

ANALYZING IMPACT FACTORS OF AIRPORT TAXIING DELAY BASED ON ADS-B DATA

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ABSTRACT:

Identifying the factors that cause taxiing delay on airports is a prerequisite for optimizing aircraft taxiing schemes, and helps improve the efficiency of taxiing system. Few of current studies had quantified the potential influencing factors and further investigated their intrinsic relationship. In view of these problems, this paper uses ADS-B data to calculate taxiing delay time by restoring taxiing route and identifying key status points, and further analyzes the impact factors of airport taxiing delay by investigating the relationship between delay time and environmental data such as weather, wind, visibility etc. The case study in Guangzhou Baiyun Airport validates the effectiveness of the proposed method.

1. INTRODUCTION

China's aviation industry has been experiencing a rapid development since the reform and opening-up policy. The aviation traffic is continuously increasing including both passenger and cargo traffic, and the growth rate is much higher than that for other modes of transport such as railway and road transport. Accompanied with the advancement of civil aviation industry is the rapid rise of flight delay rate. According to FlightStats, an American service provider of flight data statistics, China's flight punctuality rate dropped to 68.33% in 2015 from 82.79% in 2007. Especially in the year of 2015, China's average flight punctuality rate was the worst among Asian countries. By contrast, the punctuality rates of most Japanese airports are as high as 90%. Flight delays are divided into two types: air delay and airport taxiing delays, of which the latter one is usually a major cause of flight delays, and therefore, it is a hot research topic. Identifying the main factors that cause taxiing delay in airports is a prerequisite for optimizing aircraft taxiing schemes, and is helpful to improve the efficiency of taxiing system and further to reduce flight delay rate.

Domestic and foreign scholars have carried out a lot of research in taxiing optimization. Krozel et al. analyzed the seasonal features of departure delay, arrival delay, taxiing delay and weather related delays using various kinds of data sources such as the FAA's Aviation System Performance Metrics (Krozel et al., 2003). Markovic et al. used hybrid regression/time series modeling to analyze the relationship between total daily punctuality at Frankfurt Airport and weather, traffic flow and airport system state. They identified the terminal-specific delay impact factors and discussed the possibility of forecasting the punctuality rate within 24 hours (Markovic et al., 2008). Zhang et al. used the features of traffic demand and weather to develop a fuzzy linear regression model for airport arrival delay, and calculated the estimated delay. They found that the features of traffic demand and weather have a strong linear relationship with airport arrival delay (Zhang et al., 2010). Feng et al. used multiple sources such as

flight operation information, conventional meteorological observations, intensive observations of automatic weather observation, satellites, radars and model analysis products to study a historically rare incidence of extensive flight delays at Guangzhou Baiyun Airport and the associated process of severe convective weather (Feng et al., 2014).

Although scholars have done a lot of research on airport taxiing delays, they mainly use the flight delay statistics from airlines which cannot reflect the accurate taxiing route of aircrafts and cannot analyze the impact of spatial factors on taxiing delay, e.g. taxi route selection and parking location of aircrafts. Moreover, most of current studies focus on a qualitative analysis of the influence of potential factors (weather, visibility etc.) on airport taxiing efficiency. Few studies had quantified the potential influencing factors and further investigated their intrinsic relationship.

The popularity of global satellite positioning technology has led to the widespread use of Automatic Dependent Surveillance-Broadcast (ADS-B) in civil aviation, which is a new air traffic control technology based on GPS. ADS-B uses air-to-ground, air-to-air data link to implement traffic monitoring and information transmission (Xu et al., 2015). It can obtain the location and movement parameters of aircrafts in real time, and provide a technical basis for fine-grained analysis of taxiing process of aircrafts. This paper aims to use ADS-B data and environmental data in the same period, to establish a potential influencing factor dataset, and identify the major influencing factors and effects of taxiing delay by correlation analysis and regression analysis.

2. METHODOLOGY

The overall workflow is shown in Figure 1. On the one hand, the aircraft's taxiing route is reconstructed based on ADS-B data and airport traffic network, and then the taxiing delay time of aircrafts, spatial distribution of taxiing starting points and airport traffic flow are calculated. On the other hand, the

environmental factors related to taxiing process such as weather events, visibility, affiliated airlines etc. are collected and quantified, and then the important factors affecting taxiing

delay time and the corresponding influence effect are analyzed by correlation analysis methods.

