

# The Establishment of Multi-goal Dispatch Algorithm Model of the Airport Special purpose vehicle

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**Abstract**—With the continuous development of domestic aviation industry, the number of special purpose vehicle serving for aircrafts within the airport is increasing. Owing to the high cost of the special purpose vehicle, airport management personnel becomes more and more concerned about the following problems, including how to dispatch the vehicle in a reasonable way, how to ensure that the vehicle can run safely and efficiently, and how to ensure that the flights can take off on time. This paper makes a particular introduction about the intelligent schedule system for the special purpose vehicle within the airport at first. This paper not only summarizes the intelligent scheduling system of the airport special purpose vehicle briefly, but also sets up the dispatching model of the airport special purpose vehicle, which can efficiently guarantee the operation efficiency and the operation security of the special purpose vehicle at the airport, and save the cost of the vehicle operation.

**Keywords**- *special purpose vehicle at the airport; intelligent scheduling; multi-goal model; dispatching model; heuristic algorithm*

## I. INTRODUCTION

With the rapid development of Chinese civil aviation industry, the size of airline expands increasingly. At the airport, the takeoffs and landings of the airplanes are so frequent that various customers of aviation shipping industry ask for the higher quality of the airport ground service. Therefore, the special purpose vehicles of airport ground service are increasing day by day. Faced with the immense challenge, the airport ground operation departments have to consider the problems, including how to manage the more and more special purpose vehicle effectively and reasonably under the limited space, how to promote the operation efficiency of the special purpose vehicle of the ground service fully, how to ensure the accuracy rate of the scheduled flights, as well as how to save the resources cost of the special purpose vehicle[1].

The overseas researches about the dispatching problems of the airport special purpose vehicle are mainly concentrating on the reliability allocation of the ground resources, the human resources management as well as the equipment maintenances and so on[2]. The earliest research derives from Baker [3]; the perseus system was developed by the German airline Lufthansa to carry on the plan and the real-time dispatch of the passenger service staff [4]; Neiman with his research team develop the multi-Agent Dis-DSS system for dispatching the airport special purpose vehicle [5], which has not got the in-depth research in the algorithm optimization for the dispatching.

In China, the management of the airport special purpose vehicle is mainly basic on the practical experience or operational research. At the present exploratory stage of the research of the dispatching of the airport special purpose vehicle, there is little research achievement which can be learnt about. Liu Yudong et al., from BUAA, have solved the dispatching problems of the airport operation by using the resource-constrained project approaches[6]; Liu Chang et al., from CAUC, have been researching the different problems about the airport special purpose vehicle, such as the arrangement of the airplane's gate position, the process of the airport scheduled flight arrivals and so on[7]. Above-mentioned correlation research mostly aims at the partial questions of the research; however, this article has applied the theory research results in the actual production system to further study, which will realize the general dispatch optimization and carry on a synthetical implementation to the system.

## II. THE ESTABLISHMENT OF DISPATCH ALGORITHM MODEL

### A. *The intelligent scheduling system of special purpose vehicle at the airport*

The intelligent scheduling system of special purpose vehicle at the airport consists of two parts: car-mounted terminal subsystem and monitoring and dispatching

platform subsystem, as shown in Fig.1. At first, the locating information of special purpose vehicle at the airport can be received by GPS Receiver Unit. Meanwhile, the basic information of special purpose vehicle at the airport processed by the car-mounted terminal subsystem, as well as the locating information, can be sent to the monitoring and dispatching platform subsystem by wireless data transmission system. After that, the vehicle location can be shown on the electronic map of the monitoring and dispatching center so that the real-time monitoring can be realized, which can send the relevant monitoring information to the car-mounted terminal subsystem via counting the information of the flights at the airport and vehicle operating condition. Finally, the car-mounted terminals can carry out the dispatch function by dispatching the vehicle at the airport.

