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1. Research on Efficiency Intelligent Evaluation Model and Optimization System of Airport Surface Operation

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Abstract **The multi-airport collaborative departure release strategy allocates takeoff time slot windows for flights to meet downstream operating interval or capacity constraints. The time slot window range is usually set based on actual operating experience, which is mainly affected by the uncertainty characteristics of flight departure operations. And then affect the implementation efficiency of the multi-airport collaborative release strategy. According to the planned departure time, the flight can calculate the entry point time of the congested airspace. Based on the entry point time, the paper adjusts the ground waiting for the same-direction flight. Finally, the effect of reducing flight delays is achieved. At the same time, it can also ensure the green and optimized operation of the airport scene.**

Keywords—ground waiting; green efficiency; energy efficiency evaluation; optimization system; coordinated departure

I. Introduction

In 2011, the Civil Aviation Administration issued the guiding opinions on "Accelerating the Promotion of Energy Conservation and Emission Reduction", which emphasized the work ideology, principles and goals of accelerating energy conservation and emission reduction in the whole industry. According to the work deployment of the Civil Aviation Administration, and combined with the pilot situation at the Capital Airport, Pudong Airport, Hongqiao Airport and Baiyun Airport, in 2012, the promotion of the use of bridge-mounted equipment to replace the APU in civil airports was officially launched. In 2009, the promotion of remote camera-mounted bridge equipment to replace APU began. With the increase in the application of bridge equipment in China year by year, the cumulative utilization rate of bridge equipment has reached 85.7%, and the promotion of bridge equipment has shown a good development trend.

The original intention of bridge-mounted equipment is to save energy, which has been generally recognized by the Civil Aviation Administration and various civil aviation units. However, its advantages of less energy consumption, no pollution and refined management are associated with increased airport operation and maintenance costs, undetermined equipment effects, and complex management systems. Disadvantages such as disputes over electricity bills between airports and airlines coexist, and the comparison of advantages and disadvantages between airports and airlines is quite different. Therefore, an accurate and quantitative data system is needed to evaluate the introduction of bridges between airports in various regions from the perspective of overall operation [1]. It can objectively, accurately and completely describe the role of bridge-mounted equipment in the development of energy conservation and emission reduction in the industry, and at the same time Provide a set of tracking and evaluation system for grass-roots energy conservation work for industry management agencies.

II. Collaborative Release

Collaborative release is actually a new multi-airport flight departure time slot allocation method, which provides a new departure time application mechanism. Each airport no longer applies for departure time from the superior unit, but is adjusted by the superior unit. After the departure time is released, the decision-making will be completed by the upper-level agencies in a unified manner. Therefore, the coordination process of departure time slots at various airports has changed a lot. The take-off flow control decision under the coordinated release mode is issued by the flow control room, and the restriction information, flight plan, flight information, flight schedule and other information of multiple control units are summarized here, and the flight schedule coordination and take-off sequence adjustment are carried out according to certain principles [2]. The decision made by the flow control room directly affects the actual flight operation, so the optimization and implementation of the auxiliary decision-making is very important. The traditional takeoff flow control method is the ground holding strategy. However, due to the application flow, input information, and attention to airspace changes, the traditional single airport ground holding strategy limited by the runway capacity of the landing airport can no longer meet the existing takeoff flow control requirements. Therefore, this paper proposes a new ground-holding strategy, a ground-holding strategy based on cooperative release. The research object of this strategy is the departure flights from multiple airports, and these flights all pass through a common airspace unit. The capacity limitation of this airspace unit is the core, A take-off sequence is output through a certain algorithm, which can meet the airspace unit capacity limitation during the flight and improve the airport take-off flow.

Multi-airport systems serve the same area and are geographically close together, usually in the same terminal area, forming a multi-airport terminal area. Compared with the single-airport terminal area, the route structure of the multi-airport terminal area is more complex, and the airspace used for arrivals and departures between airports is coupled with each other. The operation of an airport is usually limited by the influence of adjacent airports [3]. Therefore, in the new flow management, in order to solve the problem of coordination between multiple airports in densely populated areas, the concept of expanding the terminal area will be adopted, that is, the range of the terminal area will be expanded from the original 50 nautical miles to 120 nautical miles or more. The range of the solid line in Figure 1 is the range of the original terminal area (the picture is quoted from A comprehensive wireless sensor network reliability metric for critical Internet of Things applications). The dotted boundary is the extension of the terminal area in the new flow management concept. China will set up 5 to 8 terminal control areas around 2020.

