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Evaluation Model of Line Schemes in Complex Geological Area Based on Virtual Geographic Environments

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Abstract

When design lines in complex topography are a such as mountain areas, the selection of route schemes are usually restricted by the geological conditions because of complex terrain. According to the characters of line-selection design in complex topography areas of mountain areas, from the perspective of geological line selection, built the evaluation model of route schemes in complex geological area using the analytic hierarchy process and fuzzy optimization algorithm to solve the comprehensive evaluation problem having multilevel indices of line- selection multi-scheme from bottom to top and realized selection and decision of line schemes based on virtual geographic environments. Examples show that the established evaluation model reduced decision makers subjective influence on the results, made human-computer interaction content reduce to a minimum, and improved the accuracy and reliability of the decision.

Keywords: *railway route, complex topography, evaluation model of schemes, virtual geographic environments, fuzzy mathematics*

1. Introduction

Scheme comparison and selection of line-selection design is a complex problem of multi-objective decision. The factors affecting scheme comparison and selection are very complicated. It is involved in many aspects of technology, economy, environment, *etc.* The factors include both quantitative index and qualitative description and various factors are all linked. Many researchers were widely studied on the aspect of multi scheme evaluation in railway line-selection and many results have been achieved. Literature 1 synthesized the characteristics of several kinds of multi-objective decision model and built a multi-scheme and multi-objective grey correlation degree decision model considering the preference information of schemes. The Model has been successfully used to Intelligent Railway Line CAD system. Literature 2 researched multi-objective decision analysis of passenger dedicated railway lines' trend. Literature 3 researched the method and model of multi objective decision-making of railway schemes based on grey and fuzzy set theory. Literature 4 built a fuzzy optimization model of comprehensive optimal scheme design of railway line decision system using fuzzy set theory of multi objective decision-making. The researches above have a common feature, that is, taking many factors affecting railway scheme selection(such as social benefits, the ability of applicability, line capacity, operation indices, technology rationality, *etc.*,) into account to be involved in line scheme selection decision and want to synthesize these factors and realize route scheme selection. Besides, some researchers studied influence of route scheme focusing on one aspect of these factors. Literature 5 applied environmental factors

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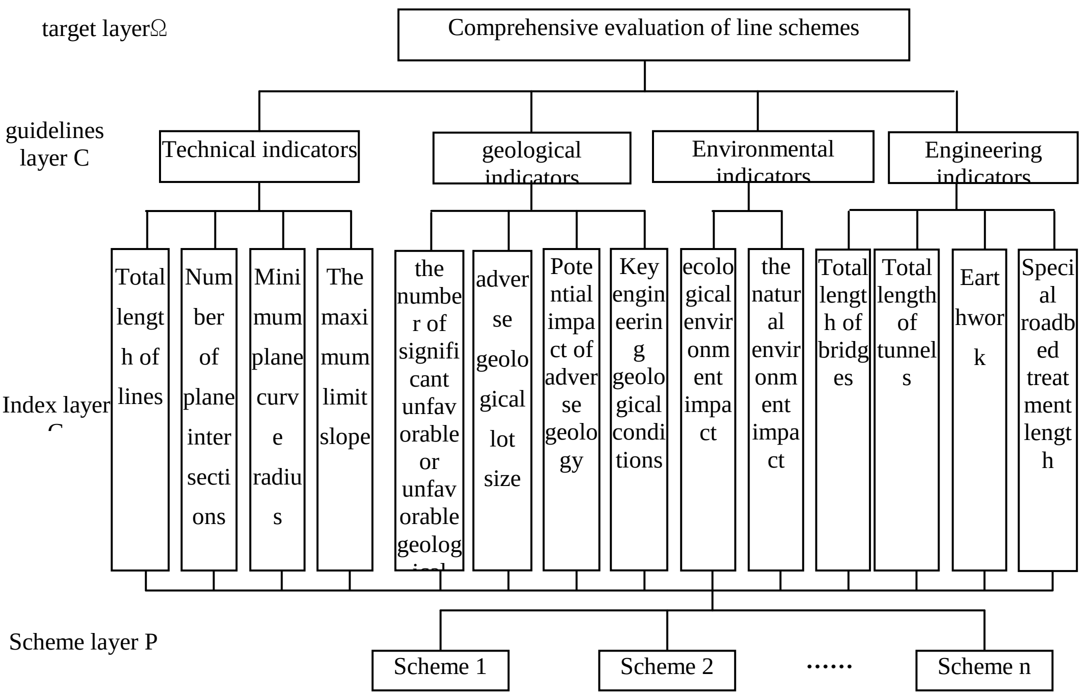
to selecting railway route schemes from environmental impact content of railway construction projects and using multi-objective fuzzy optimization model, and focused on the impact on the environment of the railway line.