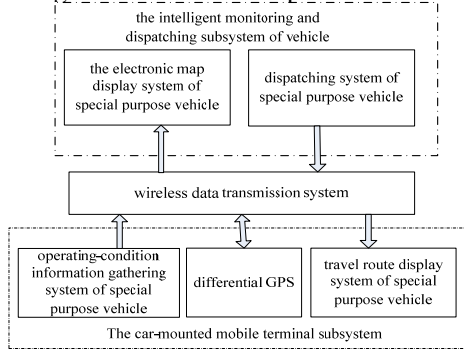


Figure 1. Schematic diagram of the monitoring and dispatching system of the airport special purpose vehicle

### B. The establishment of dispatching model

The airport apron stipulated that the special purpose vehicle under steam must follow the specific route. Therefore, the travel distance between the different services is fixed. At the same time, airport special purpose vehicle travels at a fixed speed. So, transfer time of vehicles between different services can be used to describe the service travel distance. The transfer time of vehicles between different services is smaller than as far as possible or is equal to the resident time of scheduled flights at the airport. Otherwise, it will cause the flight delay. When considered the shortest total distance, the lowest total expense, the smallest number of vehicles used, taking the minimum total quantity of scheduled flight delay is the first goal. In order to avoid the uneven scheduled flight delay time, namely the imbalanced special purpose vehicle operating time, minimizing variance of the scheduled flight delay time takes the second goal.

In a planning cycle  $H$  of some airport, there are  $N$  flights arriving at the airport in proper order. The hypothesis of the first goal sets as minimizing the total number of scheduled flight delays in time  $H$ , which is caused by the special purpose vehicle, expressed as follow:

$$\min \sum_{i=1}^N \text{sgn}(d_i) \quad (1)$$

Firstly,  $d_i$  is for scheduled flight delay time, and sign function  $\text{sgn}(d_i)$  can be used to judge whether the flight  $i$  delay or not. When  $d_i \geq 0$ ,  $\text{sgn}(d_i) = 1$ , otherwise, value is 0.

Secondly, in order to avoid the individual scheduled flight delay time is too long, and ensure the delay time of delay flights is balanced, the second goal setting as follows:

$$\min \sqrt{\sum_{i=1}^N \text{sgn}(d_i)(d_i - \bar{d})^2} \quad (2)$$

where

$$\bar{d} = \sum_{i=1}^N d_i / N \quad (3)$$

is the over-carriage scheduled flight average delay time in time  $H$ .

For the trailer hauling starts to carry on after the parallel workflow is all completed, then the start time of the trailer hauling service permitted by scheduled flight will be equal to the last parallel service time, that is:

$$T_{i,m}^r = \max_{m \in \{1,2,\dots,M-1\}} y_{i,m,k} (t_{i,m,k}^l + s_{i,m}) \quad \forall i = 1, 2, \dots, N; k = 1, 2, \dots, K_m \quad (4)$$

Where,  $M$  is for the trailer hauling service.

$y_{i,m,k}$  stands for 0-1 variables, which can be used to decide whether Vehicle  $k$  among the  $m$  type of the service vehicles serves for Flight  $i$ .  $t_{i,m,k}^l$  is the start time of the service. According to the experience,  $s_{i,m}$  is the average service time of the same type of Flight  $i$ .

However, the scheduled flight final delay time can be determined when the last item of trailer service time is completed. Thus, the formula as:

$$d_i = t_{i,m,k}^l + s_{i,m} - T_i^d \quad \forall i = 1, 2, \dots, N; k = 1, 2, \dots, K_m \quad (5)$$

A service truck may continuously serve for many scheduled flights. Because of the service in part needed for adding resources for the scheduled flight, such as refueling, watering, extra meal and so on, the corresponding service vehicles can be restricted by the surplus service resources if they work continuously. Service vehicles have certain loading capacity; the same type of service vehicles has the same loading capacity as well. However, the different scheduled flights have the different demands for resources offer. When a service truck serves for two scheduled flights continuously, the surplus amount of resources in the vehicle, after serving the former scheduled flight, must satisfy the latter scheduled flight to this service resources demand, that is:

$$x_{i,j}^{m,k} (c_{i,m,k} - p_{j,m}) \geq 0 \quad \forall i, j = 0, 1 \dots n; m = 1, 2 \dots M \quad (6)$$

