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RESEARCH ON OPTIMIZATION OF MOTORWAY ROUTE DESIGN SCHEME IN MOUNTAIN AREAS BASED ON ENTROPY WEIGHT-TOPSIS MODEL

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ABSTRACT

During the design process of a new mountainous motorways, multiple route schemes are often proposed for a comprehensive design effort. Each route scheme will have its advantages and disadvantages, so it is often difficult to choose a route scheme. Usually the expert decision method is used to screen the route schemes, but this method mainly relies on the personal experience of experts, and it is difficult to measure the criteria, which can lead to the embarrassing situation that different experts do not agree on the choice of the routes. In order to optimize the route scheme for the design process of mountainous motorways and improve the efficiency and scientificity of route scheme selection, evaluation indicators were selected from traffic safety, construction economy, and environmental friendliness. The Entropy Weight Method (EWM) was used to assign the weight of the evaluation indicators. By improving the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), the problem of subjective opinions and excessive reliance on objective data by designers in the multi factor evaluation process was overcome. An EWM-TOPSIS evaluation model was proposed. By analyzing specific examples of mountainous motorway construction, research results were obtained. The results indicate that the model can reflect the designer's intention towards the route scheme and the actual construction project. There is a high degree of consistency with the expert's empirical judgment, which verifies the feasibility and accuracy of the model. This model can provide reliable reference and basis for the decision-making of motorway route schemes in mountainous areas.

KEYWORDS

Mountainous motorway, Route design scheme, EWM-TOPSIS Model

INTRODUCTION

The support role of motorway construction to the national economy is becoming increasingly evident with the development of society. In China, the construction of motorways in mountainous areas is vigorously underway. The design process can determine the direction and operational level of the motorway, and plays a decisive role in the construction of mountainous motorways [1]. The route scheme is the beginning of road design, and leads to other professional design work such as roadbed, pavement, bridges, and tunnels. In the design process of mountainous motorways, especially in the early stage of route selection, designers need to consider factors such as the difficulty of construction, environmental benefits, economic benefits, investment costs, and vehicle safety, passenger comfort and travel time in the later operation process, while also taking into account factors such as the topography and geological conditions, weather and climate conditions, and local socio-economic development level of the region where the motorway is located.

The geological and topographical conditions of mountainous motorways are complex, and the construction requires a large amount of work, resulting in high costs. In the construction and operation process of mountainous motorways, there may be various problems that need to be solved, and the generation and feasible solutions of these problems are closely related to the route scheme selection. An excellent route scheme refers to a centerline that is technically feasible, economically reasonable, environmentally friendly, and able to meet the needs of multiple parties between the determined starting point and ending point, based on the natural geographical environment, socio-economic environment, technical standards, etc. A scientific and reasonable route plan is the key to achieving the social, economic, and environmental benefits of motorways. A poor route scheme will result in an increase in engineering quantity and construction difficulty. In the later operation stage, there will also be adverse consequences such as high energy consumption, high traffic safety risks, and high maintenance costs. Therefore, route scheme selection is the most important part of the entire design task. In the design process, multiple route schemes are often proposed, which is the result of comprehensive consideration of multiple factors. For multiple schemes, due to different focus areas, there are often difficult to choose optimal route scheme. Given this, scholars have conducted extensive research on this topic.

Regarding the geographical environment where the highway is located, Chen compared and selected route schemes from various aspects such as technical indicators, engineering scale, and cost, social and environmental impact based on the Moyu-Hotan motorway project as an example in desert oasis of Xinjiang, China. After comprehensive analysis, it proposed a recommended scheme [2]. Cao conducted a systematic analysis of the specific impacts of motorway construction on the natural environment, ecological resources and social environment in the selection of design routes in a reservoir area of the Yellow River in China [3]. Through the theoretical method of multiple indicator comprehensive evaluation, it established an environmental impact assessment index system and evaluation model for the motorway route scheme. It screened indicators from environmental impact and technical and economic aspects, and determined 15 evaluation indicators. Wang proposed that at the beginning of conducting route scheme research, it is necessary to understand the regional characteristics and constraints of the project location, sort out the project characteristics and difficulties, propose targeted countermeasures, and then determine the principles of route scheme [4]. Based on comprehensive selection concepts such as standards, terrain, geology, safety and cost, multiple scheme comparisons are proposed. After comparing technical and economic indicators, the recommended plan is ultimately selected to improve the quality of the plan. Zhang et al. introduced the spatial data analysis technology and intelligent evolutionary algorithm of Geographic Information System (GIS) into the road routing process in permafrost regions of the Qinghai-Xizang Plateau to solve the problem of road routing in complex geographical environments [5]. Zhang et al. proposed a scheme optimization method which could realize by using quantum particle swarm algorithm in view of the comparison between through mountain highway and winding mountain highway in mountain highway route selection [6]. GIS, raster space analysis and Google Earth are also commonly used software tools which can be used for rough selection of route design schemes [7][8]. Some highway route selection schemes focus on economic indicators [9].

