Research on Control Positions Allocation Based on Controller Workload

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Abstract—With the rapid development of the civil aviation industry, more and more aircraft sorties operate within limited airspace resources. It is necessary to finely manage the equipment resources of sectors/control areas and control units to ensure the safety of aircraft operations. In order to ensure the safety of the control operation, each job of the control position of the air command should be reasonably allocated to achieve the purpose of optimizing the allocation of control resources. Firstly, the factors that affect the control positions for air command and the various components that constitute the workload of the controller are studied. Then, the three-scale Analytic Hierarchy Process (AHP) is used to determine the weight of each factor that affects the position allocation. It is to establish the workload system that affects the control position allocation. Finally, a control position allocation method for air command based on the workload of the controller is proposed in the case of ensuring the safety of the control operation.

1. Introduction

Air traffic controllers (hereinafter referred to as controllers) issue various control commands to the aircraft through communication, surveillance, and other auxiliary equipment to ensure that they can operate safely and effectively, occupying an important position in the flight of the aircraft. Those involve all process of launching, taxiing, takeoff, landing and other aircraft operations [1]. The factors that affect the safety of the controller to command the aircraft are not only the controllers of the control command post that directly communicate with the pilot, but also the controllers of other control posts, including the controller responsible for monitoring duties, and the controller responsible for coordination. It may also include the reliability of regulatory aids that perform monitoring functions. Under the premise of ensuring control safety, how to configure the control positions reasonably has become an urgent problem to be solved.

Air traffic control requires control, monitoring, and coordination of three jobs/positions, overall planning, reasonable division of labor, and collaboration to complete the command safely. The negligence or slackness of the duties of a job/position will affect safety and operational efficiency of control operations. The Civil Aviation Administration of China formally implemented the “Civil Aviation Air Traffic Management Rules” (CCAR-93-R5) on May 1, 2018, which canceled the “More than 2 (including) licensed controllers should be on duty at the control positions in the tower, approach, and regional control rooms”. That means the positions responsible for monitoring duties should be configured without rigid regulations. Each air traffic control unit can consider various factors to configure control positions based on the actual situation of the unit [2].

According to the investigation and analysis of air traffic control units, since there is no upper-level legal basis for the allocation of air control command positions, the current civil aviation air traffic control units are still maintaining the previous practice. Configure a monitoring position or a position with monitoring responsibilities (such as coordinated and monitoring positions) to effectively monitor the
communication between the controller and the pilot of the control command to ensure that the control commands issued are accurate and correct. However, it takes a long period to train a qualified controller (capable of independent command), and due to work pressure and nature, the phenomenon of controllers changing jobs frequently occurs, which causes greater pressure on the human resources of the air traffic control unit. In addition, the control unit needs regular training and re-training of the controller every year, and needs a large amount of funds to support these. In the case of the new version R5 "Civil Aviation Air Traffic Management Regulations" no longer requires the controller "dual-positions" clearly, how to optimize the control of human resources and rationally configure the air control command positions has become the urgent need of the control unit to solve problem. Therefore, it is a general trend to carry out research on the allocation methods of control positions.

2. Control position allocation rules for air command

2.1 Influencing factors of control position allocation for air command

The quality of the air control position configuration directly affects the control operation efficiency and control safety. If the configuration is unreasonable, it will affect the control operation efficiency, and it will also cause a great hidden danger to the aircraft operation safety. Therefore, each air traffic control unit should comprehensively consider the actual situation of its own unit, and reasonably allocate various jobs for air control positions, including the capacity of the controller, the complexity of the sector environment, the coordination of the command post and the monitoring post, etc.

The factors that affect the allocation of control positions for air command are mainly divided into the following three categories: people, environment, and equipment. The person refers to the controller. The ability level of the controller directly affects the position configuration. If the control level is high, and the flight flow is appropriate, you cannot set up a special monitoring position for the controller. Besides, you can also coordinate work concurrently, so that only one position is needed to complete the air command.

There are many factors included in the environment, which are roughly divided into the airport environment and the sector. See Table 1 for details:

| Environmental factors affecting the allocation of control positions |
|---------------------------------------------------------------|
| **Influencing factors of airport environment**                |
| Runway configuration | Number of runways |
| Taxiway configuration | Number of taxiways |
| Airspace structure near the airport | Flight trips entry and exit per hour |
| ……etc.            |
| **Influencing factors of control sectors**                    |
| Airspace structure | Intra-sector flight flow |
| Number of air routes (lines) in the sector | Number of airway intersections in the sector |
| ……etc.            |

Equipment mainly refers to auxiliary equipment that can perform monitoring duties, mainly by obtaining monitoring data (radar, ADS-B, MLAT, GNSS data, etc.) and other information, etc. Then, by establishing a model algorithm to determine, that equipment can judge whether the command issued by the controller is consistent with the altitude set by the pilot, whether there is a flight conflict with the aircraft in the jurisdiction, and whether it is consistent with the altitude of the click on the sign, it can avoid the risk of potential hidden dangers the controller’s and the pilot’s themselves.

