Research on Operation Arrangement for Waiting Hall in Railway Passenger Station

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Abstract—The waiting hall is an important part for railway passenger station. To optimize and analyze the usage of waiting hall has great significance for improving operation efficiency of railway passenger station. Based on the research on the passenger volume and passenger flow construction, distribution regularities of passenger arrival time, passenger waiting time and the capacity of checking tickets windows can be obtained. On the basis of optimization and analysis of large scale railway passenger stations, algorithm for passenger stream lines of different platforms can be obtained and 0-1 planning model of the minimum waiting areas divided can be established. Based on the above work, constrains on whether there exist parallel operations for railway staffs are established, and phrases are divided into several time blocks, the object function is the balance usage of waiting halls in large scale railway stations in one day and the shortest passenger stream lines in waiting halls, then a multiple-objective model on operation arrangement for waiting halls of large scale railway passenger stations is proposed, and its optimal algorithm is also present. Finally, a case study is carried out to verify the validity, objectivity and applicability of this model and its algorithm through calculated and analyzed practical data based on Lanzhou railway station. Optimal results show that the model on operation arrangement for waiting hall in large scale passenger stations, total number of waiting hall set is $L_1 \cup L_2 \cup \cdots \cup L_n$, the number of passengers getting on train in the station is $N_j$, the set of platforms in the station is $Z = \{Z_1, Z_2, \cdots, Z_r \}$.

Based on the passenger waiting mode of railway large-scale passenger station, total number of waiting hall $m$, total trains $n$ including origin trains and passing by trains with passengers going on, there exists the relation that $n \gg m$. That means there are passengers waiting for different trains maybe wait in the same waiting room at the same moment [12, 13, 14].

If one day can be divided into a series of time sequences $T_p$, $p$ is the period number, $I_p^i$ represents train subset in $p$ period, $T = \{1, 2, \cdots, k \}$, $I_p^i \in T$. Meanwhile, waiting room $J_j$ is divided into several waiting subareas $\{J_j^1, J_j^2, \cdots, J_j^s_j \}$, $s_j^i$ is the capacity of waiting subarea $J_j$ which satisfies $\sum s_j^i \leq S_j$ and then one

Index Terms—waiting distributing region; passenger flow line, 0-1 linear programming; dynamic programming; algorithms
waiting subarea is occupied by corresponding passengers at the period. So, the problem can be simply described as, in the consecutive time subsequence $T_{e_i}$, every waiting subarea should be distributed to corresponding passengers to balance the usage of waiting hall in the basis of suitable passenger flow line [15, 16].

In [20], the maximum waiting time and the escalator service intensity were identified and the waiting time simulation model was established. With the passenger delivery data at A railway station, a detailed analysis was made on the escalator allocation, power and energy consumption on holidays, ordinary working days and the largest-passengers-volume days. In [21], the application of a two-layered artificial neural network as a decision-making support associated with the mentioned assignment problem was investigated. The neural network reached very encouraging results with regard to the studied problem, which enables its profitable utilization.

To optimize and analyze the usage of waiting hall has great significance for improving operation efficiency of railway passenger station. Based on the research on the passenger volume and passenger flow construction, distribution regularities of passenger arrival time, passenger waiting time and the capacity of checking tickets windows can be obtained. On the basis of optimization and analysis of large scale railway passenger stations, algorithm for passenger stream lines of different platforms can be obtained and 0-1 planning model of the minimum waiting areas divided can be established. To the railway stations which have mixed or sub-end arrangement and which have disorder passenger stream lines, more efficient results can be achieved with optimal model in the paper.

This paper is organized as follows. In section II, the waiting characteristics are analyzed. In section III, optimization model are established. In Section IV, optimization algorithm is designed. In Section V, a case study is carried out to verify the validity, objectivity and applicability of this model and its optimization algorithm, the conclusions are given in section VI.

II. ANALYSIS OF WAITING CHARACTERISTICS

A. Analysis of Passenger Station Waiting Time

The procedure of passenger gathering in large-scale railway passenger station is very complex which is influenced on the passenger flow structure, urban traffic reliability in the located city and other factors.