Regarding the determination of indexes used in the evaluation of route schemes, the following methods have been mainly used. Analytic Hierarchy Process (AHP) method is used to determine the weights of various indexes [10]. An improved Fuzzy Analytic Hierarchy Process (FAHP) method is adopted to calculate weights [11] [12]. The method that combines AHP and GIS is used [13]. The weights of each index are determined by combining AHP with EWM [14]. The method of combining AHP with variable weight calculation is used to determine index weights [15].

A multiple-criteria weighting method is applied, which involves combining multiple weighting methods to determine the weights of each index comprehensively [16].

In terms of comparing and selecting route schemes, the following methods have been mainly used. Fuzzy Comprehensive Evaluation Method [17], a comparison made by listing and comparing each item one by one [4], Cloud Model Theory [18], TOPSIS method [19] and improved TOPSIS method [20], game decision model [21], Preference Ranking Organization Method for Enrichment Evaluations method [22].

In the evaluation of route schemes, the determination of index weights plays a crucial role and is also the focus of research. In previous studies, the methods used either relied too heavily on experts' experiences, required a lot of effort for 3D modeling, or could be influenced by subjective factors. Thus, there is still no widely accepted method for evaluating route schemes for motorways in mountainous areas, indicating that the evaluation of route schemes is a sustained and worthy research topic. This paper uses EWM to determine the weights of indexes and TOPSIS model to calculate the proximity values of each scheme for optimal selection, which avoids the limitations of consulting a large number of experts and ensures the scientificity of the evaluation results [23].

METHODS

The EWM-TOPSIS evaluation method used in this article can be summarized into 6 steps, as shown in Figure 1. The first step is to screen and determine the primary evaluation indexes for the design scheme of mountainous motorway routes. The second step is to screen and determine the secondary evaluation indexes. The third step is to form an index set. The fourth step uses the EWM to calculate the weights of each index. The fifth step is to use the optimized TOPSIS to construct a calculation evaluation model and calculate the relative closeness values of each route design scheme and the ideal solution. The sixth step is based on the size of the relative closeness values, optimal route scheme is decided.