$x_{i,j}^{m,k}$  stands for 0-1 variables, which can be used to determine whether Vehicle  $k$  among the  $m$  type of the service vehicles serves for Flight  $j$ , after serving for Flight  $i$ .  $c_{i,m,k}$  is the resources demand provided by the  $m$  type of service.  $i = 0, j = 0$  stands for the service vehicle returning to the garage, which means the service vehicle needs to return to add resources, because the surplus amount of resources in the vehicle, after serving the former scheduled flight, can't satisfy the latter scheduled flight demand. The vehicle resources recruitment must be as much as its loading capacity. Assuming that  $c_m$  stands for

the loading capacity of the  $m$  type of the service vehicles, the formula as

$$c_{0,m,k} = c_m, \quad \forall m=1,2,\dots,M; k=1,2,\dots,K_m \quad (7)$$

What's more, only one service truck is needed to complete all the services demanded by the scheduled flight. That is

$$\sum_{k=1}^{K_m} y_{i,m,k} = u_{i,m} \quad \forall i=1,2,\dots,N; m=1,2,\dots,M \quad (8)$$

When a service truck serves for two scheduled flights continuously, its service time starts no earlier than the time when it has finished serving the preceding scheduled flight and arrive the gate position of the latter scheduled flight.

$$x_{i,j}^{m,k} (t_{i,m,k}^l + s_{i,m} + T_{i,j} - t_{j,m,k}^l) \leq 0, \quad \forall i, j = 0, 1, \dots, N \quad (9)$$

In view of the fact that all types of ground service vehicles are the special purpose vehicle, whose cost is quite high. Therefore, it's thought that all types of the service vehicles are restricted by the resources limit. Especially, when several scheduled flights need to accept the similar service at the same time, a service trucks can only serve for one of the scheduled flights.

$$\text{If } t_{i,m,k}^l \leq t_{j,m,k}^l \leq t_{i,m,k}^l + s_{i,m} + T_{i,j},$$

$$\text{then } y_{i,m,k} + y_{j,m,k} \leq 1 \quad \forall i, j = 0, 1, \dots, N \quad (10)$$

$$\sum_{i=0}^N x_{i,j}^{m,k} = y_{j,m,k} \quad \forall j = 1, 2, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m \quad (11)$$

$$\sum_{j=0}^N x_{i,j}^{m,k} = y_{i,m,k} \quad \forall i = 1, 2, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m \quad (12)$$

$$y_{i,m,k} \leq u_{i,m} \quad \forall i = 1, 2, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m \quad (13)$$

$$t_{i,m,k}^l \geq T_i^r \quad \forall i = 1, 2, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m \quad (14)$$

$$t_{i,m,k}^l \geq T_{i,M}^r \quad \forall i = 1, 2, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m \quad (15)$$

Where

$H$  is planning cycle (8:00-24:00)

$N$  is total number of the scheduled flights needing serving in the time  $H$

$M$  is the number of the types of service vehicle

$i$  is serial number of over-carriage scheduled flights,  $\forall i = 1, 2, \dots, N$

$m$  is serial number of services items,  $\forall m = 1, 2, \dots, M$

$K_m$  is total number of the  $m$  type of the service vehicle

$k$  is serial number of services items, to Service  $m$ ,  $\forall k = 1, 2, \dots, K_m$

$T_i^r$  is the permitted service start time of Flight  $i$

$T_i^d$  is the scheduled departure time of Flight  $i$

$s_{i,m}$  is the average service time offered to Flight  $i$  by the  $m$  type of the service vehicle

$T_{i,j}$  is the time from the gate position of Flight  $i$  to the gate position of Flight  $j$ ,  $\forall i, j = 0, 1, \dots, M$

