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Airport Simulation Technology in Airport Planning, Design and Operating Management

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Abstract: The promotion and application of airport simulation technology can help improve the soft power of China's civil aviation, and achieve the scientific assessment and refined decision-making for airport planning, construction and operating programs. This paper first sorted out the concepts and types of airport simulation, namely airport airside ground operating simulation, terminal area and airway airspace simulation, terminal building internal process simulation and airport landside curbside traffic simulation, highlighting its relevant applications in airport planning, design and operating management. Taking airport airside ground operating simulation as an example, the application of simulation technology to airport operating capacity of parallel runways was introduced. Finally, the problems and developments of airport simulation technology were discussed in depth.

Keywords: Airport Simulation, Airfield, Airport Planning and Design, Operating Management

1. Introduction

Large airport runways are diverse in structure, complex in taxiway, terminal, land side transport and terminal area airspace. Traditional planning and design methods and operating management experience are difficult to achieve effective decision-making and quantitative analysis on the problems encountered in airport construction and operating management [1]. In Europe and American countries with developed civil aviation, airport simulation technology has been widely used in airport planning and design and daily operating management. It is of great significance to the comparison, selection and optimization of airport construction plans and the improvement of operating management models. At present, airport simulation technology is still in the promotion stage in China, lacking general cognition. This paper first briefly described the types of the technology, highlighting its relevant applications in airport planning, design and operating management, and then conducted a discussion on the problems in its development.

2. Types of Airport Simulation

According to different research objects, the airport simulation can be divided into four types, namely airport airside ground operating simulation, terminal area and airway airspace simulation, terminal building internal process simulation and airport landside curbside traffic simulation. In addition, there are also simulations for service vehicles, baggage systems, controller workloads, and integrated transportation connection and transfer in the airfield.

(1) Airport airside ground operating simulation

The research scope of the airport airside ground operating simulation mainly involves the analysis of the operating efficiency of aircrafts in the runway-taxiway-station site system inside the airfield, and the evaluation of the flight delay level, taxiing time, take-off & landing efficiency, and the ground operating capacity of an airport, etc. [2, 3], as shown in figure 1.

