Airline service quality ranking based on TOPSIS-VIKOR-AISM

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Abstract—The service quality ranking of airlines is a crucial factor for their sustainability in the intensely competitive airline market. This study intends to offer further insights in this field to produce simpler and explanatory results, however previous studies have been lacking in terms of sample size, efficiency, and reliability. In order to develop an airline service quality evaluation system that incorporates customer utilities, ideal points, and regret values and performs a confrontation hierarchy topology analysis based on the computation of compromise solutions, the TOPSIS-VIKOR-AISM model is proposed in this work. In addition to supporting consumer choice and airline development, this study offers fresh perspectives on how to assess the effectiveness of airlines and other industries.

Index Terms—Airline, Service quality, TOPSIS, VIKOR, AISM

I. INTRODUCTION

The rankings of airlines’ service quality are a significant factor for their profitability and sustainability in the highly competitive airline sector [1]. Consumers are highly sensitive to issues such as airline reputation [2], frequent flyer programs [3], safety [4], and on-time performance [5]. Airlines must comprehend customer wants and offer top-notch services [6]. Some of the quality rankings are based on consumer surveys, which have the drawbacks of being few in number, subjective, using variable standards, and being difficult to compare. Such complex decision issues can be successfully handled using multi-criteria decision analysis (MCDM) techniques. Occupational health risk assessment [7], planning urban garbage stations [8], supply chain network analysis [9], and healthcare scenario decision-making [10] are a few examples.

In the field of airline service quality ranking, some scholars have conducted studies with the help of MCDM methodology. [11] used the FUCOMAHP method to evaluate four Libyan airlines and showed the importance of airline reliability; [12] used the integrated CRITIC and CODAS methods to evaluate the performance of Star Alliance member airlines; [13] used the Fucom-Marcos method to develop a decision support system for airline selection in Indonesia; [14] focused on the operational and environmental performance of Chinese airlines and used the SBM-NDEA method to construct a good evaluation system; using the PARIS and TOPSIS methodology, [15] performed a multi-criteria evaluation analysis of airline quality; with the aid of the VIKOR approach, [16] assessed the financial success and corporate reputation of airlines. On the other side, some academics have also used statistical techniques for analysis. [17] assessed the dynamic carbon emission performance of Chinese airlines with the aid of GMCPI index data indicators, whereas [18] created a new DEA model to assess the degree of performance of Iranian airlines.

Prior research still has some drawbacks, though: (1) the amount of data needed is excessive; (2) the ranking is inefficient; (3) the ranking is less stable; and (4) the primary focus is on historical quantitative data, whereas airline quality ranking is a complex system problem that also calls for qualitative judgment. The issue that needs to be optimized is how to fully combine numerous criteria to deliver more reliable and effective ranking outcomes. In order to assist airlines in identifying potential issues in the company’s business at the current stage and provide customers with a clear list of airline service quality rankings, we propose a comprehensive MCDM model, which is a more flexible tool for taking into account the interrelationship between criteria and extracting the basic criteria objectively by taking into consideration the weight of each relevant criterion.

The optimal alternative has the shortest geometric distance to the positive ideal solution and the longest geometric distance to the negative ideal solution, according to the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique. The viseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) approach is used to resolve decision problems involving many assessment criteria that are incompatible and at odds with one another. It can provide a compromise that comes the closest to the optimum answer. Using Boolean, topological procedures, the Adversarial Interpretive Structure Modeling Technique (AISM) method helps to determine the hierarchical structure of various solutions. We combine TOPSIS, VIKOR, and AISM methodologies, which will make it easier to create a fair and understandable quality rating system. To downscale the data and determine the average of ideal solution distances, compromise solutions, and positive and negative ideal solution distances, respectively, we employ the TOPSIS and VIKOR algorithms. Additionally, we execute a partial order operation on the data we’ve received to obtain the corresponding relationship matrix. The final directed hierarchical topological plot, or the list of airline service quality, is produced with the aid of the AISM approach by continuous clip-forcing approximation.

Our proposed TOPSIS-VIKOR-AISM based decision analysis model
(1) Making the most of taking into account diverse aspects and integrating their functions.

(2) An adequate quality rating system, a prompt and thorough examination of airline quality, and a solution to the issue of insufficient data volume.

(3) Giving airlines and customers useful decision-supporting information in the form of a directed topological hierarchical diagram, which represents the evaluation outcomes.

Section II of this paper summarizes earlier studies, Section III illustrates the TOPSIS-VIKOR-AISM method, and Section IV conducts an empirical case study on airline service quality and provides a conclusion. Section V concludes by outlining the model’s limitations and making recommendations for additional research.

