Study on the Configuration and Capacity of the Lateral Runway Based on the Airport Green Operation

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Abstract. Airport as an important transportation infrastructure, its efficient operation, energy saving and emission reduction are of great significance for the sustainable development of the city. The planning of the lateral runway is gradually being applied in the construction of large airports. First, the different utilization modes of the lateral runway and adjacent parallel runway were analyzed. After which four operational correlations and intervals were discussed, i.e.: independent operation, take-off & take-off dependent operation, take-off & landing dependent operation and fully dependent operation. Taking Chengdu new airport as an example, the airfield simulation models were established to evaluate the efficiency of the lateral runway. The simulation result suggests: A group of longitudinal and transverse runways can meet the hourly take-off and landing movements of about 75-77 in the case of independent operation. The take-off & landing dependent operation has relatively large impact on capacity. Under the conditions of fully dependent operation, the hourly movements are only 65, lower by about 16%, 10% and 6% compared with other three modes.

1. Introduction

The continuous growth of social economy drives China air transport on the fast-growing track, during which China civil aviation has become the second largest air transport system in the world. The growing demand for air transport leads to the increasing scale of airport system in a response to the higher requirement. As an important transportation infrastructure, the airport is of great significance to the sustainable development of the city. To build a green airport, we should reduce the impact on the environment while utilizing the resources at the same time; realize the harmony between man and nature, development and environment. However, the key to achieving green airport is the airport green operation, that is, to improve the efficiency of the airport ground operation, reasonable planning runway configuration to enhance the airport capacity.

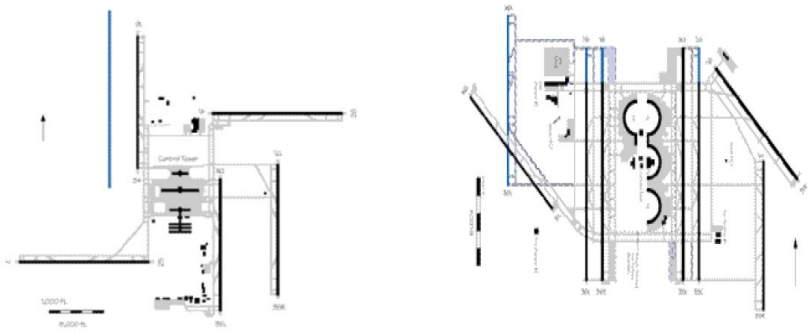
In conventional airport planning and design, parallel runway configuration is usually the first choice for large airports planning multi-runway system. But too many parallel runways will reduce the efficiency of the ground operation, bypass taxiways and runway-crossing taxiways are to be planned as support. Considering the factors such as airspace, terrain, noise and terminal layout, the lateral runway has been applied in new airports, such as Beijing New Airport and Chengdu New Airport. Therefore, it is of great significance to research the capacity of airport multi-runways system, particularly of the lateral runway and adjacent parallel runway (LR&APR) system, which will be used to instruct the construction of China airports in the future.

Three methods are usually employed to evaluate the capacity and operational efficiency of airport runways, i.e.: statistical data analysis, mathematical analysis and computer simulation. (1) Statistical data analysis is used to estimate the airport capacity based on the capacity envelope diagram drawn against the statistical flow data of existing airports, a model usually performed in the early stage of capacity analysis, but the disadvantage is that it can only evaluate the capacity of existing airport runways system[1]. (2) Mathematical analysis is used to obtain the capacity of runways by establishing the mathematical equation set of airport and airspace operational parameters through the appropriate hypothesis, which is mainly used for macro-level capacity evaluation [2,3]. (3) Computer simulation is an alternative in the most extensive application to evaluate the airport capacity and operational efficiency, which turns out the capacity level and efficiency index through the analysis of simulated operational data [4-6]. Simmod (Airport and Airspace Simulation Model) and TAAM (Total Airspace & Airport Modeller) are the most popular simulation software for the evaluation of airport capacity [7,8].

However, the existing airport capacity studies mostly focus on single runway or parallel runway configurations, lacking in-depth analysis of lateral runway operation mode and capacity. This paper will present in-depth study on the use patterns and operating efficiency of LR&APR. The simulation model of the runway was established by using Simmod software. Efficiencies of two runway operation modes based on different operation intervals, namely take-off & landing isolated operation and mixed operation, were considered separately. Then, evaluations on runway capacity were given, by which theoretical references was provided for the planning and construction of lateral runways.

