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Economic Adaptability Evaluation of Airport Construction Scale: Taking Chengdu Shuangliu International Airport as an Example

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Abstract

The airport construction scale should be compatible with the level of social and economic development. If the scale of civil airport is too small, it will become a "bottleneck" of socioeconomic development. If the scale is too big, it will bring about waste of resources and hinder the sustainable development of society and economy. However, it is a complex and difficult task to evaluate the economic adaptability of airport construction scale. In view of the fact that there is no systematic research on the economic adaptability evaluation of airport construction scale, this paper sets up evaluation indices from the dimensions of demand satisfaction rate, supply efficiency and operation efficiency and gives the corresponding calculation formula by analyzing the intersection of relevant research fields and the suggestions of industry experts. In the meantime, this paper compares the economic adaptability of the construction scale of Chengdu Shuangliu International Airport and the three major airports in Beijing, Shanghai and Guangzhou by the fuzzy matter-element model and the multi-objective lattice-order decision-making. The comparison between the two evaluation methods reveals that all evaluation indices are reasonably constructed and can serve as technical basis for evaluating the construction scale of regional airports.

Key words

Civil airport, construction scale, economic adaptability, fuzzy matter-element model

1. Introduction

As an important part of the comprehensive transportation system, the civil airport is characterized by publicness, externality and commercialization. Thanks to scale development and the formation of aviation hubs, the airport has an increasingly important influence over the regional socioeconomic development. It is evolving into a new engine of urban or regional economic growth, involving urban economy, society, environment and many other areas. Besides, the airport also changes the city's appearance and pace of development in time and space. The relationship between airport development and socioeconomic development has become more and more complex. On the one hand, the airport is playing a more prominent role in promoting urban and regional competitiveness. As civil aviation fails to keep up with socioeconomic development, the airport has been turned into a "bottleneck" of socioeconomic development. On the other hand, as the total social resources are limited, two problems may emerge due to the over-development of civil airport in the regions with rapid economic development and huge demand for investment in all areas of the society. The first problem is the waste of resources as airport facilities are left unused or insufficiently used. The second problem is the "crowding out effect" on the development of other sectors of the national economy. Ought to be diverted to other sectors, the excessively high investment on the airport suppresses the development of other sectors and even hinders the sustainable development of local economy. As a result, it is of great practical significance to study airport construction scale.

As an important step from theoretical research to practice, the economic adaptability evaluation of airport construction scale should be carried out in a scientific and reasonable manner. Both qualitative theoretical analysis and quantitative analysis are needed. Hence, it is of great necessity to construct a relatively complete and comprehensive system of evaluation indices. Currently, the research on the relationship between airport scale and economic development is mainly performed with methods like the regression model, data panel model, input-output model, DEA model and fuzzy evaluation. Most of researchers either focus on the airport economic and operational efficiency, or determine the construction scale of the airport in future by predicting the demand of airport. Little research has been done on whether the airport scale is compatible to the economy. There is also the lack of unified evaluation criteria. To fill in the gap in the research, this paper conducts a comparative study, involving evaluation research and empirical analysis of the economic adaptability of airport construction scale by fuzzy matter-element model and the multi-objective lattice-order decision-making.

2. Construction of Evaluation Indices

Due to the absence of systematic study on the economic adaptability of airport construction scale and in light of the varied technical characteristics of different airports, this paper integrates and summarizes the intersection of the research fields, results, and methods of Literatures [1] to [8] for the purpose of fully demonstrating the main features and conditions of the economic adaptability of airport construction scale [1~8]. Through the summarization, the author holds that the evaluation indices should reflect the internal and external causes of the airport-economic system which has a huge influence on the supply and demand system and operational efficiency of the airport. Besides, secondary indices should be set up based on the main influencing factors of the said causes. According to the purpose and principle of the evaluation, the author solicits opinions from various industry experts, carries out repeated demonstrations and adjustments, and eventually establishes a comprehensive index system for economic adaptability evaluation of the construction scale of airport, which consists of 3 primary indices and 9 secondary indices.

2.1 Construction of Primary Indices of Economy Adaptability

For in-depth analysis and evaluation, this paper measures the socioeconomic adaptability of the airport from such three dimensions as the satisfaction of demand, the resource allocation, and the level of operation and management of the airport, and sets up the three primary evaluation indices of demand satisfaction rate, supply efficiency and operation efficiency, as shown in Table 1.

The demand satisfaction rate measures how the airport construction scale satisfies the demand of aviation business generated by socioeconomic development, which is the primary goal of airport construction. The supply efficiency measures how the capacity of airport construction meets the demand of aviation business generated by socioeconomic development. Since airports at the same level boasts basically the same facilities, the airport supply efficiency is directly illustrated by the efficient use of facilities and equipment. The operation efficiency mainly measures whether the airport generates economic benefits while meeting the passengers' demand of services. Due to the requirement of profitability, the airport cannot operate at a loss in the long run. The measurement of operation efficiency helps the airport make profits. Among airports of the same scale, those with high economic benefits are more adapted to the economic development.

