The Influences of Various Delay Factors for Chinese Flight

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Abstract: Through the data analysis, the various factors of the flight delay in China are studied. After considering all airports of the delay propagation effect with exponential decreasing trend, we establish the modified dynamic 2M/M/2 queuing model, and use domestic airports data simulate by adopting *the Monte Carlo Method* .At last ,we obtain the macro factors, and the frequency and influence degree of various micro factors for the delay of China's flight.

Introduction

The paper analyzes various factors for Chinese flight delay. Two evaluation index for fight delay are the number of times for delay and duration for delays ,so these two index must be considered in the analysis of factors for the delay. We consider the flights departure and arrival of the aircraft obey Poisson distribution, so decide to establish queuing theory model, adopting mathematical treatment to the occurrence and transmission characteristics of flight delays. Also taking various factors and uncertainty of each delay time duration into account, we use mathematical simulation to analyze the various factors.

Assumption

1. The data is true and reliable in the paper.
2. The influences of departure distribution, arrival distribution and service capacity in the different airport in the dynamic queuing model are ignored.
3. We assume that all airports adopt a double track mode.

The establishment of dynamic 2M/M/2 queuing model

Because flights departure and arrival of the aircraft obey Poisson distribution, the dynamic queuing model is established to further identify and analyze key factors and their impact for flight delay. In China, flight delays occurs in large and medium-sized hub airport, which has two runways .Aircrafts' departure and arrival are able to use same runway ,and observe the rule of "first-come, first-serve" .Besides, we assume source of aircrafts and airport's capacity are infinite. Based on the above , we establish a 2M/M/2 model abiding by the rule of "first-come, first-serve".
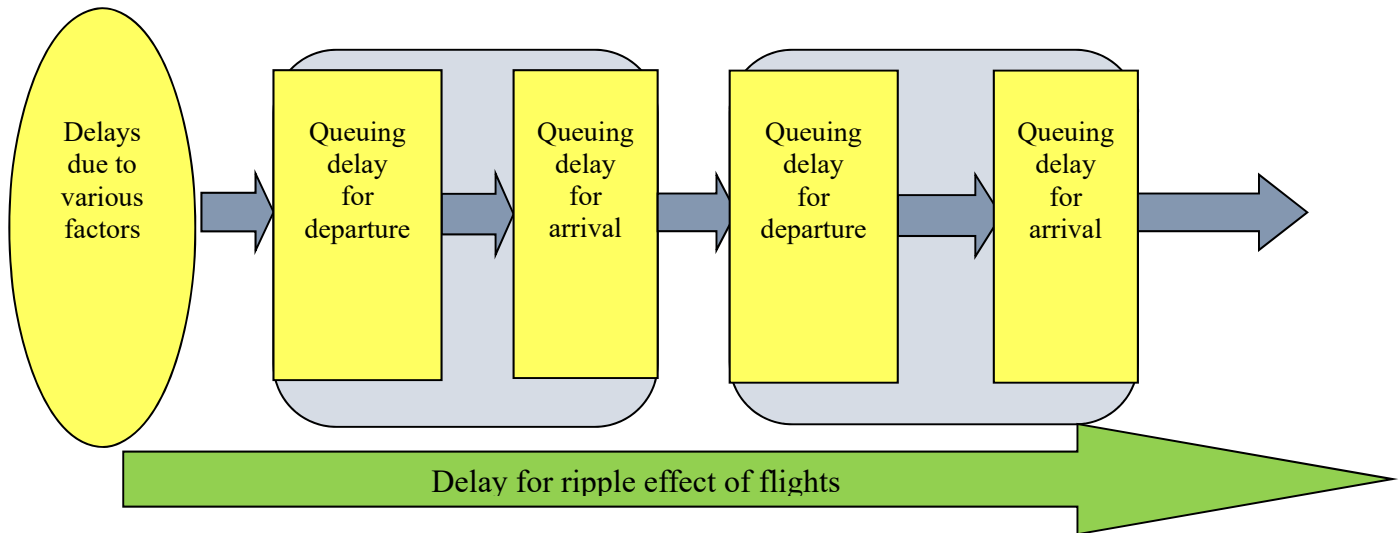
Figure 1: Dynamic Queuing Model

The model considers the delay caused by an accident and ripple effect due to an accident .As delay caused by security check is tiny and negligible. so:

The total delay of a section = Initial delay + Delay caused by queuing.

or : **The total delay of a section =Delay by ripple effect + Delay caused by queuing.**

The model assumes that the airport use double runway mixed mode, without separate analysis for flight arrival and departure ,so airport can be regarded as a whole .Flight departure and arrival are separately subject to the Poisson distribution of parameters defined as λ_1、 λ_2 ,while time for departure and arrival are respectively subject to the negative exponential distribution of parameters defined as μ_1、μ_2 Thus, queuing aircrafts obey the Poisson distribution of parameters defined as $\lambda = \lambda_1 + \lambda_2$,while total service time obeys exponential distribution of parameters defined as $\mu = \mu_1 + \mu_2$.