In line-selection design of complex topography area including mountain area, many special geology, such as landslide, debris flow, fracture, may be encountered because of complex terrain. It plays a vital and even decisive role for geological conditions along the railway engineering in evaluating line design schemes and determining the level of the cost. Geological conditions along the route should be fully studied in line scheme comparison, bypassing complex and serious adverse geological sections, and selection of route schemes are usually restricted by the geological conditions. The paper learns from the existing decision theory and mathematical model of line schemes selection, considers scheme selection as the fuzzy selection problem of multi-objective decision making system using fuzzy set theory of multi-objective decision making in Literature 6. According to the characters of line-selection design in complex topography areas of mountain areas, from the perspective of geological line selection, build the evaluation model of route schemes in complex geological area. And focus on line multi-scheme selection decision model in virtual geographic environments base on remote sensing geological line selection. It realizes comprehensive selection of line schemes from geological perspective, based on Regional remote sensing interpretation partition of engineering geological condition and adverse geological phenomenon distribution and mainly according to basic engineering geological conditions and adverse geological phenomena of each line.

2. Hierarchical Structure of the Evaluation Model

More professional of line-selection design and heterogeneous system of domain knowledge determines hierarchical structure from the detail to the overall of comprehensive evaluation of multiple schemes. According to the evaluation indexes of schemes and the relationship between them and combined with the principle of line selection, makes comprehensive evaluation of schemes layered, builds the hierarchical structure of the evaluation model and constructs multi-level analysis model of comprehensive evaluation of multiple schemes, including target layer, index layer and guidelines layer, as is shown in Figure 1.



3. Indexes Analysis and Property Values Quantification of the Evaluation Model

3.1. Indexes Analysis

Technical indicators (total length of the line, the number of plane intersections, minimum plane curve radius and the maximum limit slope), engineering indicators (the total length of the bridge, the total length of the tunnel, earthwork, *etc.*,) and geological indicators (the number of significant unfavorable or unfavorable geological groups passed through, adverse geological lot size) can be obtained directly from the results of engineering design.

In complex topography areas including mountain areas, the more the plane intersections are, the more circuitous the line is and the more the unfavorable geology areas which lines is passing through and bypassing. The smaller the least plane curve radius, the worse the geological conditions of line areas may be. Therefore, to some extent, the number of plane intersection and least plane curve radius of technical indicators also reflects the engineering geology of line schemes.

The number of significant unfavorable or unfavorable geological groups passed through by lines, undesirable geological lot size and the potential impact of unfavorable geology (unfavorable geological number or area which the line is not passing through but in the buffer zone of lines) are calculated by statistical calculations according to engineering design results and can be reflected by the weighted sum of unfavorable geological area passed through by lines and the corresponding risk coefficients:

$$A_G = \sum_{k=1}^{r} \gamma_{GK} A_{GK} \tag{1}$$

In this formula, γ_{GK} is risk coefficient of the unfavorable geological region k and A_{GK} is the unfavorable geological area.

Key engineering geological conditions is geological conditions of key projects such as long tunnels and super bridges. According to the location of key projects, geological conditions in the region, including the number and area of unfavorable geology passed through by lines, was added up and analyzed from remote sensing geological database. According to the geological knowledge base, add up and analyze that whether or not line selection of the sections passing unfavorable geological area of key projects follows the geological line-selection requirements get key engineering geological conditions by analyzing them.

Environmental indicators mainly include the natural environment impact and ecological environment impact. Both of them are qualitative indicators and can apply ten point system or centesimal system to quantify them. The smaller the points, the better the situation. The natural environment impact refers that after constructing railway natural environment may be damaged and causes new geological disasters. Ecological environment impact refers that when environment sensitive area, such as nature reserves, source water protection areas and scenic area, are passed through by railway line, the idea of environmental route selection should be carried out. Railway lines should be away from the environmental sensitive area as soon as possible and environmental protection and conservation of water and soil should be strengthened in order to reduce adverse impact of engineering projects on the environment.