Table 1. The primary indices of the economic adaptability evaluation of airport construction scale

	Primary indices	Index meaning
The economic adaptability of airport construction scale	Demand satisfaction rate	As the primary goal of airport construction, the index measures how the airport construction scale satisfies the demand of aviation business generated by socioeconomic development.
	Supply efficiency	The index measures how the capacity of airport construction meets the demand of aviation business generated by socioeconomic development. The airport supply efficiency is directly illustrated by the efficient use of facilities and equipment.
	Operation efficiency	The index measures the level of airport operation. Among airports of the same scale, those with high economic benefits are more adapted to the economic development.

2.2 Construction of Secondary Indices of Economy Adaptability

1. Demand satisfaction rate

The demand satisfaction rate of airport construction scale is demonstrated by the following three aspects: First, the demand for airport aviation business is mainly reflected in the sum of the demand for aviation business in the region where the airport is located and the areas related to the aviation business. In this case, the demand satisfaction rate of airport construction scale is showcased by the average passenger throughput and the cargo and mail throughput of each navigable city. For the sake of simplicity, the cargo and mail throughput is not taken into consideration. Second, the demand satisfaction rate is also manifested by the change of the growth rate of airport throughput every year. If the growth rate is under sustained and steady growth, the airport scale can meet the total demands generated from socioeconomic development. Third, the service quality is the lifeblood of the airport, reflecting the airport’s soft power [9~12]. It is a comprehensive demonstration of the “hardware” and “software” of the airport, such as service facilities, management level, staff quality, etc. Poor service quality reduces the attractiveness of the airport to passengers, and indirectly affects the economic adaptability of airport construction scale. The demand satisfaction rate is described in Table 2.

Table 2. The demand satisfaction rate

Primary indices	Secondary indices	Index explanation	Calculation method
Demand satisfaction rate	Passenger throughput of unit navigable city	The index reflects the relationship between the number of navigable cities of the airport and the number of passengers	Passenger throughput/number of navigable cities
	Service quality	The index reflects the relationship between airport	Skytrax passenger evaluation data

		services and passenger demands as well as the airport's soft power	
	Mean square error of the growth of passenger throughput in the past three years	The index reflects the stability of the growth of passenger throughput	The mean square error formula of the growth of passenger throughput in the past three years

2. Supply efficiency

The airport supply efficiency examines the input and output of airport facilities and equipment, and reflects the service efficiency of facilities and equipment among airports of the same scale. Those with high efficiency are more adapted to the economic development. The supply efficiency is illustrated by the passenger throughput of unit terminal, the aircraft movements of unit gate, the aircraft movements of unit runway, and the cargo throughput of unit freight station. See Table 3 for detailed description [13].

Table 3. The supply efficiency

Primary indices	**Secondary indices**	**Index explanation**	**Calculation method**
Supply efficiency	The passenger throughput of unit terminal	The index reflects how efficiently the terminal serves passengers and how the scale of terminal adapts to the passenger demand	Passenger throughput/Terminal floor space
	The aircraft movements of unit gate	The index reflects how efficiently the gate serves aircrafts and how the number of gates adapts to the demand	Aircraft movements/number of gates
	The aircraft movements of unit runway	The index reflects how efficient is the use of the runway and how the number of runways to the demand.	Aircraft movements/number of runways
	The cargo throughput of unit freight station	The index reflects how efficiently the cargo station serves cargoes and how the number of cargo stations adapts to the demand of cargo transport.	Cargo and mail throughput/Freight station floor space

3. Operation efficiency

The operation efficiency examines the airport's operational efficiency and reflects the airport's ability of financial management and commercial development capabilities. It is mainly illustrated by the income of unit aircraft movement and the non-aviation income ratio. The more the income of unit aircraft movement, the higher the level of charges in the airport, and the less attractive the airport is to passengers in the state of perfect competition. In this case, the socioeconomic adaptability of the airport will be affected. The main business income of the airport consists of aviation income and non-aviation income. Among the airports at the same level, the higher the proportion of non-aviation income, the better the commercial development and operation and management level of the airport. In this case, the airport constructions scale boasts strong socioeconomic adaptability. See Table 4 for detailed description [14~15].

Table 4. The operation efficiency

Primary indices	**Secondary indices**	**Index explanation**	**Calculation method**
Operation efficiency	The income of unit aircraft movement	The index reflects the level of aviation income and the level of charges in the airport	Aviation income/aircraft movements
	The proportion of non-aviation income to the total income	The index reflects the level of commercial development of the airport	Non-aviation income/the total income

To sum up, the author explains the evaluation indices and corresponding calculation methods of the economic adaptability of airport construction scale in Table 5.

