

## Article

# A Combined Multi-Criteria Decision Making Approach for Improvement of Airlines' Ground Operations Performance: A Case Study from Türkiye

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**Abstract:** The airline sector is critical in today's globalized society, supporting the efficient movement of people and products worldwide. Airlines continuously seek methods to enhance their operational performance to remain competitive in the face of increased competition. This study focuses on the application of multi-criteria decision making (MCDM) techniques to improve the ground operational performance of low-cost carriers (LCCs), also known as low-cost (budget) airlines. In recent years, MCDM techniques have gained considerable attention in addressing complex decision problems with complex goals. This research aims to bridge this gap by proposing a comprehensive framework combining MCDM techniques to enhance airline operational strategies and increase performance. The study utilizes qualitative and quantitative data, drawing on previously published materials on MCDM techniques in the aviation sector. It utilizes a fuzzy Analytic Hierarchy Process (AHP) and a fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodologies. A case study is conducted to evaluate the ground operational performance of three airline companies based in Türkiye, considering five main criteria and eighteen sub-criteria. The findings of this research will contribute to a comprehensive understanding of operational performance in the airline sector. The study's findings show that five primary criteria's estimated weights are examined; it is seen that "Flight Schedule and Routes (FSR)" has the highest importance weight of 0.30. With a weight value of 0.26, "Counter Services (CS)" has the second most significant impact. "Ticketing (T)", which ranks third in terms of its impact on the solution, has a weight value of 0.19. Upon reviewing the analysis's findings, it can be seen that the third alternative is relatively prominent among the others. Airline\_3 ranked first with a weight value of 0.361, while Airline\_2 ranked second with a weight value of 0.331. Airline\_1 ranked last with an actual weight of 0.308. The study provides highlights of the implications and limitations of the research and suggests future research directions.

**Keywords:** MCDM; multi-criteria decision making; fuzzy AHP; fuzzy TOPSIS; selection; evaluation; airline sector; operational performance; low-cost carriers; low-cost airline



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## 1. Introduction

In today's globalized world, the airline business is essential to the quick and effective transport of individuals and products worldwide. Airlines continually seek ways to improve their business operations and obtain a competitive edge due to the growing competition. Several main factors, including both long- and short-term planning, fleet and crew planning, safety, reliability, cost-effectiveness, customer satisfaction, and environmental impact, are included in an airlines' operational performance. Airlines face several optimization and decision-making challenges. A robust decision-making structure that considers all the factors and offers efficient performance improvement solutions is needed to solve these multifaceted difficulties. Recently, the airline industry has drawn substantial attention to MCDM methods as a way to deal with complicated business decision problems

comprising numerous divergent goals. The interdependencies and alternatives between various performance metrics are considered when using MCDM approaches to assess and rank alternatives in accordance with a set of criteria. Airlines can systematically evaluate their operational performance and discover opportunities for improvement by using combined MCDM strategies and techniques.

The study will refer to previously published materials on MCDM techniques and their use in the aviation sector. To build a robust decision-making model that can accurately represent the intricacies and dynamism of airlines' operational performance, it will make use of both qualitative and quantitative data. The advancement of new methods for improving airlines performance is critical; however, that sort of problem takes time to solve due to the vast number of complicated factors concerned.

Even though MCDM techniques have been widely used in other industries, their use in the aviation sector still needs to be more consistent [1]. The few studies that examined the application of MCDM techniques to the airline industry have mainly concentrated on specific decision issues, including route selection and traffic management [2]. Earlier studies mostly concentrated on the different parameters regarding service quality issues. Wang et al. (2011) evaluated "customer perceptions on airline service quality in uncertainty" with the DEMATEL approach [3]. The dimensions on the study were set as "reliability, care and concern, tangibility, assurance, and reaction". The sub-criteria for the ground services were set as "on-time flights, training of personnel, attitude, and behavior of service staff, handling complaints, easy booking process, and optimal ticket prices" [3]. Nejati et al. (2009) similarly ranked airline service quality using fuzzy TOPSIS [4]. Chen and Chen (2010) constructed "a revolutionary aviatic innovation system (AIS) to equip Taiwanese airlines with innovative strategies for future strategic development" [5]. They used a fuzzy MCDM with the VIKOR model. Tsai et al. (2011) proposed a "model for the evaluation of web-based marketing" to attract loyal customers [6]. They employed DEMATEL, ANP, and VIKOR to rank and evaluate the criteria where web-based marketing actions were proposed to the managers for better strategic decision making. Chen (2016) used "DEMATEL and ANP for the selection of quality improvement" of airline services in Taiwan [7]. The main criteria selected were "safety, service, satisfaction, and management". Similarly, Delbari et al. (2016) examined "the key indicators and drivers" of airline services in terms of competitiveness [8]. They employed Delphi and AHP techniques. Those main eight criteria follow as "price, quality, profitability, productivity, cost, market share, timeliness, and safety". Barros and Wanke (2015) analyzed airline efficiency in 29 African airlines using the TOPSIS method [9].

Some studies focused on the airport and facilities in relation to the airline service sector. Chien-Chang (2012) evaluated the quality of the airport services in addition to airline company offerings. The study concentrated on four main criteria: "check-in, immigration process, customs, inspection, and overall service parameters," with twenty sub-criteria sets for Taoyuan and Kaohsiung Airports [10]. Pandey (2016) evaluated the quality of service in two main airports, namely the Suvarnabhumi and Don Mueang airports in Thailand, using AHP and IPA methods [11]. The main criteria for evaluation were "access, check-in, security, finding your way, facilities, environment, and arrival services", with thirty-three sub-criteria including "parking, baggage, ground transportation, waiting time, efficiency, staff assistance, safety, ease to find all information regarding flight or navigation, connection support, restaurants, facilities, wi-fi, lounges, cleanliness, passport control, and custom services". Janic (2015) also studied the "solutions and alternatives for matching capacity to demand in an airport system facility" for building a runway to solve the problem in terms of the given operating scenarios [12]. The study compared three airports in London: Heathrow, Gatwick, and Stansted.

