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Airline Quality Rating Using PARIS and TOPSIS in Multiple Criteria Decision Making Analysis

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***Abstract*—**This paper presents a multiple criteria evaluation analysis for airline quality rating using the preference analysis for reference ideal solution (PARIS) and the technique for order of preference by similarity to ideal solution (TOPSIS) approaches. The airline quality rating was developed as an objective method for assessing airline quality on combined multiple performance criteria and the importance weights of criteria. The selected multiple performance criteria were determined as on-time arrivals, mishandled baggage, involuntary denied boardings, and consumer complaints. The multiple criteria decision making analysis results show that the alternative (a_2) airline is the best-rated airline.

***Keywords*—**airline quality rating, multiple criteria decision making, multiple criteria decision making analysis, entropy weight, MCDMA, PARIS, TOPSIS.

I. Introduction

AIRLINE quality rating is an important assessment for profitability and sustainability in dynamic competitive aviation industry. The quality rating problem usually is based on multiple decision criteria that frame the evaluation process. In the most complex decision situations, multiple criteria decision making analysis (MCDMA) methods can be applied efficiently to deal with such challenging decision problems.

Various MCDMA methods have been proposed to deal with complex decision problems, such as Additive Weighted Model (AWM) [1-6], Multiplicative Weighted Model (MWM) [7], Analytical Hierarchy Process (AHP) [8-10], Composite Programming [8-9], Compromise Programming [11-15], Entropic Programming [16], Preference Analysis for Reference Ideal Solution (PARIS) [17-21], ELimination Et ChoixTraduisant la REalité (ELECTRE) [22-23], Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) [24-28], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [29-34], VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [35-37]. Uncertainty in decision making processes is often modeled using fuzzy [38-47], intuitionistic [48], neutrosophic [50], and plithogenic [51-52] decision analysis methods. In addition, it is considered that the complex applications of various techniques contribute to the revealing of computational analysis processes [53-62].

Airline quality rating is briefly summarized to cover the main aspects of the decision making problem. Currently, consumer interest and sensitivity remain high on issues such as on-time performance, mishandled baggage, involuntary denied boardings (bumping or oversales), and treatment of customers in the aviation industry. Since these evaluation criteria are central to the airline quality rating evaluations, it is important to provide more objective complete data for individual airlines in these areas.The air transport data provide a detailed look at the performance of each of the airlines required to report performance in certain areas, such as on-time arrivals, mishandled baggage, involuntary denied boardings, and consumer complaints [61-62].

The airline quality rating is the study of airline performance quality, it sets the industry standard, providing consumers and industry stakeholders a means to compare performance quality among airlines using objective performance-based data .The airline quality rating is the study in the aviation industry based on performance measures. Evaluation criteria included in the decision problem are screened to meet two basic elements: They must be readily obtainable from published open data sources for each airline, and they must be important to consumers regarding airline quality. The resulting criteria include areas such as baggage handling, customer complaints, involuntary denied boardings and on-time arrivals [61-62].

The airline quality rating system is briefly defined to outline the elements and criteria of the decision problem. In the aviation industry, existing quality ratings are based on subjective surveys of rarely collected consumer opinions. This subjective quality rating approach gives a quality rating that is essentially incomparable from survey to survey for any given airline.The timeliness of survey-based results can also be an issue in the fast-paced aviation industry. This is because there is no effectively consistent method for monitoring the quality of airlines on a timely, objective, and comparable basis. The airline quality rating system uses an objective multiple-factor approach in the airline industry [61-62].

The method relies on the use of published, publicly available data that reports actual airline performance on critical quality criteria important to consumers and combines them into a rating system. The result is a rating for individual airlines with comparable range scale characteristics across airlines. Airline quality rating is a weighted assessment of multiple factors important to consumers when assessing the quality of airline services. Elements considered for inclusion in the rating scale are screened to meet two key decision criteria: i) An element should be available from published data sources for each airline, and ii) An element must be related to consumer concerns regarding airline performance

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quality. Data on the elements used in calculating the ratings represent airlines' performance aspects that are important to consumers (on-time arrival, mishandled baggage, involuntary denied boardings, and customer complaint areas) [61-62].

The importance weights of criteria were objectively determined using the mean weight method and standard deviation method. Each weight and element are given a plus or minus sign (optimization direction) to reflect the nature of this criterion's impact on a consumer's perception of quality. For example, the on-time performance criterion is included as a positive element as it is reported in terms of on-time success, suggesting that a higher number is favorable for consumers [61-62].