II. LITERATURE REVIEW

A. Related methods

In the recent several decades, the MCDM approach has become a popular area of research in the field of operations research [19]. Its primary goal is to assess the optimal solution among those that are viable based on a variety of competing criteria (either quantitative or qualitative). MCDM methods that are widely used include AHP [20], TOPSIS [21]–[23], VIKOR [24], [25], COPRAS [26], and PROMETHEE [27], [28].

The TOPSIS method was first proposed in 1981 [21]–[23], and the VIKOR method was first proposed by Opricovic [24], [25]. Both methods have gained a lot of popularity in recent years and have good empirical results in a variety of fields, including supply chain management [29], environmental management [30], performance evaluation [31], marketing [32], risk assessment [33], transportation [34], and engineering [35]. In the area of assessing the performance and quality of airline services, TOPSIS and VIKOR methodologies are also widely used. By concentrating on the situation of Africa, [36] introduced the use of TOPSIS in airline performance evaluation. [37] calculated the efficiency scores of Asian airlines using TOPSIS. [38] demonstrated the viability of using VIKOR to rank Taiwanese airlines based on service quality. Our study has a solid theoretical and empirical base, and taking into account the benefits of merging the two TOPSIS and VIKOR approaches could result in whole new findings.

The explanatory structural model (ISM), which was first developed in 1973 to identify the relationships between various specialized factors [39]–[41], can frequently be used to evaluate particular niche issues like supply chain management [42]–[44]. The extension of ISM known as the Adversarial Interpretive Structural Model (AISM), which has applications in environmental governance [45], cultural heritage [46], technological innovation [47], industrial manufacturing [48], performance evaluation [49], and appearance design [50], introduces the game adversarial idea and produces results that are more clearly hierarchical. Additionally, AISM is frequently used with other methods, such as TOPSIS [51], VIKOR [30], DEMATEL [52], and others, to have a greater explanatory capacity for a particular issue.

Since its introduction, TOPSIS, VIKOR, and AISM have found widespread use in a variety of sectors and have helped to address several practical issues thanks to their advantages. It has been confirmed that no article has ever employed TOPSIS, VIKOR, and AISM simultaneously. This study will use the TOPSIS-VIKOR-AISM method to provide a comprehensive ranking of airlines and to offer fresh insight for customers and airline decision-makers.

B. Indicator selection

Service quality can be summed up as the customer’s assessment of the overall efficiency of the service provider and its offerings [53], as well as any possible interactions between those two aspects and other potential influencing factors [54]. It could also be thought of as the customer’s overall assessment of a service procedure [55]. Airline service quality is a significant factor in determining customer satisfaction [3], [55], [56], and the first crucial step in developing and delivering a high-quality service is having a thorough grasp of each customer’s expectations [57]. However, because of its intangibility, variety, and uniqueness, as well as the complexity of its consumer knowledge and experience, its service quality is challenging to precisely characterize and quantify [58].

Recent studies have broken down the criteria for evaluating the quality of airline services into a wide range of subcategories, including price [59], safety [60], on-time performance [61], the qualities of in-flight catering [5], baggage transport services [62], seat comfort [63], pre-boarding services [63], in-flight services [63], and the capacity to address and resolve complaints [64].

In the past, researchers have measured the level of service quality provided by airlines using various evaluation methods. [65] investigated the relationship between airline passengers’ pleasure, perceived value, and service quality using structural equation modeling (SEM) [66] employed fuzzy partitioning to assess the technical and functional quality of the American airline sector in order to gauge passenger satisfaction. [67] applied the Kano model for a study on the quality risk assessment of Taiwanese airlines, noting that poor airline service quality results in unsatisfied customers.

The most complete and commonly used model for comprehending service quality is the SERVQUAL scale, which [68] proposed. The scale’s five dimensions—tangibility, dependability, responsiveness, assurance, and empathy—can effectively separate clients with various views of the quality of the services they receive. Tangibility describes how services are physically presented, such as in-flight technology and catering standards. Reliability indicates the credibility of the airline in terms of aircraft safety and crew skills. Responsiveness describes the communication and interaction between the crew on the ground or aboard and the customer. Assurance represents the certainty of the service provided by the airline to the customer, such as the crew’s language skills. Empathy indicates how the airline will handle customer complaints and whether it can provide attentive service [68]. [69] Understanding the nature and factors that influence customer expectations and how they perceive service quality is at the
core of SERVQUAL. Only when the service provider meets or exceeds the client’s expectations will the customer regard quality favorably [70].

The researchers had success evaluating the service levels of various airlines in South Africa [71], Dubai [72], Taiwan [53], and the transatlantic route [73] using SERVQUAL. Additionally, SERVQUAL has been applied in a wide range of areas, including hospitality [74], tourism [75], banking [76], healthcare [77], and public services [78].

We created evaluation criteria that included five aspects and 15 service quality evaluation indicators, as shown in Table I, by using the structure of five aspects as the skeleton and including other research and practical considerations.

