Study on Capacity Improvement of Close Range Dual Runway of Shuangliu Airport under New Wake Classification Standard (RECAT)

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Abstract. With the increasing number of flights, the gap between the front and rear aircrafts is gradually reduced. The wake separation becomes one of the important factors restricting the reduction of aircraft separation, which results in the runway occupation time can not be further reduced, and the runway capacity is also restricted to a certain extent. In recent years, the wake reclassification (Recat) promoted by FAA has been applied to runway capacity the increase has played a positive role.

In this paper, the capacity of Chengdu Shuangliu International Airport is studied, and the capacity models of approach runway and departure runway are established respectively. According to the relevant characteristics of Chengdu Shuangliu International Airport, the runway capacity model under one landing operation mode is established, and the runway capacity is calculated by using MATLAB software with reference to the new American wake classification standard (Recat). Finally, it is concluded that under the condition of introducing Recat, the capacity of Chengdu Shuangliu International Airport can be increased by 12.3% in theory.

1. Analysis and Processing of Runway Operation Data in Shuangliu Airport

At present, one runway (02R or 20L) is dedicated to take-off and departure, and one runway (02L or 20R) is dedicated to approach and land at Shuangliu Airport. Among them, the length from the final approach positioning point of 20R end to the runway threshold is 12 km, and the length of the glide slope of 02L is 10.9 km. Due to the prevailing northerly wind in Chengdu all year round, according to the principle of aircraft taking off and landing against the wind, the aircrafts in Chengdu usually approach and land at the end of runway 20R and take off at runway 02L. The time of approach aircraft from main wheel grounding, taxiing stop and leaving runway is about 50 seconds (i.e. the runway occupation time is 50 seconds); the time for departure aircraft to enter the runway to align the runway is about 60 seconds to 90 seconds; the takeoff run time is about 60 seconds; the initial climbing altitude of the takeoff aircraft is 1200 meters of corrected sea level pressure. The final approach speed (downwind) of the aircraft is about 270-310 km / h and 210-250 km / h in headwind. The initial climbing speed of aircraft leaving the port is about 380 km / h for light and medium-sized aircraft and 350 km/h for heavy-duty aircraft[1].

The object of this paper is the aircraft flying with instruments. Therefore, in order to simplify the model, idealization is required. That is, when the aircraft distance is greater than or equal to 8km, the departure aircraft in front can be arranged to take off; when the aircraft distance is less than 8km, the departure aircraft can not enter the runway to take off.

In order to calculate the probability of aircraft light, medium and heavy aircraft. This paper intercepts the real-time situation of Chengdu Shuangliu International Airport during the peak period of
spring transportation (unit hour) for one week. [2] Details are shown in Table 1. The line chart is shown in Figure 1.

**Table 1.** Statistics of aircraft landing sorties

| time          | All sorties in the same period of the day | Heavy landing | Medium landing | Light landing |
|---------------|------------------------------------------|---------------|----------------|---------------|
| January 11th  | 38                                       | 1             | 37             | 0             |
| January 12th  | 39                                       | 2             | 37             | 0             |
| January 13th  | 38                                       | 0             | 38             | 0             |
| January 14th  | 40                                       | 2             | 37             | 1             |
| January 15th  | 41                                       | 3             | 37             | 1             |
| January 16th  | 40                                       | 2             | 38             | 0             |
| January 17th  | 39                                       | 0             | 39             | 0             |

**Figure 1.** Sublinear diagram of aircraft landing gear  
**Figure 2.** Proportion of aircraft types

According to the above chart data information, it can be analyzed that in Chengdu, medium-sized aircraft are the main ones, a small part are heavy-duty aircraft, and there is almost no light aircraft taking off and landing. The visualization processing of the proportion of aircraft is shown in Figure 2.

2. Practical Calculation of Capacity Model based on Current Standard of Wake Separation

The calculation of this model will have the following provisions: all aircrafts approach and land from runway 20R and take off from runway 02L. Airport related facilities and equipment (such as lighting system, communication, navigation and monitoring, etc.) are in normal condition; the weather meets the minimum standards for the instrument take-off and landing of aircraft in Chengdu; the staff of all departments work in accordance with the corresponding regulations and operate normally; there is no special danger; the wake interval is based on the current standard of wake separation in China\(^3\).