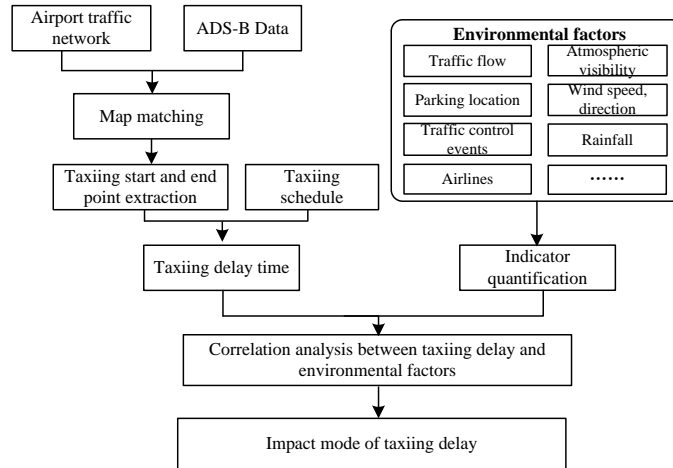


Figure 1. General workflow

Address code	Airlines	Lon.	Lat.	VSPEED	GSPEED	Altitude	Flight No.	Direction	Time
78067D	SZAir	113.3053	23.36052	-195	261	129	9C8514	13.9378	2016-9-16 00:46:39
7BB0FF	SZAir	113.2926	23.40356	-195	35	53	CA433U	14.0625	2016-10-18 13:14:50
7809BE	SZAir	113.2924	23.39616	-214	19	60	MU2301	14.0625	2016-9-14 12:32:21

Table 1. Sample ADS-B data

We chose Guangzhou Baiyun International Airport as a case study, and collected the vector map of airport traffic network including taxiway, runway, parking lots, etc., as shown in Figure 2. The ADS-B data collected from September to November 2016 were also used. Table 1 shows a sample ADS-B dataset on this airport.

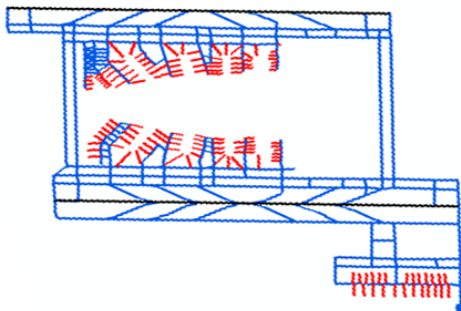


Figure 2. Traffic network of Guangzhou Baiyun Airport

In view of the characteristics of taxiway network, we proposed a map matching model based on (Zhao et al., 2012), which is composed of three matching rules: (a) Distance criteria: the distance between a target and its matching taxiway is closest; (b) direction criteria: the movement direction is closest to the direction of its matching taxiway; (c) connectivity: the matching taxiways of adjacent points are consistent. A map matching result is shown in Figure 3.

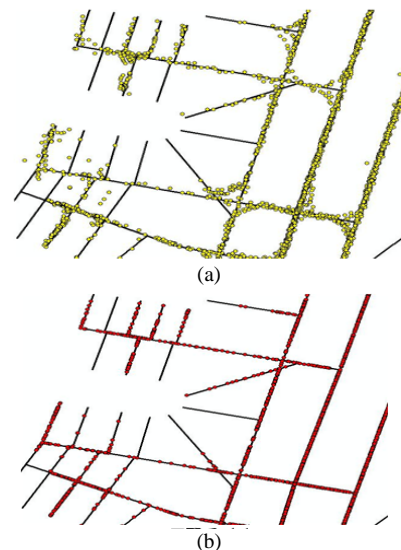


Figure 3. ADS-B data before (a) and after (b) map matching

An aircraft is in a stationary state before take-off, and then switches to the accelerated state after taxiing, and taxis on taxiways until it enters the runway. When the moving speed of aircraft reaches to a certain threshold, it begins to take off and owns a vertical speed. Therefore, for the continuous ADS-B data of any aircraft, the start and end point of taxiing process can be determined by the ground speed and vertical velocity, and the taxiing delay time is calculated.

