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*Research Article*

# The Optimization of Passengers' Travel Time under Express-Slow Mode Based on Suburban Line

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The suburban line connects the suburbs and the city centre; it is of huge advantage to attempt the express-slow mode. The passengers' average travel time is the key factor to reflect the level of rail transport services, especially under the express-slow mode. So it is important to study the passengers' average travel time under express-slow, which can get benefit on the optimization of operation scheme. First analyze the main factor that affects passengers' travel time and then mine the dynamic interactive relationship among the factors. Second, a new passengers' travel time evolution algorithm is proposed after studying the stop schedule and the proportion of express/slow train, and then membrane computing theory algorithm is introduced to solve the model. Finally, Shanghai Metro Line 22 is set as an example to apply the optimization model to calculate the total passengers' travel time; the result shows that the total average travel time under the express-slow mode can save 1 minute and 38 seconds; the social influence and value of it are very huge. The proposed calculation model is of great help for the decision of stop schedule and provides theoretical and methodological support to determine the proportion of express/slow trains, improves the service level, and enriches and complements the rail transit operation scheme optimization theory system.

## 1. Introduction

Starting from the beginning of the 21st century, the urban rail transit in China entered a rapid period of development, the urban development grows faster, the urban traffic congestion of metropolises has become more and more serious, and people's living costs continue to increase, so the advantage of suburban is very obvious, and the suburban passenger flow surges forward; therefore, it is of great market demand to attempt express-slow mode between city and suburbs. The suburban line is longer than the ordinary one, and the passenger flow has more obvious spatial and temporal distribution. Lin and Sheu [1] found that more flexible stop schemes can be determined according to the passenger flow under this mode, including the proportion of express/slow trains. Jin and Sendhoff [2] stated that the travel time of express passenger decreases, while the slow ones will prolong because of the express trains' overtaking. The total travel time of passengers is an important index to reflect the services level of rail transport, so it is of good practical significance to study the optimization modelling of the travel time under express-slow mode. Liu and Sun [3] established a multiobjective 0-1 programming model, in which three optimization goals are considered. The construction of the model laid the foundation for the development of the train plan, which has a good reference value for the study of this paper. Dündar and Şahin [4] introduced the Dijkstra algorithm to solve the shortest path problem and added angle increasing function in the cost matrix to determine priorities. With the minimal complexities of decision trees representing rules defined for features and functionalities of online learning community, the feasible space for complexities of decision trees can only be implicitly reflected by relationships of subtables and associated objective functions due to the great number of possible trees. Shi et al. [5] showed that the railway transport market was subdivided from the passenger travel time, travel expenses, convenience and comfort, and several other aspects, the optimized the model was established, and the operation scheme was developed at last; this study was of good academic value. Castelli et al. [6] studied the passenger flow, passenger flow characteristics, and direction characteristics between the lines, and an optimization method of train schedules was proposed based on features of each passenger line. Wong et al. [7] discussed the passenger transfer problem in the urban rail network, assumed the minimum waiting time as the goal, established a mixed integer programming model, and obtained the coordination train timetable. Zhou [8] attempts to propose the theory and methodology with regard to real-time predictive scheduling based on the branch-and-bound approach. The mathematical description and model for train operation and scheduling have been established based on the job-shop scheduling theory and alternative graph theory. Besides, the branch-and-bound rules were proposed to simplify the computing based on the model. Peng [9] studied the train delay propagation with the condition of joint operation and under network and analysed the important influence of passenger flow on the train delay management under network conditions. The optimization model and method of train operation delay management were compared from both the operational point and passengers, which is of great practical guidance. Zhang and Chen [10] established a blocking constraint hybrid flow shop model to describe the solution space about the double track train scheduling problem and proposed an optimization algorithm of hybrid particle swarm as a solution. Ji and Meng [11] proposed a robust train dispatching model to solve the network train dispatching problem with stochastic information of capacity breakdown duration. The objective is to minimize expected total train delay time and then introduce unique route selection constraints to guarantee the robustness of dispatching solutions. Model and algorithm can effectively generate robust train operation adjustment plan and provide the necessary auxiliary decision-making information for the dispatchers. He [12] studied the robust wagon-flow allocation models, and three wagon-flow allocation models are proposed step by step. Firstly, a WFA model that considers different train size limitations of departure trains is formulated. Secondly, a WFA model considers the uncertainty of the breakup time of inbound trains and the makeup time of outbound trains is formulated; the uncertain impacts on the stage plan can be reduced if the yaps of estimated and actual values are decreased. Thirdly, an equity objective function is introduced for the WFA model that considers the uncertain of arrival time of inbound trains. This equity objective function can optimize the distribution of waiting time for classification of the inbound trains from different directions.