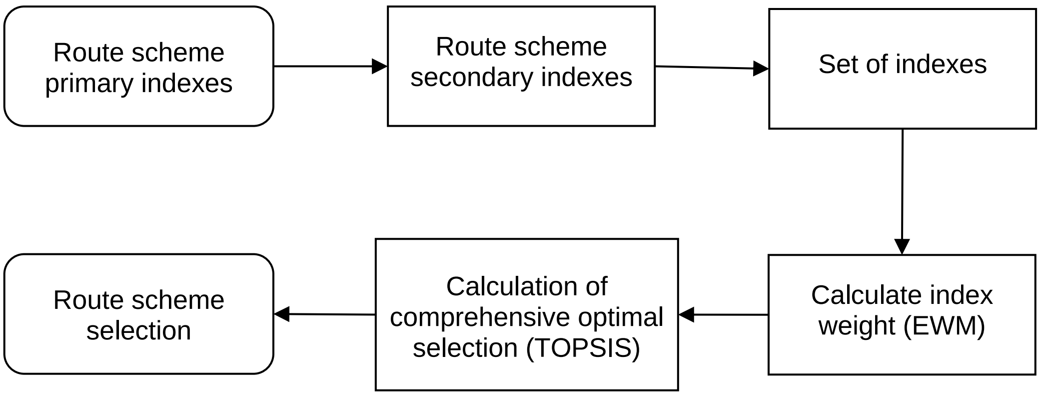

Fig. 1 – Steps of comprehensive optimization selection for route schemes

Evaluation indexes

AHP method is used for establishment of an index system. According to the degree of profit and loss of the objective, evaluation indexes can be divided into several types. A satisfactory route design scheme for a mountainous motorway needs to achieve the goals of traffic safety, good economic benefits, and ecological friendliness. Therefore, safety, economy, and ecology are set as the target. Based on the goals that need to be achieved, evaluation indexes should be constructed from the perspectives of alignment, cost, and environment, which are the primary indexes. In the selection of evaluation indexes, it keeps being consistent with the design indicators proposed in Technical Standard of Highway Engineering and Design Specification for Highway Alignment in order to facilitate the adoption of designers [24] [25].

In the design process of mountainous motorways, horizontal curves are one of the commonly used alignment types. The horizontal curves consist of circular curves and spiral. Their length and radius directly affect the safety and driving comfort of traffic [26] [27], and are also closely related to the visual physiological and psychological load levels of drivers. It is generally believed that the larger the radius and length of the horizontal curve, the higher the safety of driving [28]. Therefore, horizontal curve indexes can be used as the profit-type indexes in the alignment. Based on the same consideration as the horizontal curve, the radius value of the vertical curve can also be used as the profit-type index. The steep slope section is a traffic accident-prone section. In the design of mountainous motorways, the route scheme is often restricted by the terrain and has to use greater grade. It is generally believed that the larger the grade, the more unfavorable to traffic safety [29]. Therefore, the maximum grade can be used as one of the loss-type indexes of the alignment. The composite slope is an important alignment index for comprehensive evaluation of traffic safety [30], which is the combination value of horizontal and vertical cross. The extreme value usually appears where horizontal curves and steep slopes are combined. It is determined according to the design speed of the motorway. The composite slope is an interval-type index.

The construction and installation cost is that the project construction party needs to raise for the construction. This index belongs to the loss-type. Generally, there is a large amount of excavation and filling work in the construction of mountainous motorways, and the excavation work is usually more than the filling work, which will cause a lot of waste materials, not only increasing the excavation cost but also increasing the disposal cost. The filling and excavation balance degree is the ratio of the waste materials to the difference between the excavation and filling before and after soil and rock mass allocation. This index belongs to the interval-type, and 0 is the optimal value. The construction volume of the high-fill and deep excavation section is huge and is also the focus of the later operation and management stage. This index belongs to the loss-type. The length of tunnels is a loss-type index that the construction party strives to control. The separated roadbed is a design work that compromises with the terrain. Compared with the integral roadbed, its cost is lower. Therefore, the length ratio of the separated roadbed can be used as a profit-type index.

For the environmental evaluation index of mountainous motorways, the spatial are divided into open, closed and semi-closed form, which are expressed by the ratio of the height to length in the roadside space, which is degree of closure. The larger this index, the narrower the driving vision, and the more unfavorable it is for safety [31], which is a loss-type index. The slope masonry ratio is the ratio of the exposed masonry to the whole slope area in the surface area of the roadside slope. It is found that the raw and dull masonry structure will increase the psychological load of the driver, which is unfavorable to the driving safety, and this index is loss-type. In the construction of mountainous motorways, there are often adverse geological sections, including landslide slopes, karst caves, debris flows, etc. If the motorway route passes through these sections, there will often be serious hidden dangers, and the impact of motorway construction on the environment will be significant. Therefore, the adverse geological section ratio is proposed as an index, which is the ratio of the length of the adverse geological section to the length of the motorway, and is a loss-type index. The primary and secondary indexes are listed as shown in Table 1.