The environment of aircraft taxiing process includes its own attributes (such as associated airlines), airport environment (traffic flow, parking position), meteorological condition (such as wind speed, wind direction, atmospheric visibility, rainfall, weather, etc.). The calculated taxiing delay time and its associated environmental factors is shown in Table 2.

According to the type of influencing factors, the factors that have important influence on taxiing delay are selected, and the influence of each factor on delay is analyzed.

Flight No.	Actual take-off time	Delay time /seconds	Lon.	Lat.	Airlines	Visibility /km	Wind direction	Wind speed	weather
3U8162	2016/9/14 13:37:09	1029	113.3075	23.38364	Sichuan Airline	10	NNW	25.2	Partly Cloudy
3U8162	2016/9/16 13:34:56	896	113.3081	23.38583	Sichuan Airline	10	North	18	Mostly Cloudy
3U8162	2016/9/26 13:38:33	1113	113.2898	23.4001	Sichuan Airline	4	WSW	7.2	Haze
3U8162	2016/9/28 13:39:23	1163	113.2867	23.38882	Sichuan Airline	8	NW	32.4	Mostly Cloudy
3U8162	2016/10/2 13:40:25	1225	113.2856	23.38466	Sichuan Airline	10	ENE	7.2	Partly Cloudy
3U8162	2016/10/3 13:33:44	824	113.308	23.38549	Sichuan Airline	10	NE	7.2	Scattered Clouds
3U8162	2016/10/5 13:31:02	662	113.3084	23.38681	Sichuan Airline	14	NE	10.8	Clear

Table 2. Taxiing delay time and associated environmental factors

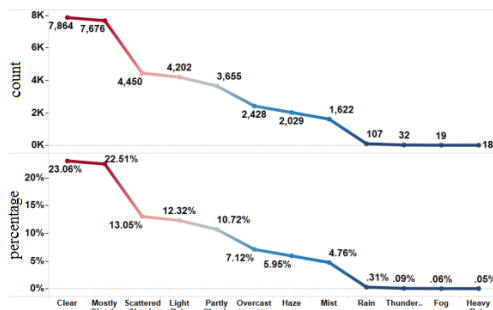


Figure 4. Occurrence percentage of different weather

Classifying cloudy, haze, thunderstorms, and precipitation as bad weather and classifying other weathers as ordinary weather. The probability of taxiing delay in bad weather is 78.78%, while that in ordinary weather is 67.39%. It can be seen from Table 3 that the proportion of taxiing delay in ordinary weather is significantly lower than that of bad weather.

Weather	Count	Percentage of occurrence	Percentage of delay
Clear	7864	23.06%	62.52%
Partly Cloudy	3655	10.72%	64.49%
Scattered Clouds	4450	13.05%	66.11%
Mostly Cloudy	7676	22.51%	66.25%
Overcast	2428	7.12%	68.48%
Mist	1622	4.76%	68.62%
Haze	2029	5.95%	68.85%
Light Rain	4202	12.32%	79.82%
Rain	107	0.31%	88.89%
Heavy Rain	18	0.05%	90.41%
Thunderstorm	32	0.09%	93.75%
Fog	19	0.06%	100.00%

Table 3. Flight taxiing delay ratio under different weather conditions

Weather

The most frequent weather in Guangzhou Baiyun Airport from September to November of September 2016 is cloudy, including mostly cloudy, Scattered Clouds, Partly Cloudy and Overcast. It occurred 12319 times and the percentage is 36.17%. The lowest frequency of weather is heavy rain, it only occurred 18 times, and its frequency is 0.05%, as shown in Figure 4.

Wind power

The maximum wind speed is 43.2km/h in Guangzhou Baiyun Airport from September to November of September 2016, and the minimum wind speed is 3.6km/h. Classifying the winds, as shown in Figure 5. The frequency of strong winds is the lowest with a frequency of 0.21%. The frequency of light air is the highest, and its frequency is 39.50%.

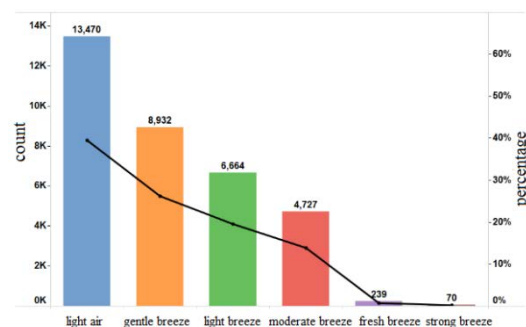


Figure 5. Occurrence percentage of different levels of wind

The effect of wind at each level on taxiing delay is not obvious as shown in Table 4.

