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The Passenger Demand Prediction for Airport Line of Rail Traffic

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Abstract
The passenger flow prediction use the construction necessity and feasibility of the rail traffic of airport line as an important base. Based on the analysis of characteristics of passenger flow, it states the trip distribution prediction based on construct matrix method and predication method and corresponding model which are split based on SP questionnaire survey. It shows that the model has a direct and practical characteristic from an example.
Keywords: AIRPORT, RAIL TRAFFIC, PREDICTION AND ANALYSIS OF PASSENGER FLOW, CONSTRUCT MATRIX METHOD, DISAGGREGATE MODEL

1. Introduction

With the rapid development of China social and economy in recent years, there is an increased demand for high-speed passengers and cargos transportation among domestic and international. The transportation volume of air grow rapidly, which lead to ground passenger transportation system base on original roads could not keep pace with the requirement of air transportation in speed, convenient and comfortable. Rail is getting deeply attention and wide application in urban-airport connection system for the feature in speed and huge-volume.

There are many research conclusions in rail transportation witch connected airport. The relatively important results of them are: Rong-Chang Jou et. al. (2011) investigated the airport ground access mode choice behaviours of air passengers who are travelling overseas from Taiwan, and fund out that while out-

of-vehicle travel time and in-vehicle travel time are two important factors in affecting outbound travelers' choice of airport access mode (Rong-Chang Jou, et al,2011). Xiaowen Fu et. al. (2012) investigated the effects of the HSR (high-speed rail) services on Chinese airlines. And the result shows that the HSR service will be competitive in terms of network connectivity, total travel time and cost efficiency (Xiaowen Fu et al.2012). D. Tsamboulas et. al. (2012) presented models to simulation the airport employees' commuting mode choice using a combination of revealed and stated preference data. And the result shows that the employees are particularly sensitive to travel time, money costs, and their income in making modal choices, but do not distinguish between time costs of different components of their journey to work(D. Tsamboulas et al, 2012).Li Yujin & Zhang Zhiyong (2013) proposed a technology system about comprehensive transportation plans of the airport economic zone in some aspects such as intercity rail, freeway, urban roads, freight transportation channel and public transport system. And practiced the technology as an example of airport economic zone in Xiaogan (Li Yujin et al.2013).Changmin Jiang & Anming Zhang (2014) analyzes the effects of cooperation between a hub-and-spoke airline and a HSR operator with a airport capacity-constrained. And the research conclusion shows that the economies of traffic density alone cannot justify airline–HSR cooperation(Changmin Jiang et al.2014).Daniel Albalate et. al. (2014) studied the impact of HSR lines on air service frequencies and seats offered by airlines in large European countries, and provided that the HSR can take feeding services to long haul air services in hub airports, particularly in hub airports with HRS stations(Daniel Albalate et al.2014).

It mostly utilizes economic index to simply estimate passenger flow, which could not deeply describe the space relationship of passenger flow and the competitive relationship of the available transportation models, and it is difficult to guiding the planning, design and practical work of rail traffic. In this paper, based on the analysis of characteristics of passenger flow, it states the trip distribution prediction based on construct matrix method and predication method and corresponding model which are split based on SP questionnaire survey.

2. Airport Passenger Flow Feature Analysis

Airport passenger flow not only has the same features as all passenger traffic hubs do, but also have its particularity. This thesis focuses on the features of airport passenger and its travel behaviour and draws a conclusion of these main features as follow:

(1)Long trip distance

According to statistics, the average distance between airport and urban center both domestic and abroad is 23.23km; the data of London-Gheit Will, Montreal, Washington-Dulles, Tokyo Narita is even up to over 40km.According to the layout of airports themselves, the appropriate distance between airports and urban is over 10km. In the planning and design of airport in our country, the distance between airport and city are in the range of 20-30km. In other word, the traffic mileage of airport to urban is above 20-30km.

(2)High requirements of travel speed

According to the conclusions of cases studied from some main airports from US: when the running time of rail traffic and cars is close, the share rate of rail traffic is higher. When the time difference is over 23min, the share rate of rail traffic will show a clear downward trend. When the time difference is over 45min, the ratio is less than 1.7%. Thus, the running time is an important factor for passengers to choose rail traffic whether or not.