Conversely, the criterion that includes mishandled baggage is included as a negative element and reported in terms of mishandled baggage, suggesting that a higher number is unfavorable for consumers. Weights and impacts (positive/negative signs) are independent of each other. Weights reflect the importance of the criteria in the consumer decision-making process, while the signs reflect the direction of the impact of the criteria on the consumer's rating of airline performance quality. Combining all criteria, weights, and impacts for an airline throughout the year yields a single interval scaled value [61-62].

Airline quality rating criteria and weighted average methodology provide a focused comparison of airline performance. Unlike other consumer opinion approaches that rely on consumer surveys and subjective opinions, airline quality rating uses a mathematical MCMDA approach that considers multiple weighted objective criteria to arrive at a single comparable rating for airline industry performance.The airline quality rating provides both consumers and industry stakeholders with a tool to timely monitor comparative quality for each airline using objective, performance-based data. Airline quality rating is an aviation industry standard for comparing airline performance. Currently, airline quality rating is an objectively published rating for airline performance. With the ongoing global trend in airline operations alliances, the argument for the airline quality rating as a standard method for comparing the quality of airline performance for global operations is getting stronger [61-62].

In this study, the airline quality rating assessment process is considered a multiple criteria decision analysis problem. This is because the decision making process considers a number of alternatives to be evaluated together with often conflicting evaluation criteria for the airline quality rating problem. This study uses PARIS and TOPSIS methods to rank all important factors and to identify critical factors of airline quality rating practice. The mean weight method and the entropy weight method are used to calculate the importance weights of all evaluation criteria integrated into PARIS and TOPSIS methods.

The remainder of this paper is structured as follows. Chapter 2 presents the MCDMA methodology, including the entropy weight, PARIS, and TOPSIS methods. Chapter 3 presents a numerical application of the airline quality rating problem. Finally, Chapter 4 presents the conclusion.

II. Methodology

A. PARIS Programming Method

Suppose that multiple criteria decision making analysis (MCDMA) problem has I alternatives $a_i = (a_1, ..., a_i)$, $i \in \{ i = 1, ..., I \}$, and J criteria $g_j = (g_1, ..., g_j)$, $j \in \{ j = 1, ..., J \}$, and the importance weight of each criterion (ω_j, $j \in \{ j = 1, ..., J \}$) is known. The procedural steps of PARIS method for evaluation of the alternatives with respect to the decision criteria are presented as follows:

Step 1. Construction of decision matrix $X = (x_{ij})_{ixj}$

$$X = \begin{pmatrix} a_1 \\ \vdots \\ a_i \end{pmatrix} \begin{pmatrix} \overset{g_1}{x_{11}} & \cdots & \overset{g_j}{x_{1j}} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix}_{ixj} \quad (1)$$

where $X = (x_{ij})_{ixj}$ represents the decision matrix and x_{ij} is the value of ith alternative with respect to jth indicator g_j.

Step 2. Normalization of the decision matrix

For benefit criteria

$$r_{ij} = \frac{x_{ij}}{x_j^{\max}}, \; i = 1, ..., I, \; j = 1, ..., J \quad (2)$$

For cost criteria

$$r_{ij} = \frac{x_j^{\min}}{x_{ij}}, \; i = 1, ..., I, \; j = 1, ..., J \quad (3)$$

where x_{ij} are the evaluation indices and $i = 1, ..., I$, number of alternatives, and number of criteria, $j = 1, ..., J$.

$$x_i^{max} = \max_j \left\{ x_{1j}, x_{2j}, ..., x_{ij} \right\}, \; x_i^{min} = \min_j \left\{ x_{1j}, x_{2j}, ..., x_{ij} \right\} \quad (4)$$

Upon normalizing criteria of the decision matrix, all elements x_{ij} are reduced to interval values [0, 1], so all criteria have the same commensurate metrics.

Step 3. Computation of the weighted normalized matrix

$$z_{ij} = \omega_j r_{ij} \quad (5)$$

Step 4. Computation of the weighted summation of the evaluation indices

$$\pi_i^{\omega} = \sum_{j=1}^{J} \omega_j r_{ij}, \ i = 1,...,I, \ \ j = 1,...,J \qquad (6)$$

Step 5. Rank the alternatives according to decreasing values of π_i^{ω}. The alternative with the highest appraisal score is the best choice among the candidate alternatives.

Step 6. Determination of the elements of reference ideal solution (z_j^*)

$$z_j^* = \left\{ z_1^*,..., z_j^* \right\} = \left\{ (max_i \ z_{ij} \mid j \in B), (\min_i \ z_{ij} \mid j \in C \right\} \qquad (7)$$

Step 7. Computation of distance from the reference ideal solution (z_j^*)

$$\pi_i^* = \sum_{j=1}^{J} (z_j^* - z_{ij}), \ i = 1,...,I, \ \ j = 1,...,J \qquad (8)$$

Step 8. Rank the alternatives according to increasing values of π_i. The alternative with the lowest appraisal score is the best choice among the candidate alternatives.