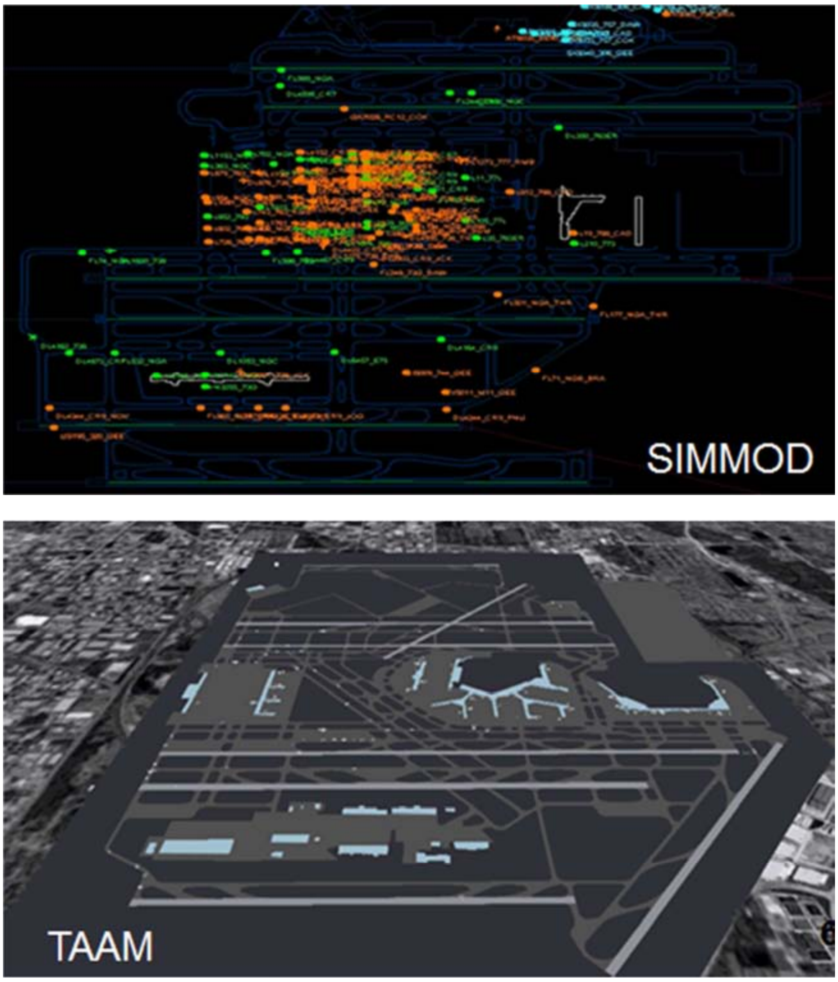
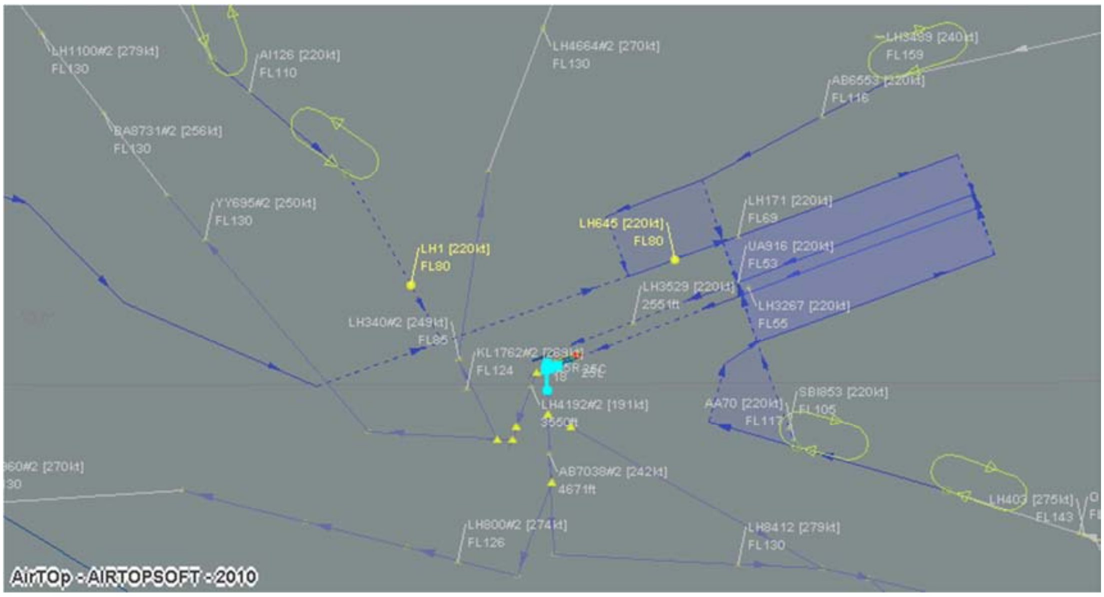


Figure 1. *Airside ground operating simulation.*

(2) Terminal area and airway airspace simulation

The research scope of terminal area and airway airspace simulation mainly involves the analysis of the flight efficiency of aircrafts in the arrival and departure route network inside the terminal area and in the route network under large-scale airspace, and the evaluation of the terminal area airspace capacity, the route network loading capacity, route conflict point analysis, and airspace optimal design, etc. [4], as shown in figure 2.



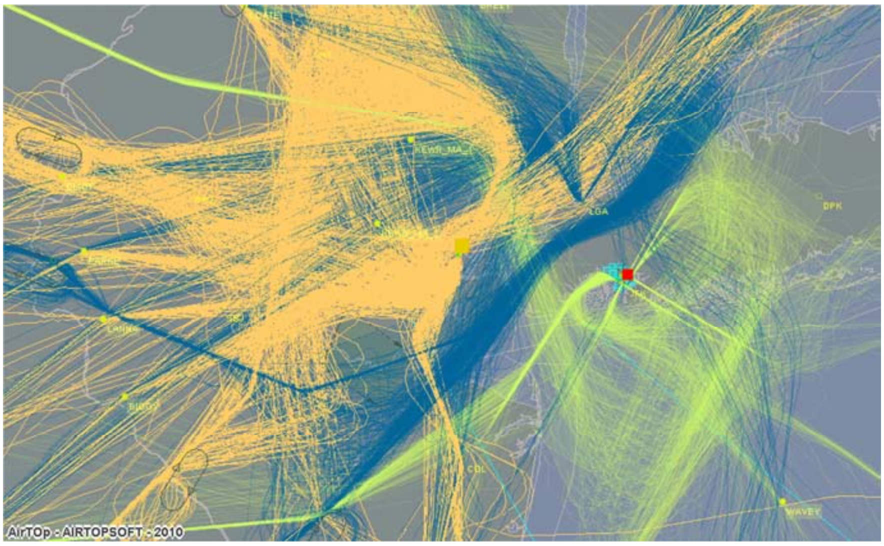


Figure 2. *Terminal area and airway airspace simulation.*

(3) Terminal building internal process simulation

The research scope of the terminal building internal process simulation mainly involves the analysis of the service level and efficiency of arrival, departure and transfer processes in the terminal building, the evaluation of the proper quantity and staffing of key facilities such as check-in counters, customs and security checkpoints, the comparison of and selection among different terminal building layout plans and service procedures in passenger traffic efficiency and walking distance, etc. as shown in figure 3.