In complex topography areas such as mountain areas, the greater the values of the total length of tunnels, bridges and treated special roadbed, to some extent, the worse engineering geological conditions of the line scheme.

From analysis of indicators above, in the required indicators of scheme evaluation, only the environmental indicator belongs to the qualitative indicators and other are quantitative indicators which values can be proposed according to the design scheme information directly. For individual qualitative factors, fuzzy quantization is carried out by the decision makers by means of human computer interaction. This idea not only greatly reduces the subjective influence of decision makers on the selection results, but also makes interaction content of comprehensive evaluation subsystem reduce to a minimum degree.

3.2. Property Values Quantification of the Evaluation Model

In the indicators above, two main types are involved, that is, benefit indicators and cost indicators. Benefit indicators refer to indicators which greater is better, such as least plane curve radius. Cost indicators refer to indicators which smaller is better, such as adverse geological lot size, the length of special roadbed treatment and the number of plane intersections.

Generally, different evaluation indicators always have different dimensions and dimensional units. In order to eliminate incommensurability caused by different dimensions and dimensional units, first, evaluation indicators should be standardized before making policy. Standard processing method should be determined according to evaluation indicator types [6].

①For benefit indicators,

$$r_{ij}=\frac{x_{ij}-\bigwedge_{j} x_{ij}}{\bigvee_{j} x_{ij}-\bigwedge_{j} x_{ij}} \qquad i=1,2,\ldots,n \tag{2}$$

Or

$$r_{ij}=\frac{x_{ij}}{\bigvee_{j} x_{ij}+\bigwedge_{j} x_{ij}} \qquad i=1,2,\ldots,n \tag{3}$$

In the formula above, $\underset{j}{\vee} x_{ij}$ and $\underset{j}{\wedge} x_{ij}$ refer to the maximum and minimum values indicator V_j.

Formula 3 is suitable for the situation that indicators change little. For example, there are 3 candidate schemes. Their least plane curve radiuses are 800m, 800m and 1000m, and the greater the better. Calculate their relative membership degree using Formula 3 and get the value 0.40, 0.40 and 0.50. Their objective membership degrees have little difference and are consistent with the actual situation that least plane curve radiuses of 3 schemes have little difference. If calculate their relative membership degree using Formula 2, get the value 0, 0, 1, and obviously are not consistent with the actual situation. Therefore, selecting suitable calculation formula should treat different situation of index feature x_{ij}.

② For cost indicators,

$$r_{ij} = \frac{\underset{j}{\vee} x_{ij} - x_{ij}}{\underset{j}{\vee} x_{ij} - \underset{j}{\wedge} x_{ij}} \qquad i = 1,2,\ldots,n \tag{4}$$

Or

$$r_{ij} = 1 - \frac{x_{ij}}{\underset{j}{\vee} x_{ij} + \underset{j}{\wedge} x_{ij}} \qquad i = 1,2,\ldots,n \tag{5}$$

Implications of $\underset{j}{\vee} x_{ij}$ and $\underset{j}{\wedge} x_{ij}$ are the same as the above.

Formula 5 is suitable for the situation that objective eigenvalues change little, because when $\underset{j}{\vee} x_{ij}$ and $\underset{j}{\wedge} x_{ij}$ have little difference, their target relative membership degrees calculated by Formula 5 also have little difference and the actual situation of target feature value changes can be reflected better. For example, there are 3 candidate schemes. Their areas covered are 500 mu (a unit of area, 1 mu =0.0667 hectares), 450mu and 400mu and the smaller the better. Calculate their relative membership degree using Formula 5 and get the value 0.44, 0.5 and 0.56. Their objective membership degrees have little difference and are consistent with the actual situation that areas of 3 schemes have little difference. If calculate their relative membership degree using Formula 4, get the value 0, 0.5, 1, and obviously are not consistent with the actual situation. Therefore, selecting suitable calculation formula should treat different situation of index feature x_{ij}.

