Research on airport trailer emergency scheduling model based on genetic simulation annealing algorithm

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Abstract. With the increase of air transport business year by year, the airport comprehensive service capabilities are increasingly facing severe challenges. As a key part of airport service, ground scheduling is crucial to the departure of flights on time. By analyzing the traditional rules of airport trailer and combining with the service processes and the characteristics of trailers, the paper develops a multi-target trailer emergency scheduling model with rolling windows. When the model is solved, the simulation annealing algorithm is introduced into the genetic algorithm to prevent the optimal result falling into the local optimal solution. The simulation results show that the model can more effectively solve the problem of airport trailer emergency scheduling in the case of flight delays than the traditional scheme, and to relieve the pressure of flight delay for busy airports.

1. Introduction
With the increase of air transport business year by year, the airport comprehensive service capabilities are increasingly facing severe challenges. As a key part of airport service, ground scheduling is crucial to the departure of flights on time.

At present, most of the airport flight scheduling service is still in the manual scheduling phase [1], adopting the First in first out scheduling strategy. Although the operation is simple, efficiency is low. It is obvious no value for solving the flight delay when the weather suddenly changes, flight delays, special vehicle breakdown and other emergencies. Especially, the ground scheduling of trailers during the flight access to station operation is studied by Jiayan Du [2-3], developing a VRPTW model according to the operation flow of the towing vehicle and minimizing the total scheduling time cost of the entire process. Simultaneously, Xia Feng [4] has established the coordinated scheduling model of refuel tanker and shuttle bus with taking the refueling service and pick-up service time of flights as the constraint, and aimed at the objective of minimizing the number of safeguards and making the total starting time of service earliest, and given model solution based on multi-objective genetic algorithm.

The paper develops a trailer emergency scheduling model, by analyzing the traditional rules of trailer scheduling based on the existent researches and related papers, and combining with the service flow and time characteristics of the trailer, then gives the optimized scheduling scheme.

2. Traditional trailer scheduling strategy
Now, most airports adopt the First in first out strategy in the airport trailer scheduling [5]. The strategy is to select a grouping scheme from the scheduling system, and the grouping which can be completed in the shortest time in the GPS system corresponding to the scheduling system is selected for transmission. Among all the grouping schemes waiting to be scheduled (see figure 1). It is
confirmed that the time which takes for the packet completion service lags behind the time it takes to transmit the longest packet on the process, comparing with the corresponding GPS system [6].

![Figure 1. The structure of traditional trailer scheduling.](image)

When a trailer group arrives, it will be sorted into the corresponding queue by classification. The scheduling system will calculate the completion time of the process, at the same time [7]. Then select the packet with the shortest completion time among the packets as the next packet transmitted from the output port, and the packet period is $T$.

Among them, the scheduling time is calculated as follows: $\nu(0) = 0$, and

$$
\nu(t_{j+1}+T) = \nu(t_{j+1}) = T \sum_{i \in B} \phi_i T \leq t_j - t_{j-1}, j = 2, 3, \ldots
$$

(1)

In the above equation (1), the scheduling of the trailer as one event, and $t_j$ represents the time of the $j$th event finished.

The complexity of the scheduling system is expressed as $O(M)$, and $M$ is the number of connected trailers. In the scheduling process, the $(\sigma, r_j)$ is used as the constraint of scheduling algorithm, and the node trailer scheduling delay as follows equation (2) [8]:

$$
f(\sigma_j, r_j) = \frac{\sigma_j}{r_j} + \frac{L_{\text{max}}}{C}
$$

(2)

Among them, $C$ is the service rate of the server, and $L_{\text{max}}$ is the maximum of the packet length of vehicles.

3. Trailer emergency scheduling model

The paper develops a trailer emergency scheduling model, and gives the optimized scheduling scheme.

3.1. Putting forward of the problem

According to the conventional ground specific vehicle scheduling strategy, the nearest trailer is assigned at the current time, but the actual distance between the current failed trailer and the next trailer in the group is ignored. And the trailer's work flow is chained with strict scheduling rules and time constraints. A change of a link or a group of trailers may cause subsequent trailers to fail to schedule normally and affect the normal launch of subsequent flights. In order to efficiently schedule flights under the condition, it is necessary to optimize the scheduling strategy and improve the level of ground scheduling and security.