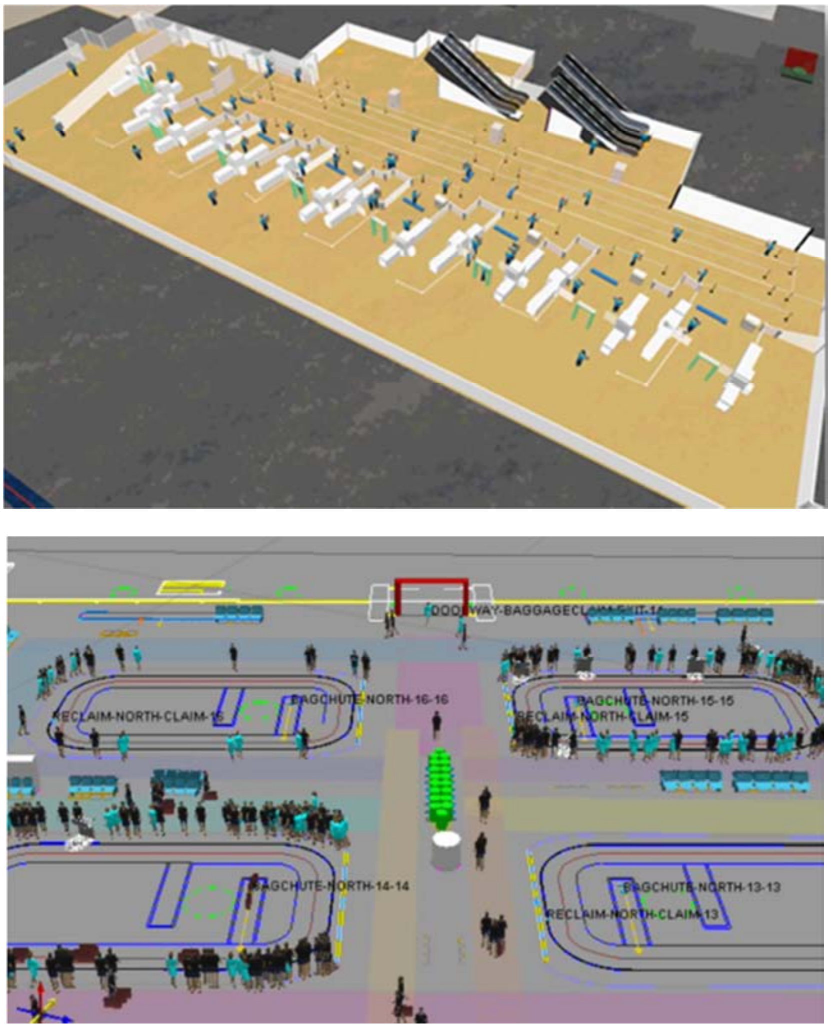


Figure 3. *Terminal building internal process simulation.*

(4) Airport landside curbside traffic simulation

The research scope of airport landside curbside traffic simulation mainly involves the evaluation of the landside traffic efficiency in airports, curbside congestion and the smoothness of traffic, as well as the comparison and selection of the impacts of different facilities and operating modes on landside traffic in airports, as shown in figure 4.

