Railway route selection based on entropy weight method-gray correlation improvement TOPSIS

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Abstract. In order to reasonably select the best railway route design scheme, the paper research the comprehensive evaluation model of TOPSIS based on entropy weight method-gray correlation. The paper establish the comprehensive evaluation index system from four aspects: technology, economy, society and environment. Then set up railway route selection model of gray correlation improvement TOPSISI, and use entropy weight method to determine the weight coefficient of each index. Finally, take the rail connection project as the example for verification. Making comparison of three alternative route design by using this model, respectively obtain the three scheme relative proximity are 0.575/0.543/0.551. The relative proximity of scheme 1 is the largest (0.575), which is the optimal design scheme, and it is consisted with the actual connection scheme. The paper use this model for railway route selection can make full use of objective data information and reduce the influence of subjective factors.

1. Introduction
Railway transportation is the foundation of national economic development and social progress[1], the development of modern science and technology has promoted the progress of the railway transportation[2]. In railway construction, comprehensive comparison and design selection[3] has an overall relationship with the project. The essence of the railway route design schemes comparison is the multi-objective evaluation[4], modern comprehensive evaluation method used to solve these problems, such as: analytic hierarchy process, fuzzy comprehensive evaluation, gray relational analysis, TOPSIS method[5], and artificial neural network.

TOPSIS method mainly reflects the similarity between each evaluation scheme and ideal solutions by calculating the relative proximity between each scheme and target scheme[6]. But this method can not reflect the relationship between the internal changes of each scheme with ideal schemes, while the gray correlation analysis method[7] just reflect the changing trend for the internal factors of each scheme, which can making up the insufficiency of the TOPSIS method entirely rely on quantitative information. Therefore, improving TOPSIS method with the idea of gray correlation can make two methods complement each other.

In addition, introduce the entropy method[8] to determine the weight coefficient of index, the qualitative index is quantified by fuzzy mathematics principle[9]. Thus, the TOPSIS comprehensive evaluation model based on entropy weight method-gray correlation can be set up, which can improve the deficiency of traditional railway route selection.
2. Evaluation index system

Establish an evaluation index system is the premise of comprehensive evaluation. The paper classify and summarize the factors which can influence the route selection, then establish a comprehensive evaluation index system. This system mainly evaluate the route design from four aspects: technology, economy, society and environment.

In the evaluation system, according to the different evaluation properties, the indicators can be divided into quantitative indicators and qualitative indicators. The quantitative indicators can be described by intuitive data, the qualitative indicators need use fuzzy mathematics to quantified, that is: combined the fuzzy theory and expert scoring method[10] to evaluate the value, Select a decimal number with a space of 0.1 between 0-1 as the rating level, the specific evaluation criteria are shown in Figure 1.

![Figure 1. Qualitative indicator evaluation standard.](image)

According to the different measurement criteria, the indicators also can be divided into benefit index and cost index. In index system: the indicator is marked with (+) as the benefit indicator, and the indicator is marked with (-) as the cost indicator. In addition, attention should be paid: Some evaluation indicators should be the cost indicator, but in the quantifying and scoring process, the smaller value of the index, the higher score is. For example: the construction difficulty should be the cost index, but if the difficulty design scheme is smaller, the corresponding evaluation score is higher, so the construction difficulty transformed from cost index into benefit index. Other evaluation indicators are analyzed and defined as this process, which is not repeated here. The evaluation index system is shown in Figure 2.

![Figure 2. Comprehensive evaluation index system.](image)

3. Model Details

According to the comprehensive evaluation index system, establish the TOPSIS comprehensive evaluation model based on entropy weight method and gray correlation. The specific process is as follows:
3.1. Initial evaluation index matrix
Suppose there are \( m \) schemes to be evaluated, and each scheme has \( n \) indexes, \( x_{ij} \) represents the original value of the \( j \)-th index of the \( i \)-th scheme, then get the initial evaluation index matrix \( X=(x_{ij})_{m \times n} \).

3.2. Initial index matrix standardization
The benefit indicators and cost indicators cannot directly compare as their different dimensions. It is necessary to use a dimensionless formula standardized initial matrix, denoted as \( Y=(y_{ij})_{m \times n} \).

3.3. Entropy method to calculate index weight
Each evaluation index in the standardized evaluation matrix \( Y=(y_{ij})_{m \times n} \) is normalized as entropy method. Then to obtain the normalized weight of each index.

3.4. Weight of standardized matrix and ideal solution determination
The standardized index matrix is multiplied by the weights of each index determined by entropy weight method, the \( n \) obtain the weighted standardized evaluation index matrix \( Z=(z_{ij})_{m \times n} \), the optimal value \( z_{0j} \) of each evaluation indicators is selected as a reference index.

3.5. Determination of gray correlation coefficient matrix
Calculate the correlation coefficient between the actual evaluation value \( z_{ij} \) and the ideal solution \( z_{0j} \) of the \( i \)-th evaluation scheme for the \( j \)-th index, then get the gray correlation coefficient matrix.

3.6. TOPSIS sorting based on gray correlation coefficient matrix
Take the obtained gray correlation coefficient matrix as the new evaluation matrix, select the new ideal solution. Then calculate the distance. Finally, calculate the relative closeness of each evaluation scheme and sorting them.