So, the paper develops a multi-target trailer emergency scheduling model with rolling windows and gives a certain number of delayed flights and serviceable trailers, we construct a coordinated emergency scheduling model for all kinds of trailers with flight delays and assign them to service...
needed flights according to the traction of trailers, and gives the start time of services in the process of scheduling.

3.2. Model building

3.2.1. Model description and symbolic description

In this paper, the rolling window strategy is used to divide the flight delay time into multiple equal time periods. After that, the flights in each time period are optimized according to their planned take-off time and delay time. In this way, not only can the scheduling plans of delayed flights be developed quickly, but also the real-time processing of flight information can be ensured.

In the actual operation of the airport scheduling, the trailers are divided into three categories called small, medium and large. The specific information is shown in Table 1.

| Aircraft type     | Representative | Carrying capacity | trailer type |
|-------------------|----------------|-------------------|--------------|
| Large airliner    | B747/A340/A380 | Over 200 people   | Large        |
| Medium airliner   | B737/C919/A320 | Between 100 and 200 | Large/Medium |
| Small airliner    | ARJ21/MA60     | Less than 100 people | All         |

Suppose the step size of the rolling window is L, the starting time value is Q, the rolling window is $RW_t$ at time $t$ is taken as $[Q+(t-1)*L, Q+t*L]$. According to graph theory, the multi-target trailer emergency scheduling model can be abstractly represented as a graph $G=(FG, EG, SE, NG)$, where FG represents the number of delayed flights N in the rolling window $RW_t$; EG represents the path from the trailer to the delayed flight position in the rolling window $RW_t$ (N scheduling paths are generated for N delayed flights); SE represents the window on which the towing flight is trailed in the rolling window $RW_t$; NG indicates the number of the trailer in the rolling window $RW_t$ (the total numbers of the trailers is p). For each late flight $i \in FG$, there is a latest departure time $I_i$ (the flight will be excluded in the current window $RW_t$ beyond which the latest departure time) and the time window $SE_i = [s_i, e_i]$ ($e_i < I_i$) [8].

For each scheduling path $k$, $s_{ij}$ represents the time when the trailer $j$ starts to schedule a delayed flight in the flight schedule path $k$, that is the trailer $j$ arrives at the scheduled downtime. If there is a trailer $j$ in the scheduling path $k$, then $x_{ij} = 1$, otherwise $x_{ij} = 0$.

3.2.2. Model assumptions

In the following study in this paper, for the delay of departure flights, the establishment is based on the following assumptions:

- Each flight happens to be towed once.
- The flight has been completed refueling, boarding and other work, the trailer towed to the taxiway can be released takeoff.
- During the process of receiving the towing service, the towing vehicle will not malfunction and other events that affect scheduling will occur.
- Once the trailer has started its work, it will not be interrupted until the end of the service.

3.2.3. trailer emergency scheduling model constraints

Trailer emergency scheduling model constraints is extremely limited and in order to operate safely, all kinds of special vehicles must travel at a fixed path and speed. in the flight scheduling process, the use of the trailer must be in accordance with the "flight-trailer" corresponding mode to draw the flight.
Second, the number of trailers, the departure time of the flight, the constraints in the rolling window 
\[ Q + (t-1) \times L, Q + t \times L \] are now defined as follows.

Due to delayed flight and scheduling path one by one, so there \( x_{ij} = x_{ij} \). For subsequent convenience and verification, the following \( x_{ij} \) is indicated by \( x_{ij} \). The number of trailers and delayed flights as follows equations (3)-(4):

\[
\sum_{a=1}^{1} p_a = P, \quad \sum_{b=1}^{N} n_b = N, \quad i = 1, 2, 3 \ldots N, \quad j = 1, 2, 3 \ldots P. \tag{3}
\]
\[
\sum_{i=1}^{N} \sum_{j=1}^{P} x_{ij} \leq P \tag{4}
\]

Time constraints in the scheduling process are as follows equations (5)-(7):

\[
\sum_{i=1}^{N} x_{ij} \leq O_i, \quad \forall i \in FG \tag{5}
\]
\[
e_{i-1} + T_{i-1} < s_j < e_i \tag{6}
\]
\[
Q + (t-1) \times L < s_j < Q + t \times L, \quad i \in EG \tag{7}
\]