4. Realization of Evaluation Model

Let $C = \{C_1, C_2, \ldots, C_m\}$ be the evaluation scheme set which has m candidates. Let $O = \{O_1, O_2, \ldots, O_q\}$ be the evaluation target set which consists of q factors. If some $O_i (i \in 1,2,\ldots,q)$ also consists of q_i sub-target, set evaluation target subset as $O_i = \{O_{i1}, O_{i1}, \ldots, O_{iq_i}\}$. Indicator set U consists of all evaluation indicators and divide U into n subsets U_i according to an evaluation indicators which cannot be divided. Then $U = \{U_1, U_2, \ldots, U_n\}$ and meets

$$\bigcup_{i=1}^{n} U_i = U, U_i \cap U_j = \phi \qquad i \neq j, i, j \in \{1,2,\ldots,n\} \tag{6}$$

(1)Construct judgment matrix

First, do the multiple comparisons on the relative importance of indicators in same layer, which is, do the multiple comparisons on importance of each element of this layer on some upper element, and obtains the ratio of relative weights w_i / w_j . Apply this ratio to constructing judgment matrix B , and B is an n order phalanx.

$$B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix}$$

In the formula, is the ratio of the importance degree of the criteria of Target i (w_i) and the importance degree of the criteria of Target j (w_j), and apply Analytic Hierarchy Process to assigning importance degrees. b_{ij} has reciprocity and consistency, $b_{ij} = 1/b_{ji}$.

(2)Solve the weight vector

Construct an optimization problem and solve the weight vector having minimum weight of error square sum [7].

$$\min z = \sum_{i=1}^{n}\sum_{j=1}^{n}(b_{ij}w_j - w_i)^2 \quad (7)$$

$$s.t.\sum^{i=n} w_i = 1 \qquad (w_i > 0, i = 1,2,...,n) \quad (8)$$

Solve above optimization problem and construct Lagrange function L .

$$L = \sum_{i=1}^{n}\sum_{j=1}^{n}(b_{ij}w_j - w_i)^2 + 2\lambda(\sum_{i=1}^{n} wi - 1) \quad (9)$$

In the formula, λ is the Lagrange multiplier. Solve partial derivative for some w_i , and make it be zero, that is,

$$\sum_{i=1}^{n}(b_{ik}w_k - w_i)b_{ik} - \sum_{j=1}^{n}(b_{kj}w_j - w_k)b_{ik} + \lambda = 0 \qquad (k = 1,2,...,n) \quad (10)$$

Obtain component w_i of weight vector using Formula 8 and 10 simultaneously.

(3)Construct scheme layer matrix

Specific annihilator index layer according to system hierarchical structure analysis model of Picture 1. Let $O = \{O_1, O_2, O_3, O_4\}$ be the evaluation target set of system. Let $U_i = \{u_{i1}, u_{i2},..., u_{in_i}\}$ be evaluation index set of O_i . The total index set $U = \{U_1, U_2, U_3, U_4\}$ consists of all assessment sub-indicators. And it meets $u_{mn} \cap u_{pq} = \phi, u_{mn}, u_{pq} \in U$ and $mn \neq pq$. Now suppose schemes set $C = \{C_1, C_1,..., C_m\}$ consists of m candidate schemes and i scheme vector $X_i = \{u_{11}^i, u_{12}^i,..., u_{1n_1}^i, u_{21}^i, u_{22}^i,..., u_{2n_2}^i, u_{31}^i, u_{32}^i,..., u_{3n_3}^i, u_{41}^i, u_{42}^i,..., u_{4n4}^i\}$ consists of $n_1 + n_2 + n_3 + n_4$ sub-indicators. Take front n_1 components of each candidate scheme and constitute the technical evaluation data matrix $(R_1)_{m \times n_1}$. Take the components from $n_1 + 1$ to n_2 of each candidate and constitute the economical evaluation data matrix $(R_2)_{m \times n_2}$. Take the components from $n_2 + 1$ to n_3 of each candidate and constitute the environmental evaluation data matrix $(R_3)_{m \times n_3}$. Take the components from $n_3 + 1$ to n_4 of each candidate and constitute the environmental evaluation data matrix $(R_4)_{m \times n_4}$.

