The Study of High-Speed Passenger Train Operation Plan

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Abstract

The paper sums up the factors with passenger's travel demand, passenger's need of comfort and the wasted train capacity. On the basis of these factors, this paper provides a new idea to solve high-speed passengers train operation plan problem. First, all the possible train operation plans are listed, and then with the aid of intelligent algorithm those train operation plans which can not be sended out are excluded. Finally, the rest of the train operation plans just can meet passenger's travel demand. The paper uses the genetic algorithm to get the best solution and will get train operation quickly.

Keywords: *Passenger Transportation Organization, High-speed Passenger Train Operation Plan, Passenger OD Equilibrium, genetic algorithm.*

1. Introduction

The operation plan of high-speed railway passenger train includes passenger train operation quantity, train type, train operation section and stops along the way, etc. The train operation is the core of the high-speed railway passenger transport organizational management, and it is the basis of establishing the train working diagram and the train schedules. It is a good indicator of the railway passenger transport business strategy and service quality. Excellent passenger train operation plan can improve the business performance of railway passenger transport.

This paper provides a new idea to solve high-speed passenger train operation plan problem. First, all the possible train operation plans are listed, and then with the aid of intelligent algorithm those train operation plans which can not be sended out are excluded. Finally, the rest of the train operation plans just can meet passenger's travel demand. In this way, combining the genetic algorithm the corresponding algorithm is designed in this paper, and by means of an example we can verify the model and the algorithm.

2. Literature Review

In recent years, researchers have done a lot of related researches in the operation plan of high-speed railway passenger train, and have attained some good outcomes.

Some scholars studied the operation plan of high-speed passenger train operation plan considering the influential factors of the passenger train operation plan. Zhang Yongjun, Deng Lianbo, Shi Feng et al. mainly considered stopping at intermediate stations to study the high-speed train operation, established some corresponding models, and put forward the 0-1 programming, multi-objective programming, and intelligent algorithm to the solve the models[1-4]. Cui Bingmou, Luo Yupin et al. studied the problem from the economic perspective, such as the railway transport enterprise cost, the railway transport enterprise profit, passenger traffic fare, waiting cost, transfer cost, congestion tolls. They converted the economic cost into uniform, and established corresponding models [5-9]. Zhou Lixin, Zha Weixiong et al. studied the problem from the passenger OD passenger travel flow and path, and established multi-objective bi-layer models [10-12].

Some scholars studied the operation plan of high-speed passenger train operation plan considering the high speed and convenience of high-speed railway. Ye Huaizhen, Li Qingyun et al. studied the problem from high-speed railway high-speed characteristics, considering minimum train stop time and passenger waiting time, established corresponding model, and designed the solving method [13-14]. Shi Feng, Zheng Li, Qian Yongsheng et al. established some multi-objective bi-layer models considering the passenger convenience degree at different time [15 -17].

In summary, almost no one has studied this problem with the idea of this paper. The paper transforms the high-speed passenger train operation plan problem into passenger's demand of OD equilibrium assignment problem. On the basis of the the OD equilibrium, we gradually eliminate redundant operation train plan, and this paper is innovative.

3. The Influential Factors of High-speed Passenger Train Operation Plan

Many factors influence the operation plan of high-speed passenger train. For instance, the train's plan, capacity, use ratio of seats, fluctuation coefficient of passenger flow, the relationship of capacity and service frequency, the quantity of passengers, the section density of passengers, the quantity of trains.

The paper sums up the factors with passenger's travel demand, passenger's need of comfort and the wasted train capacity.

4. The Model and Algorithm

4.1 The Model

The symbols are defined as follows:
The stations are defined as S , $S=\{s_i | i=1,2,\cdots,N\}$;
a_{ij}--the train travels from i to j;
m_{ij}--the number of passengers travels from i to j;
A_{ij}^{pq} --the number of passengers gets on the train a_{ij} from p to q;
L^{pq} --the distance of p to q;
a_{ij}^0--the number of passengers gets on the train a_{ij} in the first station i;
a_{ij}^k --the number of passengers gets on the train a_{ij} in station k;
G—passengers' quota of a passenger train;
We defined x_{ij}^k （$i,j\in S, i<k<j$） as stops variable: x_{ij}^k =1 if the train a_{ij} stops in the station k and x_{ij}^k =0 otherwise. Consider a variable x_{ij} such that x_{ij}=1 if exist train from station i to station j and x_{ij}=0 otherwise.

(1)Passenger's travel demand: we assume that if there exists a train a_{kp} starting from station k, which can meets the k station passenger's travel demand, namely $m_{kp} \le G$.