**TABLE I**

| Indicator Category | Evaluation Indicators          |
|--------------------|--------------------------------|
| Tangibility        | C1: Seat comfort               |
|                    | C2: Quality of meals           |
|                    | C3: In-flight entertainment    |
| Reliability        | C4: Staff professionalism      |
|                    | C5: Aircraft punctuality       |
|                    | C6: Aircraft safety            |
| Responsiveness     | C7: Staff attitudes            |
|                    | C8: Service attentiveness / efficiency |
|                    | C9: Problem solving skills     |
| Assurance          | C10: Staff language skills     |
|                    | C11: Staff grooming            |
|                    | C12: Service fairness          |
| Empathy            | C13: Vulnerable group services |
|                    | C14: Pre-boarding procedures   |
|                    | C15: Transfer and arrival services |

From m evaluation objects and n evaluation indicators, an original evaluation matrix O is created, where $x_{ij}$ is the intersection of each evaluation object and evaluation indicator, see Table II.

**TABLE II**

| Airline | C1 | C2 | ... | Cm |
|---------|----|----|-----|----|
| A1      | x11| x12| ... | x1m|
| A2      | x21| x22| ... | x2m|
| ...     |    |    |     |    |
| An      | xnm|     |     |     |

Where n and m stand for the quantity of airlines $i$ and indicators $j$ respectively:

$$O = x_{ij}, i = 1, \ldots, n; j = 1, \ldots, m. \quad (1)$$

**III. METHODOLOGY**

A. Construction of TOPSIS-VIKOR-AISM model

Figure 1 depicts the complete model development procedure.

We normalize the compiled data on airline service quality scoring and arrange it into a raw matrix including the different airlines, indications, and scores. We compute utility values $S^+, S^-$, Euclidean distances $D^+, D^-$, regret values $R^+, R^-$, respectively, using the TOPSIS, VIKOR, and AISM methods described in Section III-B, III-C, III-D. We then compute the mean of distances to positive and negative ideal points $SDR^+, SDR^-$ with the compromise solution $Q$. Three sets of adversarial hierarchical topologies are successively computed for the acquired adversarial topologies using the AISM approach, which is depicted on the right side of figure 1. An intuitive hierarchical link between airline service quality and $S^+, S^-, D^+, D^-, R^+, R^-, SDR^+, SDR^-$, and $Q$ is obtained.

B. TOPSIS method

The TOPSIS method was created in 1981 by Hwang, Ching-Lai, and Yoon, Kwangsun [21]. It is a thorough ranking method with its core based on choosing the ideal solution that has the minimum geometric distance from the positive ideal solution and the maximum distance from the set of negative ideal solutions, then ranking the alternatives [22]. The following are the precise steps in implementation:

(a) Calculate the positive and negative ideal solution, $F_j^+$ and $F_j^-$ respectively:

$$F_j^+ = [t_1^+, \ldots, t_j^+, \ldots, t_n^+] = [\max(t_{11}, t_{21}, \ldots, t_{nj}), \ldots, \max(t_{1j}, t_{2j}, \ldots, t_{nj}), \ldots], \quad (2)$$

$$F_j^- = [t_1^-, \ldots, t_j^-, \ldots, t_n^-] = [\min(t_{11}, t_{21}, \ldots, t_{nj}), \ldots, \min(t_{1j}, t_{2j}, \ldots, t_{nj}), \ldots], \quad (3)$$

(b) Calculate the alternative solution and positive ideal solution distance $D^+$ and negative ideal solution distance $D^-$ respectively:
\[ D^+ = \sqrt{\sum_{j=1}^{m} (t_{ij} - t_j^+)^2}, i = 1, \ldots, n. \]  

\[ D^- = \sqrt{\sum_{j=1}^{m} (t_{ij} - t_j^-)^2}, i = 1, \ldots, n. \]  

\[ f^+_j = \max_i t_{ij}, i = 1, \ldots, n; j = 1, \ldots, m. \]  

\[ f^-_j = \min_i t_{ij}, i = 1, \ldots, n; j = 1, \ldots, m. \]  

C. VIKOR method

The VIKOR technique was proposed by Opricovic, Serafim, and Gwo-Hshiung Tzeng in 1998 to resolve multi-criteria situations with conflicting criteria [24]. Finding a compromise solution involves ranking and selecting options in the context of competing criteria [25]. The following are the specific steps for implementation.

(a) Determine the best and worst evaluation functions \( f^+_j \) and \( f^-_j \).

\[ f^+_j = \max_i t_{ij}, i = 1, \ldots, n; j = 1, \ldots, m. \]  

\[ f^-_j = \min_i t_{ij}, i = 1, \ldots, n; j = 1, \ldots, m. \]  

(b) The weighted normalized Manhattan distance and the weighted normalized Chebyshev distance should be calculated, accordingly.

\[ S_i = \sqrt{\sum_{j=1}^{m} w_j \frac{f^+_j - f^-_j}{f^+_j - f^-_j}}, i = 1, \ldots, n; j = 1, \ldots, m. \]  

\[ R_i = \max_j \frac{w_j (f^+_j - f^-_j)}{(f^+_j - f^-_j)}, i = 1, \ldots, n; j = 1, \ldots, m. \]  

Where \( w_j \) is the weight of each indicator, indicating its relative importance derived from the entropy weighting method (see section IV-C).

