Research on the method of determining the service scope of civil airport – the case of Chengdu Shuangliu airport

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Abstract

Airport hinterland is the most important of influencing factors for civil aviation airport layout. By using methods of breaking point, expert consultation and entropy weights, the formula of computing the acting radius for airport hinterland was set up according to breaking point theory, and the idea and method were proposed to determine the service scope of an airport in an economic region. Then demonstrate the rationality of airport layout in the Chengdu-Chongqing economic zone by calculating the actual case of airport in the Chengdu-Chongqing economic zone. And get a conclusion that Leshan airport is inappropriate expansion in the near future.

Keywords: Civil airport; Breaking point theory; Entropy weights; Service scope

1 Introduction

Because of several constraints such as environment, resources and land use, major city groups in the world have a common problem of high density airports, the use of core city airport resource has been saturated, flight delay are serious and airport service quality has declined as well, but the airport facilities of surrounding cities are idle and lots of airport resources have not been fully used.

Civil airport lives with city. It is a crucial place for exchanging information between cities and cities and people communication, is also an important basic platform for regional economic social development. With the development trend of civil airport towards large-scale and hub type, including from regional city group to small towns around airport. The function coverage of some civil airports not only serves its home city also gradually extend to serve the entire economic region. Therefore, to accurately define the area of civil airport ground service, carry out overall planning in the region, and reasonably distribute aviation resources, avoid duplicated construction are important for the sustainable development of transportation system in the regional economy.

Airport service area or airport radiation circle means the area that airport ground radiation capability can cover. It includes the roads, railways and other ground transportation connected to the airport, which may generate passengers and goods supply for airport, and make the passengers and export goods consumption through airport.

According to the features of service needs, there are two levels of meaning should be taken into consideration. The first level is airport space radiation, i.e. radius from the airport; the second level is airport economic radiation, including core market and radiation market. The civil airport service objects studied in this paper are the passengers who need land to air transfer inside airport, airport ground radiation area is the airport ground attractive area under the background of integrated transport system and regional economic development.

In recent years, some experts and scholars using quantitative methods to study the reasonableness evaluation for the choice of airport site, mostly considering the factors of owned by city with technical point of view to study without the radiation factors around the airport; Zhang Xiaobin , Wang Wuke [1] have deeply analysed other factors affecting the construction of airport which can be divided into two categories; the background reflecting the development potential and service -based radius reflecting the potential pressure. For those have good economic foundation, but outside the airport layout that cannot meet the needs of small and medium cities, the recent urban planning should consider reserving the area for airport. Yang Xiuyun, Yao Shujie [2] thought that the structure, ground transportation and economic openness region are also major factors affecting the development of the airport and should be included in the analysis model. When other conditions remain unchanged, the impact of regional location on the airport development is significant. Wang Jiao, Jin Feng-jun [3] using two different methods of the shortest

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distance and reasonable service radius to divide the space radiation range of each airport. With the rapid development of regional economy, integrated transport, it seems that both methods have some limitations today.

Based on the absorption of results from previous studies, through expert consultation analysis, the airport ground radiation impact factor is selected and uses Entropy Method and combination weight to obtain the relative attractiveness M of the airport. Then the airport ground services area is qualitatively and quantitatively determined by using breaking point theory to identify the airport ground radiation range which could guide the urban airport planning and construction within the economic area.

2 The definition of the civil airport attraction

2.1 THE ESTABLISHMENT OF EVALUATION INDEX SYSTEM OF CIVIL AIRPORT ATTRATION

The factors which affect ground radiation scope of civil airport include the following items [4].

The first point is economic attractiveness of the hinterland city. Economic attractiveness is the major indicator which reflects degree of the city's production factors exchange with outsides, including resource distribution, industrial scale, the number of the employed population, economic structure, the openness of city, etc. These factors will affect the generation and attracting passenger flow, and determine the demand characteristics of civil airports.

The second point is accessibility and smoothing of transportation network around airport. The development of civil airport depends on the support of transportation network. In general, the wider of airport services cover, the farther the average distance to the airport, the weaker accessibility is, and vice versa; the greater population of the airport serves, indicating that more people use is, and the weaker smoothing is.