2. Application of lateral runway

The lateral runway is relative to the main parallel runways of the airport. A lateral runway is normally located on one side of the parallel runway, with their center line extensions intersecting. In the US, runway configurations of Denver International Airport and Dallas International Airport are parallel runways + lateral runways, as shown in Figure 1.



Denver International Airport Dallas International Airport

Figure 1. Airport with lateral runway in the US.

Multi-runway configurations of China's existing airports are parallel runways. Beijing and Chengdu are both planning the construction of a new airport that equipped with lateral runways. The runway configuration in current construction program is shown in Figure 2. Beijing new airport is planned to build four runways (N1, E1, W1 and W2). Chengdu new airport is planned to build three (N1, E1, W1).

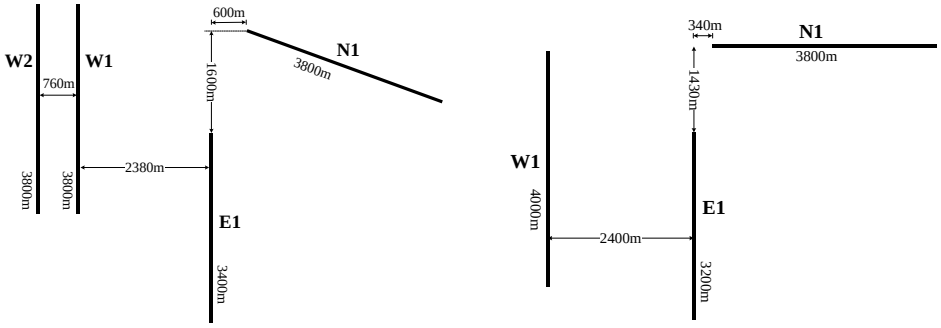


Figure 2. Airport with lateral runway in China.

Taking Chengdu new airport as an example, when a group of parallel + lateral runways runs northward from the airport, there are mainly two modes of operation: (1) isolated operation, N1 for take-off, and E1 for landing; (2) Semi-mixed operation, N1 for take-off, E1 mainly used for landing and auxiliary take-off. When the airport is operating southward, the runway use pattern is similar.

3. Operational Correlations and Intervals

As to the correlations between lateral runway and adjacent parallel runway, as well as the requirements on operational intervals, there is no clear stipulation given by the International Civil Aviation Organization (ICAO) or the Civil Aviation Administration of China (CAAC) [9]. Therefore, according to different runway operation modes, this paper analyses four operational correlations and take-off & landing intervals.

(1) Independent operation (IO). The aircraft taking off on the lateral runway (N1) does not interfere with the aircraft taking off or landing on the parallel runway (E1), taking no account of the take-off & landing coordination.

(2) Take-off & take-off dependent operation (TTDO). The aircraft taking off on the lateral runway (N1) runs in relation to the aircraft taking off on parallel runway (E1). Suppose that the departure protection area (DPA) boundary of runway E1 and the center line of runway N1 intersect in the point A, on runway E1 a flight flies over point A with t_z seconds, and a take-off flight on runway N1 taxies to point A with t_h seconds. Then, the departure clearance of a flight on runway E1 is t_h seconds after the take-off flight on runway N1 starting to taxi; departure clearance of a flight on runway N1 is t_z seconds after the take-off flight on runway E1 starting to taxi.

(3) Take-off & landing dependent operation (TLDO). The aircraft taking off from the lateral runway (N1) runs in relation to the aircraft landing on the parallel runway (E1). This mode takes into account mainly the impact of the runway E1 touch-and-go flights on the N1 departure flights. Draw a circle arc with the runway threshold of N1 as center and 3Nm as radius. The arc intersects with the extension of runway E1 at point C, as shown in the Figure 3. The distance between end of runway E1 and point C is d_c. Suppose that the miss-approach plane boundary of a landing flight on runway E1 and center line of runway N1 intersect at point B, and that take-off flights on runway N1 taxi to B point in t_m seconds. The duration from pilot hearing the take-off command to the aircraft starting to taxi is t_n seconds. The distance of an approach flight on runway E1 flies within t_m+t_n seconds is d_y. Then, the release time of take-off flight on runway N1 must meet the condition: landing flight on runway E1 having a distance from the runway end greater than d_c+d_y.