The ending time $t_{e_i}$ that passengers getting on train $I_i$ ended occupying waiting hall can be obtained by the ending time of checking tickets, $t_{e_i} = t_i - \Delta T_i$ ($\Delta T$ is the period between the end of checking tickets and train departure), but the time that passengers occupy the waiting room cannot be calculated from the first passenger occupying the hall, suppose that the beginning time of occupying is $t_{b_i}$, $t_{b_i} = t_i - T$ ($T$ represents sometime before train departure), then the efficiency time $T_{e_i}$ of passengers getting on train $I_i$ occupying the waiting hall can be denoted as

$$T_{e_i} = (t_i - \Delta T_i) - (t_i - T) \ (\text{min}) \ (1)$$

$t_i$ can be found from train working diagram, $T_i = N_i/v$ is the needed time for checking tickets for train $I_i$. Checking tickets speed rate is associated with passenger flow structure, passenger flow volume and the structure of station. Based on and the investigation for the paper, this time can be $31 \sim 38$ (per person/min), and passenger volume belonging to train $I_i$ can be found by passenger number notification. So, passenger station generally stops checking tickets when there is $\Delta T$ time before the train leaves.

According to the references [5, 6, 7, 8, 9], the time between passengers who get on train $I_i$, arriving at station and train departure belongs to logarithm distribution approximately.

$$P_i = \int g(t)dt \ (2)$$

Where $P_i$ represents the ratio that the arriving passenger accounts for the total passengers getting on train $P_i$ at the time $t$, $t$ represents computing time, $t_0$ represents the computing time when $i$-th passenger enters the waiting room, $g(t)$ represents passenger arrival distribution density function.

$$g(t) = \begin{cases} \frac{1}{\sqrt{2\pi} \delta} \exp \left[ -\frac{(\ln t - \mu)^2}{2\delta^2} \right] & x \geq 0 \\ 0 & x < 0 \end{cases} \ (3)$$

Consider that all passengers must arrive the waiting room before train departure, then

$$\int_0^t g(t)dt = 1 \ (4)$$

The investigations have been conducted on Lanzhou railway station, xi’an railway station and xining railway station during 3~4 month in 2009 and 8~9 in 2010 [10]. The parameters $\mu$ and $\sigma$ have been studied, and the mixed analysis results belong to logarithm distribution $\mu = 3.6796, \ \delta = 0.4567$ approximately. (See Figure 1).

![Figure 1](http://example.com/figure1.png)

**Figure 1. Statistic distribution of passenger waiting time**

The figure 2 illustrates that passenger waiting time varies from large-scale passenger stations which relates to...
urban traffic reliability in the located city, passenger time value, passenger flow structure to some degree. This means that the value of parameter T is determined by practical situation which can be 85~90 min.

\[ T = P_{erxog} \int v + \delta + T_{a} \text{(min)} \]

where, \( P_{erxog} \) represents departure passenger volume of train q in this station which can be obtained from passenger volume notification, \( v \) represents speed of checking tickets (person/min), \( \delta \) represents time between ending time of checking tickets and train departure time, \( T_{a} \) represents average passengers’ walking time from checking tickets windows to platforms.

According to Pearson Theorem [13]

\[ \chi^2 = \sum \frac{f^2}{p_f} - \pi \]

where \( f \) is the observation frequency of the \( \pi \)-th range, \( p_f \) is the probability that falls into the \( \pi \)-th range on the basis of the hypothetic theoretical distribution.

Given significance level \( \alpha \), if the statistics value \( \chi^2 \) and \( \chi^2_{\alpha}(r-s-1) \) meet the condition[14]

\[ \chi^2 < \chi^2_{\alpha}(r-s-1) \]

Divide the statistical data into k intervals as \( (0, a_1), (a_1, a_2), \ldots, (a_{r-2}, a_{r-1}), (a_{r-1}, +\infty) \), and note \( a_0 = 0 \), \( a_r = +\infty \), \( \rho = 1 + \log \pi \).

Where \( \rho \) represents interval number, \( \pi \) represents sample size.

According to surveys in this paper, speed of checking tickets \( v \) is 31 (person/min). However, the experienced data in literature [15] was 35 (person/min).

