Evaluation of Approach Runway Capacity under Medium Heavy Aircraft Combination

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Abstract. In recent years, civil air traffic has grown rapidly, however airspace resources are limited, which makes the flight delay rate increasing year by year. Through research we have found that airport runway capacity is a key factor limiting air traffic flow, and among various factors that affect runway capacity, the impact of landing aircraft occupation time on runway capacity is more obvious. After analyzing the runway occupation time of front and rear aircraft combination of common airport types, we find that the runway occupation time has a very obvious effect on runway capacity when the middle aircraft is the front aircraft. This paper mainly analyzes the effect of two continuous landing aircraft occupying the runway time on runway capacity when the middle type non aircraft is the front aircraft. Under the specified interval standard, the approach runway capacity mathematical model is constructed, and the actual data of different types of landing aircraft in a certain period of time at Chengdu Shuangliu Airport are used for simulation calculation, Runway capacity predicted using runway occupancy time is compared to runway capacity at fixed distance intervals. The results show that the runway capacity can be greatly improved by analyzing the runway occupancy time when the medium aircraft is the front aircraft, with high research value.

Keywords: Runway Capacity; Combination of Aircraft Types; Runway Occupation Time; Modeling Simulation

1 Introduction

Since entering the 21st century, with the rapid growth of the world economy and the rapid growth of civil aviation transport volume, the pressure of air traffic management is increasing. Runway capacity has become an important factor limiting the growth of civil aviation traffic, particularly in the final stages of flight. Until then, countries around the world have increased airport capacity primarily through new airports and the addition of runways and taxiways, but in the long term, this approach is expensive, covers a large area, and has a long cycle, and cannot fundamentally solve the problem

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of traffic flow. In addition, new airports or additional runways can only solve flight congestion in the short term, and cannot radically increase airport capacity.

The study of runway time occupation by foreign scholars started early, in the 1980s, there have been some achievements. Barrer et al. collected runway occupancy times at several large airports using tower digital clock recordings in 1984, comparing the runway occupancy times of the same aircraft at different airports to find differences, but the data were collected by naked eye observation, and were not accurate in timing aircraft overflying runway inlets as well as completely exiting the runway, providing only a theoretical basis [1]. Kim et al. have estimated the trajectory of the aircraft's landing roll through simulation algorithms and in-situ observations, and used it to predict the aircraft's landing performance and runway occupancy [2]. Martinez et al. used simulation techniques to model runway occupancy times and performed simulation verification [3].

Research on Statistical Model of Landing Aircraft Runway Occupation Time by Jin Jing et al. uses the method of function fitting to establish the characteristic curve of landing roll under specific meteorological conditions using the speed time statistical data of Boeing 737's landing roll to achieve the prediction of aircraft landing runway occupation time. The availability of this method is verified by simulation, providing a basis for controllers to judge takeoff interval [4]. In his Study of Landing and Takeoff Aircraft Position and Time, Tian Dongshan proposed that runway utilization has the greatest impact on airport capacity, and that runways are the easiest to form a bottleneck, affecting the operational capability of the entire airport [5]. Li Zhennan and Zhao Yi combed out the problems in the design of service lanes in "Reflections on Key Design Points of Airport Airside Service Lane", proposed the design key points of airport Airside Service Lane, improved the service lane operation efficiency, guaranteed the operation safety, and better served the airport ground and airport passengers [6]. Pan Weijun et al.'s "Runway Occupation Time Forecasting Based on Artificial Nerve Network" proposed a BP (back propagation network, BP) based method for predicting runway occupancy time of airport arrival flights, and proved its accuracy in predicting runway occupancy time [7].

By analyzing the effect of runway occupation time on the combination of medium and heavy aircraft types, and comparing the methods of adjusting landing aircraft with fixed time interval, the analysis results show that applying runway occupation time to aircraft landing can greatly increase runway capacity.

2 Runway Occupation Time Contributing Factors

2.1 Aircraft Wake Rating

According to the maximum takeoff weight of the aircraft, we can divide the aircraft into three categories: light, medium and heavy, with different types of aircraft having different runway occupancy times. Table 1 below shows the samples collected over a period of time, presenting the average runway occupancy time for different types of aircraft.

Table 1. Average Runway Occupation Time for Different Aircraft Types

Model	No./set	Average runway occupancy time/s	Minimum/s	Max/s
A320	7284	58.78	52	73
ARJ21	259	58.46	52	73
B737	2156	58.82	52	73
total	9699	58.78	52	73

By comparing the runway occupation times for these three categories of aircraft, we can see that there are significant differences in runway occupation times for different types of aircraft, the higher the wake rating, the longer it takes to slow down for a roll, and the longer it takes to occupy the runway [8]-[10].

2.2 Model

Of the three types, the number of midplanes is far higher than the other two, so we cite three midplanes to analyze the impact of runway occupancy time for the type, as shown in Table 2 below.

