

Research on the Model of Air Passengers Travelling Time

ShuLong ZHAO

Research base of economics and management of air transportation, Tianjin, China

Email: zhaoshulong@caacsc.cn

Abstract. This paper firstly analyzes the characteristics and influencing factors of passenger's travel, and constructed the sub-model for each stage according to the theories of Poisson process, queuing and directly service time. The 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. Introduction

For the passenger, time and cost are the most important factors when choosing between different transportation modes[1-3], according to the theory of transportation economy. Compared with other modes, the core feature of air transportation is faster. In foreign, there are many studies related air passengers travelling time[4], and many statistics about cities or airlines could be acquired even in the official website of Department of Transportation (DOT). But, in China, only a few papers are made, such as Rong Chaohe (2011)[5], Li Xiaojin etc. (2016)[6]. So, it is absolutely necessary to construct a model of city air passengers travelling time based on the characteristics and influence factors of each stage.

2. 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 this phase mainly reflects the comprehensive traffic level of the 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, planning 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 off to airport(A) to city centre. The index is similar to the phase of Time of Departure Place to Airport (D).



3. 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.

3.1. 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:

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

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

Thus,

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

3.2. 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 place to airport(D) by the mode j ;

3.3. 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, as follows:

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, as follows:

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

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

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

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:

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

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

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

Therefore, we can derived the corresponding target parameters, as follows:
Average queue length in system:

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

Queue up average queue length:

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

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

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

Similarly, the average queuing time of air passengers is,

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

In which: s_0 satisfies the equation:

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

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:

$$L_{nq} = \frac{\rho}{s_0^r - 1} \tag{15}$$

The mean of queue up average queue length is:

$$L_{ns} = \frac{\rho s_0^r}{s_0^r - 1} \tag{16}$$

Average service time of queue up:

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

The average queuing time of air passengers in the system:

$$T_{ns} = \frac{s_0^f}{s_0^r - 1} \tag{18}$$

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

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

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:

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

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:

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

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 (including the time of luggage out), 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 as follows:

$$T_D = T_{BZ} + T_{DZ} + T_{BA} + T_{DA} + T_{DH} + T_{DD} \tag{22}$$

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

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

$$T_T = T_{TB} + T_{AY} \tag{23}$$

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.

3.5. 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:

$$T_A = \alpha \cdot T_{AW} + \beta \cdot T_{AX} \tag{24}$$

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} .

3.6. 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:

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

4. Conclusion

In sum, the paper firstly analyzes the characteristics and influencing factors of passenger's travel, tries to divide the air passenger travelling time into 6 stages, and gives the special definition of each stage.

And then, tries to apply the theory of Poisson process in the imitate the process of air passenger actual waiting time after tickets, and apply the theory of queuing to calculate the waiting time and service time in the links of check-in services, security checks service, baggage checks service, terminal services, boarding service, and constructed the sub-model to describe the time of passengers spends. The time of other stages, could be acquired by the related survey or actual operational data. Only constructed the sub-model by the directly service time. The model of city air passengers travelling time is beneficial to calculate the travelling time of cities, and could make relative decision more scientific, comprehensive and accurate for domestic airlines, airports, local government and the civil aviation authority etc.

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