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Demand Discipline of Air Transportation for Passengers

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Abstract

The Yangtze River Delta (YRD) region in China is taken for an example to research demand discipline of air transportation for passengers in this paper. The discipline includes three parts: demand generation, distribution and flow. First of all, the key factors influencing demand generation are got with information entropy. A threshold is set to choose more important factors and weights of these factors are calculated at the same time. Contribution rate of a factor is defined to analyze the difference of the factors for different city. By comparing demand distribution with airports' throughput, we can analyze the demand flow. There are some conclusions. The factors have different contribution rate to different city for demand generation. Aircraft movement is the most important factor influencing demand flow. It provides more accurate basis for market positioning and developing, airport layout in a multi-airport system.

Keywords*: air transportation; demand discipline; information entropy*

1. Introduction

Demand of air transportation in a region is the basis of the planning and development of an airport. In a region lacking in air transportation demand, it won't have any benefits even if we provide more and better air transportation service. So demand analysis is one of the most important work of air transportation development. Demand of air transportation is closely related to social activity, economic development, environment and aviation supply. Demand of air transportation for passengers have been researched in lots of bibliographies [1-5]. But these research is mainly about demand generation. With continuous development of cities and airports, multi-airport systems have appeared in China. A multi-airport system means many airports exist in a region of closely-related cities. In the multi-airport system, analysis of demand discipline of air transportation should contain three parts: demand generation, demand distribution and demand flow. This paper mainly analyzes demand discipline of air transportation for passengers, which provides a more accurate basis for the planning and development of airports in the increasingly multi-airport systems.

2. Factors Choosing and Weight Calculation

In order to reflect problems more comprehensively and accurately, we need to consider many variables in the research of economy and management. It increases the complexity of analysis inevitably and makes us different to find the real characteristics and inherent discipline of things. In previous bibliographies, principal component analysis is often adopted [6-7]. However, this way cannot be applied to every case. And when function load of principal component is positive or negative, the meaning of comprehensive evaluation function is not clear and named clarity is low.

Concept of Entropy is originated from thermodynamics, which refers to the degree of chaos in the system. It is extended a more specific concept in different subjects and is an important parameter in different fields. Using the concept of thermodynamics for reference, Claude Elwood Shannon named the average amount of information as information entropy, excluding the redundancy. And he got the mathematical equation for information entropy calculation. If the smaller information entropy of some factor is, the more information is supplied, and the larger function this factor is in the evaluation. So the greater its weight is. Therefore, the

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way to confirm weight based on information entropy belongs to objective weight. It is superior to other ways in most cases [8].

Based on information entropy, this paper confirms factor weight and gives a minimum weight threshold. If weight of a factor is smaller than the minimum weight threshold, the factor will be ignored in order to filter the critical factor. The following are the concrete steps [9]:

 A multi-attribute decision consists of n objects and m factors. a_{ij} is an original value of the object *i* in the factor *j*, which forms decision matrix $\boldsymbol{A}=(a_{ij})_{n*m}$. Then standardize it, namely ***A'***.

 Do normalization for ***A'***, and get matrix $\boldsymbol{R}=(r_{ij})_{n*m}$, $r_{ij}=a_{ij}^{'}\Big/\sum_{i=1}^{n}a_{ij}^{'}$

 Calculate information entropy E_j of the jth factor, $E_j=-k\sum_{i=1}^{n}r_{ij}\ln r_{ij}$, $k=1/\ln n$.

 Calculate weight of the jth factor w_j, $w_j=(1-E_j)\Big/\sum_{j=1}^{m}(1-E_j)$, and $0\le w_j\le 1$, $\sum_{j=1}^{m}w_j=1$。

 Filter factors according to weights, if $w_j\le 0.01$, delete the jth factor and return to . Calculate weights of the rest factors again until weights of all the rest factors are more than 0.01, which means these factors are effective.

To calculate according to the steps from to , we can get corresponding weights and the key factors. The process of calculation is simple, and the foundations of filtering is clear.