Dincer et al. (2017) contributed to the MCDM field by utilizing "fuzzy DEMATEL, fuzzy ANP, and MOORA" on a "balanced scorecard-based performance measurement of European airlines" [13]. The criteria used for the research were mainly "customer profitability, employee perspective, and strategic initiatives" to understand the overall performance

indicators. Gudiel Pineda et al. (2018) proposed a solution on “improving airline operational and financial performance” using integrated MCDMs by using DRSA data mining, DEMATEL ANP, and VIKOR [14]. The large-scale of criteria falls into two dimensions: operational and financial. Those factors were “freight, weather delays, diverted delays, canceled flights, security, aircraft arrivals late, labor, and baggage, operating revenue, and net income, fees for various services, fuel cost and consumption”. Dozic (2019) contributed to the airline sector with a detailed literature review and highlighted the main dimensions and related criteria as follows: airlines’ “service quality, partner selection, fleet management, competitiveness, financial performance, safety, responsibility, and operational factors”; airports’ “performance, service quality, location, safety, others”; and Air traffic Management (ATM). The other dimensions were “maintenance, military issue, air cargo, mode of transport, web-based marketing, aircraft, helicopter, and sustainability” [15]. Bakir et al. (2020) studied an MCDM approach (PIPRECIA and MAIRCA methods) to conducting an operational performance evaluation in the full-service airline carriers of emerging markets, namely Mexico, China, Indonesia, Brazil, India, and Türkiye [16]. The study covered 11 leading companies with a list of criteria including “operating cost, operating revenues, fleet size, load factor, number of employees, passengers carried, available seat kilometers, and revenue passenger kilometers”. Mahtani and Garg (2018) analyzed the factors affecting the airline’s financial performance in six main categories using a fuzzy AHP [17]. One of the main categories was the operational factors: “load factor, average passenger carried per departure, crew working hours, departures by per aircraft, pilots for each departure, international operations, average age of aircraft fleet, and different brands of aircraft”.

Moreover, various aviation applications considered various operational and technical aspects. Akyurt et al. (2021) suggested that airport selection is vital for pilot training academy programs; the right decisions lead to a positive impact on the operations [18]. They employed a “Rough MACBETH and RAFSI-based decision-making analysis”. They identified the four main criteria as “weather, cost, technical, environmental and social” and twenty-four sub-criteria related to them. Liang et al. (2022) proposed the effectiveness of airspace planning by evaluating “air traffic flow (ATC)” with a real-time simulation and utilizing the MCDM TOPSIS method [19]. Those criteria were set as “air traffic flow, airspace operational performance, flight procedure quality, cost, controller workload, and pilot workload.” Deveci et al. (2022) concentrated on reducing the risk of schedule problems for carrier airline operations [20]. Their research’s four main criteria were “passenger preference, competition, availability, and connection”, with twelve sub-criteria related to the schedule, departure time, location-based slot availability, and types of availability at different levels. The information, frequency, operational, and commercial constraints were the most prolific elements considered for the operational performance improvement areas.

Some of the other indirect but similar research concentrates on and contributes to the MCDM methods from a general perspective in addition to airline sector research. Wanke et al. (2015) analyzed the Asian airline companies using TOPSIS in efficiency and service operations proposals [21]. Sengul et al. (2015) studied “ranking renewable energy supply systems” using a fuzzy TOPSIS [22]. Kavus et al. (2022) proposed “a three-level framework to evaluate airline service quality” using an AHP [23]. Şahin et al. (2023) used fuzzy SWARA and fuzzy COPRAS methods for a “Green Lean Supplier Selection” [24]. Pandey (2020) assessed “the strategic design parameters of Thailand airports”. The research aimed “to meet service expectations of Low-Cost” carriers [25]. A fuzzy-based QFD method was employed, and twenty-two main evaluation criteria were set.

Furthermore, studies are looking at the different perspectives on how well airlines operate, and there is a research gap when it comes to creating a comprehensive framework for making decisions that incorporate multi-criteria decision making (MCDM) methods to improve operational performance in the airline industry. There is, however, a dearth of research that considers the multidimensional character of operational performance and offers a comprehensive strategy that concurrently addresses several performance criteria.

A research gap that must be filled in creating a thorough MCDM strategy designed particularly for enhancing airline operational performance. The suggested study intends to close this research gap by proposing a combined MCDM strategy that considers numerous main factors, such as quality assurance, employee perspective, process efficiency, capacity planning and management, and cost-effectiveness, to improve low-cost airline operational performance. This research will lead to a broader and complete knowledge of operational outcomes in the airline sector by combining multiple performance indicators into an integrated decision-making framework. This study also aims to evaluate the operational performance of the three airline companies within the abovementioned five main criteria and eighteen sub-criteria. The company's headquarters are located in Türkiye and operate various domestic and international destinations. The paper focuses on selecting the best alternative airline due to its business operation, services, and main qualities according to the evaluation criteria. The research questions are formulated as follows in light of the study's aims and scope:

RQ1\_ What are the criteria for the operational performance evaluation of airlines?

RQ2\_ What are the weights of the operational performance criteria, and how are the alternatives ranked?

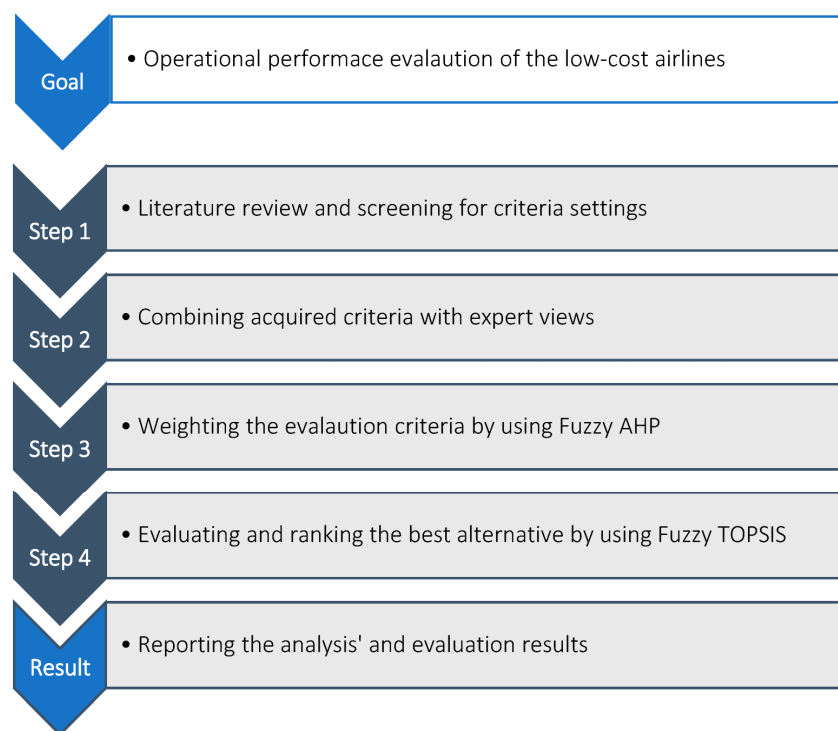
RQ3\_ How are the best operationally performing airlines selected?

The paper is organized as follows: an introduction with an extensive literature review, the materials and techniques (the fuzzy AHP and fuzzy TOPSIS methodologies utilized as a hybrid multi-criteria decision-making approach), and a case study conducted to evaluate the airline company's operational performance. The criteria were chosen via a literature search with expert opinion, and after being categorized in the criteria list, they were weighted using fuzzy AHP. Fuzzy TOPSIS was used for the process evaluation step to identify and rank the top-performing airlines. The final part of the manuscript contains the discussion and conclusion, including the implications and limitations of the study, and potential future research directions.