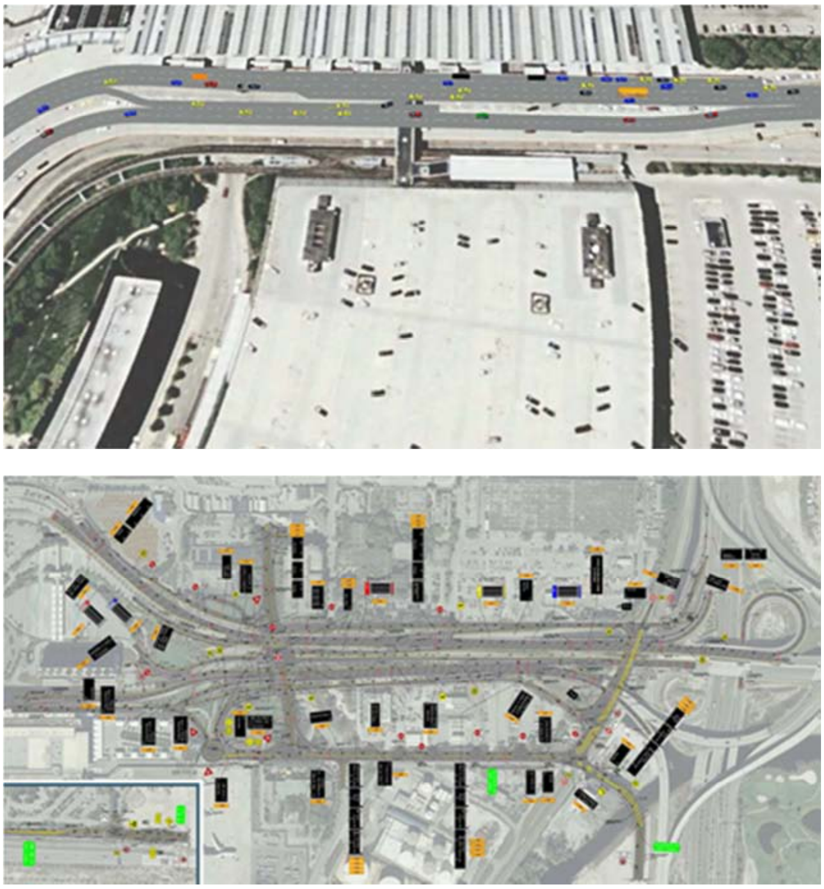


Figure 4. *Airport landside curbside simulation.*

3. Application in Airport Planning and Design

In airport planning and design, the research of simulation focuses on the evaluation, comparison and selection, and further optimization and adjustment of airport ground or airspace planning and design programs. Airport simulation research can be divided into three levels according to the depth of the research: rough simulation, moderate simulation, and refined simulation. In the stage of planning and design, simulation is mainly at rough and moderate levels. For core issues that the principal focuses on, refined simulation may be considered.

According to different stages of airport planning and design, such as site selection, overall planning, feasibility study, and preliminary design, airport simulation research has different emphases. In the stage of site selection, basic plans of the number and configuration of runways are emphasized, and rough simulations on airside ground operation and terminal area airspace are generally used. In the stage of overall planning, the airport's long- and near-term planning plans and their corresponding target capacity are emphasized, and moderate simulations on airside ground operation and terminal area airspace are usually performed. In the stage of feasibility study, the relevant content of the current construction plan is emphasized and accurate estimates are performed on the construction costs. Therefore, the current planning program can be combined to carry out moderate simulations on airside ground operation, terminal area airspace, terminal building internal process, and airport landside curbside traffic. In the stage of preliminary design, the planning and design programs for the airfield, terminal area, landside and airspace are relatively stable, so targeted and localized refined simulations can be further conducted to test, improve and optimize design programs.

4. Application in Airport Operating Management

Compared with the application in the stage of airport planning and design, the application of simulation technology in the operating management stage of Chinese airports is relatively weak [5]. With only a few large airports have a complete simulation model for the current operating situation, and keep long-term maintenance and regular updates, such as the internal process simulation model established by Beijing Capital International Airport for its T3 terminal.

Foreign large and busy airports usually have complete simulation models and employ professional consulting companies for long-term maintenance, such as Atlanta Airport and Chicago O'Hare International Airport. When an airport needs to improve service processes, increase or decrease service facilities, or try out new technologies, a simulation model will first be built to preview the plan, study and judge the efficiency gains and benefits it can bring, and then make refined decision-making, so as to reduce the potential investment and management risks triggered by the blind start of the project.

The Technical Specification for Airport Flight Time Capacity Evaluation issued by Air Traffic Management Administration Office of CAAC in January 2017 is worth learning and promoting. This Specification clearly put forward that simulation technology should be used during the adjustment and evaluation of the capacity of terminal area, runways and terminal buildings in an airport, thus to determine the final flight time capacity of the airport [6]. This fully embodies the important role of simulation in airport operating management, as well as the refined and scientific development of airport operating management.

5. Example Analysis of Airside Ground Operating Simulation

This paper operates Simmod Plus 7.6 to make a simulation analysis of the operational efficiency in different operational patterns of parallel runways. 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].