(c) Below is a calculation of the compromise solution.

\[ Q_i = (1 - k) \frac{(R_i - R^+)}{(R^- - R^+)} + k(S_i - S^+), \]  

where

\[ S^- = \min_i S_i; \quad S^+ = \max_i S_i; \quad R^- = \min_i R_i; \quad R^+ = \max_i R_i. \]  

D. AISM method

The AISM method is an extension of the ISM method, which aims to break down a complex system’s constituent parts into smaller parts, arrange those parts in a cause-and-effect hierarchy through a series of Boolean and topological operations, and then identify the topological structure hierarchical graph. Based on the result-oriented hierarchical ranking rules of ISM, the Adversarial Interpretive Structure Model (AISM) adds the cause-oriented hierarchical ranking to provide a collection of directed topological diagrams that are in opposition to the ISM ranking rules. By using AISM to analyze complicated systems, the system’s structure can be determined without affecting the system’s complete functionality, and a simple, hierarchical directed topology diagram can be provided.

When it comes to the presentation of results, AISM is much more logical and understandable than text, tables, and mathematical notation. If there is at least one backward path connecting any two nodes in a directed graph, they are considered to be strongly connected. Any two points \( v_1 \) and \( v_2 \) in the directed graph are said to be strongly connected if there is a path from \( v_1 \) to \( v_2 \) and a path from \( v_2 \) to \( v_1 \) between them. Any two nodes are accessible to any other if the AISM directed graph has strong connections, hence a loop must be able to traverse the entire graph. The directed topological hierarchical graph must have at least one cycle as the modeling premise for the inverse solution ordering comparison procedure known as AISM (Adversarial Interpretive Structure Modeling Method). AISM might not be consistent with the internal relationships of the elements and the produced directed topological hierarchical networks as a result of the various ordering rules. The correlation and hierarchical relationship between the influencing indicators can be found, as well as the influence relationship between the indicators, by comparing the UP-type and DOWN-type diagrams of a set of directed topological diagrams and thoroughly studying each indicator. The basic steps for building the model in accordance are illustrated below.

(a) First, the adjacency relationship matrix is built. The partial order relationship operation transfers the evaluation matrix on the left to the relationship matrix on the right based on the partial order rule’s calculation. These are the guidelines for partial orders. For an evaluation matrix \( D \) containing \( m \) columns, any one of the columns, i.e., the indicator dimensions, has the same property and the premise of being comparable. This comparison of advantages and disadvantages of dimensions has at least two properties. The larger the value the better, and the smaller the value the worse, then it is called a positive indicator. It is denoted as \( p_1, p_2, \ldots, p_m \). Similarly, the negative indicator is denoted as \( q_1, q_2, \ldots, q_m \). For any two rows \( x, y \) in \( D \), if they are positive indicators, we have

\[ d(x, p_1) \geq d(y, p_1), d(x, p_2) \geq d(y, p_2), \ldots, d(x, p_m) \geq d(y, p_m) \]  

In case of negative indicators, there are
\[ d(x,q_1) \leq d(y,q_1), \; d(x,q_2) \leq d(y,q_2), \ldots, \; d(x,q_m) \leq d(y,q_m) \] (13)

The partial order connection between \( x \) and \( y \) is noted as \( x \prec y \), which suggests that \( y \) is superior to \( x \), if the aforementioned rule is satisfied. The internal relationship between the influencing factors can then be discovered by expert scoring in accordance with the various evaluation indexes, and the element \( a_{ij} \) in the adjacency matrix \( A \) can then be written as

\[ a_{ij} = \begin{cases} 0, & x \prec y \\ 1, & \text{No perfect relationship between } x \text{ and } y. \end{cases} \] (14)

(b) The accessible matrix explains the length at which a path connecting two nodes in a directed connected network can be reached. It is necessary to first compute the multiplicative adjacency matrix \( B \) for any given basic matrix:

\[ B = A + I, \] (15)

where \( B \) is the multiplicative adjacency matrix and \( I \) is the unit matrix. The concatenation of \( B \) results in the reachable matrix \( R \):

\[ B^{k-1} \neq B^k = B^{k+1} = R \] (16)

The cycle in the reachable matrix \( R \) is treated as a point in the point reduction operation on the reachable matrix \( R \), from which a new reachable matrix \( R' \) can be generated. Afterward, use the edge reduction technique to \( R' \) to obtain the skeleton matrix \( S' \), which essentially eliminates the redundant routes:

\[ S' = R' - (R' - I)^2 - I \] (17)

The general skeleton matrix \( S \) can be obtained if the cyclic loops in \( S' \) are modeled as minimum daisy chains.