## 2. Materials and Methods

The goal of the research area known as "Multiple Criteria Decision Making" (MCDM) is to assist decision makers when they must weigh several competing criteria or objectives. In such complex decision-making scenarios, MCDM provides a structured framework to analyze, evaluate, and rank alternatives based on their performance across different criteria [26]. MCDM is significant because of its capacity to manage decision complexity, improve decision quality, involve stakeholders, and allow domain-specific solutions. MCDM enables decision makers to negotiate the obstacles of multi-criteria decision problems while making more informed and beneficial decisions by providing organized methodologies and tools [27–29].

The study offers an evaluation approach that prioritizes the corresponding weights of three low-cost carriers (LCC), also known as low-cost (budget) airline companies, for ground service operations. The suggested method comprises several subsequent phases. In the first stage, five primary criteria and eighteen distinct sub-criteria are developed from the support of the current literature provided in the "Introduction section" with expert opinions; similar methodologies are applied as in previous research [30]. In the second stage, the defined criteria are weighted by relevant stakeholders using the fuzzy AHP method, which helps further analysis. Hereafter, the fuzzy TOPSIS approach was used to rank the three Turkish low-cost carriers (airlines) in the third stage. The fuzzy technique is utilized in decision making because the selection criteria are not represented numerically. Figure 1 depicts the research flow of the assessment procedure.



**Figure 1.** The research procedure.

### 2.1. The Fuzzy AHP Method

The fuzzy AHP approach was developed utilizing fuzzy logic [31] and a classical AHP method [32–34] together and is commonly used to remove ambiguity from decision-making processes [35]. In the fuzzy AHP method, fuzzy integers are employed in pairwise comparisons to convey expert judgments.

In the MCDM literature, there are many fuzzy AHP methods such as “Buckley’s (1984) Fuzzy AHP method” [36], “Chang’s extent analysis method” [37,38], Enea and Piazza’s (2004) fuzzy AHP method [39], and Van Laarhoven and Pedrycz’s (1983) fuzzy AHP method [40]. Chang’s extended analysis approach has become the most popular in the literature since it is extremely close to the traditional AHP phases and is simple to implement. This study explains the method in detail, and the solution is conducted with Chang’s method. According to this method, verbal comparisons between criteria are expressed using fuzzy triangular numbers (Table 1).

**Table 1.** Fuzzy numbers corresponding to linguistic expressions [37].

Verbal Importance	Triangular Fuzzy Numbers	Inverse Triangular Fuzzy Numbers
Equal importance	(1,1,1)	(1/1,1/1,1/1)
A little more important	(1,3,5)	(1/5,1/3,1/1)
Strongly important	(3,5,7)	(1/7,1/5,1/3)
Very strongly important	(5,7,9)	(1/9,1/7,1/5)
Totally important	(7,9,9)	(1/9,1/9,1/7)

When the literature is screened, it is seen that the fuzzy AHP method has a wide application area. Among these applications, the “shipping registry selection” [41], “supplier selection” [42,43], “evaluation of open and distance education websites” [1], “performance evaluation” [44], “evaluating machine tool alternatives” [45], “the evaluation of e-service quality in the airline industry” [46], “determining best teaching method” [47], “integrated



Quality Function Deployment methodology for hazelnut production" [48], "evaluating teaching performance" [49], "hospital site selection" [50], "selecting the suitable bridge construction method" [51], and "renewable energy dissemination program evaluation" [52] can be mentioned.

Step\_1:

With Equation (1), the fuzzy synthetic order value for the criteria is calculated as shown below.

$$S_i = \sum_{j=1}^m M_{gi}^j * \left[ \sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} \quad (1)$$

The following addition is performed to obtain the  $\sum_{j=1}^m M_{gi}^j$  value in the equation.

$$\sum_{j=1}^m M_{gi}^j = \left( \sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right) \quad (2)$$

According to Equation (3), the expression  $\left[ \sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]$  in Equation (1) is calculated.

$$\left[ \sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} = \left( \frac{1}{\sum_i^n u_i}, \frac{1}{\sum_i^n m_i}, \frac{1}{\sum_i^n l_i} \right) \quad (3)$$

Step\_2:

The probability of the expression  $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$  in obtaining the synthesis values is defined as follows:

$$V(M_2 \geq M_1) = \begin{cases} 1 & m_2 \geq m_1 \\ 0 & l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{other} \end{cases} \quad (4)$$

In order to compare  $M_1$  and  $M_2$ , both the values of  $V(M_2 \geq M_1)$  and  $V(M_1 \geq M_2)$  are required.

Step\_3:

The minimum values are taken because of the comparisons of all rows among themselves. Similarly, the second row is compared to all previous rows, and the lowest value is chosen. This procedure is repeated for all rows. The weight vector is created by adding the lowest values obtained for every single row.

$$W' = d'(A_1), d'(A_2), \dots, d'(A_n)^T \quad (5)$$

Step\_4:

W is computed by normalizing the weight vector produced in step 3.

$$W = d'(A_1), d'(A_2), \dots, d'(A_n)^T \quad (6)$$

W ceases to be a fuzzy number.

$$d(A_i) = \frac{d'(A_i)}{\sum_{i=1}^n d'(A_i)} \quad (7)$$

## 2.2. The Fuzzy TOPSIS Method

The "Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)" is a "comprehensive distance-based evaluation method" developed by Hwang and Yoon (1981) and can be expressed as a method for ranking the ideal solution [43,53]. TOPSIS focuses on locating the solution point nearest to the positive ideal solution while being the furthest away from the negative perfect solution [54]. The ideal solution or the most suitable alternative is the one that maximizes the benefit criterion and minimizes the cost criterion.

Fuzzy TOPSIS is a decision-making method used to select, rank, and evaluate the alternatives in quantitative and qualitative multi-criteria decision-making problems [55–62].

Fuzzy decision-making methods are necessary to incorporate human thoughts and evaluations in the solution process and make more realistic evaluations in ambiguous situations and events. In applying the fuzzy TOPSIS method, decision makers verbally express their judgments about the decision criteria and alternatives. The similarity coefficient for the alternatives is calculated by converting the decision makers' assessments about the criteria and alternatives into fuzzy numbers. The alternatives are listed using the calculated similarity coefficients, and the solution is presented. The fuzzy TOPSIS method developed by Chen (2000) is a method that can be applied in individual or group decision making. The linguistic evaluations and fuzzy number equivalents proposed by Chen and used in evaluating alternatives are shown below Table 2 [63].

