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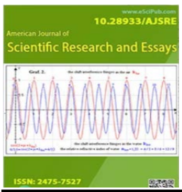

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Maintenance of Bullet Train Based on Mathematical Planning and Workshop Scheduling

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ABSTRACT

Nowadays, bullet train service stations often suffer from the phenomenon of low operating efficiency due to the unreasonable arrangement of bullet trains that stay in service stations for too long. In order to solve this problem, based on the information of bullet train arrival in two periods of a bullet train service station, this paper comprehensively considered the input source, queuing rules and overhaul intensity of the train service system, determined the objective function and multiple constraint conditions, and established the 0-1 programming model and Uncorrelated Parallel Machine Optimization Model. The model established in this paper can relieve the load pressure of bullet train service station to a great extent, improve the operation efficiency of the service station under the condition of ensuring the maintenance quality of bullet train, and provide theoretical basis for realizing the shortest maintenance time of bullet train service station.

Keywords: 0-1 programming; Queuing theory; Nncorrelated parallel machine; Fruit fly optimization algorithm; Workshop scheduling

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1. Introduction

With the rapid development of China's economy, the comprehensive transportation system is gradually improved, and the demand for railway transportation is increasing. With the speeding up of railways and the construction of passenger dedicated lines, bullet trains, as the main transportation means of passenger dedicated lines, will have more and more traffic, and their purchase and maintenance costs will be higher, and they will occupy a larger investment in passenger dedicated lines. To increase the utilization ratio of bullet train is an effective way to save investment and reduce costs. The utilization efficiency and maintenance quality of bullet trains are directly related to the safe operation of passenger dedicated lines. So, it is necessary to carry out efficient and high-quality maintenance work on bullet trains. Therefore, the use of bullet train service stations was born for use.

The scientific name of the bullet train service station is the high-speed railway maintenance station, which specializes in the inspection, testing, maintenance, and maintenance of bullet trains to ensure that all parts of the train are in good condition and to make the train safe and practical. It belongs to a type of railway vehicle maintenance base. The bullet train service station is responsible for the maintenance and maintenance of bullet trains. There are more than 50 bullet train service stations installed in the country. They are mainly located near the railway section where bullet trains are operated. There are special railway branches to connect the main railway line and the bullet train the group's launch plan runs concurrently. The importance of the bullet train service station as a place for maintenance of the bullet train and inspection of the unit is self-evident. Every bullet train should be regularly inspected at the service station to improve the utilization of the bullet train and ensure the safety of the bullet train and passengers. However, the construction cost of bullet train service stations is too high, and the number of bullet train service stations across the country does not support too many bullet train s to perform simultaneous maintenance operations. Nowadays, it is very important to solve the congestion problem of bullet trains and provide them with the maintenance plan of bullet trains[1].

This paper hopes to study the maintenance rules of a bullet train service station, find using the maintenance to traffic laws, to establish the corresponding mathematical model and give a reasonable maintenance scheme, effectively guarantee the normal operation of the service station, improve the efficiency of the operation of service stations, for the transportation system and the improvement of the railway transportation has a very good role in promoting[2-3].

The maintenance of the bullet train is divided into different maintenance grades according to the driving conditions. Different grades correspond to different working procedures, and different types of bullet train correspond to different combination of working procedures, and the time required for the same working procedure is also different. The number of workshops in each process of the service station and the arrival time required by various processes of each bullet train are known. This paper hopes to design a reasonable overhaul plan for the service station through the known information, so that the shorter the total overhaul time is the better on the premise of ensuring the overhaul quality of the bullet train.

2. Model assumptions

Before analyzing the problem and establishing the mathematical model, we need to put forward some assumptions to simplify the problem. The assumptions made in this article are as follows:

1) It is assumed that all the bullet trains arrive at the station on time according to the schedule, and there is no case of delay;
2) It is assumed that the equipment in all process workshops will not damage the delay;
3) It is assumed that the maintenance time of each workshop is fixed;
4) The transfer time between the repair workshop of the last working procedure and the repair workshop of the next working procedure is ignored;
5) It is assumed that the time required by different workshops of the same process is the

same for the same type of bullet train.

3. Analysis of problem

First of all, we consider that the same type of bullet trains go through the same several processes, each process has its own workshop and different time consumption, when two consecutive bullet trains arrive at the service station at the same time interval, calculate the shortest maintenance time, and give the best plan to arrange the overhaul. Due to the randomness of the arrival and maintenance time of the bullet train, the phenomenon of queuing in reality is almost inevitable. In this problem, the queuing service process is the continuous input of the bullet train to the maintenance workshop, including the maintenance sequence, until the end of the repair. From the perspective of queuing theory[4], it is necessary to clarify the relevant indicators in this problem and queuing theory problem. We call the bullet train that needs to be repaired the customer, and the process workshop that serves the customer, namely the overhaul of the bullet train, the service organization. When the process workshop is full, the bullet train needs to wait in the previous process workshop, which causes the queuing phenomenon. Since the time of customer arrival and the time of service are generally random, the service system is also called random service system. However, in this problem, the time of arrival of the bullet train and the time for the repair of the bullet train in the process workshop are both determined, that is, are fixed values, which belong to D/D/C type problem in queuing theory, at the same time, this question is also an optimal programming problem, so we can analyze it from three aspects of mathematical programming, namely, objective function, decision variables and constraint conditions. The specific flow chart of thinking is as follows:

