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Aircraft Selection Decision Support Model for Fleet Planning of the Low Cost Airlines

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Düşük Maliyetli Havayollarının Filo Planlaması için Uçak Seçimi Karar Destek Modeli

Öz

Bu çalışmada, düşük maliyetli havayolunun filo planlama kararında uçak tipi seçimi için bir karar destek modeli oluşturulmuş ve model için teknik, ekonomik, çevresel, politik ve diğer kriterler olmak üzere 5 ana grup kriteri içinde 21 alt kriter belirlenmiştir. Bu karar destek modelinde Bulanık TOPSIS ve Bulanık MOORA çok kriterli karar verme yöntemleri kullanılmış ve Airbus, Boeing, Embraer ve Airbus/Bombardier uçak üreticilerine ait 17 farklı dar gövde uçak tipleri değerlendirmeye alınmıştır. Değerlendirmede uçak tipleri içinde düşük maliyetli havayolu iş modeli için en uygun ve tercih edilen uçağın Airbus A321 NEO olduğu belirlenmiştir.

Anahtar Kelimeler: Düşük Maliyetli Havayolları, Uçak Seçimi, Bulanık ÇÖKV, TOPSIS, MOORA

JEL Kodları: M00, C00

Aircraft Selection Decision Support Model for Fleet Planning of the Low Cost Airlines

Abstract

In this study, a decision support model was created for the aircraft type selection in the fleet planning decision of a low-cost airline and 21 sub criteria were determined for the model in five main groups as technical, economic, environmental, political and other criteria. In this decision support model, the Fuzzy TOPSIS and Fuzzy MOORA Multi Criteria Decision methods were applied, and 17 different narrow body aircraft types produced by Airbus, Boeing, Embraer, and Airbus/Bombardier aircraft manufacturers were evaluated. In the evaluation, it was found that Airbus A321NEO was the most preferable aircraft for the low-cost airline business model among the aircraft types.

Keywords: Low-Cost Airlines, Aircraft Selection, Fuzzy MCDM, TOPSIS, MOORA

JEL Codes: M00, C00

Araştırma ve Yayın Etiği Beyanı	Bu çalışma bilimsel araştırma ve yayın etiği kurallarına uygun olarak hazırlanmıştır.
Yazarların Makaleye Olan Katkıları	Çalışmanın tamamı iki yazar ile birlikte oluşturulmuştur.
Çıkar Beyanı	Yazarlar açısından ya da üçüncü taraflar açısından çalışmadan kaynaklı çıkar çatışması bulunmamaktadır.

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1. Introduction

Since the 1980s, with the effect of deregulation, liberalization, and privatization trends in air transportation, airline companies have tried to take advantage of the opportunities offered by these trends and have introduced new business models (Kiracı and Akan, 2020:1).

One of these new business models has been the low-cost airline model. Airline companies that adopt the low-cost airline business model prefer point-to-point flight network structure, use secondary airports at flight points, have similar aircraft types in terms of operational costs in their fleets, provide limited services within the aircraft and the terminal building, and provide transportation to passengers who care about price by reducing costs. These airlines aim to provide the highest level of service to their demand at a low cost and maximize their profitability within the framework of the business model they have adopted.

One of the most essential strategic decisions of low-cost airlines in line with their visions and missions is the decision made on fleet planning to hold on to the market, maintain their existence in the long term and be successful in competition against traditional airlines. While making the company's future strategic decisions, airline companies first set their goals within the framework of the business model they have adopted.

In achieving these goals, it is of vital importance which criteria will be taken into consideration for the aircraft acquisition, which requires very large capital, and which aircraft will be included in the fleet as a result. In fleet planning, aircraft selection plays a very important role both in terms of the financial income and in terms of operating within the frame of the business model adopted by airline companies (Belobaba, 2009:154). Because aircraft fleets are capital-intensive, long-lasting investment assets for an airline, they can affect the company's performance and future for decades (Brüggen, 2010: 299).

In the literature, many studies have been performed for different fields of the air transport sector on aircraft selection. In these studies, mainly Multi-criteria Decision Making (MCDM) applications were used, decision support models were studied on the selection of fighter aircraft, trainer aircraft, aircraft for the general aviation sector, and passenger aircraft and cargo aircraft for commercial airline companies.

In this research, the problem of aircraft selection among the alternatives composed of new generation and classical aircraft models for the fleet planning of low-cost airlines has been studied. Since different technical and economic advantages and disadvantages of the alternatives, requirements of the environments in which they operate, the preferences and perceptions of the passengers served, and the considerations of the airlines for their own strategies, require many criteria to be considered aircraft selection decision creates an uncertain environment with many alternatives and criteria. For this reason, MCDM methods were thought to be appropriate for the decision support model, and since the experiences and perceptions of decision makers are very effective in their evaluations within the framework of the dynamics of the sector, the Fuzzy Logic application was used for selected MCDM methods which are TOPSIS and MOORA. The following parts of the study are formed as follows. Part 2 covers research on aircraft selection models, Part 3 covers methods and materials, Part 4 covers model setup and findings and results, and Part 5 provides the conclusion.

2. Literature Background

There are many studies in the literature on aircraft selection decision support models for fleet planning of airline companies. When the models in these studies are examined from the methodological point of view, it is seen that MCDM methods are mainly used, and the alternative aircraft selected is determined according to the business models of the airlines.

Some of the studies on aircraft selection are on aircraft used for activities other than passenger transport, such as business jet selection in civil aviation within the scope of general aviation (Gürün, 2015), selection of training aircraft (Wang and Chang, 2007; Ardil, 2020a; Küçükyılmaz et al.,2020), selection of fighter aircraft (Ardil et al. al. 2019; Hoan and Ha, 2021).

Among these studies, the Analytical Hierarchy Process (AHP) method was used by Gürün (2015) for the selection of business jets. In the studies on the selection of fighter aircraft, the full consistency method (FUCOM)- the additive ratio assessment (ARAS) approach (Hoan and Ha, 2021), the combination of entropy index and additive multiple criteria decision making analysis (Ardil, et al. 2019), AHP based TOPSIS combined with Fuzzy Logic (M.Sánchez-Lozano et al.2015), and in studies on the selection of trainer aircraft, the AHP integrated TOPSIS method for a flight school (Küçükyilmaz, et al. 2020) and integrated objective weighting procedures (the mean weight, entropy weight) and PARIS, and TOPSIS methods (Ardil, 2020a) were used. On the other hand, Wang and Chang (2007) studied the application of Fuzzy TOPSIS model for the selection of initial trainer aircraft for Taiwan Air Force.

In the literature, the studies are mainly on aircraft selection models for airline fleets operating on passenger transportation. The types and evaluation criteria of the aircraft considered for the fleets of airlines operating on passenger transport are quite different from business jets, trainer aircraft and fighter aircraft. In the studies on passenger transportation, for regional scheduled and non-scheduled airlines, aircraft with low seat capacity such as Cessna Fairchild Metro, Beechcraft, De Havilland, Dornier, Bombardier, ATR, Embraer, and Mitsubishi models have been evaluated and they have been compared with the criteria related to the technical features, financial, quality, interior design (Gomes et al. 2014: 231; Doziç and Kalic, 2015: 912; Bruno et al.2015: 5584; Doziç et al. 2018: 170; Sk et al.2020: 72; Kocakaya et al.2021:45; Ardil, 2020b: 381; Bakır et al., 2021: 435).