Table 5. The economic adaptability evaluation indices of airport construction scale

	Primary indices	**Secondary indices**	**Formulas and data sources**
The economic adaptability of airport construction scale	Demand satisfaction rate	Passenger throughput of unit navigable city	Passenger throughput/number of navigable cities
		Service quality	Skytrax passenger evaluation data
		Mean square error of the growth of passenger throughput in the past three years	The mean square error formula of the growth of passenger throughput in the past three years
	Supply efficiency	The passenger throughput of unit terminal	Passenger throughput/Terminal floor space
		The aircraft movements of unit gate	Aircraft movements/number of gates
		The aircraft movements of unit runway	Aircraft movements/number of runways
		The cargo throughput of unit freight station	Cargo and mail throughput/Freight station floor space
	Operation	The income of unit	Aviation income/aircraft movements

efficiency	aircraft movement	
	The proportion of non-aviation income to the total income	Non-aviation income/the total income

Note: Skytrax is a consultancy engaging in surveys on airline services, including airport service evaluation, cabin check and passenger satisfaction survey. The company is known for its annual release of the World Airline Awards and World Airport Awards. The company's research is an important reference for the British government in developing air traffic policies.

3. On the Evaluation Method of Economic Adaptability of Airport Construction Scale

3.1 Economic Adaptability Evaluation of Airport Construction Scale based on Fuzzy Matter-element Method

3.1.1 Fuzzy matter-element model

On the basis of the matter-element analysis model and fuzzy mathematics, the fuzzy matter-element analysis fully demonstrates the overall level of the object by quantitative results. It applies to various incompatibility problems. Since the economic adaptability evaluation of airport construction scale is a multi-index evaluation problem, the index empowerment is of great significance. It is impossible to make a comparison if the evaluation is based on a single index. Besides, the service quality index has some ambiguity. More importantly, there is no unified evaluation criterion for the economic adaptability of airport construction scale. As a result, this paper adopts the information entropy theory and the expert consultation method, and analyzes and summarizes the incompatibilities between the multiple influencing factors of the economic adaptabilities of airport construction scale. For the airports of the same scale or different scales, it is feasible to determine their economic adaptabilities by the matter-element model.

The steps of the fuzzy matter-element model are as follows [16]:

1. Establishment of fuzzy matter-element and compound fuzzy matter-element

Anything can be described with the three elements of "thing, characteristic and magnitude". Suppose that a given thing M has m characteristics $C = (C_1, C_2, \cdots C_m)$ with corresponding magnitudes$x = (x_1, x_2, \cdots x_m)$. Then, the ordered triple $R = (M, C, x)$ is called the matter element. If the magnitude x is ambiguous, R is called the m-dimensional fuzzy matter-element. The m-

dimensional fuzzy matter-elements of n things are combined into the compound fuzzy matter-elementR_{mn}:

$$R_{mn} = \begin{bmatrix} & M_1 & L & M_n \\ C_1 & x_{11} & L & x_{1n} \\ C_2 & x_{21} & L & x_{2n} \\ M & & & \\ C_m & x_{m1} & L & x_{mn} \end{bmatrix}$$

(1)

2. Calculation of the optimal membership

Known as the optimal membership, the fuzzy magnitude of a single index of the object is subordinate to the degree of membership of the fuzzy magnitude of the corresponding index evaluation standard. The eigenvalues of the evaluation indices fall into two categories: the bigger the better and the smaller the better. The membership degree $\mu_{ij}$is calculated by the following formulas:

The larger the better $\mu_{ij} = \frac{x_{ij}}{max\, x_{ij}}$

(2)

The smaller the better $\mu_{ij} = \frac{min\, x_{ij}}{x_{ij}}$

(3)

Construct the membership degree matrixR_{mn}^*:

$$R_{mn}^* = (\mu_{ij})_{mn} = \begin{bmatrix} \mu_{11} & \mu_{12} & L & \mu_{1n} \\ \mu_{21} & \mu_{22} & L & \mu_{2n} \\ M & & & \\ \mu_{m1} & \mu_{m2} & L & \mu_{mn} \end{bmatrix}$$

(4)

3. Standard fuzzy matter-element and difference squared matrix

The maximum or minimum value of the optimal membership degree of each index in the optimal membership degree matrix R_{mn}^* is the standard fuzzy matter-elementR_{m0}. As this paper regards the maximum value of each index as the optimal value, the optimal membership degrees of all indices are 1. Therefore, the standard fuzzy matter element R_{m0} can be expressed as:

$$R_{m0} = \begin{bmatrix} & M_0 \\ C_1 & 1 \\ C_2 & 1 \\ L & \\ C_m & 1 \end{bmatrix}$$

(5)

If the square of the difference between each element of R^*_{mn} and R_{m0} is expressed by$\Delta_{ij}(i = 1\sim m; j = 1\sim n)$, the difference squared matrix R_Δ should be expressed as follows:

$$R_\Delta = \begin{bmatrix} \Delta_{11} & \Delta_{12} & L & \Delta_{1n} \\ \Delta_{21} & \Delta_{22} & L & \Delta_{2n} \\ M & & & \\ \Delta_{m1} & \Delta_{m2} & L & \Delta_{mn} \end{bmatrix}$$

(6)

Where $\Delta_{ij} = (\mu_{i0} - \mu_{ij})^2$.