III. OPTIMIZATION MODEL ESTABLISH FOR WAITING HALL

During the different periods in one day, there are batches of passengers arrive at waiting areas of large scale station from the main entrances and then they arrive at the platforms, finally, they get on trains. The above processes can be regarded as a multistage decision process with correlative chain structure. Function equations with optimal theory can be applied to solve this dynamic programming problem. However, there is no standard method to deal with this kind of problem. Methods to solve the problem vary from mathematical skills based on practical details.

Suppose \( S_k \) represents state variable in the \( k \)-th phase, \( S_k = \{s_1, s_2, \ldots, s_k\} \) represents state set, \( x_k \) represents decision variable in the \( k \)-th phase. \( f_k(s_k) \) describes the optimal function value which is obtained after the chooses decision variable is executed in the \( s_n \) state of the \( k \)-th phase [16]

\[ f_k(s_k) = \text{Opt}_{s_k} \{f_k(s_{k+1}) + f_{k+1}(s_{k+1})\} \]

Recurrence relations of multistage decision dynamic programming problem can meet requirements of time slice algorithm which are based on train working diagram and literature[17], where split one shift or one day into \( k \) phase. Suppose represents the beginning time of one phase, represents passenger trains set in the \( k \)-th phase.

Due to factors that departure time of train, passenger volume, package volume and waiting hall capacity, there exist problems, such as mutual interference and limited capacity, when passengers that are corresponding to two or more than two trains are at the different waiting areas in the same waiting room at the same time.

Passenger volume varies from the corresponding passenger trains. If passenger volume exceeds the maximum capacity of relevant waiting area, then another waiting area in this waiting room of which passenger volume is less than the maximum capacity can be occupied. However, the total number of passengers cannot exceed the maximum capacity of this waiting hall.

Based on railway train working diagram, suppose that the time on train working diagram of any two trains \( I_a, I_b \) is \( t_a, t_b \). And the departure time interval is \( T_{ab} = |t_a - t_b| \).

The beginning time occupying the waiting room is \( t_a', t_b' \) respectively and the ending time is \( t_a'' , t_b'' \) respectively.

To avoid arrange the different passengers n the same waiting room whose checking tickets time is the same or very closed to, then

\[ (t_a'' - t_b')(t_a' - t_b') > 0 \]
Independent occupied time of waiting area $T_{min}$ and efficient occupied time of waiting area $T_s$ can be determined as constraints in the paper. Based on analysis of needed waiting areas in one day, 0-1 programming model is established.

Define 0-1 variable $x_i$

$$x_i = \begin{cases} 1, & \text{passenger s of train } k \text{ occupy waiting area independently} \\ 0, & \text{other} \end{cases}$$

Suppose that $T_{ab}$ represents time interval between any two departure trains $a, b$.

If $T_{ab} \leq T_{min}$, then the constraint can be denoted as

$$x_a + x_b = 2$$

If $T_{ab} > T_s$, then the constraint can be denoted as

$$x_a + x_b \leq 1$$

Then the least number of waiting area in one day can be denoted as

$$\min Z = \sum_{i=1}^{n} x_i$$

Because that train departure and arrival frequencies in large-scale railway passenger station exist obviously unbalancedness, which means that there are two departure and arrival rush phases 7:00~9:00 and 17:00~19:00, and the trains during 00:00~5:00 account for less. Accordingly, on the basis of time slice division algorithm, the search for time slice begins from 00:00~5:00 and then search slices in sequence.

Suppose that time slices (phase) set $D = \{D_1, D_2, \ldots, D_s, D_k\}$, $I_k$ represents passengers trains set in phase $k$. $s_k$ represents phase begins, then, remaining conversion seats (or reminding accommodating passengers number) of the waiting hall $J_k$. $T_k$ is the beginning time of phase $k$, $N_i^k$ is the expected number of passengers who get on train $I_i$ in phase $k$. Then

$$N_i^k = \left\{ \begin{array}{ll} N_i \cdot \int_{s_k}^{t_i + k} g(t) dt & t_i \geq T_k \\ 0 & t_i < T_k \end{array} \right. \quad (10)$$

Decision variation $x_j^k$ is denoted as

$$x_j^k = \begin{cases} 0 & I_i \not\in I_k \\ 1 & I_i \not\in I_k, N_i < S_j^k \end{cases} \quad (11)$$

Decision variation $x_j^k$ represents that whether the $i$-th waiting regional of the $j$-th waiting hall is occupied by passengers getting on train in the $k$-th phase or not.

