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Research On The Operational Efficiency Of Major Airports In China Based On DEA

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Abstract:
Based on the current development status of Chinese airports, the paper selects twenty major domestic airports as the research objects, establishes an input-output indicator system, and then uses Data Envelopment Analysis (DEA) method to comprehensively analyze the operational efficiency of the sample airports. On this basis, the paper points out the problems in the operational efficiency of the sample airport and proposes improvement suggestions based on actual situations.

Keywords –*DEA, airport, operational efficiency*

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I. INTRODUCTION

In today's era of economic globalization, the economy needs to respond quickly to market demand. The efficient operation of air transportation can promote the rapid integration of the global economy and industrial clusters. The development of airports has become an important driving force for expanding the economic spatial pattern and is more in line with the needs of the times. Airports play a crucial role in the civil aviation transportation network and are also the infrastructure for national economic development. Studying the operational efficiency of airports not only accurately reflects the actual situation of airport operations in China, but also helps to enhance the competitiveness of airports and promote the sustainable development of China's civil aviation industry.

II. THE CONNOTATION OF AIRPORT OPERATIONAL EFFICIENCY

The operational efficiency of an airport is first manifested in its flight throughput and passenger throughput. Airport flight throughput refers to how many flights an airport can arrange for takeoff and landing. Airport passenger throughput refers to the amount of passenger traffic that an airport can handle. How to allocate resources reasonably and effectively coordinate the relationship between airlines and ground service providers is an important factor affecting the efficiency of airport operations. Secondly, the operational efficiency of the airport is reflected in providing high-quality services to passengers in order to obtain higher profits. At this time, the main activity of the airport is to respond to customer needs. Finally, the operational efficiency of airports can be manifested as promoting their own development while also driving the overall economic development and improving regional transportation modes, thereby promoting the improvement of airport economic level.

As a large-scale public facility, airports are one of the fundamental industries that local governments are concerned about. It has created a large number of job opportunities for the local area and made significant contributions to the development of taxation, service industry, and tourism. The improvement of airport operational efficiency is directly related to the changes in various economic statistical indicators and affects the competitiveness of the overall economic volume between regions.

III. SAMPLE AIRPORT SELECTION

The sample airports selected in this article are shown in Table 1:

Table 1：list of twenty sample airports

airport	airport
Beijing Capital International Airport	Chengdu Shuangliu International Airport
Shanghai Pudong International Airport	Guangzhou Baiyun International Airport
Shanghai Hongqiao International Airport	Shenzhen Bao'an International Airport
Kunming Changshui International Airport	Xi'an Xianyang International Airport
Chongqing Jiangbei International Airport	Hangzhou Xiaoshan International Airport
Nanjing Lukou International Airport	Zhengzhou Xinzheng International Airport
Xiamen Gaoqi International Airport	Wuhan Tianhe International Airport
Changsha Huanghua International Airport	Qingdao Liuting International Airport
Haikou Meilan International Airport	Urumqi Diwobao International Airport
Tianjin Binhai International Airport	Guizhou Longdongbao International Airport

These twenty sample airports were selected based on the provincial capitals of major cities in China, including the three major gateway composite hub airports in China, eight regional hub airports with important strategic positions, and the vast majority of provincial capital city airports. The comprehensive strength can represent the current situation of airport development in China and is highly representative.

IV. EVALUATION INDEX SYSTEM

Principles for selecting indicators

In order to build an evaluation index system for the operational efficiency of major airports in China, it is crucial to select input and output indicators reasonably. Because the selected input and output indicators will affect the accuracy and authenticity of the analysis, the selected evaluation indicators should cover the main aspects of the airport operation process as much as possible. Therefore, the following principles should be followed:

(1) The accessibility of data. In order to obtain corresponding indicator data, we should obtain data from reliable literature or publicly available databases. These data can be directly used for evaluation or obtained through calculation and processing. In addition, these data must be quantifiable in order to be effectively analyzed and compared.

(2) Comprehensiveness. To ensure the accuracy and comprehensiveness of performance evaluation, it is not necessary to consider it unilaterally, but rather to comprehensively consider the overall situation of the airport. The selected input indicators should have a certain impact on the output indicators, and the output indicators should be direct indicators that can comprehensively reflect performance.

(3) Mutual independence. The selected indicators should be independent of each other and there should be no duplication or redundancy to avoid affecting the accuracy and reliability of the evaluation results.

