2020 software. The data were diversified through the generation of interview questions based on expert opinions and consultation with multiple experts during the analysis process. The adequacy and saturation of the emerged themes were examined in conjunction with participant feedback and expert opinions. Confirmation was sought by verifying the participants' understanding of their expressions and meanings. Expert validation was performed by engaging with experts who have knowledge in qualitative research within the aviation and psychology fields. The results of the interviews were evaluated in collaboration with these experts during the confirmation process. The inclusion of participant quotes aimed to enhance interpretive competence. Additionally, to maintain research reliability and prevent personal biases, the researchers employed the bracketing technique (Morrow, 2005).

3. Result

The themes and sub-themes explaining how cabin crew members' experiences of fatigue affect their work-life balance are given in Table 2. The participants were coded as (P1, P2, P3, P4, ...P20) while giving the results of the themes and sub-themes.

Table 2. Themes explaining the effect of participants' fatigue experiences on work-life balance.

	Themes	Sub-themes
Perception of fatigue among cabin crew members	**Theme 1:** The characteristics of this profession	Work hours, Short rest periods, Inability to spend time with family members, Inability to allocate time for oneself
	Theme 2: Finding satisfaction in the profession	Professionalism, Pre-flight preparation, Enjoyment of the job, Liking the work environment
	Theme 3: Adapting to the profession	Adapting to the rewards of the profession, Time management, Being flexible
The impact of fatigue on work-life balance	**Theme 1:** Physical effects	Body aches, Decline in cognitive abilities, Loss of strength, Fatigued physical appearance
	Theme 2: Psychological effects	Sudden mood swings, Feeling of exhaustion, Withdrawal behaviors
	Theme 3: Social effects	Lack of time for family members, Relationship problems, Isolation
Strategies for coping with fatigue	**Theme 1:** Individual coping strategies	Accepting the rewards of the profession, Getting good sleep, Eating healthy, Exercising, Spending time with family members, Socializing with friends, Receiving psychological support
	Theme 2: Organizational coping strategies	Increasing rest periods, Reducing uncertainty in working hours, Avoiding consecutive flights, Showing more respect for employees' personal lives, Enhancing social benefits for employees, Providing psychological support

When examining the statements describing the impact of fatigue on work-life balance as experienced by cabin crew members, it is evident that participants discuss how they perceive fatigue, how fatigue affects their work-life balance, and the individual and organizational strategies to cope with fatigue. Below are examples of statements that constitute the most frequently expressed sub-themes within the theme of the perception of fatigue among cabin crew members.

Examples of statements related to the theme of the perception of fatigue among cabin crew members, forming the most frequently expressed sub-themes, are provided below:

The characteristics of this profession: *"I don't see it as a problem because I know what needs to be done beforehand and I am prepared for it." (K6)*

"Fatigue doesn't negatively affect my job performance because I am accustomed to it. We already receive training during university, and we know what to expect. On the other hand, I believe that every profession has its own challenges, and I think fatigue can be present anywhere. Individuals should come up with their own solutions to cope with it." (K10)

Finding satisfaction in the profession: *"Although I sometimes feel tired due to the nature of my profession, I absolutely love my job. This definitely helps me cope with fatigue." (K17)*

"I get tired and make sacrifices in many aspects, but I truly love my job. Therefore, dealing with negative factors becomes easier for me." (K20)

Adapting to the profession: *"Aviation is particularly an error-free field. That's why we constantly receive trainings, and these trainings are always kept up to date. The importance of safety and security is always emphasized. Being aware of the seriousness of the job, we pay great attention to not let it negatively affect our performance. In fact, our preparation process begins almost 2.5-3 hours before the flight. So, if you have already made this plan in your mind, it is easier to adapt to it." (K8)*

"Once you get used to the demands of the profession and plan your life accordingly, things become a bit easier. After all, our

job requires us to adapt and establish a routine in our personal lives as well." (K18)

Examples of statements representing the sub-themes that explain the impact of fatigue on work-life balance, as highlighted by the participants, are provided below:

Physical effects: *"My job greatly affects my fatigue. Sometimes I forget what I need to do. Sometimes I forget what I was going to say." (K9)*

"My performance is initially fine during the flight, but towards the end, there are declines. Or sometimes sleepiness hits me. This can lead to mistakes. Irregular sleep is a challenging situation." (K12)

Psychological effects: *"I want to dedicate myself to my job. However, due to fatigue, sometimes I cannot perform as well as I want. Or if I focus on my work, my communication may suffer." (K16)*

"Sometimes I can feel unhappy and low in energy because of being tired from my job." (K1)

Social effects: *"Unfortunately, it negatively affects my personal life. I can't spend enough time with my son. There's hardly any personal life left. I got married once, but it didn't work out. My son is my whole personal life, but I can't be there for him during his precious moments. It saddens me, especially during graduations or meetings, etc." (K17)*

"Due to the fast-paced nature of our profession, I have observed in myself and many of my colleagues that when we are tired, we tend to distance ourselves from social life and experience moments of solitude. After long shifts, our bodies crave sleep, rest, and energy replenishment. Therefore, we may seek moments of tranquility and peaceful environments in our personal lives, even if only to some extent." (K15)

Here are some examples of statements that explain the sub-themes, which constitute the theme of coping with fatigue, and were most frequently mentioned by the participants:

Individual coping strategies: *"I believe I should prioritize my exercise routine to reduce my fatigue. Additionally, I haven't been able to see my old friends for a long time. I need to pay more attention to my social life. If I had longer rest periods, I could allocate time for all of them." (K4)*

Organizational coping strategies: *"In order to achieve work-life balance, I need to have more time for my personal life. Currently, my personal life is about resting at home. Because it's a demanding job, having longer rest periods would be beneficial." (K2)*

"Finding balance is challenging. Plans often get disrupted. We include personal activities in our plans, but sometimes the flight schedule changes, and our own plans change as well. Rest and off-days should be increased. Flight schedules should undergo fewer changes. Companies should provide psychological support to their employees. The physiological and psychological effects of flights are already increasing on a daily basis, especially in today's conditions." (K3)

4. Discussion

Cabin crew is an integral component of a healthy flight team. The demanding working conditions often lead to fatigue, which can disrupt the work-life balance of cabin crew and negatively impact their health and performance. To enhance performance and preserve their well-being, cabin crew must establish a balance between their work and personal lives. Despite the significant impact of fatigue on work-life balance, there is a lack of qualitative studies specifically examining the effects of fatigue on the work-life balance of cabin crew in the Turkish context. Understanding the reasons for fatigue and its implications on work-life balance is best achieved by deeply exploring the perspectives of cabin crew members themselves. By sharing their subjective experiences, individuals within the system can provide a clearer understanding of the existing situation. According to the results obtained from this study in line with the objectives and sub-objectives of the research, it was seen that three main themes titled "Fatigue perception in cabin crew, the effect of fatigue on work-life balance and coping strategies with fatigue" and eight sub-themes explaining these themes emerged. When the sub-themes explaining the perception of fatigue in cabin crew are examined, it is seen that the majority of the participants stated that the things that cause fatigue are actually the characteristics of the profession and that it is necessary to accept this, and that getting satisfaction from the profession and adapting to the profession are important factors affecting fatigue. When the sub-themes explaining the effect of fatigue on work-life balance are examined, it is seen that they can be handled separately as physical effects, psychological effects and social effects. The sub-themes obtained from the participant views on coping with fatigue show that it is important to consider coping strategies separately, both individual and organizational.

In the literature, it has been shown that fatigue has a significant effect on the quality of life of cabin crew, which supports the results obtained from this study (Chung & Chung, 2009). Supporting the results of this study, Berg et al. (2019) conducted semi-structured focus group interviews with 25 cabin crew members. Participants identified sleep loss, circadian disruption, inadequate rest, high workload, work environment, lack of company support and inadequate fatigue management training as the main causes of fatigue. The study also emphasises the importance of adequate rest to achieve sufficient restful sleep and work-life balance. It is seen that the results obtained show that the factors affecting the fatigue and work-life balance of the cabin crew members constituting the study group are similar. The ICAO (2016) regulation states that all staff in an organisation should understand that staffing alone cannot eliminate fatigue and should not be an organisation's only fatigue management strategy. However, Aguirre (2005) concluded that the effectiveness of fatigue management training may be reduced when employees are dissatisfied with existing staff or other management and organisational issues. On the other hand, fatigue management training can improve employees' understanding and perceptions of the challenges of staffing and working irregular hours and correct misconceptions about fatigue. According to the results of the study by Kumari and Aithal (2022), emotional labour has a significant negative impact on job performance, while high levels of work-life balance and job satisfaction reduce the negative effects of emotional labour on job performance.

This study aims to investigate the causes of fatigue among cabin crew, examine how fatigue manifests in their personal lives, and explore its effects on their work-life balance. Through this examination, concrete recommendations can be offered to employers, other cabin crew members, and researchers on how to reduce fatigue and improve the establishment of work-life balance. Airlines should establish comprehensive Implementation of Fatigue Risk Management Systems (FRMS) that include fatigue mitigation strategies. This may include scheduling practices that take into account circadian rhythms, ensuring adequate rest periods between flights, and implementing fatigue monitoring and reporting systems. Offering flexible work schedules can help cabin crew better manage work-life balance. Airlines should explore options such as part-time contracts, job-sharing arrangements, and the ability to request specific duty preferences to accommodate personal commitments. Airlines should develop and promote well-being programs specifically for cabin crew. These programs could include stress management workshops, physical activity initiatives, mental health support services, and resources to maintain healthy lifestyles.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. All ethical rules required by scientific research were followed in data collection. For this study, ethics committee approval was obtained from Kırklareli University Publication Ethics Committee on 17.02.2023 with the number E-35523585-302.99-78526.

Conflicts of Interest

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

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Air Traffic Controllers' Perspectives on Unmanned Aerial Vehicles Integration into Non-Segregated Airspace

Arif Tuncal

Directorate General of State Airports Authority and Air Navigation Service Provider of Türkiye (DHMI), Ankara Air Traffic Control Center, Ankara, Türkiye. (atuncal@gmail.com)

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Abstract

The integration of Unmanned Aerial Vehicles (UAVs) into non-segregated airspace presents both opportunities and challenges for air traffic control (ATC). The aim of the study is to explore the perspectives of air traffic controllers on the current and anticipated challenges, workload, stress factors, performance errors, and mitigation strategies related to UAV integration. The sample consisted of 213 air traffic controllers in Türkiye. UAV operations have been available in Türkiye not only for military purposes but also for purposes such as forest fires, earthquakes, security, and others for a long time, and these UAV operations are provided with air traffic services (ATS) by air traffic controllers. The results show that air traffic controllers are concerned about mid-air collisions due to UAV technology limits and regulatory gaps, along with managing risks and unique flight characteristics. Addressing technology limitations, regulatory ambiguity, and other factors necessitates a comprehensive strategy. Solutions must prioritize collision avoidance systems, clear communication guidelines, and defined no-fly zones. It is recommended that future studies focus on the comprehensive impact of UAVs on air traffic operations and the development of regulations.

1. Introduction

Advances in aviation technology and societal demands have contributed to the growing popularity and increasing use of unmanned aerial vehicles (UAVs), also known as unmanned aircraft systems (UAS) (Cyganczuk, & Roguski, 2023; Shaaban Ali et al., 2022). UAVs present considerable financial benefits in contrast to traditional manned aircraft (Malone et al., 2013). UAVs are extensively utilized in various domains such as health, agriculture, package delivery, disaster management, and surveillance (Bhatt, Pourmand, & Sikka, 2018; Euchi, 2021; Otto et al., 2018; Pathak, Mohod, & Sawant, 2020; Politi et al., 2021; Shah et al., 2020; Sujit, Saripalli, & Sousa, 2014; Thiels et al., 2015). Their rapid rise challenges integrating them harmoniously into traditional aircraft-dominated airspace (Correa et al., 2012; Pop et al., 2017; Shaaban Ali et al., 2022).

The growing popularity of UAVs has the potential to reshape the future of the aviation industry. The operations of UAVs were planned to take place within segregated airspace (Pastor et al., 2014; Simpson, & Stoker, 2006). However, there are significant challenges to integrating UAVs safely and efficiently into non-segregated airspace. There has been a growing necessity for the integration of UAVs into the entire existing airspace and the current air traffic control (ATC) system faces technical challenges in accommodating higher tempo and density for heavy UAV operations (Thipphavong et al., 2018). Emphasized within this integration process is the need for UAVs to access non-segregated airspace and conduct operations within the same environment as traditional aircraft (Grote et al., 2021). The coexistence of mixed traffic, comprising both UAVs and manned aircraft, within the same airspace has the potential to impact various functions of ATC (DeGarmo, 2004).

The integration of UAVs into airspace directly impacts the role and responsibilities of air traffic controllers. It affects ATC by necessitating changes in procedures, automation, and policies concerning flight plans, patterns, communication, and more (Kamienski, & Semanek, 2015). Integrating UAVs can present controllers with different challenges and potentially compromise their performance and aviation safety (Wang et al., 2022). Developing specialized systems to manage UAVs separately from traditional air traffic is essential for ensuring safe integration within non-segregated airspace.

Controllers are responsible for the safe, expeditious, and orderly flow of air traffic in aerodromes and airspaces (Bakare, & Junaidu, 2013; Malakis et al., 2019; Mooji, & Corker, 2002; Pavlinovic, Juricic, & Antulov-Fantulin, 2017). Controllers must ensure that all aircraft, including UAVs, fly safely and without any issues in airspace. This introduces a new and dynamic situation faced by controllers, presenting new challenges in terms of safety, efficiency, and organization. The new systems and technologies may bring challenges by increasing aircraft volume and complexity in designated airspace, necessitating additional requirements in ATC (Miller et al., 2020; Mueller, Kopardekar, & Goodrich, 2017). With the implementation of new technologies, controllers must balance a greater influx of data and information flow while effectively managing their workload. Additionally, the interaction between traditional airspace users and UAVs must be considered, as it can further complicate the controllers' task of ensuring the safe and efficient operation of both sides. Integrating UAVs in a shared airspace poses challenges such as interaction adaptation, controlled information sharing, and continuous monitoring and adaptation (Anisetti et al., 2020), which align with the increased workload and complexities faced by controllers due to the implementation of new technologies (Brookings, Wilson, & Swain, 1996; Debernard, Vanderhaegen, & Millot, 1992; Tattersall, Farmer, & Belyavin, 1991).

A scalable solution for the integration of airspace is important for the operations of commercial UAVs while mitigating the impact on ATC (Ferguson, & McCarthy, 2017). UAV Traffic Management (UTM), as highlighted by Ancel et al. (2017) and Sandor (2017), stands as a traffic management system ensuring the safe and efficient integration of UAVs into airspace. It encompasses frameworks and services designated to manage UAV traffic within the airspace (Chin, Li, & Pant, 2022). UTM mitigates challenges in airspace integration (Mueller, Kopardekar, & Goodrich, 2017) and minimizes associated risks (Cauwels et al., 2020). For the support of unmanned aircraft systems, UTM necessitates the adaptation of existing Air Traffic Management (ATM) regulations, acknowledging the differences between manned and unmanned flight operations, and the integration of Communication, Navigation, and Surveillance (CNS) Technologies (Ali, 2019).

A review of the literature reveals numerous studies on Unmanned Aerial Vehicle (UAV) integration into airspace (Allouche, 2000; Carr, 2013; Dalamagkidis et al., 2008; DeGarmo, 2004; Ho et al., 2019; Lacher et al., 2010; Peterson, 2006; Radmanesh, 2016; Ribeiro et al., 2017). However, a critical gap exists – the limited involvement of air traffic controllers, who are central to airspace management. Despite the study by Kamienski & Semanek (2015) focusing on flight planning and automation, the control link, specific information and procedures, ATC training, and interaction with the future airspace of UAVs, this research was acknowledged as an initial step, highlighting the need for further studies. Given the rapid advancements in UAV technology and their increasing use in airspace today, there is a need for a comprehensive study focusing on air traffic controllers, which would bridge the gap in the existing literature and provide guidance for future studies on UAV integration into airspace. This study aims to examine how UAVs, with their new technology and performance, are integrated into non-segregated airspace from the perspective of controllers, compared to traditional aircraft. It discusses the experiences, challenges, technical barriers, regulations, and human factors faced by controllers. Additionally, it presents solutions to ensure flight safety, effectiveness, and operational efficiency during this integration process. The aim is to understand the significant changes in the aviation industry and develop effective strategies to overcome emerging challenges. Integrating UAVs into non-segregated airspace shapes the future of aviation, and this research aims to aid in comprehending and managing this transformation from the viewpoint of air traffic controllers, important figures in the aviation sector.

2. Literature Review

Integrating UAVs into non-segregated airspace poses complex challenges for ATC operations. Defining the correlation between UAVs and ATC and understanding potential issues is crucial (Baum et al., 2019; Neto et al., 2022). Addressing these challenges is critical to ensure safe and efficient operations in non-segregated airspace. Specific issues faced by controllers in UAV integration are identified through a literature review.

2.1. Collision Avoidance Capability

The systems such as Traffic Alert and Collision Avoidance System (TCAS) and Ground Proximity Warning System (GPWS) are used to prevent collisions between aircraft or with obstacles in traditional aviation. The current UAV technology has been developed to improve flight safety by providing visual data to remote UAV pilots at ground stations (Karthick, & Aravind, 2010). However, collision avoidance systems and protocols should be developed, especially for smaller UAV models, to prevent accidents in increasingly congested airspace. Collision avoidance systems are emerging as a major focus of recent research on UAVs (Shan et al., 2023). Collision avoidance systems should be used to enable UAVs to continue their operations safely and efficiently in urban and other airspaces alongside traditional air traffic (Barfield, 2000; Van der Veeken et al., 2021).

2.2. Different Operating Characteristics

UAVs differ significantly from manned aircraft. UAVs can cruise at different speeds, fly at varying altitudes, and exhibit a variety of maneuvering capabilities. The integration of these diversities into controlled airspace requires extremely precise planning (Albaker, & Rahim, 2011; Jack, & Hoffler, 2014; Kamienski, & Semanek, 2015; Valavanis, & Vachtsevanos, 2015; Wilson, 2018). This is because detailed planning and coordination are required to manage and use these variable characteristics in a compatible manner. A strategic approach is required to safely and efficiently control the dynamics that are quite different from manned aircraft in separation and contingency management (Pastor et al., 2014).

2.3. Technology Limitations & Limited Detectability

In traditional air traffic, the detection of aircraft in controlled airspace using radar is important for air space management. Different equipment is available on traditional aircraft for this detection. However, the detection of UAVs flying at low altitudes close to the ground, especially with their small and complex shapes, can be difficult for traditional radar systems (Hasan, Pandey, & Raj, 2022; Khawaja et al., 2022; Shao, Zhu, & Li, 2022; Song et al., 2019). This situation requires the use of alternative technologies in ATC systems (DeGarmo, 2004).

