

Research on Train Over-taking Organization of Urban Rail Transit

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Abstract. Study on train over-taking organization of urban rail transit and propose calculation methods of local train's waiting time as well as the length of the cross section. Combining with actual operation of urban rail transit, the effects of departure interval, tracking interval and the maximum operating speed difference of express/local train on local train's waiting time and the length of the cross section are analyzed. The result shows that with the increasing of express/local train's departure interval the local train's waiting time displays periodic variation. Under specific parameters, the cycle is 54s. In a single cycle, the waiting time increases linearly with the departure interval. If the tracking interval is within 90-150s and the departure interval is greater than 133s, the local train's waiting time increases with the increase of tracking interval. If the overtaking occurs in the section, the length of the cross section increases with the increase of the tracking interval. If the tracking interval increases from 90s to 120s, the length of cross section will increase by 25.00% when the maximum operating speed difference of express/local train is 0km/h. And under the same tracking interval, the length of the cross section decreases with the increase of the maximum operating speed difference. If the maximum operating speed difference between express/local train increases from 0km/h to 20km/h, the length of the cross section will decrease by 25.00% when the tracking intervals is 90s.

1. Introduction

Express/local operation is suitable for long distance suburban lines with large distances. It has practical significance for Chinese urban rail transit system, which is expanding continuously. Scholars in the field of transportation have done a lot of research on over-taking organization of Urban Rail Transit. Qingrui Zhou proposed the express train passed the local slow train at certain stations or intervals under the common line operation mode of the express/local train [1]. Saeed Zolfaghari, etc. confirmed that the average waiting time for passengers in the crossing station is prolonged [2]. Li Zheng put forward an optimization model of single objective cross-stop train operation scheme with minimum total travel time [3]. Xinmiao Zhao studied the path selection of passenger perception time difference under the express train [4]. Baoguo Zhang studied the problem of the quantity and position about the overtaking station as well as impact on capacity [5]. Daoping Miu studied the influence of the auxiliary line of the common crossing station on the construction difficulty and the cost of the station [6].

The existing research mainly focus on the skip stop train plan optimization, passenger travel choice, the setting, number of stations, construction cost etc. Only a few documents put forward the problem of passenger waiting time extension at the crossing station, and there are few studies on the time of waiting and the length of the crossing interval. Based on the above research results, the over-taking organization process is studied. And the influence of the tracking interval, the departure interval of the express/local train and the maximum running speed of the express/local train have on local train's waiting and the length of cross section have been analyzed.

2. Train Over-Taking Organization

According to the crossing location, the urban rail transit train over-taking can be divided into station and section. Stop time difference and interval time and other factors related. The location of the overtaking station or interval is related to the interval between the start of the express/local train, the difference between the interval operation, the time of the stop and the interval time. According to the operation characteristics of the express/local train, puts forward the following hypothesis: the express/local train is unbalanced, and the departure interval between the ahead slow train and the rear express train is T_{l-e} . In order to reduce the influence of the crossing station, the express train just skips one station. The express will skip-stop as it overtakes the slow train. Every local train is up to overtake once more, every express train overtakes local train once more most.

If the time interval a_m the ahead slow train and the rear express train arrives at M station is greater than or equal to the tracking interval I but the departure interval h_m is less than I , M station should be set as overtaking station or the first stop of cross interval. If the departure interval h_m is greater than or equal to I but the time interval a_{m+1} the ahead slow train and the rear express train arrives at M station is less than I , M station should be set as overtaking station or the first stop of cross interval.

2.1 Local Train's Waiting Time

If express train over-takes local train at M station, local train stops at the side track to avoid express train. After it passing through M station, the local train leaves the station. The waiting time of local train is shown in figure 1.

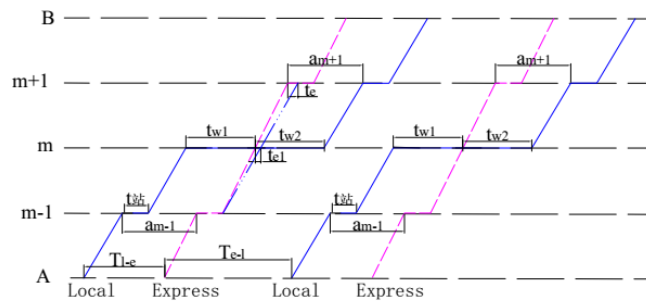


Figure 1. Schematic diagram of waiting time of local train

Local train collision waiting time calculation formula is (1) - (4). The formula (3) constrains the departure interval between the ahead slow train and the rear express train and the formula (4) restricts the time t_{w2} component of the slow train.