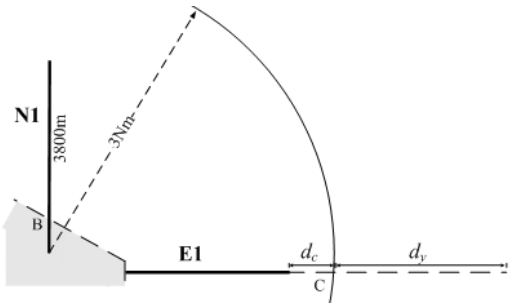


Figure 3. Take-off & landing dependent operation intervals.

（4）Fully dependent operation (FDO). The operational interval standards in (2) and (3) above are applicable for aircraft take-off on the lateral runway (N1) and those take-off or landing on parallel runways (E1).

4. Simulation modeling

This paper operates Simmod plus 7.6 to make a simulation analysis of the operational efficiency in different operational patterns of LR&APR. Simmod, one dynamic and comprehensive airport simulation micro-software firstly proposed by FAA in 1978, through the continuous upgrading and perfection, has become one of the most applied airport and airspace simulation software [7,8].

Given that this paper focally analyses the capacity and efficiency of airport runways system, the simulation modelling will put aside the restrictive factors of airspace. Airfield layout is given with Chengdu new airport as a reference, runway use modes are considered in two situations: (1) E1-N1 isolated operation, (2) E1-N1 semi-mixed operation. The take-off & landing proportion is allocation as shown in Figure 4. On this basis, simulation models are established for four kinds of operational correlations and take-off & landing intervals.

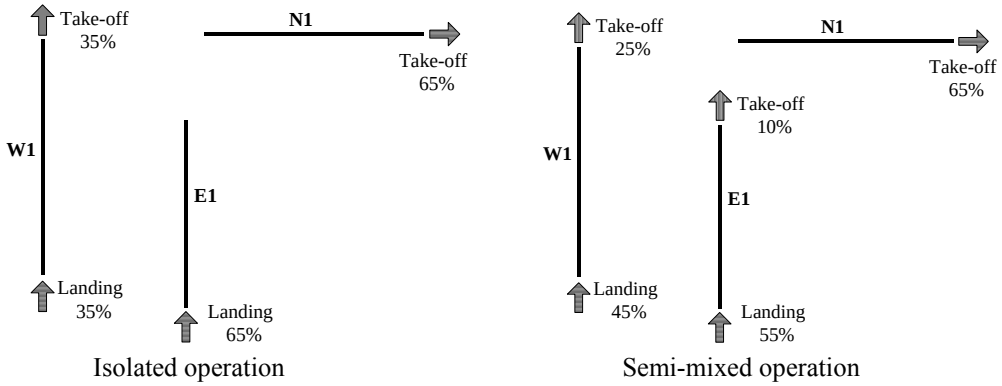


Figure 4. Runway operation modes.

Landing interval is controlled mainly based on wake vortex separation, as shown in Table 1. In addition, extra safe redundancy is taken into account. According to differences between aircrafts, departure separation of each runway is arranged at 90~130 seconds. When one single runway is in alternate operation and distance from landing flight to runway is less than 8km, departure flights are forbidden to taxi out from waiting point. This paper assumes that the ratio of heavy and middle aircraft is p_h=18%, p_m=82%, respectively.

Table 1. Wake vortex separation of landing flights.

Latter aircraft	Former aircraft		
	A380	Heavy	Medium

A380	8km	6km	6km
Heavy	12km	8km	6km
Medium	13km	10km	6km

For operation of N1 and E1, t_h=25 seconds，t_z=70 seconds，d_c+d_y=4.63km (2.5Nm).Taking the airfield model, under northward operation, as example, the simulated operation demonstration is shown in Figure 5.

