Route Optimization of Rail Transit Travel Chain under Bounded Rationality

Changfeng Zhu, Zongfang Wang, Xuejiao Ma, and Xianen Yang

Abstract—The route selection of the rail transit travel chain is studied based on the concept of rail transit collaborative optimization. Considering the influence of passenger travel time, passenger flow changes in rail transit, and different types of rail transit on passenger route selection, proposed a theory of path selection behavior analysis based on prospect theory. Based on passenger travel time, the generalized travel cost, the comfort cost, and taking travel path, transfer times, and travelers’ travel mode as constraint conditions, an optimization model of rail transit travel chain path was constructed under bounded rationality. An example verifies the rationality of the established model and the designed algorithm. The results show that the larger the general overcrowding extra cost coefficient $w$ and the overcrowding additional cost coefficient $s$, the lower the perceived cost of travelers. The smaller the section traveler flow, the larger the departure frequency, and the higher the perceived cost of travelers. In other words, the perceived cost of travelers is inversely proportional to the section traveler flow and the departure frequency.

Index Terms—Rail transit, travel chain, optimal path selection, NSGA-II algorithm

I. INTRODUCTION

In order to better describe the complex travel formed by passengers’ displacement in the urban space through different modes of transportation, the mathematical model of passenger travel is constructed with the help of the travel chain. [1] studied the relationship between travelers’ travel modes, activities and proposed the concept of the tourism chain and its primary research ideas. Subsequently, the theory was further applied to the field of transportation by scholars.

For the concept of a travel chain, scholars put forward different views. [2] believed that a series of trips linked to each other in space and time constitute a travel chain. [3] thought that travel chain refers to a round-trip trip composed of travel purposes arranged in time order to complete one or more activities. [4] thought that the travel chain should contain much information, such as the travel time, space, way, and activity type. The research results of domestic and foreign scholars mainly focus on the intercity transfer and connection or various transportation modes. There are few studies on passenger travel choice of the whole travel chain, even less on rail transit travel. Among the current research results, the study of travel chains mainly adopts the logit model. [5] the improved mixed logit model was applied to study the relationship between the travel mode selection and activity chain. [6] used a multinomial logit model to analyze personal preference on transportation choice behavior. In the same year, [7] used the logit model to analyze the blocking effect of complex travel chains on the choice of public transport mode. [8] established a stereotype logit model to study the influence of the travel chain complexity on travel mode selection. [9] described the joint selection behavior of the travel chain, travel mode, and departure time based on the cross-nested logit model. [10][11] established different logit models to study the interaction between travelers’ choice of travel chain type and mode. The above research focuses on the relationship between the travel chain and travel mode in the travel process.

In addition, other scholars mainly reveal the factors that affect tourism choice behavior by studying tourism chain behavior. [12] established the binary-ordered probability model and the binary poisson regression model to study the travel chain behavior of commuters during commuting. [13] used statistical analysis methods to analyze and study the overall characteristics of the travel chain, the travel mode, and space-time characteristics. [14] built a joint probability model of traveler characteristic variables from the travel chain perspective, aiming at the connection modes at both ends of urban rail transit, and revealed the connection rules of urban rail. [15] put forward the concept of an intercity travel chain and introduces latent psychological variables to build travelers’ intercity travel chain model. [16] studied the intercity passenger transfer choice behavior based on travel chain and revealed the impact of individual socio-economic attributes, travel characteristics, and latent psychological variables of passengers on travel mode choice. The travel route selection mainly focuses on network construction and model-soliving research. Among them, [17][18] analyzed and researched route selection based on prospect theory, [19][20][21] combined with the logit model, constructed a path selection model.

To sum up, relevant scholars have researched the travel path selection of passenger travel chains, but there are still the following areas for improvement. Firstly, most existing
scholars mainly study the route optimization of single mode of transportation in cities and need more consideration of the travel chain problem of multiple modes of transportation. In addition, existing studies assume that travelers are entirely rational but fail to consider the route optimization under bounded rationality. Finally, only some scholars study the travel chain of regional rail transit.

Based on this, by analyzing the complexity of rail transit travel problem and the characteristics of travel behavior under the condition of bounded rationality. Considering the influence of rail transit passenger flow and vehicle type on passenger route selection, a travel chain path optimization model was constructed under the condition of bounded rationality.