$$t_w = t_{w1} + t_{w2} \quad (1)$$

$$t_{w1} = T_{l-e} - (N-1)(t_e + t_s) - t_{e1} \quad (2)$$

$$s.t. \quad T_{l-e} - (N-1)(t_e + t_s) - t_{e1} \geq I \quad (3)$$

$$s.t. \quad t_{w2} \geq I \quad (4)$$

In the above formula t_w refers to the local train's waiting time when the local train stops to avoid the express train and it consists of two parts: t_{w1} and t_{w2} . N refers to number of express train's crossing stations when it overtakes the local train. t_e refers to the total running time to save when express train skip-stops one station and t_{e1} refers to the running time saved by the express train from the previous station to the crossing station. According to the operation results of the simulation experiment system of urban rail transit train [7], the t_e value is about 24s and t_{e1} values about 13s. t_s refers to the stop time of express/local train, all of which are taken for 30 s. I refers to track train interval time, this paper assumes that the minimum tracking interval time is 90 s.

2.2 Length of Crossing Interval

The m station of a certain urban rail transit line is the first station in the crossing section, and there are a total of k stations in the interval. From the station m to $m+k-1$, the local train stops at the

side track and the express train passes through the main line .The express and local train runs relatively independently and the tracking operation should be kept before the m station and after the $m+k-1$ station, namely, $a_m \geq I$, $h_{m+k-1} \geq I$.

The express train completes the local train in m to $m+k-1$ interval and the local train does not need to extend the stop time to avoid the express train. The formula for calculating the interval length is (5) - (7), the formula (6) and (7) constrain the express/local train track the operation outside the line.

$$L = \min \sum_{i=m}^{m+k-2} L_{(i,i+1)} \quad (5)$$

$$s.t. \quad a_m \geq I \quad (6)$$

$$s.t. \quad \sum_{i=m}^{m+k-2} \Delta t_{(i,i+1)} + k \cdot t_s - a_m \geq I \quad (7)$$

In the above equation, L refers to the length of the crossing interval, that is, the distance between the center lines of the first station and the end of the line. $L_{(i,i+1)}$ refers to the distance between center line of the station i and the station $i+1$ in the crossing interval. $\Delta t_{(i,i+1)}$ refers to the time difference between station i and station $i+1$.

3. Analysis on Waiting Time of Local Train

It is assumed that the distance between urban rail transit stations is 1.5km and above and express/local train's formation, speed grade is the same, the maximum running speed is 100km/h when express train overtakes local train at station. This chapter analyzes the local train's waiting time under different organization modes.

In order to ensure the track operation of the express/local train, the minimum interval between the ahead local train and the rear express train in the starting station is restricted by N . Under different tracking intervals, the relationship between the N and T_{l-e} is shown in Table 1.

Table 1. Relationship between N and T_{l-e} under different tracking intervals

I T_{l-e} N	1	2	3	4
90	[103,157)	[157,211)	[211,265)	[265,319)
120	[133,187)	[187,241)	[241,295)	[195,349)
150	[163,217)	[217,271)	[271,325)	[325,379)

Table I shows when $I = 90$ s and $103 \leq T_{l-e} < 157$, it is possible to determines that $N = 1$. Combined type (1-2), local train's waiting time $t_w = T_{l-e} - 13 + t_{w2}$. In order to reduce the influence of overtaking on the local train, this article takes $t_{w2} = I$. Therefore, in this range, the local train's waiting time increases linearly with T_{l-e} . The minimum is $2I$ and the maximum is close to $2I + t_e + t_s$. If $157 \leq T_{l-e} < 211$, in order to reduce waiting time, the express train will overtake the local train in the second skipping, and the waiting time will increase with the increase of T_{l-e} . The range of change will be $[2I, 2I + t_e + t_s)$. In summary, under different tracking intervals, the change rule of t_w with T_{l-e} is shown in figure 2.