According to queuing theory, queuing model fits in with following equations:

$$\begin{cases} \mu P_1 = \lambda P_0 \\ (n+1)\mu P_{n+1} + \lambda P_{n-1} = (\lambda + n\mu)P_n & (1 \le n \le c) \\ c\mu P_{n+1} + \lambda P_{n-1} = (\lambda + c\mu)P_n & (n > c) \end{cases}$$

(P_n express probability of n aircrafts' arrival within a time period t .)

Obviously, $\sum_{i=0}^{\infty} P_i = 1$, $\rho = \dfrac{\lambda}{c\mu} \le 1$.

The state probability can be obtained by using the recursive method to solve the difference equations:

$$\begin{cases} P_0 = \left[\displaystyle\sum_{k=0}^{c-1} \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k + \frac{1}{c!} \cdot \frac{1}{1-\rho} \cdot \left(\frac{\lambda}{\mu}\right)^c \right]^{-1} \\ \\ P_n = \begin{cases} \dfrac{1}{n!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (n \le c) \\ \\ \dfrac{1}{c! c^{n-c}}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (n > c) \end{cases} \end{cases}$$

Average length of queue L_s and average length of waiting queue L_q :

Average waiting time W_q and average staying time W_s :

$$\begin{cases} L_s = L_p + \dfrac{\lambda}{\mu} \\[2mm] L_q = \displaystyle\sum_{n=c+1}^{\infty} (n-c)P_n = \dfrac{(c\rho)^c}{c!(1-\rho)^2} P_0 \end{cases} \qquad \begin{cases} W_q = \dfrac{L_q}{\lambda} \\[2mm] W_s = \dfrac{L_S}{\lambda} \end{cases}$$

Obviously, ripple effect of flight delay is progressively decreasing in all sections, so its transmission may be assumed as the geometric progression with common ratio $1/2$. The airport has adjustment capability for the flight delays, so we assume delay time which can be adjusted is H. If the total delay of a airport is less than H, it can be directly eliminated.

Assume that the initial delay is D_0 and delay in each section decreases to half of the former section. So:

The delay time in each section: D_1, D_2, Λ, D_n

$$\text{Total spread delay} = D_1 + D_2 + \Lambda + D_n = \left(\frac{1}{2} + \frac{1}{4} + \Lambda + \frac{1}{2^n} \right) D_0$$

For the initial airport:

The delay for aircraft departure (or arrival) queuing$= D^0 = L_q \cdot W_q + D_0$,

(D^n express the delay of the $n-th$ airport, $n = 0,1,2\Lambda$)

The first airport associated with the initial airport:

$$D^1 = L_q \cdot W_q + \frac{1}{2} D^0 = \frac{3}{2} L_q \cdot W_q + \frac{1}{2} D_0$$

The $n-th$ airport associated with the initial airport:

$$D^n = \frac{2^{n+1}-1}{2^n} \cdot L_q \cdot W_q + \frac{1}{2^n} \cdot D_0$$

Monte Carlo Method simulation:

Table 1 :Proportion of factors for flight delay

Year	Flow control	Airline	Weather	Military activity	Airport	Passengers
2006	0.22	0.48	0.18	0.02	0.02	0.02
2007	0.28	0.47	0.15	0.07	0.02	0.01
2008	0.19	0.43	0.27	0.06	0.04	0.01
2009	0.23	0.39	0.19	0.11	0.05	0.03
2010	0.24	0.41	0.23	0.09	0.02	0.01
2011	0.28	0.37	0.20	0.12	0.01	0.02
2012	0.22	0.36	0.21	0.17	0.02	0.02
s Average	0.2275	0.42125	0.20125	0.08375	0.0275	0.01875

Data sources: 《 Statistical Data on Civil Aviation of China (2006—2012) 》

According to above table, we can acquire conclusion that frequency of factors causing delay: ***airline> flow control>weather> military activity> airport> passengerss.***