The basic problems such as studying the formulation rail transit line planning and establishing the operation scheme of multigoal programming model according to the general situation of dedicated passenger line and high-speed rail line planning from passengers' travel time and cost benefits were studied. It involves some new concepts, such as the calculation model of passenger transfer fatigue recovery time, the consumption choice model of passenger lines, the calculation of the number of trains, and so forth. Through the analysis and calculation above, programming model, integrating the railway operation scheme optimization problem, was determined, and at last, a high feasibility optimization method of operation scheme was proposed.

This paper intends to study the dynamic quantitative relation between the passengers' total travel time and train stop scheme and express/slow trains ratio in the express-slow mode and then aim to establish the optimization model of passengers' travel time.

## 2. The Analysis of the Factors That Affect the Passengers' Travel Time

*2.1. The Analysis of the Factors That Affect the Travel Time.* The passengers on suburban lines can be divided into two categories: the slow passengers, who at least get down at one common station, and express passengers, in which the OD is usually large passenger stations. The slow train passengers can get more satisfied service with single station stop scheme, while it will affect the travel time of express passengers [13]; when under the express-slow mode, it will increase the waiting time of slow trains, but for the express passengers, they can reach their destination station more quickly.

According to the actual situation, the passengers of the same direction continued to reach the station one after another in section $[0, t]$. There are $A_j$ $(1 \leq j \leq m)$ kinds of trains for passengers to select. We can assume that the amount of passengers arriving at the station obeys the Poisson process which is subject to the intensity of $\lambda$, and the probability of taking the train $A_j$ is $p_j$ $(j = 1, 2, \ldots, m;\ \sum_{j=1}^{m} P_j = 1)$, using $N_j(t)$ to indicate the amount of passengers who take on train $A_j$ in section $[0, t)$.

$N(t) = \sum_{j}^{m} N_j(t)$, in which $N_j(t)$ are units independent to each other. So using $\tau_{n,j}$ to express the arrival time of the $n$th passenger to reach the train $A_j$, the cumulative distribution function and probability density are shown in formulas (1) and (2), respectively.

$$F_{\tau_{n,j}} = \begin{cases} 1 - \sum_{k=0}^{n-1} \dfrac{\left(P_j \lambda t\right)^k}{k!} e^{-\lambda P_j t} & t > 0 \\ 0 & t \leq 0, \end{cases} \tag{1}$$

$$f_{\tau_{n,j}} = \begin{cases} \dfrac{\lambda P_i \left(\lambda P_j t\right)^{n-1}}{(n-1)!} e^{-\lambda p_j t} & t > 0 \\ 0 & t \leq 0. \end{cases} \tag{2}$$

Assuming that the amount of passengers arriving at the station is $n$, time that needs to wait at the station can be expressed as a mathematical expectation shown in formula (3):

$$E\left(\tau_{n,j}\right) = \int_0^{+\infty} t f_{\tau_{n,j}}(t)\, dt$$
$$= \int_0^{+\infty} t \frac{\lambda p_j \left(\lambda p_j t\right)^{n-1}}{(n-1)!} e^{-\lambda t} dt$$

