Evaluation of Airport Operation Production Performance Based on Entropy Weight-VIKOR Method

Xiang Lai

International economics and trade, School of Maritime Economics and Management of Dalian Maritime University, Liaoning, China

1025730977@qq.com

Abstract. The operational production status of an airport is an important factor influencing airport operational efficiency. The effective evaluation of the operational production performance of an airport has significant guiding significance for improving airport quality management and enhancing market competitiveness. Taking the monthly operational situation of Hangzhou Xiaoshan International Airport, China in China as an example, this paper establishes an airport operational production index system and uses the entropy weight-VIKOR method to evaluate the operational production performance of the airport. The results show that when different decision coefficients are taken, the optimal month for the operational production capacity of the airport is always October. Through sensitivity analysis of the worst performing month, which is February, it is found that the main indicators influencing that month are aircraft takeoff and landing movements and passenger satisfaction. Airport managers should pay high attention to these two indicators, compare them with internal benchmark months to seek improvement measures, and guide continuous improvement of airport operational production performance.

Keywords: entropy weight method; performance evaluation; multi-criteria decision-making; takeoff and landing frequency; passenger satisfaction; quality management.

1 Introduction

In recent years, China's civil aviation transport industry has developed rapidly, and the trend of commercialization and globalization has promoted the increasingly fierce competition in the civil aviation transport market. Airport operation and production status is an important influencing factor of airport operation efficiency, and for airport quality managers and stakeholders, effective evaluation of airport operation and production performance has important guiding significance for clearly understanding airport operation efficiency, correctly reflecting the quality management level, and enhancing market competitiveness. Parker (1997) conducted a comparative study of nine major airports in East and Southeast Asia using fuzzy evaluation methods [1]; Sarkis (2004) evaluated the operational efficiency of 44 airports in the United States from 1990 to

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1994 using a multi-criteria non-parametric method[2]; Li Lanbing et al. (2007) used data envelopment analysis and Malmquist productivity index to make an overall evaluation of the production efficiency of airports opened to the outside world in China[3]. Most of the studies of experts and scholars at home and abroad use non-parametric methods to evaluate airport operation efficiency and use statistical regression model to analyze the influencing factors, but the research on the production efficiency of airport operation is relatively lacking. Entropy weight method is a research method with strong operability and objectivity, which is widely used in performance evaluation, quality management and safety evaluation. VIKOR method is a good MCGDM analysis method, which can propose a compromise solution, pursue the maximization of group benefits while ensuring the minimum individual regret, reduce conflicts between decision-makers, and provide support for supplier selection and lean management decision-making [4]. Taking the monthly operation of Hangzhou Xiaoshan International Airport,China in 2018 as an example, this paper evaluates the performance of airport operation and production by establishing the airport operation production index system and using the entropy weight-VIKOR method, and the research results have important guiding significance for the improvement of airport qual

ity management and market competitiveness.

The first section of this paper introduces the selection of airport operation production index framework, the second section uses the entropy weight method and VIKOR method to establish the airport operation production level evaluation model, the third section selects Hangzhou Xiaoshan Airport for case analysis and sensitivity analysis, and the fourth section discusses and concludes.

2 Establish an indicator framework

Since the 1990s, many experts and scholars have begun to study the efficiency evaluation of airport operation. Sarkis (2000) selected airport operation costs, the number of airport staff, the number of boarding gates, and runway numbers as input indicators, and operational revenues, passenger throughput, commercial takeoff and landing cycles, general aviation takeoff and landing cycles, and cargo and mail throughput as output indicators for airport efficiency evaluation [5]. Sun Xinxiang et al. (2006) selected actual capital, net fixed assets, and airport service fees as input indicators, passenger and cargo throughput, aircraft takeoff and landing cycles, and main business income as output indicators to choose a suitable airport management model. Chu Yanchang (2009) subdivided the production efficiency indicators of airport operation into passenger throughput per employee, passenger throughput per waiting hall, takeoff and landing cycles per parking space, takeoff and landing cycles per runway, cargo throughput per cargo waiting hall, and minimum connection time (MCT) [6]. Considering the actual situation of airport operation production work, we have established the indicator system shown in the table 1.

Table 1. Airport Operational Performance Metrics.