(c) The extraction of the hierarchy is performed below. A reachable set \( R \), an a priori set \( Q \), and a common set \( T \) exist for an accessible matrix, where \( T = R \cap Q \). Consider a relational matrix \( A \) as an illustration. For each of its elements, \( e_{ij} \), there are two possible scenarios:

1. All elements of an element whose corresponding row value is 1 are called the reachable set, and \( R = (e_{ij}) \);
2. The entire set of elements in an element with a column value of 1 is referred to as the prior set \( Q(e_{ij}) \). The common set of the reachable set \( R = (e_{ij}) \cap Q(e_{ij}) \) and the prior set is called \( T(e_{ij}) \).

The layer extraction method is as follows.

(1) Extraction of the topology of UP-type structures. The term “result-first hierarchical extraction” also refers to the UP-type structure. It follows the rule \( T(e_{ij}) = R(e_{ij}) \). The main idea behind this approach is to take the system’s components that make up the end result, put them at the top level, and then take them out via analogy.

(2) Topology extraction of the DOWN-type. With the following guidelines, the DOWN type is a cause-based hierarchical extraction technique. \( T(e_{ij}) = Q(e_{ij}) \). The fundamental idea behind this approach is that the system components that are the root causes are first isolated and positioned at the bottom of the hierarchy, after which they are extracted via analogy.

(d) Last but not least, the directed topological hierarchy diagram is performed. The directed topological hierarchy diagram can be created using the connections between the elements and the outcomes of the adversarial hierarchy extraction.

IV. EMPIRICAL STUDY

A. Data

The world has long been concerned about the level of airline service. Skytrax is an international air transport ranking organization with headquarters in London, United Kingdom. Based on Skytrax’s rankings from 2012 to 2022, we have chosen 10 airlines, which are displayed in Table III.

**TABLE III**

| Airline                 | Country                        |
|-------------------------|--------------------------------|
| 1 Qatar Airways         | The State of Qatar             |
| 2 Singapore Airlines    | Republic of Singapore          |
| 3 Emirates              | The United Arab Emirates       |
| 4 ANA All Nippon Airways| Japan                          |
| 5 Qantas Airways        | Commonwealth of Australia      |
| 6 Japan Airlines        | Japan                          |
| 7 Turkish Airlines      | The Republic of Türkiye        |
| 8 Air France            | The French Republic            |
| 9 Korean Air            | Republic of Korea              |
| 10 Swiss International Air Lines | Swiss Confederation |

We requested 15 experts to assess the airlines listed in Table III and asked them to score each airline indicator on a scale of 1 to 5. The questionnaire may be found in Table X in Appendix. We discovered through interviews and questionnaires that they had all traveled on the airlines listed in Table III and had sufficient knowledge of these airlines prior to evaluating the service level. Table II lists the metrics they were instructed to assess.

B. Data pre-processing

To produce \( N \), the initial evaluation matrix \( O \) is normalized:

\[ N = r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kij}^2}}, i = 1, \ldots, n; j = 1, \ldots, m. \] (18)

The weighting of each component results in the following:

\[ t_{ij} = x_{ij} \cdot w_{ij}, i = 1, \ldots, n; j = 1, \ldots, m. \] (19)

C. Weighting of indicators

The objective assignment approach employs actual data from the study item as its original data, placing a greater emphasis on the application of mathematical theory than the subjective assignment method does. The influence (weight) of an indication on the overall evaluation decreases as its entropy value increases, as does the degree of concentration,
and vice versa. This study uses the entropy weighting method to determine the weights of the 15 indicators in Table I in order to make the clustering results more objective and the segmentation of client groups more logical. Below are the detailed steps of the entropy weighting approach.

(a) The weight of the sample for that indicator under the indicator is

\[ \rho_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}}; i = 1, \cdots, n; j = 1, \cdots, m. \]  

(b) The entropy value of the indicator is

\[ e_j = -k \sum_{i=1}^{n} \rho_{ij} \times \ln (\rho_{ij}); j = 1, 2, 3, \cdots, m. \]  

where \( k \) is usually taken as a constant \( k = \frac{1}{\ln(n)}, (0 \leq e_j < 1) \). The coefficient of variation of the indicator is \( d_j = 1 - e_j \), and the weight of the indicator is

\[ \omega_j = \frac{d_j}{\sum_{j=1}^{m} d_j}; j = 1, \cdots, m. \]  

The weights of each indicator are obtained using Eq. (22) as shown in Table IV.