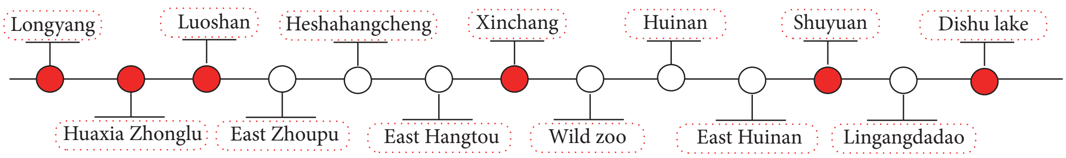


Figure 1: The stop scheme of Shanghai Metro Line 16.

$$= -\frac{(\lambda p_j t)^{n-1}}{(n-1)!} e^{-\lambda p_j t} \Bigg|_0^{+\infty} + n \int_0^{+\infty} \frac{(\lambda p_j t)^{n-1}}{(n-1)!} dt$$
$$= \frac{n}{\lambda p_j} \int_0^{+\infty} \frac{\lambda p_j (\lambda p_j t)}{(n-1)!} e^{-\lambda p_j t} dt = \frac{n}{\lambda p_j}. \quad (3)$$

So let the departure time for train $A_j$ be $t_j = E(\tau_{n,j})$; the reasonable train departure interval can be expressed in formula (4):

$$\Delta T_j = t_j - t_{j-1} \quad (1 \le j \le m;\ T_0 = 0). \quad (4)$$

We can assume that the amount of passengers getting on the train $A_j$ is $N_j(t)$ in the period $[0, t)$, and the time for the passenger $i$ to arrive at the station is $W_{ji}$, so the sum of the waiting time for train $A_j$ can be described as in formula (5):

$$W_j(t) = \sum_{i=1}^{N_j(t)} (t_j - W_{ji}). \quad (5)$$

So the mathematical expectation of waiting time can be shown in formula (6):

$$E\left[\sum_{i=1}^{n} W_{ji} \mid N_j(t) = n\right] = E\left[\sum_{i=1}^{n} Y_{(i)}\right] = E\left[\sum_{i=1}^{n} Y_i\right] = \frac{nt_j}{2}. \quad (6)$$

Through the analysis above, the train departure interval is very important, according to which the reasonable waiting time can be obtained, so the mathematical expectation value can be expressed as $\lambda t_j^{\,2}/2$. This calculation method of waiting time is of great value for travel time optimization research; the other main factors that also affect the passengers' travel time are as follows.

*(1) Station Passenger Flow.* Obtaining the accurate passenger flow of rail transit line especially prediction is very complex, which will influence stop scheme, and so forth. Besides, passenger flow changes dynamically, the stop scheme and ratio of express/slow trains will react to passenger flow, forming a dynamic interaction relationship. Compared with high-speed railway, the traffic density is still relatively large; passengers' arrival can be regarded as independent of the train schedule, random distribution [14]. When the traffic interval is smaller, the average waiting time of the passengers is close to half of the interval. In express-slow mode, the average waiting time by express trains can be expressed as in formula (7):

$$T_{\text{wait}} = \frac{1}{2} \frac{T_i}{f_i}, \quad (7)$$

in which $T_i$ is operation time, min; $f_i$ is the quantity of trains involved in operation.

And the waiting time by slow trains can be expressed as in formula (8):

$$T_{\text{wait}} = \left[\theta_i + \frac{(1-\theta_i)}{m_i}\right] \times \frac{1}{2} \frac{T_i}{f_i}, \quad (8)$$

in which $\theta_i$ is the sharing rate of passengers whose original plan was to take the slow trains, its value, and $m_i$ is passenger flow of section $i$.

*(2) The Stop Scheme.* When the train enters the station and stop, it includes the process of acceleration and deceleration, from the theoretical analysis; the more stations the train stops in, the more additional time consumption due to stop and start [15]. When considering more stations for express trains to stop, it will obviously save some time by transferring with slow ones, but it will prolong the travel time; in fact, the more stations the trains stop in the better, so suitable stop scheme should be made according to the passengers' flow, aiming to shorten the travel time. The common stop scheme can be shown as in Figure 1 [16].

Passengers' travel time is an important indicator of the services level of urban rail transport, so how to save the total passengers' travel time is an important goal to study the optimization of stop scheme. The passenger' travel time can be divided into waiting time, train running time, and stop time at station; if the transfer is included at the same line [17], transferring time also needs to be considered between the express and slow trains.