Considering that various trains leads to various passenger flow structure and various package number, passenger flow structure coefficient $\eta$ ( in the case passenger flow structure consisting of students, migrant workers and passenger flow with a lot of packages, coefficient is 1.2. In other cases, the coefficient is 1.0 ) is introduced.

The converting passenger’s number of waiting hall $J_k$ in phase $k$ is denoted as $N_i^k$

$$N_i^k = \sum_{j=1}^{m} N_j^k x_j^k$$

Based on large-scale passenger station optimization object, accounting for normal passenger flow and providing service for the passengers in waiting hall, $N_i^k \leq S_j$ must meet $N_{\text{aver}} = \sum_{j=1}^{m} \sum_{k=1}^{n} N_i^k / m$ . Considering passenger flow fluctuation during holidays or other special phases is a bit severe, the accommodating capacity of each waiting hall can add up $\Delta S$ , then $N_i^k \leq S_j + \Delta S$ .

Suppose that daily phase number is $\Gamma$, the daily average number of passengers in each waiting hall is

$$N_{\text{aver}} = \sum_{j=1}^{m} \sum_{k=1}^{n} N_i^k / m$$

To make sure that passengers know their own walking routes and to obtain the shortest walking routes (which means the minimum walking time), the shunting process of passengers can be divided into six parts based on station structure, the six parts are squares outside the station, entrances, passageway, platform, checking windows and platform.

A waiting hall can be divided into several areas to distribute for passengers. The shunting process of passengers in the station is shown in figure 3.

![Figure 3. Shunting process of passengers in the station](image3)

![Figure 4. Network diagram of shunting process of passengers](image4)
The network diagram on shunting process of passengers in the station is shown in figure 4.

According to Figure 5, passengers entry into the station from station entrance and be at the waiting hall $J_1$ and then get on the train at the platform $Z_1$, the total possible passenger flow lines from area outside the station to the station are $G$. Then the transformation state equation can be denoted as 
\[ \{I_{11}, I_{12}, \ldots, I_{m}, \ldots, I_{n}\} \]
and the total length of the passenger flow lines in the given passenger station is 
\[ L_{tot} = \sum_{j=1}^{m} \sum_{i=1}^{n} I_{ij} \]

At the very beginning of each phase, the remaining conversion seats $S_i^k$ in waiting hall $J_i$ (reminding accommodating passenger number) represents state set in the state. Then, $S_i = \{S_i^1, S_i^2, \ldots, S_i^k, \ldots, S_i^k\}$ represents the state variable set in k phase. $I_{i}^k \in I$ ($k=1,2,\ldots,K$) is the departure trains set in k phase.

For two contiguous state, suppose that the number of trains in train subset $I_{i}^k$ are $n_i$, the previous state of waiting hall is $S_{(k-1)}$, and the next state is $S_{i}^k$, then the transformation state equation can be denoted as 
\[ \{S_{i}^k\} = \{S_{(k-1)}^i - \sum_{n=1}^m N^{j-1} q_{x_n}^i + \sum_{n=1}^m N^j q_{x_n}^i\} \] (12)

In addition, coefficient of passenger flow line conditions $\mu_k$ is brought out, which is influenced by cross-over bridge, passageway, staircase and so on. Based on the optimal objective, optimal value function in every phase can be determined as
\[ \min V_k = \sum_{n=1}^m (N^j q_{x_n}^i - \sum_{n=1}^m \sum_{k=1}^m N^{j-1} q_{x_n}^i \mu_k) + \left( \sum_{n=1}^m \sum_{k=1}^m I_{ij} \right) \] (13)

Index of recursion equations
\[ \begin{align*}
    f_i(S_{i-1}) &= \min\{v_k + f(S_{i-1})\} \\
    f_i(S_0) &= 0
\end{align*} \] (14)

In this dynamic programming problem, the state variable in the $k$-th phase is not only with the current parking lines state, but also with all waiting hall state in previous several phases. So the dynamic programming model is not of afeffect which does not meet the requirement.