And other trains need not stop in the station k, namely

$$\sum_{i=1}^{k-1} x_{ip}^k = 0 \text{ and } x_{kp}=1 \quad . \tag{1}$$

While for a station without a start train, there must exist some trains stop in there, so it meets as follows

$$m_{kp}=\sum_{i=1}^{k-1} x_{ip}^k m_{kp} \tag{2}$$

Namely $$\sum_{i=1}^{k-1} x_{ip}^k = 1 \quad \text{and} \quad x_{kp}=0 \tag{3}$$

In summary, for a station k, it either exists a start train or exists some stations stop in station k, so it meets as follows

$$\sum_{i=1}^{k-1} x_{ip}^k + x_{kp} = 1 \tag{4}$$

Namely $$x_{kp} = 1-\sum_{i=1}^{k-1} x_{ip}^k \tag{5}$$

(2)Passenger's need of comfort: high-speed passenger train cannot overload passengers much. We stipulate a train should not overload passengers more than 10 percent. For train a_{ij}, the number of passengers is m_{ij} at station k-1, and after k stations the number of passengers is $m_{ij}+x_{ij}^k a_{ip}^k$. In order to meet passenger's comfort demand, we define that

$$1.1G < m_{ij}+x_{ij}^k m_{kp} \text{ then } x_{ij}^k = 0 . \tag{6}$$

If $$1.1G \ge m_{ij}+x_{ij}^k m_{kp}, \text{ then } x_{ij}^k = 1, x_{kp}=0 \tag{7}$$

So the number of train model is as followers:

$$z_1 = Min\sum_{i=1}^{n-1}\sum_{j=2}^{\text{n}} x_{ij}, i,j\in S, i<j \tag{8}$$

(3)The wasted capacity : Because of even the same number of trains, different train operation plan will lead to different number of passengers getting on or getting off in some station, so we should consider the wasted capacity. The wasted capacity is calculated as follows:

$$z_2 = Min\sum_{i=1}^{n}\sum_{j=2}^{n}\sum_{k=2}^{n}(G-A_{ij}^{pq}x_{ij}^k)L_{pq},$$
$$i,j,k,p,q\in S, i<j, p<q \tag{9}$$

We combine the Eq. (7) with the Eq. (8) as follows:

$$y = Min(z_1 w_e + z_2 w_s) \tag{10}$$

Where w_e is the cost when transport enterprise departures a train, w_s is the cost of the wasted capacity of a seat.

Then the problem is transformed into a 0-1 multi-objective programming model. It is very tedious to use the traditional multi-objective programming solution, and calculation work is added more with the increase of the number of station and will take much time. Therefore it is not practical to use the multi-objective programming method to solve the model. So this paper chooses the genetic algorithm which has advantage of powerful search ability and high efficiency to solve the model.

4.2 Algorithm

In this paper, we first list all the possible solution, and then remove those trains which can not send out with the aid of the genetic algorithm on the base of passenger's travel demand, passenger's comfort demand and trains capacity. We stop our work until the minimum number of trains.

This paper uses genetic algorithm to find the optimal solution. Genetic algorithm for the train operation problem is as follow:

Step 1: Setting initial parameters. Setting population scale M is 200, crossover probability P_c is 0.6, mutation probability P_m is 0.1, and termination generation T is 500.

Step 2: Producing the initial population. On the basis of population scale and chromosomes, chromosome is a string consisted of 0 and 1 in turns which represents the stop or not in a station and start or not a train. 200 chromosomes meet the Eq.(1) to the Eq.(7) are generated randomly,which consists of the initial population, and every chromosome represents a solution.

Step 3: For individual j(j=1, 2, 3, …,M), calculate its fitness $f(X_i)$ by Eq.(8), selected probability p_i , and cumulative probability λ_i, $\lambda_i = \sum_1^i p_i$.

Step 4: Generating a uniform random number ξ on the interval [0, 1]. If $\xi \le \lambda_1$, then choosing first chromosome to copy; if $\lambda_{k-1} < \xi \le \lambda_k$, then choosing the ξth chromosome to copy. Iterate this process 200 times to generate next population.

Step 5: Crossover operation. Generate N uniform random number ξ_1, ξ_2, …, ξ_k, …, ξ_N on the interval [0, 1] in turns. If $\xi_k < 0.6$, choose the kth chromosome as a paternal chromosome to make up paternal population. Then crossover operation happens in third position.
Step 6: Mutation operation. Generate N uniform random number χ_1, χ_2, …, χ_k, …, χ_N on the interval [0, 1] in turns. If $\chi_k < 0.1$, choose the kth chromosome to mutate operation in second position.

Step 7: I=I+1. If I<T+1, go to step 3; Otherwise, go to step 8.

Step 8: Stopping calculation. Showing the solution x.

4.3 Example Test

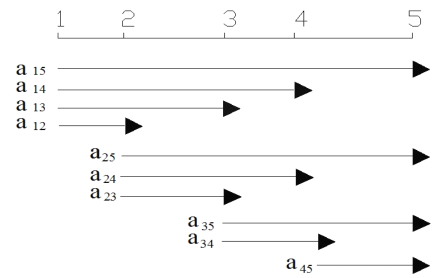

Fig.1 The stations and all train operation.

It shows in the above figure, there are five stations. For convenience, the stations are called as 1, 2, 3, 4, and 5. G=1,000. w_e = 25,000. w_s =15 .The OD traffic flow of network is shown in the following table:

Table 1: The OD traffic flow of network

Destination \ Origin	1	2	3	4	5
1	--	--	--	--	--
2	580	--	--	--	--
3	380	410	--	--	--
4	360	350	530	--	--
5	460	450	540	430	--

After using the algorithm, the best train operation is obtained as follows:
Sending out train a_{15} and it stop in station 2; Sending out train a_{14} and it stop in station 3 and 4; Sending out train a_{25} stop and it station 3 and 4.

5. Conclusion

The paper sums up the factors with passenger's travel demand, passenger's need of comfort and the wasted train capacity. On the basis of these factors, this paper provides a new idea to solve high-speed passengers train operation problem and establishes a train operation model. The paper uses the genetic algorithm to get the best solution and will get train operation quickly.

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