The third is overall strength of the airport. The overall strength of the airport is core competitiveness to attract the passenger and cargo traffic, and it is the most important factor in competition with the surrounding airports. In theory, the airport's overall strength includes airports modern equipment, management techniques, sufficient routes resources, unified and efficient operational means organizational skills, which are embodies the strength of the airport itself, and affects the degree of aggregation passenger.

Based on above factors and widely soliciting opinions from industry experts, in the principle of indicators selected scientific, operability and the combination of qualitative and quantitative indicators, the civil airport attractiveness indicator system as table1 is built.

TABLE 1 Civil airport attractiveness indicator system

Sub-function	Criterion	Indicators	Notes
Hinterland city attractiveness	Socio-economic factor	Openness of city	quantitative
		Per capita disposable income	quantitative
		GDP	quantitative
		Proportion of the tertiary industry	quantitative
Ground transportation network	The ground transportation system	Ground transportation accessibility	qualitative
		Ground transportation smoothing	qualitative
Airport overall strength	Air route resource	Air routes number	quantitative
		Navigation mileage	quantitative
	Transport organization ability	Aircraft movement	quantitative
		Airport cargo and passenger throughput	quantitative
		Transfer efficiency	qualitative

The access methods to specific qualitative or quantitative indicators are explained below.

(1) Openness of the city

Openness of the city mainly refers to the international exchange and cooperation and various factors of production flow inside and outside the city, which covers the areas of trade, investment, services, human resources, etc., it is an important indicator of the attractiveness of the city, and detailed evaluation methods can be seen in the literature [5].

(2) Per capita disposable income and GDP

These two factors reflect overall economic strength of the city and its local residents. They are important indicators for one city attractiveness.

(3) The proportion of the tertiary industry

The proportion of the tertiary industry reflects the degree of economic development of countries or regions, and there is a positive correlation relationship between it and air transport demand.

(4) Ground transportation network

Well-developed transportation system is an important manifestation of the airport's overall strength, and it is also an important reference index for passengers to select airport. Smoothing and accessibility are two core indicators of the airport transportation system, and smoothing affects the attractiveness for people around the airport and reflects the airport efficiency on integrated transport services; while accessibility embodies airport's universal service function and reflects the possibility transport services for airport passengers. Expert consultation is applied for these two evaluation methods.

(5) Route number and navigable mileage

Routes refer to the navigation lines for aircraft from one place (the starting point) fly to another place (end), and navigable mileage is the total length of routes. They are important statistical indicators to reflect the extent of route network expansion for an air transport enterprise production and business activities. Its statistical method can be seen in literature [6].

(6) Aircraft movements & airport cargo and passenger throughput

Aircraft movement refers to the maximum allowable vehicles on the airport runway, during a certain period,

and the general statistical indicators include annual average, daily average and daily peak hour aircraft movements. The number of vehicles in annual average is used here.

Since the airport's attractiveness is mostly reflected on passenger demand, and airport passenger throughput is selected as indicator here. Airport Passenger Throughput refers to the number of airport passengers arrive and depart during the reporting period which is computed in terms of Person. To some extent it reflects the size of the airport's handling capacity.

(7) Transfer efficiency

It refers to efficiency for the passengers to leave the airport or at the airport transit. It reflects the airport's internal management and organizational capability. This indicator is evaluated with the Delphi method.

2.2 NON-DIMENSION OF INDICATORS

As different indicators have different units resulting into lack of incommensurability, normalizing process for indicator evaluating data including positive, moderate, reverse and interval indicator is necessary. The characteristics of the data will be reflected by this process and the process method can be referred to literature [7].

2.3 DETERMINING THE AIRPORT ATTRACTION BY ENTROPY METHOD AND COMBINATION WEIGHTING METHOD

2.3.1 Calculation steps of entropy method

Entropy was once a concept of thermodynamics. At first it was introduced to information theory by c. e. Shannon and was called information entropy. The information entropy is an independent of the thermodynamic entropy concept, but has the basic properties of thermodynamic entropy, and has more extensive and universal significance, known as generalized entropy. The entropy weight method is a kind of objective empowerment. In the process of concrete use, based on the variation degree of each index, the entropy weight method will make use of information entropy to calculate the entropy weight of each index by entropy, then modify the weight of each index by entropy, by which more objective index weight will be obtained.

