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Operational Practices of Collaborative Trajectory Options Program(CTOP) in Sanya FIR

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***Abstract*—with the rapid development of the economy, China's air transportation volume has maintained a high growth rate of about 10% per year for nearly ten years. The consequent ever increasing air traffic congestion and flight delays have also made the Authority aware of the importance of air traffic flow management. It is clearly stated in the relevant planning and development report of the Civil Aviation Administration that an air traffic management system with air traffic flow management as the core should be established. Collaborative Trajectory Options Program (CTOP) is a tactical traffic flow management initiative (TMI). Compared to the traditional TMI such as minutes in trail (MIT) or ground delay program (GDP), the aircraft no longer passively receives the Calculated Takeoff Time (CTOT) or delay assignment (DA) given by the Air Traffic Control (ATC). Through the process of Collaborative Decision Making (CDM), airlines can send route preference to the automation system used by ATC. According to the Trajectory Options Set (TOS) submitted by the airlines, the ATC can regulate the overloaded air traffic by allocating ground delay, re-route or both, to each flight in a more reasonable manner. Such choices can effectively improve operational predictability, and are also effective in reducing operating costs and improving passenger experience. This paper describes the core concepts of CTOP and the application practice of this TMI in Sanya Flight Information Region (FIR) of China.**

Keywords—FCA, CTOP, AFP, air traffic flow management, traffic management initiatives.

I. Introduction

The tactical traffic flow management phase usually refers to the day of operation[2]. When capacity and demand imbalance of a certain airspace unit (an airport, a waypoint, or a ATC sector) will occur or have occurred, it is necessary to use some TMIs. When the constrained airspace unit is an airport, the GDP program is usually used, in reference to the Scheduled Time of Arrival (STA) of each flight, and also the Airport Acceptance Rate (AAR) of the airport, we can do the sequencing calculation and allocate each flight with a Calculated Time of Arrival (CTA), then CTOT equals CTA minus on-route flying time, and then each flight gets a CTOT, and a certain amount of delay too. In this case, there is no other option for the flight but to wait on the ground. However, if the restricted source is a sector or waypoint in the air, the flight operators can have another choice.

For example, for a flight departing Hong Kong to Shanghai, the usual route should be the yellow one as shown in Figue1, but if the weather near IKATA causes a significant drop in the capacity of that part of the airspace (flight constrained airspace, FCA), the corresponding ATC unit may issue flow control (e.g. 30 minutes for flights crossing IKATA regardless of level) to regulate the traffic counts over IKATA, which may result in long delays. If a flight choose an alternative route (the red one in the figure), it may need to be waiting less time (or zero time) on the ground but fly an extra distance with more fuel being consumed. Which way is more suitable depends mainly on the delay time a flight is assigned and how much it costs to fly that extra distance.

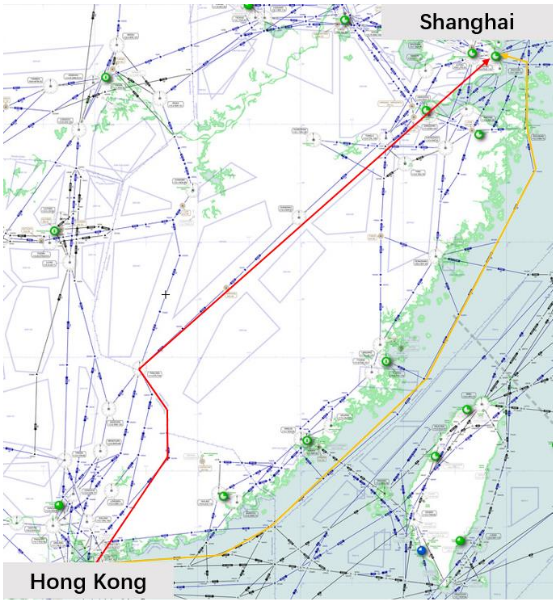

Figure 1. Two Different Route Options

For each airline, even for different aircraft types of the same airline, these cost-effective calculations may get different results, which means that even facing almost the same scenario, different flights choose differently. So a fixed set of coordination mechanisms and information sharing procedures need to be developed in advance to provide more flexibility and predictability for all stakeholders including ATC, airlines and airports.