There are also many studies on aircraft selection models for the fleet structures of airlines operating with different network structures such as full-service carriers and low-cost carriers for passenger transportation. In these studies, A319Neo, A320Neo, A321Neo, A319, A320, A321, B737-Max7, B737-Max8, B737-Max9, B737-800, B737-900, aircraft which operate in short and medium ranges were evaluated. The studies on the selection of aircraft for passenger transportation in the literature are tabulated in the Table 1.

In this study, 17 different narrow body aircraft types produced by Airbus, Boeing, Embraer, and Airbus/ Bombardier aircraft manufacturers, which are most frequently used by low-cost airlines to operate in short and medium range were determined with 7 experts responsible for airline fleet planning working at airlines operating in Turkey and the aircraft selection model was constructed with a total of 21 criteria, including 5 main criteria.

3. Methodology: Fuzzy TOPSIS and Fuzzy MOORA

3.1. Fuzzy Set Theory

The situations that people encounter in the environments they live in are quite complex. This complexity stems from the inability to make decisions due to uncertainty. In the face of many situations, people verbally express their opinions, appreciations, and value judgments during the decision-making process. These imprecise value expressions which cannot be expressed numerically are called as fuzziness (Gökdalay and Evren,2008: 158). L.A Zadeh (Zadeh, 1965) who first introduced the concept of fuzziness in solving such problems, developed Fuzzy Set Theory.

Table 1: Summary of the Studies made on the selection of Passenger Aircraft in the Literature

Author	Methods Used	Criteria	Aircraft Type	Aim
Ardil (2022),	Entropy weighted DUD (decision uncertainty distance) hybrid/ TOPSIS	Aircraft baggage capacity, maximum take-off weight (MTOW), seat capacity, price, speed, environmental cost, cost per available seat mile (CASM)	N/A	Aircraft selection problem for a civil aviation company.
Deveci et al. (2021	Entropy-based WASPAS/ interval type-2 hesitant fuzzy sets (IT2HFS)	Revenue (expected load factor, passenger revenue, cargo revenue), Capacity (Economy cabin seat capacity, business cabin capacity), customer expectation (Economy cabin product, business cabin product), Cost (Fixed cost of operation, variable cost of operation), Competition (competitior's aircraft type)	B738, B78C, B79L, A321 A32C, A320, A319	Aircraft selection problem for a full-service carrier on a given route
Ilgın (2019)	Linear Physical Programming	fuel consumption, luggage volume, number of seats, price, range,	A319 NEO, A320NEO, A321 NEO, B798MAX 7, B737 MAX8, B737 MAX9.	Short and medium range aircraft selection for an hypotetical airline
Kiraci et al. (2018a)	TOPSIS	range, cost, speed, seat capacity, and fuel consumption	A320, A321, B737-800 and B737-900ER	Aircraft selection problem for an airline with different flight network structure and different flight destinations
Kiraci et al. (2018b)	AHP, COPRAS, MOORA	Price, Range, Speed, Seating Capacity, Fuel Consumption, Maximum Payload	A320, A321, B737-800 and B737-900ER	Determination of the best aircraft according to the criteria selected.
Kiracı and Akan, 2020)	AHP and TOPSIS in interval type-2 fuzzy Sets	Technical (expected service life of the aircraft, fuel consumption per seat mile, maximum take-off weight, aircraft seat capacity) , Economical (price of aircraft operating cost,), Environmental (noise pollution,)	A319Neo, A320Neo, A321Neo, B737Max7, B737Max8, B737Max9	Aircraft selection problem for a commercial airline

Özdemir et al. (2011)	Analytical Network Process (ANP)	cost (maintenance cost, purchasing cost, operation and spare cost, salvage cost) , time (useful life , delivery time), physical attributes and others (Dimensions, Reliability, and Suitability for Service, Quality Security)	A319, A320, B737	medium-range aircraft selection problem for Turkish Airlines
Özdemir et al. (2011)	Analytical Network Process (ANP)	cost (maintenance cost, purchasing cost, operation and spare cost, salvage cost) , time (useful life , delivery time), physical attributes and others (Dimensions, Reliability, and Suitability for Service, Quality Security)	A319, A320, B737	medium-range aircraft selection problem for Turkish Airlines
Semercioğlu and Özkoç (2019)	AHP Supported Social Selection Process	A/C Characteristics (Seating capacity, range, MTOW), Cost (purchasing cost, maintenance cost, available seat-km cost) , other factors contributing additive values (delivery time, payment conditions, variety of in fleet structure, passenger expectation, comfort)	A319, A320, B737	the selection of three different aircraft types flying at short and medium ranges in airlines
Sun et al. 2011	ELECTRE, SAW and TOPSIS	cabin volume per passenger cruise speed, fuel consumption per seat mile,	B 747-400, B777-200 and A340-300 (wide bodied aircraft)	Aircraft selection problem,for an airline company
Yilmaz (2006)	AHP and Fuzzy AHP	general system features, technology level used in the aircraft, structural system features, engine features, maintenance features, component capability gaining features, technical support, operation and spare part costs, flight control systems, similarity to the existing fleet	A321-200, A320-200 B737-800/ 900	medium-range aircraft selection problem for Turkish Airlines

Fuzzy Set Theory has been applied to many methods and has been used in many application areas. In this study, fuzzy triangular numbers have been used because it is easy to use and calculate for the Decision Makers in the Aviation Industry.

In a fuzzy set$(\tilde{A})$, the membership function values are between 0 and 1, and the membership function is as shown in equation (1) (Gökdalay and Evren, 2009: 161).

$$\mu_{\tilde{A}}(x) = \left\{ \begin{array}{cc} 0, & x \leq a \\ \dfrac{x-a}{b-a}, & a \leq x \leq b \\ \dfrac{c-x}{c-b}, & b \leq x \leq c \\ 0, & x \geq c \end{array} \right\} \tag{1}$$

3.2. Fuzzy TOPSIS

In the studies on aircraft selection models in the literature, MCDM methods have been mainly applied and it has been seen that TOPSIS is highly preferred among these methods. TOPSIS, which is one of the multi-criteria decision-making methods, gives the ranking of alternatives from the most ideal to the least preferred alternative as a ranking technique, and in this study, it has been thought that TOPSIS method allows low-cost airlines to purchase the most ideal aircraft or to evaluate other alternatives in terms of compatibility with the aircraft in their current fleet, taking into account the ranking. For this purpose, it is aimed that the airline industry can easily use this decision support model and in the preference of the TOPSIS method, it has been effective because it is easy to evaluate many alternatives according to many criteria, calculation technique is easy, it is less time consuming and not more complicated than methods that require pairwise comparisons. In the TOPSIS method, developed by Yoon and Hwang in 1981, it is possible to choose the best solution among alternatives by using positive and negative ideal solution points, and the alternative closest to the positive ideal solution and the farthest from the negative ideal solution is evaluated as the best alternative (Razmi et al.2009: 594). Whereas the positive ideal solution is the one that maximizes the benefit criterion and minimizes the cost criterion, the negative ideal solution is the one that maximizes the cost criterion and minimizes the benefit criterion (Wang and Elhag, 2006:312). The steps of the TOPSIS method in fuzzy logic application is given as follows (Delice, 2016: 267).