3. Demand Generation and Distribution

It assumes that the real number of air transportation for passengers in some region is equal to its demand. According to the key factors and their weights choosing from the former part, we can get the comprehensive evaluation value *V* of each regional unit about demand of air transportation for passengers. Factor weights have been given according to their information, so we adopt simple weight method for a number of critical factors of each regional unit.

$$x_{ij}^{'}=\frac{x_{ij}}{\sum_{i=1}^{n}x_{ij}\Big/n} \tag{1}$$

$$V_i=\sum_{j=1}^{m}w_jx_{ij}^{'} \tag{2}$$

First, according to formula (1), we can get the original data nondimensionlized by using equalization method. Equalization method can not only eliminate the dimension, but also maintain the distribution of values. x_{ij} is respectively the original value of regional unit *i* in factor *j*, and $x_{ij}^{'}$ is the value of of regional unit *i* in factor *j* after using equalization method. This paper needs to distribute the total demand of the region belong regional units. So we can turn the comprehensive evaluation value to a rate of comprehensive evaluation [10].

$$V_i^*=V_i\Big/\sum_{i=1}^{n}V_{i(t)} \tag{3}$$

In formula (3), V_i^* is the demand share of air transportation for passengers of unit *i* in the total demand of the whole region, namely demand share. So we can get the demand of air transportation for passengers of each unit.

$$D_i=DV_i^* \tag{4}$$

In formula (4), D_i is the demand of air transportation for passengers for unit *i*, *D* is the the total demand of the whole region.

4. Application

4.1. Case Introduction

Core area of YRD in China is a super urban agglomeration. It has the core city of Shanghai, including other 15 cities of Nanjing, Hangzhou, etc. In 2009, YRD had ten civil airports, forming a a multi-airport system. Shanghai Hongqiao Airport, Shanghai Pudong Airport, Hangzhou Xiaoshan Airport and Nanjing Lukou Airport are big ones. These airports can have adequate supply of air transportation. At the same time, it is very convenient to connect cities by surface transportation in this region. So it is assumed that the actual finished throughput of air transportation for passengers of YRD equals the demand of this region. The operations of this region's airports are not optimistic. Most airports (mainly small and medium-sized airports) are in a deficit state in recent years. The studies of demand generation, demand distribution and flow of air transportation for passengers in the region can help the airports know the market and analyze their own advantages and shortcomings. All above can help the airports confirm market positioning and plan a reasonable marketing strategy.

4.2. Case Calculation

Considering the availability, 9 common statistical indexes are chosen: X_1-GDP(hundred million yuan), X_2-GDP per capita(yuan), X_3-disposable personal income of urban residents(yuan), X_4-resident population(ten thousand), X_5-number of employees(ten thousand), X_6-the proportion of tertiary industry(%), X_7-the completed amount of fixed investments(hundred million yuan), X_8-total exports(hundred million dollar), X_9-number of foreign tourists(ten thousand). We can use the data of YRD(including Shanghai, Zhejiang Province and Jiangsu Province) to filter factors. The time is from 1998 to 2009, and the data is got from the statistical yearbooks or statistical bulletins. Because the high-speed railway is opened in the YRD in 2010, and the speed and comfort of ordinary railway is inferior to air transportation, so we cannot take railway transportation into consideration for the demand of air transportation. Table 1 shows the factors and weights.

Table 1. Factors and weight

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Original value	0.1489	0.1304	0.0804	0.0008	0.0019	0.0064	0.1688	0.3110	0.1515
Final value	0.1502	0.1315	0.0811	-	-	-	0.1703	0.3139	0.1528

After making the calculation of 9 original factors, three factors are deleted. The weights of rest factors are all more than 0.01 which means these factors are effective. Therefore, key factors that have impact on demand of air transportation for passengers in the core area of YRD region are: GDP, per capita GDP, urban per capita disposable income, completed amount of fixed investments, total export, number of foreign tourists. The six factors are respectively expressed as x_1, x_2, x_3, x_4, x_5, x_6.