**Table 2.** Linguistic variables for the ratings of alternatives.

Linguistic Variable	Triangular Fuzzy Number
Very Poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium Poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium Good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very Good (VG)	(9,10,10)

In a group of  $K$  decision makers, the aggregated fuzzy importance weight of the decision criteria affecting the problem and the aggregated fuzzy ratings of the alternatives according to each criterion can be calculated with the following equations.

$$\tilde{W}_{ij} = \frac{1}{K} [\tilde{w}_{ij}^1 + \tilde{w}_{ij}^2 + \cdots + \tilde{w}_{ij}^K] \quad (8)$$

$$\tilde{X}_{ij} = \frac{1}{K} [\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \cdots + \tilde{x}_{ij}^K] \quad (9)$$

The decision matrix ( $\tilde{D}$ ) and criterion weights ( $\tilde{W}$ ) of a multi-criteria decision problem can be represented as follows:

$$\tilde{D} = \begin{matrix} & \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ \cdots \\ A_m \end{matrix} & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{matrix}, \quad \tilde{W} = [\tilde{w}_1, \tilde{w}_2, \cdots, \tilde{w}_n] \quad (10)$$

where  $\tilde{x}_{ij}, (\forall i, j)$  ve  $\tilde{w}_j, j = (1, 2, 3, \cdots, n)$  are linguistic variables and  $A_1, A_2, A_3, \cdots, A_m$  are alternatives;  $K$  are the decision makers and their number;  $C_1, C_2, C_3, \cdots, C_n$  are the decision criteria;  $\tilde{x}_{ij}$  is the criterion value of the alternative  $A_i$  with respect to a decision criterion  $C_j$ ; and  $\tilde{w}_j$  is the importance weight of the criterion  $C_j$ .  $\tilde{D}$  is expressed as a fuzzy decision matrix and  $\tilde{W}$  as a matrix of fuzzy weights. The elements and weights of the matrix are represented as fuzzy numbers  $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$  and  $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ .

The next step is to calculate the normalized fuzzy decision matrix. This matrix is represented as follows:

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n} \quad i = 1, 2, 3, \cdots, m, \quad j = 1, 2, 3, \cdots, n. \quad (11)$$

Each element of the normalized fuzzy decision matrix is calculated by the following equations, with B representing the benefit and C the cost criteria:

$$\tilde{r}_{ij} = \left( \frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), \quad c_j^+ = \max c_{ij}, \quad \forall j \in B \quad (12)$$

$$\tilde{r}_{ij} = \left( \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{c_{ij}} \right), \quad a_j^- = \min a_{ij}, \quad \forall j \in C \quad (13)$$

It is ensured that the fuzzy number values in a normalized matrix are in the range of [0, 1]. After calculating the normalized decision matrix, the weighted normalized decision matrix is calculated by considering the importance weight of the criteria. The weighted normalized decision matrix is shown as

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n} \quad i = 1, 2, 3, \dots, m, \quad j = 1, 2, 3, \dots, n. \quad (14)$$

where  $\tilde{v}_{ij} = \tilde{r}_{ij} \cdot \tilde{w}_j$ .

The weighted normalized fuzzy decision matrix is obtained by multiplying the normalized fuzzy decision matrix with the fuzzy weight matrix. In this case, the calculated  $\tilde{V}$  matrix is shown as:

$$\tilde{V} = \begin{bmatrix} \tilde{w}_1 \tilde{r}_{11} & \tilde{w}_2 \tilde{r}_{12} & \vdots & \tilde{w}_n \tilde{r}_{1n} \\ \tilde{w}_1 \tilde{r}_{21} & \tilde{w}_2 \tilde{r}_{22} & \vdots & \tilde{w}_n \tilde{r}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{w}_1 \tilde{r}_{m1} & \tilde{w}_2 \tilde{r}_{m2} & \vdots & \tilde{w}_n \tilde{r}_{mn} \end{bmatrix} \quad (15)$$

After calculating the weighted normalized fuzzy decision matrix  $\tilde{V}$ , the fuzzy positive ideal solution  $A^*$  and the fuzzy negative ideal solution  $A^-$  can be defined as:

$$A^* = \{v_1^*, v_2^*, \dots, v_n^*\} \quad (16)$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \quad (17)$$

where  $\tilde{v}_j^* = (1, 1, 1)$  and  $\tilde{v}_j^- = (0, 0, 0)$   $j = 1, 2, 3, \dots, n$ .

Then it is necessary to calculate the distances of the alternatives from  $A^*$  and  $A^-$ . In this calculation,  $d$  represents the distances between fuzzy numbers and the calculation is carried out with the following equations:

$$d_i^* = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1, 2, 3, \dots, m \quad (18)$$

$$d_i^- = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, 3, \dots, m \quad (19)$$

Finally, the closeness of the alternatives to the ideal solution is calculated. For this, the Vertex method, which is used to calculate the distances to one of the fuzzy numbers, is used. The distance between two triangular fuzzy numbers, such as  $\tilde{A} = (a_1, a_2, a_3)$  and  $\tilde{B} = (b_1, b_2, b_3)$  is calculated according to the Vertex method with the following equation:

$$d_v(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3} [(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad (20)$$



To evaluate the alternatives and make a choice, the closeness coefficients are calculated for each alternative with the help of the following equation [64].

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, i = 1, 2, 3, \dots, m \quad (21)$$

Alternatives are decided to rank according to the  $CC_i$  (the closeness coefficient) values. Suppose the closeness coefficient is equal to 1. In that case, the value of the alternative in question equals the fuzzy positive ideal solution. If the closeness coefficient is equal to 0, the value of the alternative is equal to the fuzzy negative ideal solution.

### 3. Case Study Analyses and Results

In this study, three low-cost carriers (LCC), also known as budget or low-cost airline companies, operating in Türkiye were examined regarding their ground operations performance. The procedures performed at this study stage are discussed in four subsections and explained in detail. First, LCC companies considered in the case study were introduced in detail. In the second stage, the literature was reviewed widely, and the criteria being used for the evaluation were investigated. The criteria obtained were combined with expert opinions and arranged for study use. In the third stage, the fuzzy AHP method weighed the evaluation criteria. Finally, three airlines were evaluated and ranked regarding their ground operations performance using the fuzzy TOPSIS method.

#### 3.1. Background: Low-Cost (Carriers) Airlines in Türkiye

Three low-cost airline companies are operating in Türkiye. These are Anadolu Jet [65], Pegasus Airlines [66], and Sun Express [67], in alphabetical order. All companies take domestic and international flights and aim for the most convenient and best-paid flight for their passengers.