Selection of evaluation indicators

Based on the principles of indicator selection, the input and output indicators selected in the paper are shown in Table 2:

Table 2：Input output indicators

input indicator	output indicator
terminal area	cargo throughput
number of parking spaces	passenger throughput
number of taxiways	aircraft takeoff and landing sorties

The significance of each input and output indicator is as follows:
Cargo throughput reflects the airport's cargo volume and cargo capacity.
Passenger throughput reflects the passenger flow and passenger service quality of the airport.
Aircraft takeoff and landing sorties reflect the operational efficiency and flight scheduling capacity of the airport.

The number of parking spaces reflects the ground resource allocation and reception capacity of the airport, and also affects the flight arrangement and route planning of the airport.

Terminal area, this indicator is widely used in articles studying airport efficiency, reflecting the level of investment in airport infrastructure.

The number of taxiways reflects the level of airport ground transportation capacity. The more taxiways there are, the more developed the airport ground transportation system will be, which can better adapt to the operational needs of the airport.

V. AN EMPIRICAL STUDY ON THE OPERATIONAL EFFICIENCY OF CHINA'S TOP 20 AIRPORTS

Input output data of China's top 20 airports

The 20 civil aviation airports selected in this study were used as samples. The terminal area, number of parking spaces, and number of taxiways for each airport in 2019 are shown in Table 3. The passenger throughput, cargo throughput, and aircraft takeoff and landing sorties for each airport in 2019 are shown in

Table 4:

Table 3：input index data of each sample airport in 2019

airport	terminal area (10000 square meters)	number of parking spaces (frame)	number of taxiways (strip)
Shanghai/Pudong	145.60	340	8
Beijing/Capital	141.00	314	7
Guangzhou/Baiyun	118.20	269	8
Xi'an/Xianyang	35.00	127	4
Chongqing/Jiangbei	73.70	209	9
Chengdu/Shuangliu	50.00	228	5
Wuhan/Tianhe	49.50	117	4
Zhengzhou/Xinzheng	61.40	158	3
Shenzhen/Bao'an	45.10	199	4
Kunming/Changshui	54.80	110	2
Shanghai/Hongqiao	44.46	155	4
Hangzhou/Xiaoshan	37.00	127	4
Nanjing/Lukou	42.5	143	3
Xiamen/Gaoqi	23.78	89	2

Changsha/Huanghua	26.60	87	4
Qingdao/Liuting	12.00	70	1
Haikou/Meilan	45.00	139	2
Urumqi/Diwobao	15.09	108	2
Tianjin/Binhai	36.40	59	4
Guizhou/Longdongbao	38.20	115	1

Table 4: output index data of each sample airport in 2019

airport	passenger throughput	cargo throughput	takeoff and landing sorties
Beijing/Capital	100013642	1955286	594329
Shanghai/Pudong	76153455	3634230	511846
Guangzhou/Baiyun	73378475	1919927	491249
Chengdu/Shuangliu	55858552	671904	366887
Shenzhen/Bao'an	52931925	1283386	370180
Kunming/Changshui	48075978	415776	357080
Xi'an/Xianyang	47220547	381870	345748
Shanghai/Hongqiao	45637882	423615	272928
Chongqing/Jiangbei	44786722	410929	318398
Hangzhou/Xiaoshan	40108405	690276	290919
Nanjing/Lukou	30581685	374634	234869
Zhengzhou/Xinzheng	29129328	522021	216399
Xiamen/Gaoqi	27413363	330512	192929
Wuhan/Tianhe	27150246	243193	203131
Changsha/Huanghua	26911393	175725	196213
Qingdao/Liuting	25556278	256299	186500
Haikou/Meilan	24216552	175566	164786
Urumqi/Diwobao	23963167	172801	178234
Tianjin/Binhai	23813318	226163	167869
Guiyang/Longdongbao	21910911	120110	167063

Calculation results

The paper selects the input-based CCR model and the output-based BCC model of SPSS software to calculate the technical efficiency, pure technical efficiency, scale efficiency, and scale return characteristics of China's top 20 major airports in 2019. The results are shown in Table 5:

Table 5: Efficiency Calculation Results of Twenty Major Airports in China in 2019

airport	technical efficiency	pure technical efficiency	scale efficiency	scale return
Beijing/Capital	0.930	1.000	0.930	diminishing
Shanghai/Pudong	1.000	1.000	1.000	invariant
Guangzhou/Baiyun	0.896	0.963	0.931	diminishing
Chengdu/Shuangliu	0.685	1.000	0.685	diminishing
Shenzhen/Bao'an	1.000	1.000	1.000	invariant