(3)Daily passenger flow duration of a long time

For the safety of plane taking off and landing, without considering the influence of climate and weather conditions, it requires large-volume airports to assign plane to take off and land as equally as possible on the time, which not only requiring the traffic connecting airport and city to run round-the-clock, but also resulting in passengers pass in and out airport equally all day long without peak or valley.

(4)Large number of passengers to receive and see off or commute

According to investigation by International Civil Aviation Organization, every passenger corresponding 0.8-0.9 person to see off, whose trip action is subject to the passenger and has no obvious difference on trip characteristics. Meanwhile, one thousand airport staffs are subject to one million passengers for service. They entry and exit the airport 10 times every week on average, which forms a great commuter flow between urban and airport.

3. Ideas of Passenger Flow Prediction for Airport Line

The passenger flow prediction analysis of airport line of urban rail traffic in this paper aims at research work of airport line planning and design phase. In the research of the passenger flow prediction analysis of airport line of urban rail, this paper follows the general international "four steps" method, uses it flexibly base on comprehension of the connotation of the method and full consideration of its characteristic. The work flow is shown in figure 1 as follow. In

the study process of passenger flow prediction of rail traffic for airport, there are several special technical procedures, besides the distribution chain of comprehensive transportation network is exactly the same with that of ordinary rail traffic: generation-attraction quantity forecast of airport line relative area, OD distribution prediction, mode division of travel demand forecast.

4. Generation-Attraction Volume Forecast of Airport Line Relative Area

4.1. Prediction Method of Passenger Flow Volume in Airport

As noted above, the passenger flow includes passengers take off, airport staffs, figures receive and see off. It comes up with equation (1) (2), with combination of these three parts:

$$G_i = T \times k \times (1-\alpha) \times (1+\beta) \quad (1)$$

$$A_i = T' \times k \times (1-\alpha) \times (1+\beta) \quad (2)$$

In the equation: Gi is generation quantity of traffic zone i where the airport is located in; Ai is attraction quantity of traffic zone i where the airport is located in; T is average daily arrival amount of tourists in characteristic year (deplaning); T′ is average daily take-off amount of tourists in characteristic year (boarding); k is the proportion of tourists of urban which covered the passenger flow of airport; α is transfer proportion, can be obtained by asking the local airport authority generally international airport is higher than domestic airport, trunk line airport is higher than the brunch line airport; β is proportion of airport transfers and commuters with the travellers is generally 1.4-1.9.

4.2. The Generation-Attraction Amount Prediction Method of The Passengers Into and Out of Airport In Urban

The passenger flow into and out of airport, which is calculated by the equations (1) and (2), is mostly from urban area near the airport. Taking the characteristics of passenger flow of urban rail traffic airport line into account, this paper chooses two factors the number of inhabitants and the number of full annual tourists and uses the multiple regression method to predict the travel volume of air tourists in each traffic