Given that this paper focally analyzes the capacity and efficiency of airport runways system, the simulation modeling will put aside the restrictive factors of airspace, taxiway and apron. Based on the analysis of the configuration of the typical parallel runway, 4 simulation models (simu-400, simu-760, simu920 and simu-1525, as shown in figure 5) are established in this paper, and each model is considered in the following two situations: runway crossing and bypass-taxiing.

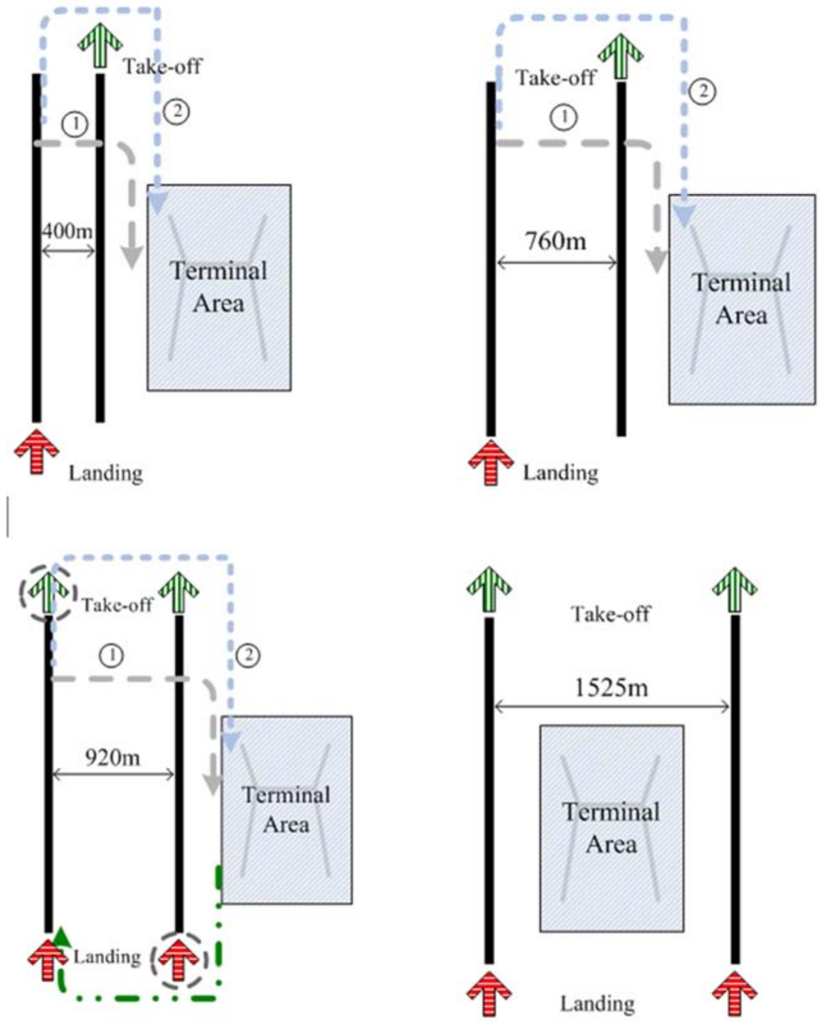


Figure 5. *Two runways spacing 400m, 760m, 920m and 1525m.*

In instrument flight rules, the separation of continuously take-off is controlled at 60~120 seconds according to the difference between front and follow aircraft type. For the flights continuously landing, the landing separation is mainly controlled by wake turbulence separation, as shown in table 1.

Table 1. *Aircraft wake turbulence separation.*

Follow \ Front	Heavy	Middle	Light
Heavy	8 km	6 km	6 km
Middle	10 km	6 km	6 km
Light	12 km	10 km	6 km

The model adopts the flight schedule, for only taking off or landing runway, peak time arrangement of flight 60 sorties per hour; for mixed operational runway per hour for 30 take-off and landing flights, respectively. The flight schedule far exceeds the maximum current single runway capacity, its purpose is to calculate the limit capacity of the parallel runways.

This paper assumes that the ratio of heavy and middle aircraft is P_h=20%, P_m=80%, respectively. In the course of runway crossing, the average taxiing speed is set to 12km/h, and the pilot reaction time is 8-10 seconds. Take the runway spacing 400m model as an example (simu-400), after running the simulation model, the video demonstration is shown in figure 6.

