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 railway passenger 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.**

***Index Terms*—waiting distributing region; passenger flow line, 0-1 linear programming; dynamic programming; algorithms**

I. Introduction

Waiting hall is one of the most important components in the railway large-scale passenger station, and operation scheme of waiting hall for railway passenger station is a complicated system engineering that is influenced by multitudinous factors, such as the time of arriving and departing trains, technique equipment conditions, and number of trains and so on [1, 2]. In recent years, a lot of researches have studied passenger gathering principle [3, 4], track usage and other problems in this field. However, there are few researchers focused on optimization of waiting hall of railway large-scale passenger station [5]. Flow line gathering characteristic and passenger flow line and other factors are taken into consideration synthetically in the paper.

Optimization of railway large-scale passenger station usage has been impacted on many factors, that is a complex multi-objects planning problem [10, 11]. Suppose that the set composed of all origin trains and passing by trains with passenger getting on in the given station in one day can be denoted as $I=\left\{I_1, I_2, \cdots, I_i \cdots, I_n\right\}$, t_i is the departure time on the train working diagram of train $I_i (i=1,2\cdots,n)$, and the waiting hall set is $J=\left\{J_1, J_2, \cdots, J_j \cdots, J_m\right\}$, m is the total number of waiting hall, S_j is the maximum accommodating capability of waiting room J_i, the number of passengers getting on train in the station is N_i, the set of platforms in the station is $Z=\left\{Z_1, Z_2, \cdots, Z_r \cdots, Z_R\right\}$.

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 $n >> m$. That means there are passengers getting on 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^f represents train subset in p period, $T=\{1,2,\cdots,k\cdots,1440\}$, $T_p \in T$, $I_p^f \in I$.

Meanwhile, waiting room J_j is divided into several waiting subareas $\left\{J_j^1, J_j^2, \cdots, J_j^n\right\}$, S_j^i is the capacity of waiting subarea J_i which satisfies $\sum S_j^i \le S_j$ and then one

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waiting subarea is occupied by corresponding passengers at the period. So, the problem can be simply described as, in the consecutive time subsequence T_p, 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_{ij}^e that passengers getting on train I_i ended occupying waiting hall can be obtained by the ending time of checking tickets, $t_{ij}^e = t_i - \Delta T_i$ (ΔT_i 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 fist passenger occupying the hall, suppose that the beginning time of occupying is t_{ij}^s , $t_{ij}^s = t_i - T$ (T represents sometime before train departure) , then the efficiency time T_{ij}^e of passengers getting on train I_i occupying the waiting hall can be denoted as

$$T_{ij}^e = (t_i - \Delta T_i) - (t_i - T) \quad (\text{min}) \qquad (1)$$

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 31～38 (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 ΔT_1 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.

$$P_t^i = \int_{t_0}^{t} g(t)dt \qquad (2)$$

Where P_t^i represents the ratio that the arrival waiting passengers accounts for the total passengers getting on train P_t^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.

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

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

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

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 μ and σ have been studied, and the mixed analysis results belong to logarithm distribution $\hat{\mu}$=3.6796, $\hat{\delta}$=0.4567 approximately. (See Figure 1) .

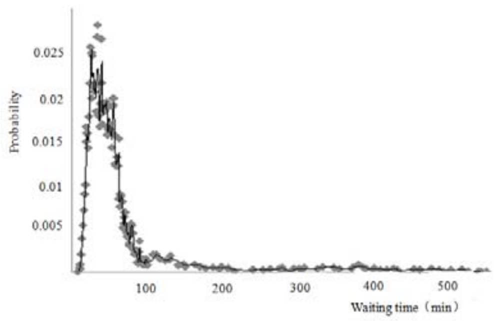

Figure 1. Statistic distribution of passenger waiting time

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* .

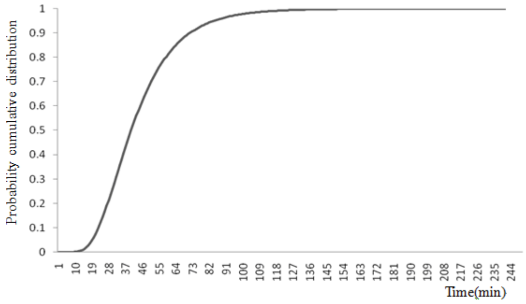

Figure 2. Accumulating function diagram

Fitting results further show that 8min instead of $t_0 = 0$ min is the beginning time of fitting curve. This result exist a bit difference from reference [11, 12]. Formulation (2) can be modified as

$$p_i^t = \int_8^{t+8} g(t)dt \tag{5}$$

B. Analysis of Checking Tickets Time

Time interval T representing time between checking tickets and train departure can be denoted as

$$T = p_{ersonq} / v + \delta + T_{zt} \text{ (min)}$$

where, p_{ersonq} 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), δ represents the time between ending time of checking tickets and train departure time, T_{zt} represents average passengers' walking time from checking tickets windows to platforms.