Tab. 1 - Set of indexes used for route design scheme evaluation

Primary indexes	Secondary indexes		Unit	Type
Alignment	Minimum radius of a horizontal curve	A1	m	Profit-type
	Minimum length of a spiral	A2	m	Profit-type
	Minimum length of a horizontal curve	A3	m	Profit-type
	Minimum radius of crest vertical curve	A4	m	Profit-type
	Minimum radius of sag vertical curve	A5	%	Profit-type
	Minimum length of vertical curve	A6	m	Profit-type
	Maximum grade	A7	%	Loss-type
	Maximum composite slope	A8	%	Interval-type
Cost	Construction and installation costs	C1	Billion yuan	Loss-type
	Cut volume	C2	10000m3	Loss-type
	Balance of filling and cutting	C3	%	Interval-type
	High fill and heavy cut section ratio	C4	%	Loss-type
	Maximum tunnel length	C5	m	Loss-type
	Separate roadbed length ratio	C6	%	Profit-type
Environment	Degree of closure	E1	%	Loss-type
	Slope masonry ratio	E2	%	Loss-type
	Adverse geological section ratio	E3	%	Loss-type

In order to not overlooked the impact of indicators with excessively small or too large values on the route scheme, it is necessary to develop a reasonable calculation method for index values. In actual cases, there may be more than one poor alignment or special section, such as small radius curve and steep grade. If the design speed is different, the required radius of the horizontal curve for the route also varies. When the design speed is 80km/h, a small radius curve refers to a curve with a radius less than 400m. In order to comprehensively consider the influence of multiple small radius curves on the overall route scheme, the formula for calculating the minimum radius of a horizontal curve for the profit-type index is as follows:

$$A = \min(b) \cdot \frac{1}{1+n} \tag{1}$$

Formula (1) is also applicable for calculating other indexes under the influence of multiple poor alignments or special sections on the overall scheme, such as the minimum lengths of horizontal and vertical curves, which are profit-type indexes. A represents this type indexes while $min(b)$ represents the minimum value of a certain indexes. n represents the number of poor alignments or special sections in the route scheme, and it is counted when its design value reaches the general value specified by the techinical standards.

For loss-type indexes such as $A7$, the formula is as follows:

$$A = \max(b) \cdot (1+n) \tag{2}$$

$max(b)$ represents the maximum value of a certain index in the route scheme.

For interval-type indexes such as $A8$, the formula is as follows:

$$A = \max(b) + \frac{1}{n} \cdot \sum_{i=1}^{n} ni \tag{3}$$

$max(b)$ represents the maximum value of a certain indexe in the route scheme. ni represents the specific value of the index corresponding to the i-th poor alignment or special section.

The above describes the principles for determining indexes considering the overall impact of multiple poor alignments or special sections within a route scheme. For other single indexes, it can be obtained directly or indirectly from the design drawings.

Weight of evaluation indexes

In the assigning weights to the above evaluation index, the influence of subjective factors cannot be completely avoided, but the relationship between various indexes should be fully considered. Therefore, the EWM is adopted to minimize the subjective tendency of designers. Entropy is a physical quantity that characterizes the disorderly distribution of information and reflects the amount of information. Entropy weight, on the other hand, reflects the amount of useful information carried and transmitted by each index. The greater the useful information carried and transmitted, the higher its entropy weight [32]. The method and steps for calculating the weights of evaluation indexes through EWM are outlined below.

(1) Assuming that there are m route design schemes to be evaluated and n indexes in each scheme, a matrix R is established.

$$R' = (r'_{ij})_{m \times n} \tag{4}$$

(2) After the normalization process, the matrix R is obtained.

If an index is positive,

$$r_{ij} = \frac{r'_{ij} - \min\{r'_{ix}\}}{\max\{r'_{ix}\} - \min\{r'_{ix}\}} \tag{5}$$

If an index is negative,

$$r_{ij} = \frac{\max\{r'_{ix}\} - r'_{ij}}{\max\{r'_{ix}\} - \min\{r'_{ix}\}} \tag{6}$$

$$R = (r_{ij})_{m \times n} \tag{7}$$

(3) Calculate the weight of each index,

$$f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \tag{8}$$

Where f_{ij} denotes the element in row i-th column j-th.

