Optimal management of multi-airport opening non-real time network system

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This paper considers the arrival, airport and departure capacity as a whole, through which, the network effect between airports is fully emphasized, the flight action is coordinated, and the flight demand pattern is reasonably assigned. The optimization problem of flight queues in multi-airport is studied in detail; the mathematical model of multi-airport opening non-real time flow management in terminal area is established, and related problems such as the parameters, the simplification and the solving of the model are discussed in detail to some extent. Appropriate decision making variables are taken to make the multi-airport network system linear 0-1 integer programming model, thus, the solving of the model is available and the central flow management is realized.

The heuristic implicit enumeration presented in this paper can effectively solve this kind of problems. Through the simulation of some airports network system, we not only validate the algorithm presented in this paper, but also give a deep analysis of the results, which would produce reference for later practicable use. The simulation proves that this algorithm offers a good way to settle the problem of multi-airport flight queue optimization in air traffic management automation system in terminal area.

1. Introduction

Over the past decade, the rapid development of China's civil aviation transportation, flight movements increased rapidly, by the backward bottleneck control methods and control equipment generated, resulting in the emergence of the phenomenon of air congestion worsening trend to air traffic safety and security and caused huge economic losses. Thus many control units starting to focus on solutions to air traffic congestion, air traffic management in order to improve the current situation in China. Since the eighties of the twentieth century, especially after the nineties, computer and network technology has become more sophisticated and applied to the field of air traffic, radar data, weather information and flight data such as the implementation of air traffic control information necessary for the integration of becoming reality, for the implementation of air traffic management automation foundation. ATFM studied in this paper is the terminal area air traffic control automation system is an important component. Aircraft traffic terminal area are often caused by different types of aircraft consisting of a different order before and after these aircraft, they need wake turbulence separation is also different. ICAO tail wind conditions with no flow of different types of aircraft separation minimal to make provision, which can get the minimum time interval, as shown in Table 1.

Table 1

Wake turbulence separation (in seconds)		After aircraft		
		Large (L)	Medium (M)	Small (S)
Former aircraft	Large (L)	113	135	170
	Medium (M)	89	89	110
	Small (S)	83	83	94

Non-real-time short-term planning of the scope of this paper multi-airport open network-based system of air traffic flow management. The issue involves a number of airports, an airport network through airports each scene and departure flight plan period projected demand and capacity, was found in an airport for a period of scheduled departure and (or) the operation of flights landing demand exceeds the airport's capacity, which requires re-adjust flight operations, the use of optimization methods can be expected of hovering in the air waiting ahead of time before the corresponding flight, and the necessary circling waiting time into ground delay waiting time. Although the non-real-time traffic management involves a number of airports, more complex, but because of the overall situation, consider the links between several airports and, in general, it can coordinate in advance the airports, effectively prevent the occurrence of congestion, traffic management effect better; the other hand, many aircraft are executed more than once a day flight operations, therefore, when a flight is delayed, in many cases, performed by the aircraft under a flight will be delayed. In addition, a hub airport, taking into account the transit passengers, a flight delay in arrival, may affect several aircraft flights delayed. All in all, when terminal area air traffic flow management research, we can not pay attention to the network effect between the airport and more. For a good solution to the growing problem of multi-airport congestion queue, and in order to reduce the complexity of the problem, this chapter from a macro point of view of strategic management, systems based on the idea of a more detailed study of the airport air traffic flow of non-real time Short-term planning issues. Through non-real-time short-term planning, on the one hand coordination of the interlinkages between the airport, on the other hand demand a reasonable allocation of the flight mode, crowded flights dispersion peak area to prevent the flight activity with respect to airport capacity is too concentrated in time, try to avoid the traffic demand exceeds system capacity generated by aircraft flying unreasonable demand distribution patterns caused by congestion, as flights can be safe, smooth and orderly, economical operation, and laid a solid foundation.

2. Basic problem

We studied more airports open network system shown in Figure 1, the figure each node (A, B, C) each represents congested airport, all flights flying arrows indicate the direction of flow. As can be seen from the graph, the network of multi-airport open (not enclosed) network system, including as a non-congested airports.

