Research on the computer system of train set shunting plan safety optimization of the hub type high-speed railway station

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Abstract. Because the high-speed railway lines have connected into a network in China, the research of safety optimization of train set shunting plan of the hub type high-speed railway station is of great practical significance. To solve this problem, a time-space conflict resolution algorithm is proposed to minimize the total wait time of the train set on the station track, to optimize the timing and route of the train set shunting operation in two dimensions, and thus eliminate the route conflict. A computer system is developed based on the algorithm, a real world case study shows that the algorithm can eliminate the train route conflicts, ensure the safety of the plan, and the total wait time of the train set on the track is significantly decreased, and the utilization efficiency of the track is improved.

1. Introduction
Because the high-speed railway lines have connected into a network in China, how to scientifically adjust and optimize the task division of different lines, how to provide passengers with the best quality transportation products, how to maximize local convenience for passengers to travel, and how to coordinate the whole network, are new challenges at present for the railway operation and management departments in terms of transportation organization and maximizing the transportation capacity of the whole network.

In the high-speed railway network, each line operates independently in the section without affecting each other. However, in the hub type high-speed railway station, there are multiple high-speed railway lines or intercity line access, which is an important connection point in the high-speed railway network, is a transfer and distribution point in the passenger flow between lines, and also is the core control node of the coordinated operation organization between lines. Therefore, the research on safety optimization of train set shunting plan of the hub type high-speed railway station is of great practical significance. The authors in [1-8] did some meaningful researches on this kind of problem.

At the junction or terminal area of main and branch railway lines, the complex composed of various railway lines, stations and other relevant equipment for transportation is called the railway hub.

Different from the concept of railway hub, the hub type high-speed railway station in this paper refers to a large-scale high-speed railway station which connects two or more high-speed railway lines or intercity railway lines and plays a pivotal role in the high-speed railway network. Because the station
layout of hub type high-speed railway station is relatively complex, the operation content is diverse, and the operation is busy, so it directly affects the safety of the operation organization of the whole railway network.

At the stage when high-speed railway is just put into operation in China, the mileage of high-speed railway is relatively short, the high-speed railway lines only connect key megacities, they are independent of each other and have no influence on each other. Therefore, the systematic function of the whole high-speed railway line group is not obvious, the interaction relationship between each line subsystem is weak, and the operation plan safety between lines is not prominent. However, in the current stage, the high-speed railway network is initially formed and will be expanded and improved in the future. The high-speed railway lines converge or cross at the hub type high-speed railway stations, strengthen the mutual influence relationship of each line subsystem, and put forward new requirements for the operation safety organization of high-speed railway network lines

2. Algorithm Design
The time-space conflict resolution algorithm of the train set shunting operation refers to the optimization and adjustment of the time and route of the shunting operation. In order to minimize the total wait time of the train set on the station track, optimize the time and route of the train set shunting operation in time dimension and spatial dimension, and thus eliminate the route conflict.

The main way to solve the conflict in spatial dimension is to adjust the operation chain arrangement of the conflicting trains, change the route of the train set shunting operation, avoid the simultaneous occupation of two train set on the same equipment as much as possible, and avoid the route conflict. If the route conflict is inevitable, the conflict degree of the two trains should be reduced as much as possible to create good conditions for the solving in time dimension.

The solving in time dimension is mainly to adjust the time if the two trains are still in route conflict when the spatial dimension solving is over, so as to avoid the simultaneous occupation of the two trains on the same equipment. In the process of time dimension solving, the cost of adjusting the operation time of the train set shunting is to increase the parking time of the train set in the station track.

For the convenience of research, two concepts, the critical conflict equipment and the conflict value, are proposed in this paper.

2.1. Critical conflict equipment
A pair of conflicting trains will overlap the occupation time on fixed equipment in multiple switch sections or station tracks, resulting in less than zero conflict redundancy and route conflict. For a train conflict $\Gamma (a, b)$, among all the fixed equipment in the station with overlapping occupation time, the equipment with the minimum conflict redundancy is called the key conflict equipment. On the key conflicting equipment, the time occupied by two train routes overlaps the most and the conflict degree is the most serious. If the time overlap on critical conflict equipment can be avoided by adjusting the time of train set shunting operation, there will be no time overlap on other equipment any more.

Figure 1. The critical conflict equipment.
As shown in the figure 1, the occupation time overlapping of train a and train b is heaviest on switch 5. The overlap is the largest and the degree of conflict is the most serious, so the switch 5 is called the critical conflict equipment of the conflict pair of train a and train b.