1. Step: Decision makers who will evaluate the problem, alternatives to be evaluated and evaluation criteria are determined.

D = {d= 1, 2, 3…t} decision makers in the problem

A_i = {i= 1, 2, 3…m} alternatives which is evaluated in the problem

C_j = {j= 1, 2, 3…n} main criteria in the problem

C_{jk}= {k=1,2,3...p} subcriteria in the problem

2. Step: The importance weights of the main criteria and sub-criteria are given by the decision makers, and the alternatives are evaluated according to the criteria. These evaluations and importance weights are first made with verbal variables and then these verbal expressions are converted into triangular numbers according to the scale used in the problem. The importance weightings and evaluations of the decision makers are combined into a group decision as in equation (2) and (3) below.

$$\tilde{w}_{ij} = \frac{1}{K}\left[w_j^1 + w_j^2 + w_j^3 \ldots \ldots \ldots . + w_j^K\right] \quad (i = 1,2,3 \ldots \ldots . m) \tag{2}$$

$$\tilde{x}_{ij} = \frac{1}{K}\left[x_{ij}^1 + x_{ij}^2 + x_{ij}^3 \ldots \ldots \ldots . + x_{ij}^K\right] \quad (i = 1,2,3 \ldots \ldots . m) \tag{3}$$

3. Step: As seen in Equation (4), fuzzy weight and decision matrices are created.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \ldots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \ldots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{bmatrix} \qquad \tilde{W} = [\,\tilde{W}_1, \tilde{W}_2 \ldots \ldots \tilde{W}_n] \tag{4}$$

$i = 1,2,3 \ldots . m;\ j = 1,2,3 \ldots n$

4. Step: The criteria in the fuzzy decision matrix are normalized by using equation (5) for the benefit criterion (B) and equation (6) for the cost criterion (C).

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad j \in B \tag{5}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \quad j \in C \tag{6}$$

$\tilde{r}_{ij}$ normalized decision values $c_j^* = max_i \, c_{ij}$, $a_j^- = min_i \, a_{ij}$

5. Step: By using Equation (7), the weighted normalized decision matrix is created.

$\tilde{U} = [\tilde{u}_{ij}]_{mxn}$ i=1,2,3..m j=1,2,3…..n

$$\tilde{u}_{ij} = \tilde{r}_{ij} \, \tilde{w}_j \tag{7}$$

6. Step: The fuzzy positive ideal solution $(\tilde{A}^*)$and the negative ideal solution ($\tilde{A}^-$) are determined as in equation (8) and equation (9).

$$\tilde{A}^* = (\tilde{u}_1^*, u_2^*, \ldots . u_n^*) \quad i = 1,2,3 \ldots \ldots \ldots m \; j = 1,2,3 \ldots \ldots \ldots n \tag{8}$$

$$\tilde{A}^- = (\tilde{u}_1^-, u_2^-, \ldots . u_n^-) \quad i = 1,2,3 \ldots \ldots \ldots m \; j = 1,2,3 \ldots \ldots \ldots n \tag{9}$$

$\tilde{u}_j^* = max_i u_{ij}, \quad \tilde{u}_j^- = min_i u_{ij}$

7. Step: By using Equation (10) and Equation (11), the distances of the alternatives from the fuzzy positive and negative ideal solutions are calculated.

$$D_i^* = \sum_{j=1}^{n} d(\tilde{u}_{ij}, \tilde{u}_j^*) \quad i = 1,2,3 \ldots . . m \tag{10}$$

$$D_i^- = \sum_{j=1}^{n} d(\tilde{u}_{ij}, \tilde{u}_j^-) \quad i = 1,2,3 \ldots . . m \tag{11}$$

The expressions $D^*(\tilde{u}_{ij}, \tilde{u}_j^*)$ and $D^-(\tilde{u}_{ij}, \tilde{u}_j^-)$ in the above equations show the distances between two fuzzy numbers, and the Vertex method in equation (11) is used to calculate these distances. In this method, the distance between two fuzzy numbers is calculated as in the equation (12). Let say $\tilde{S} = (a, b, c)$ and $\tilde{T} = (d, e, f)$

$$D(\tilde{S}, \widetilde{T}) = \sqrt{\frac{1}{3}[(a-d)^2 + (b-e)^2 + (c-f)^2]} \tag{12}$$

8.Step: For each alternative, the closeness coefficients (CC) to the ideal solution are calculated as in the equation (13).

$$CC_i = \frac{D_i^-}{(D_i^* + D_i^-)} \tag{13}$$

i=1,2, ….. , m $0 \leq C_i \leq 1$

9. Step: All alternatives are ranked according to their closeness coefficients from the largest one to the smallest one. The alternative with the largest closeness coefficient is determined as the best alternative.

3.3 Fuzzy MOORA

The MOORA method, which is used in many areas in the literature, is one that is not widely used on aircraft selection problem. Multi-objective optimization based on ratio analysis (MOORA) method, which was introduced to the literature by Brauers and Zavadskas (2006), is one of the newly developed MCDM methods. It has been applied in many areas but has not been used widely for aircraft selection problem. MOORA method can be effectively applied as an appropriate tool for the ranking and selection of the alternatives among various set of available options. Compared to the other MCDM methods, short calculation time, easiness of mathematical processes and the feature of not requiring pairwise comparisons are the reasons for selecting MOORA method.

4. Step: In step 4, the fuzzy numbers in the weight matrix are converted to crisp numbers with the following formula, for example, a triangular fuzzy number is $\tilde{S}$= (a, b, c), it is converted into the crisp number by using equation (14) (Şişman, 2016:307-308).

$$s = \frac{a_1 \ + 4 * b_2 \ + c_3}{6} \tag{14}$$

5. Step: The decision matrix is normalized with the vector normalization formula**s** in equations (15), (16), (17).

$$r_{ij}^{a} = \frac{x_{ij}^{a}}{\sqrt{\sum_{i=1}^{n}\left[(x_{ij}^{a})^2 + (x_{ij}^{b})^2 + (x_{ij}^{c})^2\right]}} \tag{15}$$

$$r_{ij}^{b} = \frac{x_{ij}^{b}}{\sqrt{\sum_{i=1}^{n}\left[(x_{ij}^{a})^2 + (x_{ij}^{b})^2 + (x_{ij}^{c})^2\right]}} \tag{16}$$

$$r_{ij}^{c} = \frac{x_{ij}^{c}}{\sqrt{\sum_{i=1}^{n}\left[(x_{ij}^{a})^2 + (x_{ij}^{b})^2 + (x_{ij}^{c})^2\right]}} \tag{17}$$

