

Study on the Model of Air passengers Accessibility

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Abstract: This paper carried on the statistical analysis to the data of city air passenger travel using big data technologies and accessibility measure theory, and constructed the model of City Air Travelers Accessibility based on the characteristics and influence factors of each stage. And then, an empirical study was conducted for domestic cities of china. The empirical results are beneficial to the domestic airlines, airports, local government and the civil aviation authority, and could make relative decision more scientific, comprehensive and accurate.

1. Research Background

“Accessibility” was first embodied in Adam Smith's description[1] that the role of transportation in the market scope and market division restriction, and proposed by Hansen[2] for the first time. In the field of transportation, accessibility usually refers to the degree of difficulty from a given location to a destination by city transport system. According to difference of objects, studies could be divided into two categories: Individual and Regional. The category of Regional studies focused on regional accessibility and regional advantages[3] (including traffic network density, traffic impact degree and location advantage), location services [4], economic impacts [5-6], traffic network accessibility [7]; However, the category of Individual studies mainly concentrated in the travel time, index of accessibility, choice of transport mode and so on. Among them, residents and local governments are high degree of attention to travel time. Studies of travel time have been more perfect abroad [8]. But, in China, only a few studies [9] involved, and empirical study is less. Therefore, it is significant that measuring and calculating the accessibility of domestic cities aviation service supply.

2. Model Building

2.1 Stage Division of Air Passenger Travel Time

Air passenger travel time can be divided into 6 stages, as follows:

Waiting Time After Tickets: It refers to the time from air passenger booking success to the departure time. The departure time means optimal time from home or other place to airport (departure, for short “D”) by all modes of transport. The time depends directly on the number of flights provided by the departure city to the destination city.

Time of Departure Place to Airport (D): It means the time air passengers set off to airport(D) from city centre. The index of time in the phase mainly reflects the comprehensive traffic level of city.

Airport(D) Service Time: It refers to the time of check-in, baggage checks, security checks, terminal services, boarding, etc. The time index of in this stage could reflect directly airport design, and effectiveness of management.



Air Travel Time: It is the actual time of air passenger in plane from airport(D) to airport(A, Arrival airport for short). The time index is the core to measure the operational efficiency of aviation system, and the key to choose the mode of air travel for passenger.

Airport(A) Service Time: It refers to the time of air passenger from landing of plane to walking out airport(A). The time index could measure the convenience and service efficiency of airport(A).

Time of Airport(A) to Destination: It means the time air passengers set from airport(A) to city centre. The index is similar to the phase of Time of Departure Place to Airport (D).

2.2 Model Building

According to the above definition, we can build a model of air passenger travel time for a city, as follows:

$$MTT = T_W + T_{G1} + T_D + T_T + T_A + T_{G2} \quad (1)$$

MTT is air passenger travel time for a specific destination provided by a city;

T_W is waiting Time after tickets;

T_{G1} is time of departure place to airport (D);

T_D is airport(D) service time;

T_T is air travel time;

T_A is airport(A) service time;

T_{G2} is time of airport(A) to destination.

2.2.1 Waiting Time After Tickets(T_W) Sub-model Construction

For closer to the process of air passenger actual waiting time after tickets, and more accurately measure the comprehensive traffic level of city, we introduce the theories of Poisson process and Poisson distribution. It assume that every air passenger choose flight by principle of nearest available. In view of the above, we could identified successful ticketing behavior of each air passenger $\{N(T), t \geq 0\}$ in accordance with the counting process of Poisson process, and the number of successful ticketing can be identified independent of each other at any time, in other words, which is an independent increment process and the number $N(t+s)-N(t)$ of ticketing occurred in the time of $[t, t+s]$ only related to s , but not t ; In sum, the time of each ticketing $X(t_1), X(t_2)-X(t_1), \dots, X(t_n)-X(t_{n-1})$ independent ($0 \leq t_1 < t_2 < \dots < t_n$), $P(X(0)=0)=1$, and the probability distribution of the increment $X(T)-X(s)(t > s)$ obeys Poisson distribution.

