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Study on Organizational Model of Apron Operation in Airport

Jie Ren[1], Weijia Hao[2], Liang Zhang[1]

[1]Guangzhou Civil Aviation College, Guangzhou 510403, China
[2]Guangdong Nanhua Vacational College OF Industry And commerce, Guangzhou 510000, China

Abstract: With the rapid development of China's economy, China has achieved a breakthrough in air transport, traffic and transport capacity of large airports has increased significantly, many large airports present a trend of large-volume, high-density transport. Based on the analysis of ramp capacity and ramp efficiency after the handover, the proper use of independent ramp control can improve the operational efficiency of the airport, increase the normal rate of flight clearance, and reduce the workload of the air traffic control tower, to improve the safety of aircraft on the Apron. By learning the advanced experience of foreign countries, the organization mode of large-scale Airport Apron operation is calculated, and the airport apron operation capacity and efficiency are analyzed. The resulting data is weighted by Analytic hierarchy process. Finally, the feasibility of the result is verified by the case of Chengdu Shuangliu International Airport.

Keywords: Apron Capacity; Apron Operation Management; Control transfer; Case study.

1. Introduction

Currently, the continuous advancement of the transportation industry has driven the rapid growth of China's civil aviation transport volume, thereby increasing the utilization rate of airport apron parking positions. However, the operation of aircraft on aprons and near apron taxiways has become increasingly difficult to manage. Therefore, it is necessary to systematically study apron operation organization, optimize existing issues, reduce delays while ensuring safety, enhance passenger comfort, and save overall economic costs.

Researchers have made significant contributions in this field. In 2007, Tumer and Agogino[1][2] proposed a multi-agent algorithm and established an optimization model for transfer intervals. Brooker[3] introduced a concept of air traffic management based on a trajectory system and analyzed trends in control methods and interval usage from safety and capacity perspectives. In 2022, Minghua Hu[4] proposed a new air traffic flow management scheme, focusing on an efficiency-fairness dual-objective optimization model. In 2012, Shen Chen[5] introduced a utility function to establish multiple control transfer interval models, enhancing control efficiency. In 2018, Wang Xinglong[6] proposed a sector flow and time-continuous control model based on transfer interval constraints to study aircraft delay issues. In 2015, Wu Haibo[7] represented changes in transfer intervals in a matrix form using time intervals and established a control transfer interval model. In 2020, Wang Junkai [8] studied the three parameters of air traffic flow and operating intervals together, establishing an improved terminal area arrival traffic flow cellular transmission model. In 2021, Wang Hongyong[9] analyzed the characteristics of the new generation air traffic management system and studied air traffic complexity. Jiang Hao[10] analyzed the research and development of apron control both domestically and internationally, proposed suitable transfer modes based on the characteristics of domestic airports, and highlighted future development directions for apron control transfer in advanced technology and collaboration. Xue Yong [11] summarized and reflected on some methods for the construction and management of apron control at Wenzhou Longwan Airport, hoping to provide reference for the development of apron control transfer. Yu Qinghua [12] reviewed the traditional apron operation control process and existing issues, summarized procedures and modes after apron control transfer, and proposed targeted measures based on issues existing after domestic apron control transfer.

Research varies between domestic and international contexts. Due to a later start, China lags behind and needs to learn from foreign experiences while considering actual domestic conditions. It is essential to establish a theoretical system suitable for China's aviation system and develop new ideas and modes for apron operation organization and management.

2. Apron Operation Organization Modes

2.1. Theories Related to Control Transfer

Apron control transfer refers to the transfer of command authority for aircraft apron operations from the air traffic management department to the airport's on-site command and management unit. This ensures comprehensive monitoring of aircraft operations, enhancing the safety and efficiency of aircraft apron operations, maintaining apron operation order, and maximizing the efficient use of airport resources. This management mechanism effectively avoids the drawbacks of traditional models in various aspects and meets future development needs, making it the optimal choice for the development of large airports in the future.

2.2. Advantages of Control Transfer

Flight operations and related support units are complex, and traditional apron management methods have significant issues. For airport management agencies, integrating aircraft apron operation management and improving flight efficiency is of great significance.