The structure of this article is as follows. In Section II, we introduced the structure of the rail transit travel chain, the construction of the travel network, and the process of transfer. In Section III, we established a travel optimization model for the travel chain. In Section IV, we designed an algorithm to solve the model established in Section III. Section V is a discussion and analysis, mainly analyzing the impact of some parameter changes on the results. Finally, the conclusion of this paper is in Section VI.

II. RAIL TRANSIT TRAVEL CHAIN STRUCTURE

The multi-system rail transit network consists of stations of different systems as network nodes. In this network, different systems form their subnetworks and are connected by transport nodes, multi-system rail transit network can be described as:

\[ G = (M, V) \]  (1)

Where, \( G \) represents the multi-system rail transit network, \( M \) represents the collection of multi-system rail transit; \( V \) represents the collection of traffic stops.

Rail transit complex network \( G \) is composed of an urban rail network, railway network, intercity rail network, suburban rail network, high-speed railway network, and bullet train network, among which the rail transit mode is \( M = \{U, R, I, S, H, B\} \). The schematic diagram of regional rail transit travel is shown in Fig. 1.

In order to accurately describe passenger travel needs, a transportation mode including urban rail transit network, intercity rail transit network, universal speed rail transit network and other transportation modes is constructed. As shown in Fig. 2, it is a schematic diagram of the regional rail transit network. In this city \( O \) and city \( D \) are composed of various rail transit systems and connected by several trans-regional rail transit lines. In order to study the rail transit travel chain and the rail transit network, it is also necessary to study travelers’ transfer in the travel process, as shown in Fig. 3, a schematic diagram of rail transit transfer stations.

III. CONSTRUCTION OF TRAVEL CHAIN MODEL

When choosing a route, travelers will comprehensively consider the chosen path based on their needs, mainly focusing on the consumption of travel time, travel money, and personal comfort. The process of selecting rail transit as the mode of travel specifically includes train operation, train parking, and passenger transfer.

A. Construction of Travel Time

The traveling time mainly includes the traveling time of the train from station \( i \) to station \( j \) and the stopping time of the train at each station. The traveling time model of travelers taking the optional path \( k \) in the traveling interval (station \( i \), station \( j \)) is:

\[ T^k_{ij} = t^k_i + \frac{d^k_{ij}}{v} \]  (2)

Where, \( T^k_{ij} \) represents travelers’ travel time (min); \( t^k_i \) represents platform stop time between station \( i \) and station \( j \) (min); \( d^k_{ij} \) represents the train distance from station \( i \) to
station \( j \) (km); \( \bar{v} \) represents the average running time of trains.

**B. Construction of Transfer Time**

Different passengers inevitably have differences in the transfer process of railway passenger hubs. When they walk to the waiting area at different times, the wait time is usually affected by the transfer times, transfer experience and purpose.

The transfer time mainly includes the passenger transfer walking time and the passenger transfer waiting time. The transfer walking time is determined by dividing the transfer distance by the walking speed, and the departure interval determines the waiting time.

Taking travelers taking high-speed rail and transferring to rail transit as an example. As shown in Fig. 4, due to passengers being relatively familiar with the travel route, low passenger flow, and high comfort, passengers choose to take the next rail transit. As shown in Fig. 5, due to external factors such as high passenger flow and unfamiliarity with the route, travelers may not take the next rail transit train and choose the next train or transfer to other transportation methods.

In the first scenario, the waiting time of the traveler is relatively short, thereby shortening the travelers’ travel time. Compared with the second scenario shown in Fig. 5, it saves departure time between two trains. The advantage of this situation is that most of the passenger volume of rail transit will not be lost, but a small portion of the traveler volume will inevitably be lost.

**C. Value Function**

Assume that \( x_0^i \) and \( x_2^i \) are the reference points of early arrival and late arrival respectively, these two reference points divide destination time into three intervals: \((-\infty, x_0^i] \cup [x_0^i, +\infty) \). If the arrival time is less than \( x_0^i \) or greater than \( x_2^i \), it is considered as early loss or late loss, it’s only in the \([x_0^i, x_2^i] \) interval, and can it gain profit. Between \([x_0^i, x_2^i] \), there must be a moment of maximum value, which is called the best arrival time, expressed by \( x \). The value function is shown in Fig. 6.

