

Research on optimization of subway operating schedule based on case database

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Abstract. Aiming at the optimization problem of subway operating schedule, this paper integrates the case retrieval method, so that enterprises can quickly find the best operating schedule corresponding to the situation. Taking Nanjing Metro as the case background, this paper analyzes the factors affecting subway operation energy consumption, uses AHP method and Entropy method to calculate subjective and objective weights, and puts forward the AHP-Entropy weighting method based on linear combination to solve the problem of large deviation between subjective and objective weights and combined weights. Then the variable weight nearest neighbor method is used to calculate the similarity of cases, and the applicable cases are obtained, and the optimal operation schedule is selected according to the operation energy consumption. Finally, the validity of the case retrieval method proposed in this paper is verified, and the results show that the linear combination-based AHP-Entropy weighting method combined with the variable weight nearest neighbor method has better stability.

Keywords: case base, Operating schedule, AHP, Entropy method, Nearest neighbor method.

1. Introduction

The subway operating schedule is the basis of the train running organization, and there are many research results on the optimization of the subway operating schedule at home and abroad. Yang [1] built a multi-objective train schedule optimization model, taking the total residence time of the train at the intermediate station and the total delay time at the originating station as the minimum optimization objectives. Ding Yi [2] and Feng Jia [3] set up an energy-saving timetable optimization model based on the total energy consumption of trains. Wang Bo [4] studied the rail transit running line problem under flat peak state, and established a rail transit train running diagram compiling model with the total passenger transfer waiting time as the target. Leiva [5] reduce costs in terms of passenger waiting time, bus travel time and enterprise operating costs, and develop timetable optimization models.

In recent years, with the development of case-based reasoning technology, it has been widely used in the field of transportation [6]. Through case reasoning, the existing case data of subway operation energy consumption schedule is analyzed, and the subway operation energy consumption model is formed. In practical applications, the problem of determining attribute weight value and distance trap is always a hot topic. Yang Yan [7], Zhao Weidong [8] conducted cluster analysis on the sample database, effectively improving the efficiency and accuracy of case retrieval. Zheng Yonghe [9] proposed a case retrieval method based on fuzzy reasoning. Through the improved KNN case retrieval method, Sun Baogui [10] effectively improved the accuracy of the retrieval results.

In this paper, the factors of subway operation energy consumption are analyzed, and a method of calculating the attribute weights of operation energy consumption cases based on linear combination of AHP-Entropy is proposed. Taking Nanjing Metro Line 10 as an example, the validity of the proposed method is verified.

2. Analysis of energy consumption factors in subway operation

Train operating diagram is the basis of train operating organization. Under normal circumstances, the train operating schedule is prepared according to the train operating diagram, so the train operating diagram is also called the subway operating schedule.

The influencing factors of subway energy consumption mainly include four first-level indexes: train attribute, operation plan, passenger flow attribute and line condition. Train attributes include train weight, rated seat, tractive force and braking force. The operation scheme includes maximum speed, average speed, departure interval, number of departure trains, grouping scheme and stopping time; The attributes of passenger flow include average passenger flow, peak hour passenger flow, average hour passenger flow in section and full load rate. Line conditions include curve radius, ramp design, and station spacing. Since this paper is to optimize the schedule of Nanjing Metro Line 10, all line conditions are consistent, so the main consideration of train attributes, operation plan and passenger flow characteristics of three attributes.

3. Case attribute weight design based on AHP-Entropy method

3.1. Basic principles of AHP and Entropy method

AHP is a qualitative and quantitative subjective empowerment research method. It adopts the pair comparison method to establish a matrix, and utilizes the relativity of number size, the larger the number, the higher the weight will be, and finally calculates the importance of each factor.

Entropy method is an objective weighting method, which uses the amount of information contained in the data to calculate the weight and get a relatively objective index weight. According to the characteristics of information entropy, the degree of dispersion of an index can be judged according to the size of entropy. If the entropy value of an index is larger, it means that the index is more discrete and provides relatively less information, so the degree of influence in the evaluation is smaller, and its weight value is smaller. On the contrary, if the entropy value of an index is smaller, it means that the degree of dispersion of the index is smaller, the more information is provided, the greater the degree of influence in the evaluation, and the greater its weight value.

3.2. Weight determination of AHP-Entropy method based on linear combination

Since the determination of each attribute weight of subway operation energy consumption cases is highly dependent on expert experience, and there are certain differences in the importance of subjective and objective weighting methods, this paper adopts the linear combination weighting method to calculate the combined weights, and the specific calculation formula is as follows:

$$w_i = \alpha w_{1i} + (1 - \alpha)w_{2i} \quad (1)$$

Where, w_{1i} represents the weight value of AHP case attribute i , w_{2i} represents the weight value of Entropy method attribute i , α is the selection preference, in order to reflect the flexibility and rigor of subjective and objective weights, $\alpha=0.5$ is selected in this paper.