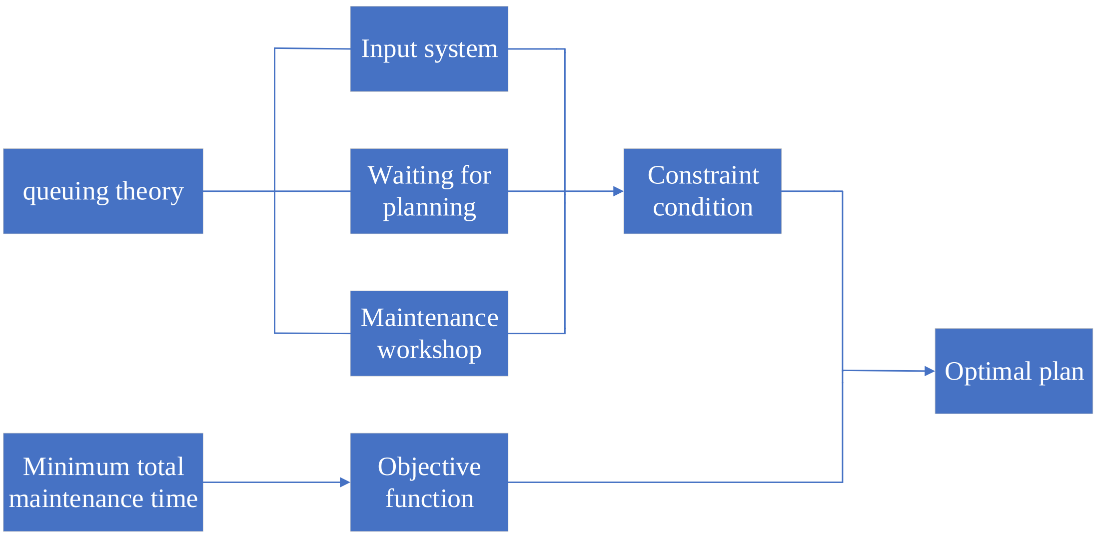

Fig. 1 Thought flow chart

We further discuss in depth and add the category of bullet trains on the basis of the first case. Different types of bullet trains spend different time in the same process, so in this case, different types of bullet trains need to be constrained separately. On the other hand, the input system is different from the first case in that it changes from a uniform and determined source to a non-uniform and determined source, and the type of the train at the maintenance point is known every time. Therefore, this is a typical mixed flow shop scheduling problem for the case of different types of bullet trains[5-6], adding constraint conditions on the basis of the first case. However, in terms of solution, the ordinary algorithm is difficult to solve, so we introduce a relatively advanced fruit fly optimization algorithm to solve the unrelated parallel machine scheduling problem that is difficult to be solved by the ordinary algorithm[7].

4. Data processing and analysis

We collected the relevant data of a group of working procedures of the service station, which consists of three working procedures a, b and c.

The number of workshops owned by each working procedure and the required time are given in the form of a table, as shown in the table below:

Table 1: relevant data of the service station

Process category	a	b	c
The number of workshop	3	8	5
Time spent(hours)	1	2	1.5

The overhaul of the current bullet train includes three working procedures a, b and c, the working workshops owned by each working procedure and the required time are shown in table 1. The time consumed by different workshops in the same working procedure is the same. The bullet train will carry out maintenance in the order of a, b and c. After completing one maintenance procedure, it will drive into the next workshop with a vacant position for the next maintenance procedure. If all the workshops in the next procedure are occupied, the bullet train needs to wait in the previous workshop. Service station a 12 hours every 15 minutes to 1 to repair the bullet train, we analysis alone this time, set the timing starting point, from the time after the start of every 15 minutes there was a bullet train station waiting, when the first bullet train station, 15 minutes at the time of 12 hours the last bullet train station, a total of 48 bullet train station maintenance, we need to the 48 bullet train reasonable arrangement planning, and calculate the shortest total maintenance time.