Step 9. The relative distance from each evaluated alternative to the reference ideal point is calculated to determine the ranking order of all alternatives.

$$R_i = \sqrt{(\pi_i^{\omega} - \pi_i^{\omega,\max})^2 + (\pi_i^* - \pi_i^{*,\min})^2} \qquad (9)$$

Step 10. Rank the alternatives according to increasing values of R_i. The alternative with the lowest appraisal score is the best choice among the candidate alternatives.

B. TOPSIS Programming Method

The technique for order of preference by similarity to ideal solution (TOPSIS) method is an MCDMA method that has been used in numerous real-life problems and extended in different uncertain environments. In the TOPSIS method, the evaluation process of alternatives is conducted with respect to the distances from the ideal and anti-ideal solutions.

Suppose that, given a set of alternatives I, $a_i = \left(a_1,...,a_i\right)$, $i \in \{ i = 1,...,I \}$), a set of criteria J, $g_j = \left(g_1,...,g_j\right)$, $j \in \{ j = 1,...,J \}$), and the importance weight of each criterion (ω_j, $j \in \{ j = 1,...,J \}$) is known. The procedural steps of TOPSIS method are presented as follows [11]:

Step 1. The construction of a decision matrix

$$X = \begin{pmatrix} a_1 \\ \vdots \\ a_i \end{pmatrix} \begin{pmatrix} \overset{g_1}{x_{11}} & \cdots & \overset{g_j}{x_{1j}} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix}_{ixj} \qquad (10)$$

where $X = (x_{ij})_{ixj}$ represents the decision matrix and x_{ij} is the value of *i*th alternative with respect to *j*th indicator g_j.

Step 2. Determination of the normalized values of the decision matrix

For benefit criteria

$$r_{ij} = \frac{x_{ij}}{x_j^{\max}}, \ i = 1,...,I, \ j = 1,...,J \qquad (11)$$

For cost criteria

$$r_{ij} = \frac{x_j^{\min}}{x_{ij}}, \ i = 1,...,I, \ j = 1,...,J \qquad (12)$$

Step 3. Calculation of the weighted normalized values

$$v_{ij} = \omega_j r_{ij} \qquad (13)$$

Step 4. Determination of the ideal and anti-ideal solutions based on the weighted normalized values

$$a_i^* = \left\{ v_1^*,..., v_j^* \right\} = \left\{ (max_i \ v_{ij} \mid j \in B), (\min_i \ v_{ij} \mid j \in C \right\} \qquad (14)$$

$$a_i^- = \left\{ v_1^-,..., v_j^- \right\} = \left\{ (max_i \ v_{ij} \mid j \in B), (\min_i \ v_{ij} \mid j \in C \right\} \qquad (15)$$

where B and C are the sets of benefit and cost criteria, respectively.

Step 5. Calculation of the Euclidean distance of alternatives from the ideal (d_i^*) and anti-ideal (d_i^-) solutions

$$d_i^* = \sqrt{\sum_{j=1}^{J} \ (v_{ij} - v_j^*)^2} \qquad (16)$$

$$d_i^- = \sqrt{\sum_{j=1}^{J} (v_{ij} - v_j^-)^2} \qquad (17)$$

Step 6. Calculation of the closeness coefficient (CC_i) of each alternative

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \qquad (18)$$

Step 7. Rank the alternatives in decreasing order of the closeness coefficient values (CC_i)

C. Entropy Weight Vector Calculation

The fundamental of the entropy weight method is the volume of intrinsic information to calculate the index's objective importance weight. The information entropy method is used to determine the importance weight of criteria. The procedural steps are summarized as follows [53]:

Step 1. The normalization of the decision matrix $X = (x_{ij})_{ixj}$

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{I} x_{ij}}, \; i = 1,...,I \tag{19}$$

Step 2. The calculation of entropy for each index

$$E_j = -\frac{1}{\ln I}\sum_{i=1}^{I} p_{ij} \ln p_{ij}, \; j = 1,...,J \tag{20}$$

Step 3. The calculation of the degree of deviation of essential information for each criterion g_j

$$d_j = 1 - E_j, \; j = 1,...,J \tag{21}$$

where d_j measures the degree of deviation of essential information for the *j*th criteria g_j.

