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Research On Paths Selection for Passenger Train Under Emergency Event

[1]Yanping Du, [2]Xiaogang Zhao, [1]Xiaohui Wang and [1]Weimin Zhang
[1]School of Mechanical Engineering, Beijing Institute of Graphic Communication, 102600, Beijing, China
[2]School of Mechanical-electronic and Vehicle Engineering, Beijing University of Civil Engineering and Architecture, Beijing 100044, China

Abstract: In face of the problem of paths selection for railway passengers' transportation, it is constructed that the model of paths selection for minimizing mileage. The model is computed by taking advantage of Ant Colony Algorithm which reconcile overlapping penalty factor to generate reasonable and feasible paths. On the basis of feasible paths, it is built that the selection of railway paths under emergency. The priority of paths is obtained by the fuzzy comprehensive evaluation method which is based on AHP. In the final part of the study, a case confirmed the validity of model and evaluation's methodology.

Key words: Emergency situation, path selection, optional paths, ant colony algorithm, fuzzy comprehensive evaluation

INTRODUCTION

China is a country with vast territory, so it is indispensable for people to choose an appropriate mode of transportation to meet their traveling demand. Railway has become the first choice for people because it is characteristic of large capacity, low cost and low energy consumption. But it is inevitable for railway system that the emergency event in consequence of instable factor which stems from personnel or device. For example: A large number of passengers were caught in train stations because of the major disaster that Baoji-Chengdu Line and Chengdu-Kunming Line were destroyed in the Wenchuan earthquake at 2008. So, it is a significative research that selecting feasible paths which are used to transporting stranded passengers on the premise that steering clear of affected line section.

Most of scholars focused on constructing model of the optimization for transport paths and designing algorithms to generate paths. In the background of adjustment to passenger dedicated line under emergency, Almodovar and Carcia-Rodena (2013) proposed an optimization method which was based on discrete event simulation model which was the goal of minimizing the transportation time and was computed two kinds of greedy algorithms. It was constructed the roundabout transport model of urban rail under emergency by Xiao (2012). It was solved by the algorithm which was combined Dijkstra methods w modified deletion algorithm for obtaining a set of feasible paths. Zheng (2012) designed a paths selection model and algorithm which was combined Dijkstra methods with modified deletion algorithm in order to obtain a set of feasible paths. Zheng (2012) designed a paths selection model and algorithm which is based on the K-short path to generate the paths set. Liu and Xu (2010) gained the optimal route for each train by using the method of fuzzy multi-objective decision-making.

MODEL OF GENERATING PATHS SET

Network of railway: On the basis of graph theory, the network of railway can be presented by G = (V, E), $V = \{v_i|i = 1, 2,\ldots, n\}$ denotes the sets of nodes, where v_i is the ith station in network. $E = \{e_{ij}|i, j\in V\}$ denotes the sets of edges, e_{ij} is the track section which composed by two adjacent nodes v_i and v_j. $R = \{r^k_{st}|k = 1, 2,\ldots, m\}$ denotes the sets of feasible paths, where r^k_{st} is the kth feasible path which is from v_s to v_t, l^k_{st} is the length of the kth feasible path:

$$l^k_{st} = \sum_{e_{ij}\in r^k_{st}} \omega_{ij}$$

ω_{ij} is the line mileage of track section which composed by two adjacent nodes v_i and v_j.

Model variable:

- x^k_{ij} denotes whether the kth path includes track section e_{ij}

Corresponding Author: Yanping Du, School of Mechanical Engineering, Beijing Institute of Graphic Communication, 102600, Beijing, China

$$x_{ij}^{k}=\begin{cases}1, \text{ yes}\\0, \text{ no}\end{cases}$$

- y_i denotes whether the station v_i has rail connecting lines:

$$y_{i}=\begin{cases}1, \text{ yes}\\0, \text{ no}\end{cases}$$

- $r(e_{ij})$ denotes the type of line of track section e_{ij}:

$$r\left(e_{ij}\right)=\begin{cases}1, \text{ high}-\text{speed}\\0, \text{ common}\end{cases}$$

Constructing of the model:

$$z=\min\sum_{e_{ij}\in E}\omega_{ij}x_{ij}^{k}$$

$$\sum_{e_{ij}\in E}x_{ij}^{k}-\sum_{e_{ij}\in E}x_{ij}^{k}=\begin{cases}1 & i=s\\0 & \text{else}\\-1 & j=t\end{cases}\tag{1}$$

$$y_{j}=0,\ r\left(e_{ij}\right)=r\left(e_{jh}\right),\ i\neq j\neq h\tag{2}$$

$$r\left(e_{ij}\right)\neq r\left(e_{jh}\right),\ y_{j}=1,\ i\neq j\neq h\tag{3}$$

The model is goal of minimizing the length of path. The constrained Eq. 1 denotes the flow conservation of source point s, terminal point t and other points in the network; The constrained Eq. 2 denotes that if the station v_j has not the rail connecting line, it must be coincident that the types of the two lines which pass the station. The constrained Eq. 3 denotes that if there are two types of rail lines which go through the station v_j, the station has the rail connecting line.