In this paper, the state transition equation is proposed with markov property
\[ S_{i}^k = d_i(S_{i-1}^k, S_{i-2}^k, \ldots, S_{i-n}^k, x_0^i) \] (15)

The function $x_0^i = g_i(S_{i-1}^k, S_{i-2}^k, \ldots, S_{i-n}^k)$ can be calculated, thus the optimal value function is
\[ \min V_k = \left( \sum_{j=1}^m \sum_{n=1}^m N^j q_{x_n}^i (g_i(S_{i-1}^k, S_{i-2}^k, \ldots, S_{i-n}^k)) \right) + \left( \sum_{j=1}^m \sum_{n=1}^m N^j q_{x_n}^i \mu_k \right) + \left( \sum_{j=1}^m \sum_{n=1}^m I_{ij} \right) \]

Time slice theory from literature [18] was applied in the paper, in which time slices can split into phases. Because the slice without passenger arriving doesn’t have influence on decisions and state variables, it can be rejected from the original time sequence to generate new consecutive time sequence.

**IV. OPTIMIZATION ALGORITHM DESIGN**

Dynamic planning program design used to be aiming at a specific optimization problem. Due to the characteristics of different problems, conditions to determine the optimization solutions are different [19]. So the methods of dynamic planning programs vary from each other which all have their own characteristics. The model in the paper uses method of exhaustion to solve the problem, the theory of algorithm shows below.

**A. The First Phase Optimization Algorithm**

**step1**: Input all trains data information.
**step2**: Sub-programs on time blocks can be passed to divide all trains based on service time.
**step3**: Based on output results from sub-programs on dividing time blocks, dynamic planning phrase $k$ can be determined.
**step4**: Establish transformation state equations and then recursive relationship equations of dynamic planning model can be achieved.
**step5**: Establish index functions, index recursive equations and optimization functions of dynamic planning model can be achieved.
**step6**: When the decision variable is 1, it shows that passengers get on trains occupy waiting areas, otherwise, passengers do not occupy waiting areas.
**step7**: Maximum seats of waiting areas can be determined as state initial variable. Define that $s[]$ records new state values producing by formal state decision values. Array $B[]$ stores formal state number which means $B[]=1$.
**step8**: Trains belonging to the first phrase can be made decisions on mapping waiting halls in sequence. The first time block is determined as the first phrase (the sequence of the other blocks can be analogized). Array $B[]=I$ uses array $F[]$ to record index values in every decision. Array $Q[]$ stores current state numbers. Then array $s[]$ records new state numbers, array $B[]=I$. And state sets and balance index can be found that belongs to different trains in one time block corresponding to each waiting hall in each phrase.
**step9**: Optimal decision of waiting halls distribution in each phrase can be achieved from the backward of the last time block, so is the most balance waiting halls distribution in the last.
**step10**: Output optimal case and the most balance distribution value.
B. The Second Phase Adjustment Optimization Algorithm based on Successive Approximation Method

Dynamic planning program design used to be aiming at a specific optimization problem. Due to the characteristics of different problems, conditions to determine the optimization solutions are different [19]. So the methods of dynamic planning programs vary from each other which all have their own characteristics. The model in the paper uses method of exhaustion to solve the problem, the theory of algorithm shows below.

POA (Progressive Optimality Algorithm) is a kind of approximation optimal algorithm. Namely, variables set of optimal tracks in every phase is optimal to neighboring state variable sets. Thus, multi-phase optimal problem can be divided into a series of two phase problems, which can be solved with one by one. After several round of iteration, approximation values converging on optimal track can be reached finally.

