Research on Domestic Airport Connectivity Based on Critic Empowerment Method

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Abstract: In order to improve the weight of airports in the aviation connectivity index model developed by the International Air Transport Association (IATA), only considering the insufficiency of annual passenger throughput, considering the influence factors such as the proportion of transit passengers, the number of departing flight seats, and the number of navigation points, the weight of the destination airport in the model is re-determined by using the critic weighting method. Using the operational data of 37 airports with a throughput exceeding 10 million in my country in 2018, the analysis found that:(1) Since the connectivity model has comprehensively considered other indicators when determining the airport weights after the improvement, the weights of most airports have changed, which has further changed the connectivity ranking of airports in my country;(2) The aviation connectivity of hub airports in my country is much greater than that of regional airports, and the connectivity rankings of hub airports are generally higher and the connectivity rankings of regional airports are lower;(3) The aviation connectivity scores of most airports in my country are generally low, and the development of airport connectivity is unbalanced. Therefore, the improved airline connectivity index model can reflect the level of airline connectivity of China's airports more objectively and accurately.

Keywords: air transportation, transport airports, air connectivity index, critic empowerment method

1 INTRODUCTION

Airport connectivity is a vague concept that measures the ease of displacement of passengers or cargo from origin to destination. There is no uniform definition, but it is essentially a measure of the degree of connectivity between nodes in the airline network [1]. The connectivity ranking of China's major airports can reflect the current status of the connectivity of each airport in China's airline network more intuitively and effectively, which can help China's airports plan and build a high-quality route network and provide directional guidance for the government to support and develop China's civil aviation industry. At present, the research on airport connectivity focuses on aviation connectivity and ground connectivity [2]. This paper studies the aviation connectivity of airports. There are few studies on airport connectivity in China, while foreign studies are more mature compared to China. In 2017, Nugraha P used the NetScan aviation connectivity model to study the aviation connectivity in Indonesia and gave suggestions for improving aviation connectivity [3]. In 2018, Charukit Chaiwan evaluated the connectivity of medium-sized airports in Thailand using the NetScan aviation connectivity model [4]. In 2020

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S. P. Li studied the connectivity of domestic airline networks under epidemics using network efficiency indicators and gave countermeasures for airline networks to resist unexpected risks [5]. In 2015, Allroggen F studied air connectivity and pointed out that the airport connection weight is positively correlated with the number of seats on the departing flight [6]. In 2017, Li selected the indicator of maximum annual seat capacity to analyze the connectivity of airports based on a factor analysis approach [7]. In 2018, Jingyi Wang pointed out that the increase in the number of destination airports can improve airport air connectivity [2]. In 2022, Zhang L empirically measured the international airline connectivity of Beijing, and this connectivity index considered the number of flights and capacity, etc [8].

To sum up, there are many methods for evaluating aviation connectivity, including traditional network efficiency evaluation methods, NetScan aviation connectivity model, World Bank's connectivity index, and IATA's aviation connectivity index. Among them, the index coefficient in the NetScan is mainly based on the actual situation of European airports, and its scope of application is some airports in Europe. Due to the difference between the actual situation of airports in other regions and European airports, so the model has certain limitations in measuring the connectivity of airports in other regions. The World Bank's uses individual countries as nodes and has no way of reflecting the connectivity of individual airports. Although the aviation connectivity model proposed by IATA can reflect the connectivity of a single airport, it only considers the passenger throughput factor when determining the weight of the destination airport, and does not comprehensively consider the main factors affecting airport connectivity, such as the number of transit passengers, number of navigation points, etc.

Based on the traditional aviation connectivity index model proposed by IATA, this paper first comprehensively considers the influencing factors such as the proportion of transit passengers, the number of seats on departure flights and navigation points, and uses the critic weighting method to redefine the purpose of the model. The weight of the airport is used to improve the aviation connectivity index model formulated by IATA, and then it is proved that the improved model is more feasible by comparing the aviation connectivity index model before and after the improvement. Finally, based on the improved air connectivity index, the air connectivity of airports with a throughput of more than 10 million in China is calculated and analyzed, and countermeasures and suggestions for improving airport connectivity are given.

2 CONNECTIVITY INDEX MODEL

2.1 IATA Connectivity Index

The Aviation Connectivity Index developed by IATA is a weighted sum of the total number of available seats from the measured airport to all destination airports, and can be expressed as:

$$Con = \sum_{n=1}^{N} Seat_n W_n \tag{1}$$

Among them, *Con* represents the aviation connectivity score of the airport, $Seat_n$ is the annual number of departure seats, W_n represents the weight of destination airport n, which is based on the annual passenger number of airport n. Based on throughput, the weight of the airport with the largest throughput is 1. The weight of each destination indicates the economic importance of the destination airport and the number of connecting flights it can provide, with the weight of the destination airport increasing as the number of destinations increases, the frequency of service increases, and larger hub airports join the connection. The aviation connectivity index developed by the International Air Transport Association is more intuitive and can be adapted to all airports. The aviation connectivity index has a time attribute and can also be used to compare the connectivity levels of different countries and regions over time. So, this indicator can reflect the level of connectivity index of cities, countries and different regions in real time.

