Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.3, No.3, pages: 61-75

Airplane Selection to Renovate Air Transportation System: a Multi-Criteria Decision-Making Problem

Arash Rasaizadi [1*], Ali Ardestani [1], Nasim Nahavandi [2]

[1*] *Department of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran*

(Arash_rasaizadi@modares.ac.ir)

[2] *Associate Professor, Department of Industrial and Systems Engineering, Tarbiat Modares University, Tehran, Iran*

(Date of received: 10/06/2021, Date of accepted: 22/09/2021)

ABSTRACT

As one of the main infrastructures of the air transportation system, the air fleet has a significant effect on the operation at a reasonable cost. Deciding on the commensurate airplane to renovate the fleet falls into the multi-criteria decision-making (MCDM) problems. Airplane comparison criteria are very diverse, and no airplane is the best based on all criteria. In this study, selecting commensurate airplanes for airlines that meet domestic air transportation demand was investigated. The alternatives considered were Airbus airplanes, which were evaluated and compared based on six indices: price, maximum takeoff weight, passenger capacity, fuel capacity, the volume of passengers' space, and volume of the cargo compartment. Also, several MCDM techniques require different levels of computational and maybe produce different outputs. The results of the different methods are not the same. To ensure consistency, accuracy and increase the reliability of the results, several methods were applied. Four different MCDM methods were used to make a comprehensive comparison, including analytic hierarchy process (AHP), simple additive weighting (SAW), and technique for order of preference by similarity to ideal solution (TOPSIS), and elimination et choice translating reality (ELECTRE). The results showed that the Airbus A318 airplane is selected as the top alternative based on these indices and using all four methods. The difference between the results of each method revealed for ranks 2-6. Based on AHP, TOPSIS and SAW, the second rank was designated to Airbus 319. However, ELECTRE had a different rank for this airplane.

Keywords:

AHP, Airplane selection, Electre Saw, Topsis.

1. Introduction

Making a balance between travel supply and demand is one of the most vital goals of transportation planning. This balance must be maintained in all aspects of transport, including air [1], rail [2], road [3], and maritime [4]. One of the most crucial procedures to meet air transportation demand is the optimal selection of the airline's fleet. In addition to meeting the demand for transportation by balancing supply and demand, the quality of service is essential in the level of air transportation service. The level of service from the passengers' point of view can include the frequency of flights, optimal service time, comfort and attractiveness of the airplanes [5]. However, lower operating costs are more desirable for airlines to achieve higher profits. In addition to the level of service specifications, the airplane's mechanical specifications play an essential role in its selection. Therefore, considering various factors such as economic issues, common interests, airplane performance, mechanical structure, budget, and market evaluation are essential in choosing the number and structure of the air transport fleet. Since there is usually no alternative superior to other alternatives regarding all these features, the MCDM problem is considered [6]. Using MCDM methods, it is possible to compare the alternatives that each have a comparative advantage over the other, and finally identify the top alternative (alternatives) [7]. In this study, the airplane was selected for an airline that plans for domestic and short distances travel. Dožić and Kalić [8] studied airplane selection in 2014. This study aims to solve the problem of optimal airplane selection for specific routes of the air transport network that satisfies the demand for air travel in the future. For this purpose, the Hierarchical Analysis Process (AHP) method is used. The reason for choosing this method to solve the problem is the relationship between the problem and the field related to AHP, the acceptable logic of the AHP method, and the relatively simple calculations. The AHP method was developed in 1980 for hourly decision making based on multiple criteria. This method examines the selected indices and available alternatives to achieve the optimal alternative and weigh the alternatives. This method's main logic is the quantitative and qualitative comparison of alternatives in two ways. Finally, quantitative and qualitative indices quantitatively compare the alternatives with each other [8]. The hierarchy used in this study based on the AHP method for the optimal selection of airplane is as follows:

At the first level of the hierarchical analysis process, the overall goal is to select the airplane type. In the second level, six indices are proposed to select the airplane to achieve the goal. These six indices include the following: airplane passenger capacity (number of seats as a factor in balancing supply and demand), airplane price (as investment cost to purchase airplane), total cargo (as the airplane capacity for cargo), Maximum takeoff weight (MTOW), payment terms (based on the offer of airplane sales companies) and total cost per seat and per mile (as operating costs). At the third level, there are the types of airplanes, including existing airplanes and new airplanes. These airplanes include the AT72-500, AT72-600, ERJ 190, Q400 NG, CRJ 700, CRJ 900, and CRJ 1000 models. After evaluating the alternatives and indices, the relative weight of the alternatives and indices are determined. Accordingly, the AT72-600 airplane is the priority, and the ERJ 190 airplane has the least priority. Also, a sensitivity analysis was performed in this study. For this purpose, the two indices' priority is reversed and compared with the other fixed numbers. For example, suppose the priority of load over the number of seats is three. In that case, the number of 0.333 is replaced, and the new results are compared in the sensitivity analysis.