Computing of the model: Paths selection models in above-mentioned studies were solved by algorithms which were based on the Dijkstra algorithm, however, the viewpoint were proposed by Chen (2007) that the Dijkstra algorithm is not able to meet calculation in the large scale network because of the limitation of the level of computer hardware. So, it is proposed a novel algorithm that is basis of ant colony algorithm which reconciles the iterative penalty factor.

Searching feasible path based on the algorithm is as follows:

Step 1: The number of feasible paths is q and initializing it to 0. Setting the number of ants is m and setting the max generation of the algorithm is iter_max

Step 2: Locating m ants in initial node v_t and making start points be saved into the sets tabu

Step 3: Making any one of the ant k(k = 1, 2,..., m) select the path,and searching any node j within specific stations set allow as the next node in the path which is selected by the ant. The probability of every node in allow is pitched on is as follows:

$$p_{ij}^{k}=\frac{\left[\tau_{ij}(t)\right]^{\alpha}\times\left[\eta_{ij}(t)\right]^{\beta}}{\sum_{s\in allow}\left[\tau_{is}(t)\right]^{\alpha}\times\left[\eta_{is}(t)\right]^{\beta}}\tag{4}$$

where, $\eta_{ij}(t) = 1/\omega_{ij}$ is heuristic function; $\tau_{ij}(t)$ is the pheromone concentration which is between the station i with station j at t moment; α is the factor of degree of importance of pheromone concentration; β is the factor of degree of importance of heuristic function.

Step 4: If ant moves to the terminal node v_t, stop searching and transferring to step 3, otherwise turning to step 3

Step 5: Calculating objective function value of the paths which were selected by every ant and choosing the least value as the current optimal solution

Step 6: Updating the pheromone:

$$\tau_{ij}(t+1)=(1-\rho)\tau_{ij}(t)+\sum_{k=1}^{n}Q/L_{k}\tag{5}$$

where, Q denotes to intensity of pheromone; ρ denotes the degree of volatilization of pheromone; L_k is the length of path which the kth ant finished

Step 7: iter = iter+1, turning to the step2,if the algorithm is end at the generation of iter_max, outputting the shortest path minRoute and its length minLength

Step 8: Making the mileage of every track section of the shortest path multiply by iterative penalty factor, the penalty function is as follows:

$$\omega_{ij}^{q+1}=\left(1+\theta/\min\text{Length}\right)\times\omega_{ij}^{q}\tag{6}$$

Step 9: q = q+1, turning to step1 and executing the algorithm again. If the q_{th} path is obtained,the whole algorithm procedure is end. The value of q is not more than 4 according to (Xiao, 2012)

EVALUATION OF PATHS

Constructing the evaluation system: The optimal path is referred to the shortest path physically under the condition of normal operation. But when the railway system is interrupted in consequences of emergency, the optimal path is not supposed to be equivalent to shortest path. It is obligatory for railway administration to take account into all kinds of factors when selecting the optimal path under emergency. It is not easy for us to quantize the priority of feasible paths because railway is a complex system which is involved to machinery, electron and transportation. So, we constructed the evaluation system of railway transport that is composed of five aspects which are personnel, management, environment, device and cost, as shown in the Fig. 1.

Method of evaluation: As is indicated in Fig. 1, the indexes of the evaluation system are character of fuzziness. So, we adopted fuzzy comprehensive evaluation method which is based on AHP. The method is as follows:

Step 1: Making use of AHP to obtain the weight of above-mentioned five indexes $W = (w_1, w_2, w_3, w_4, w_5)$ is the weight vector

Step 2: Building the set of factors. In terms of Fig. 1, the set of factors is $U = \{U_1, U_2, U_3, U_4, U_5\}$ and U_1-U_5 are correspond to the five factors

Step 3: Proposing the decision set. It is referred to $L = \{L_1, L_2, \ldots, L_k\}$; k is the number of feasible paths.

Step 4: Obtaining the evaluation matrix R. Evaluating every factor in set U_i and constructing the evaluation matrix R. By consulting the specialist, the probability of selecting the kth path is equal to $r_{ik} = S_{ik}/S$ for factor $u_i (i = 1, 2, \ldots, 5)$, where: S is the amounts of experts which is consulted, S_{ik} denotes to the number of specialists who selected the kth path in terms of factor:

$$R = \begin{bmatrix} r_{11}, r_{12}, \cdots & r_{1k} \\ r_{21}, r_{22}, \cdots & r_{2k} \\ \vdots, \vdots, \cdots & \vdots \\ r_{51}, r_{52}, \cdots & r_{5k} \end{bmatrix} \tag{7}$$

Step 5: Comprehensive evaluation:

$$B = W \times R = (w_1, w_2, \cdots w_5) \times \begin{bmatrix} r_{11}, r_{12}, \cdots & r_{1k} \\ r_{21}, r_{22}, \cdots & r_{2k} \\ \vdots, \vdots, \cdots & \vdots \\ r_{51}, r_{52}, \cdots & r_{5k} \end{bmatrix} = (b_1, b_2, \cdots, b_k) \tag{8}$$

In terms of Eq. 8, we can get the priority of every route in the feasible paths in accordance with the value of comprehensive evaluation.