**TABLE IV**

| Indicator Category | Indicator | Evaluation Indicators | Weight |
|--------------------|-----------|-----------------------|--------|
| Tangibility        | C1        | Seat comfort           | 6.438  |
|                    | C2        | Quality of meals       | 4.065  |
|                    | C3        | In-flight entertainment| 8.247  |
| Reliability        | C4        | Staff professionalism  | 5.805  |
|                    | C5        | Aircraft punctuality   | 7.221  |
|                    | C6        | Aircraft safety        | 11.769 |
| Responsiveness     | C7        | Staff attitudes        | 7.281  |
|                    | C8        | Service attentiveness / efficiency | 5.713 |
|                    | C9        | Problem solving skills | 7.722  |
| Assurance          | C10       | Staff language skills  | 7.924  |
|                    | C11       | Staff grooming         | 4.65   |
|                    | C12       | Service fairness       | 6.978  |
| Empathy            | C13       | Vulnerable group services | 4.925 |
|                    | C14       | Pre-boarding procedures| 7.115  |
|                    | C15       | Transfer and arrival services | 4.147 |

Consumer attention is higher for issues like aviation safety (11.769%) and in-flight entertainment (8.247%), according to Table IV. The new evaluation matrix \( N' \) is created by multiplying the weights of each indicator by each element.

D. Solutions and ranking

The positive and negative ideal solutions \( D^+, D^- \) can be calculated using Eqs. (4) and (5) and the results are displayed in Table V.

**TABLE V**

| Airline                  | \( D^+ \) | \( D^- \) |
|--------------------------|----------|----------|
| Qatar Airways            | 0.1093   | 0.2014   |
| Singapore Airlines       | 0.1699   | 0.1382   |
| Emirates                 | 0.1618   | 0.1703   |
| ANA All Nippon Airways   | 0.1651   | 0.1438   |
| Qantas Airways           | 0.1891   | 0.1546   |
| Japan Airlines           | 0.1579   | 0.1953   |
| Turkish Airlines         | 0.1859   | 0.1174   |
| Air France               | 0.1257   | 0.1766   |
| Korean Air               | 0.1851   | 0.1322   |
| Swiss International Air Lines | 0.1838 | 0.1437   |

Similar to above, Eq. (11) and the normalized evaluation matrix with weights \( N' \) are used to produce the positive and negative utility values \( S^+, S^- \), as well as the positive and negative regret values \( R^+, R^- \), as illustrated in Tables VI and VII.

**TABLE VI**

| Airline                  | \( S^+ \) | \( S^- \) |
|--------------------------|----------|----------|
| Qatar Airways            | 0.2645   | 0.7355   |
| Singapore Airlines       | 0.5556   | 0.4444   |
| Emirates                 | 0.4279   | 0.5721   |
| ANA All Nippon Airways   | 0.5388   | 0.4612   |
| Qantas Airways           | 0.5823   | 0.4177   |
| Japan Airlines           | 0.4282   | 0.5718   |
| Turkish Airlines         | 0.6151   | 0.3849   |
| Air France               | 0.4142   | 0.5858   |
| Korean Air               | 0.5819   | 0.4181   |
| Swiss International Air Lines | 0.5588 | 0.4412   |

**TABLE VII**

| Airline                  | \( R^+ \) | \( R^- \) |
|--------------------------|----------|----------|
| Qatar Airways            | 0.0935   | 0.0733   |
| Singapore Airlines       | 0.0712   | 0.0669   |
| Emirates                 | 0.1177   | 0.0825   |
| ANA All Nippon Airways   | 0.0771   | 0.0772   |
| Qantas Airways           | 0.0825   | 0.1018   |
| Japan Airlines           | 0.0772   | 0.1177   |
| Turkish Airlines         | 0.0945   | 0.0549   |
| Air France               | 0.0626   | 0.1110   |
| Korean Air               | 0.1102   | 0.0559   |
| Swiss International Air Lines | 0.1173 | 0.0644   |

The harmonic mean of the distances of each element to the positive and negative ideal point are displayed in Table VIII using the distances of each element to the positive ideal point and the negative ideal point as indicated in Table V, VI, VII.
from the allocation between a SDR Q be obtained using the solved consisting of advantages among evaluation objects, three decision matrices indicating that the airline is closer to the optimal solution.