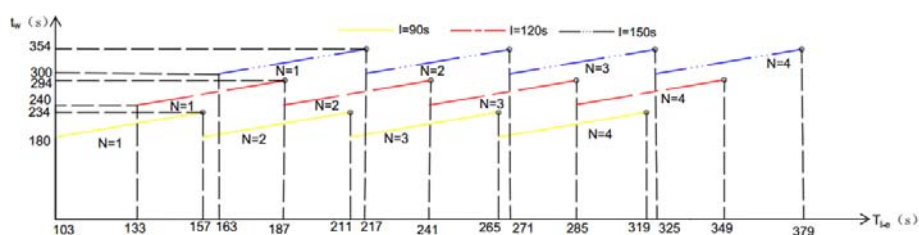


Figure 2. The changing rule of t_w with T_{l-e} under different tracking intervals

The figure 2 shows that under the same track interval, the local train's waiting time t_w changes periodically with T_{l-e} and the change period is $T = t_e + t_s$. In the single period, t_w increases linearly with T_{l-e} , and its variation range is $[2I, 2I + t_e + t_s]$. If T_{l-e} is greater than the 133s, under the same departure interval, local train's waiting time t_w increases with the tracking interval I . Net added value depends on the added value of the tracking interval, regardless of the size of the initial interval.

4. Analysis on Length of Crossing Interval

This chapter analyzes the influence of the maximum speed difference and the tracking interval on the length of the crossing interval. In order to reduce the influence of the crossing interval on the project cost, it designs $a_m = h_{m+k-1} = I$. In order to give full play to the advantages of long distance line spacing, the speed limit of the line is generally higher than 100km/h, assuming that the local train's maximum operating speed is 100km/h, the express train's is 100km/h or 120km/h, and the tracking interval is 90, 120 and 150s.

Calculated by the urban rail transit train running results of simulation experiment system the pure running time difference between the express/local trains in one station is 22s. According to formula (5)-(7), the length of crossing interval under different tracking intervals is calculated. The results show that the length of crossing interval is 6.0, 7.5, 9.0 km when the tracking interval is 90, 120, 150s. With the increase of the tracking interval, interval length is increased by 25.00% and 20.00%.

While the maximum operating speed of the express train is 120km/h but the local train's is 100km/h the pure running time difference between the express/local train in one station varies with the distance between stations as shown in table 2.

Table 2. Pure running time difference between the express/local trains

$L_{(i,i+1)}$ (km)	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
$\Delta t_{(i,i+1)}$ (s)	33	37	41	45	48	53	55	60

Combined with table 3-1 and formula (5) - (7), the length of crossing interval under different tracking intervals is calculated. The results show that the length of crossing interval is 4.5, 6.0, 7.5km when the tracking interval is 90, 120, 150s. As the tracking interval increased, the length of the crossing interval increases by 33.33% and 25.00% in turn.

While the maximum operating speed difference of express/local train is increased from 0 to 20km/h, and the length of the crossing interval decreases by 25.00%, 20.00% and 16.67%, respectively, when the tracking interval is 90, 120 and 150s. Therefore, when the tracking interval is within 90-150s, the length of the crossing interval is reduced with the increase of the maximum operating speed of the express/local train, and the larger the tracking interval is, the smaller the range of the length of the crossing interval.

5. Conclusion

1) Put forward calculation methods of local train's waiting time and the length of the crossing interval.

2) While express trains overtake local train at station, the local train's waiting time t_w changes periodically with T_{l-e} and the change period is 54s under the parameters set in this paper. In the single period, t_w increases linearly with T_{l-e} , and its variation range is $[2I, 2I + t_e + t_s]$. Tracking interval in the range of 90-150s, if $T_{l-e} \geq 133$ s, under the same departure interval, t_w increases with the tracking interval increase, net value added directly determined by the change of tracking interval.

3) While express trains overtake local train at crossing interval, the length of the interval increases with the growth of the tracking interval, and the greater the velocity difference, the greater the increase under the same maximum operating speed difference of express/local train. While the maximum speed difference of the express/local train is 0km/h, the length of the crossing interval is increased by 25.00% and 20.00% respectively if the tracking interval is 90, 120 and 150s. While the

speed difference is 20km/h, the length of the crossing interval is increased by 33.33% and 25.00% respectively. Under the same tracking interval, the length of the crossing interval decreases with the increase of the maximum operating speed difference of the express/local train, and the larger the tracking interval is, the smaller the reduction is. Under the setting parameters of the article, if the maximum operating speed difference of the express/local train is increased from 0km/h to 20km/h, the length of the crossing interval is reduced by 25.00%, 20.00% and 16.67%, respectively, when the tracking interval is 90, 120 and 150s.

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