Dožić and Kalić [9] also conducted a similar study in 2015. This study aims to evaluate the two methods of AHP and Even Swap Method (ESM) for the problem of airplane selection. This study is a continuation of their previous study, and the issue is the same. Also, the alternatives and indices did not change from the previous study. Since the details of the AHP method are studied in the previous study, the purpose of reviewing this study is to discuss the ESM method and compare the results obtained with the AHP method. The ESM method was developed in 1998 by Hammond et al. [10] to decide the alternatives based on several indices. The general basis of this method is to eliminate defeated alternatives or equal indices. In other words, unlike the AHP method, which ranked the alternatives in order of preference, the ESM method identifies only the superior alternative that dominates the other alternatives. In this method, by eliminating the defeated alternatives and equal indices, the problem is reduced to its smallest state, and the decision-maker chooses the superior alternative based on the importance of the indices. In this study, the ATR 72-600 airplane is selected as the superior alternative. The alternative selected based on the ESM method is the same as the alternative selected based on the AHP method. Lastly, the sensitivity of the results to changes in the payment terms index is investigated, which shows that the ESM method does not show any sensitivity to changes in this index. In contrast, the AHP method is sensitive to changes in this index. In 2011, Ozdemir et al. [11] used the Analytic Network Process (ANP) method to select airplanes for Turkish Airlines, Turkey's largest airline. In the ANP method, similar to the AHP method, the target levels, indices and alternatives are defined. The difference between ANP and AHP is the consideration of sub-levels that consider the internal relationship of indices or alternatives. The steps of the ANP method include the following:

Step 1: Analyze the problem and determine the primary goal

Step 2: Determine the indices and sub-indices

Step 3: Define the alternatives and sub-alternatives

Step 4: Determine the contrast between the indices, sub-indices, alternatives, sub-alternatives in the direction of the main goal

Step 5: Formation of supermatrix, weighted supermatrix and limited supermatrix

Step 6: Select the alternative with the highest priority

Indices and sub-indices are defined as follows: Cost index includes sub-indices of purchase cost, operating cost, maintenance cost and rescue cost; Time index includes sub-indices of delivery time and useful life; Physical Attributes index and others include sub-indices of dimensions, security, reliability, suitability for service quality. Alternatives include A319, A320 and B737 airplanes, and Super Decisions software is used to achieve final weights and priorities. Finally, the B737, A319 and A320 are in the top ten, respectively. In 2010, Čokorilo et al. [12] used the technique for order of preference by similarity to ideal solution (TOPSIS) method to solve the problem of selecting an airplane for an airline. This method was invented in 1981 [13]. After finding the positive and negative ideal in this method, we look for the alternative with the least distance from the positive ideal and the maximum distance from the negative ideal. Like all decision-making methods, there are several weighted indices and several alternatives. This study uses the hourly weight normalization method, which was also used in the AHP method, to find the indices' weight.

They used the following eight indices to select the airplane:

•Aerodynamic efficiency (depending on engine power and physical specification)

•Structural efficiency (maximum load over maximum structural load)

•Fuel Flow (Fuel consumption per minute for a 370 km route)

•Endurance (Time in minutes for a distance of 370 km)

•Trip fuel (Total fuel consumption on a 370 km route)

•Max range (Maximum distance traveled for a specified number of passengers, the weight of cargo, and amount of fuel)

•Ground efficiency (Includes features of the airplane that appear on the runway)

•Climb capabilities (The maximum altitude the airplane is capable of flying)

Alternatives include DO328, CRJ 100er, Saab 2000, ERJ 145 airplane models. Finally, the priority of the alternatives for this problem is as follows: 1) CRJ 100er, 2) Saab 2000, 3) ERJ 145 and 4) DO 328

There are other studies [14-20] in airplane selection as an MCDM problem; each of them is solved with only one or two methods. In this study, four different methods including AHP, simple additive weighting (SAW), TOPSIS, and elimination et choice translating reality (ELECTRE) have been investigated and compared to select more appropriate airplanes based on six indices. The study was conducted in Tehran, Iran in 2020.

2. Materials and Methods

This study aims to find an airplane with the highest profitability for a short-haul airline based on various indices. Airlines inside Iran usually have short-haul trips. For this reason, we are looking for commensurate airplanes for short-haul trips. The criteria for selecting an airplane in this study are as follows (airbus.com, 2021):

-Price: Certainly, lower-cost airplanes are more desirable for airlines, so this index is a negative index.