3.2.4. Trailer emergency scheduling optimization goals

According to the actual operation of the airport and the emergency scheduling model of the above trailer, the various types of trailers under the condition of flight delay are optimized to achieve the goal of minimizing the total service time of all delayed flights, as follows equation (8).

\[
T_{min} = \sum_{i=1}^{N} \sum_{j=1}^{P} x_{ij} \cdot T_{ij} \tag{8}
\]

3.3. Model solution

According to the above model, the key to solve the delay flight scheduling path problem is to reasonably determine the relationship between the flight and each trailer, to minimize the total delay time when the corresponding types of flights and trailers and the departure time of flight are satisfied, and to avoid genetic algorithm (GA) is easy to fall into the condition of local optimization and slow convergence of simulation annealing algorithm (SAA), and a model based on simulation annealing genetic algorithm to solve the emergency scheduling of trailers is constructed [9-11].

3.3.1. Algorithm steps

The specific idea of simulation annealing genetic algorithm is as follows:

**Step 1:** Initializing the control parameters. The population size is \( N \), the mutation probability is \( P_m \), the initial annealing temperature is \( T_0 \), the temperature cooling parameter is \( \alpha \).

**Step 2:** Construct chromosomes \( C_h (h = 1, 2, \ldots, N) \) to generate initial population. For example, chromosomes \{6, 2, 5, 4, 1, 3\} indicate that flight number 1 is the 6th towing service, flight number 2 is the second towing service, and so on.

**Step 3:** Calculate fitness. For each chromosome \( C_h \) generated in the population, to determine whether the corresponding feasible solution after decoding. If the corresponding solution is feasible, the corresponding objective function value \( Z_h \) is obtained. If the chromosome \( C_h \) corresponds to a non-feasible solution, a large integer \( M \) is assigned. The fitness function \( f_h = 1/Z_h \), \( f_h \) is the greater the value, indicating that the algorithm is close to the optimal solution.

**Step 4:** Chromosome cross. Select two individuals \( C_i \) and \( C_j \) randomly and perform partial matching crossover (PMX) to generate two new individuals \( C'_i \) and \( C'_j \), and then calculate their fitness.
function values $f'_1$ and $f'_2$. If $\min \{1, \exp(-(f'_n - f'_v)/T_{k})\} > b$, $b$ is a random number between 0 and 1, then the current individual is received;

**Step 5:** The cross after the above-mentioned individual mutation operation, combined with the fourth step of the method to determine whether to receive the variant solution.

**Step 6:** to determine whether to meet the convergence conditions. Otherwise, $T_k = \alpha * T_k$, turn to the step 3, and continue to find the optimal solution.

4. Application examples
Based on the above trailer emergency scheduling model, this section will use the delayed flight data as an example to verify the reliability of the scheduling model, and comparing with the conventional trailer scheduling method. The scheduling time for each flight is assumed to be 10 minutes. Specific flight information as follows table 2.

Table 2. Delay flight information at 19:20 on day.

| Flight number | Flight type | Original schedule | Current Flight schedule | Current Trailer state | Flight number | Flight type | Original schedule | Current Flight schedule | Current Trailer state |
|---------------|-------------|-------------------|------------------------|----------------------|---------------|-------------|-------------------|------------------------|----------------------|
| CA1302        | large       | 17:30             | 20:30                 | large1                | CZ2203        | large       | 19:50             | 20:40                  |                      |
| CZ2201        | large       | 17:40             | 19:25                 | Medium3              | CA1322        | Small       | 20:05             | 20:45                  |                      |
| CZ3105        | Medium      | 17:55             | 19:30                 | Medium4              | MF1268        | Medium      | 20:20             | 20:50                  |                      |
| HU6681        | Small       | 18:10             | 19:40                 | Small6               | CF3109        | Medium      | 20:25             | 21:00                  |                      |
| CA1308        | Small       | 18:25             | 19:45                 | Small7               | CA1338        | Medium      | 20:32             | 21:10                  |                      |
| MF1241        | Small       | 18:40             | 19:50                 | Small8               | CZ2204        | Small       | 20:45             | 21:15                  |                      |
| CZ2202        | Small       | 18:55             | 19:55                 | Medium5              | CA2356        | Small       | 21:10             | 21:20                  |                      |
| CA1307        | Medium      | 19:15             | 20:10                 | large2               | CF3111        | large       | 21:30             | 21:30                  |                      |
| CF3106        | large       | 19:20             | 20:15                 | HU6688               | Medium        | 21:35             | 21:35                  |                      |
| HU6682        | Small       | 19:30             | 20:35                 | CZ2205               | large         | 21:40             | 21:40                  |                      |