2.4. Regulatory Framework

Traditional aviation rules are not applicable to UAVs because they have different technical characteristics from manned aircraft (Sandor, 2019). This requires the development of new regulations for UAVs, which are still under development, and their harmonization at the international level. The different functional features of UAVs necessitate a separate approach from traditional methods in aviation safety regulations (Arblaster, 2018; Vidović et al., 2019). It is a serious challenge to define clear rules and regulations for the integration of UAVs into the existing air traffic without disrupting it (Huttunen, 2019; Stöcker et al., 2017).

2.5. Communication

Communication between UAVs and ATC systems presents challenges, such as different flight profiles, wider bandwidth ranges, and different ground station characteristics compared to manned aircraft (Matolak, 2015). Communication between UAVs and ATC systems is generally established through UAV ground control stations (GCS). These GCS can be simple commercial products like tablets or radio control stations, or more advanced technologies like portable, fixed, or self-propelled technologies (Vasile et al., 2019). It is essential for communication, flight control, and ensuring safe and secure operations (Dianovsky, Pecho, & Bugaj, 2023). Effective communication between UAVs and air traffic controllers is critical for airspace integration (Stansbury, Vyas, & Wilson, 2009). The current communication networks of UAVs are typically based on point-to-point communication with limited range, unlike manned aircraft (Bauranov, & Rakas, 2021). Two-way data communication between UAVs and ATC supported by automation can provide more efficient and safer integration (Geister, & Geister, 2013; Gunawardana, & Alonso, 2013; Kim, Jo, & Shaw, 2015; Koeners et al., 2006; Paczan, Cooper, & Zakrzewski, 2012; Ponchak et al., 2018; Swieringa et al., 2019). Additionally, there is potential for UAVs to create complexity and impact airspace efficiency, especially in the communication dimension, when integrated with traditional air traffic (Truitt, Zingale, & Konkel, 2016).

2.6. Risk Management

To ensure the efficient integration of UAVs into uncontrolled airspace, all safety-related challenges must be addressed (Simpson, & Stoker, 2006). Integration of UAVs into the airspace brings along challenges such as risks, threats, and potential illegal use (Pop et al., 2017). The current air traffic management has not yet reached the point of mitigating all risks associated with UAV operations (Vidovic et al., 2019). Therefore, the increasing use of UAVs in the airspace requires comprehensive risk management that not only identifies but also manages and mitigates these risks (Başak, & Gülen, 2008; Davies et al., 2021; Kobaszynska-Twardowska, Łukasiewicz, & Sielicki, 2022; Naji, & Ayari, 2023).

2.7. Security/Safety Concerns & Geofencing and No-Fly Zones

UAV operations must be conducted in accordance with the existing regulations (Kakarla, & Ampatzidis, 2018). However, UAV users who do not have sufficient knowledge of the airspace or the relevant regulations may cause serious flight safety problems by flying over restricted or prohibited airspace, such as airports (Moreira, Papp, & Ventura, 2019). Geofencing technology can be used to prevent UAVs from entering restricted or prohibited airspace by creating no-fly zones or defining areas where only flying is allowed (Yılmaz, & Ulvi, 2022). Geofences, which define virtual boundaries in a specific geographic area, can effectively organize the airspace and provide solutions to security concerns (Dasu, Kanza, & Srivastava, 2018; Hosseinzadeh, 2021; Stevens, & Atkins, 2020; Zhu, & Wei, 2016).

2.8. Training

Air traffic controllers must be adequately trained to ensure the efficient integration of UAVs into the airspace. Controllers need to understand the unique aspects of UAV operations compared to manned aircraft (Kamienski et al., 2010; Valavanis, & Vachtsevanos, 2015). National and international standards and practices should be used to update air traffic controller training programs to cover UAV-specific topics such as link and communication loss, and performance (Kamienski, & Semanek, 2015). The training process helps controllers to change their negative perceptions of UAVs, which may be caused by uncertainty, and to become more familiar with UAV operations (Truitt, Zingale, & Konkel, 2016).

2.9. Workload & Stress

The increasing number of both manned and UAVs presents significant challenges for air traffic controllers. Non-compliance with traditional air traffic standards significantly increases the workload for controllers dealing with UAV operations (Truitt, Zingale, & Konkel, 2016). Furthermore, the coordination, communication, and management of UAVs within the non-segregated airspace add to the complexity of ATC, requiring additional effort from controllers (Al-Mousa et al., 2019). The distinctive characteristics of UAVs, such as their varied speeds and altitudes, further contribute to this complexity and can lead to increased stress and additional responsibilities for controllers (Brookings et al., 1996). The innovative technology of UAVs also brings technological changes and procedures to ATC systems, which can be a source of stress (Finkelman, & Kirschner, 1980; Liu, Feng, & Zeng, 2019; Tomic, & Liu, 2017). Additionally, factors such as limited controllability of UAVs, uncertainty, increasing number of controlled traffic and changing nature of traffic, and high responsibility can also be sources of stress (Costa, 2000; Tattersall, Farmer, & Belyavin, 1991; Zeier, Brauchli, & Joller-jemelka, 1996; Zhang et al., 2023). To ensure a balanced workload and manageable stress levels while maintaining safe and efficient air traffic management, the gradual integration of UAVs into the airspace must be carefully considered, considering the working conditions of air traffic controllers (Baum et al., 2019).

3. Methodology

The study aims to answer the following research question: “What are the perspectives of air traffic controllers regarding the present and anticipated challenges, workload, stress factors, performance errors, and mitigation strategies concerning UAV integration? Furthermore, how do these perspectives differ between air traffic controllers who provide ATS (Air Traffic Services) and those who do not provide ATS?”.

This study employs a mixed-methods approach to investigate the integration of UAVs into non-segregated airspace. The study combines a comprehensive literature review with a survey of experienced air traffic controllers.

Surveys, functioning as standardized data collection tools for large samples within short timeframes, encompass four distinct question types - factual, knowledge, behavioral, and attitudinal - tailored to the measured property (Balcı, 2012; Büyüköztürk, 2005).

A comprehensive review of the literature and expert consultations were conducted to define five key categories for evaluating the integration of UAVs into non-segregated airspace. These categories are specific challenges, workload, stress, performance errors, and mitigation strategies. The details of these categories and their sub-categories are shown in Table 1.

The sample of the study consisted of 213 air traffic controllers in Türkiye. At the time of the study, there were 2035 active air traffic controllers in Türkiye. The sample size of the study (n>200) was considered sufficient for this known population (n>1000) with a 95% confidence level and a +/-5% margin of error (Krejcie, & Morgan, 1970; Yamane, 1967). The survey was conducted online. The questionnaire included items prepared on a 5-point Likert scale related to the categories and subcategories shown in Table 1, along with demographic variables. The survey was based on the voluntary participation of the participants, and all survey responses were processed anonymously. Table 2 shows the demographic characteristics of the survey participants.

Table 1. Key areas for evaluating UAV integration into non-segregated airspace

Challenges	(1) Collision Avoidance Capability; (2) Different Operating Characteristics; (3) Technology Limitations & Limited Detectability; (4) Regulatory Framework; (5) Communication; (6) Risk Management; (7) Security Concerns; (8) Training
Workload Factors	(1) Increased Traffic Volume; (2) Diverse Operating Characteristics; (3) Complexity in Integration; (4) Monitoring and Surveillance; (5) Regulatory Compliance; (6) Adaptation to New Technologies; (7) Emergency Response and Contingencies; (8) Workforce Capacity
Stress Factors	(1) Increased Workload; (2) Complexity and Uncertainty; (3) Continuous Monitoring; (4) Safety Concerns; (5) Regulatory Challenges; (6) Communication Complexity
Performance Errors	(1) Misidentification or Loss of Separation; (2) Communication Errors; (3) Procedural Errors; (4) Inattention or Overload Errors; (5) Decision-making Errors; (6) Technology-related Errors
Mitigation Strategies	(1) Geofencing and No-Fly Zones; (2) UAV Traffic Management (UTM); (3) Regulatory Framework Updates; (4) Collision Avoidance Systems; (5) Enhanced Communication Protocols; (6) Training Programs; (7) Public Awareness Campaigns; (8) Risk Assessment and Management

Table 2. Socio-demographic profile

		n	%
Sex	Female	70	32.9
	Male	143	67.1
Unit	Aerodrome Control Unit (TWR)	101	47.4
	Approach Control Unit (APP)	62	29.1
	Area Control Centre (ACC)	50	23.5
Degree	Bachelor's degree	166	77.9
	Graduate Studies	47	22.1
Experience	0-5 years	35	16.4
	6-10 years	34	16.0
	11-20 years	86	40.4
	> 20 years	58	27.2
Air Traffic Service (ATS)	ATS-providing	171	80.3
	non-ATS-providing	42	19.7
Total		**213**	**100.0**

The data collected from the participants was analyzed using IBM SPSS V 26. Descriptive statistics, such as mean scores, standard errors, and standard deviations, were employed to understand the responses comprehensively. An analysis of the differences between the perceptions of challenges, workload factors, stress factors, performance errors, and mitigation strategies by the ATS-providing and non-ATS-providing groups was conducted using independent samples t-tests. The normality assumption for the t-test was met in the study, with the condition of n>30 being fulfilled (Orhunbilge, 2000).

4. Findings

Table 3 shows the mean scores, standard errors, standard deviations, and normality of survey responses from air traffic controllers regarding the challenges, workload, stress, performance errors, and mitigation associated with integrating UAVs into non-segregated airspace. The data utilizes a 5-point Likert scale format for mean scores, where higher scores indicate a greater perception of these issues.

4.1. Challenges

According to the analysis results of challenges in the integration of UAVs into controlled airspace shown in Table 3, the mean score varies between 3.89 and 4.59 on a 5-point Likert scale. This indicates that air traffic controllers perceive these challenges as a significant concern. Additionally, the standard deviations for all challenges are relatively low, indicating a high level of agreement among the controllers on the relative importance of these issues.

Collision avoidance capability and regulatory framework topped the list with mean scores of 4.51 and 4.59 respectively. This highlights the controllers' concerns about potential mid-air collisions due to limitations in UAV technology and the lack of established regulations governing safe UAV integration. Following closely behind are risk management and different operating characteristics with mean scores of 4.49 and 4.46 respectively. These concerns highlight the perceived challenge of managing potential risks associated with UAVs as well as the challenges posed by their unique flight characteristics compared to manned aircraft. Communication emerges as a significant concern, receiving a mean score of 4.44, indicating significant concern about maintaining effective communication channels with UAVs, particularly in situations where traditional methods may prove inadequate. Technology limitations and limited detectability received a mean score of 4.37, indicating concerns about the reliability of UAV technology and the potential for them to be difficult to detect on radar. Security concerns also received a significant mean score of 4.28, emphasizing concerns regarding the potential misuse of UAVs for unauthorized purposes. Interestingly, training received the lowest mean score, at 3.89, suggesting that controllers might feel somewhat more confident in their ability to address this challenge through additional training compared to the others.

Differences in challenges between the ATS-providing and non-ATS-providing groups are shown in Table 4. There are differences in technology limitations & limited detectability, communication, risk management, security concerns, and training. In the ATS-providing group, averages range from 3.77 (Training) to 4.57 (Regulatory Framework), while in the non-ATS-providing group, averages range from 4.40 (Training) to 4.74 (Communication). Both groups perceive training as the least challenging aspect, albeit with a slightly lower mean score in the ATS-providing group. In contrast to the non-ATS-providing group's view of communication as the primary challenge, the ATS-providing group identifies regulatory framework as the predominant difficulty, similar to the overall perception.

Table 3. Mean, Std. error, Std. deviation, and Normality of results

	Mean	Std. Error	Std. Deviation	Skewness	Kurtosis
Challenges (CH)					
Regulatory Framework	4.59	.044	.642	-1.317	.542
Collision Avoidance Capability	4.51	.048	.705	-1.349	1.288
Risk Management	4.49	.044	.649	-.898	-.281
Different Operating Characteristics	4.46	.045	.662	-.837	-.408
Communication	4.44	.052	.754	-1.117	.372
Technology Limitations & Limited Detectability	4.37	.056	.811	-1.032	.113
Security Concerns	4.28	.057	.833	-1.113	.997
Training	3.89	.076	1.104	-.845	.154
Workload Factors					
Diverse Operating Characteristics	4.47	.046	.670	-1.077	.759
Complexity in Integration	4.45	.044	.640	-.742	-.463
Emergency Response and Contingencies	4.45	.049	.710	-1.064	.384
Increased Traffic Volume	4.37	.049	.713	-.680	-.772
Monitoring and Surveillance	4.29	.059	.863	-1.090	.642
Workforce Capacity	4.29	.057	.830	-.889	-.130
Regulatory Compliance	4.15	.059	.859	-.781	.141
Adaptation to New Technologies	3.99	.059	.863	-.604	-.012
Stress Factors					
Complexity and Uncertainty	4.69	.037	.537	-1.566	1.550
Safety Concerns	4.61	.042	.610	-1.293	.604
Increased Workload	4.54	.041	.602	-.959	-.078
Continuous Monitoring	4.52	.044	.648	-1.127	.593
Communication Complexity	4.46	.048	.703	-1.170	.933
Regulatory Challenges	4.21	.054	.788	-.569	-.638
Performance Errors					
Communication Errors	4.37	.050	.726	-.849	-.073
Misidentification or Loss of Separation	4.26	.052	.763	-.613	-.605
Procedural Errors	4.21	.055	.799	-.735	.176
Inattention or Overload Errors	4.19	.057	.833	-.869	.698
Decision-making Errors	4.15	.057	.833	-.733	.153
Technology-related Errors	3.91	.061	.885	-.515	.174
Mitigation Strategies					
Enhanced Communication Protocols	4.57	.044	.637	-1.214	.332
Collision Avoidance Systems	4.53	.048	.697	-1.164	-.007
Geofencing and No-Fly Zones	4.44	.048	.695	-.850	-.509
Regulatory Framework Updates	4.35	.052	.754	-.818	-.317
UAV Traffic Management (UTM)	4.34	.048	.700	-.589	-.804
Training Programs	4.32	.054	.784	-.926	.474
Risk Assessment and Management	4.29	.057	.829	-.678	-.914
Public Awareness Campaigns	4.07	.069	1.000	-.800	-.120

Table 4. t-test results of challenges by ATS

	Group	n	Mean	Std. Deviation	t	Sig.
Collision Avoidance Capability	ATS-providing	171	4.49	.706	-.857	.393
	non-ATS-providing	42	4.60	.701		
Different Operating Characteristics	ATS-providing	171	4.42	.676	-1.910	.060
	non-ATS-providing	42	4.62	.582		
Technology Limitations & Limited Detectability	ATS-providing	171	4.30	.832	-2.882	.005*
	non-ATS-providing	42	4.64	.656		
Regulatory Framework	ATS-providing	171	4.57	.660	-1.227	.224
	non-ATS-providing	42	4.69	.563		
Communication	ATS-providing	171	4.36	.780	-3.648	.000*
	non-ATS-providing	42	4.74	.544		
Risk Management	ATS-providing	171	4.43	.677	-3.217	.002*
	non-ATS-providing	42	4.71	.457		
Security Concerns	ATS-providing	171	4.18	.850	-4.785	.000*
	non-ATS-providing	42	4.71	.596		
Training	ATS-providing	171	3.77	1.134	-4.240	.000*
	non-ATS-providing	42	4.40	.798		

*p<0.05

4.2. Workload Factors

According to the analysis results of workload in the integration of UAVs into controlled airspace shown in Table 3, the mean score varies between 3.99 and 4.47 on a 5-point Likert scale. This indicates that air traffic controllers perceive all these factors as posing a workload. Additionally, the low standard deviations for all workload factors (ranging from 0.640 to 0.863) signify a significant level of consensus among air traffic controllers regarding the integration process.

The factors with the highest mean scores are diverse operating characteristics, complexity in integration, and emergency response and contingencies. These mean scores indicate that controllers are most concerned about the variety of UAV capabilities, the complex nature of integrating them into existing airspace, and managing emergencies involving UAVs. While increased traffic volume scores relatively high, its mean score is slightly lower than the aforementioned concerns. This suggests that increased traffic due to UAVs is a concern, but not the most pressing issue compared to the complexities of UAV operation itself. Similarly, monitoring and surveillance reflect a moderate concern, highlighting the need for robust systems to track and manage UAVs effectively. The data indicates that controllers are moderately concerned about workforce capacity and adaptation to new technologies.

Differences in workload factors between the ATS-providing and non-ATS-providing groups are shown in Table 5. There are differences in monitoring and surveillance, adaptation to new technologies, and emergency response and contingencies. In the ATS-providing group, averages range from 3.89 (Adaptation to New Technologies) to 4.45 (Diverse Operating Characteristics), while in the non-ATS-providing group, averages range from 4.36 (Increased Traffic Volume, Regulatory Compliance) to 4.67 (Emergency Response and Contingencies). The reason for adaptation to new technologies being perceived as having a lower workload in the ATS-providing group may be attributed to the fact that there has not been a significant change in the integration of UAVs with ATC systems, and the existing systems can still be used for surveillance and communication purposes.

Table 5. t-test results of workload by ATS

	Group	n	Mean	Std. Deviation	t	Sig.
Increased Traffic Volume	ATS-providing	171	4.37	.695	.139	.889
	non-ATS-providing	42	4.36	.791		
Diverse Operating Characteristics	ATS-providing	171	4.45	.687	-.843	.400
	non-ATS-providing	42	4.55	.593		
Complexity in Integration	ATS-providing	171	4.41	.648	-1.916	.057
	non-ATS-providing	42	4.62	.582		
Monitoring and Surveillance	ATS-providing	171	4.23	.895	-2.168	.031*
	non-ATS-providing	42	4.55	.670		
Regulatory Compliance	ATS-providing	171	4.09	.889	-1.791	.075
	non-ATS-providing	42	4.36	.692		
Adaptation to New Technologies	ATS-providing	171	3.89	.888	-3.348	.001*
	non-ATS-providing	42	4.38	.623		
Emergency Response and Contingencies	ATS-providing	171	4.40	.739	-2.720	.008*
	non-ATS-providing	42	4.67	.526		
Workforce Capacity	ATS-providing	171	4.25	.846	-1.620	.107
	non-ATS-providing	42	4.48	.740		

*p<0.05

4.3. Stress Factors

According to the analysis results of stress factors in the integration of UAVs into controlled airspace shown in Table 3, the mean score varies between 4.21 and 4.69 on a 5-point Likert scale. This indicates that the integration of UAVs is a significant source of stress for controllers. Additionally, the relatively low standard deviations for most factors (ranging from 0.537 to 0.788) indicate a significant level of consensus among controllers regarding these stressors.