Travelers tend to arrive early, so the interval distance between \( x_0^i \) and \( x \) should be larger than the interval distance between \( x \) and \( x_2^i \). Travelers tend to avoid risks in the return interval and pursue risks in the loss interval, so the slope of the loss part of the value function curve is higher than that of the gain part. As can be seen from Fig. 6, \( x \) can be divided into left and right parts. The left and right sides are approximately symmetric.
\[ v(x_i) = \begin{cases} 
\lambda_i (x_i^0 - T_j^0 - T_i^0)^0, & T_j^0 + T_i^0 \leq x_i^0 \\
\lambda_i (x_i^0 - T_j^0 + T_i^0)^0, & x_i^0 < T_j^0 + T_i^0 \leq \eta_i \\
\lambda_i (0 - T_j^0 - T_i^0)^0, & x_i^0 < T_j^0 + T_i^0 < x_i^0 \\
\lambda_i (0 - T_j^0 + T_i^0)^0, & x_i^0 \leq T_j^0 + T_i^0
\end{cases} \]

(5)

Where, \( v \) represents the value function of the \( i \)-th interval; \( \lambda_i \) represents the loss avoidance coefficient, and \( \lambda_i \geq 1, \ i = 1, 2, 3, 4 \); \( \eta_i \) represents risk attitude coefficient, and \( 0 < \eta_i < 1, \ i = 1, 2, 3, 4 \).

### D. Weight Function

The weight function is used to simulate the psychological effect on people. Generally, people will attach importance to small probability events and ignore medium and large probability events. In the face of loss, the decision-maker holds the attitude of risk preference, while in the face of income, the decision-maker holds the attitude of risk aversion. According to the research of [22], the probability weight formula is as follows:

\[
\sigma(p) = \begin{cases} 
\sigma^+(p) = \frac{p^{\tilde{c}_i}}{p^{\tilde{c}_i} + (1 - p)^{\tilde{c}_i}}, & \tilde{c}_i > 0 \\
\sigma^-(p) = \frac{p^{\tilde{c}_i}}{p^{\tilde{c}_i} + (1 - p)^{\tilde{c}_i}}, & \tilde{c}_i < 0
\end{cases}
\]

(6)

Where, \( \sigma(p) \) represents the perceived probability of an event occurrence; \( p \) represents the probability of possible arrival time from station \( i \) to station \( j \), according to the frequency of departure; \( \tilde{c}_i \) is 0.61 for gains and \( \tilde{c}_i \) is 0.69 for losses [23].

### E. Generalized Travel Cost

The ticket price of the rail transit is determined by its starting and ending stations and ticket system. The ticket price standard of different rail transit systems is also different. Therefore, this paper takes the function of train travel length as the passenger travel cost.

\[ C_{ij} = f(d_{ij}^h) \]

(7)

Where, \( d_{ij}^h \) represents the distance between station \( i \) and station \( j \).

Travelers are bounded rational, before taking rail transit, travelers will judge whether to take the train according to the number of people at the station. If there is congestion, the congestion coefficient of passengers will increase, thus increasing the cost of travel.

\[ Y_{ij} = \begin{cases} 
0, & p_{ij}^h < f_{ij}^h c_{ij}^h \\
p_{ij}^h - f_{ij}^h c_{ij}^h, & p_{ij}^h \leq f_{ij}^h c_{ij}^h \\
\frac{p_{ij}^h - f_{ij}^h c_{ij}^h}{f_{ij}^h c_{ij}^h} \cdot w_{ij}^h \cdot c_{ij}^h, & \frac{p_{ij}^h - f_{ij}^h c_{ij}^h}{f_{ij}^h c_{ij}^h} \cdot s, p_{ij}^h \geq f_{ij}^h c_{ij}^h
\end{cases} \]

(8)

Where, \( p_{ij}^h \) represents the section passenger flow between station \( i \) and station \( j \), (person/h); \( f_{ij}^h \) represents the departure frequency between station \( i \) and station \( j \) (trains/h); \( c_{ij}^h \) represents the number of passengers per train from station \( i \) to station \( j \) (person/vehicle); \( c_{ij}^h \) represents the overcrowding number of each train between station \( i \) and station \( j \) (person/vehicle); \( w \) represents the general crowding extra cost factor; \( s \) represents the overcrowding extra cost factor; \( Y_{ij}^m \) represents the extra cost coefficient between station \( i \) and station \( j \) due to congestion. When the number of travelers exceeds the train’s capacity, travelers have to wait at the platform for the next train or choose other transportation modes.