Then, S_i is assumed the time of successful ticketing, t is the departure time. So, the waiting time after tickets in $[0, t]$ can be describe as:

$$S(t) = \sum_{i=1}^{N(t)} (t - S_i) \quad (2)$$

$$E\{S(t)|N(t) = n\} = nt - E \sum_{i=1}^n S_i | N(t) = n \quad (3)$$

$$T_W = \frac{t_{i+1} - t_i}{2} \quad t_i \text{ is plan time of flight } i \quad (4)$$

2.2.2 Time of Departure Place to Airport(D)(T_{G1}) Sub-model Construction

To ensure the rationality of the index, we assume that each air passenger choose the optional mode of transport according to their own situation and traffic congestion. The mode of transport includes: private cars, taxis, buses, airport bus, subway/suburban railway. Influence factors can be preliminarily selected as: travel time and proportion of various transportation modes of:

$$T_{G1} = \sum_{j=1}^n \alpha_j \cdot T_j \quad (5)$$

α_j is the proportion of transport mode j ;

T_j is the time of departure to airport(D) by the mode j ;

2.2.3 Airport(D) Service Time (T_D) Sub-model Construction

From the service perspective, this stage includes check-in services, security checks service, baggage checks service, terminal services, boarding service. However, many of them are queuing phenomenon. Therefore, we introduced theory and model of queuing.

Check-in Service: Check-in service in the large airport is mostly responsible by the airlines themselves, but it is more open check-in service mode in the small airport. Therefore, the model of check-in service can be divided two types:

① Single Check-in Counter Service Model (Er/M/1):

The service model refers to air passenger check-in in a single counter specially appointed by airlines or airport. Here, it is assumed that arriving time of any passenger independent each other in the queue, and interval time of adjacent passenger obeys the r order Erlang distribution:

$$f(t) = \frac{r\lambda(r\lambda t)^{r-1}}{(r-1)!} e^{-r\lambda t} \quad t > 0 \quad r > 0 \quad (6)$$

The service time of the model obeys the negative exponential distribution, and its distribution density function is:

$$g(t) = \mu e^{-\mu t} \quad (7)$$

Available from equation above, the average service time is $1/\mu$, and the equation can be regarded as independent parameter and the sum of random variables obeys distribution density of common negative exponential distribution. If the queuing and service in a single check-in counter service model can be regarded as a system, the interval arriving time of air passenger divided r phase position t_i (independent each other and obeys negative exponential distribution). So, $E(t_i) = \frac{1}{r\lambda}$, $1 \leq i \leq r$.

This made a homogeneous Markov chain formed $\{X_n, n \geq 0\}$. If its absolute probability is $p_j = P(X_n = j) = \bar{p}_j$, so the stationary distribution of air passenger number in the system should be:

$$\bar{p}_n = \sum_{j=nr}^{(n+1)r-1} p_j \quad n \geq 0 \quad (8)$$

If make $\rho = \frac{\lambda}{\mu}$, K's equation is:

$$\begin{cases} r\lambda p_0 = \mu p_r \\ k\lambda p_j = k\lambda p_{j-1} + \mu p_{j+r} \quad 1 \leq j \leq r-1 \\ (r\lambda + \mu)p_j = r\lambda p_{j-1} + \mu p_{j+k} \quad j \leq r \end{cases} \quad (9)$$

Therefore, we can derived the corresponding target parameters, as follows:

Average queue length in system:

$$L_s = \sum_{n=0}^{\infty} n \bar{p}_n = \frac{\rho s_0^r}{s_0^r - 1} \quad (10)$$

Queue up average queue length:

$$L_q = \sum_{n=0}^{\infty} (n-1) \bar{p}_n = L_s - (1 - \bar{p}_0) = \frac{\rho s_0^r}{s_0^r - 1} - \rho \quad (11)$$

The average sojourn time of air passengers in the system is obtained by the Little formula:

$$T_s = \frac{L_s}{\lambda} = \frac{1}{\mu(s_0^r - 1)} \quad (12)$$

Similarly, the average queuing time of air passengers is,

$$T_q = \frac{L_q}{\lambda} = \frac{1}{\mu(s_0^r - 1)} \quad (13)$$

In which: s_0 satisfies the equation:

$$r\rho s_0^{r+1} - (1 + r\rho)s_0^r + 1 = 0 \quad s_0 > 1 \quad (14)$$

② Multiple check-in counters queuing model (Er/M/n)