-Maximum takeoff weight (MTOW): The lower weight of the airplane at takeoff is one of the operational characteristics of the airplane; the lower it is, the more desirable. In addition to the need for more takeoff power, the airplane's heavier takeoff weight may also harm the runway pavement, so this is a negative index.

-Passenger capacity (number of seats): Because short-haul flights are considered in this study, less passenger capacity is more desirable for two reasons. First, it is more difficult for larger airplanes to fill out. Second, airlines prefer to increase the number of trips rather than have more capacity because of the short travel distance. Therefore, this index is also negative.

-Fuel capacity: The higher the fuel capacity, the lower the need for refuelling. Although the airplane may weigh more, it is generally a positive index.

-The airplane volume for each passenger: The more passenger space per capita, the more passenger comfort, and it means this is a positive index [21, 22].

-The volume of cargo compartment: The cargo compartment volume is a positive index for the airplane. In other words, the larger the volume, the more efficient the airplane in transporting cargo.

Six alternatives from the French Airbus airplane are considered as a selection of alternatives in this study: A318, A319, A320, A321, A330, and A350-900. Table 1 shows the properties of the alternatives based on the indices (airbus.com, 2021).

Table 1. Properties of alternatives based on indices.

Alternative	Price (million dollars)	MTOW (kg)	Passenger capacity (seats)	Fuel capacity (liter)	Volume of passengers space (passenger/m^3)	Volume of cargo compartment (m^3)
A318	75.1	59000	132	23859	0.81	46.00
A319	98.6	64000	156	23859	0.77	59.70
A320	98	73500	180	26759	0.77	73.75
A321	114.9	83000	220	26962	0.70	110.59
A330	231.5	212000	300	97530	1.24	373.80
A350-900	308.1	268000	315	138000	1.50	390.00

In the following, four methods AHP, SAW, TOPSIS, and ELECTRE are used to solve the problem and in the results analysis section, the results are compared.

3. Results and Discussions

3.1. AHP Method

According to the AHP method, the available indices and alternatives are provided in pairs, provided by manufacturers and experts, and they are scored based on their comparative advantage. Comparing the relative superiority of the indices and alternatives includes five equal, moderate, strong, very strong and very important states. Each of them is assigned the numbers 1, 3, 5, 7 and 9, respectively. Intermediate numbers are also acceptable as intermediate states. Fig. 1 shows the sequence of the existing problem [23].

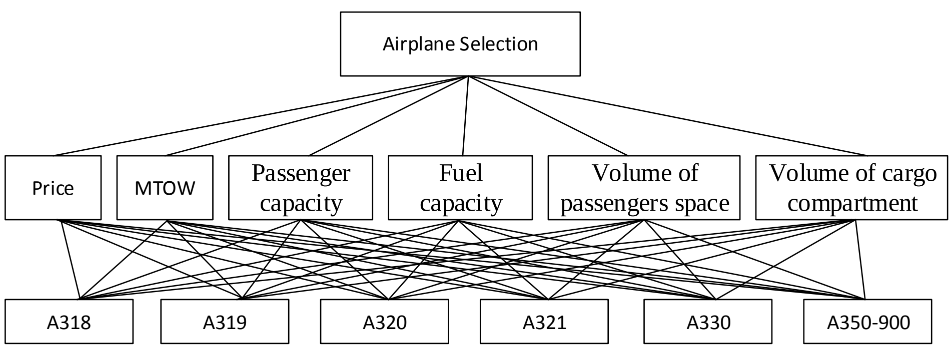

Figure 1. Hierarchy determined for the AHP method.

In this study, the Eigenvalue vector method is used to calculate weights and priorities. In fact, if we call the analogy matrix of alternatives and indices A, weights and priorities will be calculated using the largest Eigenvalue of this matrix. Also, the numbers assigned to the analogies must be logically and numerically stable [24]. For example, suppose the advantage of A to B is 3 and B to C is 1. In that case, we expect the superiority of A to C to be 3. To determine the instability of matrix A, the CR index is determined by Eq. 1 and Eq. 2 [23]:

$$CR = \frac{CI}{RI} \tag{1}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{2}$$

Where λ_{max} is the largest Eigenvalue of the matrix A; n is the number of alternatives or indices and RI is obtained from Table 2.

Table 2. RI coefficient values with respect to the value of n.

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Tables 3 to table 9 show the matrix comparison of indices and alternatives for each index. Finally, each table's critical output is the weight of the indices and the priority of the alternatives over each other separately for each index. Also, all matrices' CR index is less than the critical value of 0.1 and indicates their acceptable compatibility.

Table 3. Relative comparison of indices.