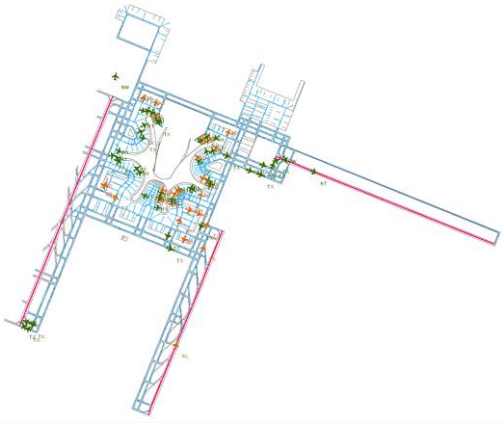


Figure 5. Airfield simulated operation demonstration.

5. Simulation results and analyses

Under the conditions of E1-N1 isolated or semi-mixed operations, four correlations and intervals are discussed, i.e.: IO, TTDO, TLDO and FDO. The peak hour take-off and landing capacity of the lateral runway and adjacent parallel runway are shown in Table 2.

Table 2. Peak hour take-off and landing capacity.

Simulation model number	Runway operation mode	Operational correlations	Take-off flights	Landing flights	Total movements
1	Isolated	IO	40	35	75
2	Isolated	TLDO	34	33	67
3	Semi-mixed	IO	48	29	77
4	Semi-mixed	TTDO	39	33	72
5	Semi-mixed	TLDO	43	26	69
6	Semi-mixed	FDO	36	29	65

In the case of IO, the semi-mixed mode, compared to the isolated mode, is more superior by about 3% in flight movements. In the semi-mixed operation mode, the FDO is with the lowest capacity, hourly movements are only 65, lower by about 16%, 10% and 6% compared with the other three modes.

Movements of LR&APR, under above mentioned use patterns, are as shown in Table 3 and Figure 6. In the case of semi-mixed operation mode, TTDO has the highest impact on the runway E1 take-off flights, with the take-off flights only 13% of IO; TLDO has the biggest impact on the take-off flights on runway N1, compared to IO, take-off flights decreased by about 10%.

Table 3. LR&APR peak hour take-off and landing flights.

Simulation model number	Runway operation mode	Operational correlations	E1 movements		N1 movements
			Landing	Take-off	Take-off
1	Isolated	IO	35	0	40
2	Isolated	TLDO	33	0	34
3	Semi-mixed	IO	29	8	40

4	Semi-mixed	TTDO	33	1	38
5	Semi-mixed	TLDO	26	7	36
6	Semi-mixed	FDO	29	1	35

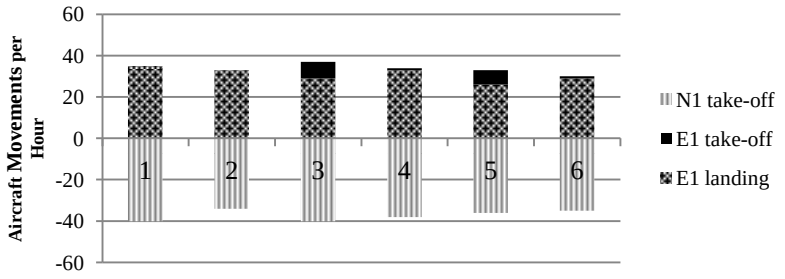


Figure 6. LR&APR movements per hour.

6. Conclusions

In this paper, Simmod simulation software is used to simulate the lateral runway and adjacent parallel runway under different operating modes and correlations. Runway capacity and the efficiency of airport green operation are evaluated. The conclusions are as follows:

(1) The planning of lateral runway and flight procedures should be designed to ensure that it operates independently with the adjacent parallel runway. In the case of independent operation, a group of longitudinal and transverse runways can meet the hourly take-off and landing movements of about 75-77.

(2) Lateral runway is mainly used for take-off, and parallel runway mainly for landing. In this way, the take-off & landing dependent operation has relatively large impact on capacity. In this case, the two runways have an hourly take-off and landing movements about 67-69.

(3) In the semi-mixed operation mode, if take-off and landing are fully dependent operation, the air traffic control and coordination would be more difficult, with the capacity only 65 per hour. Hence in this case, an isolated operating mode is recommended.

The construction and application of lateral runway are still in the initial stage in China. The collision risk analysis on take-off and landing flights, and the interval usage standards of dependent operation, are still there to be further studied.

7. Acknowledgments

This work is supported by two research projects:

(1) China civil aviation security ability building funds--Research on application of simulation technology in civil airport planning and design;

(2) National Key Technologies R&D Program (2014BAJ04B02).

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