Running production indicators	Calculations formula and data sources.
Passenger throughput X_1	The total number of passengers arriving and departing during the reporting period
Passenger throughput per unit terminal X_2	Passenger throughput/passenger terminal area
Cargo and mail throughput X_3	Number of cargo mailings arriving and leaving the port during the reporting period
Unit freight apron cargo and mail throughput X_4	Cargo and mail throughput volume/cargo terminal floor area
Number of aircraft takeoffs and landings X_5	The total number of aircraft takeoffs and landings during the reporting period
Unit stop position take-off and landing sorties X_6	Number of aircraft takeoffs and landings/number of parking spaces.
Unit runway takeoff and landing sorties X_7	Number of aircraft takeoffs and landings/runways
Passenger satisfaction X_8	Randomly selecting passengers for rating
Flight on-time performance rate X_9	From the civil aviation flight normal statistics system

Among these indicators, indicators 1, 3, and 5 can effectively reflect the production and operation level of an airport; indicator 2 reflects the production efficiency of the terminals for passengers; indicator 4 reflects the production efficiency of the freight apron for cargo and mail; indicator 6 reflects the service efficiency of the airport's parking positions for aircraft; indicator 7 reflects the production efficiency of the runway, which further reflects the level of airport operation and management; indicator 8 is a manifestation of the degree to which airport equipment, facilities, and services meet passenger expectations; indicator 9 reflects the overall production efficiency and quality of airport operation.

3 Establishment of an Airport Operational Production Capacity Evaluation Model

This model combines the entropy weight method and VIKOR method. In the evaluation of the decision-making process, the entropy weight method is used to reduce the subjective factors of decision-makers in assigning weights, while the VIKOR method is used to maximize group utility and seek a compromise solution that is acceptable to the evaluator. By doing so, this model can provide airport managers with a more objective and simple method for evaluating operational production capacity.

3.1 Entropy Weight Method

After Shen Nong introduced the concept of entropy into information theory, entropy has become an ideal measure for multi-objective decision-making and evaluation. Entropy weight method is an objective weighting method, and its basic idea is to determine objective weights based on the size of index variability. If the information entropy of an index is smaller, it indicates that the degree of variability of the index value is higher, providing more information and having a greater role in comprehensive evaluation, so its weight is also greater. The opposite is also true. The entropy weight method refers to the establishment in reference to literature [7], and after obtaining the information entropy e_j and information usefulness values d_j of various indicators, the entropy weight W_j is obtained using formula (1).

$$W_j = d_j \Big/ \sum_{j=1}^{m} d_j \quad (j = 1, 2, \ldots, n) \tag{1}$$

3.2 VIKOR method

VIKOR is a multi-attribute decision-making method proposed by Opricovic et al. [8]. The core concept of the algorithm is to first define the positive ideal solution and the negative ideal solution, and then rank the alternative solutions based on their evaluation values and their proximity to the ideal solution. Compared to the TOPSIS method, the compromise solution obtained by the VIKOR method has priorities and is closer to the ideal solution.

The main calculation steps of the VIKOR method are referenced from [9]. After the forwardization of indicators and the determination of positive solution y_j^+ and negative ideal solution y_j^-, combined with the weights of each indicator w_j determined by the entropy weighting method mentioned above, the maximum group utility value S_i of the candidate solutions is calculated using formula (2), the minimum individual regret value R_i is calculated using formula (3), and the profit ratio value Q_i of each candidate solution is calculated using formula (4), where v represents the decision coefficient, $v \in [0,1]$.

$$S_i = \sum_{j=1}^{n} w_j (y_j^+ - y_{ij}) \big/ (y_j^+ - y_j^-) \tag{2}$$

$$R_i = \max_j \left\{ w_j (y_j^+ - y_{ij}) \big/ (y_j^+ - y_j^-) \right\} \tag{3}$$

$$Q_i = v \times \frac{(S_i - \min S_i)}{(\max S_i - \min S_i)} + (1 - v) \times \frac{(R_i - \min R_i)}{(\max R_i - \min R_i)} \tag{4}$$

Finally, the selected options S_i, R_i, Q_i are sorted according to the principle of smaller being more favorable, and a comparative ranking of each alternative option is conducted.