Index	Price	MTOW (kg)	Passenger capacity (seats)	Fuel capacity (liter)	Volume of passengers space (passenger/m3)	Volume of cargo compartment (m3)	Weight
Price (million dollars)	1	3	0.333	4	4	1	0.2173
MTOW (kg)	0.333	1	0.2	3	3	0.333	0.1282
Passenger capacity (seats)	3	5	1	5	5	3	0.3586
Fuel capacity (liter)	0.25	0.33	0.2	1	1	0.333	0.0491
Volume of passengers space (passenger/m3)	0.25	0.33	0.2	1	1	0.333	0.0621
Volume of cargo compartment (m3)	1	3	0.333	3	3	1	0.1847
λ_{max}=6.539		CI=0.108		RI=1.24		CR=0.087	

Table 4. Relative comparison of alternatives based on the price index.

Price	**A318**	**A319**	**A320**	**A321**	**A330**	**A350-900**	**Weight**
A318	1.000	2.000	2.000	3.000	5.000	7.000	0.291
A319	0.500	1.000	2.000	3.000	5.000	7.000	0.269
A320	0.500	0.500	1.000	2.000	3.000	5.000	0.175
A321	0.333	0.333	0.500	1.000	3.000	5.000	0.148
A330	0.200	0.200	0.333	0.333	1.000	4.000	0.088
A350-900	0.143	0.143	0.200	0.200	0.250	1.000	0.028
λ_{max}=6.255		CI=0.051		RI=1.240		CR=0.041	

Table 5. Relative comparison of alternatives based on MTOW index.

MTOW	A318	A319	A320	A321	A330	A350-900	Weight
A318	1.000	2.000	3.000	3.000	7.000	8.000	0.319
A319	0.500	1.000	2.000	3.000	5.000	6.000	0.233
A320	0.333	0.500	1.000	2.000	5.000	6.000	0.197
A321	0.333	0.333	0.500	1.000	5.000	5.000	0.162
A330	0.143	0.200	0.200	0.200	1.000	3.000	0.063
A350-900	0.125	0.167	0.167	0.200	0.333	1.000	0.027
λ_{max}=6.319		CI=0.064		RI=1.24		CR=0.051	

Table 6. Relative comparison of alternatives based on Passenger capacity index.

Passenger capacity	A318	A319	A320	A321	A330	A350-900	Weight
A318	1.000	2.000	3.000	5.000	7.000	7.000	0.324
A319	0.500	1.000	2.000	4.000	7.000	7.000	0.279
A320	0.333	0.500	1.000	3.000	5.000	6.000	0.205
A321	0.200	0.250	0.333	1.000	3.000	4.000	0.114
A330	0.143	0.143	0.200	0.333	1.000	2.000	0.050
A350-900	0.143	0.143	0.167	0.250	0.500	1.000	0.029
λ_{max}=6.241		CI=0.048		RI=1.24		CR=0.039	

Table 7. Relative comparison of alternatives based on Fuel capacity index.

Fuel capacity	A318	A319	A320	A321	A330	A350-900	Weight
A318	1.000	1.000	0.500	0.500	0.200	0.125	0.045
A319	1.000	1.000	0.500	0.500	0.200	0.125	0.045
A320	2.000	2.000	1.000	1.000	0.250	0.143	0.087
A321	2.000	2.000	1.000	1.000	0.250	0.143	0.087
A330	5.000	5.000	4.000	4.000	1.000	0.250	0.261
A350-900	8.000	8.000	7.000	7.000	4.000	1.000	0.475
λ_{max}=6.148		CI= 0.030		RI=1.240		CR=0.024	

Table 8. Relative comparison of alternatives based on the volume of passengers' space index.

Volume of passengers space	A318	A319	A320	A321	A330	A350-900	Weight
A318	1.000	3.000	3.000	3.000	0.200	0.143	0.127
A319	0.333	1.000	1.000	1.000	0.167	0.125	0.045
A320	0.333	1.000	1.000	1.000	0.167	0.125	0.045
A321	0.333	1.000	1.000	1.000	0.167	0.125	0.045
A330	5.000	6.000	6.000	6.000	1.000	0.250	0.298
A350-900	7.000	8.000	8.000	8.000	4.000	1.000	0.442
λ_{max}=6.290		CI=0.058		RI=1.24		CR=0.047	

Table 9. Relative comparison of alternatives based on the volume of cargo compartment index.

