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Research on dynamic collaborative optimization of passenger flow line and waiting resources

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Abstract. In order to improve the resource allocation efficiency of waiting hall, the related factors is discriminated. Based on the discrimination, a dynamic programming model for collaborative optimization about the passenger flowline and waiting halls resource allocation is built by considering the complexity, dynamics and equilibrium of Passenger flow, as well as the cross interference. Besides a progressive optimality algorithm is put forward to solve the model. Finally, a case study is presented to verify the rationality of the model and algorithm. Results show that this model and its optimization algorithm above-mentioned can improve the resource allocation efficiency of waiting hall.

1. Introduction

Passenger flow line and waiting resources play an important role in railway passenger station, and it has become a current topic in recent years, therefore, some scholars make lots of research about optimization design of passenger flow line and waiting resources.

Cui et al. studies the passenger organization and analyzes the characteristics about passenger flow line in integrated traffic hub station [1]. Zhou et al. analysis the passenger interaction factors during peak period for urban rail transit station [5]. Cui et al. uses maximum entropyprinciple to research the passenger streamlines about subway transfer station [1]. Congling et al. studies the streamline in metro station by considering the safety strategy during evacuation [3]. Hu et al. evaluates the passenger streamline designation by using micro simulation program.

According to the existing literatures, researches about passenger flow line and waiting resources have got achievements in some degree. However, there is a downside that the passenger flow line and waiting resources are researched respectively, and the optimization results are not comprehensive. Based on this shortcoming, the paper comprehensive studies two questions together from the perspective of dynamic coordination optimization.

2. Analysis of Passenger Waiting Characteristics

Suppose that t_i is the departure time of I_i ($i=1,2,3,...,n$), the origin trains and passing by trains is $I=\{I_1,I_2,I_3,...,I_n\}$, the set of waiting resource is $J=\{J_1,J_2,J_3,...,J_m\}$, S_j is the capacity of waiting resource J_i, the set of platforms is $Z=\{Z_1,Z_2,Z_3,...,Z_R\}$, I_p^f is the subset of trains I_i in p period.

Suppose that t_{ij}^s is the beginning time of waiting resource occupied, $t_{ij}^s=t_i-T$. Then

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

Suppose that $g(t)$ is the density function of passenger arrival. Then

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

$$\int_0^T g(t)dt=1 \quad (3)$$

The statistic distribution of passenger waiting time is shown as Figure 1.

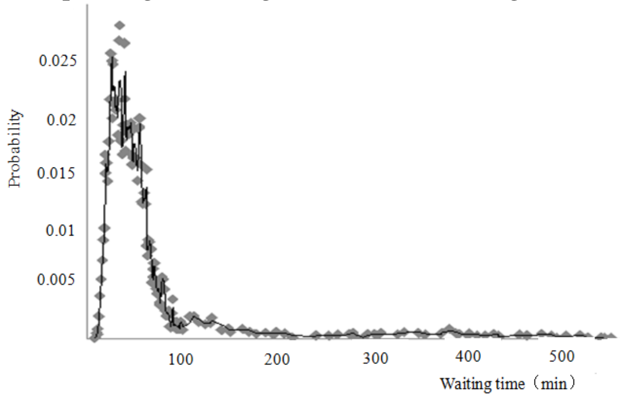

FIGURE 1. Statistic Distribution of Passenger Waiting Time

3. Establishing Model

Suppose that $S_k=\{s_1,s_2,...,s_k,...s_K\}$ is the state set of waiting resource allocation for the given passenger station, $f_k(s_k)$ is the optimal function value of the k-th phase. Then

$$f_k(s_k)=\underset{x_k}{Opt}\{r_k(s_k,x_k)+f_{k+1}(s_{k+1})\} \quad (4)$$

For any two trains I_a and I_b, the departure time at the given passenger station is t_a and t_b respectively, the departure time interval of I_a and I_b is $T_{ab}=|t_b\text{-}t_a|$,the beginning time of distributing waiting resource is t_a^s and t_b^s respectively, the ending time of distributing waiting resource is t_a^e,t_b^e respectively . Then

$$(t_a^e-t_b^e)(t_a^s-t_b^s)>0 \quad (5)$$

Define 0-1 variable x_k as

$$x_k=\begin{cases}1 & \text{occuping waiting hall for passeenger of train } k\\ 0 & \text{other}\end{cases}$$