(4) Determine the entropy of the index,

$$H_j = -k \sum_{i=1}^{m} f_{ij} \ln f_{ij}, k = \frac{1}{\ln m} \tag{9}$$

(5) Calculate the entropy weight of each index,

$$W_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{10}$$

(6) The index weight vector is $W = (w_1, \ , w_n)$, from which the weight matrix P is constructed.

$$P = \begin{pmatrix} w_{11} & 0 & \cdots & 0 \\ 0 & w_{22} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & w_{nn} \end{pmatrix} \tag{11}$$

Routed design scheme evaluation model

TOPSIS evaluation method is a multi-attribute decision analysis method suitable for evaluating multiple route design schemes until the optimal route scheme is found, allowing decision-makers to more accurately grasp the differences between various schemes [33]. This evaluation method can flexibly handle the types of evaluation indicators, and any outliers on the evaluation indicators will not affect the evaluation results. It can consider the interdependence between indicators. After determining the weights of evaluation indicators, the improved TOPSIS model is convenient for evaluating route design schemes.

(1) Initial judgment matrix.

There are M route design schemes, and which denote $M = (m_1, \ ,m_n)$, and each scheme has N evaluation indexes which denote $N = (n_1, \ ,n_n)$. Then the decision matrix A is denoted as

$$A= (a_{ij})_{m\times n} \tag{12}$$

(2) Positive management for indexes.

For loss-type indexes, $N_x = (a_{ix})$, the following formula is used for positive management.

$$\tilde{a}_{ix} = \max\{a_{ix}\} - a_{ix} \tag{13}$$

For interval-type indexes $N_y = (a_{iy})$, the positive management is performed using the following formula.

$$W = \max\{\mu - \min\{x_{iy}\}, \max\{x_{iy}\} - \nu\} \tag{14}$$

$$\tilde{a}_{iy} = \begin{cases} 1 - \dfrac{\mu - a_{iy}}{W} & , a_{iy} < \mu \\ 1 & , \mu < a_{iy} < \nu \\ 1 - \dfrac{a_{iy} - \nu}{W} & , a_{iy} > \nu \end{cases} \tag{15}$$

Where μ, ν represents the upper and lower limits of the interval.

For interval-type indexes $N_z = (a_{iz})$, the positive management is performed using the following equation.

$$M = \max\{|a_{iz} - a_{best}|\} \tag{16}$$

$$a_{iz} = 1 - \frac{|a_{iz} - a_{best}|}{M} \tag{17}$$

Where abest is the best value for the interval-type index.

(3) Standardization of the judgment matrix.

The normalized metrics are dimensionless to obtain the standard matrix X, with the following equation.

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^2}} \tag{18}$$

(4) Weighting of the standard matrix.

The weighting matrix Z is obtained by multiplying the standard matrix X with the weight matrix obtained in EWM by P.

$$Z = XP \tag{19}$$

(5) Calculation of the minimum and maximum ideal solutions.

Minimum ideal solution,

$$Z^- = (Z_1^-, Z_2^-, \ldots, Z_n^-) = (\min\{z_{i1}\}, \min\{z_{i2}\}, \ldots, \min\{z_{in}\}) \tag{20}$$

Maximum ideal solution,

$$Z^+ = (Z_1^+, Z_2^+, \ldots, Z_n^+) = (\max\{z_{i1}\}, \max\{z_{i2}\}, \ldots, \max\{z_{in}\}) \tag{21}$$

(6) Calculation the distance from each scheme to the minimum and maximum ideal solution.

Distance from the minimum ideal solution,

$$D_i^- = \sqrt{\sum_{j=1}^{n} (Z^- - Z_{ij})^2} \tag{22}$$

Distance from the maximum ideal solution,

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (Z^+ - Z_{ij})^2} \tag{23}$$

(7) Calculating the relative proximity values of each solution to the ideal solution.

$$C_i = \sqrt{\frac{D_i^-}{D_i^- + D_i^+}} \tag{24}$$

The route design schemes are ranked based on the size of their relative proximity values. The larger the value, the closer the route design scheme is to the ideal solution, resulting in a higher ranking. This model enables the determination of the priority ranking for each route design scheme for mountainous motorway.

FAHP method

In design work, designers often use the Fuzzy Analytic Hierarchy Process to select route design schemes, which is a common method and will not be repeated here for its calculation process. The FAHP method relies heavily on the subjective experience of experts, and the calculated results sometimes make it difficult for decision-makers to make up their minds. The purpose of listing the FAHP method here is to first calculate a preferred route scheme, and then use the EWM-TOPSIS method, forming a comparison between the two calculation methods.