According to Pearson Theorem [13]

$$\chi^2 = \sum_{\tau=1}^{\rho} \frac{f_\tau^2}{\pi p_\tau} - \pi \tag{6}$$

where f_π is the observation frequency of the π -th range, p_π is the probability that falls into the π -th range on the basis of the hypothetic theoretical distribution.

Given significance level α , if the statistics value χ^2 and $\chi_\alpha^2(r-s-1)$ meet the condition[14]

$$\chi^2 < \chi_\alpha^2(r-s-1) \tag{7}$$

Divide the statistical data into k intervals as $(0,\ a_1]$, $(a_1,\ a_2]$, $\cdots(a_{\rho-2},\ a_{\rho-1}]$, $(a_{\rho-1}, +\infty)$, and note $a_0 = 0$, $a_\rho = +\infty$. $\rho = 1 + \lg \pi$.

Where ρ represents interval number, π 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). The difference can be related to passenger structure of Lanzhou area in March, when most of passengers are migrant workers who generally carry large amounts of packages.

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, $S_k = \{s_1,\ s_2, \cdots,\ s_k, \cdots,\ s_K\}$ 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]

$$f_k(s_k) = \underset{x_k}{Opt}\{r_k(s_k, x_k) + f_{k+1}(s_{k+1})\}$$

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 trains, 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 $T_{ab} = |t_b - t_a|$. The beginning time occupying the waiting room is t_a^s , t_b^s respectively and the ending time is t_a^e , t_b^e respectively. To avoid arrange the different passengers n the same waiting room whose checking tickets time is the same or very closed to, then

$$(t_a^e - t_b^e)(t_a^s - t_b^s) > 0 \tag{8}$$

Independent occupied time of waiting area $T_{\min}$ and efficient occupied time of waiting area T_e 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_k

$$x_k = \begin{cases} 1, & \text{passeenger s of train } k \\ & \text{occupy waiting area independen tly} \\ 0, & \text{other} \end{cases}$$

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

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

$$x_a + x_b = 2$$

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

$$x_a + x_b \le 1$$

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

$$\min \quad Z = \sum_{k=1}^{n} x_k \tag{9}$$

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 0; 00～5; 00 account for less. Accordingly, on the basis of time slice division algorithm, the search for time slice begins from 0; 00～5; 00 and then search slices in sequence.

Suppose that time slices (phase) set $D = \{D_1, D_2, \cdots, D_k, \cdots, D_K\}$, I_k^f represents passenger trains set in phase *k*. S_j^k represent**s** phase begins, then, remaining conversion seats (or reminding accommodating passengers number) of the waiting hall J_j, 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

$$N_i^k = \begin{cases} N_i \cdot \int_8^{t-T_k+8} g(t)dt & t_i \ge T_k \\ 0 & t_i < T_k \end{cases} \tag{10}$$

Decision variation x_{ij}^k is denoted as

$$x_{ij}^k = \begin{cases} 0 & I_i \notin I_k^f \\ 1 & I_i \notin I_k^f, N_i < S_j^k \end{cases} \tag{11}$$

Decision variation x_{ij}^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 η (in the case passenger flow structure consisting of students, migrant workers and passenger flow with a lots 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_j in phase *k* is denoted as N_{ij}^k

$$N_{ij}^k = \sum_{i=1}^{n} N_i^k \eta x_{ij}^k$$

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

Suppose that daily phase number is Γ, the daily average number of passengers in each waiting hall is

$$N_{aver} = \sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1}^{\Gamma} N_{ij}^k / m$$

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, waiting hall, checking tickets 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 figure3.