Then the minimum waiting resource required is denoted as

$$\min \quad Z=\sum_{k=1}^{n}x_k \quad (6)$$

Suppose that $D=\{D_1,D_2,...,D_k,...D_K\}$ is the phase set of waiting resource allocation for the given passenger station, I_k^f is the trains set to be assigned in the k-th phase for the given passenger station. N_i^k is the estimated number of passengers which get on train I_i at the given passenger station. Then

$$N_i^k=\begin{cases}N_i\cdot\int_8^{t-T_k+8}g(t)dt & t_i\geq T_k\\ 0 & t_i<T_k\end{cases} \quad (7)$$

Define decision variation x_{ij}^k as

$$x_{ij}^k=\begin{cases}0 & I_i\notin I_k^f\\ 1 & I_i\notin I_k^f,N_i<S_j^k\end{cases} \quad (8)$$

Suppose that N_{ij}^{k} is the conversion passenger's number of waiting resource allocation J_j for the given passenger station, η is conversion factor which consider the passenger luggage. Then

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

Suppose that N_{aver} is the number of estimated waiting passengers for any waiting resource allocation J_j. Then

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

Suppose that $L=\left\{l_{11},l_{12},...,l_{jr},...l_{mR}\right\}$ is the set of passenger flow lines for the any given passenger station(See figure 2), A is the entrance of waiting resource allocation J_j, G is the platform.

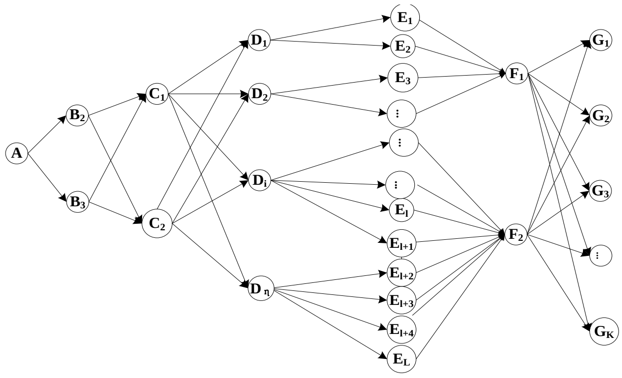

FIGURE 2. The Passenger Line in the Any Given Passenger Station

Suppose that L_{zr} is the total size of the passenger flow lines for the any given passenger station. As shown from the figure 2, the total size of the passenger flow lines L_{zr} is proposed as

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

$S_k=\left\{S_1^k,S_2^k,...,S_j^k,...S_m^k\right\}$ is the set of state variable for the any given passenger station. $I_k^f \in I$ is the set of departure trains for the any given passenger station .

The state transformation equation of collaborative optimization is proposed as

$$\left\{S_{ik}\right\}=\left\{S_{i(k-1)}-\sum_{i=1}^{n_i} N_i^k \eta x_{ij}^{k}+\sum_{i=1}^{n_{i-1}} N_i^{k\text{-}1}\eta x_{ij}^{k\text{-}1}\right\} \quad (9)$$

Index of recursion equations of passenger flow line and waiting resources is proposed as

$$\begin{cases} f_k\left(S_k\right)=\min\left\{v_k+f\left(S_{k-1}\right)\right\} \\ f_k\left(S_0\right)=0 \end{cases} \quad (10)$$

$$S_{i,k}=d_k(S_{i,k\text{-}1},S_{i,k-2},...,S_{i,k+1-m},x_{ij}^{k}) \quad (11)$$

Then, Collaborative optimization objective function is transformed as

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

4. Algorithm Design

Step1: Given any original solution $S_k^0 \in X_1, k=2,...,\Gamma$, $S_0=(S_1,S_2^0,...,S_\Gamma^0)$.

Step2: $G_1^1,...\ G_{\Gamma-1}^1)$ is computed as the following equation

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

Step3： $G_1^2,...G_{\Gamma-1}^2)$ is computed as the following equation

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

If the initial optimal solution $S_k^2(k=2,...,\Gamma,)$ is got, then the total series of solutions for the each phase S^2 is also got, namely, $S^2=(S_1,S_2^2,S_3^2,...,S_\Gamma^2)$.