6. Step: The weight matrix is combined with the normalized decision matrix with the equations (18), (19), (20)

$$v_{ij}^{a}) = W_j \, r_{ij}^{a} \tag{18}$$

$$v_{ij}^{b}) = W_j \, r_{ij}^{b} \tag{19}$$

$$v_{ij}^{c}) = W_j \, r_{ij}^{c} \tag{20}$$

7. Step: In this step, normalized performance values (S) are calculated in terms of benefit and cost criteria with the equations (21), (22), (23), (24), (25), (26).

$$S_{\text{i}}^{+a} = \sum_{j=1}^{m}\left(v_{ij}^{a} \middle| j \in J^{enb}\right) \tag{21}$$

$$S_{\mathrm{i}}^{+b} = \sum_{j=1}^{m} \left(v_{ij}^{b} \middle| j \in J^{enb} \right) \tag{22}$$

$$S_{\mathrm{i}}^{+c} = \sum_{j=1}^{m} \left(v_{ij}^{c} \middle| j \in J^{enb} \right) \tag{23}$$

$$S_{\mathrm{i}}^{-a} = \sum_{j=1}^{m} \left(v_{ij}^{a} \middle| j \in J^{enk} \right) \tag{24}$$

$$S_{\mathrm{i}}^{-b} = \sum_{j=1}^{m} \left(v_{ij}^{b} \middle| j \in J^{enk} \right) \tag{25}$$

$$S_{\mathrm{i}}^{-c} = \sum_{j=1}^{m} \left(v_{ij}^{c} \middle| j \in J^{enk} \right) \tag{26}$$

8. Step: In this step, The normalized performance values are converted into non-fuzzy performance values by using the vertex method in the equation (27).

$$S_i = \sqrt{\frac{1}{3} * [(S_i^{+a} - S_i^{-a})^2 + (S_i^{+b} - S_i^{-b})^2 + (S_i^{+c} - S_i^{-c})^2]} \tag{27}$$

9. Step: Alternatives are ranked and the alternative with the highest value is preferred.

4. Aircraft Selection Decision Support Model For Fleet Planning of Low Cost Airlines

4.1 Model Structure

One of the most essential strategic decisions for an airline is which aircraft worth millions of dollars will be invested in and included in the fleet. For this reason, the decisions to be made in the selection of aircraft in the fleet planning process play the key role that will lead an airline to success or failure, especially in the medium and long term.

In the decisions to be made on fleet planning, the airline business model adopted by the airline company is of the utmost importance in shaping these decisions. In this study, it is aimed to create a decision support model that can help the airline managers in the decision-making process for the selection of the aircraft model for fleet planning process of a low cost airline.

In determining the criteria in the decision support model, while some of the criteria were created with experts responsible for the fleet planning of 3 airline companies operating in Turkey and some of them were taken from the studies in the literature.

One of the characteristics of companies that adopt the low-cost airline business model is that they have a homogeneous fleet structure consisting of narrow-body aircraft that can fly in short and medium ranges. Having similar aircraft structure, the same cabin and flight personnel can use all aircraft, the same maintenance personnel can maintain all aircraft, and crew planning studies can be facilitated. All these conveniences can provide advantages to companies in terms of costs (Demirci, 2016: 211). In this study, both classical and new generation aircraft of Airbus (A319 Neo, A320Neo, A321Neo, A319, A320, A321,) and Boeing

(B737-Max7, B737-Max8, B737-Max9, B737-Max20, B737-700, B737-800, B737-900 ER) as well as CS100, CS300, ERJ190 and ERJ195 aircraft mostly preferred by regional airlines, are taken as the alternatives to be evaluated. In the model, 5 main criteria and 21 sub-criteria were determined, and they are given in Table 2.

Table 2: Main criteria and Subcriteria used in the Model

		CRITERIA
C_1		**Technical Criteria**
	C_{11}	Range: The longest distance an aircraft can fly on its available fuel
	C_{12}	Carrying Capacity: The weight limits that the aircraft can carry as passengers and Cargo
	C_{13}	Fuel Efficiency: The ability of the aircraft to travel more with less fuel
	C_{14}	Auxiliary Equipment: Auxiliary equipment support provided by the aircraft manufacturer to the airline
	C_{15}	Spare Part: Availability of the parts in the market if the aircraft needs spare parts.
	C_{16}	Technical Support: how accessible the companies which will provide support if needed.
	C_{17}	Maximum Take-Off Weight (MTOW): Maximum weight aircraft can carry during Take Off.
	C_{18}	Utilization Period: Evaluation of how many hours per day the airline can use the aircraft
C2		**Economical Criteria**
	C_{21}	Price Fiyat: Market price of the aircraft
	C_{22}	Demand: Demand for the aircraft in the market.
	C_{23}	Finance Options: Aircraft can be directly purchased or leased (dry lease/ wet lease). This criterion is an assessment of how well the aircraft manufacturer can offer these options.
	C_{24}	Aircraft Similarity: to use a single type of aircraft in the fleet or similar types of the same aircraft manufacturer.
	C_{25}	Cost per Available Seat Mile (CASM): Cost per Seat per mile
	C_{26}	Internal Rate of Return: The internal rate of return expresses how much-added value the investment will create.
C3		**Political Criteria**
	C_{31}	Embargo: Aircraft manufactured by some countries are prevented from entering the embargo-sanctioned countries
	C_{32}	Foreign Policy: It is an important criterion for mostly state-run airlines. For example, countries that have foreign policy problems with the USA may prefer different aircraft instead of Boeing.
C4		**Environmental Criteria**
	C_{41}	Noise: Evaluation of noise pollution during flight
	C_{42}	CO2 Emmision: Evaluation of the amount of CO2 emitted by airplanes
C5		**Other Criteria**
	C_{51}	Passenger Satisfaction: evaluation of how much comfort the aircraft provides to the passengers
	C_{52}	Reliability: Criterion that can affect passenger aircraft preferences, such as jet-powered over propeller aircraft
	C_{53}	In-Flight Entertainment Systems: such as television, internet, music and movies offered on the flight

In the study, since the decision makers are experts in their professions, a 7-variable scale was used for evaluating alternatives and weighting the criteria in the model. One of the important steps of the MCDM problem is the weighing of the criteria. Many weighting methods have been developed in the literature, and they are classified as objective, subjective and hybrid. While it is not possible to take the personal opinions of the decision makers in objective weighting, the opinions of expert decision makers are taken for the criteria in subjective weighting. Hybrid methods are methods in which both weightings are used together. Due to the fact that airline industry is highly influenced by international and domestic environments such as trade, competition and politics by its nature, the use and operation conditions of the airlines' own aircraft and the importance weights of the related decision criteria may vary according to dynamic business conditions. For this reason, it was thought that it would be appropriate to integrate the subjective criterion weighting method with linguistic expressions. In this study, Simple Weighting Method was preferred to make the model easy to be applied.

The degree of importance and evaluation scales used in the problem are given in Table 3.