The model refers to multiple check-in counters shared by many airlines, or an airline check-in counter service mode. It is equivalent to n channel of single queue service systems, and the average arriving rate of air passenger is distributed averagely in each channel. In the case, the availability coefficient is $\rho = \frac{r\lambda}{n\mu}$, the corresponding target parameters can be deduced, as follows:

Queue up average queue length is:

$$L_{nq} = \frac{\rho}{s_0^r - 1} \quad (15)$$

The mean of queue up average queue length is:

$$L_{ns} = \frac{\rho s_0^r}{s_0^r - 1} \quad (16)$$

Average service time of queue up:

$$T_{nq} = \frac{L_{nq}}{\lambda} = \frac{1}{\mu(s_0^r - 1)} \quad (17)$$

The average queuing time of air passengers in the system:

$$T_{ns} = \frac{s_0^r}{s_0^r - 1} \quad (18)$$

Thus, the check-in service time model of an airport can be built, as follow:

$$T_{DZ} = \alpha \cdot \frac{1}{\mu(s_0^r - 1)} + \beta \cdot \frac{s_0^r}{s_0^r - 1} \quad (19)$$

α , β is proportion of air passengers respectively in the model of Er/M/1 and Er/M/n.

Security Checks Service: The service models are similar to the models of check-in service; the only different is not dependent on airlines, but the number of security checkpoints. So, the models are same.

Terminal Service: It refers to the time air passenger come out from the security check exit to the boarding gate (including time of waiting for delay flight). The model constructed as follows:

$$T_{DH} = \frac{1}{nm} \sum_{k=1}^n \sum_{l=1}^m \gamma_{kl} \cdot T_{kl} + T_{DY} \quad (20)$$

γ_{kl} is the proportion of air passengers from security check exit k to boarding gate l, T_{kl} is the time from security check exit k to boarding gate l, T_{DY} is the delay time of flight.

Boarding service: The service of stage is mainly to calculate the boarding time of different modes, such as bridge, ladder, ferry push, and the time of waiting for the flight take off in the plane. Therefore, we can build the model as follows:

$$T_{DD} = \frac{1}{3} \sum_{o=1}^3 \delta_o \cdot T_{Do} + T_{DH} \quad (21)$$

From the view of spending time, the stage includes: the walking time from any airport entrance to check-in counter of special airline(include cuss), queuing time for check-in, check-in service time, the walking time from check-in counter to any security checkpoint, queuing time for security check, security check service time, walking time from security check exit to the boarding gate, waiting time and boarding time. In sum, it can be constructed:

$$T_D = T_{BZ} + T_{DZ} + T_{BA} + T_{DA} + T_{DH} + T_{DD} \quad (22)$$

2.2.4. Air Travel Time(TT) Sub-model:

According to the air travel time of direct influence factors, we can construct the model as follows:

$$T_T = T_{TB} + T_{AY} \quad (23)$$

T_{TB} is the time of air travel in flight schedule(including transfer/stopover time and corresponding waiting time);

T_{AY} is the actual arrival time minus schedule arrival time.

2.2.5 Airport(A) Service Time(T_A) Sub-model

The direct factors in the stage includes: baggage handling time, baggage submission time, baggage transfer time, the time of allocation and response related personnel and vehicle, the time of passenger stepped off the plane, the number of passengers, the number of personal luggage, the mode of deplane, etc. Due to time synchronization, it can be reduced to the time of passenger stepped off the plane, baggage pick-up and waiting time, step out of airport. Thus, we can construct model as follows:

$$T_A = \alpha \cdot T_{AW} + \beta \cdot T_{AX} \quad (24)$$

T_{AW} is the service time for no checked luggage passenger;

T_{AX} is the service time for checked luggage passenger.

α , β is the proportion of T_{AW} and T_{AX} .