① When only the slow trains are used, the passengers' total travel time can be expressed as formula (9):

$$T_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} \left[\rho_{ij} \left(t_{ij} + \sum_{k=1}^{n} (h_k^1 + h_k^2) + \frac{d_i}{2}\right)\right], \quad (9)$$

in which $\rho_{ij}$ is the passenger flow between station and station, person; $t_{ij}$ is the pure running time between station and station, minute; $h_k^1$ is the stop time at station, minute; $h_k^2$ is the additional time of start and stop consumption at station, minute; $d_i$ is train turnaround time, minute.

② While under the express/slow mode, using $\rho_{ij\text{-express}}$ as the quantity of passengers of express trains and using $\rho_{ij\text{-slow}}$

as the quantity of passengers of slow trains, the total waiting time can be expressed as formula (10):

$$T_{\text{all-waiting}} = \sum_{i=1}^{n}\sum_{j=1}^{n}\left(\rho_{ij\text{-express}}\frac{d_1}{2} + \rho_{ij\text{-slow}}\frac{d_2}{2}\right). \tag{10}$$

③ For the total time passengers spend on rail transit trains, the additional time of start and stop are included in formula (11).

$$\begin{aligned} T_{\text{trans}} = \sum_{i=1}^{n}\sum_{j=1}^{n}\Bigg[\rho_{ij\text{-express}}\left(t_{ij} + \sum_{k=i+1}^{n} h_k^2 x_k\right) \\ + \rho_{ij\text{-slow}}\left(t_{ij} + \sum_{k=i+1}^{n} h_k^2\right)\Bigg]. \end{aligned} \tag{11}$$

④ So the total time of passengers can be expressed as formula (12):

$$\begin{aligned} T &= T_{\text{all-waiting}} + T_{\text{trans}} \\ &= \sum_{i=1}^{n}\sum_{j=1}^{n}\Bigg[\rho_{ij\text{-express}}\left(t_{ij} + \sum_{k=i+1}^{j-1}\left(h_k^1 + h_k^2\right)x_k + \frac{d_1}{2}\right) \\ &\quad + \rho_{ij\text{-slow}}\left(t_{ij} + \sum_{k=i+1}^{j-1}\left(h_k^1 + h_k^2\right) + \frac{d_2}{2}\right)\Bigg]. \end{aligned} \tag{12}$$

*2.2. Analysis of Passengers' Total Travel Time under Express-Slow Mode.* Through the study in Section 2.1, the passengers' total travel time can be divided into four parts: waiting time of passengers, the transit time, the time trains stop at stations, and transfer time (if existing); the actual situation should also contain a passenger station time, because it is related to actual distance, so it is usually regarded as a constant. We can establish the time amusement model with based on the four parts.

## 3. Optimization Model of Total Passengers' Travel Time

The total time of passengers mainly consists of all passengers' time on the train and the time waiting at the station, while travel time of express and slow trains differs much; it is too hard to calculate any one separately; besides, it is not easy to compare and solve [18]. The average total travel time of rail transit passengers is studied, and the transit time is changed in the transit time compared with the existing station.

Firstly, the time consumption matrix is studied under the express-slow mode.

Suppose there are five stations numbered from A to E, including A, C, and D, three stations that express trains stop, and the range of research is limited from A to E which can be shown in Table 1. The proportion of train and the stop scheme have an effect on the $T$ value, while if the stop scheme is determined first, the proportion will also affect $T$ value; the three parameters have dynamic interactions.