(4)Fuzzy processing of scheme layer matrixes

Now suppose a scheme layer matrix

$$R_i = \begin{bmatrix} u_{i1}^1 & u_{i2}^1 & \cdots & u_{in_i}^1 \\ u_{i1}^2 & u_{i2}^2 & \cdots & u_{in_i}^2 \\ \vdots & \vdots & \vdots & \vdots \\ u_{i1}^m & u_{i2}^m & \cdots & u_{in_i}^m \end{bmatrix} = (u_{ip}^q)_{m\times n_i} \qquad p = 1,2,\ldots,n_i \qquad q = 1,2,\ldots,m$$

In this formula, u_{ip}^q represents the eigenvalue of p-th sub-indicator of indicator O_i corresponding to scheme *q*. Generally, it includes qualitative and quantitative indicators eigenvalues. The target of selective preference is to find out the optimal design scheme according to eigenvalues matrix. Superiority and inferiority of schemes is a fuzzy concept, and there is no clear boundaries between them. The extension which fuzzy concepts is corresponding to is not an ordinary set, but a fuzzy set. Such a set is described by mapping of membership function, and it is defined as follows[8]: The set described by mapping

$$u_A : U \to [0,1]$$
$$u \to u_A(u)$$

Can be named as a fuzzy subset $\underset{\sim}{A}$ of U . Among this mapping, $u_A(u)(\in [0,1)$ is a appointed figure for any $u \in U$ and named as the membership degree of u on A . In this model, it can apply the following formula to calculating quantitative indicators of cost type.

$$u\underset{\sim}{R_i} = \begin{cases} 1 & u_{ip}^q < \min(u_{ip}^j) \\ \dfrac{\max(u_{ip}^q) - u_{ip}^q}{\max(u_{ip}^j) - \min(u_{ip}^j)} & \min(u_{ip}^j) \le u_{ip}^q < \max(u_{ip}^j) \qquad (j = 1,2,\ldots,m) \\ 0 & u_{ip}^q \ge \max(u_{ip}^j) \end{cases} \tag{11}$$

It can apply the following formula to calculating quantitative indicators of benefit type.

$$u_{R_i}(u_{ip}^q) = \begin{cases} 1 & u_{ip}^q \ge \max(u_{ip}^j) \\ \dfrac{u_{ip}^q - \max(u_{ip}^q)}{\max(u_{ip}^j) - \min(u_{ip}^j)} & \min(u_{ip}^j) < u_{ip}^q < \max(u_{ip}^j)\,(j = 1,2,\ldots,m) \\ 0 & u_{ip}^q \le \min(u_{ip}^j) \end{cases} \tag{12}$$

The qualitative indicators can be quantified by two element relative ratio ordering method[9]:

A pair number $[f_j(u_i), f_i(u_j)]$ indicates that in the comparison of sub-indicator U of Scheme i and Scheme j, if $f_j(u_i)$ is the degree that Scheme i is close to superior, $f_i(u_j)$ is the degree that Scheme j is close to superior.

Set

$$f_u(i/j) = \frac{f_j(u_i)}{\max(f_j(u_i), f_i(u_j))} \qquad i, j = 1,2,\ldots,m \tag{13}$$

Obviously,

$$f_u(i/j) = \begin{cases} f_j(u_i)/f_i(u_j) & , f_j(u_i) \le f_i(u_j) \\ 1 & f_j(u_i) > f_i(u_j) \end{cases} \tag{14}$$

A matrix consistent with $f_u(i/j)$ and in which $f_u(i/j)$ equals to 1 is named as Associated Matrix. Its form is as follows:

$$\begin{array}{c} \\ C_1 \\ C_2 \\ \ldots \\ C_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \end{array} \\ \begin{bmatrix} 1 & f_u(1/2) & \cdots & f_u(1/m) \\ f_u(2/1) & 1 & & f_u(2/m) \\ \vdots & \vdots & \vdots & \vdots \\ f_u(m/1) & f_u(m/2) & \cdots & 1 \end{bmatrix} \end{array}$$

In above matrix, take the minimum of each column and set minimum of j-th column as $f_u(j)$. $f_u(j)$ is membership degree of sub-indicator u of scheme j