Anadolu Jet was founded in 2008; the parent company is Turkish Airlines and its headquarters are in Ankara. The main operating bases of the airline are Ankara and Istanbul Sabiha Gokcen Airport. With a fleet size of 81, the flying destinations are spread across 164 routes. The frequent flyer program is “Miles & Smiles”, a Star Alliance (affiliate) member.

Pegasus Airlines was founded in 1991; the parent company is Esas Holding, and its headquarters are in Istanbul. The airline’s main hubs are Adana, Ankara, Antalya, Ercan, Istanbul Sabiha Gokcen Airport, and Izmir. With a fleet size of 95, the flying destinations are spread across 126 routes. The frequent flyer program is “Pegasus Bol Bol”.

Sun Express was founded in 1989; the parent companies are Turkish Airlines and Lufthansa Group, and its headquarters are in Antalya. The airline’s main hubs are Izmir Adnan Menderes Airport and Antalya Airport. The fleet size of 53, and the flying destinations are spread across 66 routes. The frequent flyer program is “SunExpress your benefits”.

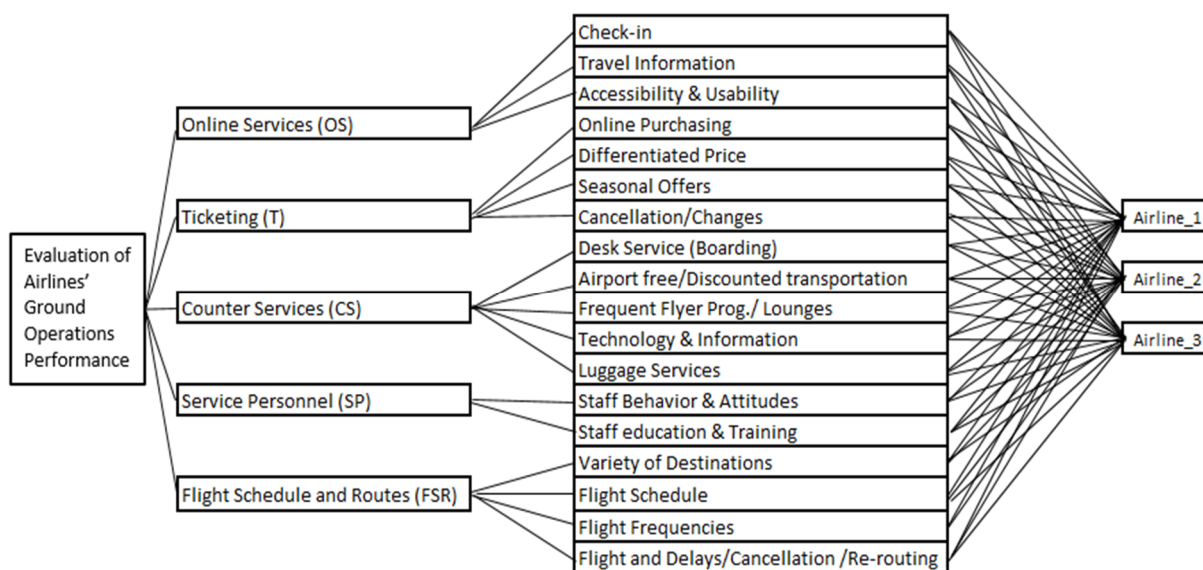
#### 3.2. Determining the Evaluation Criteria

The second stage of the study is to determine the criteria to be used to evaluate the alternatives. For this purpose, a detailed literature review was conducted, and the five main criteria and eighteen sub-criteria given in Table 3 were obtained with expert support.

These criteria categories are coded for each primary and sub-criterion as follows; Online Services (OS) (three sub-criteria; OS1 to OS3), Ticketing (T) (four sub-criteria; T1 to T4), Counter Services (CS) (five sub-criteria; CS1 to CS5), Service Personnel (SP) (two sub-criteria; SP1 and SP2) and Flight Schedule and Routes (FSR) (four sub-criteria; FSR1 to FSR4). In addition, the hierarchical model of the decision problem is given in Figure 2.

**Table 3.** Evaluation of main and sub-criteria.

Main Criteria	Sub-Criteria	
Online Services (OS)	Check-in	(OS1)
	Travel Information	(OS2)
	Accessibility and Usability	(OS3)
Ticketing (T)	Online Purchasing	(T1)
	Differentiated Price	(T2)
	Seasonal Offers	(T3)
	Cancellation/Changes	(T4)
Counter Services (CS)	Desk Service (Boarding)	(CS1)
	Airport Free/Discounted Transportation	(CS2)
	Frequent Flyer Program/Lounges	(CS3)
	Technology and Information	(CS4)
	Luggage Services	(CS5)
Service Personnel (SP)	Staff Behavior and Attitudes	(SP1)
	Staff education and Training	(SP2)
Flight Schedule and Routes (FSR)	Variety of Destinations	(FSR1)
	Flight Schedule	(FSR2)
	Flight Frequencies	(FSR3)
	Flight and Delays/Cancellation/Re-routing	(FSR4)

**Figure 2.** The hierarchical structure of the study.

Six experts were consulted in the evaluation of the study. In order to categorize the criteria and compare them pairwise with the fuzzy AHP approach, the views of six experts were employed, and an evaluation of the airlines with the fuzzy TOPSIS method was conducted. Three of them are professionals and passengers who travel frequently with airlines, and the other two are experts with many years of airline experience in various ground service roles. One is an airline employee with many years of flying experience. The other expert is an industrial/process engineer with experience in process management and specializes in airline and travel issues. The average experience of the experts is 10+ years. The five-point linguistic expression scale given in Table 1 is used for the pairwise comparisons. According to the results of the observations, the data obtained were summarized, and the average estimates of the six experts were used in this article.

### 3.3. The Weighting of Evaluation Criteria with Fuzzy AHP Method

The primary criteria, as well as sub-criteria of the decision issue, are weighted using the fuzzy AHP approach at this point. The critical criteria for the study were first established, and the experts then conducted pairwise comparisons utilizing the fuzzy triangular numbers shown in Table 1. The verbal assessments were quantified by converting them into the fuzzy triangular numbers shown in Table 4. The calculations were carried out by using the equations given in the fuzzy AHP application stages mentioned in the preceding sub-section, and the fuzzy triangular weight values (W) for the primary criteria listed in Table 5 are generated.