From the perspective of tower workload, control transfer can reduce the workload and pressure on air traffic control towers.

From the airport's perspective, establishing an apron tower better connects aircraft maintenance, vehicle guidance, ground services, and apron command, resulting in more orderly and secure airport ground operations. This makes ground services at the airport more convenient, orderly, and time-saving.

Apron operation control transfer can fully address many issues and hidden dangers in non-visible apron operations, ensuring the safety and efficiency of aircraft in airport operation areas and on aprons, while also contributing to the rational allocation of airport resources.

3. Evaluation Indicator System for Large Airport Apron Operations

To reduce flight delays and improve apron operation efficiency, it is necessary to establish a scientific capacity assessment method and implement unified national control measures. This requires the construction of a comprehensive evaluation indicator system.

3.1. Target Indicators: Large Airport Apron Operation Organization Modes

First-level indicators: Apron capacity, conflict models, special situation control.

Second-level indicators: Aircraft taxiing time, apron capacity calculation, parking position utilization rate, dynamic conflicts, static conflicts, conflict procedure design, uncontrollable situations, optimizable situations, handling methods.

3.2. Analyzing Weights Using Analytic Hierarchy Process (AHP)

Construct a hierarchical objective model, dividing the decision-making goals, criteria, and objects into the highest level, intermediate level, and lowest level based on their mutual relationships.

3.3. Constructing the Evaluation Matrix

The relative importance of each factor to every other criterion within the matrix is generally different. Therefore, by comparing these factors pairwise and using a scale to describe their importance, a judgment matrix can be constructed. If necessary, experts can be consulted to assist in constructing the judgment matrix.

4. Case Study

4.1. Capacity Calculation

1.Information Collection

Based on flight information and statistical induction, there are 178 parking positions across three parking areas at Chengdu Shuangliu International Airport, including 74 near-field positions and 104 far-field positions. The daily peak reaches 545 flights, with an hourly peak of 35 flights. The actual average occupancy times for different aircraft types are 65 minutes, 77.5 minutes, 80 minutes, and 83 minutes.

2.Delay Time

Out of 547 flights, 369 flights did not arrive as scheduled based on their Estimated Time of Arrival (ETA), resulting in a total delay time of 2713 minutes. The probability of aircraft delay (g) is 0.678, with an average delay time (t) of 5.58 minutes, yielding a parameter m of 0.12.

3.Latency Time

Data shows that out of 547 flights, 465 did not complete turn-around services, with an average delay of 45.87 minutes and a total delay time of 25091 minutes. The probability of delay (u) is 0.852, resulting in a parameter v of 0.019.

4.Operating Time

The airport operates 24 hours a day, denoted as Tc=24h. For calculation purposes in formulas, hours are used as the unit, but to solve for daily and hourly parking position capacities, ten-minute intervals are used as the basic unit.

In the formulas, considering the actual situation discussed earlier, the average conflict delay is 35 minutes. For traffic conflicts without delay, the average delay is also 35 minutes, with a parking position capacity of 3 flights per hour per position. The daily parking position capacity is 708, and the actual number of flights is 547, resulting in a parking position utilization rate of 77.6%. Similarly, for traffic conflicts with delay, the utilization rate is 97.7%.

According to the table, the conclusion drawn from nonlinear optimization shows a utilization rate of 64.6%, which does not align with the actual situation. Through calculations of traffic conflicts with and without delay, it is found that there is a shortage of parking positions at the airport. This can be addressed by extending boarding bridges, optimizing algorithms through the apron control tower, and reducing delay times to improve apron operation efficiency and parking position utilization.

4.2. Apron Conflict Analysis at Chengdu Shuangliu International Airport

Apron conflicts are categorized into two types:

Static conflicts, where due to a shortage of parking positions, two or more aircraft occupy one parking position after entering the apron.

Route conflicts, where due to narrow boarding bridges, departing and arriving aircraft collide on their routes, preventing normal entry and exit from parking positions.