2.2 Improvement of Aviation Connectivity Index

The weight W_n of destination airports in the aviation connectivity index model developed by IATA depends on the annual passenger throughput. By reviewing relevant literature, indicators such as the proportion of transit passengers at the airport, the number of departing flight seats and the number of waypoints are important for airport connectivity.   It will also have a greater impact. In the IATA Connectivity Index, the airport weight only considers the number of passengers handled by the destination airport. Obviously, this does not consider the annual passenger throughput, the number of transit passengers and departures. The number of port seats and flights can reflect the indicators of forward connectivity. Considering the divergence ability of the destination airport to other airports, the number of waypoints can also be used as an important indicator to determine the weight of the destination airport. Therefore, the destination airport weight can be expressed as:

$$W_n = W_{nh} \times w_{nh} + W_{nt} \times w_{nt} + W_{nd} \times w_{nd} + W_{ns} \times w_{ns} \quad (2)$$

The improved connectivity index model is then expressed as:

$$Con = \sum_{n=1}^{N} \left(Seat_n * (W_{nh} \times w_{nh} + W_{nt} \times w_{nt} + W_{nd} \times w_{nd} + W_{ns} \times w_{ns}) \right) \quad (3)$$

Where *Con* denotes the airline connectivity score of this airport, $Seat_n$ is the annual number of departing seats, W_n denotes the destination airport *n* weight, W_{nh}, W_{nt}, W_{nd}, W_{ns} denote the weight of passenger throughput, share of transit passengers, number of seats on departing flights, and number of through points of airport n, respectively, and w_{nh}, w_{nt}, w_{nd}, w_{ns} respectively represent the weight of the above indicators in the weight of the airport.

3 CRITIC EMPOWERMENT ACT

Considering that the selected indicators are all objective indicators of the airport, the objective weighting method is applied to determine the indicator weights. At present, there are three kinds of objective weighting methods in common use, CRITIC weighting method, standard deviation method and entropy weighting method. CRITIC weighting method is a better weighting method compared with standard deviation method and entropy weighting method, which is not only based on the comparison strength of evaluation indicators and the conflict between indicators to measure the objective weight of indicators, but also consider the correlation between indicators while considering the size of variability of indicators, and completely uses the objective properties of data itself for scientific evaluation. Therefore, this paper adopts an objective weighting method - CRITIC weighting method to determine the weight of these indicators in the weight of the airport.

(1) First establish the initial indicator data matrix.

(2) The data are dimensionless to eliminate the influence of the difference in the magnitude on the evaluation results. If the value of the indicator is positively related to the weight, use forward processing, otherwise use reverse processing:

$$x_{ij}^{'} = \frac{x_j - x_{\min}}{x_{\max} - x_{\min}} \tag{4}$$

$$x_{ij}^{'} = \frac{x_{\max} - x_j}{x_{\max} - x_{\min}} \tag{5}$$

(3) Calculation of index variability and conflict

The CRITIC weighting method uses the standard deviation to represent the fluctuation of the value difference within each index. If the standard deviation is larger, the greater the numerical difference of the index, it can reflect more different information, and further explain the value of the index itself. The stronger the evaluation strength, the more weight should be assigned to the indicator.

$$S_j = \sqrt{\frac{\sum_{i=1}^{n}(x_{ij} - \overline{x}_j)^2}{n-1}} \tag{6}$$

$$R_j = \sum_{i=1}^{p}(1 - r_{ij}) \tag{7}$$

(4) Calculate the amount of information and determine objective weights

$$C_j = S_j \sum_{i=1}^{p}(1 - r_{ij}) = S_j \times R_j \tag{8}$$

The larger the value of C_j, the greater the role of the evaluation index *j* in the entire evaluation index system, that is, more weights should be assigned to it. The objective weight of the *j*-th indicator can be expressed as:

$$W_j = \frac{C_j}{\sum_{i=1}^{p} C_j} \tag{9}$$

4 EMPIRICAL ANALYSIS OF MAJOR AIRPORTS

This paper proves that the improved model is more feasible by comparing the improved before and after aviation connectivity index model, and uses the improved model to analyze the airline connectivity of domestic airports, considering the difficulty of data collection and the complexity of processing, 37 domestic airports with throughput over 10 million in 2018 are selected in this paper to study their aviation connectivity. Annual passenger throughput, number of seats on departing flights, and number of access points were obtained from the SRS Analyser database, and transit passenger percentage data were obtained from the CADAS database. As shown in Table 1, reveal that the indicator of the percentage of transit passengers has the largest information quantity, then it indicates that the percentage of transit passengers plays the largest role in the evaluation of airport weights.