Volume of cargo compartment	A318	A319	A320	A321	A330	A350-900	Weight
A318	1.000	1.000	0.500	0.333	0.125	0.125	0.042
A319	1.000	1.000	0.500	0.500	0.143	0.143	0.045
A320	2.000	2.000	1.000	0.500	0.200	0.200	0.081
A321	3.000	2.000	2.000	1.000	0.250	0.250	0.116
A330	8.000	7.000	5.000	4.000	1.000	0.500	0.348
A350-900	8.000	7.000	5.000	4.000	2.000	1.000	0.369
λ_{max}=6.109		CI=0.022		RI=1.24		CR=0.017	

Finally, with the relative weights obtained for the alternatives and indices, the alternatives are ranked as Table 10.

Table 10. Final comparison of alternatives based on the AHP method.

Indices	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment	Final Vector	Ranking
Weight	0.217	0.128	0.359	0.049	0.062	0.185	-	-
A318	0.291	0.319	0.324	0.045	0.127	0.042	0.238	1
A319	0.269	0.233	0.279	0.045	0.045	0.045	0.202	2
A320	0.175	0.197	0.205	0.087	0.045	0.081	0.159	3
A321	0.148	0.162	0.114	0.087	0.045	0.116	0.122	6
A330	0.088	0.063	0.050	0.261	0.298	0.348	0.141	4
A350-900	0.028	0.027	0.029	0.475	0.442	0.369	0.139	5

3.2. SAW Method

The SAW uses the weights obtained from AHP for each index. First, the values of each alternative for each index are unscaled using Eq. 3 and Eq. 4. Finally, the ranking is done using a weighted average [25]. Table 11 shows the ranking results based on the SAW method

For positive index: $r_{ij} = \frac{x_{ij}}{max_j x_{ij}}$ (3)

For negative index: $r_{ij} = \frac{min_j x_{ij}}{x_{ij}}$ (4)

.

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.3, No.3, pages: 61-75

Table 3. Ranking of alternatives based on the SAW method.

Indices	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment	Final Vector	Ranking
Weight	0.217	0.128	0.359	0.049	0.062	0.185	-	
Index	r_{ij}						$\sum_{j=1}^{6} w_j r_{ij}$	
A318	1.000	1.000	1.000	0.173	0.539	0.118	0.768	1
A319	0.838	0.922	0.846	0.173	0.512	0.153	0.672	2
A320	0.766	0.803	0.733	0.194	0.514	0.189	0.609	3
A321	0.654	0.711	0.600	0.195	0.469	0.284	0.539	4
A330	0.324	0.278	0.440	0.707	0.825	0.958	0.527	6
A350-900	0.244	0.220	0.419	1.000	1.000	1.000	0.527	5

3.3. TOPSIS Method

In this method, after finding the positive and negative ideal answer, we look for the alternative with the least distance from the positive ideal and the maximum distance from the negative ideal [26]. Like all decision-making methods, there are several weighted indices and several alternatives. This study uses the hourly weight normalization method, which was also used in the AHP method, to find the indices' weight. Having the weight of indices from the AHP method, the steps of the TOPSIS method are performed as follows [27].

Step 1: Form a decision matrix that shows the performance of alternatives concerning indices.

Step 2: Calculate an unscaled decision matrix (Eq. 5).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{5}$$

Step 3: Calculate a weighted unscaled decision matrix (Eq. 6).

$$v_{ij} = w_{ij} * r_{ij} \tag{6}$$

Step 4: Calculate the ideal and counter-ideal answers.

Step 5: Calculate the distance of each alternative from the ideal and counter-ideal answers (Eq. 7 and Eq. 8).

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - A_j^+)^2} \tag{7}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - A_j^-)^2} \tag{8}$$

Step 6: Calculate the final vector for ranking (Eq. 9)

$$C_i = \frac{S_I^-}{S_I^- + S_I^+} \tag{9}$$

The results of these steps are presented in Table 10 to Table 14.

Table 4. The unscaled decision matrix.

R_{ij}	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment
A318	0.175	0.160	0.236	0.135	0.327	0.082
A319	0.208	0.173	0.279	0.135	0.310	0.106
A320	0.228	0.199	0.322	0.152	0.312	0.131
A321	0.267	0.225	0.394	0.153	0.284	0.197
A330	0.538	0.574	0.537	0.553	0.500	0.666
A350-900	0.716	0.725	0.564	0.782	0.607	0.695

Table 5. The unscaled weighted decision matrix.

V_{ij}	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment
A318	0.038	0.020	0.085	0.007	0.020	0.015
A319	0.045	0.022	0.100	0.007	0.019	0.020
A320	0.050	0.025	0.116	0.007	0.019	0.024
A321	0.058	0.029	0.141	0.008	0.018	0.036
A330	0.117	0.074	0.193	0.027	0.031	0.123
A350-900	0.156	0.093	0.202	0.038	0.038	0.128
max	0.038	0.020	0.085	0.038	0.038	0.128
min	0.156	0.093	0.202	0.007	0.018	0.015

Table 6. The distance of each alternative from the ideal answer of each index.