$p_{i,m}$  is the resource quantity demanded provided by the  $m$  type of the service vehicle for Flight  $i$ ,  $\forall i = 1, 2, \dots, N; m = 1, 2, \dots, M$

$c_m$  is the resource loading capacity provided by the  $m$  type of the service vehicle for Flight  $i$ ,  $\forall m = 1, 2, \dots, M$

$u_{i,m} = 1$ , on the condition that Flight  $i$  need Service  $m$ ; otherwise  $u_{i,m} = 0$ ,  $\forall i = 1, 2, \dots, N; m = 1, 2, \dots, M$

Decision variables :

$t_{j,m,l}^l$  is the service start time of Flight  $i$  offered by Vehicle  $k$  of the  $m$  type of the service vehicle for the  $l$  time,  $\forall i = 1, 2, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m$

When  $i \neq 0$ ,  $l = 1$ ; when  $i = 0$ ,  $\forall l = 1, 2, \dots, n$

$c_{i,m,k}$  is the resource surplus of Vehicle  $k$  of the  $m$  type of the service vehicle, after serving for Flight  $i$ ,  $\forall i = 0, 1, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m$ . On the condition that Vehicle  $k$  of the  $m$  type of the service vehicle serves for Flight  $k$  after serving for Flight  $i$ , otherwise, the result is 0,  $\forall i, j = 0, 1, \dots, N$  ( $i \neq j$ ).

$y_{i,m,k} = 1$ , on the condition that Vehicle  $k$  of the  $m$  type of the service vehicle serves for Flight  $i$ ; otherwise  $y_{i,m,k} = 0$ ,  $\forall i = 0, 1, \dots, N; m = 1, 2, \dots, M; k = 1, 2, \dots, K_m$

$d_i$  is the delay time of Flight  $i$ ,  $i = 1, 2, \dots, N$

In summary, (1) and (2) is the objective. (3) stands for the average delay time of the over-carriage scheduled flight in the time  $H$ . (4) expresses that the trailer service can start after other services have completed totally. (5) means that the difference between the time of the trailer service and the estimated departure time is equal to the flight delay time. (6) ensures that when a service truck serves for two flights continuously, its resource surplus in the cabin must be sufficient for the need of the latter flight.

(7) expresses that the resource surplus of a service truck, when it returns to garage, must be equal to its loading capacity. (8) ensures that the service needed by a scheduled flight should be offered by one service truck for once. (9) means that when a service truck serves for two scheduled flights continuously, its service time starts no earlier than the time when it has finished serving the preceding scheduled Flight  $j$  and arrives the gate position of the latter scheduled Flight  $j$ . (10) ensures that a vehicle must only serve for one of the two scheduled flights, if the service time conflicts. (11) - (12) means that the starting point and the destination of a service truck must be the preceding flight or the latter flight's gate position or garage. (13) expresses that the logical relationship between the variables 0-1. (14) - (15) ensures that the start time which the scheduled flight recipients can offer must not earlier than the service time that the scheduled flight is able to accept.

### III. CONCLUSION

Taking the airport in special purpose vehicle service as a background, this article has studied the intelligent monitoring and dispatching problems of the airport special purpose vehicle, and carried on the modeling to the vehicles dispatching problem by combining the characteristics of the airport special purpose vehicle service. The characteristic of the dispatching model is that the airport special purpose vehicles basically realize that various vehicles to perform its own functions. Because the aircraft parking area at the airport all has a certain limit to the travel route, the moving velocity as well as the current capacity of special purpose vehicle, and the cost is high, therefore, the service process is restricted by the number of the vehicles.

It will has the vital practical significance to apply the dispatching system to the management of the airport special purpose vehicle in China. To a great extent, it can solve the monitoring and dispatching problems of the airport station site vehicles effectively, guarantee the operation efficiency and the operational security of the airport special purpose vehicle, save the operating cost, and has the extremely obvious social and economic efficiency.

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