Table 3: Scale used for Importance Weights and Evaluations of the Criteria

Scale for Importance Degree		Verbal Variables for Evaluation of Criteria	
Very Low (VL)	(0.0, 0.0, 0.1)	Very Poor (VP)	(0, 0, 1)
Low (L)	(0.0, 0.1, 0.3)	Poor (P)	(0, 1, 3)
Less Low (LL)	(0.1, 0.3, 0.5)	Less Poor (LP)	(1, 3, 5)
Moderate (M)	(0.3, 0.5, 0.7)	Moderate (M)	(3, 5, 7)
High Moderate (HM)	(0.5, 0.7, 0.9)	More Good (MG)	(5, 7, 9)
High (H)	(0.7, 0.9, 1.0)	Good (G)	(7, 9,10)
Very High (VH)	(0.9, 1.0, 1.0)	Very Good (VG)	(9,10,10)

Source: (Chen, 2000: 5)

4.2 Results and Discussion

In the study the calculation steps are as follows;

1. 2, and 3. Steps: The individual and integrated importance weights of the criteria in the model determined by the aircraft acquision experts according to equation (1) and the performance decision matrix values for the alternatives determined according to equation (2), (3), (4) are shown in the Table 4 and Table 5 successively.

Table 4: Sub Criteria Weights and their Integrated Weights

Main Criteria	SubCriteria	Weights of Main and Sub Criteria	Integrated weights of the Criteria
C_1	**Technical Criteria**	**(0.786; 0.943; 1.000)**	
	C_{11} Range	(0.757; 0.900; 0.971)	(0.595; 0.849; 0.971)
	C_{12} Carrying Capacity	(0.671; 0.871; 0.986)	(0.528; 0.822; 0.986)
	C_{13} Fuel Efficiency	(0.871; 0.986; 1.000)	(0.685; 0.929; 1.000)
	C_{14} Auxiliary Equipment	(0.557; 0.743; 0.871)	(0.438; 0.700; 0.871)
	C_{15} Spare Parts	(0.671; 0.843; 0.957)	(0.528; 0.795; 0.957)
	C_{16} Technical Support	(0.643; 0.814; 0.943)	(0.505; 0.768; 0.943)
	C_{17} Max. Take off Weight	(0.557; 0.757; 0.929)	(0.438; 0.714; 0.929)
	C_{18} Utilization Period	(0.614; 0.800; 0.929)	(0.483; 0.754; 0.929)
C_2	**Economical Criteria**	**(0.871; 0.986; 1.000)**	
	C_{21} Price	(0.843; 0.971; 1.000)	(0.734; 0.958; 1.000)
	C_{22} Demand	(0.500; 0.700; 0.871)	(0.436; 0.690; 0.871)
	C_{23} Financial Options	(0.786; 0.943; 1.000)	(0.685; 0.929; 1.000)
	C_{24} Aircraft Similarity	(0.729; 0.900; 0.986)	(0.635; 0.887; 0.986)
	C_{25} CASM	(0.843; 0.971; 1.000)	(0.734; 0.958; 1.000)
	C_{26} Internal Rate of Return	(0.529; 0.729; 0.900)	(0.461; 0.718; 0.900)
C_3	**Political Criteria**	**(0.343; 0.529; 0.714)**	
	C_{31} Embargo	(0.529; 0.729; 0.900)	(0.181; 0.385; 0.643)
	C_{32} Foreign Policy	(0.400; 0.571; 0.729)	(0.137; 0.302; 0.520)
C_4	**Environmental Criteria**	**(0.343; 0.529; 0.714)**	
	C_{41} Noise	(0.471; 0.657; 0.829)	(0.162; 0.347; 0.592)
	C_{42} CO_2 Emissions	(0.500; 0.686; 0.843)	(0.171; 0.362; 0.602)
C_5	**Other Criteria**	**(0.329; 0.529; 0.729)**	
	C_{51} Passenger Comfort	(0.486; 0.657; 0.800)	(0.160; 0.347; 0.583)
	C_{52} Reliability	(0.614; 0.786; 0.914)	(0.202; 0.415; 0.666)
	C_{53} In-Flight Entertainment Systems	(0.300; 0.471; 0.657)	(0.099; 0.249; 0.479)

Table 5: Fuzzy Decision Matrix of Aircraft Alternative Models

CRİTERİA		A1 A319	A2 A320	A3 A321	A4 A319NEO	A5 A320NEO	A6 A321NEO
C_1	C_{11}	(6.667; 8.500; 9.500)	(5.333;7.333; 9.333)	(5.333;7.333; 9.333)	(7.333; 8.833;9.500)	(5.667; 7.667; 9.167)	(7.000; 8.667; 9.667)
	C_{12}	(4.333; 6.333; 8.000)	(6.333; 8.167; 9.333)	(8.000;9.167; 9.500)	(4.000;6.000;7.6667) (6.333; 8.000; 9.167)	(6.333; 8.000; 9.167)	(8.333; 9.500; 9.833)
	C_{13}	(3.571; 5.667; 7.333)	(3.667; 5.667; 7.667) 7.667)	(4.333; 6.333; 8.333)	(6.667; 8.167; 9.167)	(6.667; 8.500; 9.667)	(7.333; 9.000; 9.833)
	C_{14}	(5.286; 7.000; 8.667)	(5.333; 7.333; 9.333)	(5.667; 7.667; 9.333)	(7.333; 9.000; 9.333)	(7.333; 9.000; 9.333)	(7.333; 9.000; 9.833)
	C_{15}	(5.571; 7.571; 9.000)	(6.714; 8.429; 9.429)	(6.429; 8.429; 9.714)	(6.429; 8.143; 9.429)	(7.000; 8.714; 9.714)	(7.000; 8.714; 9.714)
	C_{16}	(6.714; 8.429; 9.286)	(7.000; 8.714; 9.571)	(7.000; 8.857; 9.857)	(6.714; 8.714; 9.857)	(7.286; 9.000; 9.857)	(7.286; 9.000; 9.857)
	C_{17}	(4.333; 5.833; 7.167)	(5.000; 7.000; 8.500)	(7.667; 9.167; 9.833)	(6.000; 7.833; 9.167)	(6.000; 7.833; 9.167)	(8.333; 9.500; 9.833)
	C_{18}	(5.000; 7.000; 8.714)	(5.571; 7.571; 9.286)	(5.571; 7.571; 9.286)	(6.714; 8.571; 9.714)	(6.429; 8.286; 9.571)	(6.714; 8.571; 9.714)
C_2	C_{21}	(3.857; 5.857; 7.714)	(3.571; 5.571; 7.429)	(2.714; 4.714; 6.571)	(2.714; 4.714; 6.714)	(1.286; 3.000; 5.000)	(2.286; 4.143; 6.143)
	C_{22}	(5.143; 6.571; 7.714)	(5.857; 7.857; 9.286)	(6.714; 8.429; 9.571)	(5.571; 7.286; 8.429)	(8.714; 9.857; 10.00)	(8.714; 9.857; 10.00)
	C_{23}	(5.571; 7.571; 9.000)	(5.000; 7.000; 8.714)	(5.000; 7.000; 8.714)	(6.143; 7.857; 9.000)	(5.571; 7.571; 9.000)	(5.571; 7.571; 9.000)
	C_{24}	(6.143; 8.143; 9.571)	(6.714; 8.571; 9.714)	(6.714; 8.571; 9.714)	(5.857; 7.857; 9.429)	(6.714; 8.429; 9.571)	(6.714; 8.429; 9.571)
	C_{25}	(5.857; 7.857; 9.286)	(5.000; 7.000; 8.714)	(4.714; 6.714; 8.143)	(7.286; 8.857; 9.714)	(6.714; 8.429; 9.571)	(6.714; 8.143; 9.000)
	C_{26}	(6.143; 7.857; 9.000)	(6.143; 8.143; 9.571)	(5.857; 7.857; 9.429)	(7.571; 9.000; 9.714)	(7.571; 9.143; 9.857)	(7.857; 9.429; 10.00)
C_3	C_{31}	(6.429; 8.286; 9.571)	(5.857; 7.714; 9.000)	(6.429. 8.286; 9.571)	(4.857; 6.714; 8.286)	(5.143; 7.000; 8.571)	(4.571; 6.429; 8.000)
	C_{32}	(5.857; 7.714; 9.143)	(5.857; 7.714; 9.143)	(6.143; 7.857; 9.143)	(5.857; 7.714; 9.143)	(5.857; 7.714; 9.143)	(6.429; 8.000; 9.143)
C_4	C_{41}	(3.000; 4.429; 6.143)	(2.714; 4.429; 6.429)	(2.714; 4.429; 6.429)	(5.857; 7.857; 9.429)	(5.571; 7.571; 9.143)	(5.857; 7.857; 9.286)
	C_{42}	(4.286; 6.143; 7.857)	(4.429; 6.429; 8.143)	(4.714; 6.714; 8.429)	(6.429; 8.143; 9.286)	(6.429; 8.143; 9.286)	(7.000; 8.714; 9.571)
C_5	C_{51}	(4.286; 6.000; 7.571)	(4.143; 6.143; 8.143)	(5.286; 7.286; 8.857)	(6.714; 8.429; 9.571)	(7.000; 8.857; 9.857)	(7.571; 9.143; 9.857)
	C_{52}	(5.000; 7.000; 8.714)	(5.571; 7.571; 9.143)	(6.143; 8.143; 9.571)	(7.286; 9.000; 9.857)	(7.857; 9.286; 9.857)	(7.857; 9.286; 9.857)
	C_{53}	(2.333; 3.667; 5.333)	(2.667; 4.667; 6.667)	(3.333; 5.333; 7.333)	(4.667; 6.667; 8.500)	(5.000; 7.000; 8.833)	(5.333; 7.333; 9.167)