**Table 4.** Main criteria pairwise comparison matrix with fuzzy numbers.

Main Criteria Pairwise Comparison Matrix with Fuzzy Numbers					
	Online Services	Ticketing	Counter Services	Service Personnel	Flight Schedule and Routes
Online Services	(1,1,1)	(1/5,1/3,1/1)	(1/5,1/3,1/1)	(1,1,1)	(1/5,1/3,1/1)
Ticketing	(1,3,5)	(1,1,1)	(1/5,1/3,1)	(1,3,5)	(1/5,1/3,1)
Counter Services	(1,3,5)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)
Service personnel	(1,1,1)	(1/5,1/3,1/1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)
Flight Schedule and Routes	(1,3,5)	(1,3,5)	(1,1,1)	(1,3,5)	(1,1,1)

**Table 5.** Calculated fuzzy weights for main criteria.

Online Services (OS)						Flight Schedule and Routes (FSR)					
OS1			OS2			FSR3			FSR4		
l	m	u	l	m	u	l	m	u	l	m	u
0.293	0.325	0.310	0.414	0.440	0.501	0.418	0.401	0.320	0.114	0.098	0.174

The following steps demonstrate the evaluation of the main criteria and all sub-criteria. This reflects the evaluation in terms of the degrees of relation of the main criteria to each sub-criterion. Pairwise comparison matrices showing the sub-criteria evaluations for each main criterion are given in Tables 6–10.

**Table 6.** Sub-criteria—Online Services pairwise comparison matrix.

Online Services (OS)			
	OS1	OS2	OS3
OS1	(1,1,1)	(1/5,1/3,1/1)	(1,3,5)
OS2	(1,3,5)	(1,1,1)	(1,1,1)
OS3	(1/5,1/3,1/1)	(1/1,1/1,1/1)	(1,1,1)

**Table 7.** Sub-criteria—Ticketing pairwise comparison matrix.

Ticketing (T)				
	T1	T2	T3	T4
T1	(1,1,1)	(1/5,1/3,1/1)	(1,1,1)	(1,3,5)
T2	(1,3,5)	(1,1,1)	(1,1,1)	(1,3,5)
T3	(1,1,1)	(1,1,1)	(1,1,1)	(1,3,5)
T4	(1/5,1/3,1/1)	(1/5,1/3,1/1)	(1/5,1/3,1/1)	(1,1,1)

**Table 8.** Sub-criteria—Counter Services pairwise comparison matrix.

Counter Services (CS)					
	CS1	CS2	CS3	CS4	CS5
CS1	(1,1,1)	(5,7,9)	(5,7,9)	(1,1,1)	(1,3,5)
CS2	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)
CS3	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1/5,1/3,1/1)	(1/5,1/3,1/1)
CS4	(1,1,1)	(3,5,7)	(1,3,5)	(1,1,1)	(1,3,5)
CS5	(1/5,1/3,1/1)	(3,5,7)	(1,3,5)	(1/5,1/3,1/1)	(1,1,1)

**Table 9.** Sub-criteria—Service Personnel pairwise comparison matrix.

Service Personnel (SP)		
	SP1	SP2
SP1	(1,1,1)	(1,3,5)
SP2	(1/5,1/3,1/1)	(1,1,1)

**Table 10.** Sub-criteria—Flight Schedule and Routes pairwise comparison matrix.

Flight Schedule and Routes (FSR)				
	FSR1	FSR2	FSR3	FSR4
FSR1	(1,1,1)	(1/5,1/3,1/1)	(1/7,1/5,1/3)	(1,3,5)
FSR2	(1,3,5)	(1,1,1)	(1,1,1)	(1,3,5)
FSR3	(3,5,7)	(1,1,1)	(1,1,1)	(1,3,5)
FSR4	(1/5,1/3,1/1)	(1/5,1/3,1/1)	(1/5,1/3,1/1)	(1,1,1)

As a result of analyzing the expert opinions given in Table 6 through Table 10 using the fuzzy AHP method, the final weighting values given in Table 11 were obtained. In the next stage of the study, the fuzzy numbers provided in Table 5 are used to analyze the three airlines using the fuzzy TOPSIS method. However, the defuzzified weighting numerical value calculations given in Table 11 were introduced to understand the impact of each criterion for the solution results.

**Table 11.** Main and sub-criteria weightings.

Main Criteria	Weights of Main Criteria	Sub-Criteria	Weights of Sub-Criteria
Online Services (OS)	0.11	Check-in	0.309
		Travel Information	0.452
		Accessibility and usability	0.239
Ticketing (T)	0.19	Online Purchasing	0.234
		Differentiated Price	0.356
		Seasonal Offers	0.283
		Cancellation/Changes	0.127
Counter Services (CS)	0.26	Desk Service (Boarding)	0.382
		Airport Free/Discounted Transportation	0.057
		Frequent Flyer Program/Lounges	0.078
		Technology and Information	0.299
		Luggage Services	0.184
Service Personnel (SP)	0.14	Staff Behavior and Attitudes	0.694
		Staff education and Training	0.306

Table 11. Cont.

Main Criteria	Weights of Main Criteria	Sub-Criteria	Weights of Sub-Criteria
Flight Schedule and Routes (FSR)	0.30	Variety of Destinations	0.162
		Flight Schedule	0.330
		Flight Frequencies	0.380
		Flight and Delays/Cancellation/Re-routing	0.129

Table 11 shows that the Flight Schedule and Routes (FSR) criteria, with a weight value of 0.3, have the greatest effect on the solution results with the highest value among the five main criteria. This is followed by Counter Services (CS), which ranks second highest with a weight value of 0.26, and then by Ticketing (T), the third criterion with a weight value of 0.19.

### 3.4. Evaluation of Operational Performance with Fuzzy TOPSIS Method

In this step of the study, the fuzzy TOPSIS method was applied to rank the alternative airlines (Airline\_1, Airline\_2 and Airline\_3), taking into account the determined criteria. The airline companies described alphabetically in Section 3.1 are named randomly, not in the order described in the previous section, to ensure data and analysis confidentiality.

At this study stage, the decision makers verbally expressed the three alternatives based on all sub-criteria. The expert opinions used in evaluating the alternatives are given in Table 12.

Table 12. Linguistic expressions used in the evaluation of alternatives.

	(OS1)	(OS2)	(OS3)	(T1)	(T2)	(T3)	(T4)	(CS1)	(CS2)	(CS3)	(CS4)	(CS5)	(SP1)	(SP2)	(FSR1)	(FSR2)	(FSR3)	(FSR4)
Airline_1	MP	VG	VG	MG	G	G	P	MP	MP	F	G	MG	MG	G	F	F	MP	F
Airline_2	G	G	MG	G	F	MG	MP	MG	MP	VG	MG	G	F	MG	G	MG	G	F
Airline_3	VG	MP	G	G	MG	VG	F	G	F	MG	MG	G	G	G	VG	G	MG	MP

Fuzzy linguistic phrases are translated to triangular fuzzy integers using Table 2. As a result, the first fuzzy decision matrix is obtained. Equation (13) is used to create the normalized fuzzy decision matrix illustrated in Table 13. At this stage, each criterion should be treated as a benefit or cost criterion. In our study, since all criteria are benefit-based, the calculation was carried out using Equation (12).

Table 13. The normalized fuzzy decision matrix.