4. Weight determination and close degree calculation

To avoid ignoring the experts' experience, this paper combines the objective weight and the subjective weight in the operation, i.e.:

$$w_i = \frac{w_i^s \cdot w_i^o}{\sum_{i=1}^{n} w_i^s \cdot w_i^o} \tag{7}$$

Where $w_i^o$is the objective weight, w_i^s is the subjective weight, and w_i is the total weight. The subjective weight is obtained by AHP, and the objective weight of each index is determined by the entropy weighting. $H_i = -k\sum_{j=1}^{n} f_{ij}\, lnf_{ij}$, where $f_{ij} = {r_{ij}}\Big/{\sum_{j=1}^{n} r_{ij}}$

$$w_i^o = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{8}$$

The degree of closeness refers to the degree to which an evaluated sample is close to the standard sample. The higher the degree, the closer the evaluated sample is to the standard sample, and vice versa. This paper sort the superiority of the economic adaptability of airport construction scale based on the degree of closeness. The higher the degree, the better the economic adaptability is. The composite fuzzy matter-element matrix $R_{\rho H}$ for the Euclidean degree of closeness is as follows:

$$R_{\rho H}=\begin{bmatrix} & M_1 & M_2 & L & M_n \\ \rho H_j & \rho H_1 & \rho H_2 & L & \rho H_n \end{bmatrix} \tag{9}$$

Where ρH_j is the j-th degree of closeness of $R_{\rho H}$, and $\rho H_j = 1 - \sqrt{\sum_{i=1}^{m} W_i \, \Delta_{ij}} (j = 1 \sim n)$.

3.1.2 Fuzzy matter-element evaluation of economic adaptability of airport construction scale

1. Data calculation for evaluation indices

According to the level of airports, the author selects the airports above 4E level as the objects, such as Beijing Capital International Airport, Shanghai Pudong International Airport, Shanghai Hongqiao International Airport, Guangzhou Baiyun International Airport and Chengdu Shuangliu International Airport. See Table 6 for the evaluation indices. All source data of the indices are downloaded from the official websites of the airports. The passenger evaluation data of Skytrax is used to illustrate the service quality. Shanghai Pudong International Airport and Shanghai Hongqiao International Airport are collectively referred to as Shanghai Airports because they are affiliated to the same company: Shanghai Airport Authority.

Table 6. The economic adaptability evaluation indices of airport construction scale

Target layer	Criteria layer	Index layer	Beijing Capital International Airport	Shanghai Airports	Guangzhou Baiyun International Airport	Chengdu Shuangliu International Airport
The economic adaptability of airport construction scale	Demand satisfaction rate	Passenger throughput of unit navigable city (10,000 ppl/pair)	35.3	35.0	27.5	15.6
		Service quality (0—10)	7.6	6.4	6.6	8
		Mean square error of the growth of passenger throughput in 2012-14	0.96	1.72	2.32	3.46
	Supply efficiency	The passenger throughput of unit terminal(ppl/m^2)	61	71	110	75
		The aircraft movements of unit gate (sortie/gate)	1853	1685	4793	1862
		The aircraft movements of unit runway (10,000 sorties/runway)	19.4	13.1	20.6	13.5
		The cargo throughput of unit freight station (ton/m^2)	3.23	7.21	12.98	5.09
	Operation efficiency	The income of unit aircraft movement (RMB	1.32	0.88	1.34	0.99

	10,000yuan/sortie)				
	The proportion of non-aviation income (%)	43	49	46	34

2. Construction of the fuzzy matter-element evaluation model

The fuzzy matter-elements of the economic adaptability evaluation of the construction scale of the four airports are as follows:

$$R_{10*4}=\begin{array}{cc} & \begin{array}{cccc} M_1 & M_2 & M_3 & M_4 \end{array} \\ \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{array} & \begin{bmatrix} 35.3 & 35.0 & 27.5 & 15.6 \\ 7.6 & 6.4 & 6.6 & 8 \\ 0.96 & 1.72 & 2.32 & 3.46 \\ 61 & 71 & 110 & 75 \\ 1853 & 1685 & 4793 & 1862 \\ 19.4 & 13.1 & 20.6 & 13.5 \\ 3.23 & 7.21 & 12.98 & 5.09 \\ 1.32 & 0.88 & 1.34 & 0.99 \\ 43 & 49 & 46 & 34 \end{bmatrix} \end{array} \tag{10}$$