2.2 Controller workload

As can be seen from the previous section, there are many factors that affect control command positions, and each air traffic control unit has different requirements for command control positions due to the different personnel capabilities, airspace structure, airport environment and equipment configuration. The method and configuration requirements are also different. The appropriate allocation principles and
requirements in a certain place may not be suitable in other units. It is more complicated to configure the control positions for air command by comprehensively considering so many factors. In order to reasonably configure the control command positions under the condition of simple configuration and feasible operation, it can be set according to the workload of the controller. In the final analysis, air traffic control is controlled by controllers, and the work of controllers in aircraft command is divided into three categories according to categories:

1. Control and command. That is, the job responsibility of the control position, responsible for conducting radiotelephony communication with pilots and issuing control instructions.
2. Coordinate. Responsible for coordination with other units, including other departments of this unit, airlines, airports, military and other units or companies.
3. Monitoring. Responsible for monitoring the control position, including the accuracy of issuing instructions and the accuracy of clicking signs. In different units, the monitoring responsibilities may be different. The monitoring positions of some units are only responsible for monitoring the control position, but not others. And some monitoring positions need to click signs according to the requirements of the control position. The monitoring positions of some units need to repeat all the actions of the control position, except for radiotelephony.

The workload of the controller includes physical and mental aspects. The sources of the workload mainly include: radiotelephony communication with pilots, coordination with other units, flight sorties within the jurisdiction, complexity of the airspace within the jurisdiction, and the difficulty of the airport environment, etc. Among them, each source is related to mental and physical aspects [4].

3. Control position allocation method based on three-scale analytic hierarchy process

The control positions for air command generally have three responsibilities: control command, monitoring and coordination [5]. According to the content and workload of the controller, position allocation can be divided into three stages:

Firstly, the controller conducts control and command under the conditions of low flight flow, simple airspace environment, no military aviation activities, and good weather conditions, that is, the deployment of aircraft has fewer separations and few potential conflicts. Currently, a qualified controller is fully qualified for the control work of this position.

Secondly, as the flight flow is large, the airspace structure is more complicated, or military aviation activities occur, or the weather is poor, or there are major activity guarantees, etc., the pressure of the controller is gradually increasing, and the load is also increasing. When the controller oversees the control command and cannot perform the necessary coordination work, then the coordination responsibilities need to be assigned to other people. At this time, an additional position needs to be set up: the coordination position. At this time, the controller controls and directs the aircraft with clear thinking and proper command, and there will be no low-level errors or potential hidden dangers.

Finally, as the control command pressure increases, the flight flow or the deployment separation may cause the controller to make some potential low-level errors or errors. Or, as the control pressure increases, the controller feels more and more tired, and at this time additional monitoring position is needed. This is done to monitor the accuracy of the instructions issued by the controller of the control command position, and at the same time be responsible for some click signs to reduce the pressure of the control command position [6].

3.1 AHP

AHP is a practical multi-plan or multi-objective decision-making method. It is a qualitative and quantitative decision-making analysis method. It is often used in multi-objective, multi-criteria, multi-element, multi-level unstructured complex decision-making problems, especially strategic decision-making problems. It has a very wide range of practicalities. Generally, a 9-level scaling method will be used. By comparing each level and each index element, and then forming a judgment matrix, and then using MATLAB calculation and analysis, the mutual weight coefficients between the indexes are finally determined. However, because the 9-level scaling method is in operation, experts have different
interpretations and understandings of such methods, and there is a certain degree of difference. Compared with the nine-level scaling method, the improved three-scale method can make it easier for experts to construct the matrix. This avoids the shortcomings of excessive calculation, large deviation, strong subjectivity and complicated operation in the evaluation process of traditional methods [7].

3.2 Allocation method for air command and control positions
In summary, each air traffic control unit can configure the control seats for air command based on the controller's workload and the actual situation of the unit. Use the analytic hierarchy process to construct an index system, a mathematical model and comprehensive evaluation for each factor that affects the controller's workload are established, and the controller load value for setting up the coordination position and monitoring position is determined [8]. The specific steps are as follows:

1) Determine the factors that affect the allocation of control positions for air command. Influencing factors include the length of the controller’s effective call (including calls with pilots and various coordinating units), the complexity of the airspace structure of the control area, the scope and frequency of military aviation activities, the scope and frequency of major activities, the severity of weather conditions, and aircraft flying sorties, auxiliary equipment with monitoring responsibilities, etc.