2.1. Actual Operation of Capacity Model

According to the airport capacity model, substituting the data, the results of 7 operations are listed below, as shown in Table 2.

**Table 2.** Results of mobilization capacity

| frequency | 1     | 2     | 3     | 4     | 5     | 6     | 7     |
|-----------|-------|-------|-------|-------|-------|-------|-------|
| Mobilization capacity(CA) | 23.7  | 22.3  | 19.8  | 23.0  | 21.8  | 23.9  | 23.7  |

2.2. Practical Calculation of Departure Capacity Model

After taking off, the departing aircraft of Chengdu Shuangliu Airport will fly to the corresponding waypoint according to the corresponding procedures. In general, the approach is handed over when the aircraft reaches the corrected sea level pressure of 1200 m. Previously, it was assumed that the aircraft
was flying along a common take-off path. Since the aircraft climbs at an altitude of about 600 m / min and the initial climbing speed of the aircraft is about 380 km / h (about 350 km / h for heavy vehicles), the estimated public takeoff length of the departing aircraft is about 12 km. The results of seven consecutive runs are listed below, as shown in Table 3.

| Table 3. Results of departure capacity |
|---------------------------------------|
| frequency | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| Departure capacity(CD) | 31.2 | 31.2 | 30.2 | 27.5 | 30.5 | 33.9 | 31.7 |

2.3. Practical Operation of Alternate Takeoff and Landing Capacity Model

The results of seven consecutive runs are listed below, as shown in Table 4.

| Table 4. Alternate takeoff and landing capacity results |
|--------------------------------------------------------|
| frequency | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| Alternate takeoff and landing capacity(CAD) | 38.0 | 36.8 | 38.1 | 34.8 | 34.5 | 39.6 | 42.1 |

2.4. Practical Calculation of Capacity Model of Isolated Operation Close Range Runway Based on Improved Model

Some studies have shown that, when $N^* = 1$, $q = 0.5$, That is to say, the capacity of runway system is the largest, that is, the operation management of inserting one departure aircraft between two approaching aircrafts is adopted[4].

The results of seven consecutive runs are listed below, as shown in Table 5.

| Table 5. Calculation results of improved capacity model of isolated operation close range runway |
|------------------------------------------------------------------------------------------------|
| frequency | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| Runway capacity(COAOD) | 44.0 | 43.8 | 43.3 | 40.7 | 39.1 | 45.9 | 45.4 |

Through simple data processing of the above operation results, the average calculation results under the traditional wake interval standard are obtained

(1) Runway approach capacity CA: 22.6 sorties per hour
(2) Runway departure capacity CD: 30.9 sorties per hour
(3) CAD of runway capacity under alternate takeoff and landing: 37.7 sorties per hour
(4) Improved coaod of close range dual runway capacity: 43.2 sorties per hour

It is learned from Chengdu tower that the current maximum capacity of Huanghua Airport is 41 sorties per hour. According to the above calculation results of runway capacity of Chengdu Shuangliu International Airport. The calculation results are close to the actual results of the current operation, which is in line with the facts. Therefore, the above four capacity calculation models can be used in practice[5].

3. Operation Analysis of Capacity Model based on Recat

This paper has made a detailed introduction to the new standard of wake separation, recat. The following is a list of all takeoff and landing aircraft and their numbers during the peak hour (one hour) of Chengdu airport for three consecutive days, as shown in Table 6.
Table 6. Statistics of aircraft types

| Model date | B747 | A330 | B737 | A321 | A320 | A319 | New boat |
|------------|------|------|------|------|------|------|----------|
| March 1st  | 1    | 1    | 22   | 4    | 16   | 0    | 0        |
| March 2nd  | 0    | 1    | 17   | 1    | 17   | 2    | 0        |
| March 3rd  | 2    | 0    | 24   | 2    | 9    | 0    | 1        |

According to the actual number of aircraft, combined with the new standard of wake classification, the above are classified into 6 categories, as shown in Table 7 and Figure 3.