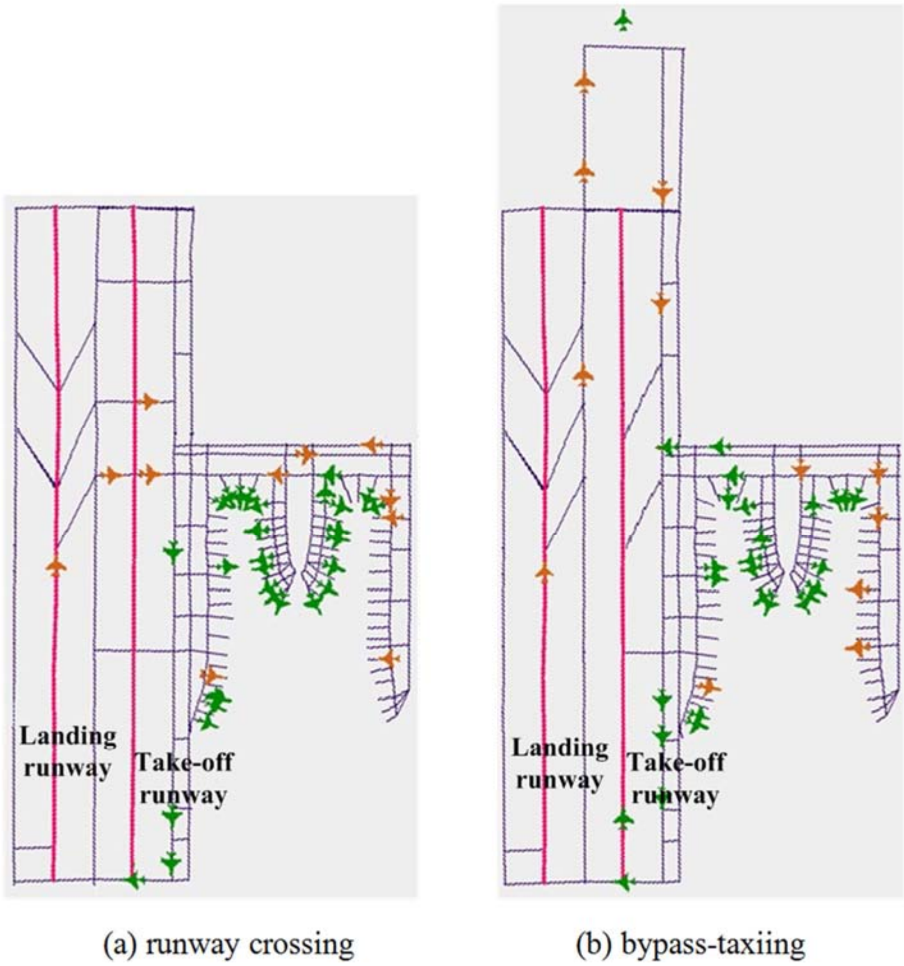
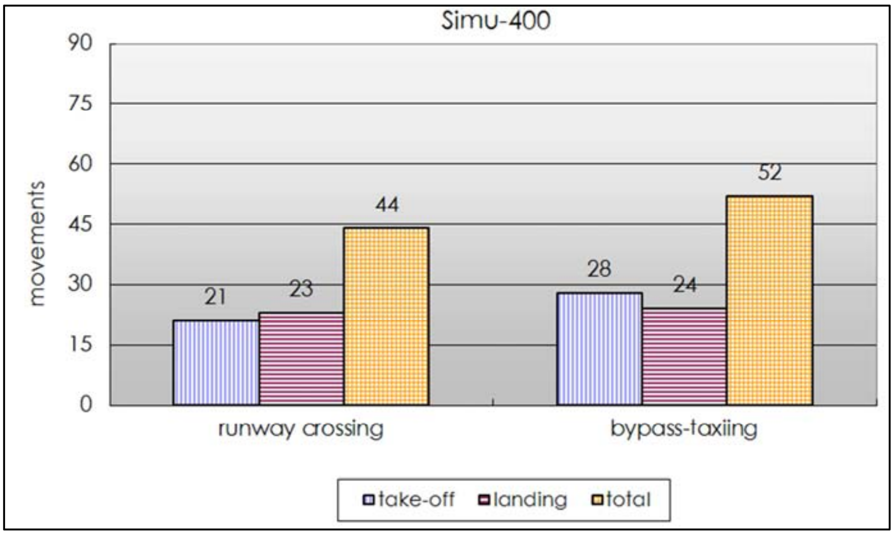