4 Results and Cases Analysis

4.1 Entropy-weighted evaluation of operational production status of Hangzhou Xiaoshan International Airport, China in 2018

Using the data from reference [9], the entropy-weighted VIKOR method was used to evaluate the operational production status of Hangzhou Xiaoshan International Airport,China for each month in 2018. In this example, all indicators were positive. The weight matrix was obtained by using the entropy method to calculate the weights of the nine indicators as shown below:

$$W = \begin{pmatrix} 0.130473 & 0.130172 & 0.072136 & 0.072259 & 0.101034 & 0.101031 & 0.103254 & 0.17684 & 0.112801 \end{pmatrix}$$

The VIKOR method is implemented using MATLAB. Formula (6) is used to standardize the initial decision matrix, and the positive and negative ideal solutions are determined shown in Table 2. Formula (7) and (8) are used to calculate the maximum group utility value S_i and minimum individual regret value R_i, respectively.

Table 2. Standardized values and ideal solutions for each index

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
January	0	0	0.982979	0.977778	0.258065	0.258091	0.266667	0.25	0.877121
February	0.187135	0.1875	0	0	0	0	0	0.25	0.603393
March	0.678055	0.681818	0.876596	0.866667	0.709677	0.709545	0.733333	0.25	0.698762
April	0.676054	0.676136	0.753191	0.755556	0.612903	0.612864	0.6	0.125	0.596057
May	0.545245	0.545455	0.834043	0.822222	0.645161	0.645227	0.666667	0.75	0.495186
June	0.454294	0.454545	0.855319	0.844444	0.483871	0.483818	0.466667	0	0.503897
July	0.839181	0.840909	0.53617	0.533333	1	1	1	0.375	0
August	1	1	0.582979	0.577778	0.935484	0.935682	0.933333	1	0.134801
September	0.562173	0.5625	0.880851	0.866667	0.709677	0.709545	0.733333	0.375	0.564878
October	0.847799	0.846591	0.765957	0.755556	0.83871	0.838591	0.866667	1	1
November	0.273315	0.272727	1	1	0.419355	0.4195	0.4	0.5	0.55204
December	0.280394	0.284091	0.978723	0.977778	0.483871	0.483818	0.466667	0.625	0.917928
Positive ideal solution	1	1	1	1	1	1	1	1	1
Negative ideal solution	0	0	0	0	0	0	0	0	0

Given the practical significance of airport operational performance evaluation, decision coefficient v was set at 0.5, 0.2, and 0.8 respectively. Formula (9) was used to calculate the benefit ratio values for each month, and then sorted accordingly. The results obtained are presented in the following table 3:

Table 3. Values of R, S, Q and Ranking Results for Each Month

	R	S	Q	S sorting	v=0.5 Q sorting	v=0.8 Q sorting	v=0.2 Q sorting
January	0.132630	0.635605	0.717546	11	10	11	9
February	0.132630	0.838904	0.859088	12	12	12	10
March	0.132630	0.354782	0.522030	5	8	6	8
April	0.154735	0.439716	0.651620	8	9	9	11
May	0.059333	0.350585	0.285486	4	2	3	2
June	0.176840	0.556046	0.803068	10	11	10	12
July	0.112801	0.332197	0.443102	3	4	4	6
August	0.097595	0.178087	0.287342	2	3	1	3
September	0.110525	0.378123	0.467825	6	6	5	7
October	0.019970	0.120744	0.000000	1	1	1	1
November	0.094813	0.507699	0.507958	9	7	8	5
December	0.093889	0.425159	0.447548	7	5	7	4

The results show that when the decision coefficient v=0.5, which represents a compromise between maximizing collective benefits and minimizing individual regrets, the maximum operating production capacity of Hangzhou Xiaoshan International Airport,China is in October, followed by May, while the performance in February and June is relatively poor. When the decision coefficient v=0.8, which prioritizes maximizing collective benefits, the optimal operating production capacity of this airport is in October and August, and the worst is in January and February. When the decision coefficient v=0.2, which prioritizes minimizing individual regrets, the optimal operating production capacity of this airport is in October and May, and the worst is in April and June.