In market economy, the development of social economy should reply on the harmonious development of investment, consumption and exportation. (1) The area of YRD region only covers 2% of total territory of China, but GDP of this region from 2001 to 2009 keeps about 20% of China, and regional total export as a share of China's total export has increased from 30% to 40%. Developed economy and consistent increase of export improves reginal economic vitality and foreign economic relations, which will effectively promote demand generation of air transportation for business passengers in this region. (2) GDP of YRD region and urban per capita disposable income are more than the national average. Number of air leisure travelers has increased with the improvement of residents' paying ability. Meanwhile, with rich tourism resources in this region, foreign tourists number as a share of China has increased from 6% in 2001 to 13.88% in 2009. Air transportation is the first important way of

traveling for foreign tourists. So rapid development of tourism will strongly support the development of air transportation for this region. (3) The second important factor is completed amount of fixed investments. It is the general term of the workload and relative expenses of fixed investments that was built and purchased recently in a certain period in the form of currency. Increase of investments will bring the growth of economy, employment and income. All of these will promote demand increase of air transportation for passengers.

Data of 16 cities in YRD core region is used with formula (1) to formula (4). The demand distribution of air transportation for passengers. Part of the results are listed in table 2.

Table 2. Demand generation of each city(million people)

i	city	2001	2003	2005	2007	2009
1	Shanghai	1014.53	1160.55	1966.83	2447.68	2764.48
2	Nanjing	188.63	211.49	366.06	473.74	551.63
3	Wuxi	172.45	221.32	377.71	496.78	564.82
4	Changzhou	88.39	115.43	203.30	274.11	340.64
5	Suzhou	294.36	438.91	801.92	1064.74	1238.84
6	Nantong	83.23	97.67	177.58	251.07	328.92
7	Yangzhou	60.46	71.19	125.94	186.06	248.36
8	Zhenjiang	71.87	84.59	144.35	201.93	266.04
9	Taizhou	47.60	54.99	100.62	152.46	204.33
10	Hangzhou	253.58	275.96	451.36	597.70	699.36
11	Ningbo	173.69	219.11	379.05	506.27	593.18
12	Jiaxing	99.61	125.91	218.97	278.19	327.01
13	Huzhou	59.00	73.16	124.71	161.23	192.51
14	Shaoxing	98.74	129.31	213.40	284.49	337.49
15	Zhoushan	46.55	56.97	99.88	147.26	183.98
16	Taizhou2	78.40	99.44	160.56	212.75	234.52

4.3. Case Analysis

It takes cities as nodes of demand distribution in the region. And airports are nodes for demand flow.

4.3.1. Demand Generation

(1) Differences of key factors. Degree of influence on demand generation of key factors is different from one another. So it is necessary to make quantitative analysis on the differences in key factors in each city. Here a new index is defined, names as contribution rate. the share of weight of factor j in comprehensive evaluation value of city i is defined as contribution rate of factor j to city i.

$$C_{ij} = w_j x'_{ij} / V_i \quad (5)$$

In Equation (5), C_{ij} is the contribution rate of factor j to city i, other symbols have the same meaning as above. The table 3 shows the contribution rate of different factors to 16 cities in 2009.

Table 3 shows that the same factor has different impact to different cities. For Hangzhou(i=10), the order of contribution rate of six factors is: number of foreign tourists > completed amount of fixed investments > total export > GDP > per capita GDP > urban per capita disposable income. For Nanjing(i=2), the order is: amount of fixed asset investment > GDP > number of foreign tourists > per capita GDP > total export > urban per capita disposable income.