The factors with the highest mean scores are complexity and uncertainty, with both exceeding 4.6. This indicates that controllers experience the most stress regarding the complex nature of managing UAVs within existing airspace and potential safety risks associated with their presence. Increased workload and continuous monitoring also score highly, suggesting that the additional workload and constant vigilance required for UAVs significantly contribute to ATC stress. Communication complexities are also identified as stressors, highlighting the challenges of coordinating with diverse UAVs and ensuring effective mitigation strategies in case of emergencies. Interestingly, regulatory challenges score the lowest, with a mean below 4.3, suggesting that while regulations present some challenges, they are a less prominent source of stress compared to the operational complexities of UAV integration.

Differences in stress factors between the ATS-providing and non-ATS-providing groups are shown in Table 6. Statistical differences were found among safety concerns, regulatory challenges, and communication complexities. The average scores for the ATS-providing group range from 4.16 (Regulatory Challenges) to 4.68 (Complexity and Uncertainty), whereas the non-ATS-providing group's averages range from 4.43 (Regulatory Challenges) to 4.88 (Safety Concerns). It is considered that the higher average scores of the non-ATS-providing group are due to less knowledge and lack of experience regarding the subject.

4.4. Performance Errors

According to the analysis results of performance errors in the integration of UAVs into controlled airspace shown in Table 3, the mean score varies between 3.91 and 4.37 on a 5-point Likert scale. This indicates a moderate level of concern for all error factors. Additionally, the standard deviations (ranging from 0.726 to 0.885) indicate some difference in the level of concern among controllers.

Communication errors and misidentification or loss of separation emerge as the error types with the highest mean scores. This indicates that controllers are most concerned about breakdowns in communication with UAV and the potential for losing track of or maintaining safe separation between UAVs and manned aircraft. Procedural errors and inattention/overload errors also score relatively high. This highlight concerns regarding adapting existing procedures to accommodate UAVs and the potential for cognitive overload due to the increased complexity of managing a more diverse airspace. Decision-making errors also appear as a moderate concern. Interestingly, technology-related errors score the lowest. This could imply that controllers have greater confidence in the reliability of technology compared to human factors like communication and decision-making. However, it is crucial to remember that even with reliable technology, human interaction points can still introduce errors.

The differences in performance errors between ATS-providing and non- ATS-providing groups are shown in Table 7. Statistical differences were found among misidentification or loss of separation, communication errors, decision-making errors, and technology-related errors factors between these two groups. The non- ATS-providing group has a higher average. A significant difference was observed in technology-related errors. ATS-providing group perceived technology-related errors as a less significant threat, with a score of 3.83. In contrast, non- ATS-providing group scored technology-related errors higher, with a score of 4.21. This indicates that those with experience in UAV integration may have greater confidence in technology's reliability.

Table 6. t-test results of stress factors by ATS

	Group	n	Mean	Std. Deviation	t	Sig.
Increased Workload	ATS-providing	171	4.52	.607	-1.182	.239
	non-ATS-providing	42	4.64	.577		
Complexity and Uncertainty	ATS-providing	171	4.68	.547	-.582	.561
	non-ATS-providing	42	4.74	.497		
Continuous Monitoring	ATS-providing	171	4.50	.672	-1.248	.216
	non-ATS-providing	42	4.62	.539		
Safety Concerns	ATS-providing	171	4.54	.644	-4.858	.000*
	non-ATS-providing	42	4.88	.328		
Regulatory Challenges	ATS-providing	171	4.16	.807	-2.010	.046*
	non-ATS-providing	42	4.43	.668		
Communication Complexity	ATS-providing	171	4.39	.739	-3.895	.000*
	non-ATS-providing	42	4.74	.445		

*p<0.05

Table 7. t-test results of performance errors by ATS

	Group	n	Mean	Std. Deviation	t	Sig.
Misidentification or Loss of Separation	ATS-providing	171	4.20	.779	-2.505	.013*
	non-ATS-providing	42	4.52	.634		
Communication Errors	ATS-providing	171	4.30	.744	-3.206	.002*
	non-ATS-providing	42	4.64	.577		
Procedural Errors	ATS-providing	171	4.16	.817	-1.759	.080
	non-ATS-providing	42	4.40	.701		
Inattention or Overload Errors	ATS-providing	171	4.14	.856	-1.854	.065
	non-ATS-providing	42	4.40	.701		
Decision-making Errors	ATS-providing	171	4.09	.867	-2.230	.027*
	non-ATS-providing	42	4.40	.627		
Technology-related Errors	ATS-providing	171	3.83	.914	-3.038	.003*
	non-ATS-providing	42	4.21	.682		

*p<0.05

4.5. Mitigation Strategies

According to the analysis results of mitigation strategies in the integration of UAVs into controlled airspace shown in Table 3, the mean score varies between 4.07 and 4.57 on a 5-point Likert scale. This indicates a high level of importance for all strategies in addressing the challenges of UAV integration. Additionally, the standard deviations for mitigation strategies range from 0.637 to 1, indicating a considerable degree of consensus among controllers on the importance of these approaches.

The factors with the highest mean scores are enhanced communication protocols, collision avoidance systems, and geofencing and no-fly zones. This suggests that controllers prioritize clear communication protocols, robust collision avoidance systems, and well-defined restricted airspace zones to mitigate safety risks and ensure efficient traffic management. Both collision avoidance systems and UTM score highly, highlighting the importance of technological advancements in managing UAV traffic. Regulatory framework updates and training programs also receive relatively high scores, emphasizing the need for updated regulations and comprehensive training programs to prepare for controllers. Risk assessment and management scores moderately high, indicating a focus on proactive risk mitigation strategies. Public awareness campaigns score the lowest, suggesting that controllers might perceive them as less critical compared to other strategies.

Table 8 shows the t-test results comparing the perceived importance of mitigation strategies for UAV integration between ATS-providing and non- ATS-providing groups. The analysis reveals no statistically significant differences for all strategies between the ATS-providing and non-ATS-providing groups. This suggests that regardless of prior exposure to the strategy, ATCs perceive their importance similarly.

Table 8. t-test results of mitigation strategies by ATS

	Group	n	Mean	Std. Deviation	t	Sig.
Geofencing and No-Fly Zones	ATS-providing	171	4.43	.694	-.362	.718
	non-ATS-providing	42	4.48	.707		
UAV Traffic Management (UTM)	ATS-providing	171	4.35	.673	.306	.761
	non-ATS-providing	42	4.31	.811		
Regulatory Framework Updates	ATS-providing	171	4.38	.753	1.094	.275
	non-ATS-providing	42	4.24	.759		
Collision Avoidance Systems	ATS-providing	171	4.55	.687	.810	.419
	non-ATS-providing	42	4.45	.739		
Enhanced Communication Protocols	ATS-providing	171	4.59	.629	.825	.410
	non-ATS-providing	42	4.50	.672		
Training Programs	ATS-providing	171	4.28	.799	-1.452	.148
	non-ATS-providing	42	4.48	.707		
Public Awareness Campaigns	ATS-providing	171	4.06	1.030	-.179	.858
	non-ATS-providing	42	4.10	.878		
Risk Assessment and Management	ATS-providing	171	4.26	.844	-.825	.410
	non-ATS-providing	42	4.38	.764		

5. Discussions

A prominent concern is the potential for mid-air collisions due to limitations in UAV technology and the lack of established regulations. Controllers also expressed concerns about managing UAV-related risks and their unique flight characteristics compared to manned aircraft, challenges that were highlighted in previous studies (Colgren, & Holly, 2009). Communication emerged as another concern, highlighting potential difficulties in maintaining reliable communication channels with UAV. Interestingly, training received the lowest mean score. While still a concern, this suggests that controllers might feel somewhat more confident in their ability to address this challenge through additional training compared to the other topics. These findings emphasize the urgency for advancements in UAV technology, the development of a comprehensive regulatory framework, and the establishment of robust risk management strategies. One of the most notable differences between ATS-providing and non-ATS-providing groups is the perceived difficulty of the regulatory framework. The non-ATS-providing group emphasized regulatory compliance to a greater extent, while the ATS-providing group considered it to be of lesser priority. This may be due to the ATS-providing group's greater familiarity with existing ATC systems and their belief that these systems can be adapted to accommodate UAVs.

The analysis also identified workload factors associated with UAV integration. Controllers expressed the most concern regarding diverse operating characteristics, complexity of integration, and emergency response procedures for UAVs. These concerns highlight the need for adaptations in existing ATC procedures and training programs to address the unique challenges posed by UAVs. In terms of workload factors, the ATS-providing group had lower concerns about adapting to new technologies compared to the non-ATS-providing group. While integrating new concepts into the ATC system, particularly those impacting the controller human-machine interface, is a challenge (Ellejmi et al., 2015; Miller et al.,2020), the ATS-providing group is aware of these difficulties but believes that existing ATC systems can be successfully adapted for this task.

Furthermore, the study showed that UAV integration is a significant source of stress for air traffic controllers. The complexity and uncertainty, and safety concerns scored the highest. Controllers typically employ strategies to manage complexity and uncertainty (Corver, & Grote, 2016) because it is well-known that complexity and uncertainty are among the major sources of stress in ATC (Bongo, 2017; Lecchini-Visintini, & Lygeros, 2010). Increased workload, continuous monitoring, and communication complexities were also identified as stressors. These findings emphasize the need for strategies to mitigate stress and improve psychological well-being among controllers during the UAV integration process. The non-ATS-providing group had higher levels of concern about regulatory challenges and communication complexities. This group may perceive UAV integration as more challenging and less familiar than the ATS-providing group.

The analysis of performance errors showed moderate concern for all error types, with communication errors and misidentification/loss of separation scoring the highest. This highlights the importance of developing clear communication protocols and procedures to minimize the risk of errors (Gupta, Jain, & Vaszkun, 2016; Kozak, Platenka, & Vrsecka, 2022). Additionally, concerns regarding procedural errors, inattention/overload errors, and decision-making errors emphasize the need for ongoing training and support for controllers as they adapt to managing a more complex airspace environment. Interestingly, technology-related errors received the lowest mean score, suggesting that controllers have greater confidence in technology compared to human factors. However, it is crucial to acknowledge that even with reliable technology, human interaction points can still introduce errors. Additionally, it was found that the non-ATS-providing group has a higher level of concern regarding communication errors and technology-related errors. The ATS-providing group's confidence in technology and their greater experience may be effective in reducing errors.

Finally, the study explored various mitigation strategies for addressing the challenges of UAV integration. The highest scores were attributed to enhanced communication protocols, collision avoidance systems, and geofencing/no-fly zones. These findings highlight the importance of technological advancements, clear communication protocols, and well-defined airspace restrictions for safe and efficient UAV integration. Additionally, controllers emphasized the need for updated regulations, comprehensive training programs, and proactive risk assessment and management strategies. Furthermore, no significant differences were found between ATS-providing and non-ATS-providing groups. Both groups placed similar importance on strategies such as communication protocols, collision avoidance systems, and regulatory framework updates.

6. Conclusion

This study examined the integration process of UAVs into airspace from the perspective of air traffic controllers. The findings of this study about integrating UAVs into controlled airspace are critical for the future of aviation.

The potential for mid-air collisions due to limitations in UAV technology and regulatory gaps emerged as a prominent concern, alongside challenges in managing UAV-related risks and communication difficulties. However, it is noteworthy that while training received the lowest mean score among the identified concerns, controllers may perceive it as a manageable challenge through additional training efforts. The urgency for advancements in UAV technology, the development of a comprehensive regulatory framework, and robust risk management strategies are highlighted as essential steps towards addressing these challenges effectively. Notably, differences between ATS-providing and non-ATS-providing groups regarding the perceived difficulty of the regulatory framework suggest varying levels of familiarity and confidence in existing systems. Moreover, workload factors associated with UAV integration, such as diverse operating characteristics, complexity of integration, and emergency response procedures, underscore the need for adaptations in existing ATC procedures and training programs. While concerns about adapting to new technologies exist, particularly impacting the human-machine interface, the belief in successfully adapting existing ATC systems prevails among the ATS-providing group. The study also highlights UAV integration as a significant source of stress for air traffic controllers, with complexity, uncertainty, and safety concerns ranking highest. Mitigating stress and improving psychological well-being among controllers are considered crucial, given the identified stressors and their potential impact on operational efficiency. In terms of performance errors, communication errors and misidentification/loss of separation rank highest, underscoring the importance of clear communication protocols and ongoing training for error mitigation. Despite controllers' confidence in technology, acknowledging the potential for human-related errors remains crucial. Finally, exploring mitigation strategies, such as enhanced communication protocols, collision avoidance systems, and geofencing/no-fly zones, underscores the importance of technological advancements and regulatory compliance. Both groups, ATS-providing and non-ATS-providing, converge on the significance of these strategies, emphasizing the need for unified approaches in addressing the challenges of UAV integration.

The focus on the perceptions of air traffic controllers in a specific region and the ongoing development of UAV technology and regulations are considered limitations of the study. In light of these limitations, continuous research and collaboration among all stakeholders are crucial. These stakeholders include different air traffic control authorities, UAV manufacturers, regulatory bodies, and legal experts. Their collaboration is essential to develop flexible mitigation strategies that can adapt to advancements in UAV technology and operational demands while complying with evolving legal frameworks and regulations.

Specifically, air traffic control authorities must work closely with UAV manufacturers to ensure that the technology meets safety and operational standards. Regulatory bodies need to keep up with technological advancements to update regulations accordingly, ensuring that new UAV systems are integrated safely into existing airspace structures. Legal experts play a critical role in interpreting and shaping laws that govern UAV operations, ensuring that these laws protect public safety and privacy without stifling innovation.

Moreover, this collaborative effort is key to ensuring a safe and successful integration of UAVs into the aviation sector. By maintaining regulatory compliance and addressing potential operational challenges, stakeholders can mitigate risks associated with UAV integration. It is also important to consider the impact of UAV operations on traditional manned aviation, ensuring that both can coexist safely and efficiently within the same airspace.

Therefore, it is recommended that future studies focus on the comprehensive impact of UAVs on air traffic operations and the development of regulations within this collaborative framework. Such studies should investigate how different regions manage UAV integration, the effectiveness of various mitigation strategies, and the long-term implications of UAV technology on air traffic control. By doing so, researchers can provide valuable insights that will help shape policies and practices, facilitating the smooth integration of UAVs into the global aviation system. This approach will not only enhance safety and efficiency but also promote innovation and growth within the UAV industry.

Ethical approval

Yes, this study received ethical approval from the Bartin University Social and Human Sciences Ethics Committee by Protocol Number 2024-SBB-0034 (2024/03/14).

Conflicts of Interest

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

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Determination of Factors Affecting Transportation Mode Choice of Turkish Domestic Airline Passengers

Mevlüt Üzülmez[1a*], Ali Emre Sarılgan[2]

[1*]Eskisehir Technical University, Aviation Management Department, Eskisehir, Türkiye. (mevlutuzulmez@erciyes.edu.tr)
[1a]Erciyes University, Aviation Management Department, Kayseri, Türkiye. (mevlutuzulmez@erciyes.edu.tr)
[2] Eskisehir Technical University, Aviation Management Department, Eskisehir, Türkiye. (aesarilgan@eskisehir.edu.tr)

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Abstract

Increasing demand in the transportation sector is closely related to the level of meeting passengers' demands. For this reason, many studies are being carried out in many parts of the world, especially in European and Far Eastern countries, aiming to determine the factors that affect passengers' choice of transportation mode. The aim of this study is to determine the main and sub factors affecting the choice of transportation mode for domestic airline passengers traveling in Türkiye. Within the scope of the study, a face-to-face survey was conducted to 407 passengers at Sabiha Gökçen Airport. Then, exploratory factor analysis was performed with the obtained data. Three main factors that emerged as a result of the analysis were named "Trip Factor", "Transportation Mode Factor" and "Safety and Comfort Factor", taking into account the literature review, expert opinions and the characteristics of the items. While on-time departure / punctuality, total travel time and travel at the requested time are the variables that have the highest impact on the choice of transportation mode. Previous accidents/incidents, transportation cost to airport/station and entertainment service in the cabin/wagon emerged as the variables with the lowest impact.

This study is based on the doctoral thesis of the first author under the supervision of the second author

1. Introduction

In order to achieve success in many areas such as transportation, health and tourism, it is very important to know the factors affecting customer preference and, if not known, to determine them. For this reason, determining such factors and increasing them to the desired level is frequently on the agenda of industry stakeholders and businesses (Chen, et al., 2020). Accurate prediction of passengers' choice of transportation mode is vital for the transportation industry's future planning and decisions (Findlay, Chia, & Singh, 1997). Therefore, identifying these factors and understanding their impact on changing demand has become one of the main focus areas of research in the field. Studies on the air transportation demand of a country or a region begin with the selection of a few relevant measurable factors, such as forecast variables. These variables are selected based on their relevance, previous studies, and data availability. Due to the nature of forecasting studies, data for these variables are generally created in time series format. Researchers then use econometric or statistically based analytical models to investigate the effects of predictor variables on transportation mode choice (Wang & Gao, 2021). The accepted truth in all modes of transportation is that; The way to increase passenger demand for businesses is through passenger satisfaction. For this reason, the factors affecting passengers' choice of transportation mode are constantly investigated under different headings and under different names in the literature. In this study, the criteria that airline passengers take into consideration when choosing the mode of transportation are discussed (Chen Z., et al., 2021). Furthermore, factors and factor impact on the choice of transportation mode are determined. Eventually, sub-factors are listed under 3 main factors by considering literature review, expert opinions and the properties of the sub factors.

This research contributes to the literature in several ways. Firstly, the identified main and sub-factors can provide information about passengers' perspectives on different types of transportation. Secondly, results will provide resources for upcoming studies about passenger transportation mode selection. Finally, findings may be used for transportation sector management on investment of new transport projects.

In literature section, previous studies have been mentioned. Then conceptual model along with hypotheses are presented in third section. In forth section study method has been explained. Research scales are presented and explained in result and discussion section. Finally, outcomes and recommendations were discussed in conclusion section.

2. Literature

There are many studies in the literature on airline passengers' choice of transportation mode. Research on airline passengers' transportation mode choices has a wide range of literature to understand how various factors influence these choices. These factors include cost, time, comfort, safety, environmental impacts and personal preferences. In this section, studies on relevant subject will be given.

Demographic features of passenger are notable factor affecting mode choice (Budd & Ison, 2017; Wensveen, 2023). Need and desire of people generally change by their gender, age, income statues etc. So that, institutions should make allowance for this information (Tyrinopoulos & Antoniou, 2013; Nadeeshan & Mudunkotuwa, 2018; Buehler, 2011). Since each feature has their own criteria, they need to be investigated individually before analyzing as a block veriable set. For example, young passengers tend to fly more and are often price sensitive, while older passengers may prioritize comfort (Demirsoy, 2012). However, when other variables included, interaction grade of age factor may be at negligible level.

Transportation cost and travel time are quite vital factors in selection process. Since price and time prominent variable for customer, they give weight to these criteria more than others (Park & Ha, 2006; Shi, Hussain, & Kong, 2022; Xia & Zhang, 2016; Zhang, Wan, & Yang, 2019; Li, Tian &, Li 2016). Moreover, frequency and comfort factors are also found as critic factor on passenger choices (Pagliara, Vassallo, & Román, 2012; Yang & Zhang, 2012).