Based on the above analysis, regardless of the value of the decision coefficient, the operating production capacity of Hangzhou Xiaoshan International Airport,China in October 2018 always ranks first. Therefore, the airport should take October as a benchmark, analyze the main influencing factors, and propose appropriate solutions and improvement methods.

5 Sensitivity Analysis

From the perspective of sensitivity analysis, this section studies the impact of changes in different indicator variables on the output results of the model. Taking the ranking of airport's monthly operational production level as an example when the coefficient of determination is 0.5, it is assumed that the operational production capacity score for the month ranked first is 90 points, and the score decreases by 4 points for each subsequent ranking. Through analysis, it is found that the operational production scores for each month from January to December are 74, 66, 90, 70, 82, 78, 50, 86, 58, 62, 46, and 54.

Assuming that a score of 60 is the minimum acceptable level for airport operational production, it can be seen that the performance of the airport in January, February, April, and June did not reach this level. Therefore, the management needs to use the benchmark management method in quality management, with October as the internal benchmark, to analyze the reasons and carry out rectification to effectively improve the airport's operational production performance.

Taking February, which has the lowest production performance score, as an example for sensitivity analysis, the airport's terminal area, apron area, parking position quantity, and runway quantity cannot be changed in the short term. Therefore, there is interaction between indicators 1 and 2, indicators 3 and 4, and indicators 5, 6, and 7. Assuming that each of the above indicators varies from 0% to 25%, and the variation percentage of indicator 8 is from 0% to 1%, the sensitivity analysis of the airport's production performance ranking in February 2018 is shown in Figure 1.

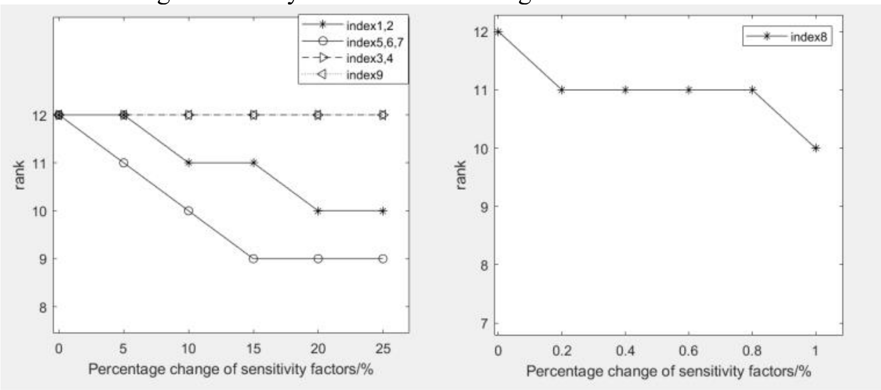

Fig. 1. Sensitivity analysis line chart

According to sensitivity analysis, the indicators that have the greatest impact on the operational performance of the airport in February are aircraft takeoff and landing frequencies and passenger satisfaction. Therefore, airport managers should pay close attention to these two indicators and conduct detailed analyses from various aspects, such as flight area capacity, runway utilization efficiency, airport operations command capability, air traffic management capability[6], and the completeness of airport equipment and facilities, as well as the attitude of airport staff. They can compare these aspects with benchmark months, find corresponding responses, set reasonable and credible goals, and guide the continuous improvement of airport operational performance.

6 Discussion and Conclusions

In this study, the entropy weight-VIKOR method is used to evaluate the operational performance of the airport, and the empirical analysis is carried out by taking Hangzhou Xiaoshan International Airport, China in 2018 as an example. The results show that when different decision coefficients are used, the optimal month for the airport's operational productivity is October. Therefore, managers need to use October as the internal benchmark, compare months such as February and June, which have not reached the minimum acceptable level of performance, and systematically analyze the main reasons. They can adopt methods such as Six Sigma management and comprehensive quality management, combined with relevant indicators, to provide improvement suggestions and measures. By considering both the maximization of group benefits and the minimization of individual regret, sensitivity analysis is conducted on the worst-performing month of February, which indicates that the main indicators affecting this month are aircraft takeoff and landing frequencies and passenger satisfaction. Airport managers should pay close attention to these two indicators, find corresponding responses from aspects such as runway utilization efficiency, operational command capability, and the attitude of staff, and guide the continuous improvement of airport operational performance.

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