Table 3. Contribution rate of key factors

i	x_1	x_2	x_3	x_4	x_5	x_6
1	12.40%	3.12%	1.99%	10.35%	53.24%	18.90%
2	17.47%	15.25%	8.81%	26.23%	15.15%	17.09%
3	20.13%	17.91%	8.44%	22.93%	20.85%	9.73%
4	16.84%	20.81%	13.29%	27.15%	14.45%	7.46%
5	14.23%	12.34%	4.05%	12.99%	41.69%	14.70%
6	19.90%	15.25%	12.17%	29.72%	15.39%	7.58%
7	17.03%	20.79%	14.90%	23.23%	7.31%	16.74%
8	14.32%	25.65%	15.00%	20.60%	6.02%	18.40%
9	18.41%	21.66%	16.86%	30.96%	9.34%	2.77%
10	16.61%	13.33%	7.32%	17.77%	17.59%	27.38%
11	16.19%	15.98%	8.79%	18.33%	29.50%	11.22%
12	13.36%	20.56%	14.39%	20.46%	17.08%	14.15%
13	13.15%	25.39%	23.04%	17.97%	9.59%	10.86%
14	16.03%	20.07%	15.17%	16.96%	21.14%	10.63%
15	6.60%	37.35%	24.94%	11.81%	9.20%	10.09%
16	19.68%	18.69%	19.85%	19.29%	19.43%	3.06%

(2) Demand predication. When making market plan, airports should not only concentrate on its throughput, but also should consider the demand of air transportation for passengers in airport coverage. In that case, it is necessary to predict demand. First, according to key factors and historical data, fit the curve of demand generation. Then predicted value of key factors are taken into the curve equation, so we can get the future demand generation. Taking Changzhou(*i*=4) as example and using multiple linear regression analysis with data from 2001 to 2009, we can get the following equation:

$$D_4=1984.53x_{41}+27.51x_{42}+30.82x_{43}-2741.21x_{44}-7214.71x_{45}+88092.82x_{46}-1109843 \quad (6)$$

Symbolic meaning of equation (6) is the same as above. R=0.992, R^2=0.984. It means the model is well consistent with sample data here. When significant level is0.025, F=70.9. It represents that independent variables has remarkable linear relation with dependent variable. Therefore, we could accurately predict demand of Changzhou in the future by equation (6).

4.3.2. Demand of Distribution

With the development of economy, demand of air transportation for passengers in each city has been increasing year by year. But regional demand distribution is centralized. From 2001 to 2009, Shanghai has the most demand all the time, which demand share is about one-third of total demand in YRD core region. And Zhoushan has the lest demand, which only takes up 2%.

Table 4. Demand share

	Shanghai	Nanjing	Hangzhou	Changzhou	Zhoushan
2001	35.84%	6.66%	8.96%	3.12%	1.64%
2002	34.62%	6.21%	8.83%	3.19%	1.63%
2003	33.78%	6.16%	8.03%	3.36%	1.66%
2004	33.81%	6.03%	7.80%	3.29%	1.62%
2005	33.27%	6.19%	7.63%	3.44%	1.69%
2006	32.16%	6.14%	7.81%	3.42%	1.81%
2007	31.64%	6.12%	7.73%	3.54%	1.90%
2008	31.17%	6.09%	7.76%	3.70%	1.98%
2009	30.46%	6.08%	7.71%	3.75%	2.03%

Table 4 shows the demand share of some cities. As the representatives of large cities, demand share of Shanghai, Nanjing and Hangzhou has been decreasing year by year. Meanwhile, demand share of small and middle-sized cities such as Changzhou and Zhoushan keeps increasing rapidly. Continuous increase of demand provides a good market basis for airports in small and middle-sized cities.

4.3.3. Demand Flow

In Table 5, Pudong airport and Hongqiao airport are merged. It is assumed that airport serves the city, where it is located firstly. Demand finishing rate =airport throughput/demand of the city where airport is located. When the demand finishing rate is bigger than 1, the airport attracts demand of other cities except the local demand. So passengers inflow happens. On the contrary, if demand finishing rate is less than 1, it shows that the airport couldn't complete local demand. And this is outflow. For example, the demand finishing rate of Nanjing airport in 2001 is 149.24%, which represents Nanjing airport was a node with passenger inflow in 2001. The demand finishing rate of Ningbo airport in 2009 is only 67.96%, which shows that Ningbo airport was passenger outflow node and only completed 67.96% of local demand.