Wind power	Count	Taxiing delay ratio
light air	6664	69.19%
Breeze	13470	68.63%
gentle breeze	8932	68.91%
moderate breeze	4727	68.44%
cool breeze	239	66.57%
Gale	70	65.71%

Table 4. Taxi delay ratio under wind power

Wind direction

The number of occurrences of each wind direction is shown in Figure 6.

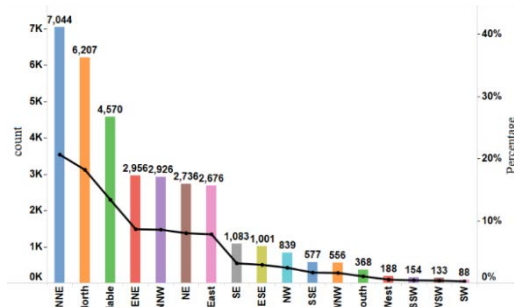


Figure 6. The number and proportion of wind direction

The three runways at Guangzhou Baiyun Airport are distributed in parallel. The wind direction that is the same as the aircraft take-off direction is defined as downwind, while the wind direction that is opposite to the take-off direction is defined as upwind. The other wind directions are defined as crosswinds as shown in Table 5. The taxiing efficiency of the upwind flight is obviously better, while that of the crosswind flights is slightly higher than that of the downwind flights.

Port	No of flights	taxiing time for downwind	taxiing time for upwind	taxiing time for crosswinds
01R-19L-01R	14422	1965.264	1871.975	1918.629
01R-19L-19L	3049	1632.763	1513.634	1534.92
02L-20R-02L	12561	1818.843	1405.966	1478.643
02L-20R-20R	2767	1610.515	1562.279	1638.323

Table 5. The average delay time of each port in different wind directions

● Visibility

The range of visibility in the study area is 0.9 to 30 km, and they are classified into five grades according to the sight distance as shown in Table 6.

level	status	Sight
1	Very poor	0-2km
2	bad	2-4km
3	medium	4-10km
4	good	10-20km
5	very good	20-30km

Table 6. Visibility levels

The taxiing delay rate increases as the visibility decreases as shown by Table 7.

level	sight	Number of flights	Number of delays	delay rate
Very poor	<2km	153	122	79.74%
bad	2km-4km	3253	2338	71.90%
medium	4km-10km	25359	17428	68.70%
good	10km-20km	3430	2225	64.90%
Very good	20km-30km	1706	1082	63.42%

Table 7. Percentage of taxiing delays under different visibilities

● Airline Company

In Guangzhou Baiyun Airport, Southern Airlines owns the largest share (42.98%) in terms of flight, and its flight taxiing delay rate is 62.77%. The airline with the lowest share (0.28%) is Malaysia Airlines, but the flight delay is as high as 98.48%. Airlines are classified according to the airline's taxi delay ratio as shown in Table 8. It can be seen that the number of flights is not a direct cause of taxiing delay. The operation efficiency of airline is probably a major factor affecting taxiing delay.

level	airline	Delay ratio
Very poor	Malaysia Airlines	98.48%
	Thai International Airways Limited	95.97%
	China International Airlines	80.26%
bad	Indonesia Eagle Airlines	82.24%
	China West Airlines	61.11%
	Limited Liability Company	62.77%
medium	China Southern Airlines	53.41%
	Chongqing Airlines	53.33%
	Zhejiang Changlong Aviation Co., Ltd	53.33%

Table 8. Taxiing delay ratio for different airlines

3. CONCLUSION

In order to obtain the quantitative impact effect of various factors on taxiing delay, this paper uses ADS-B data to calculate taxiing delay time by restoring taxiing route and identifying key status points, and further analyzes the impact factors of airport taxiing delay by investigating the relationship between delay time and environmental data such as weather, wind, visibility etc. The proposed method is applied to the Guangzhou Baiyun Airport. The experimental results validate the effectiveness of the proposed method.

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