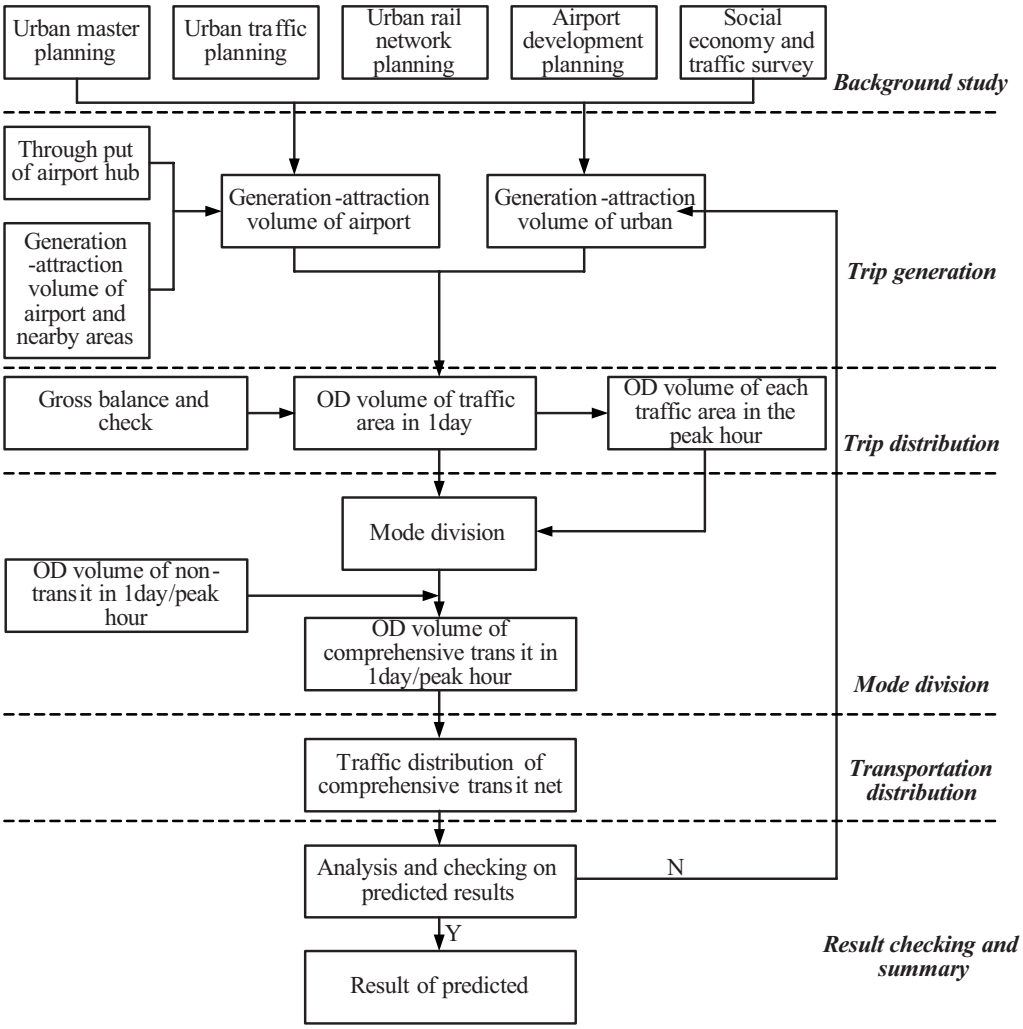

Figure 1. Prediction process of the passenger flow analysis

zone. The prediction equation of passenger flow into and out of airport in the traffic zone j as follows.

$$G_j = \mathrm{A}_i \times \frac{\left(a_0 + a_1 X_{\mathrm{j1}} + a_2 X_{\mathrm{j2}}\right)}{\sum_{k,k\neq i}\left(a_0 + a_1 X_{k1} + a_2 X_{k2}\right)} \tag{3}$$

Where: Gj is generation quantity of passenger flow into and out of airport in traffic zone j, j≠i; Ai is passenger flow attraction amount of traffic zone i; Xi1 is the number of residents of traffic zone j; Xi2 is the annual average daily number of tourists of traffic zone j; a0,a1,a2 is parameters, obtained by socio-economic indexes over the years of the airport service area.

Considering the characteristics of passenger flow of airport line of rail traffic, this paper applies two factors per person GDP and the number of jobs, and uses the multiple regression method to predict the travel demand of air tourists in each traffic zone. The attraction amount of air tourists in traffic zone i is as follows.

$$A_j = \mathrm{G}_i \times \frac{\left(b_0 + b_1 Y_{j1} + b_2 Y_{j2}\right)}{\sum_{k,k\neq i}\left(b_0 + b_1 Y_{k1} + b_2 Y_{k2}\right)} \tag{4}$$

Where: Aj is the attraction amount of air tourists in traffic zone j,j≠i; Gi is the generation amount of passenger flow leaving airport of traffic zone i ; Yj1 is per person GDP of the region which belongs to traffic zone j; Yj2 is the number of jobs of the region which belongs to traffic zone j ; b0,b1,b2 is parameters, obtained from the socio-economic indexes over the years of the airport service area.