Suppose that \( X_{k,1} \) stands for bounded closed convex set in \( M \) dimension space. Expression \( S_{k+1} = d_i(S_k, S_{k+1}, \ldots, S_{k+n_k}) \) represents the strictly convex function defined on sequence \( X_{k,1} \), to strictly convex function on bounded closed convex set, the solutions sequence can converge on the objective values finally.

step1; For original solution \( S_0 = (S_1, S_2, \ldots, S_0) \), it can be denoted as \( S_k = (S_1, S_2, \ldots, S_k) \).

step2; solve with below optimal problems

\[
G_1' = \min_{S_k} \{(g_1(S_k, S_{k+1}), \sum_{k=1}^{n_k} g_k(S_k, S_{k+1}, S_{k+n_k}))
\]

\[
G_2' = \min_{S_k} \{(g_2(S_k, S_{k+1}), \sum_{k=1}^{n_k} g_k(S_k, S_{k+1}, S_{k+n_k}))
\]

\[
G_{r-1}' = \min_{S_k} \{(g_{r-1}(S_k, S_{k+1}), \sum_{k=1}^{n_k} g_k(S_k, S_{k+1}, S_{k+n_k}))
\]

Step3; go on the second round optimization

\[
G_1'' = \min_{S_k} \{m(S_k, S_{k+1}), \sum_{k=1}^{n_k} g_k(S_k, S_{k+1}, S_{k+n_k})\}
\]

\[
G_2'' = \min_{S_k} \{m(S_k, S_{k+1}), \sum_{k=1}^{n_k} g_k(S_k, S_{k+1}, S_{k+n_k})\}
\]

\[
G_{r-1}'' = \min_{S_k} \{m(S_k, S_{k+1}), \sum_{k=1}^{n_k} g_k(S_k, S_{k+1}, S_{k+n_k})\}
\]

Suppose that optimal solution of the \( k \)-th problem is \( S^{(k)} = (S_1, S_2, \ldots, S_k) \), so a series of solutions can be denoted as \( S^* = (S_1, S_2, \ldots, S_k, \ldots, S_{r-1}) \).

Step4; based on \( S^* \), \( S^{*'} = (S_1, S_2, \ldots, S_{r-1}, S_r) \) can be derived.

V. EMPIRICAL ANALYSIS

There are 4 waiting halls in Lanzhou railway station. There are 76 trains in one day (except 3 trains for staffs), the departure time distribution of all passenger trains is shown in figure 3.

Based on the research in the paper, average departure passengers in Lanzhou railway station is 22024 per day, and the average passengers in each waiting hall is 5506. The arrival time distribution of passengers in the station is shown in figure 4.

And from 18 o’clock to the same time on the next day, there are 22 departure and arrival passengers trains needed to have placed-in and taken-out operation. Generally, the departure operation time of corresponding trains is 40 min, the arrival operation time of corresponding trains is 30 min. But the minimum operation time the departure operation is more than 5 min, the minimum operation time the arrival operation is more than 25 min, servicing work time for carriages is more than 30min.

And time needed to run between the garage and the station is more than 10min (to signal running shunting locomotive, the time includes time of connecting carriages). There are 3 shunting locomotives in the stations which are for placing-in and taking-out operation. There are adequate parking lines in the garage. At 18 o’clock, \( D_1 \) was in the garage, \( D_2 \) was in the arrival yard, and \( D_3 \) was in the departure yard.

![Figure 5. Departure time distribution of all passenger trains for Lanzhou railway station in one day](image)

![Figure 6. Arrival time distribution of passengers for Lanzhou railway station in one day](image)

![Figure 7. The arrival time of arrival trains and the departure time of departure trains](image)
time on the next day. The arrival time of arrival trains and the departure time of departure trains is shown in Figure 5.

According to the time slice theory and its optimization algorithm from literature [16], the classification result of time slices is shown in Table 1.

In Table 1, the beginning of time slices and the end of time slices are described with minute, and the negative number represents sometime of the day before, for example, -17.5 represents (1440 - 17.5) min.

Based on the arrangement of arrival and departure lines in Lanzhou railway station, the optimization model and optimization algorithm, the optimal results of the waiting halls in the station are achieved using simulation calculation with Matlab 6.0. And optimal results of the waiting halls in the station in one day finally are shown in Table 2, Table 3, Table 4, and Table 5.