Set up the membership degree matrix R^*_{10*4}:

$$R^*_{10*4}=(\mu_{ij})_{10*4}=\begin{array}{cc} & \begin{array}{cccc} M_1 & M_2 & M_3 & M_4 \end{array} \\ \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{array} & \begin{bmatrix} 1.000 & 0.9915 & 0.779 & 0.4419 \\ 0.950 & 0.8 & 0.825 & 1 \\ 0.2775 & 0.4971 & 0.6705 & 1 \\ 0.5545 & 0.6455 & 1 & 0.6818 \\ 0.3866 & 0.3516 & 1 & 0.3885 \\ 0.9417 & 0.6359 & 1 & 0.6553 \\ 0.2488 & 0.5555 & 1 & 0.3921 \\ 0.9851 & 0.6567 & 1 & 0.7388 \\ 0.8776 & 1 & 0.9388 & 0.6939 \end{bmatrix} \end{array}$$

(11)

Due to the lack of evaluation criteria, create a virtual standard fuzzy matter-element:

$$R_{90} = \begin{array}{c} \\ \left[\begin{array}{cc} & M_0 \\ C_1 & 1 \\ C_2 & 1 \\ L & \\ C_9 & 1 \end{array}\right] \end{array}$$

(12)

Thus, the difference squared matrix R_Δ is:

$$R_\Delta = \left[\begin{array}{ccccc} & M_1 & M_2 & M_3 & M_4 \\ C_1 & 0.000 & 0.0001 & 0.0488 & 0.3114 \\ C_2 & 0.0025 & 0.0400 & 0.0306 & 0 \\ C_3 & 0.5221 & 0.2529 & 0.1086 & 0 \\ C_4 & 0.1984 & 0.1257 & 0 & 0.1012 \\ C_5 & 0.3763 & 0.4205 & 0 & 0.3740 \\ C_6 & 0.0034 & 0.1326 & 0 & 0.1188 \\ C_7 & 0.5642 & 0.1976 & 0 & 0.3695 \\ C_8 & 0.0002 & 0.1178 & 0 & 0.0682 \\ C_9 & 0.0150 & 0 & 0.0037 & 0.0937 \end{array}\right]$$

(13)

The calculated weights are shown in Table 7.

Table 7. The weights of the evaluation indices of the target airports

Type of weight	The weights of the evaluation indices of the target airports								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
W^s	0.0860	0.1076	0.0496	0.1434	0.1213	0.1660	0.0971	0.0298	0.1955
W^o	0.1102	0.1057	0.1163	0.1082	0.1186	0.1076	0.1201	0.1070	0.1062
w	0.0862	0.1034	0.0525	0.1410	0.1308	0.1623	0.1060	0.0290	0.1888

See Table 8 for the degree of closeness$R_{\rho H}$:

Table 8. The ranking of the degrees of closeness of the evaluated samples

Evaluated sample	$R_{\rho H}$	Ranking
Beijing Capital International Airport	0.590053	3

Shanghai Airports	0.631192	2
Guangzhou Baiyun International Airport	0.882602	1
Chengdu Shuangliu International Airport	0.589937	4

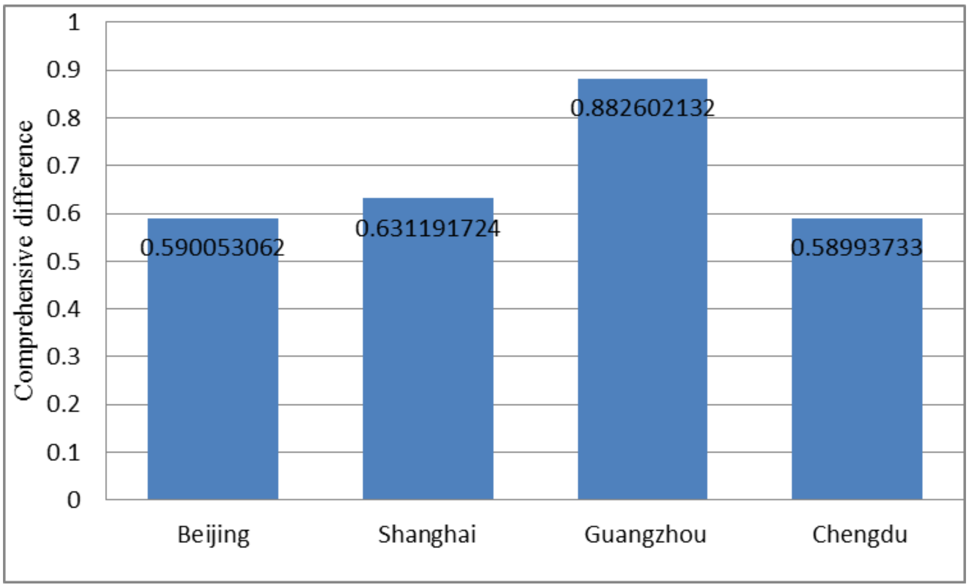

Fig.1. Comparing the economic adaptabilities of the construction scale of the four big airports in 2014

Finally, the author makes an intuitive comparison between the economic adaptabilities of construction scale of the four target airports by displaying the degrees of closeness to the virtual standard fuzzy matter-element in Figure 1. Generally speaking, there is no big difference between the four airports, but the adaptability of Chengdu Shuangliu International Airport is slightly weaker.