To obtain accurate $T_{ij}$, traction calculation is called for according to the vehicle and the related technical parameters, combining with the rail transit line of horizontal and vertical curve data. It involves many parameters and related quantities. During the course of the calculation of train running time, it is approximately divided into accelerating time, uniform operation time, and deceleration time, and the running time of each interval can be calculated by

Table 1: The running time matrix in certain conditions.

| | A | B | C | D | E |
|---|---|---|---|---|---|
| A | $T_{AA}$ | $T_{AB}$ | $T_{AC}$ | $T_{AD}$ | $T_{AE}$ |
| B | | $T_{BB}$ | $T_{BC}$ | $T_{BD}$ | $T_{BE}$ |
| C | | | $T_{CC}$ | $T_{CD}$ | $T_{CE}$ |
| D | | | | $T_{DD}$ | $T_{DE}$ |
| E | | | | | $T_{EE}$ |

$$T_{ij} = \frac{v_{\max}}{a_{\text{acc}}} + \frac{v_{\max}}{a_{\text{dec}}} + \frac{D_{ij} - \left(v_{\max}^2/2a\right)\times 2}{v_{\max}}, \tag{13}$$

in which $v_{\max}$ is the maximum speed; $D_{ij}$ is the length from section $i$ to $j$; $a_{\text{acc}}$ is the acceleration of trains leaving stations; $a_{\text{dec}}$ is the deceleration of trains entering the stations.

The spacing of suburban lines between stations is usually larger than the ordinary ones; the train speed can reach the maximum value in each interval, so each running time of section can be calculated from (13).

The total passengers' travel time can be expressed by formula (14), and the minimum time can be shown in formula (15).

$$T_{ij} = \min \sum_{i=1,j=1}^{i=n,j=m}\frac{O_i D_j T_{ij}}{O_i D_j}, \tag{14}$$

$$\begin{aligned} \min \quad & T_{\text{all}} \\ & = \sum \frac{u_{ij}\times n\times Tz}{2n_{ij}} \\ & \quad + \mu_{pq}\left(h + \tau_t + \tau_q\right)\frac{\sum_r^R x_{ijr}\times f_r}{n_{ij}}. \end{aligned} \tag{15}$$

The subjects to the model are as formula (16) to formula (19):

$$\sum_{r=1}^{R}\mu_{ijr} = \mu_{ij} \geq D_{ij}, \tag{16}$$

$$\sum_{p=s}^{i-1}\sum_{q=i}^{z}\mu_{pq} \leq Qf_r, \tag{17}$$

$$k \leq \sum_{i=1}^{n} x_{ijr} \leq k', \tag{18}$$

$$\sum_{r=1}^{R}\sum_{i=2}^{n-1}\left(\frac{\sum_{p=s}^{i-1}\sum_{q=i}^{z}\mu_{pq}x_{ijr}}{Qf_r}\right) \geq \lambda, \tag{19}$$

in which $r$ is the amount of stations left except the section from station $i$ to station $j$; $u_{ij}$ is the amount of passengers from


Figure 2: The route map of Shanghai Metro Line 22.

station $i$ to station $j$; $D_{ij}$ is transport capacity; $Tz$ is time of cycle operation diagram; $n_{ij}$ is amount of trains from station $i$ to station $j$; $n$ is the total amount of cycle; $\mu_{pq}$ is the amount of passengers who get on at the former station $p$ and get off at the next station $q$; $R$ is all types of trains; $x_{ijr}$ is the amount of times of stop of trains from station $i$ to station $j$; $f_r$ is the frequency of corresponding trains; $h$, $\tau_t$, and $\tau_q$ are average stop time, stop time, and the additional time due to start/stop.

Formula (16) ensures that the transport capacity is greater than the passenger demand of various categories of trains. Formula (17) ensures that the train passengers must not exceed the total load ratio of the train. Formula (18) represents the lower and upper bound of amount of train stops. Formula (19) ensures the average attendance rate to meet a certain threshold.

## 4. Verification and Analysis of the Optimization Passengers' Total Travel Time

*4.1. Analysis of an Example.* The length of Shanghai Metro Line 22 is 56.4 kilometers from Shanghai South Railway Station to Jinshanwei Station, passing by Xuhui District, Minhang District, Songjiang District, and Jinshan District [19], with a total of eight stations; the stations and route map are shown in Figure 2.

During the course of modelling, it is assumed that each station is of skip ability, and each station has the potential as an express stop station. The steps of the algorithm are as follows.