S^+	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment	Sum
A318	0.000	0.000	0.000	0.001	0.000	0.013	0.014
A319	0.000	0.000	0.000	0.001	0.000	0.012	0.013
A320	0.000	0.000	0.001	0.001	0.000	0.011	0.013
A321	0.000	0.000	0.003	0.001	0.000	0.008	0.013
A330	0.006	0.003	0.012	0.000	0.000	0.000	0.021
A350-900	0.014	0.005	0.014	0.000	0.000	0.000	0.033

Table 7. The distance of each alternative from the counter ideal answer of each index.

S^-	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment	Sum
A318	0.014	0.005	0.014	0.000	0.000	0.000	0.033
A319	0.012	0.005	0.010	0.000	0.000	0.000	0.028
A320	0.011	0.005	0.008	0.000	0.000	0.000	0.023
A321	0.010	0.004	0.004	0.000	0.000	0.000	0.018
A330	0.001	0.000	0.000	0.000	0.000	0.012	0.014
A350-900	0.000	0.000	0.000	0.001	0.000	0.013	0.014

Finally, the alternatives are ranked using the TOPSIS method, as shown in Table 14.

Table 8. Final ranking based on TOPSIS method.

Alternative	Final Vector	Ranking
A318	0.700	1
A319	0.673	2
A320	0.639	3
A321	0.569	4
A330	0.405	5
A350-900	0.302	6

3.4. ELECTRE Method

According to this method, the alternatives are ranked according to their dominance over each other. The weights used for this method are the same as the weights of the hourly method. The steps of this method are as follows [28]:

Step 1: Form a decision matrix that shows the performance of alternatives concerning indices.

Step 2: Determine the unscaled decision matrix (Eq. 10)

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{10}$$

Step 3: Calculate the unscaled weighted decision matrix (Eq. 11)

$$\mathrm{v_{ij}} = \mathrm{w_{ij}} * \mathrm{r_{ij}} \tag{11}$$

Step 4: Form the agreement and disagreement vector (Eq. 12 and Eq. 13)

$$\mathrm{C_{ke}} = \{\mathrm{J} \,|\, \mathrm{v_{kj}} \geq \mathrm{v_{cj}} \text{ for possitive attributes}, \mathrm{v_{kj}} \leq \mathrm{v_{cj}} \text{ for negetive attributes}\} \tag{12}$$

$$\mathrm{D_{ke}} = \{\mathrm{J} \,|\, \mathrm{v_{kj}} < \mathrm{v_{cj}} \text{ for possitive attributes}, \mathrm{v_{kj}} > \mathrm{v_{cj}} \text{ for negetive attributes}\} \tag{13}$$

Step 5: Form the agreement and disagreement matrix (Eq. 14 and Eq. 15)

$$C_{kc} = \sum_{J \in C_{ke}} W_j \tag{14}$$

$$D_{kc} = \frac{max_{J \in D_{ke}} \left| v_{kj} - v_{cj} \right|}{max_J \left| v_{kj} - v_{cj} \right|} \tag{15}$$

Step 6: Form the agreement and disagreement dominance matrix (Eq. 16 to Eq. 19)

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.3, No.3, pages: 61-75

$$\bar{C} = \sum_{k=1}^{m} \sum_{c=1}^{m} \frac{C_{kc}}{m(m-1)} \tag{16}$$

$$F_{kc} = \begin{cases} 1 \; if \; C_{kc} \geq \bar{C} \\ 0 \quad\quad else \end{cases} \tag{17}$$

$$\bar{D} = \sum_{k=1}^{m} \sum_{c=1}^{m} \frac{D_{kc}}{m(m-1)} \tag{18}$$

$$G_{kc} = \begin{cases} 1 \text{ if } D_{kc} \geq \bar{D} \\ 0 \quad\quad \text{else} \end{cases} \tag{19}$$

Step 7: Form the final dominance matrix (Eq. 20)

$$E_{kc} = F_{kc} * G_{kc} \tag{20}$$

Table 15 to Table 20 show the steps of the ELECTRE method for ranking alternatives.

Table 9. The unscaled weighted decision matrix.

V_{ij}	Price	MTOW	Passenger capacity	Fuel capacity	Volume of passengers space	Volume of cargo compartment
A318	0.038	0.020	0.085	0.007	0.020	0.015
A319	0.045	0.022	0.100	0.007	0.019	0.020
A320	0.050	0.025	0.116	0.007	0.019	0.024
A321	0.058	0.029	0.141	0.008	0.018	0.036
A330	0.117	0.074	0.193	0.027	0.031	0.123
A350-900	0.156	0.093	0.202	0.038	0.038	0.128

Table 10. The agreement matrix.