Figure 3. Linear graph of aircraft type

Table 7. Statistics of landing sorties of aircraft types

|       | A | B | C | D | E | F |
|-------|---|---|---|---|---|---|
| March 1st | 0 | 2 | 0 | 42 | 0 | 0 |
| March 2nd  | 0 | 1 | 0 | 37 | 0 | 0 |
| March 3rd  | 0 | 2 | 0 | 35 | 1 | 0 |

Actual calculation of runway capacity based on recat
Before the actual calculation, there are the following provisions:

1. The calculation of this model is a rough calculation, which only provides reference for the capacity results under the operation standard.
2. This model is an ideal model. All aircrafts land on runway 36R and take off from runway 02L.
3. In order to ensure the accuracy of the data as much as possible, this model only changes the standard of wake classification interval, and the rest data are consistent with the calculation in the previous chapter.
4. The wake separation is based on the new wake classification standard Recat.
5. Other conditions (including weather, facilities and equipment, personnel operation, etc.) remain normal and have no impact on the calculation results[6].

Through MATLAB programming calculation, the results of continuous operation for 7 times are shown in Table 8.
Table 8. Calculation results of capacity under recat (capacity unit / sortie)

|       | first | second | third | fourth | fifth | sixth | seventh |
|-------|-------|--------|-------|--------|-------|-------|---------|
| CA    | 24.9  | 26.9   | 24.5  | 25.3   | 28.1  | 24.7  | 25.6    |
| CD    | 35.1  | 38.1   | 32.6  | 31.6   | 35.9  | 31.2  | 31.4    |
| CAD   | 45.6  | 49.0   | 38.5  | 47.9   | 50.8  | 44.3  | 45.1    |
| COAOD | 46.8  | 51.2   | 45.5  | 48.8   | 52.3  | 47.1  | 47.5    |

The average operation results under the new standard of wake separation (recat) are obtained by data processing:

1. Runway approach capacity CA: 25.7 sorties per hour.
2. Runway departure capacity CD: 33.7 sorties per hour.
3. CAD of runway capacity under alternate takeoff and landing: 45.9 sorties per hour.
4. The improved coaod of close range dual runway capacity is 48.5 sorties per hour.

Comparative analysis of current wake separation standard and Recat capacity results

Through the actual calculation of the first two sections, the runway capacity of Chengdu Shuangliu International Airport under the current standard of wake separation and the new standard of wake separation (Recat) are finally obtained[7]. The detailed comparison is shown in Figure 4.

![Figure 4. Capacity comparison line chart](image)

Through the capacity comparison line chart, it can be clearly seen that the runway capacity calculated under the new standard of wake separation (Recat) is greater than that under the traditional wake separation standard, whether using the approach capacity model, departure capacity model, alternate take-off and landing capacity model and the improved close range runway capacity model. It can be concluded that compared with the traditional wake separation, the new standard of wake separation (Recat) can increase the runway capacity of Chengdu Shuangliu International Airport to a certain extent, so as to improve the operational efficiency of Chengdu Shuangliu Airport. The specific capacity improvement rate is shown in Table 9.
Table 9. Reference for capacity improvement

| Traditional wake separation | New standard for wake separation | Capacity improvement rate |
|-----------------------------|----------------------------------|--------------------------|
| CA                          | 22.6                             | 25.7                     | 13.7%                    |
| CD                          | 30.9                             | 33.7                     | 9.1%                     |
| CAD                         | 37.7                             | 45.9                     | 21.7%                    |
| COAOD                       | 43.2                             | 48.5                     | 12.3%                    |

4. Summary
This paper verifies whether the new standard of wake separation (Recat) can improve the runway capacity of Chengdu Shuangliu International Airport. Combined with the operation rules and schemes of Chengdu airport, four mathematical models are constructed from easy to difficult (i.e. approach capacity model, departure capacity model, alternate take-off and landing capacity model and improved one down capacity model). These four models are simple and easy to operate. And they represent one case respectively, which can comprehensively analyze and calculate the relevant capacity of Chengdu local close range double runway. This paper first calculates the runway capacity under the traditional wake interval by MATLAB, and then calculates the runway capacity under the new standard of wake spacing (Recat) by using the control variable method. Finally, by comparing the calculation results of runway capacity one by one, it is verified that the new standard of wake separation (Recat) can improve the runway capacity of Chengdu Shuangliu International Airport. Among them, the capacity of approach runway is increased by 14.4%, the capacity of departure runway is increased by 8.2%, and the total capacity of runway is increased by 9.5%. The new standard of wake classification can improve the operation efficiency of Chengdu airport, and provide certain practical reference value for the future optimization operation mode of Chengdu Shuangliu Airport.

5. Reference
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