The compromise solution \( Q_i \) can be solved below using Eq. (4 or 5).

\[
Q_i = (1 - k) \left( \frac{SDR_i^+ - \min (SDR_i^+)}{\max (SDR_i^+)} \right) + k \left( \frac{\max (SDR_i^-) - SDR_i^+}{\max (SDR_i^-) - \min (SDR_i^-)} \right).
\]

(23)

Let

\[
a_i = \frac{SDR_i^+ - \min (SDR_i^+)}{\max (SDR_i^+)} - \min (SDR_i^+),
\]

\[
b_i = \frac{\max (SDR_i^-) - SDR_i^+}{\max (SDR_i^-) - \min (SDR_i^-)}.
\]

(24)

Then the Eq. (23) can be written as

\[
Q_i = (1 - k)a_i + kb_i.
\]

(25)

In Eq. (25), \( k \) is the allocation coefficient, which comes from the allocation between \( a \) and \( b \) and is usually taken as \( k = 0.5 \). As a result, the TOPSIS-VIKOR ranking scheme can be obtained using the solved \( Q_i \), as illustrated in Table IX.

| Airline                  | \( SDR^+ \) | \( SDR^- \) |
|--------------------------|-------------|-------------|
| Qatar Airways            | 0.1558      | 0.3367      |
| Singapore Airlines       | 0.2656      | 0.2165      |
| Emirates                 | 0.2358      | 0.2750      |
| ANA All Nippon Airways   | 0.2604      | 0.2274      |
| Qantas Airways           | 0.2846      | 0.2247      |
| Japan Airlines           | 0.2211      | 0.2949      |
| Turkish Airlines         | 0.2985      | 0.1857      |
| Air France               | 0.2008      | 0.2911      |
| Korean Air               | 0.2924      | 0.2020      |
| Swiss International Air Lines | 0.2867   | 0.2164      |

| Airline                  | \( a \)   | \( b \)   | \( Q_i \) | Ranking |
|--------------------------|-----------|-----------|-----------|---------|
| Qatar Airways            | 0.0000    | 0.0000    | 0.1558    | 1       |
| Singapore Airlines       | 0.7693    | 0.7962    | 0.782726  | 6       |
| Emirates                 | 0.5605    | 0.4090    | 0.484723  | 4       |
| ANA All Nippon Airways   | 0.7328    | 0.7240    | 0.728409  | 5       |
| Qantas Airways           | 0.9029    | 0.7418    | 0.822346  | 7       |
| Japan Airlines           | 0.4575    | 0.2767    | 0.367053  | 3       |
| Turkish Airlines         | 1.0000    | 1.0000    | 1.0000    | 10      |
| Air France               | 0.3156    | 0.3019    | 0.308729  | 2       |
| Korean Air               | 0.9573    | 0.8918    | 0.924551  | 9       |
| Swiss International Air Lines | 0.9170   | 0.7967    | 0.856816  | 8       |

In Table IX a smaller airline’s \( Q_i \) indicates a better ranking, indicating that the airline is closer to the optimal solution.

To better grasp the hierarchy of advantages and disadvantages among evaluation objects, three decision matrices consisting of \( D^+, D^-, S^+, S^-, R^+, R^- \) and \( SDR^+, SDR^- \), \( Q \) in Tables VII, VIII, IX, and X are chosen for calculation, respectively. According to the AISM method mentioned before, the skeleton matrices of \( D^+, D^-, S^+, S^- \), \( R^+, R^- \) with \( SDR^+, SDR^- \), \( Q \) can be derived respectively, based on two different UP-type and DOWN-type extraction methods, and three sets of adversarial hierarchies can be obtained respectively topology diagram.

Combining the data in tables \( D^+, D^-, S^+, S^- \), \( R^+, R^- \), the UP-type and DOWN-type directed topological hierarchy can be plotted as shown in Figure 2. The matrix operation results of the calculation process can be found in Eq. (26, 27, 28, 29) in Appendix.

Figure 2 shows that the directed topological hierarchy diagrams of both the UP-type and DOWN-type both have a three-level structure. The results embodied in the UP-type directed topological hierarchy diagram are as follows: \{Japan Airlines, Qatar Airways, Air France\} > \{Singapore Airlines, Emirates, ANA All Nippon Airways, Qantas Airways\} > \{Turkish Airlines, Korean Air, Swiss International Air Lines\}.

It is clear from the DOWN-type adversarial hierarchical topology diagram that \{Air France\} > \{Qatar Airways, ANA All Nippon Airways, Singapore Airlines, Japan Airways\} > \{Turkish Airlines, Qantas Airways, Korean Air, Swiss International Air Lines, Emirates\}.

Up to this point, the ranking of airlines in many tiers is still not fully determined and further pinch-force calculations are required.

The following AISM analysis of the results of \( SDR^+ \) and \( SDR^- \) is performed using the same method, as shown in Figure 3. The matrix operation results of the calculation process can be found in Eq. (30, 31, 32, 33) in Appendix.

The hierarchical relationship has become increasingly apparent, as seen in Figure 3 and both the UP-type and DOWN-type directed topological hierarchy diagrams have displayed an 8-layer structure. These two diagrams represent the same
topological structure. The results of their reactions are as follows: \{Qatar Airways\} > \{Japan Airlines, Air France\} > \{Emirates\} > \{ANA All Nippon Airways\} > \{Singapore Airlines, Qantas Airways\} > \{Swiss International Air Lines\} > \{Korean Air\} > \{Turkish Airlines\}. However, there are still two layers of airlines that are not fully reflected in the figure.