*Step 1.* Obtain the related information of Shanghai Metro Line 22, as shown in Table 2.

*Step 2.* Calculate the running time interval matrix, based on the operation data of each station. The acceleration and deceleration of the trains are about $0.41\,\mathrm{m/s^2}$ in normal condition, the maximum speed is 27.8 m/s, and it requires 67.8 s to the maximum speed. The section running time of South Shanghai Railway Station to Chunshen is

$$t_{\mathrm{acc}} = t_{\mathrm{dec}} = \frac{27.8}{0.41} = 67.8\ \mathrm{s},$$
$$D_{\mathrm{acc}} = D_{\mathrm{dec}} = \frac{1}{2} V_{\max} t_{\mathrm{acc}} = \frac{1}{2} * 27.8 * 67.8 = 942.48\ \mathrm{m},$$

Table 2: The related information of Shanghai Metro Line 22.

| Section | Length (km) | Running time (s) | Stopping time (s) |
|---|---|---|---|
| South Shanghai~Chunshen | 8.90 | 239.0667 | 65 |
| Chunshen~Xinqiao | 5.70 | 191.869 | 45 |
| Xinqiao~Chedun | 6.70 | 206.618 | 40 |
| Chedun~Yexie | 8.50 | 233.167 | 45 |
| Yexie~Tingling | 5.10 | 183.019 | 50 |
| Tingling~Jinshanyuanqu | 8.10 | 227.267 | 50 |
| Jinshanyuanqu~Jinshanwei | 11.20 | 272.989 | 55 |

$$T_{ij} = t_{\mathrm{acc}} + t_{\mathrm{dec}} + \frac{D_{ij} - D_{\mathrm{acc}} - D_{\mathrm{dec}}}{V_{\max}} = 67.8 * 2 + \frac{8900 - 942.48 * 2}{67.8} = 239.1\ \mathrm{s}. \tag{20}$$

*Step 3.* After calculating the time matrix in Step 2, the corresponding OD matrix is required for the next study; the OD matrix is shown in Table 3.

*Step 4.* Calculate the average of $O_i D_j T_{ij}$.

When calculating the interval time matrix, the stopping time in each station is also needed; during weekday peak time, the operation interval is 32 minutes [20]. If properly divided, the passengers entering stations can be assumed to obey negative exponential distribution. The waiting time of passengers can be approximated to be half of the interval, just 16 minutes.

The corresponding interval running time matrix can be drawn as shown in Table 4. Using the same calculation method as Step 2, the running time matrix of each section can be obtained under the 1 : 1, and the corresponding ODT matrix can be obtained at the same.

Sum all elements of ODT matrix and the OD, so the average travel time is 2335 s; when facing the same passenger flow, the average spending time is 2335 s in express/slow mode, that is 39 min 2 s, compared to the ordinary mode 40 min 28 s, per capita reduced time by 1 min 26 s.

*4.2. The Analysis of Optimization Results.* For single passenger, 1 min 26 s is not of great importance, but more important to the peak period, the total passengers' travel time is reduced, and the main advantage reflected can be described as follows.

① From the GDP calculation: according to the 2015 GDP data of Shanghai it has reached 24964.99 billion yuan [21]; according to the resident population, the average GDP reached 10.31 million yuan. Due to the express/slow mode, when one train is used, the average time 1 min 26 s (86 s) can be converted into economic benefits: $C_{\mathrm{GDP}}$

$$C_{\mathrm{GDP}} = \frac{103100\ \text{yuan/year} \cdot \text{person}}{(365 - 12 \times 8 - 7 - 7) \times 8 \times 3600} \times 86 \times 8516 = 12810\ \text{yuan}. \tag{21}$$

Table 3: The OD matrix of Metro Line 22.