Table 2. Average Runway Occupation Time by Type

Model	No./set	Average runway occupancy time/s	Minimum/s	Max/s
Light aircraft	2154	47.52	43	64
medium-size	9247	58.63	52	73
Heavy aircraft	3256	69.25	60	85
total	14657	59.35	43	85

By comparing the three types above, as shown in Figure 1 below, we find that the runway occupation times for different aircraft of the same type vary little.

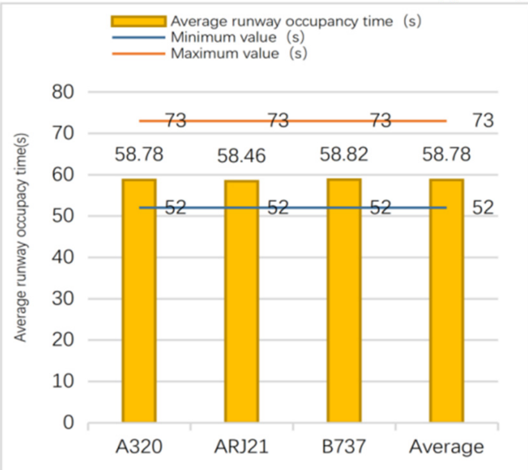

Fig. 1. Average Runway Occupation Time by Type

In addition, the runway occupation time is also affected by the runway configuration, the position of rapid de runway and the approach speed of landing aircraft. this paper mainly analyzes the influence of the front and rear models, so other factors are not analyzed too much.

3 Dynamic Approach Runway Capacity Model

Runway capacity is the maximum number of gear that an airport runway can take off and land an aircraft in a unit time with uninterrupted operations and without violating air traffic control rules [11]. We use ε for the runway maximum capacity, $E(t)$ for the average service time of the runway, $P_{\alpha\beta}$ for the probability that a β aircraft will follow an α aircraft, $T_{\alpha\beta}$ for the time interval between two aircraft landing on the runway when a β aircraft follows an α aircraft, Expressed the proportion of α aircraft in P_{α} and β aircraft in P_{β}. A dynamic approach runway capacity model was constructed as follows:

$$\varepsilon = \frac{1}{E(t)} \tag{1}$$

$$E(t) = \sum_{\alpha=1}^{n} \sum_{\beta=1}^{n} P_{\alpha\beta} T_{\alpha\beta} \tag{2}$$

$$P_{\alpha\beta} = P_{\alpha} P_{\beta} \tag{3}$$

When two aircraft approach continuously, with the front aircraft at m and the rear aircraft at n, the maximum of the runway occupation time of the front aircraft and the minimum air separation standard between the two aircraft is its actual time interval, which we denote with T_{mn}, we denote with t_m the runway occupation time of the front aircraft m, and with t_{mn} the time interval between successive approaches of the I aircraft and the J aircraft fore and aft. As shown above, we can get the following formula:

$$T_{mn} = Max[t_m, t_{mn}] \tag{4}$$

As this article we mainly consider the front aircraft for the medium aircraft, the rear aircraft for heavy aircraft such as such, then the speed of the front aircraft is accordingly greater than the rear aircraft. When the approach speed v_m of the front aircraft is greater than the approach speed v_n of the rear aircraft, we denote the standard deviation of the aircraft m from n continuous landing runway occupation time as δ_{mn}, then the time interval t_{mn} of successive approaches before and after the two aircraft can be represented by the following formula:

$$t_{mn} = \frac{\delta_{mn}}{v_n} \tag{5}$$

In order to avoid aircraft collisions as much as possible during actual operations, we also take into account the controller's reaction time versus the pilot's operational error, and add a buffer time, which we denote with B_{mn}, and additionally with q for the probability of no runway conflict occurring, we can get the following formula:

$$B_{mn} = \delta_{mn} q \tag{6}$$

A weighted sum of all time intervals for all aircraft arriving continuously gives the average time of service $E[T_{mn}]$ for the runway, which can be calculated using the following formula:

$$E[T_{mn}] = \sum_{m=1} \sum_{n=1} P_{\alpha\beta} [T_{mn} + B_{mn}] \tag{7}$$

From the above formula, the expression for dynamic runway capacity is:

$$\varepsilon = \frac{1}{E[T_{mn}]} \tag{8}$$

4 Model Simulation Validation

The final approach parameters for the two common types of aircraft with the medium aircraft at the front and heavy aircraft at the rear are shown in Table 3 below.

Table 3. Medium Heavy Combined Speed parameters

Model	Approach speed	Scale (%)	Approach speed	Scale (%)	Approach speed	Scale (%)
A319	120	5	125	5	130	5
A320	130	5	135	7	140	5
A321	135	5	140	4	145	5
B737	125	1	130	2	135	1
B738	135	1	140	2	145	1
A330	140	7	145	15	150	7
B787	145	5	150	8	155	5

By studying the relevant data, we can obtain a set of predicted values for the average time spent on runways by different aircraft types at different departures, as shown in Table 4 below.