One of the factors that effecting passenger choice is location of airport. While an increase is seen at central airports, there was a decrease in flights at secondary airports (Zhang, Wan, & Yang, 2019; Behrens & Pels, 2012; Loo, 2008; Liu, 2017).

Since accidents and problems during flight have significant effect on passengers, safety and user friendly operation process are also important for passenger to choice transportation mode (Chang, 2013).

During decision process, lots of factors affect passenger's choice, this factor may be economic, demographic, psychologic, environmental and technologic. Different studies express different result on choice criteria. In the following part, most found factors affecting passenger's transportation mode choice is defined and discussed in more detail.

3. Factors Affecting Passengers' Transportation Mode Choice

3.1. Total travel time

Total travel time is among the important factors affecting passengers' preference criteria (Boonekamp, Zuidberg, & Burghouwt, 2018). Shortening travel time means more trips, allowing passengers to reach their desired destination as quickly as possible (Belobaba, Odoni, & Barnhart, 2015). Airline passengers may have to spend long periods of time at airports for check-in and security screening procedures. The time taken for these operations may vary depending on factors such as the size of the airport, time of day and security measures taken. While advanced check-in options and expedited security lanes can help reduce time spent at the airport, these factors still increase overall travel time for airline passengers (Shi, Hussain, & Kong, 2022).

3.2. Travel Frequency

While the frequency can be increased by planning more trips during the day or week, the number of seats offered can also be increased by low frequency flights with high seat capacity. However, studies in the literature show that the capacity variable is strongly related to the frequency variable (Boonekamp, Zuidberg, & Burghouwt, 2018). In order to increase travel frequency, businesses direct their flights to points that have many connections with other points. In this way, the concentration of central points creates a great synergy. As a result of this effect, passengers can find more and more frequent connecting flights when they reach the hub point.

3.3. On Time Departure / Punctuality

Another factor that passengers take into consideration when making their choice is the on-time performance of the flights (Boonekamp, Zuidberg, & Burghouwt, 2018). The difference between the planned take-off time and the real-time take-off time indicates the success of the on-time performance. It has been concluded that especially business travelers are more sensitive to flight delays (Proussaloglou & Koppelman, 1999, pp. 197-198).

3.4. Travel at the Requested Time

The variable of the travel taking place at the requested time is closely related to the travel frequency and scheduled flight service. The availability of scheduled flights increases passengers' trust in the relevant business, as it requires a more corporate structure (Duval & Schiff, 2011). The impact of scheduled service availability on international tourism has been the subject of frequent research, especially in 2010 and thereafter (Tveteras & Roll, 2014). Previous academic literature directly estimates the effects of airlines on international arrivals. Later studies revealed that scheduled flights and the frequency of these flights have a positive and significant relationship on passenger demand (Koo, Tan, & Duval, 2013; Koo, Lim, & Dobruszkes, 2017).

3.5. Ticket Price

Beyond many factors in the supply-demand relationship, the ticket price (pricing) factor is considered one of the most important tools available to businesses to stimulate sales and increase revenue (Wang & Gao, 2021). For this reason, most studies use average ticket prices as a predictive variable to explain the variability of passenger demands (Hazledine, 2017). Low-cost carriers (LCCs) tend to connect relatively smaller markets compared to full-service and regional carriers and HSR transportation. Such airlines aim to attract additional demand by offering low fares (Ghosh & Terekhov, 2015). Therefore, the proportion of passengers traveling with LCCs is another factor affecting the demand for airlines offering low fares (Boonekamp, Zuidberg, & Burghouwt, 2018)

3.6. Transportation Cost to Airport/Station

Although passengers prefer to travel quickly and comfortably between two cities, the cost of transportation to the station where they will use the mode of transportation can sometimes significantly change the choices made (Phang, 2003). For this reason, passengers are more inclined to choose modes of transportation that are close and have public transportation. This tendency is more common especially in underdeveloped or underdeveloped countries (Banister & Berechman, 2000).

3.7. Transportation Time to Airport/Station

People whose transportation time significantly affects the choice of transportation mode are generally passengers traveling for business and private purposes (Macit, 2020). The longer the total travel time, including the transportation time to the airport/station, will decrease at the same rate as the passenger's desire to choose the relevant mode of transportation (Tengilimoğlu & Öztük, 2021). Throughout Turkey, train stations are located in more central locations than airports, however, multiple transportation options are provided to airports. For this reason, it is more likely to be preferred over airlines, especially for short-distance travel.

3.8. Public Transportation to Airport/Station

The importance of transportation to stations has been explained in previous titles based on different features. Access to stations by public transportation is important in terms of both time and cost. Public transportation is among the important services that enable frequent trips to the station and transportation at low costs (Saatcioglu & Yasarlar, 2012).

3.9. Previous Accidents/Incidents

Since the perception of safety has an important place for passengers, accidents and incidents occurring in a transportation sector affect passengers' choices of transportation mode (Su, Luan, Yuan, Zhang, & Zhang, 2019). Especially elderly passengers and passengers who are not familiar enough with the process in the transportation sector may have a perception that safety is reduced when accidents or accidents occur. This situation may lead to a shift in passenger preferences towards other modes of transportation (Marzuoli, et al., 2014).

3.10. Perception of safe transportation

In the 21st century, where transportation has become extremely important, safety is a major concern for passengers traveling for both business and other purposes. When it comes to choosing the safest mode of transportation, it is stated both in the statistics announced by the countries and in the literature that air and rail transportation are reliable and safe options (Silla & Kallberg, 2012).

3.11. Safety / Security Procedures

In environments with intense human and cargo flow, safety and security practices are extremely important. These practices include various measures to protect passengers, personnel and belongings from potential dangers and to provide a trouble-free travel opportunity. Since passengers are in areas that pose many potential safety risks during their waiting, departure and arrival processes, various security measures such as security screenings, digital and controlled doors, side barriers, regular announcements and visual displays are implemented at stations and airports (Wei, Guo, Dong, & Li, 2012). Within the scope of security and surveillance, the stations are equipped with advanced surveillance systems, including CCTV cameras and monitoring stations (Szatmári, 2021).

3.12. Entertainment Service in the Cabin/Wagon

All services offered by the carrier to passengers, from the ticket purchasing process to post-travel services, can be included in the comfort factor. Convenience in ticket sales, loyalty programs, in-flight entertainment and food/beverage offerings are examples of these services. However, the research and expert opinions reveal that passengers evaluate their service perception based on the service provided during the travel (Proussaloglou & Koppelman, 1999). Especially passengers who have two different travel options with similar travel times tend to choose the mode of transportation that offers better catering and entertainment opportunities (Zhang & Findlay, 2014; Kopsch, 2012; Li & Sheng, 2016; Sofany, 2016).

4. Method

The survey used in the study was compiled in line with expert opinions, based on the scale in the literature (Gürsoy, Kuşakcı, Tanrıverdi, & Akyıldız, 2020) and related surveys (Dalkic, Balaban, Tuydes-Yaman, & Celikkol-Kocak, 2017; Yoo, 1995). Afterwards, demographic characteristics and travel-related criteria that affect passengers' choice of transportation mode are included. The created survey was adapted to the scope of the research after 10 pilot applications in the first stage and 30 pilot applications in the second stage. Survey was planned to conduct for airline passengers traveling on the Istanbul-Ankara and Istanbul-Konya lines, which have the opportunity to travel by both airline and YHT transportation in the Turkish domestic market. Since the survey will be carried out in cleared areas of airport, necessary permissions were first requested from the local authorities to which the related airports are affiliated. Only Sabiha Gökçen Airport officials responded positively to permit requests. Then, after a second permission was obtained from the airport's terminal authority, the survey was conducted on the specified days and hours. The surveys were administered face to face to passengers waiting for boarding in front of the boarding gates at Sabiha Gökçen Airport. After removing incomplete and incorrect surveys, 407 surveys suitable for evaluation were obtained. Then, by carrying out an exploratory study, exploratory factor analysis was carried out, which allows data consisting of many variables to be represented with a smaller number of variables (factors).

5. Result and Discussion

Descriptive statistics of the data obtained are shown in Table 1. 50.6% (206 people) of the passengers participating in the research are men and the remaining 49.4% (201 people) are women. It was also determined that 40.3% of the participants were 21-30 years old. This data is followed by passengers between the ages of 31-40 with 22.1%. The lowest average age group, with 9.3%, is passengers between the ages of 18-20. Passengers were asked about the level of education they had completed and 44% of the passengers declared that they had a bachelor's degree. This data is followed by passengers with high school education or below with 22.4%. The number of passengers with doctoral level education has the lowest rate at 4.9%. When asked who paid the ticket fee, a significant majority of the passengers, 57.7%, answered that they paid the ticket fee themselves. In other words, it seems that both the passenger and the customer are often the same person. One of the most important effects of this situation is that all the positive and negative services experienced by the passenger during the travel directly affect the choice of the next mode of transportation. The rate of those whose company or family-relative covers the ticket fee is 19.9% and 18.4%, respectively. It was observed that the number of passengers whose friend paid the ticket fee or who had a free-gift ticket had the lowest percentage at 2%. 31.9% of the passengers travel for business purposes, 31.2% for visiting purposes, 19.4% for holiday purposes and 10.1% for education purposes. The remaining 7.4% travel for different purposes (funerals, disasters, etc.).

Table 1 Descriptive statistics

		Frequency	Percent
Gender	Women	201	49.4
	Man	206	50.6
	Total	**407**	**100.0**
Age	51 and above	52	12.8
	41-50	63	15.5
	31-40	90	22.1
	21-30	164	40.3
	15-20	38	9.3
	Total	**407**	**100.0**
Payer	Free-Gift	8	2.0
	Friend	8	2.0
	Company	81	19.9
	Family	75	18.4
	Passenger (own)	235	57.7
	Total	**407**	**100.0**
Travel Purpose	Business	130	31.9
	Tourism	79	19.4
	Education	41	10.1
	Visitation	127	31.2
	Others	30	7.4
	Total	**407**	**100.0**

The basic assumption for most parametric tests is that the data collected within the scope of the research are suitable for normal distribution, individually or in multiple forms (Islamoglu & Alniacik, 2019). In order to understand the normal distribution of the data set, skewness and kurtosis values must be examined (Kline, 2016). Skewness and kurtosis values being within ± 2 indicate normal distribution (George & Mallery, 2010). As a result of the analysis, it is seen that these values are between -1.545 and +.702 (Table 2.). These results can be interpreted as the data set being normally distributed and all items being within acceptable limits. In addition, the means of the items in the scale vary between 2.8231 and 4.1499, and their standard deviations vary between 1.19508 and 1.61555.

Table 2 Skewness and Kurtosis Values

	Label	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error
S1	Total travel time	**-1.321**	**.121**	**.465**	**.241**
S2	Ticket Price	**-.831**	**.121**	**-.378**	**.241**
S3	Travel frequency	**-.801**	**.121**	**-.604**	**.241**
S4	On Time Departure / Punctuality	**-1.327**	**.121**	**.702**	**.241**
S5	Travel at the Requested Time	**-1.117**	**.121**	**.191**	**.241**
T1	Transportation Time to Airport/Station	**-.905**	**.121**	**-.485**	**.241**
T2	Public Transportation to Airport/Station	**-.628**	**.121**	**-1.126**	**.241**
T3	Transportation Cost to Airport/Station	**-.159**	**.121**	**-1.440**	**.241**
K1	Convenience in ticket transactions	**-1.021**	**.121**	**-.189**	**.241**
K2	Interior seating arrangement in the Cabin/Wagon	**-.487**	**.121**	**-1.180**	**.241**
K3	Entertainment Service in the Cabin/Wagon	**.144**	**.121**	**-1.376**	**.241**
E1	Previous Accidents/Incidents	**-.208**	**.121**	**-1.545**	**.241**
E2	Perception of safe transportation	**-.634**	**.121**	**-1.124**	**.241**
E3	Safety / Security Procedures	**-.519**	**.121**	**-1.200**	**.241**

The 407 surveys obtained meet the requirement of being 10 times the number of variables and at least 384 samples with a 95% confidence interval, regardless of the number of variables (Conroy, 2018).

5.1. Exploratory Factor Analysis

Firstly, KMO (Kaiser-Meyer-Olkin) sample adequacy analysis was performed to determine sample adequacy and Bartlett test was performed to test the suitability of the data for factor analysis (Capik, Gozum & Aksayan, 2002; Karasar, 2005). As shown in Table 3, the KMO coefficient of the scale is 0.821 and the Bartlett test result is significant at the $p<0.05$ significance level. The fact that the KMO value is 0.821 indicates that the sample is sufficient for factor analysis, and the significant Bartlett test result indicates that the data is suitable for factor analysis.

Table 3 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	Bartlett's Test of Sphericity	
.821	**Approx. Chi-Square**	2064.570
	df	91
	Sig.	.000

As a result of the analysis conducted on the reliability level of the scale in the study, Cronbach's Alpha value was found to be 0.842 (Table 4). Based on this result, the alpha coefficient obtained for all items shows that the applied survey can be considered reliable.

Tablo 4 Cronbach's Alpha Value

Reliability Statistics		
Cronbach Alpha	Cronbach's Alpha Based on Standardized Items	N
.842	.838	14

It is accepted that variance ratios ranging between 40% and 60% are sufficient to determine the number of factors (Tavsancil, 2019; Kline P., 1994). Additionally, factors with eigenvalues of +1 or greater need to be taken into account (Alpar, 2016; Field, 2005). Principal component analysis was used to find the factors in the explanatory factor analysis, and the oblimin rotation method was used to determine the number of factors - assuming there was a correlation between at least two factors. As a result of the analyses, a 3-factor structure emerged that explained 55.977% of the total variance in the 14-item scale and had an eigenvalue over 1.00. Alpar and Field express that; in factor analysis, factor loadings between 0.30 and 0.40 are accepted as the lowest acceptable levels (Alpar, 2016; Field, 2013). However, as a result of the first analysis, two items (K1 and K2) were removed from the analysis because the factor loadings of some items in the scale were below 0.30 (Alpar, 2016; Field, 2005). As a result of the second analysis, the factor loadings of the 12 items in the scale are between 0.341 and 0.785, as shown in Table 5.

Table 5 Factor Loads of Components

Communalities		
	Initial	**Extraction**
S1	1.000	.527
T4	1.000	.361
S3	1.000	.563
S4	1.000	.612
S5	1.000	.451
T1	1.000	.596
T2	1.000	.761
T3	1.000	.732
K3	1.000	.341
E1	1.000	.699
E2	1.000	.785
E3	1.000	.773

Extraction Method: Principal Component Analysis.

In addition, it was observed that the new factors obtained - with a higher value than the first analysis - explained 60% of the total variance (Table 6). This reveals that the factor loadings of the 12 items have application significance.

Tablo 6 Final Total Variance Explained

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**
1	4.136	34.468	34.468	4.136	34.468	34.468	3.296
2	1.902	15.851	50.320	1.902	15.851	50.320	2.442
3	1.163	9.690	60.010	1.163	9.690	60.010	3.028
4	.960	8.002	68.011				
5	.765	6.376	74.388				
6	.701	5.845	80.232				
7	.549	4.576	84.809				
8	.505	4.204	89.013				
9	.439	3.659	92.672				
10	.360	3.001	95.673				
11	.322	2.686	98.359				
12	.197	1.641	100.000				

Extraction Method: Principal Component Analysis.

When the distribution of factor loadings was examined as a result of factor analysis, it was seen that the variable coded S2 (Ticket Price) was loaded under the transportation mode factor. For this reason, it was removed from the trip factor set and listed under the transportation mode factor and named as T4. Factors that emerged (Table 7) were named "Trip Factor", "Transportation Mode Factor" and "Safety and Comfort Factor", taking into account the literature review, expert opinions and the characteristics of the items. The "Trip Factor" dimension consists of four items (S1, S3, S4, S5), the "Transportation Mode Factor" dimension consists of four items (T1, T2, T3, T4), and the "Safety and Comfort Factor" dimension consists of four items (E1, E2, E3, K3).

Additionally, Cronbach's Alpha values within each factor are shown in Table 7.

Table 7 Factors, Component Loads and Cronbach's Alpha per Factor

Factors	Components	Factor Loads 1	Factor Loads 2	Factor Loads 3	Cronbach's Alpha Per Factor
Safety and Comfort Factor	E3	.874			0.813
	E1	.873			
	E2	.849			
	K3	.531			
Trip Factor	S4		.767		0.695
	S1		.749		
	S3		.743		
	S5		.548		
Transportation Mode Factor	T3			-.852	0.750
	T2			-.822	
	T1			-.640	
	T4			-.475	

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 6 iterations.

As a result of the analysis, factors affecting transportation mode choice of Turkish domestic airline passengers listed under 3 main factors shown in Figure 1. The items such as total travel time, travel frequency, on-time departure and travel at the requested time, which have a significant impact on the transportation mode choice of airline passengers, are listed under the "Trip Factor". Ticket price, transportation cost to airport/station, transportation time to airport/station and public transportation to airport/station airport/station items are listed under the "Transportation Mode Factor". Finally, items on previous accidents/incidents, perception of safe transportation, safety / security procedures and entertainment service in the cabin/wagon are listed under the "Safety and Comfort Factor".

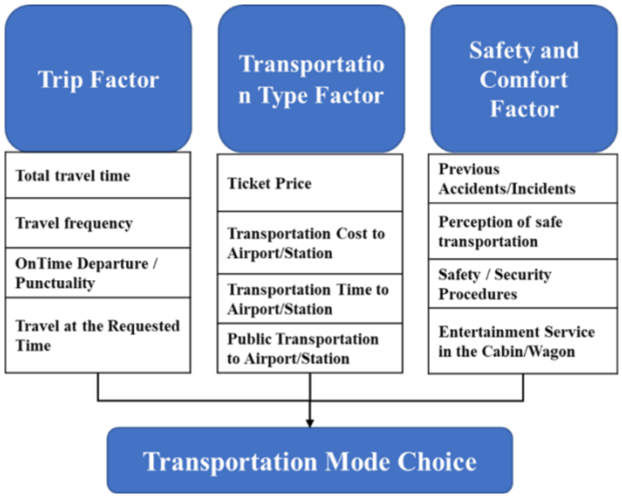

Figure 1. Factors Affecting Transportation Mode Choice of Turkish Domestic Airline Passengers

Analysis results are examined and factor impacts on the choice of transportation mode are shown, in Table 8.