The comfort of taking rail transit is positively correlated with the ticket price.

\[ C_{ij} = Y_{ij}^m \cdot f(d_{ij}^h) \]

(9)

To sum up, the objective function of traveler path optimization is as follows:

\[ \max f_1 = \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} \cdot v(p_{ij}) \]

\[ \min f_2 = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} - \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} \]

(11)

In order to ensure the continuity of the transportation process, there is only one complete route for travelers to each destination.

\[ \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}^m = \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}^m = 1, \forall i = o \]

\[ \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}^m = \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}^m = 0 \]

\[ \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}^m = \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}^m = -1, \forall i = d \]

(14)

In order to avoid excessive transfer times in the travel process, the maximum number of transfer times is set.

\[ \sum_{h=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} t_{ij}^h \leq H \]

(15)

In order to quickly and accurately locate the travel path and mode, the decision variable is set. When \( x_{ij}^m = 1 \), it means that the traveler passes station \( i \), otherwise, the traveler does not pass. When \( r_{ij}^m = 1 \), it means that when the traveler passes through node \( i \) to station \( j \), the transportation mode \( m \) is changed into transportation mode \( h \).

\[ x_{ij}^m \in \{0,1\}, \forall (i,j) \in V \]

\[ r_{ij}^m \in \{0,1\}, \forall (i,j) \in V \]

(17)

### IV. ALGORITHM DESIGN

Due to the problem of route selection, it involves the conversion of various vehicles. In order to ensure the diversity of the population, a non-dominated sorting genetic algorithm-II (NSGA-II) based on an improved elite strategy was proposed to solve the model.

#### A. Chromosome Coding and Decoding

The chromosomes are set into double chains, with the first chromosome chain representing the station of rail transit and the second chromosome chain representing the way of travel, both of which are encoded by real numbers,
the encoding is shown in Fig. 7.

Travel station: 

| 11 | 12 | 13 | ... | 13 | 12 | 11 |

Travel mode: 

| 4  | 2  | 1  | 4  | 2  | 1  | 4  |

Scheme: 

| 11 | 12 | ... | 12 | 11 |

Fig. 7. Coding diagram

B. Crossover Strategy

In order to ensure the diversity of the population, the chromosomes are crossed, the same sites (excluding the starting and ending points) existing in the two chromosomes are traversed and marked, and some chromosomes after the points are crossed and exchanged, as shown in Fig. 8.

Parent 1: 

| 11 | s | 12 | ... | s | 12 | 11 |

Parent 2: 

| 11 | s | 7 | ... | s | 7 | 11 |

Child 1: 

| 11 | s | 12 | ... | o | ... | 7 | s | 11 |

Child 2: 

| 11 | s | 7 | ... | o | ... | 7 | s | 11 |

Fig. 8. Chromosomal crossover

C. Elite Strategy

Excellent individuals in the parent generation are retained and directly entered into the child generation, reducing the computational complexity and ensuring that elite individuals are not omitted [24]. The elite policy steps of the NSGA-II algorithm are shown in Fig. 9.

Based on the above analysis, the algorithm steps are as follows:

Step 1: The initial population \( P_t \) is randomly generated, and the travel path and mode are selected.

Step 2: Through selection operator, crossover, and other operations, the offspring population \( Q_t \) is generated.

Step 3: The initial parent population \( P_t \) and the child population \( Q_t \) merge into a new population.

Step 4: Forming a non-inferior solution set by using fast non-dominated sorting.

Step 5: According to the non-dominant sequence, select chromosomes layer by layer to enter the next generation \( P_{t+1} \), until the chromosome number is the population number.

Step 6: Make \( t = t + 1 \) to determine whether the iteration termination condition is satisfied, if yes, the iteration will end. Otherwise, through the cross-operation, the offspring population \( Q_{t+1} \) will be generated and transferred to step 3.