4. Numerical Experiment
The example is quoted from the railway project of Xuyong to Bijie, the connection of the northern of the railway is the leading project of the whole project, which not only concerns follow-up railway construction, but also affects the overall construction trend. Therefore, it is necessary to select the best design scheme to ensure entire progress go well.

The paper considers the actual project environment, and combine the existing two stations of Longfeng and Xuyong to design the connection route. Finally, confirm three connection schemes. The main quantities and investments of three schemes are shown in Table 1.

| Project      | Longfeng Investment | New Xuyong Investment | Xuyong Investment |
|--------------|---------------------|-----------------------|-------------------|
| Line length  | km                  | 34.04                 | 34.85             | 30.17             |
| Land expropriation | acre        | 9.7                   | 588               | 5703.6            | 615               | 5965.5            | 523               | 5073.1            |
| Demolition building | acre    | 1.7                   | 919               | 1562.3            | 978               | 1662.6            | 874               | 1485.8            |
| Subgrade     | m³                  | 12.75                 | 22.18             | 282.8             | 25.13             | 320.4             | 20.56             | 262.1             |
| Yard         | m³                  | 11.64                 | 318.5             | 3707.3            | 298.60            | 3475.7            | 304.3             | 3542.1            |
| Masonry      | m³                  | 27.01                 | 722.8             | 19522.8           | 708.30            | 19131.2           | 698.5             | 18866.5           |
| Bridge       | 4051.37             | 1815.60              | 23910             | 15945.1           | 4221              | 1754.4            | 21398             | 16255.9           |
| Culvert      | 1506.42             | 34.04                 | 51278.5           | 52507.8           | 34.85             | 52507.8           | 30.17             | 45451.7           |

Table 1. The main engineering quantity and investment situation of each scheme.
Expansion $10^4 ¥$ 6640
Basic reserve $10^4 ¥$ 19626.29 19732.25 18495.49
Investment estimation $10^4 ¥$ 215889.17 217054.75 203450.37

According to comprehensive evaluation index system and combine the three alternative design. The quantitative index can be directly determined, the qualitative index should be comprehensively determined by fuzzy mathematical theory and expert method. Finally, determine the qualitative indicators as five scores 0.9, 0.7, 0.5, 0.3 and 0.1, the specific values of each evaluation index as follow table 2.

Table 2. The specific value of each evaluation index.

| Index                  | Longfeng connection | New Xuyong passenger station connection | Xuyong connection |
|------------------------|---------------------|----------------------------------------|------------------|
| Line length            | 34.04               | 34.856                                 | 30.172           |
| Construction difficulty| 0.7                 | 0.9                                    | 0.5              |
| Bridge and tunnel ratio| 79.2                | 78.66                                  | 78.71            |
| Minimum curve radius   | 2200                | 2100                                   | 2000             |
| Investment estimation  | 215889.17           | 217054.75                              | 203450.37        |
| Land expropriation     | 11599.7             | 12171.6                                | 10310.2          |
| Boost local economy    | 0.5                 | 0.7                                    | 0.5              |
| Investment benefit     | 0.7                 | 0.9                                    | 0.5              |
| Regional planning      | 0.7                 | 0.7                                    | 0.9              |
| Passenger attraction   | 0.7                 | 0.9                                    | 0.7              |
| Impact on industry     | 0.7                 | 0.9                                    | 0.5              |
| Exist line interference | 0.5                 | 0.9                                    | 0.7              |
| Impact on ecology      | 0.7                 | 0.7                                    | 0.9              |
| Destruction resources  | 0.9                 | 0.7                                    | 0.5              |
| Geological condition   | 0.9                 | 0.7                                    | 0.5              |
| Fit around the perimeter| 0.7               | 0.5                                    | 0.7              |

According to the evaluation model, we can calculate the euclidean distance of the three schemes, and the relative closeness of the three schemes as shown in table 3.

Table 3. Three wiring design scheme closeness table.

| Positive distance | Longfeng connection | New Xuyong passenger station connection | Xuyong connection |
|-------------------|---------------------|----------------------------------------|------------------|
| $d_1^+$           | 1.953               | 1.896                                  | 1.954            |
| $d_2^+$           | 1.443               | 1.588                                  | 1.591            |
| Closeness         | $C_1$               | $C_2$                                  | $C_3$            |
|                  | 0.575               | 0.543                                  | 0.551            |
| Ranking           | 1                   | 3                                      | 2                |

The evaluation results of each design scheme are $C_1=0.575,C_2=0.543,C_3=0.551$, so the order of the every design schemes can be ranked as follows:

$$C_1 > C_3 > C_2$$

The connection of the the three design route in order are : Longfeng connection, Xuyong connection, and the new Xuyong passenger station connection. The actual line connection is consisted with the scheme obtained from evaluation model, which verifies the correctness and feasibility of the model.

5. Conclusion
This model has stronger practicability and accuracy. But the factors affecting railway route selection
are complex and diverse, many indexes are mutually restricted. There are many risks and uncertainties in the process of railway selection, how to deal with these factors, and coordinate various evaluation indexes, improve the flexibility and applicability of the evaluation model needs further consideration and research.

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