CASE STUDY

Overview of construction of motorways in mountainous areas

The D-F-W Motorway, situated in the mountainous and hilly terrain of Chongqing, China, is currently in design process. The motorway connects to already established motorways at its starting and ending points. The project's technical specifications are extensive, with the Mingyue Mountainous Tunnel section serving as a two-way six-lane road, boasting a width of subgrade 33.5m, while the remaining sections are two-way four-lane roads with a width of subgrade 26m. The design speed for the section between the starting point and Yanjiang Motorway is set at 100km/h, while the rest is designed for 80km/h. The total length of the route is about 160km.

Proposal of route design schemes

In the preliminary design stage, when the mountainous motorway passes through Jilong Town, the designer studied and proposed five route plans, named as the Feasibility route, K, C11, C12, and C13. The project owner must choose one route plan from them as the basis for the construction drawing design, and each route design plan is shown in Figure 2.

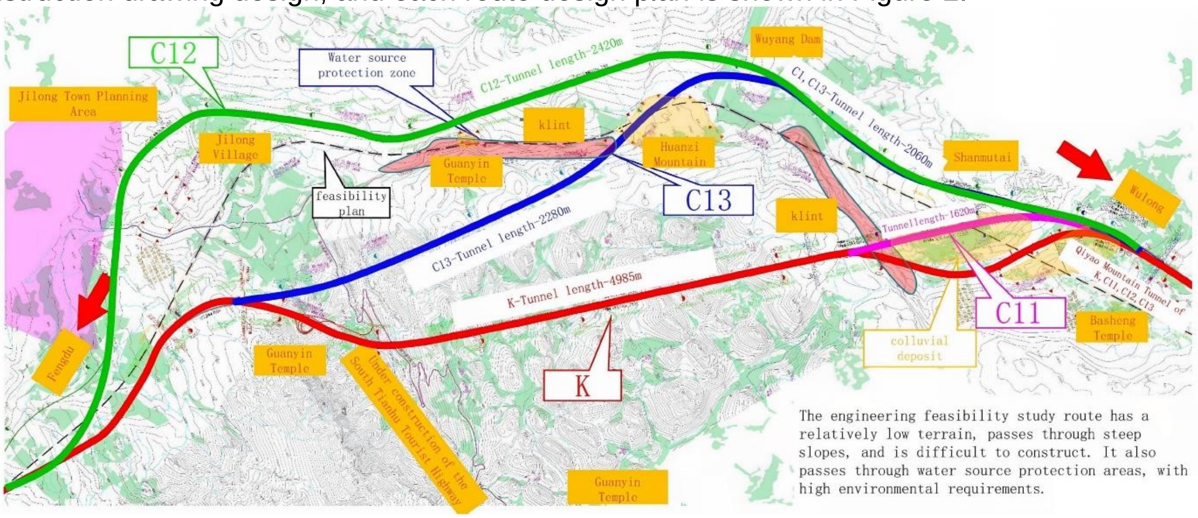

Fig. 2 – Plan of each line scheme

In Figure 2, the feasible route is located in a valley, with an overall low elevation. After passing the Guanyin Temple section, it passes through as an embankment bridge, with a steep slope and many control factors, leading to significant implementation difficulties. Additionally, there will be an extra-long tunnel with a total length of 7,600 meters, which will cause significant environmental disturbance to the first-level water source protection area. Therefore, during the on-site survey stage of the design work, the scheme was found to be not feasible. Next, it is necessary to study four route design schemes. This section of the motorway cannot avoid passing through unfavorable geological sections such as landslide deposits. After detailed work by the designer, the evaluation indexes of the four route design schemes are shown in Table 2.