Table 8 Factors, Component Loads and Cronbach's Alpha per Factor

Codes	Label	Mean Impact (out of 5)	Std. Error
S1	Total travel time.	4.1425	1.29201
S2	Ticket Price	3.7789	1.29617
S3	Travel frequency	3.7912	1.33653
S4	On Time Departure / Punctuality	4.1499	1.19508
S5	Travel at the Requested Time	4.0098	1.25156
T1	Transportation Time to Airport/Station	3.7936	1.39374
T2	Public Transportation to Airport/Station	3.5479	1.53033
T3	Transportation Cost to Airport/Station	3.1327	1.54317
K1	Convenience in ticket transactions	3.8943	1.34499
K2	Interior seating arrangement in the Cabin/Wagon	3.4472	1.49269
K3	Entertainment Service in the Cabin/Wagon	2.8231	1.49157
E1	Previous Accidents/Incidents	3.1941	1.61555
E2	Perception of safe transportation	3.5627	1.54262
E3	Safety / Security Procedures	3.4791	1.52126

It is quite essential to understand criteria with high impact rate to foreseen and attract more passenger. Tablo 8 shows that punctuality, total travel time and travel at the requested time are the most crucial choice factor in this study followed by convenience in ticket transactions, transportation time to airport/station, travel frequency and ticket price (all above 3,77).

It is quite understandable that passengers expect their trips to start and end on time. On-time departure shows that the transportation mode is reliable and professional, which increases the likelihood that passengers will choose the same transportation mode again (David Mc A, 2016). This fact is also related to travel at requested time because if company has a high delay rate, that refers to low on time departure/arrival. Total travel time is also stick with the delays. Each delay could possibly cause more travel time. Transportation time to airport/station is a complementary factor that seriously affects total traffic time. Airports/stations that are difficult to access may cause passengers to choose alternative ones. Fast and reliable public transport connections to airports/stations should be provided. Integration of metro, train and bus lines into the airport/station shortens transportation time (Rimjha et al. 2021).

Another factor that is brought up after analysis is convenience in ticket transactions. Ease of ticket sales is an important factor in passengers' choice of transportation mode. Passengers prefer fast, reliable and user-friendly ticket purchasing processes when making their travel plans. Since this factor is at the beginning of the travel experience, it directly affects passengers' overall satisfaction and preferences (Buhalis & Law, 2008). Companies must offer passengers an omni-channel experience by integrating both physical and digital ticket sales points. Kiosks, self-service machines and mobile applications can be part of this integration.

Passengers' income levels affect their sensitivity to ticket prices. Passengers in lower income groups are more sensitive to ticket prices and generally prefer cheaper modes of transportation (Hensher, 2001). This is an important point that transportation companies should pay attention to in their pricing strategies. The success of low-cost airline companies helps us to see how important the ticket price is in passenger preferences. These companies have managed to reach a wide customer base with their low price strategies (Francis et al., 2007).

Findings indicates that other factors such as public transportation to airport/station, transportation cost to airport/station, interior seating arrangement in the cabin/wagon and entertainment service in the cabin/wagon are less effective on passenger choice compared to factors explained above.

6. Conclusion

Accurate prediction of passengers' choice of transportation mode is vital for the transportation industry's future planning and decisions. Therefore, identifying these factors and understanding their impact on changing demand has become one of the main focus areas of research in the field. Previous transportation studies often relied heavily on economic and logistical factors, such as cost, time, and convenience. By incorporating behavioral theories, this study aligns with a growing body of literature that emphasizes the psychological and social dimensions of travel behavior. This approach helps in understanding the underlying motivations and perceptions that drive passengers' choices, providing a more holistic view. In this study, by using exploratory factor analysis, the factors affecting the transportation mode choice of domestic airline passengers traveling in Turkey and the importance levels of these factors were determined. The three factors that emerged as a result of the analysis were named "Trip Factor", "Transportation Mode Factor" and "Safety and Comfort Factor", taking into account the literature review, expert opinions and the characteristics of the items. The findings contribute to a more nuanced understanding of how different factors, such as socio-demographic characteristics and trip attributes, affect transportation mode choice. When the analysis results are examined, on-time departure / punctuality (S4), total travel time (S1) and travel at the requested time (S5) are the variables that have the highest impact on the choice of transportation mode. Passengers place a high value on reliability and the ability to adhere to schedules. This variable reflects the importance of minimizing delays and ensuring that flights depart and arrive as scheduled. Airlines should invest in technologies and processes that improve operational efficiency, such as advanced scheduling systems, real-time tracking, and automated maintenance systems for quick turnaround times and efficient handling of delays. The significance of total travel time underscores the role of convenience in travel behavior so that passengers prefer modes that offer the quickest route to their destination. Airlines should implement online check-in, mobile boarding passes, and self-service kiosks to reduce time spent at the airport. Moreover, they may enhance connectivity between airports and city centers through partnerships with local transportation providers which are offering seamless transfers and shuttle services. Travelling at requested time aligns with theories emphasizing the importance of temporal flexibility in travel choices. It can be easily seen that the ability to choose travel times fit personal schedules is crucial for passenger satisfaction. Airline companies should incorporate AI and machine learning algorithms to predict demand fluctuations and optimize flight schedules accordingly. They can also establish or enhance code-sharing agreements with other airlines to increase the number of available flight options at various times.

Previous accidents/incidents (E1), transportation cost to airport/station (T3) and Entertainment Service in the Cabin/Wagon (K3) emerged as the variables with the lowest impact. This study contributes to the literature by reporting highest factors of passenger choice and their weight among others and by providing empirical evidence from the Türkiye. Since each country has their own socio-economic features and regional variations in transportation infrastructure result may differ from one market to another.

Since this study was carried out by taking into account the data received from passengers between the Istanbul-Konya and Istanbul-Ankara lines between the 2022 autumn and 2023 spring seasons, the findings are limited to the relevant time and cities. It would be appropriate to increase the time interval and city pairs in order to make more comprehensive comments on the subject and to analyze passengers' preference criteria in depth. So that it will serve as a better guideline for studies aiming to explore similar topics in different contexts.

Ethical approval

Not applicable.

Conflicts of Interest

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

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Grinding of Thermal Spray Coated Aircraft Engine Parts

Özgür Poyraz[1*], Merve Gökçe Ünal[2]

[1*]The University of Sheffield Advanced Manufacturing Research Centre – Northwest, Blackburn, United Kingdom (o.poyraz@amrc.co.uk)
[2] TEI Tusas Engine Industries, Esentepe M. Cevreyolu B. No:356, Tepebasi, Eskisehir, Türkiye. (merve.gokce@tei.com.tr)

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Abstract

Aircraft engines that must be certified separately from the platform should comply airworthiness and remain unchanged for all types of operations and in all environments. Together with this, they might only be preferred by airlines if they are competitive in terms of several aspects such as fuel efficiency, speed, and maintainability. These requirements are met by an interdisciplinary effort including engine design, component materials, manufacturing techniques and electronic control. An illustrative example to this is the critical components designed and manufactured of titanium or superalloys and coated afterwards to resist various wear causes and to facilitate easy, cost-effective maintenance by keeping the component itself only via renewing the coating after certain flight hours. Although this solution sounds reasonable and feasible, it needs a considerable know-how level to apply a proper coating and subsequently to size it to an acceptable level of dimensional quality and surface integrity. In order to meet researchers' and engineers' know-how needs on the subject, this paper presents a systematic review on grinding of thermal spray coated aircraft engine parts. In this paper, spray coatings, which offer the widest substrate material range are explained in detail regarding their materials, application methods and characterizations. Later on, grinding of these is narrated considering tools and process parameters such as cutting speed, feed, and depth of cut. Finally, the influence of grinding conditions on dimensions, surface quality, hardness, residual stresses, and microstructure is discussed. The paper is concluded with a state-of-the-art summary and emphasis on research gaps and future perspectives on the subject.

1. Introduction

Commercial and military aircraft are powered by a variety of engine types, such as diesel-propeller, gasoline-propeller, turboshaft, turbofan, and turbojet. These so-called engines, especially the ones that are used for commercial aircrafts transporting humans, should be certified separately from the platform and should comply airworthiness for all types of operations and in all environments. In addition to this, airline operators and/or aircraft manufacturers purchase and use competitive engines in terms of several aspects such as fuel efficiency, speed, and maintainability. In order to meet these demands, aircraft engine developers and manufacturers put an interdisciplinary effort starting from material selection phase to engine design and component manufacturing. Critical components made of nickel and titanium alloys that are subsequently coated to withstand different wear causes and enable simple, economical maintenance by preserving the component itself by simply renewing the coating after a set number of flight hours serve as an illustrative example of this. These special materials include but are not limited to aluminum alloys, composite materials, alloyed and stainless steels, superalloys and titanium (Sjöberg, 2008). Aircraft engine designers might have different aims during the selection of these materials and these aims are mostly related to the function of the component, the temperature that the component is exposed, the rotation speed and the gas pressure. As mentioned before, the designers' aims are shaped by market demands and the safety of the part is dictated by international agencies' certification specifications. For example, a high-pressure turbine disc of the LEAP engine powering all up-to-date narrow-body aircrafts like Airbus A320Neo, Boeing 737-Max and Comac C919 should deliver more than 140kN take-off thrust, should rotate approximately at 20000RPM, should withstand an overall pressure ratio of 50:1 and should not exceed 14.4g/kN/s thrust-specific fuel consumption (EASA, 2018). On the other hand, the same part, as an equipment with high-energy rotors, shouldn't failure significantly to demolish engine's containment and should have an acceptable level of design integrity (EASA, 2020). The conflicting nature of aligning with market demands and safety regulations poses a significant challenge in developing a design solution that relies solely on specific material properties. At this point, the need for enhancing these materials' properties with additional special processes becomes prominent, and these processes might be used of core properties of materials like heat treatments or for surface properties of materials like coating.

Among the different type of aircraft engines, turbines which work in the harshest environments in terms of temperature, centrifugal forces and pressure, display the widest variety of coating materials and techniques. In order to select and apply this wide variety of coating techniques on turbine engine parts, researchers and engineers should pay sufficient attention to several criteria including coating purpose, coating material, coating technique as well as substrate part function, material, and pre or post surface condition. Previous researchers (Rhys-Jones, 1990) introduced a coating classification including wear control coatings, clearance control coatings, thermal barrier coatings, overlay coatings, and gas seal coatings. During the last decade, MTU Aero Engines AG (2017) expanded this classification to include corrosion/oxidation protection coatings, titanium fire protection coatings, abradable/sealing coatings and dimensional adjustment coatings. Further classification of these coatings can be made according to the material state being gaseous, solution and molten. While chemical vapor deposition (CVD) and physical vapor deposition (PVD) can be classified in the gaseous state, electroplating and electrochemical deposition belongs to solution state, and thermal spraying, laser cladding and electro discharge coating belongs to molten state (Tyagi et al., 2022). Within these coating methods, thermal spraying has the widest application area for aircraft turbine engine parts (Fauchais and Vardelle, 2012) and it is sub- classified to detonation gun, flame spray, high velocity oxy-fuel (HVOF), plasma spray and warm spray (Ahmed et al., 2021). There is a considerable material range difference between different thermal spray techniques and plasma spray method offers the broadest material range to include metals/intermetallic, cermets and ceramics. Fig. 1 shows the available materials for different type of thermal spray methods together with feedstock size and temperature (Ahmed et al., 2021).

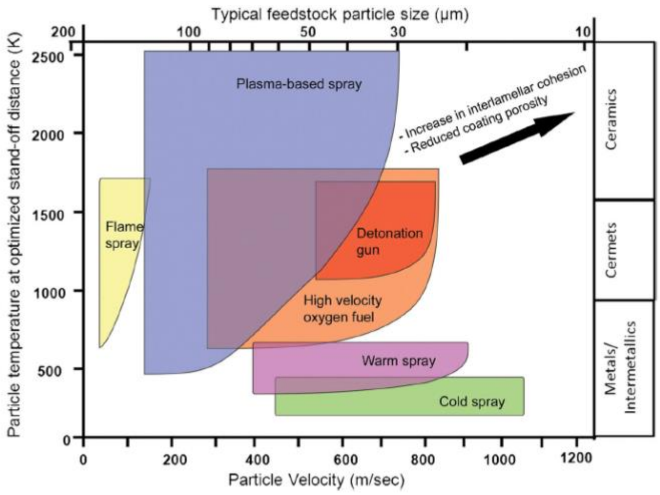

Figure 1. Spectrum of Thermal Spray Processes by Ahmed et al. (2021) licensed under Creative Commons Attribution 4.0

This broad material spectrum also leads to turbine engine part diversity and today plasma sprayed coatings are used for liners, seals, hubs, supports, guide vanes, stators and so on. Fig. 2 shows plasma spray coated parts on aircraft turbine engine section (Fauchais and Vardelle, 2012).

Still, plasma sprayed coatings might have some drawbacks. One of the main drawbacks of plasma spray coatings is the coating thickness. Of course, depending on the part/substrate and coating material, the thickness of plasma spray coatings is indicated to be between 50μm to 100μm, whereas the thickness of CVD and PVD coatings can be as low as 3μm (Fauchais and Vardelle, 2012 and Vardelle et al., 2015). Another common drawback of these plasma spray coatings is their surface quality. Their surface quality can only be as low as Ra 0.51μm, while the surface quality of CVD and PVD coatings can be as low as 0.03μm.

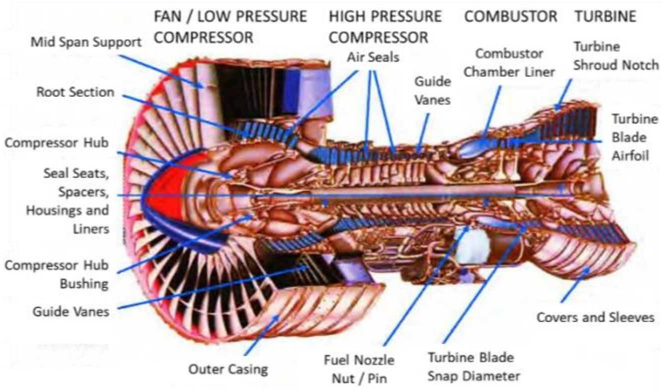

Figure 2. Plasma-sprayed coatings on aircraft turbine engine parts, reproduce from Fauchais and Vardelle (2012) licensed under Creative Commons Attribution 4.0

A widely employed practice to reduce the disadvantages of these plasma spray coatings is to grind them posterior to coating process. However, there are many aspects to consider for grinding of plasma spray coated aircraft engine parts including part/substrate material, coating material, coating method, coating characterization, grinding tool, grinding process parameters, and post grinding inspection and evaluation. Furthermore, some of these elements are hard to locate in scientific literature, while others are present but randomly distributed among numerous papers or proceedings. In this regard, this review paper aims to fill this gap in the current literature and gather all the relevant or important information on grinding of thermal spray coated aircraft engine parts.

2. Thermal Spray Coating of Aircraft Engine Parts

Plasma spray coatings can be applied on to various aircraft engine parts including spacers, liners, seals, vanes, casings, covers and sleeves. Depending on the engine module that each part exists and in accordance with the part's function and service conditions, the substrate material might be various alloys such as bearing steels, stainless steels, nickel-based superalloys, titanium alloys. These effects the selection of coating materials, coating parameters and the necessary coating characterization techniques (Rhys-Jones, 1990, Molak et al., 2017). For this reason, the following sub-sections are focused on the coating materials, coating methods and characterization techniques before jumping on the grinding of these coatings.

2.1. Substrate and coating materials in grinding research

Previous researchers and engineers have practiced various materials as substrate and reported their findings accordingly. In this context, practiced substrate and ground materials exhibit a diverse metallic alloy range including 1040 and 1050 steels (Gullu, 1995), Ti6Al4V titanium alloys (Tao et al., 2017), and Inconel 718 nickel-based superalloys (Yastikci, 2016). Still, before progressing to the grinding of coated materials, scientific and research know-how expanded by just grinding the ceramic materials themselves and it presented a considerable contribution to the further research on grinding of ceramic coatings and also other hard coatings. Pioneer researchers Mayer et al. (1995) focused on hot pressed silicon nitrides (HPSN) in their study and by reporting the surface characteristics of those being influenced by grinding parameters and also grinding wheel grit sizes. Other researchers Hwang and Malkin (1999) have investigated hot pressed silicon nitrides (HPSN) too, together with reaction bonded silicon nitride (RBSN), silicon carbides (SiC) and aluminum oxides ($A1_20_3$). In addition to these Sun et al. (2015) published a grinding force model for brittle and hard ceramic materials such as $A1_20_3$ and SiC. Although it is not the focus of this paper, research is still ongoing for the grinding of hard ceramics and for the current state-of-the-art, researchers focus on minimum quantity lubrication (MQL) techniques (Choudhary et al., 2018). A very good and relatively recent study by Kumar et al. (2018) exploits discrepancies between grinding of ceramic substrates and ceramic coatings and come up with results showing that ceramic was free from residual stress whereas in ceramic coatings, tensile residual stresses were observed.

The material range is obviously more varied when it comes to coating grades. Grinding experts started to focus on grinding of coatings in the beginning of 2000s and one of the comprehensive articles was published by Liu & Zhang (2002) on the grinding of n-Al_2O_3/13TiO_2 and n-WC/12C coatings. They have revelated important results stating that the difference of material properties of the two coatings used for the study influenced the subsurface cracks. It was also proven that different from bulk samples, large quantities of defects inherited from the thermal spray process play a significant role (Liu & Zhang, 2002). As for the further grinding research on coatings, Deng et. al. (2006), investigated the grinding forces for nanostructured WC/12C coatings and concentrated to predict grinding forces per unit area and per grit. Researchers who have carried coating grinding research to upper levels benchmarked a diverse range of coating materials (Kar et al., 2016). Kar et al. (2016) benchmarked an extensive grade of coating materials including Al_2O_3, Al_2O_3–13 wt% TiO_2, Cr_2O_3, TiO_2, YSZ and evaluated residual stresses for critical depths. They have demonstrated that surface topography and microstructures had the signs of plowing and rubbing only. In addition, their study revealed residual stresses that were linked to the ceramic coating's retention of the material's characteristics rather than heat gradients.

To summarize this section, it can be concluded that previous grinding research focused on many substrate and coating materials including steels, titanium, nickels as well as Al_2O_3, Cr_2O_3, TiO_2, WC/12C and YSZ coatings. On the other hand, while some of the published research focuses on a single substrate-material combination, other ones focus on benchmarking of different materials with a single set of process parameters.

2.2. Thermal spray coating

As discussed in the previous section, some of the published papers from the current state-of-the-art clearly related some results to the coating materials and/or coating conditions. In this respect, it would be beneficial to present a brief overview of different coating technologies here in this review article.

The main purpose of thermal spray coating techniques is to enhance the surface quality of solid materials by applying heated or melted materials to the surface under study. This co-called surface improvement can offer the product resistance to wear, abrasion, cavitation, corrosion, erosion, heat and wear (Łatka et al., 2020). Different type of energy sources can be used to melt the materials such as electricity for plasma and arc spraying or chemical energy for high velocity oxy-fuel (HVOF) or high velocity air fuel (HVAF). A second aspect to be included in the classification of this method can be the feedstock used for melting or heating. Even though there are several varieties of the feedstock, two common forms are powder and wire. Fig. 3 shows a detailed classification of thermal spray coating methods (Tejero-Martin et al., 2019).