2.2.6. Time of Airport(A) to Destination(TG2) sub-model

The stage is similar to sub-model of time of departure place to airport(D), the model constructed as follows:

$$T_{G2} = \sum_{j=1}^n \alpha_j \cdot T_j \quad (25)$$

3. Empirical Study

3.1 Data selection

In view of the fact that effective degree of airport accessibility index is closely related the connectivity with political, economic centers and Hub airport. We selected the cities of Beijing and Shanghai as specific destinations, and selected corresponding domestic flights data and transport infrastructure of domestic cities for the first half of 2016, the details as follows:

Waiting Time After Tickets: The data is derived from airlines official websites and website <http://flights.ctrip.com>.

Time of Departure Place to Airport (D) & Time of Airport(A) to Destination: The data of time mainly select from website: <http://map.baidu.com>, the number and proportion of any mode, include private cars, taxis, buses, airport bus, subway, are mainly derived from official statistics.

Airport(D) Service Time & Airport(A) Service Time: The numbers of check-in and security check points based on the survey data in the airport, the numbers of passengers is selected from airport statistics and the leg pace is set 1.5m/s.

Air Travel Time: The data selected from <http://www.variflight.com> and ATCB of CAAC. The transfer flights are limited to 45min above and in one day.

3.2 Data Cleaning and Integration

As above data derived from different websites, and for different application, there is a lot of data redundancy, more fragmented and different in fields. So, to ensure the data availability, simplicity, accuracy, we identified valid field of data at first, and set the cleaning and integration rules for the correctness, availability of each field, and successfully constructed the integrated air passenger travelling time:

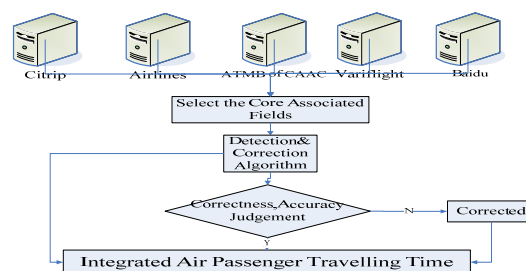


Figure 1. Flowchart of Cleaning and Integration

3.3 Results and Analysis

3.3.1 Waiting Time After Tickets

Take the cities of Beijing and Shanghai as two specific destinations; The top 5 cities (such as Figure 4) are Shenzhen, Guangzhou, Chengdu, Kunming and Xi'an respectively. Among them, the city of Shenzhen has the shortest waiting time after tickets. On average, the interval time of flights is less than 20 minutes to the cities of Beijing, Shanghai. This undoubtedly has made a strong support for the economic and trade exchanges, which also brought a great convenience to the residents in these cities.

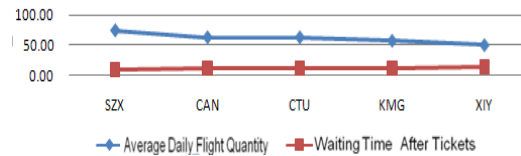


Figure 2 Waiting Time After Tickets and flights

3.3.2 Time of Departure Place to Airport (D) & Time of Airport(A) to Destination:

Here, we select the sample data of Beijing. The hub of Dongzhimen, near the center of Beijing, has the station of subway, airport express rail, airport bus, and near the airport expressway entrance. The numbers, proportion and time spending of each mode as follows:

Table 1 Proportion and Time of Each Mode

Mode	QTY-10THS	Pr. %	T-min
Subway	1193.16	12.64%	25
Taxi	2928	31.02%	38
Bus	1519.73	16.10%	61
others	3798.46	40.24%	43

The average time of departure place to airport (D) and airport (A) to destination:

$$T_{G1}(PEK)=T_{G2}(PEK) = 42.07\text{min}$$

$$T_{G1}(NAY)=T_{G2}(NAY) = 39.36\text{min}$$

$$T_{G1}(\text{Beijing})=T_{G2}(\text{Beijing}) = 41.92\text{min}$$

Other cities are same, we won't go into much detail here.