Based on the above analysis, the algorithm flow of NSGA-II is shown in Fig. 10:

![Algorithm flow chart](image)

V. EXAMPLE DESIGN AND RESULT ANALYSIS

As an example, this paper takes the path between city O and city D in a specific urban agglomeration and combines multiple transportation modes in the rail transit network. Passengers take short-distance transportation from the departure station to the hub station of the city and transfer to long-distance transport at the hub station. A combination of multiple rail transit systems provides services for passengers with different travel purposes and service characteristics. This paper takes city O and city D as examples, and the rail transit network diagrams of the two cities are shown in Fig. 11 and Fig. 12.
The cross-regional stations between the two cities provide transfer for rail transit of different systems, only stations marked as interchange stations are allowed to transfer between the two cities, as shown in Table I, which is the information on the rail transit network of different systems.

Table I: Rail Transit Network Information of Different Systems

<table>
<thead>
<tr>
<th>Rail transit system</th>
<th>Start</th>
<th>End</th>
<th>Ticket price (yuan)</th>
<th>Mileage(km)</th>
<th>Speed(km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercity</td>
<td>O_{13}</td>
<td>D_{7}</td>
<td>128</td>
<td>319</td>
<td>250</td>
</tr>
<tr>
<td>High speed railway</td>
<td>O_{13}</td>
<td>D_{7}</td>
<td>154</td>
<td>309</td>
<td>350</td>
</tr>
<tr>
<td>High speed railway</td>
<td>O_{13}</td>
<td>D_{10}</td>
<td>144.5</td>
<td>299</td>
<td>350</td>
</tr>
<tr>
<td>Railway</td>
<td>O_{13}</td>
<td>D_{7}</td>
<td>46.5</td>
<td>315</td>
<td>120</td>
</tr>
<tr>
<td>Railway</td>
<td>O_{8}</td>
<td>D_{1}</td>
<td>46.5</td>
<td>313</td>
<td>120</td>
</tr>
<tr>
<td>Bullet train</td>
<td>O_{8}</td>
<td>D_{1}</td>
<td>97</td>
<td>313</td>
<td>200</td>
</tr>
<tr>
<td>Bullet train</td>
<td>O_{13}</td>
<td>D_{7}</td>
<td>96.5</td>
<td>304</td>
<td>200</td>
</tr>
</tbody>
</table>

The operation indicators of each line in the city O rail transit network are shown in Table II, and the operation indicators of each line in the city D rail transit network are shown in Table III.

Table II: Operation Indicators of City O Rail Transit Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Line 1</th>
<th>Line 2</th>
<th>Line 3</th>
<th>Line 4</th>
<th>Line 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum departure interval/min</td>
<td>2.00</td>
<td>2.75</td>
<td>3.50</td>
<td>3.23</td>
<td>3.50</td>
</tr>
<tr>
<td>Number of train formation</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Fixed number of Train (person/train)</td>
<td>1259</td>
<td>1259</td>
<td>1259</td>
<td>1259</td>
<td>1259</td>
</tr>
<tr>
<td>Metro vehicle type</td>
<td>type B</td>
<td>type B</td>
<td>type B</td>
<td>type B</td>
<td>type B</td>
</tr>
<tr>
<td>Overcrowding (person/train)</td>
<td>1869</td>
<td>1869</td>
<td>1869</td>
<td>1869</td>
<td>1869</td>
</tr>
<tr>
<td>Speed(km/h)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

Assume that the earliest departure time of rail transit in city O and city D is 6:00, the passenger transfer time on foot is 2.5 minutes, the passengers’ transfer preparation time is 0.5 minutes, the fare of urban rail transit is 1/3 (yuan/km), Less than 3km is charged at 3km, and more than 3km is charged at 6km. At 7:30 am, a passenger departed from station 11 in city O and took the urban rail transit to station 12 in city D. After spending 3 hours in city D, return to the original route. The path from station 11 in city O to station 12 in city D is shown in Table IV.