CTOP is a TMI designed to manage air traffic through constrained airspace leveraging the use of one or more FCAs while considering flight operator's preference with regard to both delay and route as defined in a Trajectory Options Set (TOS). The TOS allows the flight operator to better manage flights by expressing delay and route preferences. Whereas a traditional flight plan contains a single request with a defined route, altitude, and speed, a TOS may contain multiple trajectory options with each one containing a different route, altitude, or speed. In addition to multiple options within a single TOS, each option may contain “start” and “end” times which they are willing to accept for that particular option. Each option will be ranked in the order of customer preference indicating their willingness to accept one option over another. This will be expressed in minutes of ground delay. Using calculation algorithms comparing capacity and demand, the CTOP will look at each trajectory option and determine the amount of ground delay that would need to be associated with that option (which may be zero). CTOP will then assign the most preferred trajectory available. Customers must file flight plans in accordance with the TOS option assigned. Customers may manage their flights through the use of the TOS or through the substitution of flights.

II. KEY CONCEPTS OF CTOP

Flight Constrained Area (FCA) refers to an area where the capacity is greatly reduced by factors such as thunderstorms and military activities. ATC limits the number of flights that will enter the FCA by setting up FCAs and their according acceptance rates to avoid ATC sector overloading. Usually, when an FCA is established, flights flying through the constrained area will be subject to varying degrees of ground delay. Meanwhile, for each FCA, a capacity is given by the ATC, and then, flight operator will be assigned either a route assignment that avoids the CTOP or a combination of assigned route through the CTOP and a CTOT.

A. TOS , RTC and Adjusted cost

During a CTOP process, a core concept is that flight operators can share their preference regarding routes and delays with ATC in the form of TOS. The TOS is an electronic message sent by the flight operator to the ATC, which contains up to 5 track options. The following is an example of TOS (Table1 and Table2) [3][4].

TABLE I. FLIGHT ID

ACID	DEPT	DEST	EOBT	TYPE	ETOT
CCA123	CTU	PVG	1830	B787	1852

TABLE II. TRAJECTORY OPTION SET (TOS)

RTC	RMNT	TVST	TVET	Route	ALT	SPEED
0				R1	350	430
15				R2	370	435
40		1830	2130	R3	330	425
60	25	1830	2130	R4	370	430
80	40	1830	2130	R5	350	430

As can be seen from the above table, in addition to traditional elements such as route, altitude, and speed, a trajectory option also includes the Trajectory Valid Start Time (TVST) and Trajectory Valid End Time (TVET) which are the earliest and latest acceptable take-off times for that TOS option, respectively, and Required Minimum Notification Time (RMNT) which allows for flight's preparation time, such as boarding the passengers. Each trajectory option is evaluated by flight operators through the use of Relative Trajectory Cost (RTC). After the flight operator's assessment, the RTC is expressed in minutes, indicating that the cost of selecting a certain route is equivalent to the amount of additional delays. Take Table2 as an example. Among all the five trajectory options, the first option is the most desirable one unless the flight is to be delayed over 15 minutes, and the operator would then prefer the second option until the delay continues to reach 40 minutes, and so on.

ATC allocate the routes to flights on a first-scheduled-first-service basis according to their earliest Estimated Time of Arrival (ETA). This is the fundamental version of Ration by Schedule (RBS). For a given flight the CTOP algorithm calculates an adjusted cost for each route option and then assigns the route option with the least cost to the flight. The besic equation here is:

Adjusted Cost = RTC + Required Ground Delay[6]

The required ground delay is that the CTOP algorithm calculates to each route option based on current constraints and available time slots, which means even the flight choose another route, it still needs to be held on the ground for a certain amount of time. As shown below:

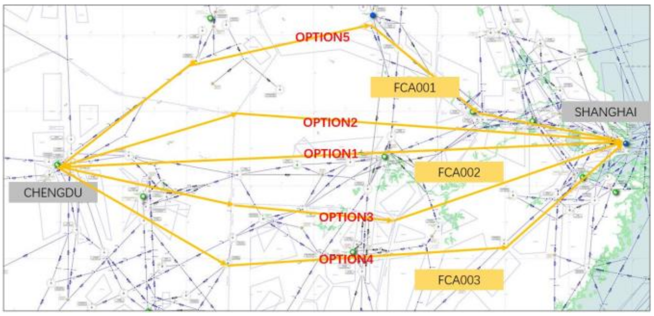

Figure 2 Trajectory Options in the TOS

For every of the 5 options, the according required ground delay is 50,30,50,25,0 minutes respectively. So now it's easy to figure out which route will be assigned to the flight.