Table 5. Demand flow

	passenger through put (million)			demand finishing rate		
	2001	2005	2009	2001	2005	2009
Shanghai	2066.04	4146.23	5699.96	203.65%	210.81%	206.19%
Nanjing	281.52	538.59	1083.72	149.24%	147.13%	196.46%
Wuxi	3.63	61.91	221.79	2.10%	16.39%	39.27%
Changzhou	12.65	31.62	53.52	14.31%	15.55%	15.71%
Nantong	7.35	8.93	22.03	8.83%	5.03%	6.70%
Hangzhou	298.13	809.26	1494.47	117.57%	179.29%	213.69%
Ningbo	121.90	253.29	403.14	70.18%	66.82%	67.96%
Zhoushan	25.07	39.79	44.80	53.85%	39.84%	24.35%
Taizhou2	14.81	22.59	52.67	18.89%	14.07%	22.46%

According to passenger throughput in 2009, the ten regional airports are classified into four types by quick cluster:

1) super large airport, including Pudong and Hongqiao airports;
2) large airport, including Nanjing and Hangzhou airports;
3) middle-sized airports, including Wuxi and Ningbo airports;
4) small airports, the rest four airports.

The real passenger throughout of each type of airports keeps increasing from 2001 to 2009, but the changing trend of demand finishing rate is different. Demand finishing rates of ultra large and large airports are more than 1. So these airports are passenger inflow nodes. The capacity of two airports in Shanghai is gradually close to saturation, which inevitably leads to reduction of service quality and increase of flight delay. Therefore, passengers begin to flow to other large airports recently. The market concentration of two airports in Shanghai started to reduce after reaching its peak. Nanjing and Hangzhou airports obtain a benefit firstly. Demand finishing rates of small and middle-sized airports are less than 1, that means in YRD core region, less throughout of middle and small airports is not lack of demand, but because of demand outflow.

Demand flow of air transportation for passenger is actually the airport selection of passengers. In multi-airport system, there are more than one airports around a city. So a passenger who travels by air would select one airport to leave or select one airport to reach when he returns. Demand flow appears when the chosen airport is not located in the city where the passenger is. There are many factors influencing demand flow, sunch as area of the terminal, number of check-in counters, number of boarding gates, surface transportation time, flight frequency, navigation condition, etc. Shanghai, Nanjing, Ningbo and Changzhou airports stand for the four categories separately. There are two curves in Figures 1, 2, 3, 4, which are proportions of throughput and flight movement changing with time. Flight movement reflects the number of air routes and flights of an airport. It is the supply of air transportation from the airport. Passenger throughput shows the outcome of demand flow.