5. Distribution Prediction of the Passenger Flow of Urban Metro Airport Line

Taking into account of the relationship characteristics of the spatial distribution of passenger flow into and out of airport, the generation-attraction amount can be use to constructed the distribution matrix directly, counting as distribution matrix Q, and the equation is as follows:

$$\grave{u}\grave{u}\grave{\imath}\grave{\imath}\left(\ kl\ \right)_{n\times n}, \begin{cases} q_{\mathrm{lk}} = A_k & \mathrm{l} = i, k \neq i \\ \ \mathrm{lk} = \ \mathrm{l} & \mathrm{k} = \ , \ \neq \\ 0 & k \neq 0, l \neq 0 \ \ or \ \ k = l \end{cases} \tag{5}$$

Where: Q is the distribution matrix of passenger flow into and out of, for n×n matrix; qkl is the passenger volume from traffic zone k to traffic zone l; Ak is the attraction amount of passenger flow of traffic zone k; Gl is the generation amount of passenger flow of traffic zone l; I is traffic zone which in the airport.

6. Division of Travel Mode of the Relevant Regional Airport Line

In view of there is always new transportation in the practical work, so this paper apply the disaggregate model method which is based on the SP survey method in the process of prediction analysis of airport passenger flow division.The disaggregate model using the concept of "utility" to describe the acceptable level of urban residents on the various modes of transportation. Utility function usually expresses as the form of linear function which is shown in the following formula (Lu Huapu. 2006).

$$U_{ki} = V_{ki} + \varepsilon_{ki}, \ i = 1,2,\cdots,n; k = 1,2,\cdots,m \tag{6}$$

Where: Uki is comprehensive utilization of the k-th traffic mode for the group of travellers i; Vki is fixed utilization of the k-th traffic mode for the group of travellers i, express as Vki=βnxnki; εki is random utilization of the k-th traffic mode for the group of travellers i.

It is assumed that the random utility obeys Gumbel distribution that is independent with each other. For a traveller who has a specific travel's purpose, the probability they accept a certain traffic mode is (Yao Yanbin. 2006):

$$P_{ki} = \frac{\exp(b \cdot V_{ki})}{\sum_{k=1}^{m}\exp(b \cdot V_{ki})} = \frac{1}{1 + \sum_{k\neq l}^{m}\exp[b \cdot (V_{ki} - V_{ki})]} \tag{7}$$

Where: Pki is the probability of the k-th traffic mode which is chosen by the group of travellers i; Vki is fixed utilization of the k-th traffic mode for the group of travellers i; m is a collection of all optional passenger traffic mode; b is parameter

For the contents of this paper, the key problems of the application of the model are how to construct the utility function. Through the passenger SP survey results this paper constructed the selection of utility function, and standardized the above parameters xi by using the maximum likelihood method, the specific process is seen analysis of examples.

7. Examples

7.1. The Research Background

(1)The present situation and planning of Xi'an Xianyang Airport

Xianyang International Airport is the main trunk airport and one of the top airports in China, which has regular international flights. It is also one of the eight aeronautic hubs which are planned by Civil Aviation Administration of China (CAAC). The grade of flight area is 4F and can meet the A380 passenger plane which has the world's largest passenger volume at present taking off and landing. In 2013 the passenger throughput broke through 26.045 million man-times. The flights of taking off and landing are 225thousand times. The operational capacity has reached the international advanced level.

(2)The present situation and planning of rapid rail traffic in Xi'an

The recent planning network of rapid rail traffic in Xi'an included six lines with the total length of 251.80km. Based on guaranteeing line stability of the urban center area and the recent construction, the network keep expanding room varies with the Xi'an development and has the flexibility of development.As Xi'an subway No. 1 line of further planning of west end has been extended to the urban area of Xianyang, the distance is near Xian Xianyang airport. At the beginning of the line of planning and design, the possibility extending to the airport may have been considered.

With the subway No. 1 and 2 lines opened to traffic, No. 3 and 4 lines are under construction, and planning network further are revised, the follow-up project is faced with the following two important decision problems. First, whether it is necessary for western side of No.1 line to further extend to the airport after extending to Xianyang. Second, if necessary, then how to define the airport line construction timing in the future? To solve the above two problems, there must be a reasonable and reliable prediction analysis of the passenger flow for the airport line.