2) Construct an index system (A) that affects the allocation of control positions for air command. Among them, the criteria-level indicators include call duration (B1), airspace environment (B2), other indicators (B3) and auxiliary equipment (B4), and 12 quantifiable sub-indices are selected for analysis and evaluation (Each control unit may choose different sub-indices because of its different environment, but it is feasible as long as it conforms to the actual situation of the unit.), as shown in the figure1.

3) Use the three-scale analytic hierarchy process to determine the weight of each factor. Since the actual situation of each control unit is different, including airspace environment, controller capacity, military aviation and major activities, etc., the conditions for forming weights are also different. This requires each control unit to invite the local frontline according to the actual needs of the unit. The controller or senior expert judges and scores the various factors that affect the allocation of air control positions by the unit. Then, it needs to construct a three-scale judgment matrix and consistency test. If the consistency ratio is passed, the consistency test is passed; otherwise, the three-scale judgment matrix is re-constructed until it is satisfied, to obtain the index of the criterion layer(B) and the sub-indices of the scheme layer(C). Weights. Finally, determine the weight value of each sub-indicator of the scheme layer(C) relative to the target layer(A). For example: effective call duration C1, controller workload weight value W1=0.152 (if, the same below) that affects seat configuration; call duration C2 with pilots, weight value W2=0.157; call duration C3 with other units, weight value W3 = 0.092.

4) Establish a load value system for various factors that affect the allocation of air command and control positions. Each control unit determines the weight value of each sub-indicator of the plan layer.
(C) relative to the target layer (A) according to the actual situation in the jurisdiction, for example: continuous call duration (T, unit: hour). If T is less than or equal to 0.5, the load value is 0.2 (If, the same below). If T is greater than 0.5 and less than or equal to 1, the load value is 0.5. If T is greater than 1 and less than or equal to 1.5, the load value is 0.8. If T is greater than 1.5, the load value is 1. Then, the load value of each factor is multiplied by the corresponding weight, and the workload value of the controller can be obtained.

(5) Each air traffic control unit determines the load value (FH) for setting up coordination positions and monitoring positions according to its own situation. Because different control units have different situations, they should combine the specific conditions of their own units, based on soliciting the frontline controllers of their own units, and through the actual experience of the controllers, they can reasonably determine the load value of the coordination position (assuming load value FH=f1) and monitoring position (assuming load value FH=f2).

(6) Combining the above circumstances and according to the dynamic variables of the controller's workload, the control unit should reasonably set up various positions or seats for air command. The airspace structure of a controlled jurisdiction is basically unchanged within a certain period. The conditions of airport runways and taxiways are also unchanged, so these factors affect the load value of the position configuration at a certain stage. The dynamic variables that affect the allocation of positions are related to the length of the call, military aviation activities, severe weather conditions, and the number of flights. As the length of time the controller controls the command increases, the value of the controller's workload also changes. When the load of the controller reaches the load value of the coordination position and monitoring position, the control unit should set the corresponding coordination position and monitoring position.

The basic flow of this method for allocating control positions for air command is shown in Figure 2:
Control position for air command
(Control Command Position)

Determine the factors affecting the allocation of control positions for air command

Clarify the weight of each factor

Establish a load value system in which various factors affect the allocation of positions

Set the load values of the coordination positions and monitoring positions to $f_1$ and $f_2$

Calculate the workload value $F_H$ of controller according to the control command time and changes in various factors

Set up coordination positions.

Calculate the workload value $F_H$ of controller according to the control command time and changes in various factors

Set up monitoring positions

End

Figure 2: Flow chart of the control position allocation based on the three-scale analytic hierarchy process.
4. Summary
With the rapid development of civil aviation transportation, flight traffic has also grown rapidly. The workload of controllers is increasing with limited airspace resources, the division of sectors is increasing, and the number of controllers required is also greater. However, the number of graduated controllers is limited each year, and the period of training a qualified controller is longer. This requires a reasonable allocation of control positions for air command to achieve the purpose of rationally optimizing and controlling human resources. The allocation method of air command and control positions based on the three-scale analytic hierarchy process is based on the reasonable allocation of control resources, the airspace environment, flight sorting, controller capacity and dynamic load during the controller working. These not only ensure the safety of control operations, but also have important implications for the configuration of control seats, equipment and human resources for air command of control units.

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