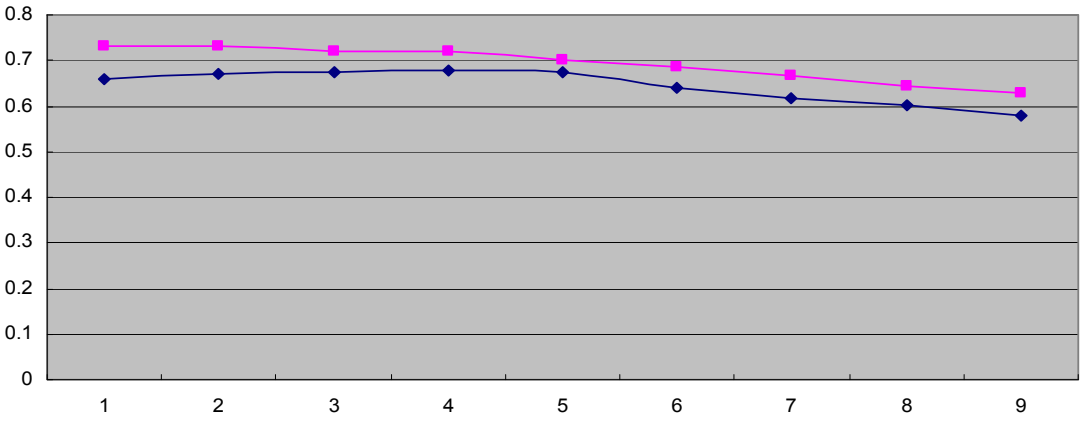

Figure 1. Shanghai airport

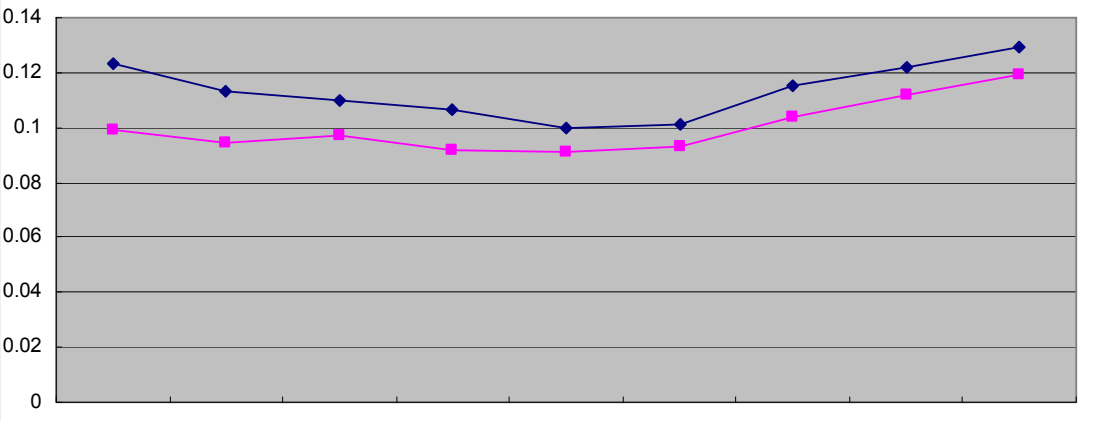

Figure 2. Nangjing airport

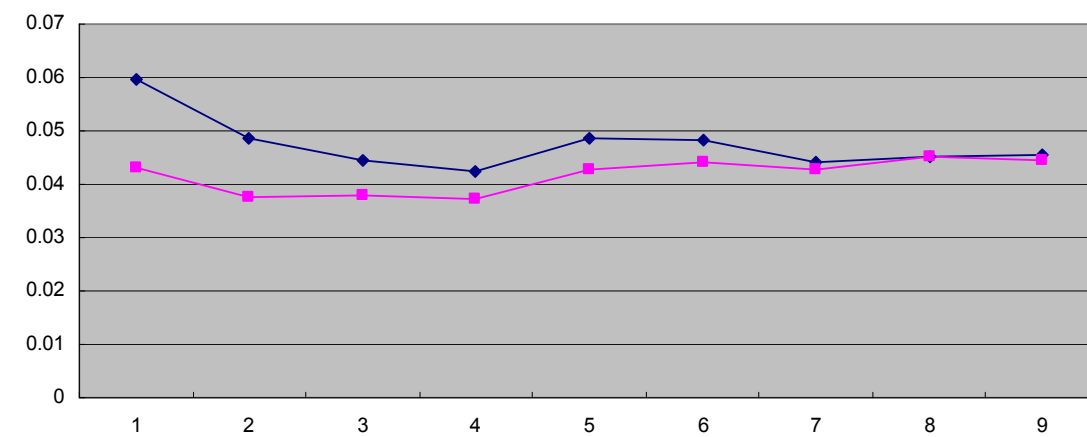

Figure 3. Ningbo airport

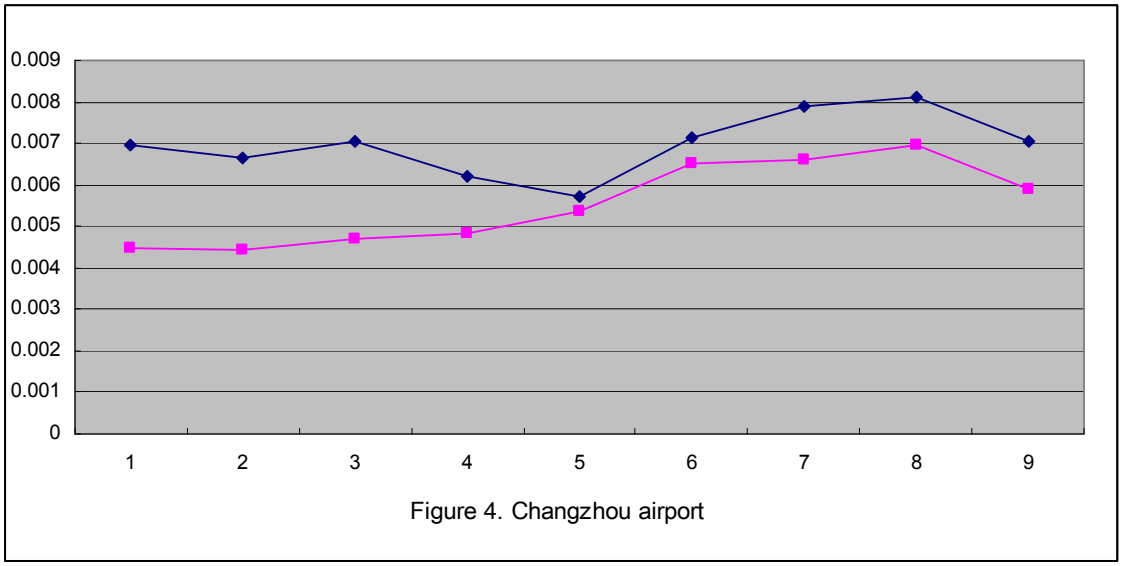

Figure 4. Changzhou airport

Whatever which type of airports, changing trend of two curves is basically consistent which shows there is large correlation between passenger throughput and flight movement when demand is sufficient. It means the number of air routes and flights have a major impact on regional air transportation demand flow. In the premise of sufficient demand, middle and small airports should plan market accurately and carry out marketing actively to increase air routes and improve flight frequency in order that airport would reduce demand outflow.

5. Conclusion

Demand discipline of air transportation for passengers consists of three parts in this paper: demand generation, demand distribution and demand flow. It takes the YRD core region as example. In demand generation analysis, based on information entropy and a weight threshold, it could get weight when selecting the six key factors influencing regional demand generation of air transportation for passengers. The selection is beneficial to simplify the complexity of calculation and can basically reflect the overall perspective of the problem. Then, a new index - contribution rate is given to analyze the differences of the same factor to each city. Secondly, in demand distribution analysis, demand distribution in YRD core region presents centralization. Shanghai, the biggest city in the area, takes up about one-third demand. However, the trend of centralization is slowing down year by year. Demand generation of small and middle-sized cities in the area is increasing more and more. Through recognising current situation and future tendency of demand distribution in its service range, airport can make a better plan. Finally, in demand flow, the most important factor that influences regional demand flow is the number of air routes and flights of airport. The more air routes and the higher the flight frequency it has, the more destination the passengers could arrive and the more flights they could select, the more attractive to passengers the airport will has. Therefore, large airports are passenger inflow nodes while most middle and small airports are passenger outflow nodes. In YRD core region, middle and small airports are located in small and middle-sized cities. These airports have deficits because of less throughout. Actually, these airports do not lack demand. Through giving accurate market orientation and demand analysis, carrying out marketing actively, seeking more air routes and flights, middle and small airports would reduce passenger outflow and increase its throughout.

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