On this basis, we added the factor of the category of bullet trains. Considering that the time consumed by the same process of different types of bullet trains is also different, we selected four types of bullet trains for analysis. The time required by each process is shown in the table below:

Table 2: maintenance data containing categories of bullet trains

Process category / Category of bullet trains	a	b	c
CRH2	1	2	1.5
CRH3	0.8	2.4	0.5
CRH5	1.3	2.5	1.5
CRH6	1	2.7	0.3

This case, we also choose bullet train is studied over a period of time, considering the general situation, the train arrive station time is not necessarily the random, is more of a random irregular began to arrive, so we are interested in the selection of a bullet train arrive station time regularity is not strong, to ensure that the results of general and universality of specific train arrive station time shown in the following table:

Table 3: arrival schedules of different types of bullet trains

Arrival time	0:16	0:47	1:22	2:00	2:21	
Category of bullet trains	CRH2	CRH5	CRH2	CRH6	CRH3	
Arrival time	3:02	3:31	3:59	4:04	4:27	5:09

Category of bullet trains	CRH6	CRH2	CRH5	CRH3	CRH3	CRH6

Compared with the first case, this case is obviously more complicated, but also more universal, and more able to reflect the general situation of bullet trains going to service stations. In order to more intuitively see the impact of the addition of the category of bullet trains, we draw a broken line diagram from the data in table 2 as follows:

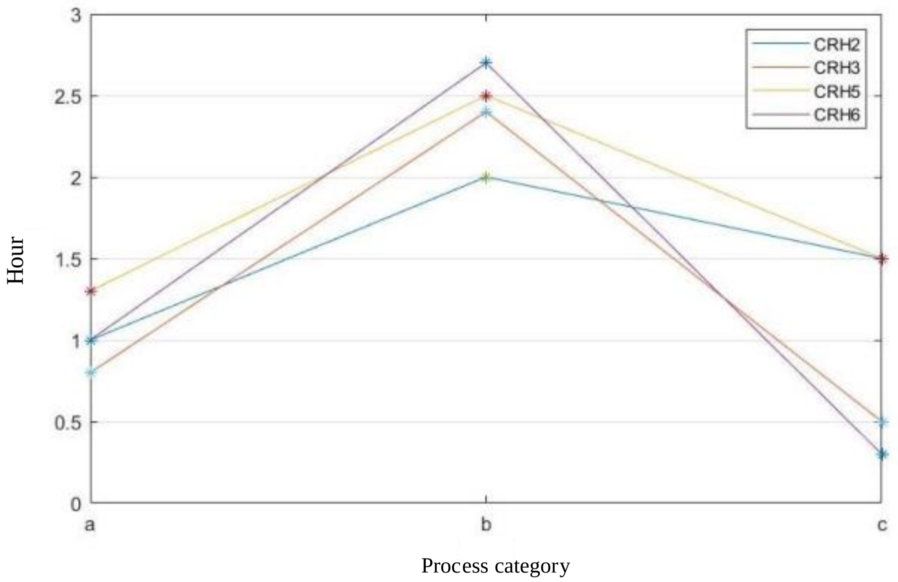

Fig.2 Line chart of the time required for each process of different types of bullet trains

In accordance with the above line chart analysis, we can see intuitive: overall, the longest number CRH5 train overhaul and the CRH2 CRH3 relatively few time-consuming, but four train maintenance takes overall difference is not big, but in the c workshop four train produced obvious differentiation, preliminary analysis we think c workshop may be a queue.

5. Establishment of 0-1 programming model

Step1: *Determination of bullet train source*

In the first case, the customer source (the bullet train to be inspected) arrives at the service station according to the 15-minute rule. In a certain 12 hours, there are 48 bullet trains, whose serial Numbers are in the chronological order of arrival at the process workshop: $n = 1, 2, \cdots, 48$

Step2: *Determination of service organization*

The service organization in the random service system here refers to the number of process workshops and the time consumed, and gives each workshop number of the three process categories of a, b and c, namely:

$$i = 1, 2, 3$$
$$j = 1, 2, \cdots, 8$$
$$k = 1, 2, \cdots, 5$$

Among them, i, j, k respectively represent the workshop serial Numbers of the three process categories a, b and c.

Step 3: *Express the time of bullet train entering and leaving the workshop*

Since we need to analyze the maintenance time, we need to express the time when each bullet train enters and leaves the workshop. We use p_{na}, p_{nb}, p_{nc} to represent the moment when the nth bullet train enters process a, process b and process c respectively, and g_{na}, g_{nb}, g_{nc} to represent the moment when the nth bullet train leaves process a, process b and process c respectively.

Step 4 **:** Because each process have more than one workshop, we need to know the train will be in which workshop for maintenance, will be able to design to avoid as much as possible of queuing phenomenon because of lack of process workshop, reasonably arrange the bullet train in and out, we need to determine which every bullet train entered which workshop, so we introduce λ_{ni}, ω_{nj} and θ_{nk} three 0-1 variables, they were used to determine whether the nth bullet train enter the ith workshop, jth workshop and kth workshop of the process a, process b and process c, respectively. If a workshop for maintenance, take 1, otherwise 0.