The specific calculation steps are as follows:

Step1. Through the field survey data and expert consultation on N evaluation objects and M index evaluation, the object and the index of evaluation matrix $R=(r_{ij})_{m\times n}$ will be formed.

Step2. According to the definition of entropy, in M index evaluation of N evaluated objects, the entropy of the i[th] indicators will be defined as:

$$H_i=-k\sum_{j=1}^{n} f_{ij}\ln f_{ij}\ ,\ \text{where}\ \ f_{ij}=\frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}\ ,$$

$k=1/\ln n$, $i=1,2,\ldots,m$, $j=1,2,\ldots,n_0$.

Step3. To calculate weight of the indicators, the entropy weight of the i[th] indicators 'will be defined as: $w_i=(1-H_i)/\left(m-\sum_{i=1}^{m}H_i\right)$.

Step4. To analyse entropy and entropy weight, when all evaluation objects is the same in a certain index, if the entropy value is 1 and the entropy is 0, it indicates that the index fails to provide useful information and may be cancelled.

2.3.2 Calculating the steps by combination weighting method as follows

Combination weighting method combines expert consultation method, analytic hierarchy process (AHP) and entropy weight method. The method not only considers the actual situation of the problem, but also combines with implicit knowledge of the experts in this field. It will avoid subjective method of assumptions and depend on the original data of mechanical properties too much by which focused analyses makes it explicit. It is more suitable for the related research work in complex system in social-economic field. The specific calculation steps are as follows.

Step1. The resulting weight by expert consultation method and analytic hierarchy process is: $W_1=\left(w_1^1,w_1^2,\ldots,w_1^k\right)$.

Step2. The resulting weight by Entropy weight method is $W_2=\left(w_2^1,w_2^2,\ldots,w_2^k\right)$.

Step3. To make $w_0^i=w_1^i\times w_2^i$ a group of weight vector $W_0=\left(w_1^1,w_0^2,\ldots,w_0^k\right)$ will be obtained.

Step4. In order to satisfy the normalization of weight, weight vector will be standardized $w^i=w_0^i/\sum_{i=1}^{k}w_0^i$, so combination weight vector is $W=\left(w^1,w^2,\ldots,w^k\right)$.

3 To confirm service scope of civil airport

The breaking point theory is about urban and regional interaction. The theory argues that a city's attractiveness to the surrounding area is proportional to the distance, and it is inversely proportional to the square of the distance. So boundary points (i.e. breaking point) of the affect areas by two cities are shown by formula such as 3-1 show.

The airport can effect deeply on the development of adjacent area. This effect also varies due to the scale of the airport and may weaken gradually with the increase of distance. That is to say, there is also a distance attenuation rule between airport and distant radiation. So radiation force of two adjacent airports will reach a balance and form a balancing point. Therefore, the calculation model of breaking point for airport will be obtained.

There must be several airports in an economic area and they will compete. Passengers choose one of them

because of its appeal. So in this article we want to build the improved model of weighted breaking point to evaluate comprehensively charm index for appealing passengers. The attracting index will be obtained by calculating synthetically index system of gravity at the airport in formula (1) by using the entropy weight method and combination weighting method. The resulting fitting curve of the breaking point will act as the ground space radiation of the research object.

$$D_a = \frac{D_{ab}}{1+\sqrt{M_b / M_a}}, \quad (1)$$

where D_a is the distance between the breaking point and civil airport A. D_{ab} is the distance between two competitive airport A and B. $M_b = \sum_{i=1}^{n} \omega_i Y_{bi}$, $M_a = \sum_{i=1}^{n} \omega_i Y_{ai}$, where Y_{ai} and Y_{bi} are influenced factors respectively. I will normalize the effect to airport A and B. N is the number of factors.