4. Operation schedule case retrieval model based on variable weight nearest neighbor method

The traditional nearest neighbor algorithm does not take into account the influence of each attribute weight of the case, so the accuracy of the result will be affected to some extent. Therefore, in this paper, the weight of case attributes is taken into account, that is, the variable weight nearest neighbor algorithm is adopted.

When applying the variable weight nearest neighbor algorithm to calculate the similarity, it is found that there are certain differences in the magnitude and dimension of each attribute. Therefore,

in order to improve the accuracy of the results, it is necessary to standardize the data according to equation (2), and then calculate the similarity.

$$X'_{ij} = \frac{X_{ij} - X_j^{min}}{X_j^{max} - X_j^{min}} \quad (2)$$

In the variable weight nearest neighbor method, the formula for calculating the similarity between the target case and each case in the historical case base is as follows:

$$sim(i, j) = \frac{1}{1 + \sqrt{\sum_{j=1}^m W_j * (X'_{ij} - M'_j)^2}} \quad (3)$$

Where X_{ij} represents the value of the j attribute of case i , and X_j^{max} and X_j^{min} represent the maximum and minimum values of indicator j , respectively. X'_{ij} is the data after standardization, M'_j represents the value of the target case after standardization, and W_j is the weight coefficient value corresponding to the attribute with serial number j .

5. Experimental Result Analysis

5.1. Analysis of experimental results

Taking Nanjing Metro Line 10 as the research object, combined with the historical case base of running energy consumption, the metro operating schedule of this line is optimized. AHP-Entropy method based on linear combination was used to assign weight to each attribute, and the weight value of each attribute was obtained as 0.0137, 0.0152, 0.0333, 0.0411, 0.1157, 0.1076, 0.0707, 0.0827, 0.0398, 0.0673, 0.1544, respectively. 0.0642, 0.1075, 0.0872.

Using the obtained attribute weights and the nearest neighbor method with variable weights constructed in Chapter 4, combined with passenger flow characteristics, the target case M1, M2 and M3 were selected to match with 3100 historical cases, where M1 and M2 were the morning and evening peaks, and M3 were the flat peaks, respectively, and the threshold of practical applicable cases was set as 0.9. The matching results of practical applicable cases can be obtained, as shown in Table 1.

Table 1. Target cases M1, M2 and M3 match the result set

Target Case	Case Number	Similarity Value	Operating energy consumption
M_1	579	0.9147	124770
	738	0.9329	121776
	1246	0.9040	142139
	1478	0.9248	149476
M_2	573	0.9095	121719
	1013	0.9132	149783
	1100	0.9241	147847
M_3	608	0.9223	128548
	894	0.9355	122343
	1438	0.9125	144717
	1850	0.9009	143711

According to the results in Table 1 and the operation energy consumption of the case, the optimal operation schedule number of the case M1 is 738, the optimal operation schedule number of the case M2 is 573, and the optimal operation schedule number of the case M3 is 894.

5.2. Validity verification analysis

In order to verify the effectiveness of the weight calculation method proposed in this paper and the accuracy of the case retrieval method, 100 pairs of target cases M are randomly selected from the subway operation energy consumption case base, and the weight values are calculated by using the Python tool and the AHP-Entropy method based on linear combination proposed in Chapter 3. In combination with the variable weight nearest neighbor algorithm in Chapter 4, the similarity algorithm was calculated for verification. The comparison of similarity results is shown in Fig 1 and Fig 2.