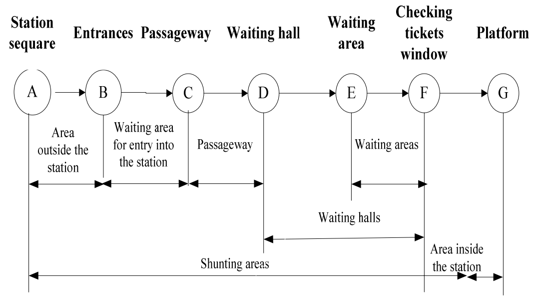

Figure 3. Shunting process of passengers in the station

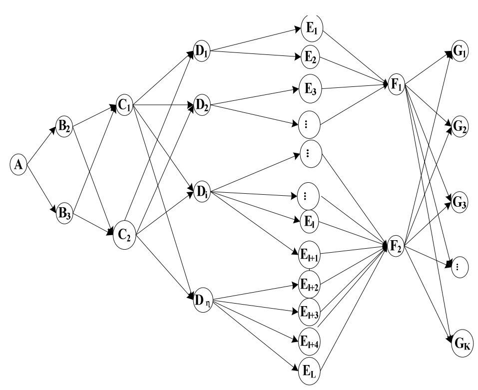

Figure 4. Network diagram of shunting process of passengers

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_j and then get on the train at the platform Z_r, the total possible passenger flow lines from area outside the station to platform *G* can be denoted as $\{l_{11},\ l_{12},\cdots,\ l_{jr},\cdots,\ l_{mR}\}$, and the total length of the passenger flow lines in the given passenger station is

$$L_{zx} = \sum_{j=1}^{m}\sum_{r=1}^{R} l_{jr}$$

At the very beginning of each phase, the remaining conversion seats S_j^k in waiting hall J_j (reminding accommodating passenger number) represents state set in the state. Then, $S_k = \{S_1^k,\ S_2^k,\cdots S_j^k,\cdots,\ S_m^k\}$ represents the state variable set in *k* phase. $I_k^f \in I$ ($k = 1,2\cdots K$) is the departure trains set in *k* phase.

For two contiguous state, suppose that the number of trains in train subset I_k^f are n_i, the previous state of waiting hall is $S_{i\,(k\text{-}1)}$, and the next state is $S_{ik.}$, then the transformation state equation can be denoted as

$$\{S_{ik}\} = \left\{ S_{i(k-1)} - \sum_{i=1}^{n_i} N_i^k \eta x_{ij}^k + \sum_{i=1}^{n_{i-1}} N_i^{k\text{-}1} \eta x_{ij}^{k\text{-}1} \right\} \tag{12}$$

In addition, coefficient of passenger flow line conditions μ_{jr} 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

$$\min v_k = \{(\sum_{i=1}^{n_i}(N_i^k \eta x_{ij}^k - \sum_{j=1}^{m}\sum_{i=1}^{n_i}\sum_{k=1}^{\Gamma} N_{ij}^k / m)^2 + (\sum_{r=1}^{R}\sum_{j=1}^{m}\sum_{i=1}^{n_i} N_i^k \eta x_{ij}^k l_{jr}\mu_{jr} \Big/ \sum_{j=1}^{m}\sum_{r=1}^{R} l_{jr})\} \tag{13}$$

Index of recursion equations

$$\begin{cases} f_k(S_k) = \min\{v_k + f(S_{k-1})\} \\ f_k(S_0) = 0 \end{cases} \tag{14}$$

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 aftereffect which does not meet the requirement.

In this paper, the state transition equation is proposed with markov property

$$S_{i,k} = d_k(S_{i,k\text{-}1}, S_{i,k-2},\ldots S_{i,k+1-m}, x_{ij}^k) \tag{15}$$

The function $x_{ij}^k = g_k(S_{k+1}, S_k, S_{k-1},\ldots S_{k+1-n})$ can be calculated, thus the optimal value function is

$$\min v_k = \{(\sum_{i=1}^{n_i}(N_i^k \eta\ (g_k(S_{k+1}, S_k, S_{k-1},\ldots S_{k+1-n})) - \sum_{j=1}^{m}\sum_{i=1}^{n_i}\sum_{k=1}^{\Gamma} N_{ij}^k / m)^2 + (\sum_{r=1}^{R}\sum_{j=1}^{m}\sum_{i=1}^{n_i} N_i^k \eta (g_k(S_{k+1}, S_k, S_{k-1},\ldots S_{k+1-n}))\ l_{jr}\mu_{jr} \Big/ \sum_{j=1}^{m}\sum_{r=1}^{R} l_{jr})\}$$

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

***step*1;** Input all trains data information.

***step*2;** Sub-programs on time blocks can be passed to divide all trains based on service time.

***step*3;** Based on output results from sub-programs on dividing time blocks, dynamic planning phrase *k* can be determined.