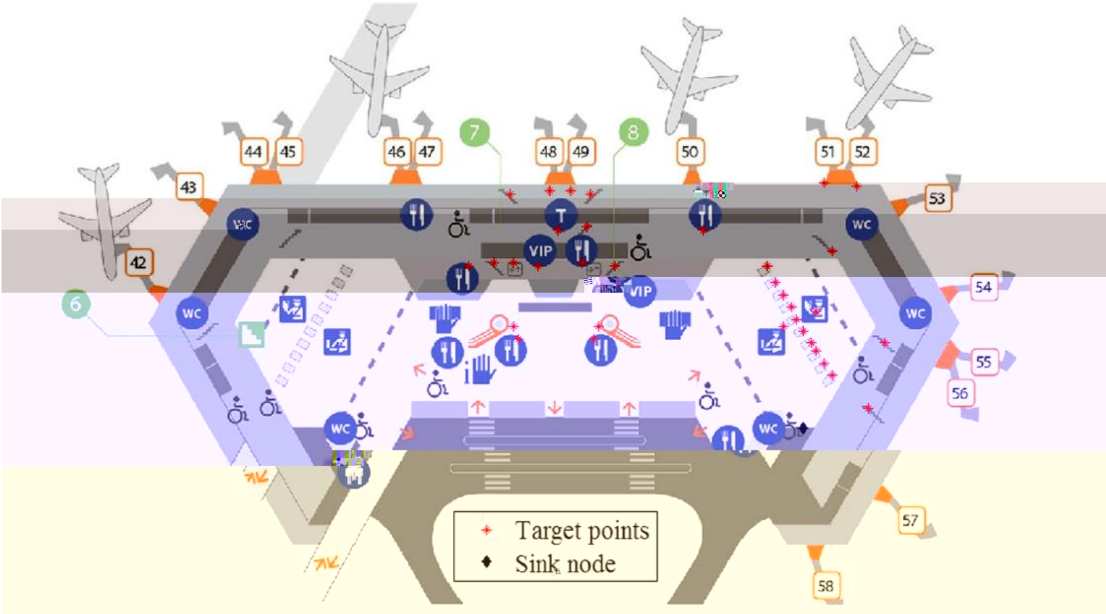

Fig. 1. Schematic diagram of the terminal area structure

The terminal area airspace system is an important part of the air traffic system, and it is also the most complex subsystem in the air traffic network. In the terminal area, the arriving flight departs from the route and starts the arrival flight, and finally land on the airport runway through different arrival procedures. After taking off from the runway, the departing flight passes through the specific terminal area exit corridor according to different standard instrument departure procedures. Enter the en-route flight. The flight status of aircraft in the terminal area is changeable, and the route structure is complicated, especially in the multi-airport terminal area [4]. Therefore, in order to ensure the safe separation between aircraft and ensure the orderly take-off and landing of aircraft in the terminal area, it is necessary to understand the multi-airport terminal airspace structure. Figure 2 shows a schematic diagram of the structure of the arrival and departure routes in the multi-airport terminal area (the picture is quoted in A framework for the classification and prioritization of arrival and departure routes in Multi-Airport Systems Terminal Maneuvering Areas). As shown in the figure, in the multi-airport terminal area, aircraft coming from or going to the same direction share the same entry and exit corridor, so that the terminal routes are intertwined. It will be required for the safe and effective operation of aircraft in the multi-airport terminal area in the future.