Step 4. The calculation of the criteria's entropy weight

$$\omega_j = \frac{d_j}{\sum_{j=1}^{J} d_j} \tag{22}$$

$$\sum_{j=1}^{J} \omega_j = 1, \; \omega_j > 0, \; j = 1,...,J$$

where ω_j is the importance weight of the *j*th criteria g_j.

D. Mean Weight Vector Calculation

The mean weight (MW) requires minimal information about the priorities of the criteria and minimal input from the decision maker. The MW method is used in multiple criteria decision analysis when there is no information from the decision maker or there is not enough information to come to a decision. The criteria weights are represented as a uniform distribution over the unit.

$$\omega_j = \frac{1}{J}, \; j = 1,...,J \tag{23}$$

$$\sum_{j=1}^{J} \omega_j = 1, \; \omega_j > 0, \; j = 1,...,J$$

where ω_j is the importance weight of the *j*th criteria g_j.

III. Application

In this study, the airline quality rating problem is considered by integrating objective weighting procedures (mean weight, entropy weight) with PARIS, and TOPSIS methods.

Airline quality rating problem is taken as a numerical example of the aviation industry, a set of airlines as alternatives{(a_1), (a_2), (a_3), (a_4), (a_5), (a_6), (a_7), (a_8), (a_9), (a_{10})}. The MCDMA problem is evaluated using four decision criteria: on-time performance (g_1), mishandled baggage (g_2), involuntary denied boardings (bumping or oversales) (g_3) and treatment of customers (g_4).

The on-time performance (g_1) attribute is considered for maximum optimization direction, and the mishandled baggage (g_2), involuntary denied boardings (bumping or oversales) (g_3) and treatment of customers (g_4) attributes are considered for minimum optimization direction. The numerical performance index values for the alternatives are presented in Table 1.

Table 1. Decision matrix

	g_1	g_2	g_3	g_4
a_1	0,849	0,03	3,95	9,13
a_2	0,713	0,01	1,48	6,34
a_3	0,834	0,2	6,38	9,05
a_4	0,863	0,01	3,71	6,96
a_5	0,839	0,24	3,23	49,3
a_6	0,88	0,01	3,19	37,63
a_7	0,821	0,01	3,81	11,29
a_8	0,86	0,06	2,68	2,64
a_9	0,866	0,09	3,79	9,6
a_{10}	0,836	0,01	4,55	29,73

The air transport data was retrieved from the U.S. Department of Transportation [62]. The numerical data was slightly adapted for the MCDMA problem.

A. PARIS Programming Method

Following the procedural steps of the PARIS method, the computational results were tabulated from Table 2 to

Table 10. The alternative (a_2) airline was selected as the best-rated decision solution.

Table 2. Normalized decision matrix

	g_1	g_2	g_3	g_4
a_1	0,9648	0,3333	0,3747	0,2892
a_2	0,8102	1,0000	1,0000	0,4164
a_3	0,9477	0,0500	0,2320	0,2917
a_4	0,9807	1,0000	0,3989	0,3793
a_5	0,9534	0,0417	0,4582	0,0535
a_6	1,0000	1,0000	0,4639	0,0702
a_7	0,9330	1,0000	0,3885	0,2338
a_8	0,9773	0,1667	0,5522	1,0000
a_9	0,9841	0,1111	0,3905	0,2750
a_{10}	0,9500	1,0000	0,3253	0,0888

The criteria importance weights determined by the mean weight (MW) and the entropy weight (EW) are given in Table 3.

Table 3. Objective decision criteria weights ω_j

	g_1	g_2	g_3	g_4
MW ω_j	0,25	0,25	0,25	0,25
EW ω_j	0,0014	0,6161	0,0523	0,3302

Table 4. PARIS weighted normalized decision matrix (MW)

	g_1	g_2	g_3	g_4
a_1	0,2412	0,0833	0,0937	0,0723
a_2	0,2026	0,2500	0,2500	0,1041
a_3	0,2369	0,0125	0,0580	0,0729
a_4	0,2452	0,2500	0,0997	0,0948
a_5	0,2384	0,0104	0,1146	0,0134
a_6	0,2500	0,2500	0,1160	0,0175
a_7	0,2332	0,2500	0,0971	0,0585
a_8	0,2443	0,0417	0,1381	0,2500
a_9	0,2460	0,0278	0,0976	0,0688
a_{10}	0,2375	0,2500	0,0813	0,0222