Step 5 **:** Every bullet train in each process workshop also has not always been maintenance, but there are have the time, we need to describe in a certain time t, whether the train takes up workshop, so again, we introduce the $x_{ni}(t)$, $y_{nj}(t)$ and $z_{nk}(t)$ three 0-1 variables, they were used to determine whether the nth bullet train in time t take up working in the ith workshop, jth workshop and kth workshop of the process a, process b and process c, respectively. If so, then take 1, otherwise 0.

5.1 Determination of objective function

Before choosing the objective function, first of all, we clearly judge a service system's merits and demerits, such as service time, queuing time and service quality. In this question, the quality of service can be regarded as the same, and the service time is fixed, that is, the time required for each process is the same. As reflected in this question, we can know the total time to overhaul all the bullet trains when we get the last bullet train leaving the last working procedure. Therefore, the time to repair all the bullet trains can be expressed as: $f = g_{48c} - p_{1a}$

Among them, g_{48c} represents the moment when the 48th bullet train leaves procedure c, and p_{1a} represents the moment when the first bullet train enters procedure a. According to the question, $p_{1a} = 15$ is a fixed value.

Since we need the shortest overhaul time, the objective function can be determined as: $\min f = g_{48c} - p_{1a}$

5.2 Determination of constraint conditions

Constraint condition 1: constraints on 0-1 variables

In order to conveniently describe whether or not the bullet train enters a workshop and the period of time it occupies the workshop, we have introduced a number of 0-1 variables for this reason. There is a functional relationship between these shaping variables. We need to describe the relationship, and use the relationship to constrain these variables, which can be related to the objective function. We take process a as an example, the specific relationship is as follows. If the bullet train occupies a workshop at time t, it shall first ensure that the bullet train enters the workshop for maintenance, that is: When $\lambda_{ni} = 0$, $x_{ni}(t) = 0$ When $\lambda_{ni} = 1$, $x_{ni}(t)$ could be 0, could be 1, so: $x_{ni}(t) \le \lambda_{ni}$

If and only if the time period occupied by the bullet train is between the time period of entering and leaving the workshop, it can be considered as occupied, that is:

If and only if $p_{na} \le t < g_{na}$, $x_{ni}(t) = 1$

Similarly, for procedure b, there is: $y_{nj}(t) \le \omega_{nj}$

When $p_{nb} \le t < g_{nb}$, $y_{nj}(t) = 1$

For procedure c, there is: $z_{nk} \le \theta_{rk}$

When $p_{nc} \le t < g_{nc}$, $z_{nk}(t) = 1$

Constraint condition 2: the constraint on the input system

Input system in the random service system. In this problem, the time for the bullet train to arrive at the maintenance site is 15 minutes, that is: $p_{na} \ge 15n$

Considering that the three workshops in process a may be occupied by the first few bullet trains, the waiting phenomenon will be caused, that is, the bullet train will not be served immediately when it arrives at the service system, so it needs to be restrained by the greater than sign.

Constraint condition 3: constraint on service time

Service time exists in each workshop of each process, is the fixed value, that is:

$$\begin{cases} g_{na} - p_{na} \ge 60 \\ g_{nb} - p_{nb} \ge 120 \\ g_{nc} - p_{nc} \ge 90 \end{cases}$$

Since the workshop of the next process may be occupied, the time occupied in the workshop of the previous process is longer than the time consumed in the workshop, so the greater than or equal sign is taken.

Constraint condition 4: because one bullet train will enter only one workshop for maintenance in each working procedure, for working procedure a, b and c, that is:

$$\begin{cases} \sum_{i=1}^{3} \lambda_{ni} = 1 \\ \sum_{j=1}^{8} \omega_{nj} = 1 \\ \sum_{k=1}^{5} \theta_{nk} = 1 \end{cases}$$

Among them,

$$\lambda_{ni} = \begin{cases} 0, \text{the nth bullet train does not enter the ith workshop} \\ 1, \text{the nth bullet train does enter the ith workshop} \end{cases}$$

For the same reason, ω_{nj}, θ_{nk} , ibid.

Constraint condition 5: in the same period of time, the workshop of any process can only be occupied by 1 bullet train at most, that is:

$$\begin{cases} \sum_{n=1}^{48} x_{ni}(t) \le 1 \\ \sum_{n=1}^{48} y_{nj}(t) \le 1 \\ \sum_{n=1}^{48} z_{nk}(t) \le 1 \end{cases}$$

Among them,

$$x_{ni}(t) = \begin{cases} 0, \text{the ith workshop is not occupied by the nth bullet train at time t} \\ 1, \text{the ith workshop is occupied by the nth bullet train at time t} \end{cases}$$

For the same reason, $y_{nj}(t), z_{nk}(t)$, ibid.