CASE ANALYSIS

Constructing a weighted undirected network,as show in Fig 1. Assuming that due to the influence of the incident, the common lines between the station 1st and the station 5th and between station 5th and 10th exiting lines were broken off which lead that a large number of passengers stranded at the station 1st.

Then the railway departments launched the emergency response plan that they would plan to choose three reasonable paths to make the passengers to move to the station 10th. The network is shown in the Fig. 2 and the basic data is shown in the Table 1.

Programming an algorithm by using MATLAB (R2008a), setting the number of ants is 5, the max generation of the algorithm is 20, the factor of degree of importance of pheromone concentration is 1, the factor of degree of importance of heuristic function is 5. Operating the program, the result is 3 feasible paths, respectively are 1-5-10, the route mileage is 610 km, 1-3-6-7-9-10, the route mileage is 617 km, 1-2-4-8-10, the route mileage is 618 km.

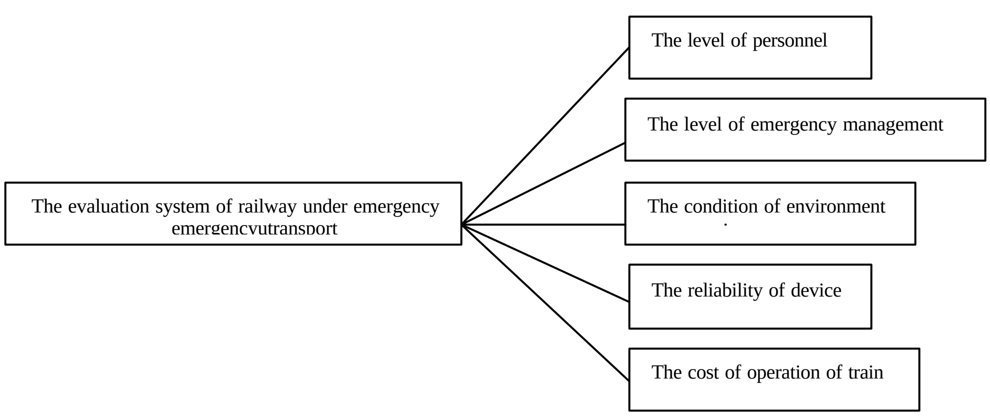

Fig. 1: Evaluation system of railway under emergency

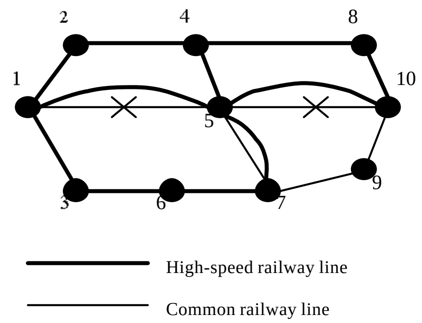

Fig. 2: Undirected weighting railway network

Table 1: Route mileage of the sections

Section	Type	Mileage (km)
1-2	High-speed	145
1-3	High-speed	150
1-5	High-speed	276
2-4	High-speed	145
3-6	High-speed	108
4-5	High-speed	152
4-8	High-speed	180
5-7	High-speed	128
5-7	Common	145
5-10	High-speed	334
6-7	High-speed	115
7-9	Common	106
8-10	High-speed	148
9-10	Common	138

These 3 feasible paths make up the paths set L = (L_1, L_2, L_3). By using the AHP, the weights of 5 indexes is W = (0.1290, 0.1290, 0.3435, 0.3435, 0.0551). Through the expert consultation, evaluation matrix is:

$$R = \begin{bmatrix} 0.3, 0.5, 0.2 \\ 0.2, 0.7, 0.1 \\ 0.5, 0.4, 0.1 \\ 0.3, 0.5, 0.2 \\ 0.4, 0.4, 0.2 \end{bmatrix}$$

Then, B = W×R = [0.3613, 0.4859, 0.1528]. It can be seen that the best path among these alternative paths is L_2 and the selecting sort is $L_2 > L_1 > L_3$.

CONCLUSION

In the background of the railway passengers' transportation under emergent circumstances, setting up reasonable path generation model for aiming at the shortest transport mileage and using the iterative penalty factor of ant colony algorithm to solve the model to get the feasible paths set. On the basis of the set, we established the evaluation which was took consideration into the staff, management, environment, equipment and cost and used fuzzy comprehensive evaluation method based on AHP to evaluate alternative path so that we can get the optimal path and path selection order. This method can be as an emergency operation of railway department to provide help and advice.

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