Kunming/Changshui	1.000	1.000	1.000	invariant
Xi'an/Xianyang	0.958	1.000	0.958	diminishing
Shanghai/Hongqiao	0.754	0.887	0.850	diminishing
Chongqing/Jiangbei	0.529	0.729	0.726	diminishing
Hangzhou/Xiaoshan	0.951	0.983	0.967	diminishing
Nanjing/Lukou	0.600	0.687	0.874	diminishing
Zhengzhou/Xinzheng	0.545	0.577	0.945	diminishing
Xiamen/Gaoqi	0.842	0.850	0.990	diminishing
Wuhan/Tianhe	0.558	0.572	0.976	diminishing
Changsha/Huanghua	0.784	0.788	0.994	diminishing
Qingdao/Liuting	1.000	1.000	1.000	invariant
Haikou/Meilan	0.475	0.551	0.861	diminishing
Urumqi/Diwobao	0.760	0.857	0.886	diminishing
Tianjin/Binhai	0.943	1.000	0.943	incremental
Guiyang/Longdongbao	0.896	0.896	1.000	invariant

Analysis of evaluation results

Technical efficiency analysis

The technical efficiency under the DEA method is the comprehensive technical efficiency. The technical efficiency values of each sample airport reflect the ratio of the actual production output of the airport to its maximum potential output under current available technology and resource inputs.

Overall, there are only 5 airports with a technical efficiency of 1, namely Shanghai Pudong Airport, Shenzhen Bao'an Airport, Kunming Changshui Airport, Guiyang Longdongbao Airport, and Qingdao Liuting Airport, accounting for 20% of the total sample. The resource utilization of these 5 airports is reasonable, and the airport operation and management level is relatively high; The technical efficiency values of other airports are all less than 1, which is in an invalid state and requires further improvement. Among all the airports that are in an invalid state, Beijing Capital Airport, Chengdu Shuangliu Airport, Xi'an Xianyang Airport, and Tianjin Binhai Airport have a pure technical efficiency of 1. The main reason for the overall invalidity is the impact of scale efficiency, and their scale return characteristics are only increasing at Tianjin Binhai Airport. This indicates that while maintaining the current management level, the first three airports can appropriately reduce investment, terminal area, and number of parking spaces to achieve optimal overall operational efficiency; For Tianjin Binhai International Airport, it is advisable to increase investment, parking spaces, and infrastructure area to achieve optimal overall operational efficiency. The remaining 11 airports are rated as less than 1 in terms of pure technical efficiency and scale efficiency. To improve operational efficiency, three aspects should be considered: firstly, optimizing the organizational structure of the airport, strengthening internal collaboration and communication, and improving collaboration efficiency among various departments; The second is to optimize the equipment configuration of the airport, adopt more advanced technology and equipment, and improve the automation level and equipment utilization rate of the airport; The third is to reasonably adjust the production layout of the airport, plan the use of facilities and equipment based on the number of flights and passenger flow, and improve production efficiency.

According to the efficiency values in Table 5, it can be calculated that the average technical efficiency of all sample airports reaches 0.805, the average pure technical scale reaches 0.867, and the average scale efficiency reaches 0.926. Overall, the operational efficiency of airports in China is relatively high, but there is still room for improvement in airport management and resource allocation.

Analysis of Scale Efficiency and Scale Characteristics

When the scale efficiency value is 1, it indicates that the scale efficiency of the airport is effective, that is, the resource scale, input, and output of the airport match each other, and the resource scale is optimally utilized. According to Table 5, there are a total of 5 such airports, and the scale efficiency values of the other airports are less than 1, including Beijing Capital Airport, Guangzhou Baiyun Airport, Chengdu Shuangliu Airport, Xi'an Xianyang Airport, Shanghai Hongqiao Airport, Chongqing Jiangbei Airport, Hangzhou Xiaoshan Airport, Nanjing Lukou Airport, Zhengzhou Xinzheng Airport, Xiamen Gaoqi Airport, Wuhan Tianhe Airport, Changsha Huanghua Airport, Haikou Meilan Airport Urumqi Diwobao Airport and Tianjin Binhai Airport. The resource scale and investment of these airports are unreasonable, resulting in a mismatch between their input-output and scale, and the scale utilization rate needs to be improved. Except for Tianjin Binhai Airport, the returns to scale of all 14 airports are decreasing, indicating that these airports are unable to fully utilize the resources invested under existing technical conditions and operational management levels, resulting in limited output. At the same time, considering the existing demand state, these airports have a certain degree of facility resource surplus and low operational management level, so it is not suitable to renovate or expand them at present; On the contrary, they need to consider optimizing the allocation of existing resources to avoid vacancies and waste. Tianjin Binhai Airport is in a state of increasing scale, indicating that the airport has vast development space. Capital investment and infrastructure resource investment should be increased to enable the airport to operate at the most suitable scale.