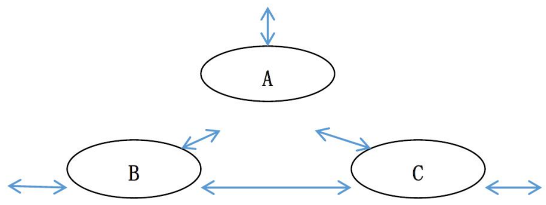

Fig 1 Multi-airport open network system

2.1 open network airports system description

Taking into account the actual flight situation, where we will define the problem as a meaning more airports open network traffic management system that considers not only flights within the network links between each congested airports, taking into account the external network uncongested airport and airport network congestion flights link between, we believe that all external network uncongested airport capacity unconstrained arriving or leaving the airport imaginary flights can realize its operation at any time, that hypothetical non-congested airport's flight operations can be any deployment. This problem can be described as a time interval [0, T] inside, a crowded airport network has a number of scheduled flights need to schedule their planned operating time is determined by the application service, while airports in chronological distribution of capacity forecasting known, in the case of airports operating plan of demand and capacity are determined by the relationship, how optimal scheduling, allocation of slots at each flight to ensure flight safety, orderly and efficient?

2.2 Problem Solving

Consider a crowded airport network at a time interval [0, T] arrived at the scene within the scheduling of flight departure. It can be analyzed, the time interval [0, T] is divided into N aliquots time period 1,2, ..., N (called period), for example, T = 2 hours, the time interval [0, T] is divided into six equal portions period, the length of each period is 20 minutes. Note: The appropriate division of time is significant for the optimization problem. If the period is divided too wide (the length of each period is large), then the validity and accuracy of airport capacity predicted worse, it will lead to optimal results it is difficult to ensure optimal and reliability; if the period is divided into narrow (the length of each period is small), on the one hand, since the description of airport capacity in a given period of time only makes sense, so it is possible to make meaningless airport capacity, on the other hand, due to the excessive time period, then the optimization problems and constraints will surge in the number of decision variables that become large-scale optimization problems, problem solving to realize that a great deal of difficulty, especially with respect to the integer programming problems, optimization problems size becomes more important. Here we delay loss delay loss into the ground and in the air in two parts delay losses (including losses due to low passenger satisfaction caused), but also by the various parts of the model are considered as a linear function of the actual delay time of each type of the number of flights within the investigated time interval total delay loss equal to the sum of the flight delays loss of each secondary airports, the total delay loss minimum target, thereby optimizing in each period, the airport's planned operating each flight to achieve systematic short-term planning purposes.

3. Open Network multi-airport system modeling

After delay period will be replaced with the number of variable allocation decisions, organize, and omitting the constant term, the airport can be much simplified model for non-real time traffic management:

The objective function

$$\min z = \sum_{f\in F} c_f^g * \sum_{t\in T_f^a} t * x_{f,t} + \sum_{f\in F_a} c_f^a * \sum_{t\in T_f^a} t * x_{f,t}$$

Subject to:

$$\sum_{f:k_f^a=k} x_{f,t} \le A_k(t), \quad \forall (k,t)\in K\times T, f\in F\cup F_a$$

$$\sum_{t\in T_f^a} x_{f,t} = 1, \quad \forall f\in F\cup F_a$$

$$\sum_{t\in T_f^a} t * x_{f,t} - (r_f - d_f) - \sum_{t\in T_{f_c}^a} t * x_{f_c,t} \ge R_{f_c}, \quad \forall f_c, f\in F_c$$

$$x_{f,t}\in\{0,1\}, \quad \forall f\in F\cup F_a, \ t\in T$$

Here :

f represents flight, f_c represents the continuous flight,

$F=1,\cdots,q$ In a crowded airport, the flights set plan to take off or land, q represents the qth flight;

$F_a=\{1,\cdots,n\}$ In a crowded airport, the flights set plan to land, n represents the nth flight;

$F_c\subseteq F$ the continuous flights set, c represents continuous;

c_f^g the ground delay unit cost of waiting period of flight f, c represents cost, g represents ground;

c_f^a the cost of air circling unit delay period of flight f, a represents air;

R_{f_c} the number of ground rest periods of the continuous flight $f_c\in F_c$, R represents rest;

$T=\{1,\cdots,N\}$ the considered period set;

$K=\{1,\cdots,k\}$ the considered congested airports set;

$A_k(t)$ the prediction arrival capacity of the congested airport k during the period t;

$k_f^a\in K$ the arrival airport of flight f;

T_f^a the possible landing slots set of flight f;

$d_f\in T$ the planning departure time of the flight f that plans to take off;

$r_f\in T$ the planning arrival time of the flight f that plans to land;