Table 4. Runway Occupation Time Forecast Mean and Scale of Runways

Model	Departure Channel 1		Departure Channel 2		Departure Way 3	
	Runway occupancy time average (seconds)	Scale (%)	Runway occupancy time average (seconds)	Scale (%)	Runway occupancy time average (seconds)	Scale (%)
A319	58.42	8.32	67.42	14.75	77.39	1.23
A320	58.34	11.87	67.48	18.96	77.29	1.76
A321	58.58	12.65	67.84	15.73	77.63	0.34
B737	57.85	1.65	65.83	4.94	74.93	0.64
B738	57.64	1.85	66.28	5.84	75.38	0.58

By comparing big data, we can get a map of the distribution of runway occupation times for successive approach landings by different types of aircraft type combinations, as shown in Figure 2 below.

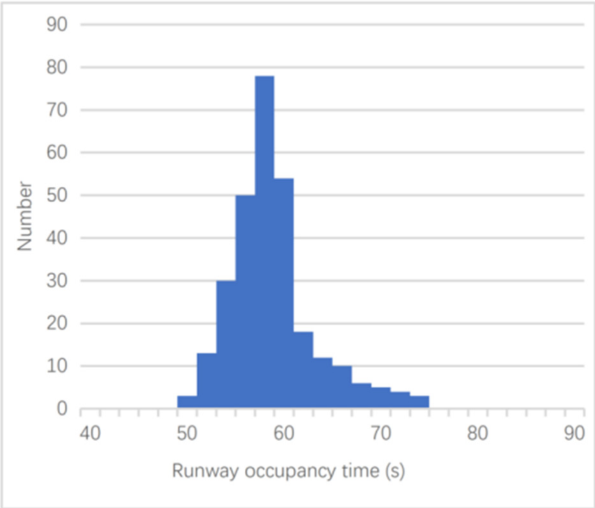

Fig. 2. Recombination Runway Capacity Forecast

From the model we built in the previous section and the data related above, we can obtain the runway capacity calculated based on the dynamic interval of runway occupancy time and the runway capacity using a fixed distance interval, respectively, and express the two sets of data in the following broken line chart over a period of time, comparing the difference in runway capacity between the two, as shown in Figure 3 below.

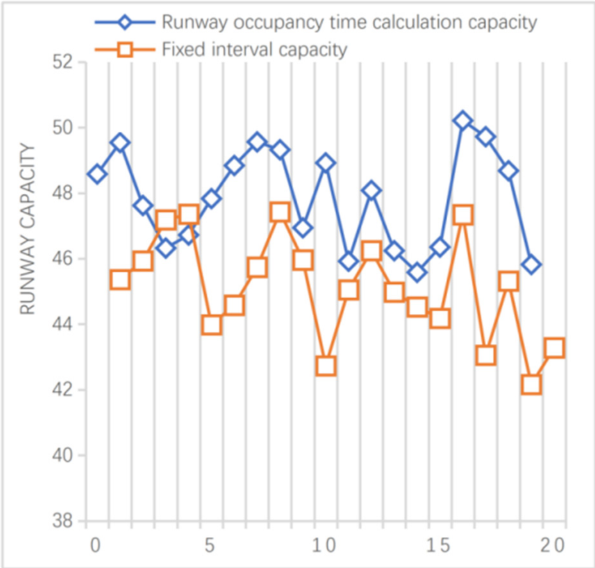

Fig. 3. Heavy runway capacity comparison

As can be seen from the broken line chart above, the maximum runway capacity calculated by runway occupancy time is 50.21 sorties/h, and the maximum runway capacity calculated by fixed interval is 47.43 sorties/h. Thus it can be seen that under the medium heavy aircraft combination, the runway capacity calculated using runway occupation time is nearly 3 sorties/h more than using a fixed interval. Comparison shows that, for continuous approach aircraft, analysis of runway occupancy time under a certain combination of front and rear aircraft types can greatly increase runway capacity, with an expected increase of 5 percentage points.

5 Conclusion and outlook

In this paper, the runway capacity model of dynamic approach runway is established by analyzing the runway capacity of medium - heavy combined aircraft type, and is verified by simulation based on a great deal of data obtained. By comparing the runway capacity under the runway occupancy time with that under the fixed distance interval, we find that the runway occupancy time adjustment can greatly increase the airport runway capacity, with high research value and significance. A deep study of runway occupancy time will lead to a substantial increase in airport runway capacity, which has profound implications for easing the pressure of air traffic management and making better use of airspace resources.

However, the article has many shortcomings. Due to the time relationship, the type combination studied is relatively single, only considering the case of the medium aircraft in front and the heavy aircraft in the rear, without analysis of several other type combinations. In addition, in modeling and simulation, the depth of this study is not enough, the follow-up will also be based on different types of combination of more in-depth research and analysis.

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