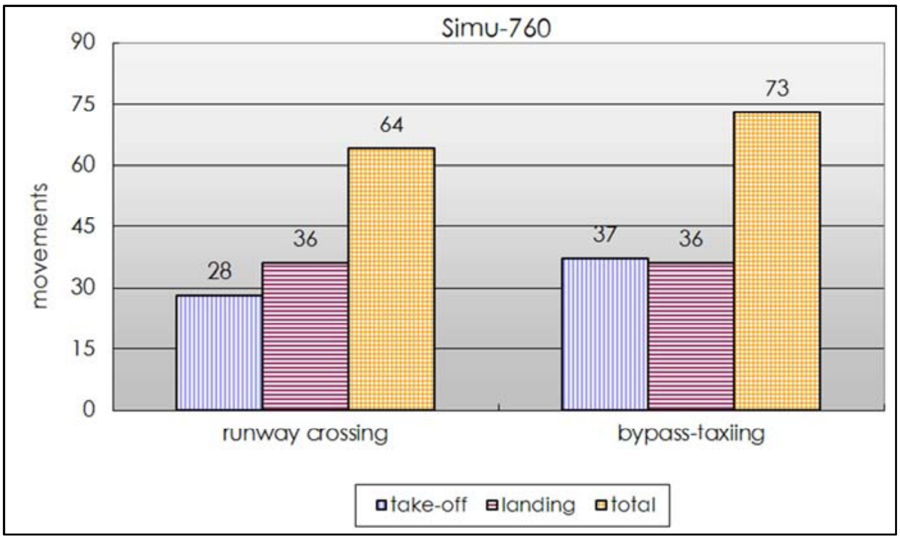
Figure 6. *Simulation model demonstration (simu-400).*

The parallel runway capacity obtained by the above simulation model is the ultimate capacity, or saturation capacity. The runway capacity limit means without considering the continuous demand delay under the runway system in unit time (1 hours) can serve the largest aircraft movements. The continuous demand refers to ready for take-off or landing aircraft flow existing, the phenomenon appears less in the actual operation, so the ultimate capacity reflects the service ability of theoretical maximum runway system [8-11].

The simu-400, simu-760, simu920 and simu-1525 four simulation models are run 5 times respectively, and the average value of the simulation results was calculated. Finally, the ultimate capacity of the parallel runway is obtained as shown in figure 7. Take-off, landing and total flights in runway crossing and bypass-taxiing conditions are analyzed.

On the basis of the ultimate capacity of parallel runways, the factual operation capacity can be obtained. The factual operation capacity is defined as the unit of time (1 hours), corresponding to an acceptable level of flight delays (usually the average delay time of 4 minutes / flight), aircrafts taking off or landing can be serviced by 85%~90% of the ultimate capacity. In this paper, according to the factual operation capacity of 90% ultimate capacity calculation, the actual running capacity of double runway is shown in table 2.





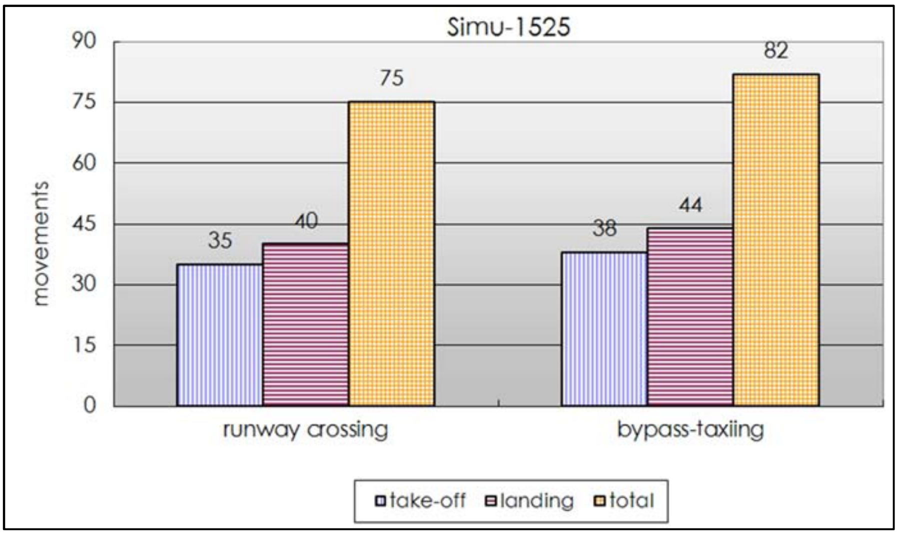


Figure 7. *Simulation results of 4 models.*

Table 2. *Double parallel runways actual operating capacity.*

Runway Distance (m)	Ultimate capacity		actual running capacity	
	Runway crossing	Non- crossing	Runway crossing	Non- crossing
400	44	52	40	47
760	64	73	58	66
920	69	76	62	68
1525	75	82	68	74