$x_f=\begin{cases}1\\0\end{cases}$ (if flight f land in period t, the value is 1, otherwise 0) ;

4. Calculations

Using the model and design optimization algorithm of this paper established in this chapter to solve the traffic management for specific multi-airport open network systems. Simulation results show the model's validity and reliability of the algorithm and write a program design. Assume the following more than one airport open network:

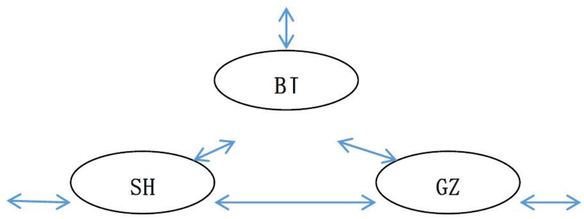

Fig 4. Multi-airport open network system

Here, the three congested airports in China are Beijing, Shanghai and Guangzhou airports.As used herein, the establishment of a database of flights, the flight is a reference to China's civil aviation ticket network http://diqnzipiao02.xiaomi001.com/ obtained.

Table 2

Flight No	De Airport	STD	STSD	Ar Airport	ETA	ETSA	Type	Gr Delay	Ai Delay	STA
F001	GZ	12:01:00	1	SH	13:22:00	5	S	1	0	13:42:00
F002	SH	12:04:30	1	GZ	13:24:30	5	M	0	0	13:24:30
F003	*	10:08:00	–	SH	12:06:50	1	M	–	0	12:06:50
F004	SH	12:08:30	1	*	12:45:15	3	S	1	–	13:05:15
F005	*	11:10:00	–	GZ	12:10:00	1	S	–	2	12:50:00
F006	*	09:55:10	–	SH	12:08:30	1	M	–	0	12:08:30
F007	BJ	12:10:20	1	*	13:15:30	4	S	1	–	13:35:30
F008	BJ	12:11:00	1	*	12:55:00	3	S	0	–	12:55:00
F009	GZ	12:08:45	1	*	12:42:35	3	L	0	–	12:42:35
F010	*	11:03:00	–	BJ	12:13:00	1	S	–	2	12:53:00
F011	*	10:54:15	–	BJ	12:15:55	1	M	–	0	12:15:55
F012	SH	12:11:00	1	*	13:05:00	4	S	0	–	13:05:00
F013	*	11:01:50	–	SH	12:14:50	1	M	–	0	12:14:50
F014	*	09:35:10	–	GZ	12:11:10	1	L	–	0	12:11:10
F015	*	11:17:50	–	GZ	12:14:50	1	S	–	0	12:14:50
F016	BJ	12:16:00	1	*	12:59:00	3	S	0	–	12:59:00
F017	SH	12:16:30	1	*	14:05:30	–	M	0	–	14:05:30
F018	*	11:06:00	–	BJ	12:18:00	1	S	–	0	12:18:00
F019	GZ	12:18:10	1	*	14:22:10	–	M	0	–	14:22:10

Airport capacity curve and operational requirements known each busy airports, for the model parameters, we are not easy to give ground delays for Consideration and circling delay unit time per unit time for each flight, this time, given only ground and air units delay the expense ratio of 0.3; in order to distinguish between different models, given the expense of medium-sized aircraft delay ratio of 1.2 and delay costs of small models ratio of 1.5; for each flight delays for the maximum number of ground and air time delay circling the maximum number of times, simply use the maximum delay time is 3 instead; continuous flight ground flight rest periods is one.

5. Conclusions

As can be seen from the table above, each of the optimization results, as we had foreseen, some flights were delayed as appropriate, to the various airlines at the lowest economic cost to transport aim.

We want to empty the unit delay than the cost of the smaller the better (here to 0.3), so if assigned to a flight delay circling a waiting period, the value of the objective function will increase a lot, which is equivalent to seeking the objective of minimizing function adds a lot of punishment, said the results of the optimization minimize the delays for the circling; for different models (big L, the M, small S), where large L, the M, S all types of small flights the ,,, successively reduced, most likely to be small flight of more delay (including ground and air).

But as we said, because we are a non-real-time multi Airport general model of open network traffic management system as the basis to solve, the model does not consider the case of cancellation of flights, so flights are planned operation has been allocated, this is compared with the requirements of the actual situation, a bit biased theoretical. In practice, researchers should work with various airlines and air traffic control authorities to establish the flights can be canceled more complex models, in this case, because some plans may delay too long flight was canceled, so will see flights operating plan has not been fully allocated.

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