The same AISM calculation is performed below for \(Q\), and the final UP-type and DOWN-type directed topological hierarchy diagrams are obtained, see Figure 4. The matrix operation results of the calculation process can be found in Eq. (34, 35, 36, 37) in Appendix.

The ranking order between any two airlines can be found using the set of directed topological hierarchy diagrams illustrated in Figure 4, which is a rigid structure. There are 10 hierarchies, allowing the ranking conclusion of airline quality rating to be drawn: \{Qatar Airways\} > \{Air France\} > \{Japan Airlines\} > \{Emirates\} > \{ANA All Nippon Airways\} > \{Singapore Airlines\} > \{Qantas Airways\} > \{Swiss International Air Lines\} > \{Korean Air\} > \{Turkish Airlines\}.

\(E.\) Sensitivity analysis

The value of the allocation coefficient \(k\) may have an impact on how \(a\) and \(b\) are allocated, as shown by Eq. (25). The service quality score of each airline will change as we examine changing the value of \(k\) in the following, as shown in Figure 5, and we will track this change.

As can be seen from Figure 5, the rankings produced by this method may be regarded stable and essentially reflect the ranking of service quality among individual airlines. Only a small minority of airlines’ service quality rankings shift up or down by no more than one place as \(k\) changes.

\(V.\) Conclusion

In this study, we developed a thorough model for evaluating the service quality of airlines using the TOPSIS-VIKOR-AISM approach, examined the utility, Euclidean distance, and individual regret values of various airlines, and arrived at a ranking tradeoff solution. Additionally, we examine various indicators hierarchically using the AISM method to produce
the ranking directed topological hierarchy diagram. It has been demonstrated through empirical analysis that the TOPSIS-VIKOR-AISM approach may be used to comprehensively assess similar service quality or performance because it is easy to compute and intuitive to draw conclusions.

This study did not provide a more thorough ranking because it used a smaller sample of data to choose the airlines. Additionally, while allocating indicator weights, the subjective weighting approach was not merged, necessitating additional study to evaluate the Q-rankings produced by various weighting techniques. Even if the assignment coefficients \( k \) employed in our calculation of the trade off solution are accurate and mostly reflect the opinions of particular subsets of airline professionals, they do not accurately reflect the broader public’s intentions with regard to airline decisions. Future research into various allocation coefficient \( k \) values may have a wide range of possibilities.

**APPENDIX A**

**ORIGIN DATA AND ARITHMETIC RESULTS**

The adjacency matrix \( A_1 \) of \( D^+, D^-, S^+, S^-, R^+ and R^- \) is

\[
A_1 = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
\end{bmatrix}
\] (26)

The multiplicative adjacency matrix \( B_1 \) of \( D^+, D^-, S^+, S^-, R^+ and R^- \) is

\[
B_1 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\
1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\
\end{bmatrix}
\] (27)

The reachable matrix \( R_1 \) of \( D^+, D^-, S^+, S^-, R^+ and R^- \) is

\[
R_i = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\
\end{bmatrix}
\] (28)

The reachable matrix \( R_2 \) of \( SDR^+ and SDR^- \) is

\[
S_1 = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
\end{bmatrix}
\] (29)

The reachable matrix \( R_2 \) of \( SDR^+ and SDR^- \) is

\[
B_2 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\
\end{bmatrix}
\] (31)

The reachable matrix \( R_2 \) of \( SDR^+ and SDR^- \) is

\[
R_2 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\
\end{bmatrix}
\]
The general skeleton matrix \( S^2 \) of \( SDR^+ \) and \( SDR^- \) is

\[
S^2 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1
\end{bmatrix}
\]

The adjacency matrix \( A^3 \) of \( Q \) is

\[
A^3 = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1
\end{bmatrix}
\]

The multiplicative adjacency matrix \( B^3 \) of \( Q \) is

\[
B^3 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1
\end{bmatrix}
\]

The reachable matrix \( R^3 \) of \( Q \) is

\[
R^3 = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1
\end{bmatrix}
\]

The questionaire we distributed to the experts was as Table X.

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| Airline | Evaluation Indicators | Evaluation |
|---------|-----------------------|------------|
| X Airline | Service attentiveness / efficiency | Bad 1 2 3 4 5 Good |
| | Problem solving skills | Bad 1 2 3 4 5 Good |
| | Staff language skills | Bad 1 2 3 4 5 Good |
| | Staff grooming | Bad 1 2 3 4 5 Good |
| | Service fairness | Bad 1 2 3 4 5 Good |
| | Vulnerable group services | Bad 1 2 3 4 5 Good |
| | Pre-boarding procedures | Bad 1 2 3 4 5 Good |
| | Transfer and arrival services | Bad 1 2 3 4 5 Good |

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