Tab.1 The weight calculation results of each indicator

Weighting Indicators	Indicator Information Volume C_j,	weight
passenger throughput	0.294	0.150
the proportion of transit passengers	0.730	0.371
the number of seats on departure flights	0.502	0.255
the number of navigation points	0.442	0.224

As shown in Table 2 below.If the airport weighting only considers the indicator of passenger throughput, the top five airports in airport weighting are PEK, PVG, CAN, CTU and SZX, if all indicators are considered, the top five airports are PEK, CAN, PVG, KMG and XIY, we can see that the re-established indicator evaluation system has a great impact on the weighting of airports, for KMG and XIY can be ranked among the top five in the country .The reason is that although the passenger throughput of KMG in 2018 was 4708 million lower than that of CTU and SZX with 52.95 million and 493.4 million passengers, but the number of transit passengers in it was more, and the percentage of transit passengers was 4.2%, higher than that of CTU and SZX with 0.84% and 1%, while XIY was connected to 162 airports in 2018, and the number of navigation points is higher than that of CTU and SZX .

Tab.2 Airport Weight Calculation Results

City / Airport	Airport Code	Pre-improvement weights	Improved weights
Beijing / Shoudu	PEK	1.000	0.914
Shanghai / Pudong	PVG	0.733	0.787
Guangzhou / Baiyun	CAN	0.690	0.853
Chengdu / Shuangliu	CTU	0.524	0.495
Shenzhen / Baoan	SZX	0.489	0.488

As shown in Table 3 below.It can be seen that the overall connectivity score of the airport is higher after the improvement of the connectivity model than before, because the airport weights are determined by considering not only the passenger throughput, but also the percentage of transit passengers, the number of seats on departing flights and the number of access points. For some airports, despite the low annual passenger throughput, larger values for indicators that have a greater impact on the airport's weight, such as the percentage of transit passengers and the number of seats on departing flights, make that airport's weight larger and indirectly make the connectivity scores of airports connected to those airports higher. For example, after the connectivity model is improved, for CTU, although its own airport weight is not as good as SZX, CTU is connected to some destination airports with a higher weight, so its connectivity exceeds SZX. In addition, HAK, SHE, TNA, TYN, and NGB have increased their connectivity rankings by one place, and NKG has increased their rankings by two places.

Tab.3 Airport Connectivity Ranking

Ranking	Airport Code	Pre-improvement connectivity score	Airport Code	Improved connectivity score
1	PEK	13465062.59	PEK	15377343.81
2	SHA	10102617.32	SHA	11016940.98
3	CAN	10005382.93	CTU	10919682.64
4	CTU	9844859.76	SZX	10618274.46
5	SZX	9538322.17	CAN	10384250.12
…	…	…	…	…
34	HET	2340852.12	NGB	2703753.33
35	NGB	2307992.80	HET	2701532.08
36	HFE	2146752.22	HFE	2558363.63
37	SJW	1787861.71	SJW	2131168.09

5 CONCLUSION

By improving the aviation connectivity index model proposed by IATA, this paper measures the aviation connectivity of 37 airports with a throughput exceeding 10 million in my country in 2018 based on the improved model. The result shows:

(1) The top five airports in China in terms of connectivity are PEK, PVG, CAN, CTU and SZX airports, among which PEK has much higher air connectivity than other transportation airports because it can provide more seats for departure;

(2) Since the airport weights are determined after the improvement of the connectivity model, the influence factors such as the percentage of transit passengers, the number of seats of departing flights, and the number of access points are taken into account, which makes the weights of most airports bigger and further makes the overall connectivity scores of China's airports higher than before the improvement;

(3) The aviation connectivity of hub airports in my country is much greater than that of regional airports, and the connectivity ranking of hub airports is generally higher than that of regional airports. Except for individual hub airports with high aviation connectivity scores, the air connectivity scores of most airports in China are generally low, and there is an imbalance in the development of airport connectivity.

Based on the above analysis, the following recommendations are given to improve the connectivity of Chinese civil airports:

(1) Encourage airports and airlines to develop the transit market, increase the volume of transit business, improve the airport transit rate, and add direct routes or intensified flights to airports

with low connectivity, so as to promote the development of airport connectivity and provide convenience for passengers to travel;

(2) Encourage airports and airlines to develop the transit market, increase the volume of transit business, increase the airport transit rate, and further improve airport connectivity.

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