3.3.3. Airport(D) Service Time & Airport(A) Service Time

Check-in service: The survey data of PEK shows that the arriving time of passengers scattered 4-120min before the flight take off, and obey normal distribution. We select the data of numbers and time at 09:00-10:00 in PEK, as follows:

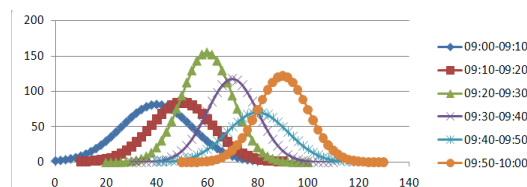


Figure 3 Arriving Time Passengers of PEK

According to above data, we can calculate the check-in time of PEK T_{DZ} is 12.73 min.

The standard(STD) and lower(LSL) time (Min) of check-in, security checks, terminal services, boarding as shown in the tables 2-5:

Table 2. Time of Check-in

Item	Category	LSL	STD
Entrance-Check-in Counter	Stepping	0	10
	First Class	0	5
Queuing Time for Check-in	Economy I	0	14
	Economy II	0	12
	Economy III	0	10

Check-in	Other	0	8
	Greeting	0	0.1
	Certificates Check	0	0.1
	Baggage Check	0	0.6
	Choose Seats, Check	0	0.2
	Cuss	0	0.7
	Online Check-in	0	0

Table 3 Time of Security Checks

Item	Category	LSL	STD
Check-in Counter To Security Point		1	8
Inspection Certificates		0.2	0.4
Guide		0.2	0.4
Waiting For Security Check	Airport I	0	12
	Airport II	0	10
	Airport III	0	8
	Others	0	6
	Manual	0.2	0.5
Security Checks	Baggage Checks	0.2	0.5
	Pack Luggage	0.2	0.5

Table 4 Time of Terminal Services

Item	Category	LSL	STD
Carrying on Bridge	Aircraft E	8	20
	Aircraft D	5	20
	Aircraft C	3	15
	Aircraft B	3	10
	Aircraft E	8	30
Removing Bridge	Aircraft D	5	30
	Aircraft C	5	25
	Aircraft B	5	20

Table 5 Time of Boarding

Stage	Item	Category	LSL	STD
Boarding	Boarding Check		0.1	0.2
		Waiting	0.2	5
	Ferry	Ferrying	1	10
		Boarding	3	13
		Stepping	0.5	1.1
	Ladder	Boarding	3	10
		Stepping	0.3	0.5
		Boarding	3	13
	Bridge		3	13
	Close the Door		3	10

3.3.4 Air Travel Time

Table 6. Top 5 Cities of Ranking by Air Travel Time

ID	Cities	QTY of Flights	Time(Min)
1	XIL	393	58.06
2	ERL	159	63.61
3	LYG	659	63.69
4	LYI	857	65.27
5	HIA	335	66.86

3.3.5 Airport(A) Service Time

The time of airport(A) service and top 8 cities to Beijing and Shanghai as shown in table7,8.

Table 7 Time of Airport(A) Service

Stage	Item	Category	LSL	STD
Baggage Pick-up	Allocation & Response Related Personnel & Vehicle	Bridge in Use	3	12
		Bridge no Use	5	15
	Baggage Handling Time	Aircraft E	10	35
		Aircraft D	8	30
		Aircraft C	7	25
		Aircraft B	6	20
		Aircraft E	15	40
	Baggage Submission Time	Aircraft D	15	30
		Aircraft C	12	25
		Aircraft B	12	20
Step off	Step off Plane		2	12
	Step out of Airport		5	18

Table 8. Top 5 Cities-To Beijing& Shanghai

ID	City	Travelling Time(Min)
1	Dalian	198.48
2	Huhehaote	209.22
3	Xiamen	235.64
4	Wuhan	239.07
5	Yantai	241.6

4. Conclusion

Overall, the paper analyzes the characteristics and influencing factors of passenger's travel, and try to apply theories of big data, Poisson process, queuing and accessibility measurement, and use technologies and methods of web crawler, big data to collect, sort, clean, integrate the data of the first half of 2016 and summarized a series of rules for data cleaning, alignment, calibration and integration, and formed integrating air passenger travel data, and then calculated the air passenger travel time of domestic city. The result is beneficial to the government to improve the city aviation service supply, and is favor to service level and efficiency for airline, airport.

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