Table 5. PARIS distance from the reference ideal solution (z_j^*) (MW)

	g_1	g_2	g_3	g_4
a_1	0,0088	0,1667	0,1563	0,1777
a_2	0,0474	0,0000	0,0000	0,1459
a_3	0,0131	0,2375	0,1920	0,1771
a_4	0,0048	0,0000	0,1503	0,1552
a_5	0,0116	0,2396	0,1354	0,2366
a_6	0,0000	0,0000	0,1340	0,2325
a_7	0,0168	0,0000	0,1529	0,1915
a_8	0,0057	0,2083	0,1119	0,0000
a_9	0,0040	0,2222	0,1524	0,1813
a_{10}	0,0125	0,0000	0,1687	0,2278

Table 6. PARIS Weighted Normalized Decision Matrix (EW)

	g_1	g_2	g_3	g_4
a_1	0,9648	0,9709	0,3747	0,2892
a_2	0,8102	1,0000	1,0000	0,4164
a_3	0,9477	0,8333	0,2320	0,2917
a_4	0,9807	1,0000	0,3989	0,3793
a_5	0,9534	0,8065	0,4582	0,0535
a_6	1,0000	1,0000	0,4639	0,0702
a_7	0,9330	1,0000	0,3885	0,2338
a_8	0,9773	0,9434	0,5522	1,0000
a_9	0,9841	0,9174	0,3905	0,2750
a_{10}	0,9500	0,9901	0,3253	0,0888

Table 7. PARIS distance from the reference ideal solution (EW)

	g_1	g_2	g_3	g_4
a_1	0,0000	0,4107	0,0327	0,2347
a_2	0,0003	0,0000	0,0000	0,1927
a_3	0,0001	0,5853	0,0402	0,2339
a_4	0,0000	0,0000	0,0315	0,2049
a_5	0,0001	0,5904	0,0284	0,3125
a_6	0,0000	0,0000	0,0281	0,3070
a_7	0,0001	0,0000	0,0320	0,2530
a_8	0,0000	0,5134	0,0234	0,0000
a_9	0,0000	0,5476	0,0319	0,2394
a_{10}	0,0001	0,0000	0,0353	0,3009

Table 8. PARIS ranking results of unweighted and weighted summation π_i^{ω} (MW)

	UW	MW ω_j	EW ω_j
a_1	7	7	7
a_2	1	1	1
a_3	9	9	9
a_4	2	2	2
a_5	10	10	10
a_6	5	5	4
a_7	4	4	3
a_8	3	3	6
a_9	8	8	8
a_{10}	6	6	5

Table 9. PARIS ranking results π_i^* using distance from the reference ideal solution (EW)

	MW ω_j	EW ω_j
a_1	7	7
a_2	1	1
a_3	9	9
a_4	2	2
a_5	10	10
a_6	5	4
a_7	4	3
a_8	3	6
a_9	8	8
a_{10}	6	5

Table 10. PARIS ranking results R_i using relative distance from the reference ideal solution

	MW ω_j	EW ω_j
a_1	7	7
a_2	1	1
a_3	9	9
a_4	2	2
a_5	10	10
a_6	6	4
a_7	4	3
a_8	3	6
a_9	8	8
a_{10}	5	5

B. *TOPSIS Programming Method*

Following the procedural steps of the TOPSIS method, the computational results were tabulated from Table 11 to Table 13. In terms of ease of procedural computing, the solution steps of the TOPSIS method that are common with the PARIS method are not given. The alternative (a_2) airline was selected as the best-rated decision solution.

Table 11. TOPSIS the ideal and anti-ideal solutions (MW)

	g_1	g_2	g_3	g_4
a_i^*	0,25	0,25	0,25	0,25
a_i^-	0,2026	0,0104	0,0580	0,0134

Table 12. TOPSIS the ideal and anti-ideal solutions (EW)

	g_1	g_2	g_3	g_4
a_i^*	0,0014	0,6161	0,0523	0,3302
a_i^-	0,0011	0,0257	0,0121	0,0177

Table 13. TOPSIS ranking results CC_i

	MW ω_j	EW ω_j
a_1	7	7
a_2	1	1
a_3	9	9
a_4	2	2
a_5	10	10
a_6	5	4
a_7	4	3
a_8	3	6
a_9	8	8
a_{10}	6	5

IV. Conclusion

Airline quality rating indicators are significant in assessments of airlines services for sustainability in the aviation industry. In this paper, selected four indicators, on-time arrivals, mishandled baggage, involuntary denied boardings and consumer complaints, were used to evaluate a set of airlines for the decision making analysis problem. PARIS and TOPSIS methods were applied to rank the airlines using the mean weights and entropy weights. Finally, the multiple criteria decision making process results revealed that alternative (a_2) airline is the best airline. Different MCMDA methods can be used in the uncertainty analysis of the airline quality rating problem.

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