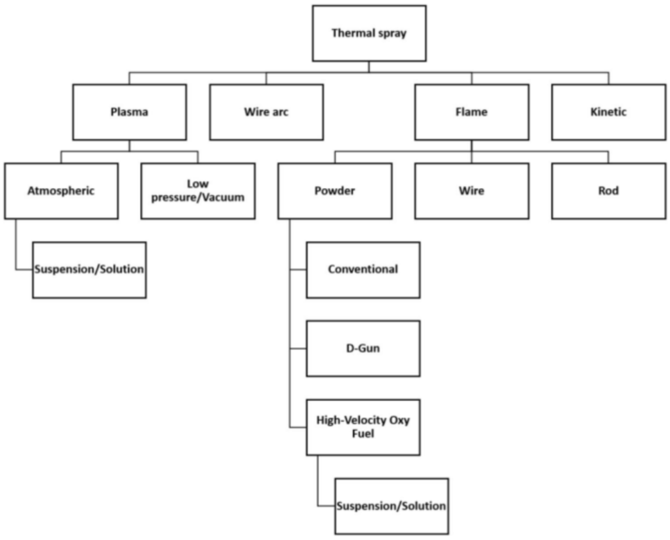

Figure 3. Classification of Thermal Spray Methods by Tejero-Martin et al. (2019) licensed under Creative Commons Attribution 4.0

Despite the fact that thermal spray methods have many different classes, a typical thermal spraying system may include major components like power supply, material feeder, spraying torch or gun, automated or manual manipulator and a control system. While the material feeder provides and moves the raw material in powder or wire form, the torch or the gun melts it through various energy sources such as arc, HVOF or plasma. Following to melting of material and spraying it onto a certain location of the part surface, the torch or gun is moved by manipulator and the manipulator is managed by control system for automated thermal spray methods. Fig. 4 shows schematic of a sample thermal spraying method which uses plasma as energy source (Łatka et al., 2020).

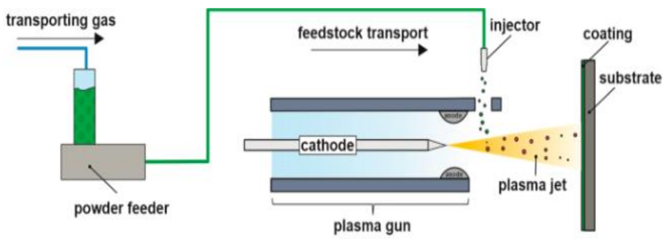

Figure 4. Schematic for Thermal Spray Method Using Plasma by Łatka et al. (2020) licensed under Creative Commons Attribution 4.0

As can be appreciated through explanations and schematic in Fig 4., this method can deposit coating materials up to several millimeter thickness and since the melted materials are sprayed in the form of droplets, the microstructural characteristic of the coating might consist of splats, pores and voids. Moreover, these splats can take lamella form when other splats stack on the previous one and deforms it from being a sphere to a flat like melted liquid. Fig. 5 shows cross-sectional morphology of a thermal spray coated specimen including lamella and pore formations (Si et al., 2020).

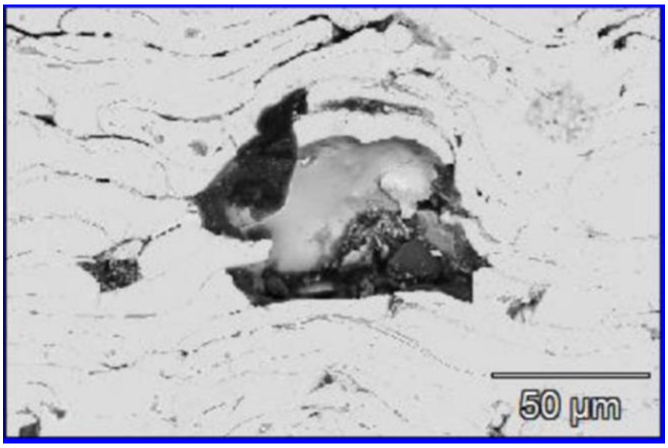

Figure 5. Cross-sectional Morphology of A Thermal Spray Coated Specimen by Si et al. (2020) licensed under Creative Commons Attribution 4.0

The phenomena seen during and after thermal spray processes may alter surface roughness and dimensional accuracy of the part on top of the microstructural condition. In this regard and depending on several issues such as substrate preparation and existence of a bond coat, the surface roughness of the thermal sprayed parts can take values between Sa 34.9µm – Sa 119µm (Curry et al., 2015). Presumably, these surface roughness values which show the average distance between the peak and valley of the surface topography may have a considerable effect on the part's dimensional accuracy. Remembering the dimensional accuracy and surface quality requirements of aircraft engine parts to change within +/-10µm (Poyraz & Yandi, 2021), the use of thermal spray coated parts in as-deposited condition cannot be expected. And due to the fact that the thermal spray coating microstructures have lamella forms with pores and irregularities, cutting processes cannot be practiced as they might lead to separation. For this reason, abrasive processes are mostly preferred being kind to the coating and grinding, which is the subject of this paper is commonly employed.

3. Grinding of Thermal Spray Coated Parts

Before going into the grinding process details and parameters used for finishing thermal spray coating faces, it would be beneficial to present an overview on the principles of this method to enhance readers' understanding. In this context, next sub-section gives a brief overview of grinding method, process parameters and terms used.

3.1. Overview of grinding and process parameters

Grinding is a subtractive process where a cylindrical grinding wheel rotates and abrades part material with the help of hard abrasive particles in order to form the part shape and comply necessary dimensional accuracy and surface quality. Grinding process is usually performed on manually or computer numerically controlled (CNC) machines. These machines which consist of a machine bed to hold the part and a machine spindle to hold the grinding wheel, might have cartesian or polar configurations depending on the need.

The used grinding wheels, which are regarded as one of the crucial technique inputs, are identified by a number of characteristics and labelled appropriately. The initial attribute emphasized for a grinding wheel is the type of abrasive it includes. Two common abrasive types used for grinding wheels are aluminum oxide and silicon carbide. Grain size comes as the second major attribute and changes between 10-600 going from coarse to finer. Of course, the level of bonding plays a critical role on the wheels' performance and is expressed as soft, medium or hard. The types of these bonds can be vitrified, silicate, resinoid, rubber, shellac or oxychloride. Among these wheel compounds, bond type is selected according to processing strategy. While resin bonds which can be more flexible in the case of epoxy grades might be used for rough grinding applications, vitrified bonds having low-impact resistance are used for relatively lower speed grinding operations (Ault, 1989).

While essential grinding parameters consist of grinding wheel speed, worktable traverse feedrate and depth of cut, special grinding operations might have more parameters like workpiece speed for cylindrical grinding or dressing infeed speed for creep feed grinding (Poyraz et al., 2019). Fig. 6 shows essential grinding parameters together with the workpiece and grinding wheel.

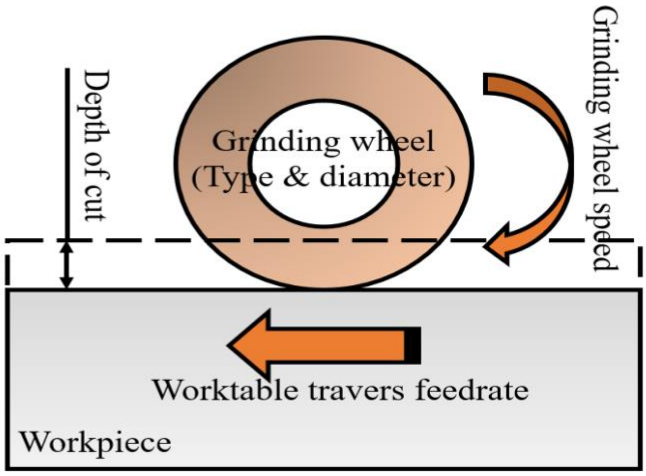

Figure 6. Essential grinding parameters

3.2. Effect of grinding parameters on thermal spray coatings

Liu et al. (2002) have investigated the aforementioned grinding parameters and highlighted the depth of cut as the most influential parameter increasing the grinding forces for nanostructured ceramic coatings on low alloy steel substrates. Furthermore, *n*-WC/12Co coatings were also reported to expose higher grinding forces comparing to other ceramics such as *n*-Al_2O_3/13TiO_2 (Liu et al, 2002). Furthermore, they came up with the conclusion that the increase in feedrate increases the surface roughness (Liu et al., 2002). The same relationship between depth of cut and grinding forces were also observed by Deng et al. (2006). In addition to depth of cut, Deng et al. (2006) also revealed the fact that under same grinding conditions, the decrease in grinding wheel grit size increases the cutting forces. Another adverse effect reported on the grinding depth of cut was local and sharp temperature rises on nano-zirconia ceramics (Li et al., 2011). Even though all pioneer researchers on the subject emphasized the cutting force effects for the depth of cut, Masoumi et al. (2014) conducted multi-factorial parametric studies and found that the forces depend not only on the depth of cut, but also on the depth of cut and feedrate interaction.

Kar et al. (2016) benchmarked superabrasive grinding of various ceramic coatings on low carbon steel. They demonstrated that the nature of the chips did not vary with change in grinding parameters. On the other hand, it was shown that ground surface topographies of Al_2O_3 and TiO_2 coatings have clear dissimilarities (Kar et al., 2016). The same group of researchers continued their evaluations by benchmarking high speed and precision grinding of plasma sprayed oxide ceramic (Kar et al., 2017). Their studies conducted on low carbon steel substrates and various ceramic coatings exhibited that surface residual stresses of samples produced during high-speed grinding are lower than those of samples using precision grinding (Kar et al., 2017).

Ghosh et al. (2018) achieved a reduction of areal surface roughness from Sa 5.04µm to Sa 53nm by applying chemical assisted shape adaptive grinding on high velocity oxy-fuel sprayed WC-Co coatings. On top of this achievement, no fracture or WC disintegration was observed on the surfaces. In a recent study by same researchers, HVOF sprayed and shape adaptive ground WC-Co coatings were exposed to wetting tests by analysing the static contact angle, sliding angle, and contact angle hysteresis (Ghosh et al., 2020). Finished coatings exhibited a lower sliding angle and contact angle hysteresis and the water droplets get completely released from the surface.

Zoei et al. (2016) investigated the effect of depth of cut, cutting speed and feedrate on high velocity oxy-fuel sprayed WC–10Co–4Cr coatings and came up with the results showing that wear resistance and the compressive residual stresses increase after grinding. In their study, increase of the depth of cut and feedrate and the decrease of the cutting speed led to higher residual stresses and improved wear resistance (Zoei et al., 2016). The same coating material's grinding have also been investigated by Pishva et al. (2020). In the scope of their research, the effect of different grinding depth of cuts were evaluated in terms of porosity, surface roughness and microhardness. It was concluded that grinding decreases surface quality while increasing microhardness and porosity (Pishva et al., 2020). Furthermore, an increase in depth of cut led to microcracks and decreased corrosion resistance.

In an interesting study by Boccarusso et al. (2022), Metco 204 NS and Amperit 421.761 commercial coating grades were applied onto Inconel 718 via air plasma spray method. Later on they were repaired by grind g and water jet processes, and their surface qualities were evaluated by different parameters. Rather than commonly used Ra and Rq parameters, better correlation was shown between less commonly used Rdq / Rlo parameters and tensile adhesion strength (Boccarusso et al. 2022).

As already narrated in Section 3.1 and Section 3.2 of this article, grinding methods have many process parameters as inputs and they have considerable influence on the results. Having that in mind the so-called parameters and the related results can differ according to substrate material, coating material and coating application, it would be beneficial to have the previous data in a tidy form. For this reason, all the reviewed data in this article is compiled, tabulated according to materials, and essential grinding parameters as depth of cut, speed, and feed, and presented in Table 1.

Table 1. State-of-the-art summary on coating grinding parameters

Reference	Substrate material	Coating material and method	Depth of cut	Speed	Feedrate
Liu et al. (2002)	Low carbon steel	WC/12Co, Al_2O_3/13TiO_2 - HVOF	2, 5, 15, 30µm	33m/s	1, 4, 8mm/s
Liu et al. (2003)	Low carbon steel	n-Al_2O_3/13TiO_2, n-WC/12Co - HVOF	2, 5, 15µm	33m/s	4 mm/s
Deng et al. (2006)	Not given	n-WC/12Co - HVOF	5-30µm	31.4m/s	20, 30, 50mm/s
Li et al. (2011)	Not given	n-ZrO2 - HVOF	1, 3, 6, 10µm	30m/s	6m/min
Masoumi et al. (2014)	Low carbon steel	WC–Co–Cr - HVOF	4-22µm	20-35m/s	142-550mm/s
Kar et al. (2016)	Low carbon steel	Al_2O_3, TiO_2, Cr_2O_3, YSZ, Ni-Al, NiCrAlY – Plasma spray	1.2-3µm	26m/s	6-12m/min
Zoei et al (2016)	AISI1010	WC-10Co-4Cr - HVOF	4-16µm	25-35m/s	273-550mm/s
Kar et al (2017)	Low carbon steel	Al_2O_3, TiO_2, Cr_2O_3, YSZ, Ni-Al, NiCrAlY-Plasma spray	1.2-3µm	30-150m/s	1-4m/min
Kumar et al (2018)	Low carbon steel	Al_2O_3 NS, Al_2O_3 SFP – Plasma spray	45µm	40-160m/s	1m/min
Ghosh et al (2018)	Low carbon steel	WC-%12Co - HVOF	5µm	25m/s	0.1m/s
Ghosh et al (2020)	Low carbon steel	WC-%12Co - HVOF	5µm	25m/s	0.1m/s
Pishva et al (2020)	Carbon steel	WC–10Co–4Cr - HVOF	4-22µm	35m/s	550mm/s
Boccarusso et al (2022)	Inconel 718	Metco 204NS (ZrO_2-%7Y_2O_3), Amperit 421.761 (NiCoCrAlTaReY)	Not given	Not given	Not given

4. Evaluation of Results

Similar to the situation with the grinding parameters, evaluated outputs, evaluation methods and reporting of results, units, etc. drastically changes according to the researchers or engineers performed the published studies in the current literature. As an example outputs such as grinding force, surface roughness as surface topography were evaluated by many previous researchers including Liu et al (2002), Liu et al (2003), Kar et al. (2006), and Kumar et al. (2018). Still, the units of the practiced evaluations show a diversity. While Liu et al. (2002) reported the cutting forces per unit area in N/mm^2, Kar et al. (2016) reported total cutting forces in N. Parallel differentiation also exist for hardness values. While Gosh et al. (2018) used GPa units to assess microhardness, Pishva et al. (2022) applied HV unit instead. A final distinction can be observed on surface roughness. Even though most of the researchers practiced Ra units to report the surface roughness values, Boccarusso et al (2022) tried varied units including Ra, Rq, Rdq, Rlo. Moreover, they showed better correlation between less commonly used Rdq / Rlo parameters and tensile adhesion strength. That's why this review article presents all the employed methods in Table 2 in order to provide aggregated know-how to prospective researchers of the subject.

Table 2. State-of-the-art summary on evaluation methods

Reference	Evaluation method
Liu et al. (2002)	Grinding force (N/mm^2), grinding pressure (N/grit), surface roughness (Ra), surface topography
Liu et al. (2003)	Grinding force (N), surface topography, subsurface damage depth (µm)
Deng et al. (2006)	Grinding force (N/mm^2)
Li et al. (2011)	Temperature (°C)
Masoumi et al. (2014)	Specific grinding energy (J/mm^3), surface topography
Kar et al. (2016)	Grinding force (N), surface topography, surface roughness (Ra), subsurface microstructure
Zoei et al (2016)	Compressive residual stresses (MPa), wear loss (mg), surface topography
Kar et al (2017)	Grinding force (N), surface topography, surface roughness (Ra), Specific grinding energy (J/mm^3), subsurface microstructure
Kumar et al (2018)	Grinding force (N), surface topography, surface roughness (Ra), Specific grinding energy (J/mm^3), subsurface microstructure
Ghosh et al (2018)	Microhardness, nanohardness (GPa), surface roughness (Ra), surface topography
Ghosh et al (2020)	Microhardness, nanohardness (GPa), surface roughness (Ra), surface topography, static wetting, dynamic wetting
Pishva et al (2020)	Microhardness (HV), surface roughness (Ra), surface topography, electrochemical behaviour
Boccarusso et al (2022)	Surface roughness (Ra, Rq, Rdq, Rlo), surface topography, tensile adhesion strength (MPa)

5. Conclusions and Future Prospects

This article presents a review on grinding of thermal spray coatings which is exquisitely used of aircraft engine parts. In this respect, spray coatings, which offer the widest substrate material range are explained in detail regarding their materials, application methods and characterizations. Later on, grinding of these is narrated considering tools and process parameters such as cutting speed, feed, and depth of cut. Finally, the influence of grinding conditions on dimensions, surface quality, hardness, residual stresses, and microstructure is discussed.

Although spray coatings are applied on to various aircraft engine parts including spacers, liners, seals, vanes, casings, covers and sleeves of stainless steel, titanium and nickel alloys (Fauchais and Vardelle, 2012), most of the current literature is focused on low alloy and carbon steels as substrate materials. This gap can be considered and filled by prospective researchers on the subject.

On the contrary, coating materials in the published literature show a diverse range including Al_2O_3, WC-%12Co, WC–10Co–4Cr, NiCrAlY and their nano grades. Coating methods also cover high velocity oxy-fuel (HVOF), high velocity air fuel (HVAF) and plasma spray.

Even though most of the research reports surface roughness and/or quality values, dimensional accuracy of the ground coatings has been barely mentioned. Considering the accuracy demand on aircraft engine parts to be below 10µm tolerance (Poyraz and Yandi, 2021), this research question should be addressed by the future researchers or engineers.

Hardness can be focused on as a last highlight on the subject. Despite the fact that a considerable increase on the hardness was reported by one of the previous researchers on the ground samples and was related to depth of cut process parameter, number of current publications reporting this result is less. In the future, this gap can also be filled by other researchers.

Ethical approval

Not applicable.

Conflicts of Interest

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

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The Importance of Brand Equity and Branding in Terms of Product / Service Preference and Internationalization: An Analysis of Civil Air Transportation with Marketing Strategies

Ahmet Aydın[1*]

[1*] İstanbul Nişantaşı University, Business Administration (Turkish) 34398, Sarıyer, İstanbul, Türkiye. (ahmet.aydin@nisantasi.edu.tr)

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Corresponding Author: *Ahmet Aydın*

REVIEW ARTICLE

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Abstract

In this study, by emphasizing the importance of brand equity and branding in terms of internationalization, the effects of quality brand perception and a strong brand positioning on product/service preference in civil airline transportation have been tried to be explained in line with service marketing strategies and through descriptive content analysis method. The data collected from the literature about civil air transport companies with the traditional compilation method have evaluated in detail through descriptive content analysis. According to the results obtained, it has been understood that the customer-consumer satisfaction factors to be obtained from the purchased products/services and their differences from competing businesses should be explained to customers/consumers in detail, and suggestions have been made to civil airline companies in order to be more preferred and gain customer loyalty.