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Tab. 2 - Value of indexes for each design scheme

Primary indexes	Secondary Indexes	K	C11	C12	C13
Alignment	A1	2050	2050	2520	2663
	A2	104	112	90	94
	A3	354	340	286	326
	A4	12000	12000	13000	12500
	A5	7000	7000	5500	6000
	A6	266	331	348	331
	A7	2.5	2.5	3.51	2.98
	A8	3.62	3.62	4.38	4.17
Cost	C1	17.985	18.881	20.387	20.135
	C2	192.289	176.715	242.431	209.004
	C3	10.6	15.9	7.5	9.1
	C4	20.6	16.1	23.4	25.9
	C5	4985	4985	2420	2280
	C6	4.3	4.5	5.8	6.1
Environment	E1	54.7	82.2	32.3	33.6
	E2	11.9	6.7	19.6	22.8
	E3	9.7	1.3	2.1	2.8

Based on the index value, a radar chart can be presented to more intuitively reflect the differences among the route schemes, as shown in Figure 3. Each route scheme has its own advantages and disadvantages. It is difficult to select excellent route design schemes. Here, the model presented in this article is used to select the optimal route scheme.

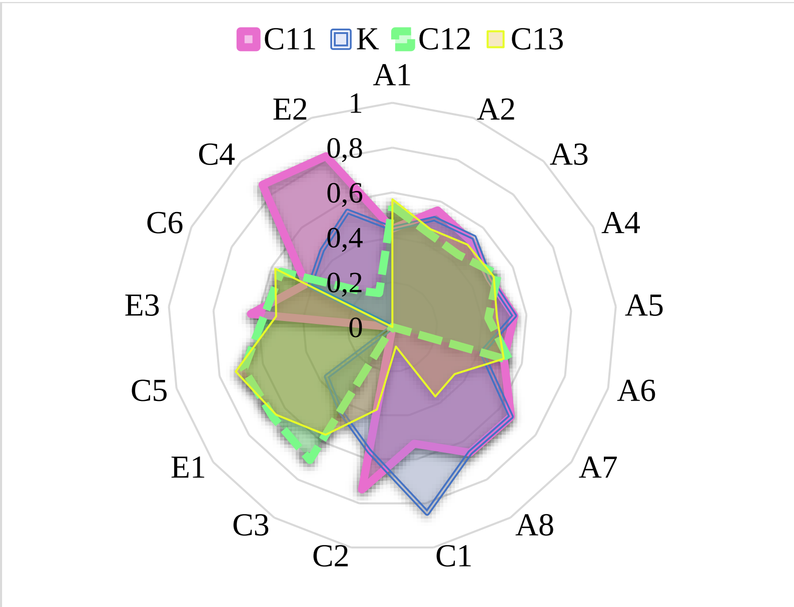

Fig. 3 – Radar chart of evaluation indexes

RESULTS

Evaluation result using FAHP method

The designer uses the Fuzzy Analytic Hierarchy Process to select the route design scheme, and the scoring results are shown in Tables 3-6. There are 20 experts recruited, all of whom are senior engineers with a working experience of no less than 20 years. Among them, 5 are in the alignment major, 5 are in the cost major, 5 are in the environmental major, and 5 are in the bridge and tunnel major. Based on the scoring results, the weights of the primary and secondary indexes are calculated as shown in Table 7. It can be seen that the cost has the highest weight in the primary indexes, followed by the linear indicator. The highest weight among the secondary indexes is the construction and installation cost, and the weight of each environmental index is greater than that of the alignment index. This indicates that cost indexes are significantly more valued by experts, while alignment indexes can make compromises when meeting the specification and standard.

Tab. 3 - Expert scoring of primary indexes

Primary index	Alignment	Cost	Environment
Alignment	0.5	0.3	0.65
Cost	0.7	0.5	0.85
Environment	0.35	0.15	0.5

Tab. 4 - Expert scoring of alignment indexes

Alignment indexes	A1	A2	A3	A4	A5	A6	A7	A8
A1	0.5	0.7	0.75	0.55	0.6	0.7	0.4	0.45
A2	0.3	0.5	0.55	0.35	0.4	0.5	0.2	0.25
A3	0.25	0.45	0.5	0.3	0.35	0.45	0.15	0.2
A4	0.45	0.65	0.7	0.5	0.55	0.65	0.35	0.4
A5	0.4	0.6	0.65	0.45	0.5	0.6	0.3	0.35
A6	0.3	0.5	0.55	0.35	0.4	0.5	0.2	0.25
A7	0.6	0.8	0.85	0.65	0.7	0.8	0.5	0.55
A8	0.55	0.75	0.8	0.6	0.65	0.75	0.45	0.5