We will obtain the breaking point D_{ab} by substituting gravity results of the civil airport calculated by integrated weight method and quantitative measured data into formula (1). Therefore, the obtained breaking point will be important reference point for determining service scope, not those simple connecting breaking points. So the location of the breaking pointing between target airport and other airports in this area will be calculated by this model. If all the breaking points are obtained, service scope of the target airport will be determined by closed curve fitting formulated by MATLAB software.

4 Application case

For example, in Chengdu-Chongqing economic zone, according to airport business ranking in 2011, the top four airports are selected. Chengdu Shuangliu Airport is marked as A, Chongqing Jiangbei Airport is marked as B, Mianyang Nanjiao Airport is marked as C and Yibin Wuliangye Airport is marked as D. Passenger throughput of these four airports is (2.9, 1.9, 0.06, 0.03)×107 respectively in 2011. In view of the coordination and cohesion between airport and road network, their distance will be marked with urban road minimum distance. It is shown in figure 1. (Unit: Km)

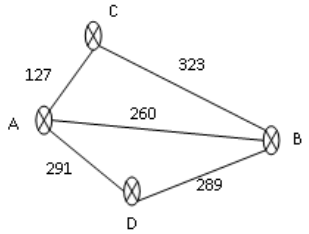

FIGURE 1 The top four airports network topology in Chengdu-Chongqing economic zone

4.1 DETERMINE THE BREAKING POINT POSITION OF AIRPORT A AND COMPETITOR

Determine the breaking point position of Airport A and competitor in Figure1 by calculation tool 'Yaahp' (Yet another AHP), entropy weight method and portfolio weighting method according to breaking point formula. The detailed process is followed.

Step1. According to questionnaire on experts, through pairwise relationship on every factor, we can obtain effect weight of airport attraction caused by every index of table 2 by 'Yaahp', as shown in table 2.

TABLE 2 Index weight by expert consultation method and AHP

Sub-function	Criterion	Indicators
Hinterland city attractiveness 0.26	Socio-economic factor 0.26	1.Openness of city 0.09 2. Per capita disposable income 0.08 3. GDP 0.06 4. The proportion of the tertiary industry 0.03
Ground transportation network 0.25	The ground transportation system 0.25	5. Ground transportation accessibility 0.13 6. Ground transportation smoothing 0.12
Airport overall strength 0.49	Air route network 0.20	7. Air routes number 0.12 8. Navigation mileage 0.08
	Transport organization ability 0.29	9. Aircraft movement 0.09 10. Airport cargo and passenger throughput 0.12 11. Transfer efficiency 0.08

Step2. Apply dimensionless method to the practical data which is collected from all airports and some empirical index from experts' scoring and then obtain the evaluation matrix R.

$$R = \begin{bmatrix} 0.54 & 0.41 & 0.02 & 0.03 \\ 0.27 & 0.25 & 0.26 & 0.22 \\ 0.43 & 0.47 & 0.05 & 0.04 \\ 0.33 & 0.51 & 0.08 & 0.08 \\ 0.26 & 0.28 & 0.23 & 0.23 \\ 0.24 & 0.29 & 0.24 & 0.24 \\ 0.41 & 0.34 & 0.14 & 0.12 \\ 0.38 & 0.33 & 0.15 & 0.14 \\ 0.52 & 0.33 & 0.07 & 0.06 \\ 0.43 & 0.34 & 0.13 & 0.11 \\ 0.38 & 0.35 & 0.14 & 0.13 \end{bmatrix}$$

Step3. According to calculate steps of entropy method in section 2.3.1, calculate the attraction indexes weight at the airport shown in table 3.

Step4. The attraction index of airport calculated through combination weighting method in section 2.3.1 was shown in table 4.