Constraint condition 6: constraint on the best choice

Only when one bullet train leaves the previous working procedure and immediately enters the next working procedure can the time be shortest, that is, the moment after leaving the previous working procedure must be equal to the moment of entering the next working procedure, that is:

$$\begin{cases} g_{na} = p_{nb} \\ g_{nb} = p_{nc} \end{cases}$$

In summary, *the 0-1 programming model* established for the first case is:

$$\min f = g_{48c} - p_{1a}$$

$$\begin{cases} \sum_{n=1}^{48} x_{ni}(t) \le 1, \sum_{n=1}^{48} y_{nj}(t) \le 1, \sum_{n=1}^{48} z_{nk}(t) \le 1 \\ \sum_{i=1}^{3} \lambda_{ni} = 1, \sum_{j=1}^{8} \omega_{nj} = 1, \sum_{k=1}^{5} \theta_{nk} = 1 \\ g_{na} - p_{na} \ge 60 \\ g_{nb} - p_{nb} \ge 120 \\ g_{nc} - p_{nc} \ge 90 \\ p_{na} \ge 15n \end{cases}$$

5.3 Analysis of model results

According to the above model, *MATLAB* software and *LINGO* software were used to substitute the data, and the shortest time from the first bullet train entering the service station to the last bullet train completing the overhaul was 1200 minutes, that is, 20 hours. By analyzing the waiting time of each bullet train, we can judge the advantages and disadvantages of the service system. In order to clearly see the changing trend of the waiting time of each bullet train with the increase of the number of bullet trains, we describe the broken line chart of each bullet train at the beginning of overhaul and observe its changing trend. The specific figure is as follows:

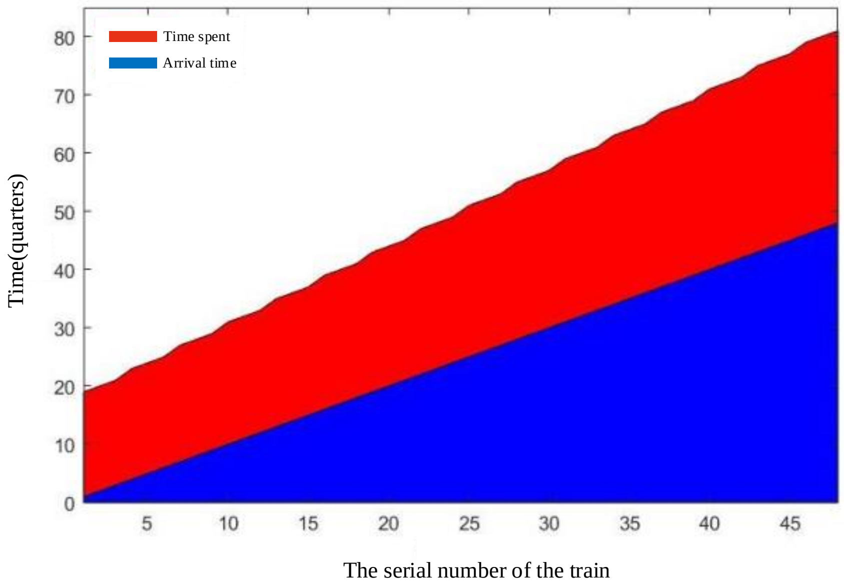

Fig. 3 Broken line diagram of vehicle maintenance time

From the above figure, we can clearly see that the slope of the image is getting larger and larger, and the increasing speed is getting faster and faster, which means that the further back the bullet train is, the longer it will take to receive the service. Therefore, we can see that the waiting time of the maintenance service system will be longer and longer. We then numbered the waiting time of each bullet train from small to large according to the time sequence of reaching the maintenance point, and made a bar chart as follows:

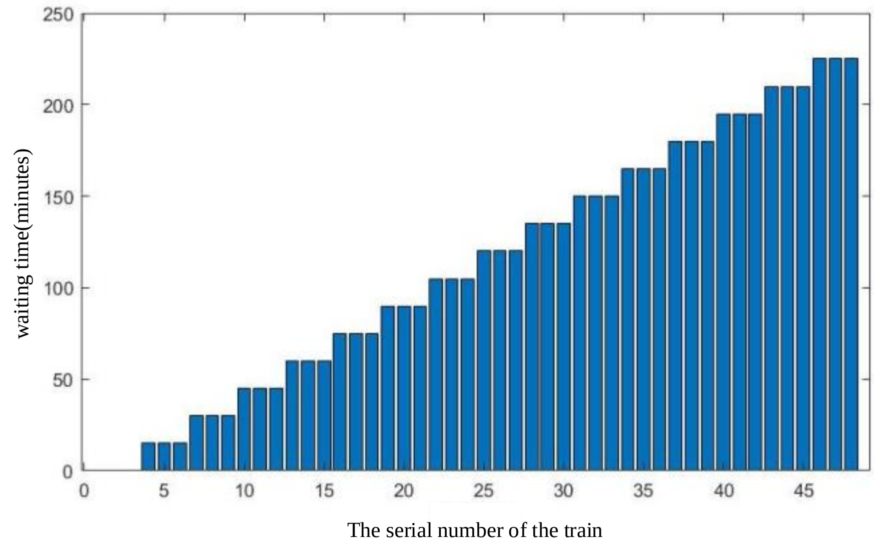

Fig. 4 Bullet train waiting time bar chart

From the figure above, we can intuitively see that with the successive arrival of the bullet trains, the waiting time increases gradually, which indicates that with the passage of time, more and more bullet trains will be waiting in line at this service station, and the workshops of the three processes will be busy. If there is no time limit, the queues of this system will be longer and longer.