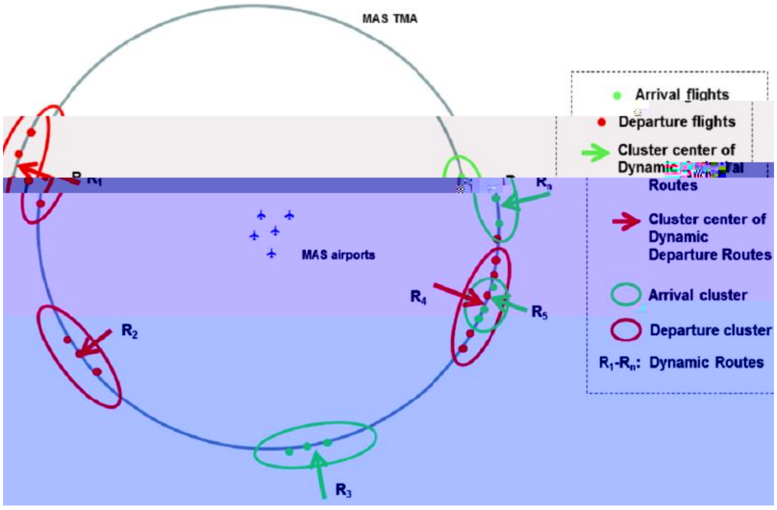

Fig. 2. Multi-airport terminal area airspace structure

III. Collaborative Decision-Making Theory

Collaborative decision-making (CDM) refers to a systematic approach to improving air traffic flow conditions through collaboration, information exchange and sharing among various departments such as airports, airlines, air traffic flow management units, and air traffic control units. The idea of CDM originated from the data exchange test conducted by the Federal Aviation Administration (FAA) and airlines. The test results show that when the FAA obtains timely flight operation data, it can provide a more optimized air traffic flow management plan. CDM is established on the basis of information sharing among various cooperative departments [5]. It realizes the sharing of air traffic information by building a unified information management platform, and provides sufficient information for all participants. Each participant combines the information provided by CDM with its own operational needs. Make the best decision. CDM transforms the original centralized decision-making model into a distributed collaborative decision-making model. Figure 3 shows the operating mechanism of CDM.

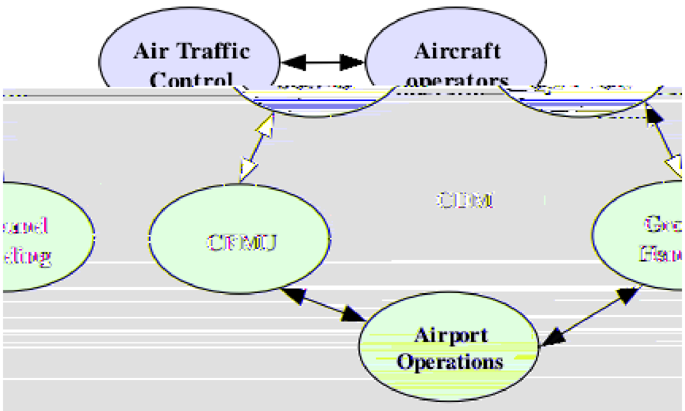

Fig. 3. CDM operating mechanism

IV. Multi-Airport Collaborative Release Problem Modeling Analysis

Considering the current airspace use contradiction and the distribution of traffic congestion areas, the research focus is shifted from the airport landing capacity to the congested airspace that the flight passes through during the flight, and the untaken flights that are expected to pass through the airspace are taken as the research object to construct a new joint release-based method. ground-waiting strategy. c indicates capacity-constrained airspace. $[t_{star}, t_{end}]$ indicates the start and end time of the limited capacity of airspace c. $A = \{A_1, A_2, ..., A_n\}$ stands for departure airport collection. $F_c = \{f_1, f_2, ..., f_m\}$ represents the same-direction pending flight passing through airspace c at each departure airport. $f_i = \{\ t, ETD, STD, N, A_i, t_{delay}, C_t\}$ indicates that the flight element contains the following information. Estimated flight time of arrival in airspace c, estimated departure time, adjusted departure time, adjusted order of arrival in airspace c, departure airport, ground waiting time, delay loss per unit time after flight delay time t. The cost of flight delay losses includes flight operating costs and lost profits [6]. If the flight is not delayed, the loss cost is 0. Consider the case where the cost of delay loss increases as the delay time increases. Let the minimum delay loss of a flight be denoted $C_{\min} = \min_{t\ 0}\{C_t\}$. $SN = \{1, ..N\}$. Sequence position set, the same-direction flight set flight is assigned a sequence position after sorting, that is, a new sorting position is obtained. For example, it means that f_i is assigned to the sequence position n, meaning that f_i is the n flight arriving at c after adjustment by the algorithm. T_t^q represents the entry time interval of capacity-constrained airspace c, that is, the time interval that should be maintained by two aircraft entering airspace c in turn at time t under the condition of q. The value of T_t^q is determined by factors such as weather, airspace utilization, and control methods. The moment when the $n(\mathrm{n} \quad [1, \mathrm{N}])$ departure flight can enter airspace c under the condition that the entry interval of airspace c is satisfied. in

$$t_1 = t_{start}; t_2 = t_1 + T_{t_1}^q + 1; \ldots; t_n = t_{n-1} + T_{t_{n-1}}^q + 1 \tag{1}$$

ground waiting, the economic loss of flight delay should be measured by the accumulated delay loss. Defining the delay loss difference:

$$CT_i = C_{i.n+1} - C_{i,n} \tag{15}$$

The meaning is that when flight f_i is delayed again to the next time slot, the delay loss will increase. The priority factor of the flight in the group is determined by the delay loss difference. The flight with the larger delay loss difference takes off earlier, which can effectively control the overall delay loss of the departure flow.