***step*4**; Establish transformation state equations and then recursive relationship equations of dynamic planning model can be achieved.

***step*5**; Establish index functions, index recursive equations and optimization functions of dynamic planning model.

***step*6**; When the decision variable is 1, it shows that passengers get on trains occupy waiting areas, otherwise, passengers do not occupy waiting areas.

***step*7**; 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[]=I.

***step*8**; 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.

***step*9**; 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.

***step*10**; 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 $S_{k+1} = d_k(S_k, S_{k-1}, \ldots S_{k+1-m}, x_{ij}^k)$ represents the strictly convex function defined on sequence $X_2, \cdots, X_{k+1}$, to strictly convex function on bounded closed convex set, the solutions sequence can converge on the objective values finally.

step1; For original solution $S_k^0 \in X_1, k = 2, \cdots, \Gamma$, it can be denoted as $S_0 = (S_1, S_2^0, \cdots, S_\Gamma^0)$

step2; solve with below optimal problems

$$G_1^1 = \min_{S_2 \in X_2} \{(g_1(S_1, S_2) + \sum_{k=2}^{\Gamma} g_k(S_1, S_2, S_3^0 \ldots, S_{k+1}^0)\}$$

$$G_2^1 = \min_{S_3 \in X_3} \{(g_2(S_1, S_2^1, S_3) + \sum_{k=3}^{\Gamma} g_k(S_1, S_2^1, S_3 \ldots, S_{k+1}^0)\}$$

$$G_{\Gamma-1}^1 = \min_{S_{\Gamma-1} \in X_{\Gamma-1}} \{(g_{\Gamma-1}(S_1, S_2^1, \ldots, S_{\Gamma-1}^1, S_\Gamma)$$

Step3; go on the second round optimization

$$G_1^2 = \min_{S_2 \in X_2} m\{(g_1(S_1, S_2) + \sum_{k=2}^{\Gamma} g_k(S_1, S_2, S_3^1 \ldots, S_{k+1}^1)$$

$$+ \sum_{k=2}^{\Gamma} g_k(S_1, S_2, S_3^1 \ldots, S_{k+1}^1)\}$$

$$G_2^2 = \min_{S_3 \in X_3} \{(g_2(S_1, S_2^2, S_3) + \sum_{k=3}^{\Gamma} g_k(S_1, S_2^2, S_3 \ldots, S_{k+1}^1)\}$$

$$G_{\Gamma-1}^2 = \min_{S_\Gamma \in X_\Gamma} g_{\Gamma-1}(S_1, S_2^2, \ldots, S_{\Gamma-1}^2, S_\Gamma^1)$$

Suppose that optimal solution of the *k*-th problem is $S_k^2 (k = 2, \cdots, \Gamma,)$, so a series of solutions can be denoted as $S^2 = (S_1, S_2^2, S_3^2, \cdots, S_\Gamma^2)$.

Step4; based on $S^n = (S_1, S_2^n, S_3^n, \cdots, S_\Gamma^n)$, $S^{n+1} = (S_1, S_2^{n+1}, S_3^{n+1}, \cdots, S_\Gamma^{n+1})$ 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.

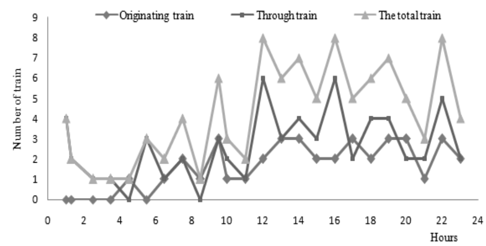

Figure 5. Departure time distribution of all passenger trains for Lanzhou railway station in one day

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 figure4.

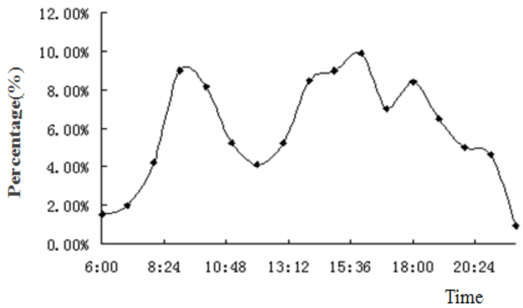

Figure 6. Arrival time distribution of passengers for Lanzhou railway station in one day

And from18 o'clock to the same time on the next day, there are 22 departure and arrival passenger 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.