Step4: According to $S^n=(S_1,S_2^n,S_3^n,...,S_\Gamma^n)$, then, $S^{n+1}=(S_1,S_2^{n+1},S_3^{n+1},...,S_\Gamma^{n+1})$ can be got.

5. Case Analysis

In this case, suppose that there are four waiting hall. The number of passenger trains and its departure time distribution is presented as figure 3, and the passenger waiting rate for every moment is presented as figure 4. The arrival time and departure time of each train is presented as figure 5.

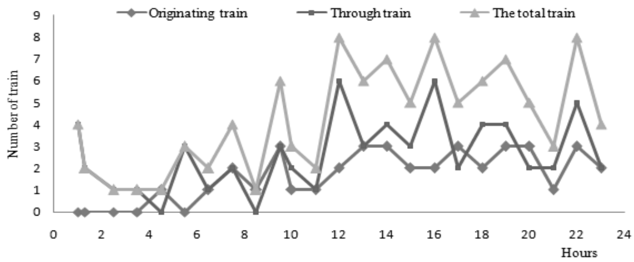

FIGURE 3. The Number of Passenger Trains and Its Departure Time Distribution

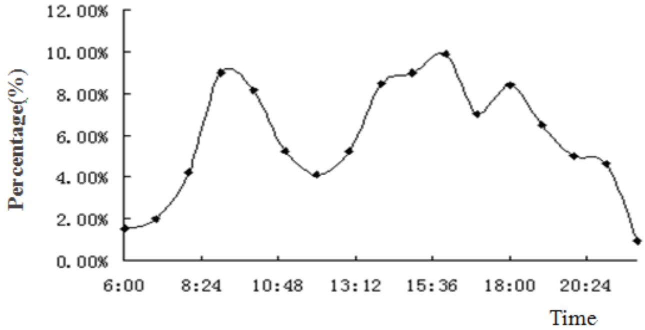

FIGURE 4. Passenger Waiting Rate for Every Moment

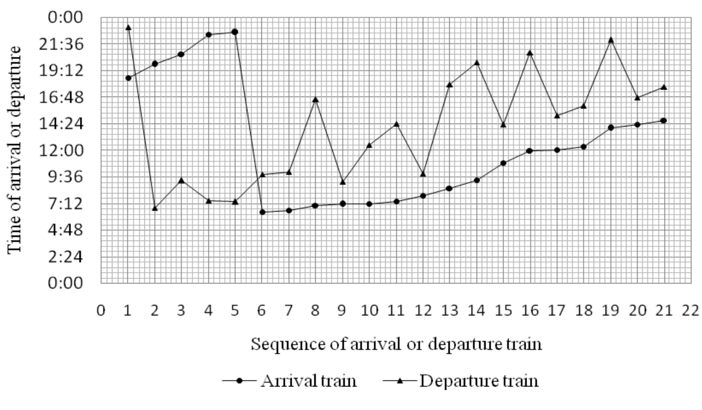

FIGURE5. The Arrival Time and Departure Time of Each Train

Table1. Optimization Result

Waiting room	number of waiting passenger in one day	Waiting room	number of waiting passenger in one day
No.1	5255	No.3	5902
No.2	5637	No.4	5320

This optimal result indicates that the model used by the main passenger train station can reach the balance between the waiting room and the shortest passenger line.About mixed stations or stations with sub-end layouts and uninterrupted passenger flow lines, We can use this model in the paper to find a more efficient result.

6. Conclusions

For shortage of previous prediction method of emergency supplies, the correlation between properties of emergencies is considered in this paper. Theory of fuzzy rough sets is used to reduce attributes so that redundant attributes of emergencies can be excluded effectively. After reduction of attributes, dimension of attributes can be reduced, thus, the retrieval efficiency can be improved. Furthermore, using the theory of fuzzy rough sets, weight of the main attributes can be distributed, making it more objective to determine the degree of importance of attributes. Thus, the prediction accuracy is improved. Rationality of the method is verified by the experimental results. And it is more efficiently to find out the similar case, and storage space is saved.

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