1. Introduction

In product/service presentation, attracting the attention and interest of consumers/customers, arousing their purchasing desire, and enabling them to take action for purchasing behavior are the primary goals of businesses. As Fettahlıoğlu (2014: 28) states, "store atmosphere factors both inside and outside the store are seen as an important marketing tool in terms of attracting consumers' attention, influencing their purchasing behavior and creating customer loyalty". In case the products and services are purchased by the individuals who make up the target audience, more information can be obtained about the product/service offered to the market and one-to-one experience can be gained regarding the benefits to be obtained. The product/service experience and appreciation of the customer/consumer audience can have a positive impact on all the products/services offered by the business and turn into brand loyalty over time. In particular, the feeling of satisfaction generated by the services in the target audience can further increase the loyalty to the business that offers the service product and therefore to the brand.

The separation of businesses from their competitors in global competition conditions and their involvement in the minds and emotions of consumers can be ensured by strong branding (Özbaysal and Onay, 2018: 181). Koçak (2018: 110) drew attention to the following factors in a study on positioning in terms of its effect on the re-preference of the airline company:

- Price referring to cheapness,
- Fast, effective, smooth and accessible website services,
- Free, varied and delicious on-board catering,
- About safety, referring to a smooth and safe journey,
- Concentrating on baggage services that will ensure timely, fast and complete transportation of baggage to passengers, advertising and promotion in these areas and positioning their brands.

While ensuring passenger satisfaction with complete services, services such as politely directing passengers to their seats by flight attendants before the flight service, offering quality refreshments, smooth completion of passenger and baggage handling service after the flight, etc. can create a positive brand value perception among passengers and the same airline firm can be preferred by passengers again. Businesses that have a positive place in the eyes of the customer/consumer and come to the fore with quality, expand their product range by giving more importance to branding, and giving priority to internationalization to be able to compete on a global scale. Reproduction of the destination countries, offering charter and scheduled flight options, adding the latest design aircraft to the fleet to create a safe and comfortable flight perception, offering comfortable and economical ticket options, high variety and quality of food and beverages offered during the flight, frequent flights to distant countries providing a price discount on subsequent trips through the points awarded to passengers, etc. practices, while creating a quality brand perception in the customer/consumer audience, may contribute to the internationalization of the civil aviation business through branding.

As a result of the literature review; it has been observed that a point of view in line with the service marketing strategy regarding the importance of brand equity and branding in terms of product/service preference and internationalization has not been developed and analysis has not been carried out for air transport businesses. In this study, which has been produced following the aim of contributing to the acquisition of different perspectives in academic studies and from the perspective of service marketing strategies, it has been understood that the products/services offered by the civil airline transport businesses should be increased by considering the principle of suitability for individuals from different countries, adding new features to the products and diversifying them, and it has been seen that the brand equity and branding concepts should be focused on to increase the quality perception in the target audience. In addition, it has been scrutinized that growth strategies, new investments, branding, and internationalization should be given priority to ensure and protect the brand equity and thus, it has been concluded that the customer/consumer satisfaction and loyalty obtained will be the most important gain.

In this study, which has been produced following the aim of contributing to the acquisition of different perspectives in academic studies and from the perspective of service marketing strategies, it has been understood that the products/services offered by the civil airline transport businesses should be increased by considering the principle of suitability for individuals from different countries, adding new features to the products and diversifying them, and it has been seen that the brand equity and branding concepts should be focused on to increase the quality perception in the target audience. Accordingly, the study begins with the conceptual framework, supported by citations, and includes sections on methodology, which includes information on traditional review method and descriptive content analysis, discussion, which analyzes the situation in Turkey by mentioning the place and importance of branding and internationalization in civil airline operations, and conclusions and recommendations.

2. Conceptual Framework

In this part of the study, product and service concepts, the importance of brand, brand value and branding for product/service, the impact and importance of brand and branding on customer preferences in civil air transport, and the place of efforts for product/service and brand preference in civil air transport are discussed.

2.1. The Concept of Product and Service

In parallel with the changing and developing demands of consumers/customers, businesses are engaged in the design, production, distribution, pricing, and promotion activities and strive to offer products/services that will be preferred. Products/services are offered to become a brand preferred by the customer/consumer and to create satisfaction, “objects offered to requesters to meet a need or request” (Anbarci et al., 2012: 180) or it can be defined as the sum of equities. What makes the product/service important is that it has features that will attract the attention of consumers/customers, arouse the desire to buy, and create satisfaction. While this requires a lot of effort and effective strategies to be achieved by businesses, it has become a necessity to design/present new and high-quality products/services and branding that brings effective, results to achieve competitive success and to be a preferred brand in the market. However, Kahn et al., as (2002: 185) mentioned, it is not enough for the quality to meet the customer/consumer expectations or just to comply with the specifications, the product or service must exceed the customer/consumer expectations. To exceed customer/consumer expectations, products/services must have useful information and this information may add equity to the lives of their customers/consumers. Exceeding the expectations of customers/consumers and providing information that adds value to their lives should be supported by advertising and image efforts. As Otalık and Koçak (2015: 89) point out, especially commercial airlines need to use some information about their destinations in their advertisements to create a global image with positive messages.

In today's competitive conditions, information assets constitute an important place in the product/service content. The correct planning and implementation of knowledge-intensive activities allow businesses to work more efficiently, to ensure quality in output and expansion in the scope of products/services offered. Thus, in each of the stages from the birth of the product/service idea to its commercialization, the new product development process can have increasing content and features with the contributions of employees from all levels of external supporters/organizations (Kulaklı, 2005: 99). Manufacturers are increasingly engaged in services and as a result offer different services along with products. However, although the variety of services seems promising in theory, in strategy practice, combining services with product offerings does not always lead to the expected performance results (Kuijken et al., 2017: 33). Therefore, the services and qualifications offered concerning the concrete products offered to the market are highly important. White goods, electronic tools, cleaning supplies and tools, clothes, foods, etc., which have emerged with the contributions of different segments at different levels and have been presented to the market presentation, delivery, installation, warranty, maintenance, etc. of the product as well as concrete products services that cover benefits are also of great importance for businesses and consumers/customers. In addition to such benefits offered in addition to concrete products, there are also some services offered directly to customers/consumers, which can be a product in itself and meet the different demands of the target audience. Transportation, communication, accommodation, education, diagnosis/treatment, personal care, cable TV broadcasting, internet connection, massage, etc. benefits directly to the services offered can be given as an example. Customer/consumer satisfaction may be more important in such services and businesses may engage in more marketing efforts to become a brand preferred by customers/consumers.

2.2. The Importance of Brand, Brand Equity, and Branding in Product/Service Preference

“When the consumption process that starts from the birth of individuals is examined, it can be seen that the needs in infancy, childhood, youth, and old age are different. Consumer behavior is affected by demographic, economic, social, psychological and situational factors” (Armağan and Taşdelen, 2012: 86) and these factors shape the product/service preference. While purchasing products and services, individuals may purchase a well-known, expensive brand due to the demographic, economic, social, psychological, and situational factors they are in, or on the contrary, they may prefer a more suitable brand in terms of price but lower in terms of quality and benefit. Due to the different factors that arise in product/service preference, consumers/customers may have to keep their information about brands up to date. Because every brand may not keep its quality level and functionality up to date or not be able to adapt to technological developments and requirements. For this reason, while brands have to provide many different requirements to compete better, customers/consumers have to make their preferences by comparing with other brands that offer similar products/services for the same needs and exist in the market.

Brand beyond being a name, it is described as a business entity that adds identity and personality to the product, is shaped by the perceptions of consumers/customers, and guides the target audience in product/service preferences. A brand is a tool that creates or shapes the relationship between a business and consumers/customers (Can, 2007: 225). A brand is the most important element that allows it to be easily recognized by consumers/customers in the market, to differentiate or stand out from other brands with its name, shape, packaging, logo, color, and appearance. The quality of the services offered in civil airline transportation, which is one of the important sectors where the brand name, logo, and color stand out, and the level of satisfaction created by the target audience are the most important factors in the re-preference of the business. Options to purchase tickets through an agency or online, check-in procedures completed without any problems (boarding statement), fast final checks before boarding, on-time/non-delayed departure and landing service, spacing between seats complying with standards, food/drinks served during the flight it is one of the reliable brands, the food and beverage service is on time, the hostesses are interested and friendly, etc. services will be decisive in the re-preference of the civilian airline transport business, as well as providing a quality brand perception and brand equity in consumers/customers.

If the service performance offered is above expectations, customers/consumers will give positive equity to the product/service. Positive equity, it will cause arousing a sense of pleasure in the audience, a state of emotional attachment to the brand will appear, the choice made will be rational, and thus high customer loyalty will appear (Ramadonna et al., 2019: 105). To gain high customer loyalty and to be a preferred civil airline transportation business, it is necessary to design the products/services offered following the consumer/customer group working in different sectors and to explain the difference or more from the products/services of other airline transportation businesses, with the right marketing strategies. To create the satisfaction that ensures customer loyalty, there is a need to promote at the right time, in the right place, and with the right methods to work with agencies that provide widespread and high-quality service to carry out sales with reasonable price strategies, and above all, a strong brand positioning is needed. Thus, while brand equity is formed in the target audience and branding is in question, it is possible to become competitive in the international dimension.

Today, individuals can easily access many products/services with the effect of technology and communication facilities/conveniences, collect information about manufacturing businesses, reach comments on the satisfaction or dissatisfaction of customers/consumers who have purchased products/services before, and determine their preferences accordingly. For example, a consumer who is considering buying a mobile phone but is undecided between two brands can read the comments of other customers/consumers about the products on different web pages or social media networks and decide which brand to prefer accordingly. Being aware of this situation, mobile phone brands make more efforts to design high-quality, long-lasting, and stylishly designed models that will meet the different communication needs of consumers. As Durmaz and Dağ (2018: 490) stated, although many brand-related features are taken into account, consumers' inclination towards other features makes the brand's originality more prominent and is effective in marketing. At this stage, the concept of branding comes to the fore and a challenging competitive environment is formed.

It is very difficult to get rid of market competition because competitors spend time and money getting their products/services to market. Especially for commercial aircraft, competitors already have established products at competitive prices, full financing opportunities, and reliable product support (Florence et al., 2020: 17). This is a compelling factor for businesses trying to brand. The branding process is related to the fact that anonymous products/services have a name, logo, and symbol. The naming of the product/service with a certain name or symbol brings the brand to the forefront in a sustainable competitive environment, but it is not enough for a product/ service to be branded in an intensely competitive environment (Aktepe and Şahbaz, 2010: 70). Successful product branding strategies focus on the image that organizations create in their customers' minds of their products. This image-building process largely focuses on communication with customers and their personal experiences with the organization's products and services. This traditional perspective in the branding process creates a basis for conceptualizing the branding of employees who offer products and services, but employee branding is also based on the understanding and practice of in-house marketing (Miles and Mangold, 2008: 67). While the qualifications and performances of the employees, who can be seen as business assets and take part in the provision of services, can lead to their branding as a business and brand equity, they can affect the purchasing behavior of individuals who benefit from the services positively or negatively.

2.3. Brand, Branding, and Customer Preference in Civil Air Transportation

Branding does not only affect the consumption patterns and shopping tendencies of the individuals that make up society but also determines the product development and sales/marketing strategies of the businesses (Hacıoğlu Deniz, 2011: 243). Considering civil airline transportation, expanding the services offered in terms of content/scope and being able to be offered in different formats/channels, not compromising on quality, easy access to services, and most importantly if they are compared to other businesses customers, when they prefer the civil airline transportation the fact that they feel more privileged and happy, the business can emerge as the determining factors in brand preference.

In recent years, the brand has become a concept that has become important in marketing components and that marketing science has emphasized. For this reason, businesses use the brand to make their customers feel the power of their products or services (Süzen, 2022: 842). The situation in civil airline transportation also requires exactly this. Namely security, speed, comfort, treats, ground transportation and goods transportation, smiling face, etc of services to individuals the provision in full and at the expected level are the most important and powerful features of the civil airline transportation business that make it stand out as a brand. Apart from providing services by highlighting its strong features, some elements can be mentioned to differentiate from competitors and to make the brand stand out. The seats should be in a way that allows the passengers to travel comfortably, the food/drinks offered are varied in accordance with their dietary habits and diet food/beverage service is available, and communication devices/channels and digital screens are open throughout the journey, there are no or least delayed flights, and there are safety and security issues. related measures etc opportunities can be listed as brand elements that affect the preference and satisfaction of individuals of all ages. In today's conditions, it can be said that the concept of health is another factor added to the brand elements. However, during the Covid-19 pandemic, the measures taken for the health of individuals and additional measures have had a positive impact on the brand perception of the target audience, while forcing civilian airline transportation businesses in terms of time and cost. However, during the Covid-19 epidemic period, the measures taken for the health of individuals and additional measures had a positive effect on the brand perception of the target audience, while challenging the civil airline transportation businesses in terms of time and cost.

According to the 2019 annual report of China Airlines, there was an increase of 0.10% in the number of passengers carried, 0.35% in passenger capacity, and 1.88% in passenger traffic compared to the previous year revenue was NT$96,177 billion (New Taiwan Dollar), up 2.05% year over year. This rate constituted 65.71% of the total operating income. In 2019 by businesses service quality, corporate governance, sustainable results, aviation security, international certifications, green energy, carbon reduction and an excellent performance have been showcased in many aspects of marketing, including corporate (https://news.china-airlines.com). However, during the Covid-19 pandemic, the 60% decrease in passenger traffic experienced worldwide has put all stakeholders in the civil aviation sector in a difficult situation in terms of financial sustainability. The fact that international airline travel increases the transmission rate of the epidemic has caused countries to close and restrict airline borders, and the concern of illness has caused passengers to worry about their trust and loyalty to airlines (Semercioğlu and Abay, 2021: 1). Despite all the negativities, the mask, social distance, hygiene and contact measures taken and applied by the civil airline transportation businesses to protect the health of the passengers during the Covid-19 epidemic that lasted for 2.5 years, and the additional products and services offered free of charge, eliminate the concerns, and the brand equity, it can be stated that it provides protection and affects customer/consumer preference positively.

In previous years and today, it can be stated that the priorities that positively affect the preferences of individuals/passengers traveling by plane are safety, speed, comfort, and price. However, the fact that civil aviation businesses offer some innovations and differences other than the advantages and conveniences provided to passengers may ensure positive results in customer/consumer preferences. As Sanyal and Hisam (2016: 355) mentioned today, as customers/consumers have a wide range of options to choose the airline product/service that suits their needs, civil airlines are constantly working on in-flight product/service development and innovation (innovation) to differentiate themselves from their competitors. These efforts can positively affect passenger/customer service and satisfaction and can be decisive in the preference and success of the entire organization and therefore the brand.

2.4. The Place of Efforts Aimed for Product/Service and Brand Preference in Civil Airline Transportation

Marketing complex effective and commercially competitive products/services of design, production, and promotion of a system of measures for the creation, in the minds of the target audience and potential customers from other competing products/services and is based on the determination of how the fixation differ from (Ryapukhin and Kalugina, 2021: 37). In brand preference product/service offering, effective market positioning of the brand, product/service offering of the brand as a model or as a whole, etc. factors are important. As Canöz (2017: 194) stated, the services offered by civil airlines or the understanding of service are shaped according to the model applied. Full service and service quality understanding prevails in businesses operating with different types and sizes of aircraft in a wide geographical area, requiring different classes of service and connecting/long flights, large fleet structure, complex service planning and process, and implementing the traditional airline transportation model. An average understanding of quality applies to businesses that reduce their costs by abandoning some of the services offered, offering products/services at cheap prices, and preferring a low-cost airline transportation model.

Despite all the efforts, as in other sectors, there may be some disruptions and problems in civil airline operations. Delays in flight service, disruptions in land transportation/port service, problems in online check-in, ticket sales at different prices instead of the price promised in advertisements, airport-related delays, poor quality or stale food and drink served on the plane, distances between seats less than previously stated, passengers being dissatisfied with the services provided by the stewardesses, etc to compensate for the dissatisfaction and complaints that may arise from the problems, it may be necessary for the civil airlines to solve the problems and try to entice the passengers with additional products/services and to offer discounts and guarantees on subsequent product/service purchases.

Passenger planes are produced in line with the needs and demands of civil airlines, and the impact of the designed products and brands on many risks that may arise is quite high. In response to this great risk, the responsibility of civil airline transportation businesses is that the efforts to be carried out for product/service and brand preference are focused on success and results. Thus, the risk rate taken by a certain industrial segment will be reduced. Among the issues that civil airline transportation businesses should pay attention to regarding their efforts towards product/service and brand preference national and international media, digital media, web, search engines and social media channels also occupy an important place. Promotion and presentation of new products/services in the media or digital environments, price reductions, discount coupons, sharing accurate information against false/slanderous and incomplete information, and informing the target audience are among the activities required for competition. Developing similar or superior strategies by following the prominent strategies of rival brands and businesses, reaching more individuals through new and different social media channels, etc activities will lead to positive results in the preference of the brand and the prolongation business' life span. These gains are directly related to the digital marketing strategies that are followed and implemented. As Işılar (2021: 43) mentioned, airline businesses are trying to adapt to digital marketing strategies to adapt to the strengthening and developing digital markets. To survive in the growing civil aviation industry, businesses trying to develop various digital campaigns and marketing tools must have the most appropriate digital marketing strategy.

3. Methodology

Traditional reviews are studies that synthesize findings, results, and evaluations by examining two or more studies published on a specific subject, and compiling information obtained from different sources and in different ways without following a specific method (Yılmaz, 2021: 1460). Accordingly the review article's, it can be stated that it has created by summarizing the results obtained from previous studies or accumulations. A review article is important in terms of revealing the general trend on the subject studied, reaching generalizations, and covering primary sources and research on the subject, but it is not generally accepted as a research article.

Descriptive content analysis, the determination of the literature on the researched subject based on certain criteria, regardless of whether it is quantitative, qualitative or mixed, is based on the process of determining and interpreting descriptive data related to the literature. The main purpose of descriptive content analysis is based on descriptive data, the aim is to reveal how the subject to be examined is handled by the researchers and how it tends over time, by making use of various topics created before or after the compilation (Bellibaş, 2018: 1).

This study is a traditional review article produced by using the literature on brand, brand equity, branding, and internationalization. In the study, previous studies on the concepts of branding and brand equity have been examined in detail and the data obtained from the related studies have been synthesized. In the study, the relationship between the concepts of brand, brand equity, branding, and internationalization has been tried to be explained with the approach of stages by showing a descriptive approach based on traditional compilation. In the study, the importance of brand equity and branding' for product/service preference and internationalization have been tried to be explained in the form of a descriptive approach and stages based on traditional compilation. In addition, the customer and brand preference, customer satisfaction and customer loyalty gains that can be achieved as a result of branding and internationalization efforts have been evaluated with an explanatory approach.