C_{kc}	A318	A319	A320	A321	A330	A350-900
A318	0.000	0.815	0.766	0.766	0.704	0.704
A319	0.234	0.000	0.704	0.766	0.704	0.704
A320	0.234	0.296	0.000	0.766	0.704	0.704
A321	0.234	0.234	0.234	0.000	0.704	0.704
A330	0.296	0.296	0.296	0.296	0.000	0.704
A350-900	0.296	0.296	0.296	0.296	0.296	0.000

Table 17. The disagreement matrix.

D_{kc}	A318	A319	A320	A321	A330	A350-900
A318	0.000	0.292	0.296	0.376	1.000	0.961
A319	1.000	0.000	0.300	0.407	1.000	0.984
A320	1.000	1.000	0.000	0.472	1.000	0.980
A321	1.000	1.000	1.000	0.000	1.000	0.942
A330	1.000	0.895	0.781	0.680	0.000	0.291
A350-900	1.000	1.000	1.000	1.000	1.000	0.000

Table 18. The agreement dominance matrix

F_{kc}	A318	A319	A320	A321	A330	A350-900
A318	0	1	1	1	1	1
A319	0	0	1	1	1	1
A320	0	0	0	1	1	1
A321	0	0	0	0	1	1
A330	0	0	0	0	0	1
A350-900	0	0	0	0	0	0

Table 19. The disagreement dominance matrix.

G_{kc}	A318	A319	A320	A321	A330	A350-900
A318	0	1	1	1	0	0
A319	0	0	1	1	0	0
A320	0	0	0	1	0	0
A321	0	0	0	0	0	0
A330	0	0	1	1	0	1
A350-900	0	0	0	0	0	0

Table 20. The final dominance matrix.

E_{kc}	A318	A319	A320	A321	A330	A350-900
A318	0	1	1	1	0	0
A319	0	0	1	1	0	0
A320	0	0	0	1	0	0
A321	0	0	0	0	0	0
A330	0	0	0	0	0	1
A350-900	0	0	0	0	0	0

Finally, the alternatives are ranked according to the ELECTRE method according to Table 21.

Table 21. Final ranking based on ELECTRE method.

Alternative	Ranking
A318-A330	1
A350-A319	2
A320	3
A321	4

4. Conclusions

Choosing an airplane to complement the airline fleet is one of the essential issues in transportation planning. Because there are several different indices, some of which may contradict each other, the decision-making process becomes complicated. In such cases, decision-making methods based on several indices can help find the right alternative. In the defined problem, the goal is to find a suitable airplane for domestic and short-haul flights. Completing a large airplane's capacity requires more time and a more significant frequency between two consecutive flights. In this case, flight services will be reduced for different hours of the day. Suppose the airline wants to provide various services at different times of the day. The airplane's capacity will probably not be full. Therefore, from the decision-makers' perspective, flights with smaller and more frequent airplanes are more economical than flying with larger and less frequent airplanes. Therefore, less airplane capacity is more desirable and this index is considered as a negative index. Regardless of this point, other indices are always positive or negative indices and their nature does not change.

In this study, four methods for selecting airplanes with different approaches are investigated. These methods include AHP, SAW, ELECTRE and TOPSIS method. Comparing the alternative and performance of the methods, gives the decision-maker the assurance that the superior alternative is evaluated and approved based on different methods. The result of this study shows that the A318 is the most suitable alternative by comparing the methods. However, the methods may have different results for the alternatives in the next priority. As the buyer of the airplane, the decision-maker has reached a particular alternative if he is only looking for a superior alternative. However, suppose he wants to buy a variety of airplanes. In that case, he can evaluate the second and subsequent rankings based on the evaluation of all four MCDM methods. For example, although the A319 is in the third rank according to the ELECTRE method, it has the second priority based on AHP, SAW and TOPSIS method. It can be considered a second alternative.