(5)Solve optimal membership degree

Through the method above, eigenvalues matrix R_i can be transformed to membership fuzzy matrix $\underset{\sim}{R_i}$, $\underset{\sim}{R_i} = (\underset{\sim}{u_{ip}^q})_{m\times n_i}$. $\underset{\sim}{u_{ip}^q}$ indicates the membership degree that eigenvalue $\underset{\sim}{u_{ip}^q}$ is corresponding to, $\underset{\sim}{u_{ip}^q} \in (0,1)$. According to concept of fuzzy and relativity of optimization, let pros vector of R_i be $Y_i = (u_{i1}^Y, u_{i2}^Y, ..., u_{in_i}^Y)^T = (\underset{\sim}{u_{i1}^1} \vee \underset{\sim}{u_{i1}^2} \vee ... \vee \underset{\sim}{u_{i1}^m}, \underset{\sim}{u_{i2}^1} \vee \underset{\sim}{u_{i2}^2} \vee ... \vee \underset{\sim}{u_{i2}^m}, ..., \underset{\sim}{u_{in_i}^1} \vee \underset{\sim}{u_{in_i}^2} \vee ... \vee \underset{\sim}{{}_{in_i}^m})^T$, and let cons vector R_i of be $L_i = (u_{i1}^L, u_{i2}^L, ..., u_{in_i}^L)^T = (\underset{\sim}{u_{i1}^1} \wedge \underset{\sim}{u_{i1}^2} \wedge ... \wedge \underset{\sim}{u_{i1}^m}, \underset{\sim}{u_{i2}^1} \wedge \underset{\sim}{u_{i2}^2} \wedge ... \wedge \underset{\sim}{u_{i2}^m}, ..., \underset{\sim}{u_{in_i}^1} \wedge \underset{\sim}{u_{in_i}^2} \wedge ... \wedge \underset{\sim}{{}_{in_i}^m})^T$.

In the formula, $\wedge$ indicates taking the minimum, and $\vee$ indicates taking the maximum.

Set the weight vector of n_i indicators of indicator I calculated by the method in "Solve the weight vector" as

$$w^i = (w_1^i, w_2^i, ..., w_{n_i}^i)^T$$

Then the distance between scheme q and pros vector is

$$D_q(\underset{\sim}{R_i}, Y_i) = [\sum_{p=1}^{n_i} (w_p^i \mid \underset{\sim}{u_{ip}^q} - u_{ip}^Y \mid)^k]^{1/k} \tag{15}$$

The distance between scheme q and cons vector is

$$D_q(\underset{\sim}{R_i}, L_i) = [\sum_{p=1}^{n_i} (w_p^i \mid \underset{\sim}{u_{ip}^q} - u_{ip}^L \mid)^k]^{1/k} \tag{16}$$

In the formula, *k* is the generalized distance parameter. When $k = 1$, it is named as hamming distance, and when $k = 2$, named as Euclidean distance.

$$D'_q(\underset{\sim}{R_i}, Y_i) = u_i^q D_q(\underset{\sim}{R_i}, Y_i) \tag{17}$$

$$D'_q(\underset{\sim}{R_i}, L_i) = (1 - u_i^q) D_q(\underset{\sim}{R_i}, L_i) \tag{18}$$

(17) and (18) is respectively named as right superior degree and right inferior degree of scheme *q*. u_i^q and $1-u_i^q$ is respectively membership degree subordinate to pros vector Y_i and cons vector L_i. u_i^q is optimal membership degree of scheme *q* for indicator O_i . Literature 8 built the following evaluation criteria: the square sum of right superior degree and right inferior degree of scheme q is minimal, that is, the objective function is

$$\min F(u_i^q) = [D'_q(R_i, Y_i)]^2 + [D'_q(R_i, L_i)]^2 \tag{19}$$

Make Formula 15, Formula 16, Formula 17 and Formula 18 into Formula 19 and get:

$$\min F(u_i^q)=\left\{u_i^q[\sum_{p=1}^{n_i}(w_p^i\,|\underset{\sim}{u_{ip}^q}-u_{ip}^Y|)^k]^{1/k}\right\}^2+\left\{(1-u_i^q)[\sum_{p=1}^{n_i}(w_p^i\,|\underset{\sim}{u_{ip}^q}-u_{ip}^L|)^k]^{1/k}\right\}^2 \quad (20)$$

Solve $dF(u_i^q)/d(u_i^q)=0$.

$$u_i^q=\frac{1}{1+\left[\dfrac{\sum_{p=1}^{n_i}(w_p^i\,|\underset{\sim}{u_{ip}^q}-u_{ip}^Y|)^k}{\sum_{p=1}^{n_i}(w_p^i\,|\underset{\sim}{u_{ip}^q}-u_{ip}^L|)^k}\right]^{1/k}} \quad (21)$$