3.2 The Economic Adaptability Evaluation of Airport Construction Scale based on Lattice-order Decision-making

3.2.1 Lattice-order decision-making [17~18]

The lattice-order decision-making theory opens a new direction towards the ordering and structuring of the decision maker's preference for the consequences of decision. In the ranking of non-totally ordered evaluation alternatives, the lattice order can better reflect the preference of the decision maker than the total order. Therefore, the lattice-order decision-making is more scientific and reasonable.

The specific steps of the lattice-order decision-making method are as follows: The first step is to carry out dimensionless processing of the evaluation index data so that the data can be commensurable. The processed data reflect how satisfied the decision maker is with the different objects on each index. The second step is to consider the objective discreteness of index data and the subjective preference of the decision maker, and to determine the weights of the evaluation indices. The third step is to construct the evaluation matrix of the set of alternatives. The fourth step is to create the positive and negative ideal solutions, make them two virtual evaluation alternatives, and expand the set of evaluation alternatives to lattices. The final step is to evaluate the difference between the object and the virtual solutions with the Euclidean distance. The object is superior if the distance to the positive ideal solution is minimized and the distance to the negative ideal solution is maximized.

3.2.2 The evaluation process of the lattice-order decision model

1. Construction of evaluation indices

According to the first step of the decision-making method, the objects of evaluation, namely Beijing Capital International Airport, Shanghai Airports (Shanghai Pudong International Airport and Shanghai Hongqiao International Airport), Guangzhou Baiyun International Airport, and Chengdu Shuangliu International Airport are respectively expressed as G_i(i=1,2,3,4), and the evaluation indices are expressed as G_j(j=1,2,3,…11). On this basis, the evaluation matrix is constructed as follows:

$$P = \begin{array}{c} \\ G_1 \\ G_2 \\ \cdots \\ G_m \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & D_2 & \cdots & D_n \end{array} \\ \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix} \end{array}$$

(14)

Where: p_{ij} is the evaluation value of airport G_i in relation to t index D_j.

2. Non-dimensional treatment of evaluation indices

Measured by different units, the indices lack commensurability. Hence, the evaluation index data should be normalized to the interval between 0 and 1.

Table 9. Dimensionless values of the evaluation indices

Target airport	Dimensionless values of the evaluation indices								
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9
G_1	0.311	0.266	0.113	0.192	0.181	0.291	0.113	0.291	0.250
G_2	0.309	0.224	0.203	0.224	0.165	0.197	0.253	0.194	0.285
G_3	0.243	0.231	0.274	0.347	0.470	0.309	0.455	0.296	0.267
G_4	0.138	0.280	0.409	0.237	0.183	0.203	0.179	0.219	0.198

3. Calculation of the decision-making matrix

Establish the evaluation matrix for the economic adaptability of construction scale in the target airports. To facilitate the comparison of the two methods, define the operator $d_{ij}=w_j \cdot p'_{ij}$, and use the same set of index weights. Table 10 displays the evaluation matrix obtained through the calculation.

Table 10. The evaluation matrix for the economic adaptability of construction scale in the target airports

Target airport	The values of economic adaptability evaluation indices of airport construction scale								
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9
G_1	0.0268	0.0275	0.0060	0.0271	0.0238	0.0473	0.0120	0.0085	0.0472
G_2	0.0266	0.0231	0.0107	0.0316	0.0216	0.0319	0.0268	0.0056	0.0538
G_3	0.0209	0.0239	0.0144	0.0489	0.0615	0.0502	0.0483	0.0086	0.0505
G_4	0.0119	0.0289	0.0215	0.0334	0.0239	0.0329	0.0189	0.0063	0.0373

4. Calculation of comprehensive difference and sorting of evaluation objects

Calculate the comprehensive difference between the economic adaptabilities of construction scale of the target airports. According to the lattice-order theory, the positive and negative ideal solutions are:

$$M^+ = \left(\max_i d_{i1}, \max_i d_{i2}, \ldots, \max_i d_{in}\right)$$

(15)

$$M^- = \left(\min_i d_{i1}, \min_i d_{i2}, \ldots, \min_i d_{in}\right)$$

(16)

The Euclidean distance between the positive and negative ideal solutions is:

$$L = \sqrt{\sum_{j=1}^{n} (\max_{i=1}^{m} d_{ij} - \min_{i=1}^{m} d_{ij})^2}$$

(17)

Thus, the Euclidean distances between airport i and the positive and negative ideal solutions are:

$$L_i^+ = \sqrt{\sum_{j=1}^{n} (\max_{k=1}^{m} d_{kj} - d_{ij})^2}$$

(18)

$$L_i^- = \sqrt{\sum_{j=1}^{n} (d_{ij} - \min_{k=1}^{m} d_{kj})^2}$$

(19)

Define the comprehensive difference of airport i as follows:

$$L_i = q\frac{L_i^-}{L} + (1-q)\frac{L_i^+}{L}$$

(20)

Where q is the optimistic coefficient ($0<q<1$). It can be given by experts based on their experience.