2.2. Conflict value
For a pair of conflict trains $\Gamma(a,b)$, if the train set shunting operation of train a is conflict to train b, it is allowed to advance the exiting time or delay the entering time to the depot of train set of train a, so as to achieve the purpose of avoiding the route conflict. In order to solve the conflict $\Gamma(a,b)$, the minimum adjustment time of train set a is the conflict value of $\Gamma(a,b)$.

![Adjust direction diagram](image1)

Figure 2. Two different case of adjust direction.

As is shown in figure 2, it should be noted that the conflict value between the pair of trains which are conflict is not only related to the occupation time overlapping on the critical conflict equipment, but also related to the operation type of the train conflict operation. If the conflicting operation of train a is the shunting operation which is getting out of the depot, in order to avoid the conflict, it is only allowed to advance the exiting time from the depot, and if the conflicting operation of train a is the shunting operation which is getting into the depot, in order to avoid the conflict, it is only allowed to delay the entering time to the depot. This rule is also suit for train b similarly.

2.3. The spatial dimension conflict resolution algorithm
The purpose of this algorithm is to solve the route conflict completely or reduce the conflict value of the train pair as much as possible.

For a pair of trains which are conflict to each other $\Gamma(a,b)$, if train a has a higher priority over train b. First of all, search the optional operation chain set of train b to find one operation chain that can avoid the conflict, if there is no such operation chain for train b that can avoid the conflict and also the conflict operations are both shunting operations in $\Gamma(a,b)$, it is allowed to adjust the operation chain of train a until finding one solution that can eliminate the conflict, and the algorithm continue to solve another pair of trains that are conflict. If there is no operation chain for train b that can avoid the conflict and also the conflict operation of train a is not shunting operation, it is not allowed to adjust the operation chain of train a.

2.4. The time dimension conflict resolution algorithm
After the search process of spatial dimension conflict resolution algorithm, if there are still some conflicts that can not be avoid, we can eliminate the conflicts by the time dimension conflict resolution algorithm.

For a pair of trains which are conflict to each other $\Gamma(a,b)$, if train a has a higher priority over train b. If the conflicting operation of train b is the shunting operation which is getting out of the depot, in order to avoid the conflict, it is allowed to advance the exiting time of train b from the depot, and if the conflicting operation of train b is the shunting operation which is getting into the depot, in order to avoid the conflict, it is allowed to delay the entering time of train b to the depot.
If it is impossible to avoid the conflict by adjusting the shunting time of train b in the max allowed time period and also the conflict operations are both shunting operations in $\Gamma(a,b)$, we can also adjust the shunting time of train a to avoid the conflict. But if the conflict operation of train a is not shunting operation, it is not allowed to adjust the operation time of train a.

It should be noted that the essence of the time dimension conflict resolution algorithm is to avoid conflict by adjusting the time of entering or exiting the depot and by extending the parking time of the train set on the track.

3. Case study

In order to verify the feasibility of the algorithm, we developed a computer system to optimize the train set shunting plan safety at the hub type high-speed railway station, the main interface of the computer system is shown in figure 3 as below. A real world data of Shenyang north railway station was taken as an example to analysis. Shenyang north railway station is a super large hub type high-speed railway station, which connects Beijing- Harbin normal speed railway, Beijing- Harbin high speed railway, Shenyang-Dalian normal speed railway, Shenyang-Dalian high speed railway, Shenyang-Shanhaiguan normal speed railway, Shenyang-Jilin normal speed railway. There are one high-speed yard and one normal speed yard in the station, and each yard independently operate different passenger trains of the corresponding railway line. In order to meet the needs of shunting operations getting in or getting out of the train set depot, Shenyang north railway station is connected with Shenyang north high speed train set depot through two connecting lines.

Figure 3. The layout structure of Shenyang north railway station.

The layout structure of Shenyang north railway station is as shown in figure 3. According to the real world data, there are 239 trains operated in the high-speed yard every day, among them, there are 41 trains arrive at this station terminally, there are 42 trains depart from this station originally, and 156 trains pass through this station.

The train which arrives at this station terminally need to be shunted into the train set depot, and the train which departs from this station originally need to be shunted out of the train set depot. The whole operation plan should have no operation conflict for the safety reason.

After the optimization of the computer system, the total wait time of the train set on the track decrease from 2832 min to 1265 min, the value decreased by 55.3%, which is significant. And after the optimization, there is no operation conflict also.

4. Conclusion

The algorithm proposed in this paper can solve the route conflict, ensure that there is no operation conflict between all the trains in the hub type high-speed railway station, and ensure the safety and
feasibility of the operation plan, and furthermore, the total wait time of the train set on the track is significantly decreased, the utilization efficiency of the track is improved.

Acknowledgments
This work was financially supported by the Fundamental Research Funds for the Central Universities (Grant: 2018RC012)

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