Table 5: (Cont.)

CRİTERİA		A7 B737-700	A8 B737-800	A9 B737-900-ER	A10 B737-MAX7	A11 B737-MAX8	A12 B737-MAX9
C_1	C_{11}	(5.000; 6.833; 8.500)	(5.333; 7.167; 8.667)	(6.333; 8.000; 9.167)	(6.000; 7.667;9.000)	(5.667; 7.333; 8.667)	(6.000; 7.667; 9.000)
	C_{12}	(5.333; 7.167; 8.500)	(6.667; 8.333; 9.333)	(7.667; 9.167; 9.833)	(5.333; 7.333; 8.833)	(7.000; 8.667; 9.500)	(7.333; 9.000; 9.833)
	C_{13}	(4.000; 5.333; 6.500)	(3.667; 5.667; 7.667)	(5.000; 7.000; 9.000)	(6.333; 7.833; 8.833)	(7.000; 8.833; 9.833)	(7.000; 8.833; 9.833)
	C_{14}	(4.667; 6.667; 8.333)	(5.667; 7.667;9.167)	(5.667; 7.667; 9.333)	(6.667; 8.333; 9.500)	(7.000; 8.667; 9.667)	(7.000; 8.667; 9.667)
	C_{15}	(5.571; 7.571; 9.000)	(6.429; 8.286; 9.429)	(6.143; 8.143; 9.571)	(6.429; 8.143; 9.429)	(7.000; 8.714; 9.714)	(7.000; 8.714; 9.714)
	C_{16}	(7.000; 8.714; 9.714)	(7.000; 8.714; 9.571)	(7.571; 9.143; 9.857)	(7.000; 8.857; 9.857)	(7.571; 9.143; 9.857)	(7.571; 9.143; 9.857)
	C_{17}	(5.000; 7.000; 8.833)	(5.333; 7.333; 8.833)	(7.667;9.167; 9.833)	(5.000; 7.000;9.000)	(6.333; 8.333; 9.667)	(7.667; 9.167; 9.833)
	C_{18}	(4.143; 6.143; 8.000)	(4.714; 6.714; 8.571)	(5.000; 7.000; 8.857)	(5.571; 7.429; 9.000)	(5.857; 7.714; 9.143)	(5.571; 7.429; 9.000)
C_2	C_{21}	(5.000; 7.000; 8.714)	(3.286; 5.286; 7.143)	(3.571; 5.571; 7.429)	(3.571; 5.571; 7.571)	(2.429; 4.429; 6.429)	(1.429; 3.000; 5.000)
	C_{22}	(6.143; 7.857; 9.000)	(7.000; 8.714; 9.714)	(5.857; 7.857; 9.429)	(6.143; 8.143; 9.571)	(8.429; 9.714; 10.00)	(6.714; 8.571; 9.714)
	C_{23}	(5.571; 7.571; 9.000)	(5.000; 7.000; 8.714)	(5.286; 7.286; 8.857)	(6.143; 8.857; 9.000)	(5.571; 7.571; 9.000)	(5.571; 7.571; 9.000)
	C_{24}	(5.571; 7.571; 9.143)	6.714; 8.714; 9.857)	(6.143; 8.143; 9.571)	(5.857; 7.857; 9.429)	(6.714; 8.571; 9.714)	(6.714; 8.571; 9.714)
	C_{25}	(5.571; 7.571; 9.143)	(5.000; 7.000; 8.714)	(4.429; 6.429; 8.000)	(7.286; 8.857; 9.714)	(7.000; 8.714; 9.714)	(6.429; 8.000; 9.000)
	C_{26}	(6.429; 8.143; 9.286)	(6.714; 8.714; 9.857)	(5.857; 7.857; 9.286)	(7.286; 8.714; 9.571)	(7.857; 9.429; 10.00)	(7.286; 9.143; 10.00)
C_3	C_{31}	(5.286; 7.000; 8;429)	(5.286; 7.000; 8.429)	(5.571; 7.286;8.714)	(3.825; 5.857; 7.714)	(3.857; 5.857; 7.714)	(3.857; 5.857; 7.714)
	C_{32}	(5.571; 7.286; 8.714)	(5.571; 7.286; 8.714)	(4.429; 6.429; 8.429)	(5.286; 7.143; 8.571)	(5.286; 7.014; 8.571)	(5.286; 7.143; 8.571)
C_4	C_{41}	(3.000; 4.714; 6.714)	(3.571; 5.571; 7.571)	(4.429; 6.429; 8.286)	(5.857; 7.857; 9.429)	(6.143; 8.143; 9.571)	(6.143; 8.143; 9.571)
	C_{42}	(4.143; 5.571; 7.000)	(4.429; 6.429; 8.143)	(5.286; 7.286; 9.000)	(6.429; 8.143; 9.286)	(7.286; 9.000; 10.00)	(7.286; 9.000; 9.857)
C_5	C_{51}	(5.000; 7.000; 8.714)	(5.286; 7.286; 9.143)	(5.857; 7.857; 9.286)	(7.286; 8.857; 9.714)	(7.286; 9.143; 10.00)	(8.143; 9.571; 10.00)
	C_{52}	(4.429; 6.429; 8.429)	(5.000; 7.000; 8.714)	(5.000; 7.000; 8.714)	(6.714; 8.429; 9.571)	(7.000; 8.571; 9.571)	(7.000; 8.571; 9.571)
	C_{53}	(2.333; 4.000; 6.000)	(2.667; 4.667; 6.667)	(4.667; 6.667; 8.500)	(5.000; 7.000; 9.000)	(5.667; 7.667; 9.333)	(6.333; 8.333; 9.667)