The Prediction of Passenger Flow with the Full Ways between the Airport and Xi'an

On the basis of Xian Xianyang Airport development planning, it is expected that until 2020 the passenger throughput will reach 28000000 man-times and total cargo will reach 360000 tons. The passenger throughput will reach 60000000 man-times and total cargo will reach 800000 tons in long terms (in 2035). The application of formula (1),(2) that this paper presents predicts the total amount of passenger flow between airport and Xi'an urban district. Each parameter in the formula was calibrated as follows:

(1) Parameter calibration

① k: According to pass-in-and-out amount of present daily airport which is surveyed by the amount of related traffic roads of airport the passenger flow starts from Xi'an constitutes about 92% of the total in 2006. It is expected that the passenger flow starting from Xi'an urban district will account for 91% in 2010, for 90% in 2015, for 87% in 2020, and for 65% in the further planning year.

② The transfer ratio α:In 2006, the airport completed a total of passenger transfer is 809000 man-times, and the transfer ratio is 8.6%. It is expected that the passengers transfer ratio will reach 11.9% by 2010, 13.8% by 2015, 17.4% by 2020, and 20% by the further planning year.

③ The passenger flow ratio of pick-up and see-off (including commuter) β:Based on the actual survey results, it concluded that the average ratio of picking-up and seeing-off to Xi'an Xianyang airport is 0.45. It is expected that the ratio of picking up and delivering passenger flow (including commuting) will reach 1.46 by 2010, 1.49 by 2015, 1.54 by 2020, and 1.7 by the further planning year.

(2) The prediction results of total amount of passenger flow between the airport and Xi'an urban district

Based on the above results of parameters calibration, the total amount of passenger flow of characteristic years starting from Xi'an urban district calculated by the formula (1), (2) are shown in table 1.

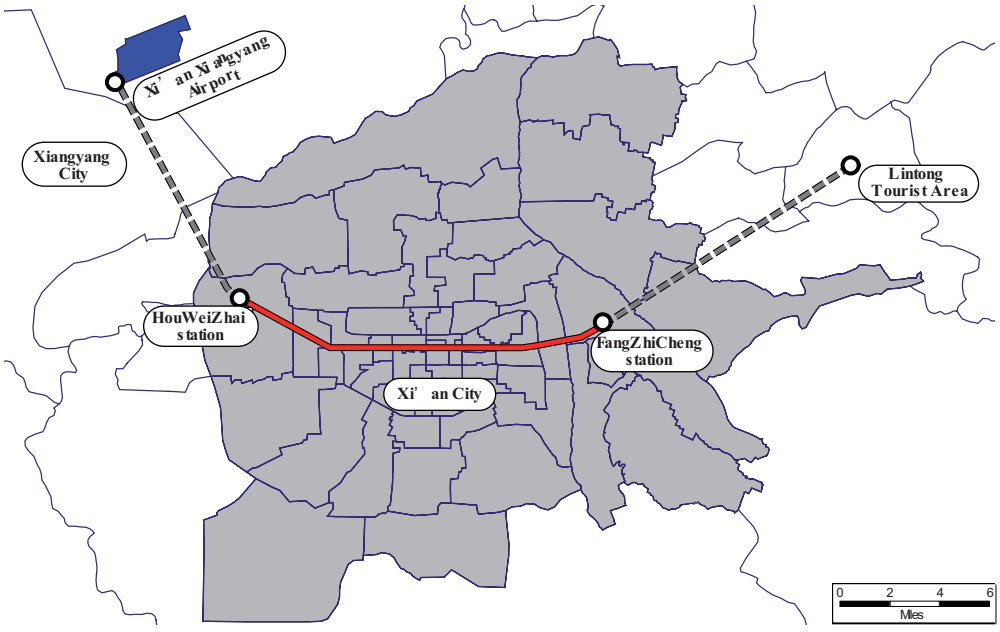

Figure 2. The position relationship between the 1st line of Xi'an Metro traffic and the possible airport line

Table 1. The total amount of passenger flow with the full way between the airport and Xi'an urban district

Year	The passenger throughput (million man-times/year)	k	A	β	Traffic Flow	
					(Two-way, million man-times/year)	(One-way, million man-times/day)
2010	1400	91%	11.9%	1.46	2761	3.8
2015	2100	90%	13.8%	1.49	4057	5.6
2020	2800	87%	17.4%	1.54	5111	7.0
Further year	4800	65%	20.0%	1.70	6739	9.2

7.2. The Prediction of Traffic Mode Assignment

(1)The analysis of SP questionnaire survey

According to a statistical result of Xi'an Xianyang International Airport in 2007, the passenger throughput capacity of average annual daily airport is 30.7thousand man-times per-day with a sampling rate of 1.30%. A total of 400 copies are investigated by using the simple random sampling method, of which 396 questionnaires are effective.