TABLE III. ADJUSTED COST COMPARISON

Adjusted Cost= RTC+ Required Ground Delay				
Route1	50=	0	+ 50	
Route2	**45=**	**15**	**+ 30**	**√**
Route3	90=	40	+ 50	
Route4	85=	60	+ 25	
Route5	80=	80	+ 0	

Although flight operators can submit TOS at any time, we still recommend that they submit as early as possible. Because if submitted too late, RMNT may also affect the calculation of adjusted cost. For CCA123, its scheduled departure time is 18:30, assume current time is 18:00, the RMNT indicates that if the operator chooses route 5, this flight can only depart after 18:00+40minutes=18:45, so the required departure time for route5 is actually 15 minutes, and the adjusted cost is actually 95 minutes.

B. Basic Steps Of CTOP

In the implementation of the CTOP, the following steps are usually followed.

First, determine which flights need to be included in the program. It is necessary to understand that some long-haul flights may have taken off at the beginning of the CTOP or some flights can be specified as very important flight by the authority. These flights are usually exempted flights, so the CTOP program should first consider these exempted flights, assign route to them, and then allocate the remaining resources to each other flight.

Then, do the sequencing using ETA. It should be noted that the ETA of a flight is the earliest time of all the route options in the TOS submitted by the flight operator, which can enter the FCA according to the scheduled departure time of the flight.

At last, calculate the adjusted cost for each option included in the TOS, and assign flights with their most preferred TOS option[7].

C. RTC Determination

CTOP concept requires users to provide Relative Trajectory Cost (RTC) information to the ATC for each trajectory in the TOS.

The calculation mechanism of RTC is relatively complicated, and there is not a uniform standard at present. according to the research of Ivan Tereshchenko, Mark Hansen, Robert Hoffman and Bert Hackney[5], they have developing Utility Maximization Framework, Random Utility Model Framework and Latent Class Model with Availability Component for RTC prediction.

Anyhow, the following factors are agreed to have influence on the RTC determination[8]:

- ✧ Cost of delay of a specific flight
- ✧ Cost of fuel consumed
- ✧ Cost of expenses (such as crew labor)
- ✧ Cost of time on the airframe and engines from a maintenance and depreciation perspective
- ✧ Direct and reputational costs of delaying and misconnecting customers

III. Operation Practices In Sanya FIR

The reason why the CTOP trial operation was set up in Sanya FIR is mainly based on the following considerations: First, the Distributed Multi-nodal ATFM project involving many countries in Southeast Asia has been carried out for several years, from the initial table-top simulation to the current daily trial operation, the participants have accumulated considerable experience in this process. Second, in addition to GDP and AFP, re-route is also the usual TMI used in Southeast Asia, thanks to the convenience and efficiency of the approval of the flight plan for flight going through ocean area , and CTOP itself can be regarded as a combination and upgraded version of GDP,AFP and re-route altogether[6][9].

In Sanya FIR, CTOP is to be used aiming to regulate traffic departing from South East Asia to North Asia via route A202, A1 and M771.(Figure3).

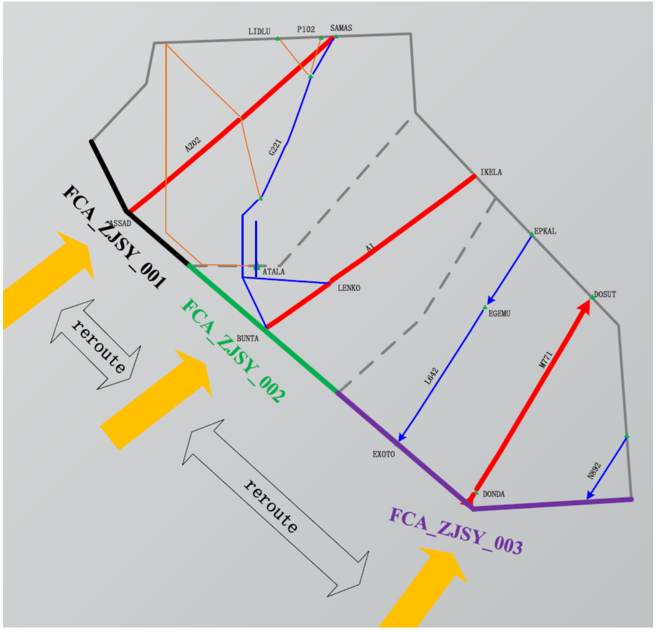

Figure 3. Sanya FIR and FCAs

As shown in the above figure, on the day of CTOP trial operation, ATC sets up three FCAs in Sanya FIR, and the acceptance rate of each FCA is different. In the mean time, for simplicity, the ‘FCA’ here not only indicates the constrained area, but also refers to other restricted airspace units, such as waypoints or airports[7].