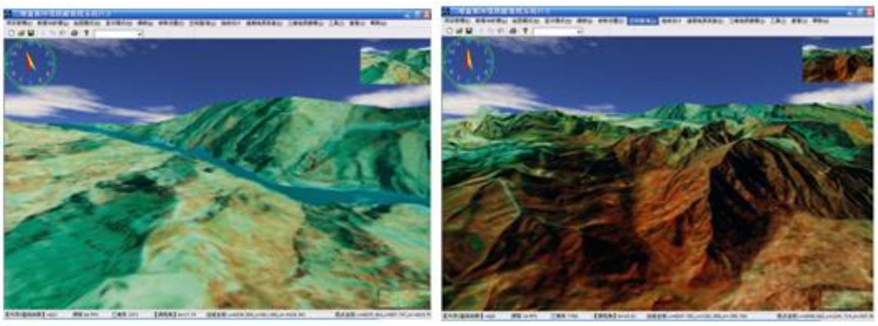
In the formula, u_i^q is scheme optimal membership vector, and $q=1,2,...,m$, $i=1,2,3$. Formula 21 is named as optimization model. If sub-indicator u_{ij} can be divided into g more detailed indicators, set $u_{ij}=v_1,v_2,...,v_g$, calculate optimal membership degree of each scheme for sub-indicator u_{ij} according to the above method and make up the j-th column vector of membership fuzzy matrix $\underset{\sim}{R_i}$.

Set $u_i=(u_i^1,u_i^2,...,u_i^m)^T$ as optimal membership vector of each scheme for indicator O_i , and the membership fuzzy matrix of target layer $\underset{\sim}{R}$ is made up of optimal membership vectors of all indicators. Find out membership degree of each scheme on the total target and sort them by size. Then ranking of pros and cons of each scheme is the same as membership degree of each scheme's.

5. Examples Checking

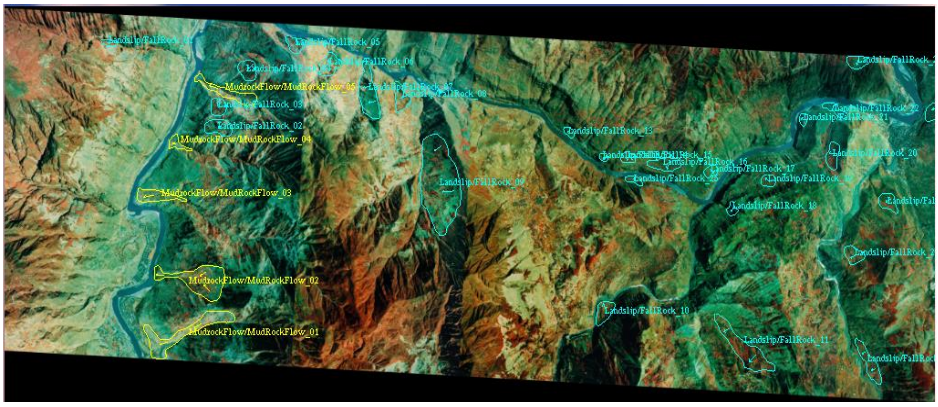
5.1. Terrain Profiles

Remote Sensing Data used in the paper is certain section of Chengdu-Kunming Railway. Its location refers to mountain gorge of Southwest of Sichuan. The image is color aerial remote sensing image which terrain length is about 200km and width is about 10km. 3D location and geographical environment of experimentation area is constructed by DEM and remote sensing orthorectification images and shown as Figure 2.



[illegible]

Remote sensing geology interpretation map is shown as Figure 3. Interpretation results are shown in Table1.



[illegible]

[illegible]

Number	Types	Quantity	Description
1	Rock flow	5	Located in gorge section of the main channel, refers to middle or small gully debris flow. The terrain is steep, valley is short and narrow, longitudinal slope is steep, consistent with slope of the hillside. There is no obvious circulation area , and has a great influence on line.
2	Collapse / Falling Rocks	17	The river is strongly incised and valleys is mostly V-shaped. Valley slope height is generally greater than 200 m and the slope is generally between 60 ° ~ 80 °. Parts are cliffs, and has an important influence on line.
3	landslide	2	Refer to small landslides and has little influence on line.

5.2. Line-selection Design Experiment

(1)In the perspective projection model, observe and analyze 3D terrain and geological conditions of the whole experimentation area and then determine the possible channels of the line. In the case of experimentation area, this area belongs to the Dadu River Valley Area and strait differences are large. The most likely paths of lines are along the river and the river and the hills are at elbow. Line selection area belongs to the valley. The main adverse geologies of both sides of valley (Geological Disasters) are rock fall and debris flow according to remote sensing interpretation results.