6. The establishment of Uncorrelated Parallel Machine Optimization Model

Step 1: determine the category of bullet train

Different from the first case, there are different types of bullet trains in this question. In order of arrival time, we number and classify the 11 bullet trains that need to be repaired, namely: $n=1,2,\cdots,11$

Among them, when $n=1,3,7$, the category of bullet train is CRH2; when $n=5,9,10$, the category of bullet train is CRH3; when $n=2,8$, the category of bullet train is CRH5; when $n=4,6,11$, the category of bullet train is CRH6.

Step 2: determination of the time matrix of the arrival of the train

First, we set up a matrix: $\alpha=\alpha_n,(n=1,2,\cdots,11)$

To indicate the arrival time of each train, that is:

$\alpha=[16,47,82,120,141,182,211,239,244,267,309]^T$

Step3: determination of different service agencies

Different types of bullet trains correspond to different service agencies, that is, different maintenance time. When carrying out the constraint, different categories of bullet trains have different constraint conditions, so we construct a matrix: $U=(u_{pq})_{4\times3}$

Where, u_{pq} represents the maintenance time required by the qth process of the pth bullet train. The specific matrix is as follows:

$$U=\begin{pmatrix} 60 & 120 & 90 \\ 48 & 144 & 30 \\ 78 & 150 & 90 \\ 60 & 162 & 18 \end{pmatrix}$$

6.1 Determination of decision variables

Step1: First we clear purpose, to determine the repair all the bullet train the shortest total time, so we start with the first bullet train maintenance at the end of a bullet train to complete all maintenance process through time to measure the overhaul the total time of need, specific to the expression, namely the 11th bullet train leave process c moment with enter process a of the first bullet train the difference of the moment. All we need to describe are the moments when each bullet train enters and leaves the process. We use to represent the moment when the first bullet train enters process a, process b and process c respectively, and to represent the moment when the bullet train leaves process a, process b and process c respectively.

Step2: Similar to the first case, we need to know the number of the workshop in process a, b and c for each bullet train to go to, so as to judge whether the workshop is occupied at a certain time, and then determine whether there will be waiting in line, which bullet train will wait in line and the required waiting time. we have introduced 0-1 variables $\lambda_{ni},\omega_{nj},\theta_{nk}$.

6.2 Determination of objective function

We take the shortest total time for all bullet trains to complete overhaul as the objective function, and the total overhaul time can be expressed as: $h=g_{11c}-p_{1a}$

Among them, g_{11c} represents the moment when the 11th bullet train leaves procedure c, and p_{1a} represents the moment when the first bullet train enters procedure a.

So, the objective function is: $\min h=g_{11c}-p_{1a}$

6.3 Determination of constraint conditions

Constraint condition 1: constraint on the arrival time

In the second case, the arrival time of the bullet train is different from the first case, which is irregular but definite. We start from time zero to constrain the arrival time of the train. Since all workshops in process a may be occupied, the bullet train arriving at the station cannot immediately enter process a for maintenance. Therefore, the time to enter process a will not be less than the time to arrive at the station, namely: $p_{na} \geq \alpha_n$ Among them,

$$\alpha_n = [16,47,82,120,141,182,211,239,244,267,309]^T .$$

Constraint condition 2: determination of maintenance time

The maintenance time of each process is different. In this case, different types of bullet trains need different maintenance time in the same process. In addition, because of the waiting phenomenon caused by queuing, it is impossible to enter the next process immediately after the completion of one process. So the time difference between leaving a process and entering the process is no less than the time that the process takes. To facilitate the expression of constraints, we introduce the established matrix U. The specific constraints are as follows:

$$\begin{cases} g_{na} - p_{na} \geq u_{p\times1} \\ g_{nb} - p_{nb} \geq u_{p\times2} \\ g_{nc} - p_{nc} \geq u_{p\times3} \end{cases}$$

Among them, $u_{p\times1}$ represents the time consumed by process a of the pth bullet train, $u_{p\times2}$ represents the time consumed by process b of the pth bullet train, and $u_{p\times3}$ represents the time consumed by process c of the pth bullet train, p_{na}, p_{nb}, p_{nc} represents the moment when the nth bullet train enters process a, process b and process c respectively, and g_{na}, g_{nb}, g_{nc} represents the moment when the nth bullet train leaves process a, process b and process c respectively.