Table 5: Cont.

CRİTERİA		A13 B737MAX20	A14 CS100	A15 CS300	A16 ERJ190	A17 ERJ 195
C_1	C_{11}	(5.667; 7.333; 8.667)	(3.667; 5.667; 7.667)	5.000; 7.000; 8.667)	(1.667; 3.667; 5.667)	(0.833; 2.667; 4.667)
	C_{12}	(7.000; 8.667; 9.500)	(2.167; 4.000; 6.000)	(4.000; 6.000; 7.833)	(1.333; 3.333; 5.333)	(1.333; 3.333; 5.333)
	C_{13}	(7.000; 9.714; 9.571)	(3.000; 4.333; 6.000)	(3.000; 4.333; 6.000)	(3.333; 5.333; 7.333)	(3.333; 5.333;7.333)
	C_{14}	(7.286; 8.857; 9.571)	(4.567; 6.500;8.167)	(4.667; 6.500; 8.167)	(4.167; 5.833; 7.500)	(4.167; 5.833; 7.500)
	C_{15}	(7.000; 8.714; 9.571)	(3.333; 5.333; 7.333)	(3.000; 5.333; 7.333)	(2.667; 4.333; 6.333)	(2.667; 4.333; 6.333)
	C_{16}	(7.286; 8.857; 9.571)	(4.667; 6.667; 8.167)	(4.667; 6.667; 8.167)	(3.000; 4.667; 6.667)	(3.000; 4.667; 6.667)
	C_{17}	(6.333; 8.333; 9.500)	(3.667; 5.667; 7.667)	(3.667; 5.667; 7.667)	(2.167; 4.000; 6.000) (2.167; 4.000; 6.000)	(2.167; 4.000; 6.000)
	C_{18}	(5.857;7.714; 9.000)	(4.667; 6.333; 7.667)	(4.667; 6.333; 7.667)	(3.833; 5.333; 6.667)	(3.833; 5.333; 6.667)
C_2	C_{21}	(1.000; 2.667; 4.667)	(6.000; 8.000; 9.333)	(4.333; 6.333; 8.167)	(7.000; 8.500; 9.167)	(7.000; 8.500; 9.167)
	C_{22}	(7.333; 9.000; 9.833)	(4.167; 6.000; 7.667)	(4.167; 6.000; 7.667)	(5.333; 6.333; 7.000)	(5.333; 6.333; 7.000)
	C_{23}	(5.667; 7.667; 9.000)	(4.333; 6.333; 8.333)	(4.333; 6.333; 8.333)	(4.333; 6.333; 8.333)	(3.000; 5.000; 7.000)
	C_{24}	(7.000; 8.833; 9.833)	(3.000; 5.000; 7.000)	(3.333; 5.333; 7.333)	(1.667; 3.667; 5.667)	(4.333; 6.333; 8.333)
	C_{25}	(7.000; 8.667; 9.667)	(3.667; 5.667; 7.667)	(5.000; 7.000; 8.667)	(4.333; 6.167; 7.833)	(2.000; 4.000; 6.000)
	C_{26}	(8.000; 9.500; 10.00)	(4.333; 6.333; 8.000)	(5.000; 6.667; 8.000)	(5.667; 7.500; 8.833)	(4.333; 6.333; 8.000)
C_3	C_{31}	(4.429; 6.429; 8.286)	(5.286; 7.286; 8.857)	(5.000; 7.000; 8.714)	(2.714; 7.714; 6.714)	(2.714; 4.714; 6.714)
	C_{32}	(4.286; 6.000; 7.714)	(5.000; 7.000; 8.714)	(5.000; 7.000; 8.714)	(2.714; 4.714; 6.714)	(2.714; 4.714; 6.714)
C_4	C_{41}	(6.333; 8.333; 9.667)	(2.000; 3.667; 5.667)	(2.000; 3.667; 5.667)	(3.667; 5.667; 7.333)	3.667; 5.667; 7.333)
	C_{42}	(7.667; 9.333; 10.00)	(2.000; 3.333; 5.000)	(2.000; 3.333; 5.000)	(3.500; 5.333; 7.333)	(3.500; 5.333; 7.333)
C_5	C_{51}	(7.000; 9.000; 10.00)	(3.333; 5.333; 7.333)	(4.000; 6.000; 8.000)	(3.000; 5.000; 7.000)	(3.000; 5.000; 7.000)
	C_{52}	(7.333; 8.833; 9.667)	(2.667; 4.667; 6.667)	(2.667; 4.667; 6.667)	(1.667; 3.667; 5.667)	(1.667; 3.667; 5.667)
	C_{53}	(6.333; 8.333; 9.667)	(2.333; 4.333; 6.333)	(2.333; 4.333; 6.333)	(2.667; 4.667; 6.667)	(2.667; 4.667; 6.667)

Fuzzy TOPSIS Application

4. Step: The decision matrix obtained by equation (4) is normalized with the linear method using equations (5) and (6) and weighted by equation (7) to obtain a fuzzy weighted decision matrix. Here, cost criteria were assessed unilaterally by the experts and evaluated by using equation (5). In the TOPSIS application fuzzy positive and fuzzy negative ideal solutions are determined by equation (8) and (9) and the distances of the alternatives from the fuzzy positive (Di+) and fuzzy negative ideal solution (Di-) are calculated by the equations (10) and (11) with the vertex method in equation (12). The positive and negative distances, the closeness coefficients of each alternatives calculated by equation (13) and ranking of the alternatives are shown in Table 6.