In light of Table 10, obtain the positive and negative ideal solutions by Formulas (15) & (16), substitute the solutions to Formula (17) to get the Euclidean distance between the positive and negative solutions, and find the Euclidean distance between each airport and the positive and negative solutions in accordance with Formulas (18) & (19). In case the results are too optimistic or pessimistic, set the optimistic coefficient q at the modest level of 0.5. Substitute the coefficient to Formula (20) to calculate the comprehensive difference of each airport. See Table 11 for the overall calculation results.

Table 11. The overall calculation results

Calculation parameters	Beijing		Shanghai		Guangzhou		Chengdu	
	Positive ideal solution	Negative ideal solution	Positive ideal solution	Negative ideal solution	Positive ideal solution	Negative ideal solution	Positive ideal solution	Negative ideal solution
Euclidean distance	0.0473	0.0060	0.0538	0.0056	0.0615	0.0086	0.0373	0.0063
Comprehensive difference	0.570718		0.563400		0.635516		0.515245	

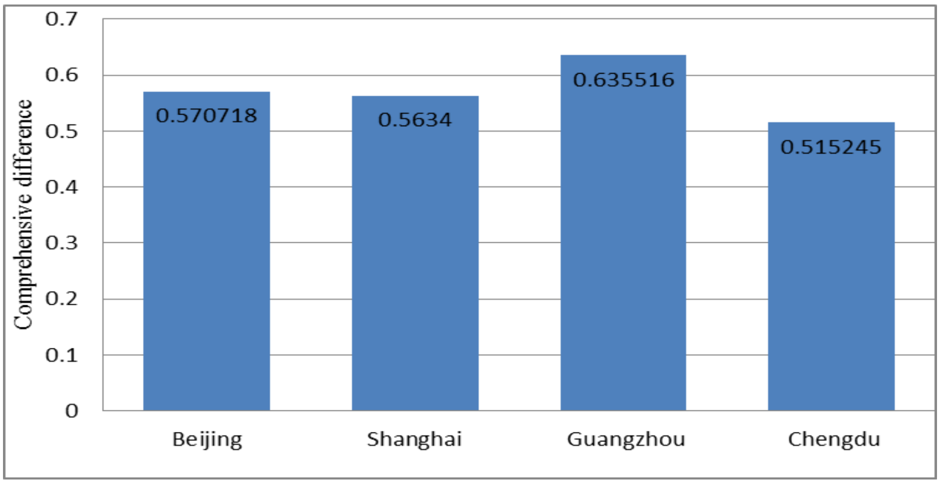

Fig.2. Comparing the economic adaptabilities of the construction scale of the four airports in 2014

As shown in Table 11 and Figure 2, the results of the evaluation method based on multi-objective lattice-order decision-making are consistent with those of the method based on fuzzy matter-element evaluation that the adaptability of Chengdu Shuangliu International Airport is slightly weaker, as is shown in figure 3.