Table III: Operation Indicators of City D Rail Transit Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Line 1</th>
<th>Line 2</th>
<th>Line 3</th>
<th>Line 6</th>
<th>Line 7</th>
<th>Loop wire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum departure interval/min</td>
<td>3.17</td>
<td>3.08</td>
<td>2.50</td>
<td>3.83</td>
<td>6.50</td>
<td>4.50</td>
</tr>
<tr>
<td>Number of train formation</td>
<td>6</td>
<td>4/6</td>
<td>6/8</td>
<td>6/8</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Fixed number of trains (person/train)</td>
<td>1440</td>
<td>632/962</td>
<td>962/1292</td>
<td>1440/1920</td>
<td>1860</td>
<td>1960</td>
</tr>
<tr>
<td>Metro vehicle type</td>
<td>type B</td>
<td>type B</td>
<td>type B</td>
<td>type B</td>
<td>type B</td>
<td>type A</td>
</tr>
<tr>
<td>Overcrowding (person/train)</td>
<td>2062</td>
<td>882/1342</td>
<td>1342/1802</td>
<td>1547/2062</td>
<td>2322</td>
<td>2580</td>
</tr>
<tr>
<td>Speed (km/h)</td>
<td>40</td>
<td>35</td>
<td>35</td>
<td>50</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>
Since passengers are boundedly rational, considering the value sensitivity coefficient and weight coefficient. It is necessary to carry out a sensitivity analysis on the influence of comprehensive prospect value. Scheme 3 is taken as an example to analyze the travel path, as shown in Fig. 13 and Fig. 14.

![Fig. 13. Influence of value sensitivity coefficient on time prospect values](image)

![Fig. 14. Influence of weight coefficient on time prospect values](image)

As can be seen from Fig. 13, both the gain sensitivity coefficient and loss sensitivity coefficient affect the time prospect value, and the influence of the gain sensitivity coefficient on the prospect value is much more significant than that of the loss sensitivity coefficient. As seen from Fig. 14, the weight gain coefficient is more sensitive to the influence of the weight loss coefficient on the time prospect values. With the weight gain coefficient increase, the time prospect values show an upward trend.

Assuming that other factors remain unchanged, taking a B-type train with 6 marshals as an example, and the cross-sectional passenger flow at all stations in scheme 3 is 15000 (person/h). The impact of the general congestion additional cost coefficient and the overcrowding additional cost coefficient on the generalized travel cost is shown in Fig. 12.

As can be seen from Fig. 15, when the general overcrowding extra cost coefficient w gradually increases, the generalized travel cost gradually decreases, indicating that when the passenger flow in the section is greater than the number of passengers that can be carried, passengers feel extremely uncomfortable and the perceived cost is negative. The larger the overcrowding extra cost coefficient s is, the smaller the perceived cost of travel. From the changes in the curve in Fig. 15, it is found that the additional cost coefficient s of overcrowding has a relatively significant impact on travel costs.

Section passenger flow, departure frequency, train size, and train overcrowding all impact the generalized travel cost, among which train size and train overcrowding are mainly related to the train type. Assuming that the departure frequency of the train is 12 trains per hour, the impact of cross-sectional passenger flow changes on generalized travel cost is shown in Fig. 16. Assuming that the cross-sectional passenger flow at each station is 15000 (people/h), the impact of train departure frequency on the generalized travel cost is shown in Fig. 17.

As can be seen from Fig. 16, it can be seen that as the passenger flow of this section increases, rail transit will become congested, and the perceived cost of passengers will correspondingly decrease. The more passengers there are, the worse the passenger experience. However, the maximum number of passengers a train can carry is the number of overloaded passengers. We should not assume that more passengers are better. Careful consideration should be given to passenger experience, operating costs, and capacity consumption perspectives.
Fig. 17. Influence of departure frequency on generalized travel cost

As can be seen from Fig. 17, the increase in the frequency of departures means that the ability to transport passengers is enhanced, and the perceived cost of passengers is also increased. The dense departures make passengers feel less crowded for the type A metro vehicle with an overcrowding of 2580.

VI. CONCLUSION

This paper mainly studies the optimization problem of regional rail transit travel chain paths. Because the travel environment is uncertain, an optimization model of the traveler travel chain is established considering the bounded rationality behavior of passengers, and an algorithm for solving the model is designed.

By analyzing the obtained objective function and related parameters, it was found that the effect of the gain sensitivity coefficient on prospect value is much greater than that of the loss sensitivity coefficient. The weight gain coefficient is more sensitive to the effect of the time prospect value than the weight loss coefficient, and the time prospect value increases with the increase of the weight gain coefficient.

The relationship between generalized perceived cost and other parameters is as follows: the larger the general overcrowding extra cost coefficient $w$ and overcrowding extra cost coefficient $s$, the lower the perceived cost of passengers. The smaller the section passenger flow, the greater the departure frequency, and the higher the perceived cost of passengers. That is, the perceived cost of passengers is inversely proportional to the section passenger flow and is directly proportional to the departure frequency.

REFERENCES


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