TABLE 3 Airport attraction indexes weight calculated by entropy method

	Openness of city	Per capita disposable income	GDP	Proportion of the tertiary industry	Ground transportation accessibility	Ground transportation smoothing	Air routes number	Navigation mileage	Aircraft Movement	Airport cargo and passenger throughput	Transfer efficiency
Weight	0.267 564	0.00 137	0.196 655	0.157 229	0.000 701	0.008 815	0.069 882	0.046 409	0.184 253	0.007 625	0.059 498

TABLE4 Airport comprehensive attraction index weight

	Openness of city	Per capita disposable income	GDP	Proportion of the tertiary industry	Ground transportation accessibility	Ground transportation smoothing	Air routes number	Navigation mileage	Aircraft Movement	Airport cargo and passenger throughput	Transfer efficiency
Weight	0.3293	0.0015	0.1613	0.0645	0.0012	0.0145	0.1147	0.0508	0.2268	0.0125	0.0651

Step5. The breaking point position of airport A and competitor

To combine and calculate quantitative matrix R and acquired index weight, we will see that attraction of airports A, B, C and D are respectively 3.278, 2.867, 0.568, 0.473. Then generate the obtained data into the formula (1), the breaking point position of Airport A will form. By matching we will see influencing range shown in figure2.

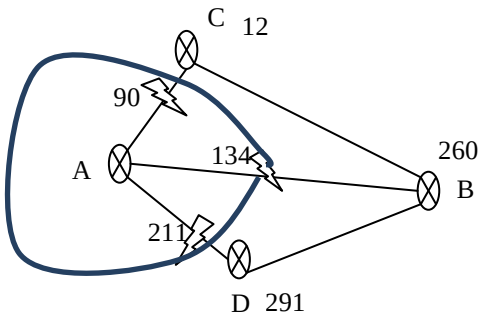

FIGURE 2 The breaking point position and influencing scope of airport A in this zone

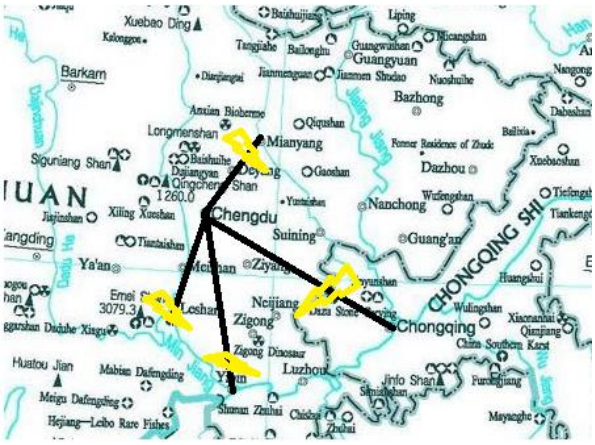

FIGURE 3 Breaking point of Chengdu Shuangliu Airport

4.2 THINKING ABOUT PLANNING AND CONSTRUCTION OF THE AIRPORTS IN CHENGDU-CHONGQING ECONOMIC ZONE

According to breaking point and influencing range of Chengdu Shuangliu Airport acquired just now, shown in figure 3, we can understand Leshang, about 169 km from Chengdu, is in this influencing range. Under development environment of the comprehensive transportation system, decision makers should apply policy guidance and management from the macroscopic angle. What is more, due to the development of highway and high-speed rail and the cause of airport resource around and self-position of airport attraction, Leshan Airport shouldn't be expanded aimlessly in the near future. The related institutions should invest auxiliary transportation infrastructure of airport, so as to realize optimization of system capacity and service in Chengdu-Chongqing economic zone airport.

Because service range of different airports crosses each other and competes drastically, in constructing and operating at airport, the relevant departments firstly consider regional coordinated development and apply flexible guidelines for the development strategy and development goals each airport. According to policy, actual condition at airport and development strategy of the airline, dynamically adjusting will be applied for development strategy of the airport. At the same time, by means of price demand control and so on, apply dynamic adjustment distribution of traffic volume in order to guarantee the maximum use of resources at the airport.

5 Conclusions

Combined with the factors that affect ground service range of the regional civil aviation airport, the formulas of calculating ground service scope of the civil aviation airport will be put forward. Among these factors, we consider not only airport itself and the surrounding geographical characteristics but also the layout of surrounding airport. Then calculating by model, we can solve ground service scope of the civil aviation airport, determine location selection and reasonable structure and avoid repetitive construction and malignant competition. And also, aiming at some blind spots on reasonable expanding in western zone especially those with plentiful travel resources, we will establish suitable layout method for China's national conditions with airport ground service theory.

Due to complicated factors involved, the theory may lack of Consideration of factors such as passenger preference. We will improve it in the future.

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