	(OS1)	(OS2)	(FSR3)	(FSR4)
Airline_1	0.100	0.300	0.500	0.900
Airline_2	0.700	0.900	1.000	0.700
Airline_3	0.900	1.000	1.000	0.100

While obtaining the weighted normalized fuzzy decision matrix in Table 14, the fuzzy criteria weights in Table 5 obtained from the fuzzy AHP analysis in the previous section were used for weighting. Meanwhile, Equation (14) was used for the calculations performed.

Table 14. The weighted normalized fuzzy decision matrix.

	(OS1)	(OS2)	(FSR3)	(FSR4)
Airline_1	0.029	0.097	0.155	0.373
Airline_2	0.205	0.292	0.310	0.290
Airline_3	0.264	0.325	0.310	0.041

Table 15 shows the calculated  $d^+$  and  $d^-$  values for each alternative airline and Table 16 gives the final alternative ranking based on the calculated closeness coefficient.

**Table 15.** The distance of each alternative  $d^+$  and  $d^-$ .

	$d^+$	$d^-$
Airline_1	14.758	3.406
Airline_2	14.483	3.662
Airline_3	14.141	3.993

**Table 16.** Rank of alternatives according to the closeness coefficient.

	$CC_i$	Rank	Weights of Alternatives
Airline_3	0.220	1	0.361
Airline_2	0.202	2	0.331
Airline_1	0.188	3	0.308

When Table 16 is examined, it is understood that although Airline\_3 ranks first in terms of its performance in ground operations with a weight value of 0.361, the alternatives generally achieve very close results.

#### 4. Discussions and Implications

The fuzzy AHP and TOPSIS methodologies were used to evaluate the ground operations performance of three low-cost airlines in Türkiye. In this regard, the necessary references were first evaluated, and the assessment criteria for the study were established. The research questions were addressed with the following research outcomes and determined in the procedure earlier for the smooth flow of the analysis steps in a systematic way. The acquired criteria were categorized hierarchically with the assistance of expert judgments. All analyses and assessments conducted within the scope of the study were carried out in two stages. The first step used the fuzzy AHP approach to weigh the assessment criteria. Fuzzy numbers were utilized since the criteria used in the evaluation did not have exact numerical values that could be represented in terms of all the decision makers.

After the analysis with the fuzzy AHP, weight values were calculated for each main and sub-criterion. When the study's five primary criteria's estimated weights are examined, it is seen that "Flight Schedule and Routes (FSR)" has the highest importance weight of 0.30. With a weight value of 0.26, "Counter Services (CS)" has the second most significant impact. "Ticketing (T)", which ranks third in terms of its impact on the solution, has a weight value of 0.19. The first three criteria are followed by "Service Personnel (SP)" with a weight value of 0.14 and "Online Services (OS)" with a weight value of 0.11. When the "Flight Schedule and Routes (FSR)" criterion with the highest priority value is analyzed in terms of sub-criteria, Flight Frequencies (FSR3) and Flight Schedule (FSR2) stand out as the most prominent sub-criteria. When the results obtained are analyzed, it is seen that the alternative that is better in terms of "Flight Schedule and Routes (FSR)" stands out more than the others and takes the first place in the evaluation of the three alternative airlines.

Following the calculation of the weights of the assessment criteria, three different airline firms were analyzed using the fuzzy TOPSIS approach. Triangular fuzzy criteria weights were utilized in the studies at this step. Fuzzy TOPSIS was chosen since it is commonly utilized in the literature and produces excellent results. The options were ranked as a result of the fuzzy TOPSIS method study. Table 16 displays the importance of the weights and alternative rankings based on the fuzzy TOPSIS method analysis results.

Upon reviewing the analysis's findings, it can be seen that the third alternative is relatively prominent among the others. Airline\_3 ranked first with a weight value of 0.361, while Airline\_2 ranked second with a weight value of 0.331. Airline\_1 ranked last with an actual weight of 0.308. When the fuzzy verbal evaluations of the decision makers for the first two alternatives, Airline\_3 and Airline\_2, are analyzed, it can be seen that Airline\_3



has the best values in terms of the first two main criteria that have more impact on the solution results.

However, considering the dynamics of the airline industry in which the study was conducted, it can be said that all three airline companies have managed to stand out as successful in certain areas in the current competitive conditions. Through a detailed examination of the study's results, separate analyses can be carried out for each of the three companies, and areas where performance needs to be improved can be identified.

The closeness of the performance values to each other is an important finding. This is expected because of competition, service quality, and regulations. In the aviation sector, companies follow strict rules and keep the service level as high as possible to meet legal and regulatory requirements. Companies should incorporate different operational requirements into their daily practices to increase the quality of the service they provide. The positive effects of technology and new business understandings should also be reflected in the airline companies' operational strategies. Low-budget airlines, which are the subject of our research, may limit the diversity of their service offerings, which is a natural business necessity. Still, in comparative analysis, if one company has an advantage over the others, the others are expected to respond competitively. The downward cost trend makes it easier for service providers to update their portfolios and offer the appropriate ones at lower costs. The low-cost carriers (airlines) could improve their operations by considering the following factors: gathering operational and constituent data; making repairs more quickly so that fewer critical components fail; preventing flight delays; reducing the amount of time that aircrafts are idle (on the ground); reducing the price of labor and replacement parts; and reducing the frequency of unplanned maintenance. Therefore, the two types of aircraft most preferred by those companies are the Boeing 737 in various model types and the Airbus 320–321, which are both selected for their size, efficiency, and economy as well as being operationally easy to handle and manage since the aircraft is the primary input for the entire process.

#### *4.1. Final Remarks and Significance of the Research*

The significance of our study reveals its potential to positively impact the aviation sector and solve the complicated difficulties that airlines confront in improving their operational performance. The following are some justifications for the significance of this study topic:

- Improved decision making: Creating a combined MCDM strategy designed specifically for enhancing airlines' operational performance can offer decision makers a comprehensive framework to assess and rank various strategies. Informed judgements that take into consideration a variety of performance parameters at once may be made by airlines, leading to more efficient resource allocation and operational enhancements.
- A combined MCDM method: may offer a comprehensive perspective on an airline's operational performance by integrating several performance criteria including safety, dependability, cost-effectiveness, customer happiness, and environmental impact. As a result, strengths, weaknesses, and potential improvement areas may be understood more thoroughly, allowing for focused interventions to improve performance.
- Operational performance: is vital in establishing an airline's competitiveness and market position in a highly competitive business like aviation. Airlines may set themselves apart from their rivals by providing higher levels of safety, dependability, customer happiness, and cost-effectiveness by utilizing a combined MCDM strategy to improve operational performance. Increased consumer loyalty, market share, and financial sustainability can all result from this.
- Allocating resources: effectively is essential for successful operations since airlines operate in a resource-constrained environment. By considering many factors at once, a combined MCDM method could help optimize the allocation of resources, such as aircraft, personnel, and maintenance. Increased efficacy, cost-effectiveness, and capacity utilization may maximize the value and benefit of the resources.