Solution: Utilize the apron control tower to design a computer program that sets parking positions and taxiways as fixed targets. Dynamic allocation is performed based on flight information as factors, matching aircraft with taxiways and apron positions to obtain the optimal solution.

4.3. Analysis Based on System Indicators

4.3.1. Determination of Indicator Levels

Based on the hierarchical objective model and the correlation of research objects, the overall goal, first-level indicators, and second-level indicators are determined. There is a direct causal relationship between the goals and indicators.

4.3.2. Construction of Evaluation Matrix and Analysis of Weights

A matrix is constructed for the selected indicators, and a comparison chart is made. The importance of each indicator is evaluated based on its dominance relationship. Through the Analytic Hierarchy Process (AHP), the judgment matrix is subjected to a consistency check; otherwise, it does not satisfy consistency. The evaluation weight results are determined based on expert scoring.

4.3.3. Determination of Results

By identifying the central node and finding the shortest path to other nodes, the node with the highest centrality is determined. This node is crucial for obtaining the maximum capacity of the airport. Based on this node, the airport's maximum capacity is obtained.

5. Conclusion

By applying the actual situation of Chengdu Shuangliu International Airport, the optimal proportion of apron capacity utilization is derived. Based on this proportion and delay times, the airport's capacity is determined. Conflict simulations are conducted on the airport's capacity, and computer programs are used to optimize taxiing routes and apron positions, improving apron operation efficiency and capacity. Finally, based on the actual situation at Chengdu Shuangliu International Airport, measures are formulated to handle special situations and enhance apron operation efficiency.

Taking into account the runway parameters of Chengdu Shuangliu International Airport and the types of aircraft taking off and landing there, combined with actual operation frequencies, formulas are established to calculate capacity. Optimization is then performed to obtain the shortest steps.

A program is designed for the airport apron, where aircraft are included in the program upon landing. Programmatic calculations are performed for taxiways and parking positions, and path and time planning are also conducted for departing aircraft to save taxiing time and increase airport capacity.

References

[1] Tumer K, Agogino A. Distributed Agent-Based Air Traffic Flow Management[J]. AAMAS’ 07, Honolulu,Hawaii, USA. May 14-18, 2007.

[2] Agogino A. Distributed Optimization for Automating Air Traffic Flow Management[A].Navigation and Control Conference and Exhibit, AIAA/IEEE. 2008.8, 18-21.

[3] Brooker P. Air Traffic Control Separation Minima:Part2-Transition to a Trajectory-based System[J]. THE JOURNAL OF NAVIGATION (2011), 64, 673–693

[4] Guo Y, Hu M, Zou B. Air Traffic Flow Management Integrating Separation Management and Ground Holding: An Efficiency-Equity Bi-objective Perspective[J]. Transportation Research Part B: Methodological, 2022, 155: 394-423.

[5] Shen Chen. Research on the Management Strategy of Air Traffic Control Transfer Interval [D]. [Master's Thesis]. Nanjing: Nanjing University of Aeronautics and Astronautics, 2012.

[6] Wang Xinglong. Dynamic Control Model of Sector Flow Based on MIT in Severe Weather [J]. Journal of Wuhan University of Technology, 2018, 40(2): 50-57.

[7] Wu Haibo. Research on the Management Strategy of Control Transfer Interval under Radar Control Conditions [D]. [Master's Thesis]. Tianjin: Civil Aviation University of China, 2015.

[8] Wang Junkai. Analysis and Research on Traffic Flow Characteristics of Terminal Area Radar Control [D]. Civil Aviation University of China, 2020.

[9] Wang Hongyong, Zhang Jiahao, Wen Ruiying. Research Progress on Air Traffic Complexity [J/OL]. Advances in Aeronautical Engineering: 1-11 [2022-04-20].

[10] Jiang Hao, Xie Yubing, Chen Yaqing. Research Progress and Mode Analysis of Apron Control Transfer [J]. Journal of Civil Aviation, 2023, 7(03): 43-48+132.

[11] Xue Yong. Reflections and Inspirations on Apron Control Transfer [J]. China Shipping Gazette, 2022(34): 54-56.