V. System Simulation

Based on the historical data, the probability distribution curve of the departure delay time of the departure flights at each airport is fitted to obtain the probability distribution function of the departure delay. The randomness of the field time and the probability distribution characteristics of the departure delay of the out-of-area take-off airport are used to simulate the randomness of the out-of-area take-off airport's entry time, and provide the required input information for the simulation model [8]. This section analyzes the implementation efficiency of the dynamic release strategy given by the release system under the influence of uncertainty. 1,000 simulations were performed on flights in the central and southern regions on 7th, 2020. The flow control condition is that flights departing from the central and southern regions and landing in Beijing must meet the 8-minute flow restriction interval, and different departure time slots are set for the departure airports in Guangzhou and Shenzhen. Window range, based on the simulation results to calculate the relevant performance indicators under different take-off time slot windows, the calculation results are shown in Figure 4 (the picture is quoted from Performance Comparing and Analysis for Slot Allocation Model).

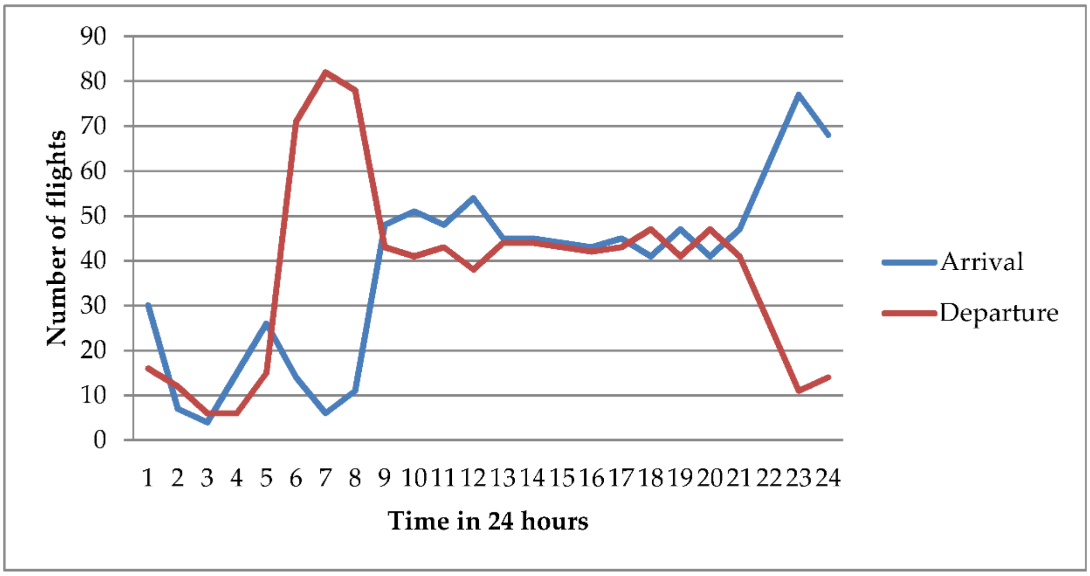

Fig. 4. Trend chart of performance index with take-off time slot window

With the expansion of the CTOT takeoff slot window, the following trends are shown: the additional ground delay decreases, the additional air delay increases, which means that the workload of the controller's air deployment increases; the weighted total delay increases, which represents the combined ground and air delay [9]. The overall efficiency, as measured by delay, decreased; the average number of reallocations decreased, indicating improved policy stability; and the CTOT error increased, indicating decreased policy predictability.

VI. Conclusion

Due to the departure uncertainty in the operation of the departure flight, by increasing the CTOT takeoff time slot window, it can provide more flexibility for the flight, which is beneficial to the airline and the airport to ensure the operation. From the point of view of the operational efficiency of air traffic control, increasing the CTOT take-off time slot window can improve the stability of the strategy and reduce the hopping of flight time slots, but it will also lead to a decrease in the predictability and efficiency of the strategy. Taking into account the multi-dimensional performance indicators, it is particularly necessary to reasonably determine the time slot window range of different departure airports. Effectively improving the efficiency of collaborative release is the future research direction.

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