Constraint condition 3: each bullet train only needs to go to one of the workshops for maintenance in a process, that is:

$$\begin{cases} \sum_{i=1}^{3} \lambda_{ni} = 1, \sum_{j=1}^{8} \omega_{nj} = 1, \sum_{k=1}^{5} \theta_{nk} = 1 \\ \sum_{n=1}^{11} x_{ni}(t) \leq 1, \sum_{n=1}^{11} y_{nj}(t) \leq 1, \sum_{n=1}^{11} z_{nk}(t) \leq 1 \\ g_{na} - p_{na} \geq u_{p\times1} \\ g_{nb} - p_{nb} \geq u_{p\times2} \\ g_{nc} - p_{nc} \geq u_{p\times3} \\ p_{na} \geq \alpha_n \\ g_{na} = p_{nb}, g_{nb} = p_{nc} \end{cases}$$

Constraint condition 4: in the same period of time, each workshop is allowed to have at most one bullet train occupation, that is:

$$\begin{cases} \sum_{n=1}^{11} x_{ni}(t) \leq 1 \\ \sum_{n=1}^{11} y_{nj}(t) \leq 1 \\ \sum_{n=1}^{11} z_{nk}(t) \leq 1 \end{cases}$$

Constraint condition 5: constraints on 0-1 variables. There is a relationship between 0-1 variables introduced in the second example, which needs to be restricted, namely:

$$\begin{cases} x_{ni}(t) \le \lambda_{ni} \\ y_{nj}(t) \le \omega_{nj} \\ z_{nk}(t) \le \theta_{nk} \end{cases}$$

If and only if $p_n \le t < g_n$, $x_{ni}(t) = y_{nj}(t) = z_{nk}(t) = 1$.

Constraint condition 6: all bullet trains should be guaranteed to enter the next process immediately after leaving the previous process, so as to minimize the total maintenance time, that is:

$$\begin{cases} g_{na} = p_{nb} \\ g_{nb} = p_{nc} \end{cases}$$

In summary, *Uncorrelated Parallel Machine Optimization Model* established for the second case is:

$$\min h = g_{11c} - p_{1a}$$

$$\begin{cases} \sum_{i=1}^{3} \lambda_{ni} = 1, \sum_{j=1}^{8} \omega_{nj} = 1, \sum_{k=1}^{5} \theta_{nk} = 1 \\ \sum_{n=1}^{11} x_{ni}(t) \le 1, \sum_{n=1}^{11} y_{nj}(t) \le 1, \sum_{n=1}^{11} z_{nk}(t) \le 1 \\ g_{na} - p_{na} \ge u_{p\times 1} \\ g_{nb} - p_{nb} \ge u_{p\times 2} \\ g_{nc} - p_{nc} \ge u_{p\times 3} \\ p_{na} \ge \alpha_n \\ g_{na} = p_{nb}, g_{nb} = p_{nc} \end{cases}$$

6.4 The result analysis of Uncorrelated Parallel Machine Optimization Model

According to the above model, we use the fruit fly optimization algorithm to solve this unrelated parallel machine problem [8-9].

The fruit fly optimization algorithm USES the principle of fruit fly foraging to continuously carry out population iteration, and finally finds the optimal solution of this problem, the specific principle flow chart is as follows:

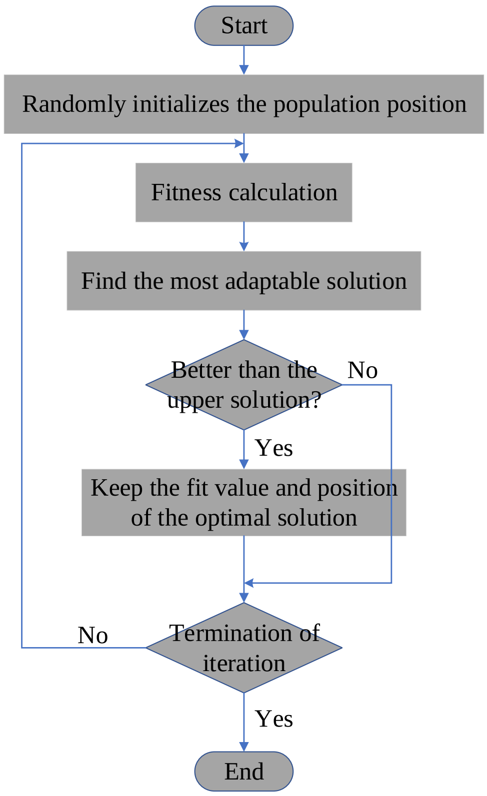

Fig. 5 Flowchart of the principle of drosophila optimization algorithm

According to the above model and algorithm, MATLAB software is used to substitute data into the software, and the shortest total time to complete the maintenance of these bullet trains is 541 minutes, that is, 9 hours and 1 minute. The arrival time and departure time of 11 bullet trains are drawn as the area diagram below:

