The Passenger Train Plan Based on Passenger Dedicated Line

Sheng-nan WANG
School of Traffic and Transportation, Beijing Jiaotong University, Beijing, China
wsn_smu@163.com

Keywords: Train Plan, Separate Steps, Running Section, Stop Scheme of the Train.

Abstract. The rapid development of railway and the sustained growth of passenger flow volume put forward higher requirement for railway transport organization. As a core of transport organization, the passenger train plan has naturally received the attention. This paper adopts the method of separate steps to formulate the train plan. Firstly, it determines the running section of the train. And then it determines the grade and number of the train. Finally, from the perspective of the railway and passengers, minimizing the railway department’s total operating cost and minimizing the passenger’s total travel fare are the two planning objectives. A multi-objective integer linear programming model established analyzes the stop scheme of the train. The model can be solved by matlab software.

1. Introduction

On July 13, 2016, The Medium and Long-Term Railway Network Planning was promulgated. The planning time is 2016-2025. By 2025, the railway network scale will be up to 175000km. In recent years, the nation promotes vigorously “green transportation”. Because the environment pollution of railway is small, it is the first choice of the green transportation, which further encourages the railway construction.

The rapid development of railway and the sustained growth of passenger flow volume put forward higher requirements for railway transport organization. As a core of transport organization, the passenger train plan has naturally received the attention. And because of the complexity of its establishment, some problems are still needed further research. Based on it, this thesis carries on optimized research.


2. The Passenger Train Plan Optimize

This paper presents the method of separate steps. The solution is divided into three steps: 1. determine the train running sections; 2. determine the grade and number of the train; 3. determine the stop schedule plan of the train. The following will introduce the concrete procedure.

2.1 Determine the train running sections

Train running sections include the starting station and destination of the train and the transport route. In the formulation of the train plan, the various elements are based on its running sections.

The choice of starting station and destination relates to rank and status of passenger station. According to the size of its passenger flow, the station can be divided into six grades: special station,
first-class to five-class station. The third-class, fourth-class and five-class stations cannot be the starting station and destination of the train.

The transport route of trains can determine the direction of passenger flow and train operation. According to the layout of the line, the transport route can be divided into the shortest path and the special path. According to the quantity, the transport route can be divided into single path and many paths. Different transport routes can meet different passenger transport demand.

2.2 Determine the grade and number of the train

2.2.1 Determine the grade of the train

According to the different way of stop, the train grade can be divided into the four categories:

(1) The direct train; if the passenger flow is large, the station can run direct train without stopping in transit, as shown in figure 1.

(2) The train stopping the big stations; the train stops only big stations, as shown in figure 2.

(3) The train choosing stops; in addition to some big stations, the train can choose the appropriate little stations for stopping, as shown in figure 3.

(4) The train stopping every station; in order to meet the passenger flow demand between each station on the way, the stations need to run some trains stopping every station, as shown in figure 4.

2.2.2 Determine the number of the train

Determining reasonably the number of the train can meet the demand of passenger flow and the benefit of the railway sector, as shown in the following formula.
\[ \frac{N^d_w}{N^d_w} = \sum_{d=1}^{m} N^d_w = \sum_{d=1}^{m} \max \frac{Q^d_w(i, j)}{A_{fix}} \times \phi \]  

In the formula, \( N^d_w \)—the number of train on the section \( W \);  
\( N^d_w \)—the number of \( d \)-level train on the section \( W \);  
\( \max Q^d_w(i, j) \)—the maximum passenger flow volume on the \( d \)-level train of the section \( W \);  
\( A_{fix} \)—the fixed number of passenger on the train;  
\( \alpha \)—the utilization ratio of the seat on the train, \( \alpha=0.8 \) in the paper;  
\( \phi \)—the fluctuation coefficient of passenger flow, \( \phi=1.0 \) in the paper.

2.3 Determine the stop schedule plan of the train

For the direct train, the train stopping the big stations and the train stopping every station, because the stopping stations are certain, the train doesn’t need to formulate the stop schedule plan.

For the train choosing stops, in addition to some big stopping stations, the train should choose some little stations to stop. The paper builds a model to solve it.