After the FCAs are defined, the ATC identifies the scope of flights that are to cross or land at these three FCAs. For some flights, however, that are already airborne when the CTOP is activated, which departed from very long distance or included within any superior priority, should be exempted from the program. Those exempted flights are assigned entering slots on a first-come-first-service basis, and they will also reduce the available capacity of the FCAs.

Then ATC will notify the operators to submit TOS for each flight which is included in the CTOP. At present, the notification work could be done either by visiting web portal or Email, for race cases, it can also be done by telephone. In the first several times of trial, several airlines were not familiar with the concept and procedure of CTOP, so it takes a lot time to explain what they should do, like choosing possibly another route extracted from historical data[8].

In a specific case, the CZ358 was flown from Bangkok to Guangzhou. The estimated departure time is 11:55. Due to FCA restrictions and thunderstorms at Guangzhou airport, if the flight chooses to fly along the original planned route, its ground delay time would be 80 minutes. The operator then considered that if ATC can approve, route A1 might be another choice. After analyzing, it is found that the extra distance required to take the A1 route is equivalent to waiting on the ground for 70 minutes. After ATC receives the TOS submitted by the operator, ATFM system calculates that if the flight chooses to take the A1 route, it can be released at scheduled departure time. Therefore, the adjusted cost of the flight according to the original plan and the re-routing of the A1 route is 80 and 70 respectively, so the operator decided to take the A1 route.

By checking the statistics, we found that through the implementation of the CTOP program, the maximum drop of adjusted cost can be reduced by 60%. CTOP itself is getting more popular with the airlines. More operators and airlines want to get involved in the trial operation.

There are also some practical difficulties encountered in the implementation process, including the following aspects:

First, the level of air traffic management in different countries in Southeast Asia varies, and the generation of TOS itself requires some extra workload, which is difficult for some small airlines;

Second, about the transmission of TOS information, the efficiency of email or telephone is not satisfied. In actual operation, the timing of decision-making may be missed due to poor communication methods.

Third, regarding RTC calculation and route and departure slots allocation algorithm, there is no unified standard yet, and further research and improvement are needed.

IV. CONLUSIONS

According to the application feedback of CTOP in the U.S. and Europe, as well as trial operation in Sanya FIR, CTOP will for the first time allow the operator to electronically negotiate trajectory options around weather and other system constrains in line with what works best for them. what CTOP comes on line, if there is a constrained piece of airspace system, and CTOP is chosen, those operators that are ready and willing to participate CTOP, will be in a great advantage in terms of being able to avoid delay and save costs[10].

It's shifting ATC from telling the operators what the delay is, or what route assignment to fly, to let the flight operators provide ATC with route preference, it enhances the CDM process, and ATC is able to better maintain the safety and capacity that's available within the system[11].

Over the next phase, it’s very important that all the participants are on board with the requirements for automation or on other words how can they make their systems talk to CTOP and to understand exactly the flexibility that they are going to be given for the first time, that's very different from the way we have been doing business before [12].

This is going to be a win-win scenario that business of aviation can benefit from the increased flexibility and efficiency and ATC can benefit on their side through being able to leverage all the automation and manage constrains through ATFM system.

The relatively flexible airspace use mechanism in the South China Sea region enables it to be a good environment for CTOP trial operation. With the continuous advancement of China's military and civil aviation integration work and the continuous implementation of airspace refinement work, the future prospects CTOP application in mainland China are very promising.

We will continue to study the relevant operational mechanism of CTOP, especially in the decision-making algorithm, aiming at formulating a mechanism that is in line with our own operational characteristics while considering comprehensively the various factors such as fairness, efficiency, availability, etc., so to lay the foundation for the fully promotion of CTOP.

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