- Impact on the entire industry: The research on a combined MCDM method for enhancing airlines' operational performance may provide discoveries and insights that have larger ramifications for the entire aviation sector. The creation of best practices, frameworks for making decisions, and optimization models may be shared and used by airlines worldwide, improving operational performance and efficiency across the board.
- Sustainable operations: There is a growing demand on airlines to operate sustainably and to lessen their environmental impact. The evaluation and selection of solutions that improve operational performance and reduce the environmental effect of airline operations can be facilitated by a combined MCDM approach. This supports the sector's sustainability objectives and reflects rising social and regulatory demands.
- By researching this subject, academics, industry practitioners, and authorities may work together to further the knowledge and execution of a combined MCDM strategy, eventually benefiting airlines, passengers, and the aviation sector.

#### *4.2. Theoretical and Research Implications*

Studying a combined MCDM method to enhance airline operational performance could have many theoretical and research implications. It advances decision making by including many factors and offering a thorough framework for assessing operational performance in the airline sector. This can improve our conceptual understanding of MCDM techniques to solve complicated decision-making issues in multidimensional settings. The study could contribute to creating and improving MCDM techniques tailored to the aviation sector. The use of MCDM techniques in the overall picture of operational performance allows researchers to improve current models and suggest fresh ideas that better reflect the particular traits and difficulties experienced by airlines. Our study also theoretically contributes to the MCDM literature by using fuzzy AHP and fuzzy TOPSIS methods and supports the airline operational performance evaluation process. The evaluations and analyses in this article are based on a single-country case study. The study's results expand our understanding of MCDM from a research perspective and direct new avenues for the development areas and research gaps.

#### *4.3. Managerial and Practical Implications*

From managerial and practical perspectives, the results of the study have significant management and operational implications for airlines and professionals in the field. Making decisions and prioritizing alternative criteria for enhancing operational performance can be made easier by decision makers with the help of a combined MCDM strategy, which can offer insightful information. The suggested model can be used by airlines to determine areas for improvement, better manage resources, and create plans that complement various performance metrics. The comparison results assist decision makers. Therefore, the research also enhances understanding of the operational structure with required performance level and administrative concerns to manage operations better.

The study results can also direct airlines to implement strategies to improve security, dependability, cost-effectiveness, customer loyalty, and environmental sustainability. This may lead to observable advantages, including higher operational effectiveness, cost savings, customer loyalty, and increased competitiveness. Strategists should focus on service requirements and quality characteristics with comprehensive features to enhance value propositions in service quality and efficiency in operations. Furthermore, with the aid of technological advancements and innovative service-providing strategies, we suggest customizing operations to meet customer needs to improve operational effectiveness and performance at large.

#### *4.4. Research Limitations*

Our study on a combined MCDM method for enhancing airline operational performance must be acknowledged for its limitations. Even though the MCDM evaluation study

has significance for the research community, this study has several drawbacks. First, given that data gathering in the aviation sector can be difficult due to its sensitivity and confidentiality, one limitation may result from data availability and quality. Access to complete and consistent datasets may be restricted for researchers, which may have an impact on the precision and generalizability of the research findings. Second, the complexity and volatility of the airline sector could be a further constraint. The numerous facets of the performance of operations and the dynamic nature of the operational environment make it challenging to create a framework that can be used everywhere. Researchers should be conscious of these restrictions and carefully consider the unique context and circumstances in which the suggested approach is used. Third, airline companies' service levels significantly influence the evaluation's results when comparing a single country and location. Finally, the MCDM method's application is viewed as a limitation as well; thus, a comparison with other approaches is not conducted.

#### *4.5. Future Research Directions*

Future studies can take a few paths to improve the subject and address the above-mentioned limitations. This study's outcomes emphasize the need for more research to analyze various performance improvements in the industry. Furthermore, the following future study directions might be suggested.

First, to validate and improve the suggested combined MCDM technique, researchers might conduct additional in-depth case studies and empirical analyses. This can increase the framework's suitability for use in practical contexts and contribute to developing a solid empirical base. Research can also be expanded by looking into the intersection of cutting-edge "technologies like big data analytics, machine learning", and artificial intelligence. Exploring how these technologies can improve the MCDM approach's precision, effectiveness, and real-time application can have significant theoretical and practical implications for the airline sector. The Analytical Network Process (ANP) may be used to examine the probable feedback and interaction between the sub-criteria. To acquire a more complete review, future research might be conducted with various levels of stakeholders directly or indirectly involved in the entire process. Moreover, future studies should concentrate on different variables such as the pre-flight (ground), in-flight, and post-flight main process parts, which would fully cover the entire airline operation.

Additionally, comparative studies that evaluate the efficacy and efficiency of various MCDM methodologies and models may assist in determining the best strategies for enhancing airlines' operational performance. To advance the comprehension and implementation of a combined MCDM approach in the airline industry, future research should concentrate on improving existing frameworks, investigating novel facets of operational performance, adopting emerging technologies, and performing thorough comparative analyses.

#### **5. Conclusions**

This study used a combined MCDM strategy to improve airline ground operations performance. Planning, fleet and crew management, safety, dependability, cost-effectiveness, customer satisfaction, and environmental impact are the general elements determined earlier for operational success in the sector. Previous research in the airline sector focused on individual decision concerns, but this study attempted to establish a robust MCDM technique explicitly geared to improving airline operational performance. To do this, the relevant literature was first reviewed, and the assessment criteria considered within the context of the study were proposed. Expert views were used to classify the acquired criteria. The analyses and assessments conducted as part of the research were conducted in two separate phases. A case study involving three Turkish low-cost airlines was conducted, with service quality, cost-effectiveness, revenue, process management, operational capacity, planning, and staff aspects all being considered. The five main criteria were set as "ticketing, online services, counter services, flight schedule and routing, and service personnel" with eighteen related sub-criteria.

The suggested technique combined the “fuzzy Analytic Hierarchy Process (AHP)” methods and the “fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).” The fuzzy AHP approach was used to assign weights to the criteria, and the fuzzy TOPSIS was used to rank and identify the best-performing airlines. The study’s findings emphasize the need to use a combined MCDM methodology to analyze operational performance in the airline sector. The suggested framework provides airlines with a systematic and comprehensive way of assessing their performance and identifying opportunities for improvement. Additional variables and criteria can be explored in future studies, such as pre-flight, in-flight, and post-flight process steps, as they broadly cover the entire operations and the methodology and applicability of the proposed framework to diverse airline scenarios.

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