We establish following simulation model by adopting Monte Carlo Method:
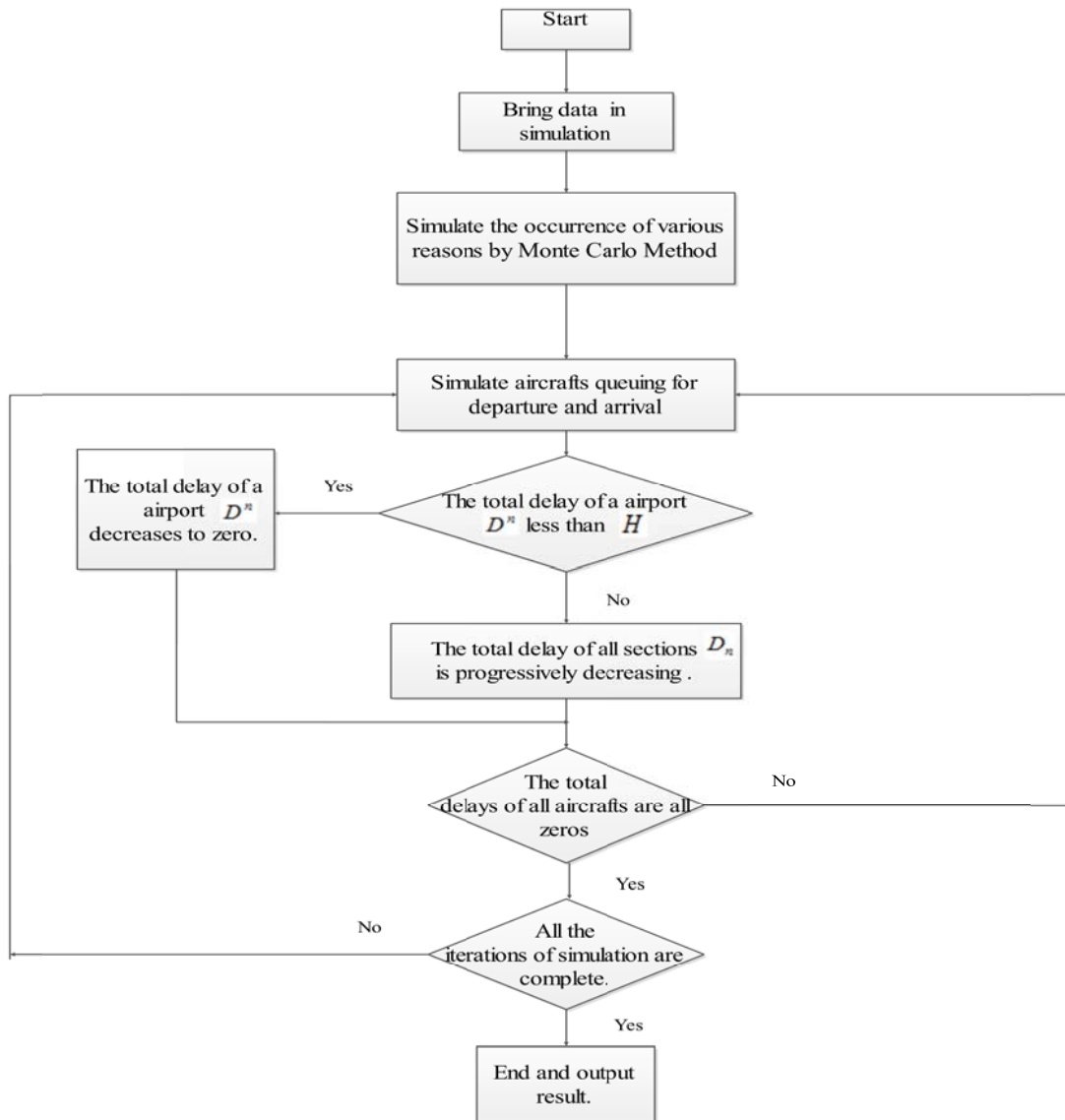
Simulation conclusion:

Table 2: Influences and Frequency of factors for flight delay

Factors	Frequency	Influence(average time)
Airline	40.96%	52.86
Other factors	6.82%	152.78
Military activity	9.52%	187.92
Weather	18.96%	50.87
Flow control	20.50%	64.72
Airport	2.54%	35.30
Passengers	0.7%	9.50

It can be seen from the results that the occurrence frequency of each factors in the simulation and that in the official statistics is close, which indicates that the simulation model is pretty successful.

Thus , occurrence frequency of some factors for flight delay are high, but the average delay time is short, that is, the frequency and delay time is not a positive correlation. Combined with the two, we use the product of frequency and delay time as an index to judge flight delay. The greater product of the two, the greater the influence of the factor for flight delay.

As : $A_i = P_i \cdot T_i$

The influences results from the simulation is: ***airline> military activity>flow control>other factors>weather> airport> passengers.***

Summary

We establish the modified dynamic 2M/M/2 queuing model, and use domestic airport data simulate by adopting the Monte Carlo Method .At last ,We obtain the macro factors, and the frequency and influence degree of various micro factors for the delay of China's flight.

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