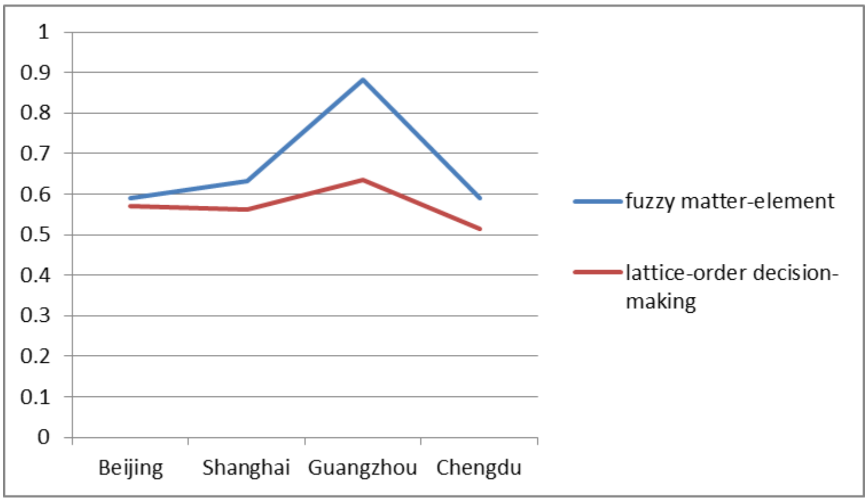

Fig.3. the evaluation results of two methods

The author analyzes the adaptability of Chengdu Shuangliu International Airport one index after another. As for demand satisfaction rate, the airport boasts the best service quality, and the highest growth of passenger throughput in the past three years. However, the passenger throughput of unit air route remains low, indicating that the airport has a big room for the growth in the demand of aviation business. As for supply efficiency, the airport is lower in terms of aircraft movements of unit runway and cargo throughput of unit freight station than the other three hub airports. This means that the runways and cargo stations of the airport have not been used efficiently, leaving a great room for improvement. For operation efficiency, the proportion of non-aviation business income of the airport is not high, indicating that the management of non-aviation businesses like franchise and store lease is yet to be improved. To sum up, the improvement economic adaptability of airport construction scale not only requires the construction scale to be reasonable and compatible with socioeconomic development, but also depends on proper internal organization and resource utilization rate of the airport.

4. Conclusion

The fuzzy matter-element model exhibits significant advantages in evaluating the economic adaptability of airport construction scale. It opens up a new path by drawing the correlation between the influencing factors and economic adaptabilities of different airport construction scales. The lattice-order decision-making does not require mature evaluation criteria, and pays more attention to the evaluation of micro-differences between the objects. With this method, the decision-makers can have a more clear and intuitive understanding of the economic adaptability of airport construction scale. The author innovatively combines the two methods and applies them to the field of the evaluation of airport construction scale. As shown by the evaluation results, the evaluation indices proposed by this paper is scientific and reasonable, and have a strong guiding significance for airport construction and development.

References

1. J. Huang, Airport hubs and competitiveness, 2011, Beijing Jiaotong University Press, pp. 40-60
2. S.F. Sun, Research on Socio-economic Benefits Evaluation of Civil Aviation Airport, 2011, Ph.D. Dissertation of Tianjin University, pp. 35-73
3. Y.Q. Zheng, Study of the Correlation between Regional Economy and Development Scale of Airport,2014, Master Degree Theses of Nanjing University of Aeronautics and Astronautics, pp. 42-64
4. Y.C. Chu, Research on Airport Operation Efficiency Evaluation and Improvement, 2009, Ph.D. Dissertation of Tianjin University, pp. 43-49
5. L. Zhang, H.Q. Hu, B. Zhang, X.N. Liu, The Adaptability of Chinese Airport Layout to Regional Economic Development, 2009, Civil Airports, vol.16 no.8, pp. 48-51
6. Z.B. Wang, An Empirical Study of Chinese Airports' Operational Efficiency Based on DEA, 2012, Journal of Transportation Systems Engineering and Information Technology, vol.12 no.6, pp.186-189

7. A. Philippe, Bonnefoy, Emergence of Secondary Airports and Dynamics of Regional Airport Systems in the United States, 2005, MIT master's degree thesis, pp.23-31
8. D. L Bryan, M. E O'Kelly, Hub-and-spoke networks in air transportation: An analytical review, 1999, Journal of Regional Science, vol 39, no.2, pp.275-295
9. The civil aviation administration of China, The Chinese transportation production statistical bulletin at the airport (2004－2014), [EB/OL].www.caac.gov.cn
10. X.N. Liu, Research on Dynamics Mechanism of The Development of Airport Economy and Its Impact in China, 2008, Ph.D. Dissertation of Nanjing University of Aeronautics and Astronautics, pp.30-56
11. E.F. Forister, Measuring the Benefits of Transportation Infrastructure Investment: Airline Scheduling, Airport Capacity Expansion, and Consumer Welfare, 2009, A Dissertation Submitted to the Graduate School of Business and the Committee on Graduate Studies of Stanford University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy, pp. 47-59
12. Putnam, J. Otis, Airport planning and its relation to the community, 1954, Massachusetts Institute of Technology, pp.17-23
13. Bogusch, L. Lynn, Rethinking the hub and spoke airline strategy : an analysis and discussion of American Airline's decision to de peak its schedule at O'Hare International Airport, 2003,Massachusetts Institute of Technology, pp.27-30
14. Bonnefoy, A. Philippe, Emergence of secondary airports and dynamics of regional airport systems in the United States, 2006, Massachusetts Institute of Technology, pp.37-38
15. A. Philippe, Bonnefoy, R.J. Hansman. Emergence and Impact of Secondary Airports in the United States, 2004, American Institute of Aeronautics and Astronautics, pp.36-47
16. S. Ma, Theory and Methods of post Evaluation on Railway Construction Project, 2014, Ph.D. Thesis of Southwest Jiaotong university, pp.50-53・・
17. S. Holos, Practical Aviation Economics, 2009, China Civil Aviation Press, pp.24-58
18. S.X. Zhao, P.H. Sun, Scheme Comparison of New Airport Site Selection Based on Lattice Order Decision Making Method in the Integrated Transportation System,2013, International Journal of Online Engineering, vol.4, no.4, pp.95-99