Tab. 5 - Expert scoring of cost indexes

Cost indexes	C1	C2	C3	C4	C5	C6
C1	0.5	0.75	0.7	0.55	0.65	0.7
C2	0.25	0.5	0.45	0.3	0.4	0.45
C3	0.3	0.55	0.5	0.35	0.45	0.5
C4	0.45	0.7	0.65	0.5	0.6	0.65
C5	0.35	0.6	0.55	0.4	0.5	0.55
C6	0.3	0.55	0.5	0.35	0.45	0.5

Tab. 6 - Expert scoring of environment indexes

Environment indexes	E1	E2	E3
E1	0.5	0.35	0.45
E2	0.65	0.5	0.6
E3	0.55	0.4	0.5

Tab. 7 - Weight of each index calculated by FAHP

Primary indexes	Weight	Secondary indexes	Weight
Alignment	32.08%	A1	4.44%
		A2	3.39%
		A3	3.13%
		A4	4.17%
		A5	3.91%
		A6	3.39%
		A7	4.96%
		A8	4.70%
Cost	47.08%	C1	9.45%
		C2	6.62%
		C3	7.19%
		C4	8.88%
		C5	7.75%
		C6	7.19%
Environment	20.83%	E1	5.90%
		E2	8.25%
		E3	6.68%

According to the weights in the FAHP method, the evaluation results of the four route design schemes are shown in Table 8. In the evaluation results, the C12 and C13 schemes were eliminated, while the scores of the K scheme and C11 scheme were relatively close. In order to obtain more accurate evaluation results, a combination of EWM-TOPSIS model will continue to be used for further research.

Tab. 8 - Evaluation results obtained by FAHP method

Scheme	K	C11	C12	C13
Score	0.46	0.49	0.36	0.39

Evaluation result using EWM-TOPSIS model

The weights of each index are calculated using the EWM as shown in Table 9. The cost index has the highest weight, accounting for 56.96% of the total weight. The weight of the environmental index is 26.31%, while the alignment index has the smallest proportion, accounting for 16.73%.

Tab. 9 - Weights of each index calculated by EWM

Primary indexes	Weight	Secondary indexes	Weight
Alignment	16.73%	A1	0.18%
		A2	0.09%
		A3	0.08%
		A4	0.01%
		A5	0.13%
		A6	0.12%
		A7	8.12%
		A8	7.99%
Cost	56.96%	C1	13.24%
		C2	8.06%
		C3	7.60%
		C4	10.50%
		C5	17.28%
		C6	0.29%
Environment	26.31%	E1	7.97%
		E2	11.09%
		E3	7.25%

In the EWM-TOPSIS model, the proximity of each route scheme obtained using the weights of indexes calculated is shown in Table 10. The results show that the proximity value of the C11-scheme is the highest, at 0.3812. The proximity value of the K-scheme is 0.2757. The values of C12 and C13 schemes are 0.2143 and 0.2288, respectively, indicating that even if the tunnel length decreases, it is still not enough to offset the contribution of other factors, and the proximity values of these two schemes differ significantly from that of the C11 and K schemes. This also demonstrates that the results obtained using the EWM-TOPSIS model proposed in this paper are consistent with the expert experience.

Tab. 10 - Relative proximity values for each scheme by EWM-TOPSIS

K	C11	C12	C13
0.2757	0.3812	0.2143	0.2288

CONCLUSION

In response to the problem of difficult selection of route schemes for mountainous motorways, it selected 17 evaluation indexers that refer to alignment, cost, and environmental characteristics, and proposed a comprehensive optimization EWM-TOPSIS model. This model was applied in a mountainous motorway project in Chongqing, China, and more intuitively determined the route design scheme than the FAHP method commonly used by designers, verifying the rationality of the model. Due to the difficulty in obtaining some data in the case study, such as the construction period and the interference of the project to surrounding residents, the evaluation index system constructed in this article needs to be improved in subsequent research. The use of EWM can quantitatively calculate the weight of indexes, which can reflect the objectivity of the method, but it cannot completely eliminate subjective bias factors, especially in the construction of mountainous motorways. The opinions of experts who have worked for many years are still important for design work.

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