### Table 1. Classification results of time slices

<table>
<thead>
<tr>
<th>Serial number of time slices</th>
<th>The beginning of time slices (min)</th>
<th>The end of time slices (min)</th>
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<td>block[0]</td>
<td>-17.5</td>
<td>20</td>
</tr>
<tr>
<td>block[1]</td>
<td>24.6</td>
<td>31</td>
</tr>
<tr>
<td>block[2]</td>
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<tr>
<td>block[26]</td>
<td>1353.3</td>
<td>1370</td>
</tr>
</tbody>
</table>

### Table 2. Operation scheme of waiting hall No.1 in one day

<table>
<thead>
<tr>
<th>Waiting hall</th>
<th>Waiting area</th>
<th>Serial number of train</th>
<th>Departure time</th>
<th>number of waiting passenger in one day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K375/6; 29, K417/9; 56, T118/12; 41; K163/20; 34, K105/22; 10</td>
<td>5255</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>K263/9; 37, T152/14; 45, K81/17; 54, K261/19, 35, K322/21; 08, K501/22; 40</td>
<td>5255</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>T207/7; 12, 1351/12; 10, K858/15; 48, 889/16; 54, K120/21; 58</td>
<td>5255</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3. Operation scheme of waiting hall No.2 in one day

<table>
<thead>
<tr>
<th>Waiting hall</th>
<th>Waiting area</th>
<th>Serial number of train</th>
<th>Departure time</th>
<th>number of waiting passenger in one day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K902/7; 30, K165/10; 56; T72/11; 49; 881/15; 51, K163/20, 34, K105/22; 10</td>
<td>5637</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>K361/8; 37, K301/10; 12, K823/16; 08, K71/20; 51, K321/23; 40</td>
<td>5637</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>T116/9; 12, T232/13; 45, T9201/13; 05, T314/18; 35, K322/22; 18</td>
<td>5637</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Operation scheme of waiting hall No.3 in one day

<table>
<thead>
<tr>
<th>Waiting hall</th>
<th>Waiting area</th>
<th>Serial number of train</th>
<th>Departure time</th>
<th>number of waiting passenger in one day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K375/6; 29, K417/9; 56, 889/16; 54, K163/20; 34, K120/21; 58, K105/22; 10</td>
<td>5902</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>K263/9; 37, 1351/12; 10, T152/14; 45, K81/17; 54, K322/21; 08, K501/22; 40</td>
<td>5902</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>T207/7; 12, T118/9; 41, K858/15; 48, K261/19, 35, 261/21; 35, 3162/22; 55,</td>
<td>5902</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 5. Operation scheme of waiting hall No.4 in one day

<table>
<thead>
<tr>
<th>Waiting hall</th>
<th>Waiting area</th>
<th>Serial number of train</th>
<th>Departure time</th>
<th>number of waiting passenger in one day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K902/7; 30, K165/10; 56, 9201/13; 05, 881/15; 51, K163/20, 34, K105/22; 10</td>
<td>5320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>K361/8; 37, K301/10; 12, T232/13; 45, K823/16; 08, K71/20; 51, K321/23; 40</td>
<td>5320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>T116/8; 12, T72/9; 49, T314/12; 35, K32/16; 3201/19; 18, K21/22; 18</td>
<td>5320</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Optimal results show that the optimal model for usage of waiting halls in large scale passenger railway stations can reach the usage balance of waiting halls and the shortest passenger stream lines. The maximum difference between simulation passenger flow volume of each waiting hall and actual waiting passenger flow volume is 296, and the minimum difference is 131. To the railway

VI. Conclusions

Optimal results show that the optimal model for usage of waiting halls in large scale passenger railway stations can reach the usage balance of waiting halls and the shortest passenger stream lines. The maximum difference between simulation passenger flow volume of each waiting hall and actual waiting passenger flow volume is 296, and the minimum difference is 131. To the railway
stations which have mixed or sub-end arrangement and which have disorder passenger stream lines, more efficient results can be achieved with optimal model in the paper.

Due to the symmetrically distributed of waiting halls and clear passenger stream lines of Lanzhou railway station, the model does not play an important role in finding passenger stream lines. But to the stub-end and mixed arrangement railway stations which have complex arrangement and disorder passenger stream lines, the model can have a big effect on optimal usage of waiting halls.

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REFERENCES


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