| Station | South Shanghai | Chunshen | Xinqiao | Chedun | Yexie | Tingling | Jinshanyuanqu | Jinshanwei | Total |
|---|---|---|---|---|---|---|---|---|---|
| South Shanghai | 0 | 24 | 98 | 154 | 18 | 24 | 15 | 147 | 480 |
| Chunshen | 67 | 0 | 31 | 57 | 8 | 11 | 34 | 14 | 222 |
| Xinqiao | 59 | 31 | 0 | 54 | 2 | 0 | 3 | 27 | 176 |
| Chedun | 117 | 53 | 11 | 0 | 8 | 20 | 27 | 38 | 274 |
| Yexie | 47 | 8 | 9 | 34 | 0 | 2 | 5 | 1 | 106 |
| Tingling | 68 | 12 | 21 | 17 | 0 | 0 | 3 | 0 | 121 |
| Jinshanyuanqu | 34 | 17 | 14 | 38 | 6 | 19 | 0 | 14 | 142 |
| Jinshanwei | 106 | 61 | 96 | 118 | 51 | 36 | 94 | 0 | 562 |

Table 4: The corresponding interval running time matrix ODT (s).

| | South Shanghai | Chunshen | Xinqiao | Chedun | Yexie | Tingling | Jinshanyuan | Jinshanwei |
|---|---|---|---|---|---|---|---|---|
| South Shanghai | 0 | 7297.68 | 53012.12 | 121284.2 | 19183.14 | 31170 | 23640.3 | 279889.5 |
| Chunshen | 0 | 0 | 7342.97 | 27558.93 | 6093.28 | 10941.48 | 43246.3 | 22399.16 |
| Xinqiao | 0 | 0 | 0 | 13317.48 | 1049.58 | 0 | 3105.24 | 36802.89 |
| Chedun | 0 | 0 | 0 | 0 | 2225.36 | 10223.4 | 21287.88 | 42424.34 |
| Yexie | 0 | 0 | 0 | 0 | 0 | 466.04 | 2551.45 | 838.28 |
| Tingling | 0 | 0 | 0 | 0 | 0 | 0 | 831.81 | 0 |
| Jinshanyuanqu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4591.86 |
| Jinshanwei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

When the time interval is 6 minutes and the daily total operating time is 5:50–22:00, the total time is 970 minutes, and there are 320 trips a day, the total economic benefits of conversion are as follows [22]:

$$320 \times C_{\mathrm{GDP}} = 4099200 \text{ yuan}. \tag{22}$$

② If passengers cannot get their company on time, they may be subject to penalty units or absenteeism in the workplace, affecting the professional evaluation and promotion, and so forth.

③ For business people, if late, it will affect signature of major contract or lead to economic losses, and so on.

From the stop scheme calculation, it can save 2 min 59 s; if the stop plan can be further optimized, it will attract more passengers OD and cause more influence on the stop time, and the average travel time can be further reduced to 4 min 38 s. It is of great importance for going-work passengers during the peak time; in addition, the passengers' total travel time can be reduced. Through the calculation and analysis, the train stopping at the express station will have more effect on the travel time of passengers. Because the passenger flow of the express station is large, when summing all the passengers' travel time, calculate the average value; the travel time is less than the ordinary stop scheme [17, 23]. If we change the ordinary stations of which the passenger flow is large into express station, the reduced time will be more obvious. If we take the ratio of express/slow trains and position of overtaking into consideration, the optimization results will be more excellent.

## 5. Conclusions

The next 10–20 years is an important development period in which China's economy will reach a higher stage, the 13th Five-Year Plan and the 14th Five-Year Plan will more focus on the construction of the city, and urbanization will further accelerate and promote the passengers. In this paper, a method of travel time optimization model is proposed, and the optimization object is defined as the minimum mean value of ODT. The smaller the average value of ODT is, the less time passengers spend on the trip, and it better benefits the passengers. Under the condition of imbalance flow, the express/slow mode can reduce passengers' total travel time and improve the satisfaction of passengers, while during peak stage, it is not suitable to use express/slow mode. The demand for transport capacity and service level will be improved with the rapid increase of the passenger flow in the suburbs. The optimization result will be better if the passengers' travel time, the proportion of trains, and the carrying capacity are considered. It is of great help to the operation practice of urban rail enterprise.

## Competing Interests

The authors declare that they have no competing interests.

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