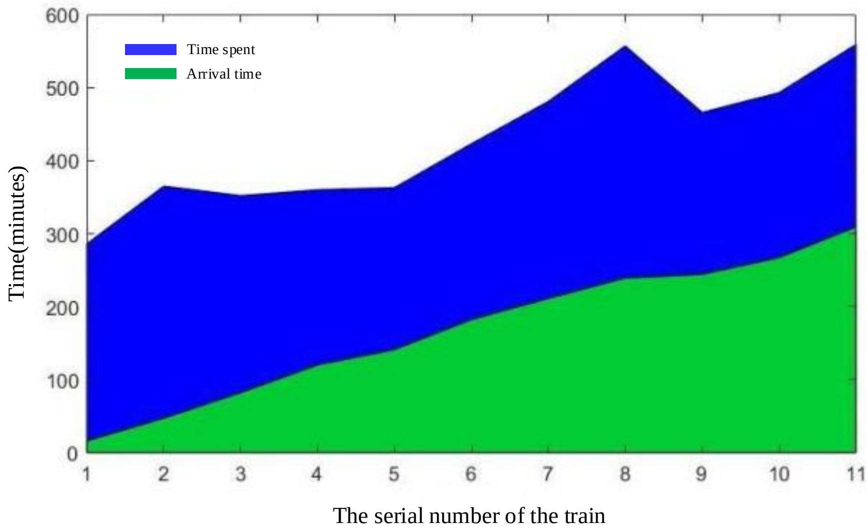

Fig. 6 Area diagram of arrival time and departure time of the bullet train

From the analysis of the figure above, we can know that most of the bullet trains leave within 300-500 minutes, while only a few bullet trains with complicated processes spend more than 500 minutes. According to the idle conditions of each workshop and the processing time of bullet trains, the vast majority of bullet trains do not have waiting time. And the complex process of 8 moving car processing time than the last one, so the time of 8 car the lag, so the results should be 8 car finally arrive station time, namely 9 hours 17 minutes, minus the first 16 minutes to get the answer, in conformity with the we get the answer, so we believe that we can get the result is accurate and correct.

7. Advantages of the model

1) We established an optimization model based on the queuing theory problem, which more specifically expressed the relationship between workshop capacity and maintenance time, making it more convenient to express the maintenance rules and sequence;
2) When determining whether a workshop is occupied or not and the workshop to which a certain bullet train is going, 0-1 variables are subtly introduced to make the objective function and constraint conditions easier to solve;
3) Aiming at the different categories of bullet trains, the excellent optimization algorithm is applied to solve the problem, which is difficult to be solved by the general algorithm;
4) The drosophila fly optimization algorithm adopted in the model has better adaptive and self-organizing ability, and has the characteristics of simple iterative process, strong global convergence and short algorithm execution time.
5) Shortcomings of the model
6) Although the dynamic programming model can obtain the global optimal solution to solve the optimal route planning, there is no unified and fixed standard model, and the constraint conditions need to be constantly modified when the situation is different;
7) Situation 1 according to the recursive thought to solve the dynamic maintenance route planning problem, many variables, complicated calculation.

8. Promotion of the model

First of all, in the production practice of people, often meet how to make use of existing resources to arrange production, the life problem, in order to obtain maximum benefit in modern scientific decision-making, often with the help of the mathematical programming method, using the tools of mathematics, determine the objective function and constraint conditions, so as to get the best solution. As an important branch of operational research, mathematical programming has become increasingly extensive and in-depth in practice. Especially after the computer can deal with the programming problem of thousands of constraints and decision variables, the application of mathematical programming has become more extensive and has become one of the basic methods often used in modern management. In addition, the queuing theory following Poisson process can also be widely applied to the port berth design of transportation system, machine maintenance inventory control and other service systems.

9. Conclusion

In this paper, aiming at the problem of optimal arrangement and corresponding solution of shortest overhaul time of emu, a 0-1 programming model based on queuing theory and an unrelated parallel machine optimization model are established, relevant data of a service station in our country, and two periods of the bullet train station information, sure to repair all the bullet train the shortest time as objective function, considering the bullet train arrive station time rule, to repair the bullet train number and the number of processes all workshop and maintenance time, and other factors, to determine the multiple constraints, with the help of *MATLAB* and *LINGO* software to calculate the shortest total duration of maintenance, and gives the best maintenance plan. On the basis of this, a new class of bullet trains was added, and the arrival time matrix of different classes of bullet trains was established. This article gives service to arrange a reasonable scheduling workshop bullet train maintenance plan, and provides a mathematical programming method of calculating the shortest total time maintenance, so that using maximize workshop resources become systematic, effectively guarantee the normal operation of the service station, improve the operational efficiency of the service station, to a certain extent promoted the transportation system and the improvement of the railway transportation.

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