4. Discussion

In this part of the study; the effect of branding on internationalization and its use in civil aviation, branding, brand equity and internationalization in terms of civil airline transport in Turkey and marketing of civil aviation products and services in Turkey are evaluated from a controversial perspective.

4.1. The Effect of Branding on Internationalization and Its Use in Civil Aviation

Branding has tremendous potential for international marketing. Branding is considered to be an important element of international marketing strategy and a driving force in internationalization. Specifically, two mechanisms have been added to branding beyond what the current global brand literature considers. In the first one, importance is given to managerial cognition related to branding, which is coded as brand orientation. In the second one, the repositioning of international brands takes place in terms of contributing to performance (Wong and Merrilees, 2007: 384-385). Civil airline businesses that would like to be competitive in international markets should prioritize branding, which has a significant impact on internationalization and develop marketing strategies that appeal to citizens of different countries. While positioning, the design and use of a logo with shapes, symbols, colors, and words that distinguish the brand from other brands and arouse interest can contribute to the formation of an international business perception in the target audience. Briefly, while determining the brand name, logo, and symbol is the first step toward branding, it is also the first step toward internationalization. The figure below may be more descriptive in relation to branding, brand equity, internationalization, and customer satisfaction, which are intertwined and are assumed to be customer loyalty at the top.

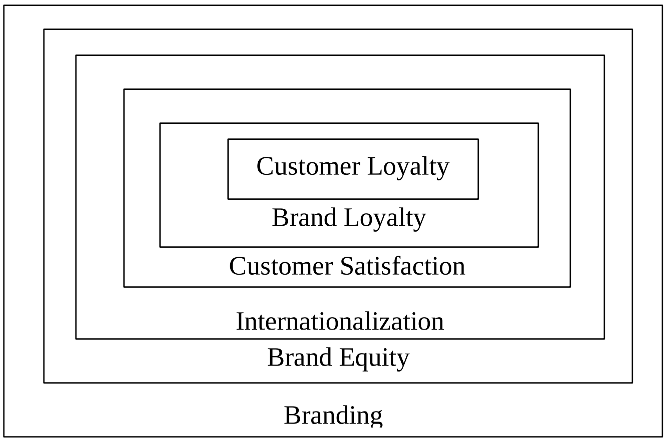

Figure 1. Stages from Branding to Customer Loyalty
Source: Produced by the author

As can be seen from Figure1, it can be stated that the purpose of branding and brand equity is to gain customer satisfaction and loyalty, and internationalization is an important stage that serves this purpose and contributes to the competitiveness and growth of the products/services and thus the brand/business. Carried out at these stages, determining the brand logo and symbols that may occupy a place in the minds, determining a memorable brand name, participating in international fairs and promotions, resorting to visually impressive advertisements in the media, digital tools, and social media, etc. with the activities, positive results such as target audiences in different countries buying products/services, associating themselves with the brand and recommending it to their surroundings are tried to be achieved.

Brands provide dissemination in different countries and popular cultures (Cayla and Arnould, 2008: 86). Consumers may not see any difference between products and brands in terms of physical elements and other criteria. Each marketer has adopted a different approach to attracting consumers, and therefore branding plays a vital role in gaining a foothold in the minds of consumers. Branding is a powerful tool in the hands of management that differentiates a product from the products of its competitors (Akram et al., 2014: 49). For example, THY's logo, designed inspired by the wild goose, emphasizes the ability of the wild goose to fly in the sky for a very long time and from a very high altitude. It can be said that THY gives a positioning message to its customers and consumers in the form of 'we can fly high for a long time and we can safely transport you, our equitied passengers, to the place you want to go' with the logo symbolizing the wild goose. Behind the success of brands that arouse cognitive and emotional interest and form loyalty, in addition to the presence of impressive logos and symbols, there is the creation of high-quality and strong brand perception and correct positioning. To achieve a strong brand positioning and internationalization, target-oriented and correct management activities should be carried out by civil aviation business managers who absorb the importance of branding, interactive communication should be established with employees and branding strategies should be transferred correctly. In addition, the use of colors and logos will take place and attract attention to the brand name and symbols, transferring the meanings of trust and quality to the brand logo/symbols in promotions to the target audience in promotions in national/international media, digital media, and open spaces, emphasizing convenience and comfort will have a positive effect on the internationalization of the brand. Ensuring the price and benefits balance for customers/consumers and ensuring that the music/song played in promotions is in a style that can be liked by citizens of different countries, etc. the elements will also contribute to the branding of brands/organizations and therefore to their internationalization.

Branding that emerges institutionally gives specific messages in line with the targets and reduces information getting and transaction costs of customers/consumers by reducing the information overload problems caused by the branding of product/service ranges (Burt and Sparks, 2002: 196). Harun and the others (2018) as pointed out marketers of civilian airline carriers should strengthen in-flight services, place great emphasis on consumer reviews on social media, and continue to train and upskill their employees to develop their brands. These efforts will help civil airline businesses maintain and maximize their operations in the long term, and contribute to their efforts to serve their customers in the best way through branding efforts.

The reason for the existence of the enterprises is the customers and to use the competitive advantage, they must understand the demands and demands of the customers well and act accordingly (Çağlar and Türk, 2023: 142). Thus, the right methods and practices can be determined to ensure customer satisfaction. Customer satisfaction and brand loyalty will be facilitated as customers/consumers who gain certain advantages in terms of information acquisition and transaction costs can easily access content related to products/services. It can be expected that the brand/business with which the loyalty is formed will be preferred in the next product/service purchases in the masses where the brand loyalty is formed. Individuals from different countries are satisfied with the products/services offered by a civil aviation business, identify themselves with the brand, and communicate comfortably with the employees, the logo and brand name create positive emotional and cognitive connotations on them, and the formation of brand loyalty, etc. effects it can be possible for product/service preferences to be positive.

4.2. Civil Airline Transportation in Turkey in Terms of Branding, Brand Equity, and Internationalization

A brand is a name, symbol, shape or a combination of these that determines the identity of manufacturers' or sellers' products and distinguishes them from competitors. The brand may have different goals for businesses and customers/consumers, but the common goal is to make effective use of the brand and branding in a strategic sense (Alan and Yeloğlu, 2013: 14). Nowadays, a brand has ceased to be a logo, name, identity or sign, and has become a collection of traces in the memory of customers/consumers due to the influence of advertising, those who use the product/service, and social activities (Gemci et al., 2009: 105). Creating a memorable brand name for a product/ service requires, first of all, providing a competitive advantage. Therefore, to have a positive place in people's minds, businesses are trying to make their brands a power that can influence the masses and gain their loyalty (Bilsel Engin, 2016: 278). It can be stated that the way to gain a positive place in the minds of the masses starts with branding. In this respect branding, customer equity, customer loyalty, and customer satisfaction are important for gaining. Prominent in branding, differentiation and competition with the effect of factors such as brand and design harmony, customer service, using technology at a high level, product/service features being higher and higher quality than competitors, being the first business to enter the market in line with the needs in the market, and marketing strategies being more functional in terms of content and application advantage can be achieved.

Differentiation in a new or existing market, branding, creation of brand equity, and protection of brand equity is as difficult as important tasks to gain competitive advantage. It is necessary to establish and follow certain strategies against the disruptions and problems that may arise. Altunışık (2015: 334) states that strategies such as compensating customers against product/service malfunctions and complaints, solving problems, providing service guarantees, and monitoring consumer behavior after compensation are important for brand equity. It should be known that the efforts to solve the problems that arise should be aimed at protecting brand equity. Marketing efforts are carried out to ensure customer satisfaction and protect brand equity in civil airline transportation businesses, as in service businesses, and these efforts are also a requirement of marketing strategies. It can be said that the primary priority of civil airline transportation businesses in Turkey is to ensure customer satisfaction to create brand equity and brand loyalty. As Topal et al., (2018: 119) stated, the service quality perceived by domestic and international passengers in Turkey from the services provided by domestic airline businesses has reflections on customer satisfaction and repeat purchase behavior of customers.

Ensuring and protecting brand equity in terms of branding and being able to compete in international markets should be among the priority marketing strategies of Pegasus, Anadolu Jet, Atlas Jet, Sun Express, and other civil aviation businesses operating in the civil aviation sector in Turkey. Its logo is in the form of a red wing, the use of turquoise color as the dominant color in inflight designs, the flight attendants wear stylish dresses with traditional colors, commercials with Turkish and foreign famous actors are filmed and broadcast on national/international media channels, etc. it can be stated that the activities are the factors that enable Turkish Airlines to be successful in branding and internationalization. In addition, it can be seen in national media channels and digital networks that Pegasus is making more marketing efforts to compete with Turkish Airlines on a national and international scale and trying to highlight its brand with different services.

Although there have been recent economic crises in Turkey, the civil air transport sector has made good use of the opportunities that have emerged and has provided important developments in the airport terminal and ground handling services, maintenance/repair and renewal services, food/beverage services, design/production, and training. According to Aksoy and Dursun (1067), between 2003 and 2023, the number of passengers in Turkey increased from 30 million to 130 million, while the number of passengers worldwide increased from 3.4 billion to 4.1 billion. In other words, Turkey's passenger growth rate is higher than the world average. In parallel with the rapid developments in the aviation sector in the world, Turkey; With the records broken in the number of aircraft traffic and passengers, investments that set an example to other countries, developments in the domestic and international flight network, and regulations on flight and aviation security, it has become an internationally important position in civil airline transportation. Being a council member of the International Civil Aviation Organization (ICAO), which determines the international aviation rules in 2016, Turkey is a country that contributes to flight safety and aviation safety at an international level. The worldwide success of Turkish Airlines, Turkey's public-autonomous airline business and also its most valuable brand, is the result of the importance given to civil airline transportation (Aksoy and Dursun, 2018: 1060).

4.3. Marketing of Civil Aviation Products and Services in Turkey

The official start of the first aviation movements in Turkey dates back to the Ottoman Period with the start on the military field after the Italian air attack during the Tripoli War in 1911-1912. Civil aviation activities started in 1912 with the construction of a small square and two hangars in Sefaköy, located near Atatürk Airport (Istanbul Dinçer and Taskiran, 2016: 195). Accordingly, it can be said that each new development initiates the emergence of a new sector and the activities of the civil aviation sector in Turkey started in 1912. Although developments such as the Çanakkale War that took place between 1915-1916 and the War of Independence that started in 1919 initiated the development of the aviation sector in terms of the defense industry, the vehicles/equipment needed by the army, equipment, weapons, clothing, food, etc. Since the materials had to be transported by air, the process that started for military purposes later led to the emergence of civil air transport. The global economic recession, which started with the 1929 Economic Depression and continued with the global economic crises in 1948, 1958, 1960, 1980, 1982, 1990, 1994, 2001, and 2008, emerged with the Covid-19 epidemic between 2020-2022, and which broke out in 2022 with the effect of serious events such as the Russia-Ukraine War, positive developments could not be achieved in international civil air transport in Turkey as well as in the world. The global economic recession that started with the 1929 Economic Depression and continued with the global economic crises in 1948, 1958, 1960, 1980, 1982, 1990, 1994, 2001, and 2008, and the global economic recession that emerged with the Covid-19 epidemic that between 2020-2022, and in 2022 Russia-Ukraine with the effect of serious events such as the war, positive developments could not be achieved in international civil air transport in Turkey as well as in the world. Despite the problems on an international scale, things have developed a little differently on a national scale. With the opportunities and investment incentives that emerged in the civil aviation sector, the marketing activities of products/services became easier, and the developments achieved at the national level were carried to the international dimension in the next period.

Marketing orientation is a certain philosophical way of correct understanding of all circles consisting of customers, competitors, marketers and suppliers, with a strategic approach to meet their real and imaginary needs (Calle Piedrahita et al., 2020: 98). Identifying and meeting the needs of individuals and therefore the society in detail with accurate analyzes can positively affect the perception of quality. In ordinary and extraordinary situations, this becomes even more important for service businesses where satisfaction or dissatisfaction based on customers'/consumers' perceptions of quality is a determining factor. It is a natural result that civil air transport businesses are affected by the difficulties and extraordinary situations affecting the service sector. As in the world, the civil airline transportation sector in Turkey has gone through a very difficult period during the coronavirus epidemic. However, as in many major airline businesses serving globally, a rapid adaptation to the epidemic process has been achieved in Turkish businesses, most of the civilian passenger transportation has been stopped for a certain period of time, and all measures related to the health and safety of their passengers have been taken and implemented.

As the rapidly spreading Covid-19 epidemic could not be brought under control, and the country's administrations imposed travel restrictions on other countries and domestic routes, the aviation industry came to a standstill, and it was observed that global measures were similarly implemented for the Turkish civil aviation industry (Macit and Macit, 2020: 110). With the circular published on March 27, 2020, only Turkish Air Lines (THY) allowed domestic flights to 14 destinations, and all domestic and international flights of other airlines were stopped, but cargo flights, government agency flights, emergency health, and technical flights were excluded from the circular. While the uncertainty about the epidemic continued, air cargo transportation activities continued, especially for basic products, THY has played a vital role in the rapid delivery of drugs, medical equipment and materials, organs, or other important items (Şen and Bütün, 2021: 116). As a result of these developments, it can be said that brand trust and loyalty have emerged by creating a sense of trust in the target audience through the measures taken and applied related to the health and safety of passengers.

Civil aircraft, according to the type of transportation performed in accordance with the nature of the tasks performed and the characteristics of the product, and the destination; passenger transport, cargo transport, special purpose transport, mainline transport, regional or local transport, etc. it has a clear classification in forms (Kalugina, 2021: 4). It can be seen that the service that occupies the largest place in the sector within this classification is passenger transportation. For this reason, it would not be wrong to state that more importance should be given to the quality of service in civil airline transportation. Because the perception of quality products/services formed in the customer/consumer audience positively affects brand equity and contributes to increasing the competitiveness of businesses. Considering the civil airline transportation companies in Turkey, it is seen that Turkish Airlines stands out more in terms of quality service. Ataman et al., in a study where the quality of service offered in the airline market for business purposes was measured and suggestions were tried to be determined a way to improve the five quality dimensions of the service provided (2011: 73), they concluded that Turkish Airlines is very close to meeting expectations and found that the physical characteristics are the closest to meeting expectations. In addition, according to the 2021 annual report (https://investor.turkishairlines.com/tr) it has been determined that significant distances have been covered in important issues of ground handling services such as departure timing and baggage disruption rate, and satisfaction at passenger contact points continues to increase. Accordingly it is understood that Turkish Airlines, which has a leading position in civil airline transportation in Turkey, tries to ensure customer/consumer satisfaction by focusing on quality in the marketing of products/services.

5. Conclusion and Recommendations

To be a preferred brand, products/services must be promoted at the right time, through the right channels, to the right audiences, and appropriate marketing efforts should be undertaken. For this purpose, firstly it is necessary to create a quality brand image in the target audiences. After the quality brand image and perception to be formed, it will be easier for the formation of brand equity and loyalty in the audiences addressed. But above all, the important point is that the products/services offered must-have features that will create real satisfaction. The job of aviation businesses that offer flight services, especially in the field of civil aviation, is a little more difficult and complex. Because flight service such as ticket reservation/sale, brokerage/agency, transportation of passengers/baggage to the airport, transportation of passengers/baggage from the airport to the city center, ground handling services including baggage handling/control and security control, refreshments and announcements, guidance by stewardesses, before the flight, during and after the flight, etc covers many services. It is quite difficult for civil airline transportation businesses, where customer/consumer satisfaction can be formed by ensuring that the products/services offered are in integrity/harmony and that there are no disruptions, to become a preferred brand. One of the most accurate strategies against this difficulty in being a preferred brand is brand positioning.

A positioning strategy is about creating, communicating, and maintaining distinctive differences that will be noticed and equitied by the customers with whom the firm most wishes to develop a long-term relationship. A successful positioning requires managers to understand the preferences of customers, their understanding of equity, and the characteristics of their competitors' offers (Lovelock and Wirtz, 2011: 61). A brand that creates a perception that it is different, interesting, and functional can always be a reason for preference on the target audience. For this reason, priority should be given to reflect the parties and advantages that are different from competitors to the products/services by considering branding and internationalization targets when brand positioning is made. Civil air transportation businesses, who want their brand to be preferred more in national/international markets, should explain/offer their target audience the satisfaction factors to be obtained from their products/services, additional benefits, differences, and advantages from other brands in an accurate and detailed manner.

With the increasing number of aviation companies and flights, the competition in the aviation sector in Turkey has intensified, and it can be predicted that the sector will grow even more with the increase in the number of airports opened over time. The perception of high service quality and the resulting customer satisfaction in civil aviation businesses, where the growth potential is evident, is decisive in the competition. Businesses that want to maintain or increase their competitiveness need to correctly determine customer/consumer expectations and do the necessary work to meet these expectations (Çırpın and Kurt, 2016: 85). Among these works, branding, internationalization, and brand equity creation activities are included in the first place for businesses. Customer satisfaction and loyalty can occur as a result of the quality product/service perception and customer/consumer preference that may occur in the target audience with the brand equity. As with many service sector representatives, ensuring customer/consumer satisfaction should be the main goal for civilian airline transportation companies. Because product/service experiences can be shared by the satisfied masses on social media, blogs, or websites, so that the products/services, and therefore the brand, can be promoted to potential customers and other audiences without the need to spend additional money and effort.

In line with service marketing strategies, the following recommendations can be offered for civil airline transportation businesses to make products/services more preferred in national and international markets and to create customer loyalty by emphasizing the brand, brand equity, branding and internationalization:

• At the national/international level, different content and innovations that will attract attention should be added to the products/services offered before, during and after the flight, to the factors that are preferred such as safety, speed and reasonable price.

• To create a strong and high-quality brand perception and to be successful in national and international markets, it is necessary to have successful expert graphic designers make logo, symbol and brand name designs.

• It should not be overlooked that customer/consumer satisfaction, which is created by the effect of strong and quality brand perception, can positively affect the preferences of customers/consumers in their next product/service purchases.

• It should be seen as a necessity to follow growth strategies, to attach importance to/continue new investments, to give priority to branding and internationalization to ensure and protect brand equity.

• In line with branding and internationalization, it should be ensured that product/service contents have features that can appeal to individuals from different countries and that they are included in promotions accurately and effectively.

• The primary purpose should be in airline businesses that, offer comprehensive or uniform products/services, to provide products/services that can create a quality brand perception, and to gain customer preference, customer satisfaction, and customer loyalty by making use of branding and internationalization.

• The positive results achieved are not an end, it should always be taken into account that the brand/business should be differentiated from its competitors in terms of product/service at national and international levels and that the product/service content should be updated and enriched at regular intervals.

• Always keeping customer/consumer satisfaction at the forefront, making effective promotions to potential customers, etc. It should not be forgotten that the continuation of the activities is the requirement that positively affect the brand and customer/consumer preference.

Ethical approval

Not applicable.

Conflicts of Interest

There is no conflict of interest with any person or institution.

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