According to the traditional "First in first out" strategy, the trailer number 1-8 is a scheduling group. The actual scheduling time as shown in the table 3.

Table 3. The traditional scheduling strategy actual scheduling situation.

| Flight number | Schedule trailer | The actual scheduling time | Schedule trailer | The actual scheduling time |
|---------------|------------------|---------------------------|------------------|---------------------------|
|               |                  | First group               | Second Group     | Third group               |
| CA1302        | large1           | 20:30                     | CZ2203           | large1                    |
| CZ2201        | Medium3          | 19:25                     | CA1322           | Small7                    |
| CF3105        | Medium4          | 19:30                     | MF1268           | Medium3                   |
| HU6681        | Small6           | 19:40                     | CF3109           | Medium4                   |
| CA1308        | Small7           | 19:45                     | CA1338           | Medium5                   |
| MF1241        | Small8           | 19:50                     | CZ2204           | Small8                    |
| CZ2202        | Medium5          | 19:55                     | CA2356           | Small6                    |
| CA1307        | large2           | 20:10                     | CF3111           | large2                    |
| CF3106        | large2           | 20:40                     | HU6688           | Medium3                   |
| HU6682        | Small6           | 20:45                     | CZ2205           | large1                    |

According to the table 2 and table 3, we can know that total actual delay time of the flight is 75 min.
However, according to the proposed cooperative scheduling of various types of trailers based on genetic simulated annealing algorithm for scheduling flights, set $L = 30\text{min}$, $N = 20$, the mutation probability $P_m = 0.005$, initial temperature $T_0 = 100^\circ C$, the actual scheduling situation is as follows figure 2 and table 4.

![The change curve of energy Function](image)

**Figure 2.** The change curve of energy Function.

**Table 4.** The trailer coordinated emergency scheduling plan actual scheduling situation.

| Flight number | Schedule trailer | Scheduling time Window | Flight number | Schedule trailer | Scheduling time Window |
|---------------|------------------|------------------------|---------------|------------------|------------------------|
| CA1302        | large2           | 20:30                  | CA1322        | Small8           | 20:45                  |
| CZ2201        | Medium3          | 19:25                  | MF1268        | Medium4          | 20:50                  |
| CF3105        | Medium4          | 19:30                  | CF3109        | Medium5          | 21:00                  |
| HU6681        | Small6           | 19:40                  | CA1338        | Medium3          | 21:10                  |
| CA1308        | Small7           | 19:45                  | MF1241        | Small8           | 20:00                  |
| MF1241        | Small8           | 19:50 20:00            | CZ2204        | Small6           | 21:15                  |
| CZ2202        | Small6           | 20:05                  | CA2356        | Small7           | 21:20                  |
| CA1307        | Medium3          | 20:10                  | CF3111        | large1           | 21:30                  |
| CF3106        | large1           |                        | HU6688        | Medium4          | 21:35                  |
| HU6682        | Small7           | 20:35                  | CZ2205        | large2           | 21:40                  |

According to the table 2 and table 4, can see that the above trailer emergency scheduling method which is only a total delay of 15 minutes on the basis of the current flight schedule.

5. summary

By analyzing the traditional rules of airport trailer and combining with the service processes and the characteristics of trailers, the paper develops a multi-target trailer emergency scheduling model with rolling windows. And the simulated annealing algorithm is introduced into the genetic algorithm to prevent the optimal result falling into the local optimal solution when the model is solved. The simulation results show that the model can more effectively solve the problem of airport trailer emergency scheduling in the case of flight delays. In the future research work, we can refine the relevant factors and go further quantitative analysis to improve the efficiency of airport scheduling.

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