2.3.1 Main parameters definitions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m )</td>
<td>The total number of train grades</td>
</tr>
<tr>
<td>( N )</td>
<td>The total number of stations</td>
</tr>
<tr>
<td>( n^d )</td>
<td>The number of ( d )-level train</td>
</tr>
<tr>
<td>( c^d_i )</td>
<td>The stopping cost of ( d )-level train on the station ( i )</td>
</tr>
<tr>
<td>( c^d )</td>
<td>The cost of every kilometer for ( d )-level train</td>
</tr>
<tr>
<td>( t^d_{ij} )</td>
<td>The distance travelled from station ( i ) to station ( j ) of ( d )-level train</td>
</tr>
<tr>
<td>( C_{total} )</td>
<td>The total cost of railway department</td>
</tr>
<tr>
<td>( q^d_{ij} )</td>
<td>The passenger flow volume from station ( i ) to station ( j ) of ( d )-level train</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>The average fare rate (( yuan / person \cdot km ))</td>
</tr>
<tr>
<td>( v^d )</td>
<td>The travelling speed of ( d )-level train</td>
</tr>
<tr>
<td>( t^d_{ik} )</td>
<td>The station dwell time of ( d )-level train ( k ) on the station ( i )</td>
</tr>
<tr>
<td>( \tau )</td>
<td>The average fare of time value (( yuan / person \cdot min ))</td>
</tr>
<tr>
<td>( Z_{fare} )</td>
<td>The total travel fare of passengers</td>
</tr>
<tr>
<td>( Q^d_{ij} )</td>
<td>The number of passengers on the ( d )-level train ( k ) from station ( i ) to station ( j )</td>
</tr>
<tr>
<td>( \varepsilon_{fix} )</td>
<td>The minimum number of passengers on the train</td>
</tr>
<tr>
<td>( M_i )</td>
<td>The maximum capacity of stopping station</td>
</tr>
<tr>
<td>( \phi^d_{ik} )</td>
<td>The maximum quantity of stopping for ( d )-level train ( k )</td>
</tr>
</tbody>
</table>

Decision variables:

\[ x^d_{ik} = \begin{cases} 
1, & \text{\( d \)-level train \( k \) stops on the station \( i \)} \\
0, & \text{\( d \)-level train \( k \) doesn’t stop on the station \( i \)} 
\end{cases} \]
\[\delta_{ij} = \begin{cases} 1, & d\text{-level train’s departure station is } i \text{ and destination is } j \\ 0, & \text{others} \end{cases}\]

### 2.3.2 Objective function

The paper has two objectives. From the perspective of the railway, the cost of railway department is the lowest cost as the objective; from the perspective of passengers, the travel fare of passengers is the lowest cost as the objective.

1) The minimum cost of railway department

The cost contains mainly the running cost and stopping cost of train. It can be shown as follows.

\[
\min C_{\text{total}} = \sum_{d=1}^{m} n_d c_{d} l_{ij}^d \delta_{ij} + \sum_{d=1}^{m} \sum_{k=1}^{N} \sum_{i=2}^{N-1} x_{ik}^d c_{ik}^d
\]  
\tag{2}

2) The minimum travel fare of passengers

The fare contains mainly ticket price and the fare of time value. It can be shown as follows.

\[
\min Z_{\text{fare}} = \sum_{d=1}^{m} \sum_{i=1}^{N} \sum_{j=1}^{N} \lambda n_d l_{ij}^d \delta_{ij}^d + \left( \sum_{d=1}^{m} \sum_{i=1}^{N} \sum_{j=2}^{N-1} n_d l_{ij}^d \times 60 v^d \right) + \sum_{d=1}^{m} \sum_{k=1}^{N} \sum_{i=2}^{N-1} \chi_{ik}^d l_{ik}^d \right) \cdot \tau
\]  
\tag{3}

### 2.3.3 Constraint conditions

1) The utilization ratio of the seat constraint

The number of passengers on each train should be no less than the minimum value \(\varepsilon_{\text{fix}}\). It can be shown as follows:

\[\varepsilon_{\text{fix}} \leq Q_{ij}^d \leq A_{\text{fix}}\]  
\tag{4}

2) The capacity of stopping station constraint

The number of trains that the stopping station train can hold should not exceed the station capacity. It can be shown as follows:

\[\sum_{d=1}^{m} \sum_{k=1}^{N} \chi_{ik}^d \leq M_i\]  
\tag{5}

3) The quantity of stopping constraint

In order to reduce the traveling time of passengers, the quantity of stopping is not overmuch and should have certain limit constraint. It can be shown as follows:

\[\sum_{i=2}^{N-1} \chi_{ij}^d \leq \phi^d\]  
\tag{6}

4) 0-1 variable constraint

\[\chi_{ij}^d, \delta_{ij}^d \in \{0,1\}\]  
\tag{7}

### 2.3.4 The stop schedule plan of the train model

According to the analysis of the objective function and constraint conditions, the paper can set up model: objective function: (2) and (3); constraint conditions: (4), (5), (6) and (7).

### 3. Analysis of the Model

According to the section 3.3 for compiling process of train plan, we determine the running section of the trains. Then if we know the OD passenger flow between stations, we can calculate the number of trains according to the formula (1). And then by the known parameters and the calculated data, according to stop solution model established, we can use matlab software to calculate the stop solution of the train stopping every station. Finally, it can determine the passenger train plan of the section.
4. Conclusion

Based on domestic and foreign research, the paper studies the passenger train plan of passenger dedicated line. First, it determines the running section of the train, and then it determines the grade and number of the train. Finally, the model established can confirm the stop scheme of the train stopping every station. The model can be solved by matlab software. In this paper, the research on train plan simplifies the solution step by step. In the later research, we can also try to set up a comprehensive model of the train plan.

References