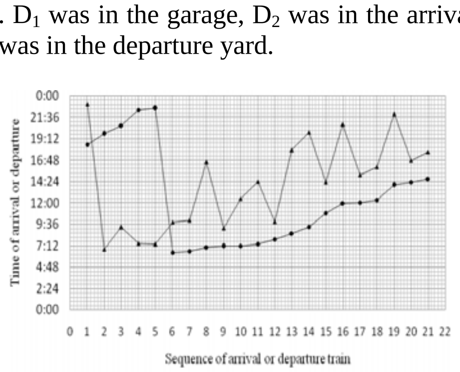

Figure 7. The arrival time of arrival trains and the departure time of departure trains

There are 21 arrival trains and 43 departure trains in this passenger station between 18 o'clock and the same 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 Table1.

In Table1, 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 matlab6.0. And optimal results of the waiting halls in the station in one day finally are shown in Table2, Table3, Table4 and Table5.

TABLE 1.
CLASSIFICATION RESULTS OF TIME SLICES

Serial number of time slices	The beginning of time slices (min)	The end of time slices (min)
block[0]	-17.5	20
block[1]	24.6	31
block[2]	83.5	96
block[3]	282.1	314
block[4]	342.3	351
block[5]	358.9	367
block[6]	413.5	439
block[7]	453.9	463
block[8]	503.4	516
block[9]	519.6	548
block[10]	550.3	577
block[11]	578.6	625
block[12]	636.7	648
block[13]	693.9	781
block[14]	805.7	824
block[15]	826.2	855
block[16]	862.5	885
block[17]	887.6	910
block[18]	914.6	921
block[19]	923.1	1006
block[20]	1009.4	1088
block[21]	1089	1104
block[22]	1110.5	1170
block[23]	1176.5	1197
block[24]	1228.5	1250
block[25]	1285.5	1352
block[26]	1353.3	1370

TABLE 2.
OPERATION SCHEME OF WAITING HALL *NO*.1 IN ONE DAY

Waiting hall	Waiting area	Serial number of train/ Departure time	number of waiting passenger in one day
No.1	1	K375/6; 29, K417/9; 56, T118/12; 41, K163/20; 34, K105/22; 10	5255
	2	K263/9; 37, T152/14; 45, K81/17; 54, K261/19; 35, K322/21; 08, K501/22; 40	
	3	T207/7; 12, 1351/12; 10, K858 /15; 48, 889/16; 54, K120/21; 58	

TABLE3.
OPERATION SCHEME OF WAITING HALL *NO*.2 IN ONE DAY

Waiting hall	Waiting area	Serial number of train/ Departure time	number of waiting passenger in one day
No.2	1	K902/7; 30, K165/10; 56, T72/11; 49 881/15; 51, K163/20; 34, K105/22; 10	5637
	2	K361/8; 37, K301/10; 12, K823 /16; 08 , K71/20; 51, K321/23; 40	
	3	T116/9; 12, T232/13; 45, T9201/13; 05, T314/18; 35, K32/22; 18,	

TABLE 4.
OPERATION SCHEME OF WAITING HALL *NO*.3 IN ONE DAY

Waiting hall	Waiting area	Serial number of train/ Departure time	number of waiting passenger in one day
No.3	1	K375/6; 29, K417/9; 56, 889/16; 54, K163/20; 34, K120/21; 58, K105/22; 10	5902
	2	K263/9; 37, 1351/12; 10, T152/14; 45, K81/17; 54, K322/21; 08, K501/22; 40	
	3	T207/7; 12, T118/9; 41, K858 /11; 48, K261/19; 35, 1261/21; 35, 3162/22; 55,	

TABLE5.
OPERATION SCHEME OF WAITING HALL *NO*.4 IN ONE DAY

Waiting hall	Waiting area	Serial number of train/ Departure time	number of waiting passenger in one day
No.2	1	K902/7; 30, K165/10; 56, 9201/13; 05, 881/15; 51, K163/20; 34, K105/22; 10	5320
	2	K361/8; 37, K301/10; 12, T232/13; 45, K823 /16; 08 , K71/20; 51, K321/23; 40	
	3	T116/8; 12, T72/9; 49, T314/12; 35, K32/16; 18, 3201/19; 18, K21/22; 18	

Operation arrangement of parking lines in railway large-scale passenger technology stations is a complicated system engineering that is influenced by multitudinous factors, such as the scheduling of shunting locomotive and mutual interference in throat area and so on, which has a direct influence on the efficiency of railway passenger technology stations.

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 is131. 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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