Sensitivity analysis

The efficiency value obtained using the DEA method is only the relative efficiency value of each airport, and its sensitivity is extremely high, which may be influenced by factors such as the number of samples and changes in input-output indicators. Therefore, this article attempts to remove the two indicators of terminal area and parking space respectively, and then analyze the technical efficiency of major airports in China again. By comparing their differences with the original technical efficiency values, we can evaluate whether the use of input factors by each sample airport is efficient or redundant. The results are shown in Table 6:

Table 6：sensitivity analysis results based on 2019 statistical data

airport	original technical efficiency	removing terminal area indicators			removing number of parking spaces indicators		
		current technical efficiency	reduce value	reduce the proportion	current technical efficiency	reduce value	reduce the proportion
Beijing/Capital	0.930	0.922	0.008	0.86%	0.797	0.133	14.30%
Shanghai/Pudong	1.000	1.000	0.000	0.00%	1.000	0.000	0.00%
Guangzhou/Baiyun	0.896	0.890	0.006	0.67%	0.647	0.249	27.79%
Chengdu/Shuangliu	0.685	0.607	0.078	11.39%	0.585	0.100	14.60%
Shenzhen/Bao'an	1.000	0.868	0.132	13.20%	1.000	0.000	0.00%
Kunming/Changshui	1.000	1.000	0.000	0.00%	0.957	0.043	4.30%
Xi'an/Xianyang	0.958	0.851	0.107	11.17%	0.636	0.322	33.61%
Shanghai/Hongqiao	0.754	0.684	0.070	9.28%	0.482	0.272	36.07%

Chongqing/Jiangbei	0.529	0.497	0.032	6.05%	0.285	0.244	46.12%
Hangzhou/Xiaoshan	0.951	0.873	0.078	8.20%	0.722	0.229	24.08%
Nanjing/Lukou	0.600	0.548	0.052	8.67%	0.451	0.149	24.83%
Zhengzhou/Xinzheng	0.545	0.545	0.000	0.00%	0.521	0.024	4.40%
Xiamen/Gaoqi	0.842	0.763	0.079	9.38%	0.606	0.236	28.03%
Wuhan/Tianhe	0.558	0.538	0.020	3.58%	0.272	0.286	51.25%
Changsha/Huanghua	0.784	0.708	0.076	9.69%	0.475	0.309	39.41%
Qingdao/Liuting	1.000	1.000	0.000	0.00%	1.000	0.000	0.00%
Haikou/Meilan	0.475	0.475	0.000	0.00%	0.474	0.001	0.21%
Urumqi/Diwobao	0.760	0.508	0.252	33.16%	0.760	0.000	0.00%
Tianjin/Binhai	0.943	0.943	0.000	0.00%	0.307	0.636	67.44%
Guiyang/Longdongbao	0.896	0.896	0.000	0.00%	0.896	0.000	0.00%

After removing the input indicator of the number of parking spaces, only the technical efficiency values of Shanghai Pudong Airport, Shenzhen Bao'an Airport, Qingdao Liuting Airport, Urumqi Diwobao Airport, and Guiyang Longdongbao Airport have not changed. The sensitivity to changes in the number of parking spaces is low, indicating that their construction level meets the existing output requirements. The other 15 airports are highly sensitive to changes in the number of parking spaces, with as many as 6 airports experiencing a decrease of over 30%, especially Tianjin Binhai Airport, which achieved a decrease of 67.44%. This means that the changes in the number of parking spaces in these sample airports have a significant impact on technical efficiency, so increasing the number of parking spaces in a planned manner can effectively improve the overall operational efficiency of the airport.

After removing the investment indicator of terminal area, only Urumqi Diwobao Airport, Chengdu Shuangliu Airport, Shenzhen Bao'an Airport, and Xi'an Xianyang Airport have relatively significant reductions, while the sensitivity of the other 16 sample airports is relatively low. This reflects the efficient operation and management of Chinese airport terminals.

VI. CONCLUSION

Reasonable planning of airport construction scale, scientific arrangement of terminal layout, and improvement of scale efficiency can achieve the goal of optimizing airport planning and management. In terms of airport construction, we can plan and construct in advance according to the actual characteristics of the airport, but we should not blindly expand the scale. We should provide feedback on whether it is worth further expansion based on the benefits generated by expanding a certain scale. We also need to continuously explore and optimize airport operation management to improve the utilization of airport resources and improve the technical efficiency of airport operations. For the situation where the technical efficiency of major airports in China is generally not optimal, a comprehensive review of airport operation processes should be conducted to identify existing problems and deficiencies, develop improvement plans, and learn from the advanced experience of other airports to learn their successful management methods and technical means, in order to improve efficiency.

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