(2)In the orthographic projection mode, select control points and the design intersections of line scheme and decide line trends of each scheme.

(3)According to geological conditions, modify the parts of each line scheme and ultimately determine the final direction and position of the line schemes. According to topographic and geologic conditions of gorge area, the main ways to avoid geological disasters are constructing bridges across the river or shifting lines to the inside and constructing tunnels.

According to Ground coordinates selected method in three dimensional environment, three line schemes are built. As is shown in Figure 4, Scheme 1 is the green line, Scheme 2 is the red line and Scheme 3 is the blue line.

Due to restrictions of aerial maps, each scheme uses straightened tunnel scheme at the top of the left.

[illegible]

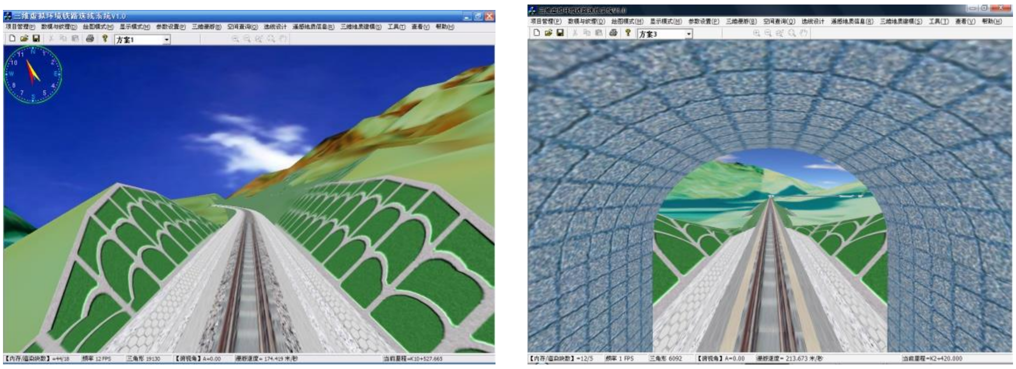
The main indicators of the designed results of each scheme are shown in Table 2.

[illegible]

Indicator name	Scheme 1	Scheme 2	Scheme 3
Total length of lines(km)	17.520	17.713	17.280
Number of plane intersections	12	16	10
Minimum plane curve radius(m)	800	800	600
The maximum limit slope (‰)	12	12	15
Number of adverse geology	4	5	8
Number of adverse geology groups passed through	1	0	0
Total length of bridges	1	0	0
Total length of tunnels	2	2	3
Total length of special roadbeds	1156.899	1316.194	4007.88
Total length of adverse geology area passed through	754.994	779.654	898.122
Potential impact of adverse geology	More serious impact	No impact	General impact
Key engineering geological conditions	The 2nd tunnel goes through the collapse zone	The 3rd tunnel goes through the collapse zone	Neither bridges nor tunnels is passing through adverse geological areas.
Earthwork (10^4 m^3)	W: 91.40 T: 212.77	W: 72.39 T: 107.98	W: 114.18 T: 88.74

We apply multi-objective decision fuzzy comprehensive optimization model to evaluating and analyzing the line schemes and find out optimal membership degree of each scheme u ={0.285133 , 0.399546 , 0.315320}. Sort u by size of membership degree and the result is $u_2 > u_3 > u_1$. So Scheme 2 is most optimal and recommended.

3D model renderings of Scheme 2 are shown as Figure 5.



[illegible]

6. Conclusions

According to the characters of line-selection design in complex topography areas of mountain areas, from the perspective of geological line selection, evaluation model of line schemes of complex geological area based on virtual geographic environments is built. The paper established hierarchy of comprehensive evaluation of line-selection schemes combined with the actual situation of the line-selection design and solved the comprehensive evaluation problem having multilevel indices of line- selection multi-scheme from bottom to top using the analytic hierarchy process and fuzzy optimization algorithm. This hierarchical algorithm makes comprehensive evaluation problem of line-selection schemes simple and clear and let the decision of each layer be a small sample decision problem. Most of decision indicators for evaluating schemes can be proposed according to the design scheme information directly, and only for individual qualitative factors, fuzzy quantization is carried out by the decision makers by means of human-computer interaction. It made human-computer interaction content reduce to a minimum, and improved the accuracy and reliability of the decision. Finally, application examples and 3D design renderings of the optimal scheme were given.

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