According to SP survey, the passengers of Xi'an Xianyang International Airport are mainly the middle-aged and the youth, and the youth share the proportion as much as 69%. Since most passengers aboard the plane are the staffs from enterprises and institutions, so they have a high ratio on business travel, and the ratio of the student passengers follows them.

In the present means of traffic, the ratios of passengers using the airport bus and taxi are basically the same. The ratio of using private cars follows the ratio of airport bus and taxi. Most of the groups have a better economic foundation and higher incomes, generally, the people who send them to the airport are no less than one person, and the possibility of transfer to other traffic is almost zero. The ratio of using the office or institutions cars ranks third. These passengers are mainly on a business trip with someone sending them to the airport so it's also unlikely for them to change to the metro traffic.

Since the subway joins the traffic system, 54% passengers, more than half, prefer to choose this transportation. When the costs are equal, the ratio of the airport bus and taxi reduce significantly, passengers who used to take the taxi and airport bus would like to choose the metro traffic. It shows that, the major part of the passenger flow of the future airport metro is transferred from the passengers flow used to take the taxi and airport bus.

(2)The model and the prediction process

There are 4 types means of transportation which people may choose to get to the airport: taxies, airport bus, private cars, and office cars. When the rail metro to the airport had been completed, the means of transportation which the passengers may choose to arrive at the airport can be divided into five categories: taxies, airport bus, private cars, office cars and metro. According to the factors which may influence the various modes of traffic, their utility functions are respectively defined as below:

$$V_n = a_1 T_n + a_2 C_n + a_3 I_n + \varepsilon_n \quad (8)$$

Where: Tn—travel time of the n-th individual;

Cn—costs of the n-th individual;

In—monthly income of the n-th individual.

a1, a2, a3 are undefined parameters. According to the data obtained from the SP survey, by using the professional analytical software--Trans CAD to calibrate the model and modifying it in combination with the application experience data of disaggregate model of Beijing and other places, the calibration results for each factor coefficient are as shown in Table 2:

Table 2. Calibration of influencing factors of each coefficient

Influencing factors	Cn	Tn	In
Factor coefficient	a1	a2	a3
Calibration value	-0.00021	-0.00623	0.0000298

Considering the Xianyang airport's development planning and the future development of XI'an urban, after the introduction of airport metro traffic line in 2015, the share rate of traffic mode between Xi'an and Xianyang airport is as shown in Table 3:

Table 3. The share rate of traffic mode between Xian Xianyang airport and Xi'an urban district

Year / Traffic mode	2015	2020	Further year
Taxi	18%	16%	12%
The car of institutions	18%	16%	10%
The airport bus	16%	16%	14%
The private car	18%	18%	19%
Metro traffic	30%	35%	45%

8. Conclusion

Based on the analysis of composition and characteristics of the airport passenger flow, this paper applies the airport throughout to build the models which

predict the amount of generation and attraction. It also proposed and applied the travel distribution prediction based on the method for constructing matrix and the prediction method of mode division based on the way of the SP questionnaire survey and the corresponding model. Finally, it has been verified by the example of Xian Xianyang Airport. The predicted results as show below:

(1) From the necessity of the construction of the airport rail line, the one way passenger throughout will reach 42,000 passengers / day, when the rail traffic has been completed around in 2035.

(2) From the view of construction timing, there is no internal passenger flow demand for metro line of Xi'an Xianyang International Airport before 2015. But the unidirectional passenger amount of the metro would reach 17 thousand to 25 thousand people one day during 2015 and 2020, which reaches the passenger scale to construct the light rail. And there will be the passenger amount demand for airport construction in the further year.

Acknowledgements

Thanks for the support of the central college fund of China (2013G1411077).

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