5. References

[1]-Loh, H. S., 2020, **Airport selection criteria of low-cost carriers: A fuzzy analytical hierarchy process**, Journal of Air Transport Management, 83,101759.
[2]-Du, Y., 2020, **Decision-making method of heavy-duty machine tool remanufacturing based on AHP-entropy weight and extension theory**, Journal of Cleaner Production, 252, 119607.
[3]-Batouei, A., 2020, **Components of airport experience and their roles in eliciting passengers' satisfaction and behavioral intentions**, Research in Transportation Business & Management, 37, 100585.
[4]-Celik, E. and Akyuz, E., 2018, **An interval type-2 fuzzy AHP and TOPSIS methods for decision-making problems in maritime transportation engineering: the case of ship loader**, Ocean Engineering, 155, 371-381.
[5]-Zaim, H., 2009, **Analysing business competition by using ahp weighted topsis method: An example of turkish domestic aviation industry**, in International Symposium on Sustainable Development, Citeseer.
[6]-Liu, Y., Eckert, C. M. and Earl, C., 2020, **A review of fuzzy AHP methods for decision-making with subjective judgments**, Expert Systems with Applications, 113738.
[7]-Janic, M. and Reggiani, A., 2002, **An application of the multiple criteria decision making (MCDM) analysis to the selection of a new hub airport**, European Journal of Transport and Infrastructure Research, 2(2/3), 121-134.
[8]-Dožić, S. and Kalić, M., 2014, **An AHP approach to aircraft selection process**, Transportation Research Procedia, 3, 165-174.
[9]-Dožić, S. and Kalić, M., 2015, **Comparison of two MCDM methodologies in aircraft type selection problem**, Transportation Research Procedia, 10, 910-919.
[10]-Hammond, J. S., Keeney, R. L. and Raiffa, H., 1998, **Even swaps: A rational method for making trade-offs**, Harvard business review, 76, 137-150.
[11]-Ozdemir, Y., Basligil, H., and Karaca, M., 2011, **Aircraft selection using analytic network process: a case for Turkish airlines**, in Proceedings of the World Congress on Engineering (WCE).
[12]-Čokorilo, O., 2010, **Multi attribute decision making: Assessing the technological and operational parameters of an aircraft**, Transport, 25(4), 352-356.
[13]-Hwang, C. L. and Masoud, A. S. M., 2012, **Multiple objective decision making—methods and applications: a state-of-the-art survey**, Springer Science & Business Media, 164.

[14]-Bruno, G., Esposito, E., and Genovese, A., 2015, **A model for aircraft evaluation to support strategic decisions**, Expert Systems with Applications, 42(13), 5580-5590.
[15]-Gomes, L. F. A. M., de Mattos Fernandes, J. E., and de Mello, J.C.C.S., 2014, **A fuzzy stochastic approach to the multi criteria selection of an aircraft for regional chartering**, Journal of Advanced Transportation, 48(3), 223-237.
[16]-Janic, M., 2015, **A multi-criteria evaluation of solutions and alternatives for matching capacity to demand in an airport system: the case of London**, Transportation Planning and Technology, 38(7), 709-737.
[17]-Lashgari, A., 2012, **Equipment selection using fuzzy multi criteria decision making model: key study of Gole Gohar iron mine**, Engineering economics, 23(2), 125-136.
[18]-Wang, Y., J. Zhu, and H. Sun, 2016, **A decomposition approach to determining fleet size and structure with network flow effects and demand uncertainty**, Journal of Advanced Transportation, 50(7), 1447-1469.
[19]-Zavadskas, E. K. and Z. Turskis, 2011, **multiple criteria decision making (MCDM) methods in economics: an overview**, Technological and economic development of economy, 17(2), 397-427.
[20]-Kazemi, A., Attari, M. Y. N. ,and Khorasani, M., 2016, **Evaluating service quality of airports with integrating TOPSIS and VIKOR under fuzzy environment**, International Journal of Services, Economics and Management, 7(2-4), 154-166.
[21]-Pamucar, D., 2021, **Multi-criteria decision analysis towards robust service quality measurement**, Expert Systems with Applications, 170, 114508.
[22]-Bakioglu, G. and Atahan, A. O., 2021, **AHP integrated TOPSIS and VIKOR methods with Pythagorean fuzzy sets to prioritize risks in self-driving vehicles**, Applied Soft Computing, 99, 106948.
[23]-Saaty, T. L., 2004, **Decision making—the analytic hierarchy and network processes (AHP/ANP)**, Journal of systems science and systems engineering, 13(1), 1-35.
[24]-Zhou, H., Y. Li, and Y. Gu., 2021, **Research on evaluation of airport service quality based on improved AHP and Topsis methods**. In Proceedings of the Institution of Civil Engineers-Transport. Thomas Telford Ltd.
[25]-Anggraeni, E. Y., 2018, **Poverty level grouping using SAW method**, International Journal of Engineering and Technology, 7(2.27), 218-224.
[26]-Keskin, B. and E. Ulas, 2017, **Does privatization affect airports performance? A comparative analysis with AHP-TOPSIS and DEA**, in new trends in finance and accounting, 335-345.
[27]-Opricovic, S. and G.-H. Tzeng, 2004, **Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS**, European journal of operational research, 156(2), 445-455.
[28]-Kou, G., 2012, **Evaluation of classification algorithms using MCDM and rank correlation**, International Journal of Information Technology & Decision Making, 11(01), 197-225.