Table 6: Ranking of the Aircraft types according to Fuzzy TOPSIS Method

Alternatives (A_i)	**D_i^+**	**D_i^-**	**Closeness Coefficients (CC_i)**	**Ranking**
A321 NEO	7.288	10.198	0.583	1
B737 MAX8	7.485	9.996	0.572	2
B737 MAX9	7.627	9.848	0.564	3
B737 MAX20	7.607	9.801	0.563	4
A320 NEO	7.694	9.828	0.561	5
A319 NEO	7.773	9.682	0.500	6
B737 MAX7	7.775	9.651	0.554	7
B737-900 ER	8.046	9.453	0.540	8
A321	8.181	9.322	0.533	9
B737-800	8.324	9.074	0.522	10
A320	8.413	9.037	0.518	11
B 737-700	8.554	8.698	0.504	12
A 319	8.627	8.640	0.500	13
CS 300	9.614	7.450	0.437	14
CS 100	9.857	7.195	0.422	15
ERJ 190	10.035	6.588	0.396	16
ERJ 195	10.138	6.395	0.387	17

Fuzzy MOORA Application

Steps 1-3 are the same as in the TOPSIS method and in step 3, the fuzzy weights are converted into non-fuzzy numbers (crisp) with equation (14).

4-5 Steps: The decision matrix is normalized by using Equation (15) (16) and (17) and the weighted normalized fuzzy matrix is obtained by using equations (18), (19) and (20).

Step 6: In this step, the fuzzy normalized performance values (S) and crisp values are calculated by the equations (21), (22), (23), (24), (25), (26), and (27) successively.

The crisp preference values of the aircraft and their rankings according to Fuzzy MOORA Method are given in Table 7.

In both methods, it is seen that the rankings of the aircraft are the same. According to both methods, the A321Neo model was preferred in the first rank. Considering the ranking of classical and new generations of the aircraft produced by Airbus and Boeing, new generation aircraft were preferred by the airline experts.

After the preference for new generation aircraft, B737-900ER and A321, which are the classical aircraft types took the first two rankings. CS and ERJ, mostly preferred in regional air transportation over short distances, have been among the aircraft that are not preferred within the framework of the low-cost airline business model.

Table 7: Ranking of the Aircraft types according to Fuzzy MOORA Method

Alternatives (A_i)	**Crisp Scores**	**Ranking**	**Alternatives (A_i)**	**Crisp Scores**	**Ranking**
A321 NEO	18.550	1	B737-800	14.913	10
B737 MAX8	17.778	2	A320	14.824	11
B737 MAX9	17.450	3	B 737-700	14.001	12
B737 MAX20	17.370	4	A 319	13.923	13
A320 NEO	17.349	5	CS 300	10.928	14
A319 NEO	16.789	6	CS 100	10.464	15
B737 MAX7	16.568	7	ERJ 190	9.289	16
B737-900 ER	15.949	8	ERJ 195	8.867	17
A321	15.677	9			

In the researches carried out within the framework of commercial air transportation in the literature, it has been seen that the classical types of narrow body aircraft models of Airbus and Boeing are mainly selected for evaluation in alternative aircraft models. The aircraft models which were taken as the alternatives evaluated and the best suitable aircraft in the literature are shown in the Table 8.

Table 8: Aircraft Alternatives and The Best Results in the Literature

Authors	**Methods**	**Alternatives**	**Best A/C**
Özdemir et al. (2011)	Analytical Network Process.	A319, A320, B737	B737
Kiraci et al.(2018a)	AHP, COPRAS and MOORA	A320, A321, B737-800 and B737-900ER	B737-800
Kiraci et al.(2018b)	TOPSIS	A320, A321, B737-800 and B737-900ER	B737-800
Deveci et al (2021)	Interval type-2 hesitant fuzzy Entropy-based WASPAS method.	B738, B78C, B79L, A 321 A32C, A 320, A319	A320C
(Kiracı et al. 2020)	AHP and TOPSIS in interval type-2 fuzzy sets	A319Neo, A320Neo. A321Neo, B737Max7, B737Max8, B737Max9	A321Neo
(Ilgın, 2019)	Linear Physical Programming	A319Neo, A320Neo, A321Neo, B798MAX 7, B737 Max8, B737 Max9.	A321 Neo

As seen the results in Table 8, the best alternative aircraft in the literature (Kiracı et al, 2020; Ilgin, 2019) are consistent with the results obtained by Fuzzy TOPSIS and Fuzzy MOORA methods in this study. When considered two studies, alternative aircraft were selected only from the new generation aircraft models of Airbus and Boeing. However, in this study, classical and new generation of aircraft models of Airbus and Boeing and different types of CS and ERJ aircraft models could be considered for low-cost airlines.

5. Conclusion

Fleet planning is a long-term strategic decision leading an airline to success or failure, both financially and in prestige. For fleet planning, the business model adopted by the airlines and the criteria, which are determinants of the current dynamics and conditions, are very important in aircraft selection decisions. These criteria, which can cause very different decisions for companies, create a multi-criteria decision-making environment for aircraft selection decisions. In this study, a decision support model that can be used for aircraft type selection in fleet planning for an airline that adopts a low-cost airline business model was created, and Fuzzy TOPSIS and Fuzzy MOORA were used for evaluation.

This study is the one in which the highest number of aircraft models are evaluated together for the first time in the literature. In the model, alternative aircraft to be evaluated is composed of classical and new generation narrow-body aircraft models of the world's two most known manufacturers, Airbus and Boeing companies, as well as Brazilian (Embraer) and Bombardier-Airbus Partnership models (CS 300-100). Methodologically, for the first time, the Fuzzy MOORA method was applied in this field.

In the researches and the interviews made with the airline fleet planning experts, it has been understood that economical and technical main criteria have very important weight for low-cost airlines. When the sub-criteria are examined, the highest importance weights are given to range, carrying capacity and fuel efficiency, which are the subcriteria of technical criteria and aircraft price, financing opportunities, aircraft similarity and cost per available seat-mile, which are the subcriteria of economic criteria.

Since the development of the technical features of the aircraft is effective in providing economic benefits in the operation of the aircraft, it has become the focus of interest of low-cost airline companies and has been the factor in giving more importance to the technical features of the aircraft types in their fleet structures. Political criteria, on the other hand, have not been included in any study in the literature and they were included in this decision support model for the first time.

In countries where political relations are problematic, embargoes applied to those countries are seen as very important criteria in terms of purchasing and supplying spare parts of the aircraft. The best example of this situation is the difficulty faced by Iranian airline companies in the supply of aircraft as the consequence of the embargo put by the United States of America

Looking at the evaluations in the decision matrices made by the experts, it has been determined that the new generation aircraft are more preferred over the classical models. The new generation aircraft's features, which are fuel efficiency, passenger satisfaction, less noise pollution and CO_2 emissions and high demand, have been effective in these choices. However classical models also have a price advantage over new generation aircraft.

Among the alternatives, although Embraer and Bombardier aircraft, which are generally preferred for regional transportation, have significant price advantages, they are at the bottom of the ranking due to low scores in almost all other criteria. If the low-cost airlines aim to provide regional transportation, Embraer and Bombardier aircraft preferences may be able to come to the fore.

In this study, the aircraft selection decision support model for low-cost carriers has been developed and proposed. This decision support model can be easily applied and modified by the airlines having different business models according to the considerations of the criteria.

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