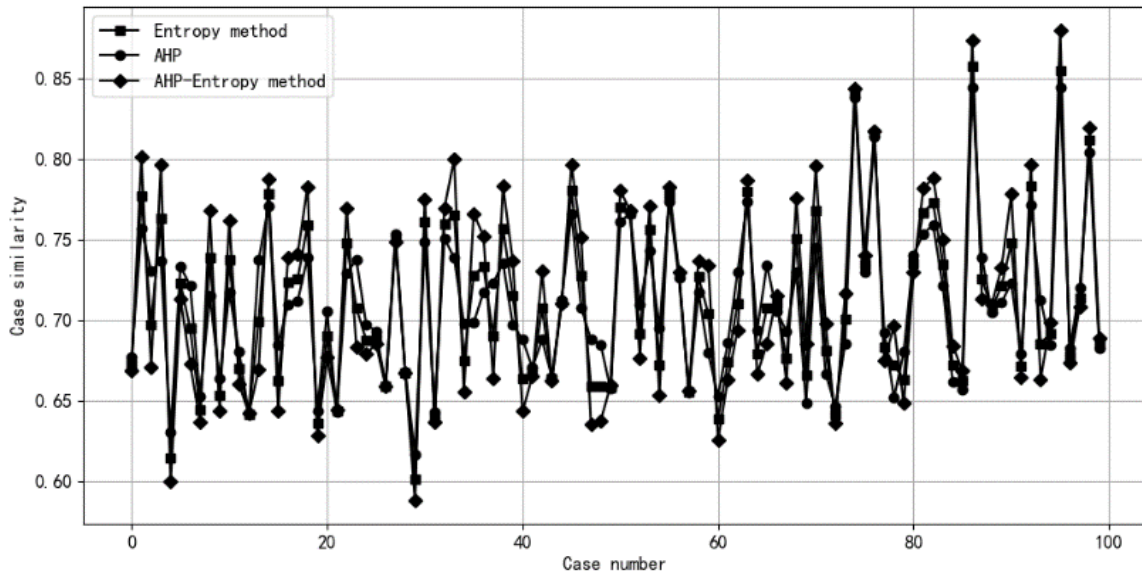


Figure 1. Similarity comparison diagram of three weight calculation methods

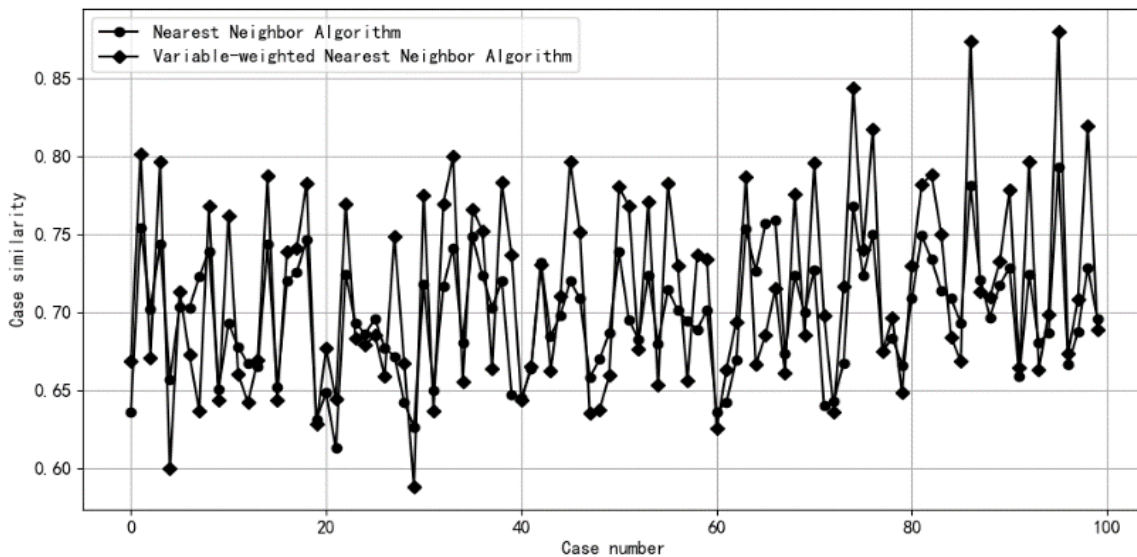


Figure 2. Comparison of results of similarity calculation between two retrieval methods

It can be seen from Fig. 1 that the overall trend of case similarity obtained by the three weight calculation methods is roughly the same. For cases with high similarity, the similarity value calculated by AHP-Entropy method is greater than that of the other two methods. For the case with small similarity value, the similarity value calculated by AHP-Entropy method is smaller than that of the other two methods. Therefore, the case attribute weight calculated by AHP-Entropy method has a good effect on finding clearly similar cases and ignoring cases with low similarity.

It can be seen from Fig. 2 that the overall trend of case similarity obtained by the variable weight nearest neighbor algorithm and the nearest neighbor algorithm is roughly the same. However, compared with the traditional nearest neighbor algorithm, the variable weight nearest neighbor algorithm has a higher recognition degree. For cases with high similarity, the similarity value is higher, and for cases with low similarity value, the similarity value is smaller, so it can better obtain similar cases.

In summary, it can be seen that the combination of AHP-Entropy method based on linear combination and variable weight case retrieval method is of great value for case retrieval.

6. Summary

In this paper, case retrieval technology is introduced to optimize the subway schedule, and the weights of each index are determined by AHP-Entropy method based on linear combination, which comprehensively considers subjective and objective factors. For morning and evening peak and off-peak periods, the nearest neighbor retrieval method with variable weights is proposed, which can obtain multiple operating schedule cases, and select the optimal operating schedule combined with operating energy consumption.

However, when selecting the optimal operating schedule, this paper only considers the operation energy consumption of the subway, but does not consider the interests of passengers, nor does it consider the impact of weather, line emergencies and other aspects. In view of the above shortcomings, it will be further improved in the future research.

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