By analyzing the simulation results of the above is not difficult to see that the runway spacing 1525m, two runways, about 74 movements per hour; when the runway spacing is 400m, the capacity of about 47 movements per hour, if we consider the runway crossing, its capacity is only 40 movements per hour. In the case of setting bypass taxiway or no runway crossing, the factual operation capacity of the dual runway system can be increased by about 13%. Under the simu-760 operating mode, the runway system capacity is more than 40% of the simu-400 operation mode. Simu-920 mode of operation compared with simu-760 mode, the capacity change is small, an increase of about 3~7%.

6. Analysis of Current Problems

The application of airport simulation technology in China is gradually being promoted, and its role and benefits are gradually emerging. Although the future is bright, at this stage, it still faces many problems that constrain the further sound development of simulation technology.

(1) Collection and sharing of airport operating data

The core principle of airport simulation is to simulate future or current operating scenarios with a math model. Whether a scenario is well simulated depends on the parameter and assumption settings of the model. Therefore, large amounts of actual operating data should be collected, organized and analysed before simulation. In reality, however, it is not easy to obtain such operating data. There are four main causes for this: (a) Lacking systematically recorded and organized key data due to insufficient attention in operating data management. (b) Without cross-departmental data integration, a complete flight-passenger-vehicle operating data chain is difficult to form. The continuous operating data of an object are usually in the charge of different management departments such as airports, airlines or air traffic control. (c) Some operating data have vague concepts and are recorded in different format standards. (d) A sharing platform and a searching mechanism for operating data have not been established yet.

(2) Active participation of frontline operating personnel

Airport simulation involves many aspects of airport operation, and researchers are difficult to independently complete a refined simulation merely with limited surveys or data analyses. Therefore, the active participation and in-depth cooperation of frontline operating personnel are the key to a successful refined simulation. Frontline operating personnel usually include air traffic controllers, pilots, ground commanders, and various service personnel in terminal buildings.

(3) Objectivity and limitations of simulation results

The simulation results are directly affected by the parameters input. Therefore, people who are in charge of a simulation should perform the simulation with a professional and responsible attitude toward programs and the industry, and reflect objective simulation results, avoiding interference from the owner or other factors.

In addition, simulation is not equivalent to reality. Airport simulation should give a maximum reflection of the impacts of key factors on the operation of the program, but it cannot cover all factors, especially the interference of random uncontrollable factors. Therefore, for simulation results, we should not be dogmatic but should make rational judgments and comprehensive analyses.

(4) Verification and post-evaluation of simulation projects

Currently, there are many entities and organizations carrying out simulations in the fields of airport planning and design and airport capacity evaluation. These entities and organizations include planning and design units in the civil aviation, consulting and evaluation companies, colleges and universities, and foreign aviation consulting companies, with uneven power in simulation research. Therefore, it is imperative to establish an effective and simple project verification mechanism to make objective and fair verification on the evaluation results and conclusions obtained from simulation.

In addition, there is little progress in the post-evaluation of simulation projects. Post-evaluation on the one hand is conducive to verifying the rationality of the simulation results and making a timely and proper revision of the simulation results; on the other hand, it can help guide and optimize future simulations, summarizing lessons learned and promoting the sound development of airport simulation research.

(5) Development of simulation software in China

At present, commercial airport simulation software programs are all developed by foreign companies. Although some domestic universities have carried out the programming of some airport simulation software programs, these programs are only for academic research, and they are neither conditioned for commercial promotion nor verified by sizeable practical operating.

From the perspective of grasping the core competitiveness of civil aviation technology, it is suggested that at a proper time, colleges and universities, airport planning units, airport management units, air traffic control, airlines, and software development organizations should come together to build a research team and to jointly develop China's own airport simulation software products.

7. Conclusion

The promotion and application of airport simulation technology are of great significance to both the comparison, selection and optimization of airport construction plans and the improvement of airport operational management models. The technology will help improve China's soft power in civil aviation development. The application of simulation technology in airport planning and design has achieved a relatively wide consensus, but in other areas of civil aviation, it still lacks sufficient recognition and wide application. Therefore, it is necessary to accelerate the promotion and application of the technology, in order to achieve the scientific evaluation, comparison and selection, and refined decision-making in airport and airspace planning, construction, operating and management.

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