Study on Optimal Evaluation Model of Comprehensive Treatment Scheme for Loess Landslide

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Abstract. The quality of the landslide control plan not only affects the project cost, but also affects the success or failure of the entire landslide control. This paper analyzes the main control measures of loess landslide, studies the main factors affecting the decision-making of loess landslide comprehensive treatment plan, proposes the optimization weight calculation method of loess landslide treatment plan evaluation index, and establishes the optimal model of loess landslide treatment plan. The model is used to optimize the comprehensive treatment plan of a loess landslide, the resulting treatment plan is reasonable.

1. Introduction

In actual engineering, there are often several landslide control schemes to choose from at the same time. In this case, they must be optimized and choose a satisfactory solution. After the preferred treatment plan is determined, the sub-item design and construction are carried out according to the actual project conditions. From the current research status at home and abroad, most of the optimization of landslide control programs are based on expert experience and lack quantitative evaluation. In this paper, the optimization weighting method is used to calculate the weight of the evaluation index of the loess landslide treatment plan, and the optimal model of the comprehensive treatment plan for loess landslide is established.

2. Optimal index system for comprehensive treatment plan of loess landslide

Although there are many indicators for influencing factors in the decision-making of loess landslide control schemes, there are three types of generally accepted indicators, including economic indicators, technical indicators and environmental impact indicators. According to the system engineering and system hierarchy principle, through the analysis and classification of a number of practical projects, the hierarchical hierarchical structure of the comprehensive evaluation index for the loess landslide treatment plan is shown in Table 1.

3. Fuzzy Optimal model for comprehensive treatment plan of loess landslide

3.1. Establishment of evaluation matrix

There are a total of m indicators for the optimization of the loess landslide comprehensive treatment plan, and there are n treatment plans. The matrix of each indicator is quantized and the matrix is $x=(x_{ij})_{n\times m}(i=1,2,\cdots,n;j=1,2,\cdots,m)$

Standardize raw data using Equation 1：

$$x_{ij}' = (x_{ij} - \overline{x}_j) / s_j \tag{1}$$

In the formula: $\overline{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}; s_j \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{ij} - \overline{x}_j)^2}, (i = 1, 2, \cdots, n; j = 1, 2, \cdots, m)$

Table 1. Landslide plan optimization evaluation index

Target layer	Criteria layer	Indicator layer
Preferred indicator system	Economic Indicators	Total investment Annual maintenance fee Monitoring fee
	Technical goal	Construction technology reliability Governance effect Construction difficulty Construction period Project validity period Risk
	Environmental impact indicator	Construction impact on the environment Engineering impact on the environment The possibility of secondary disasters during construction

3.2. Determination of weight

In the optimization problem of loess landslide treatment plan, the determination of the weight of the evaluation index is a very important content. In order to avoid the defects of the above single application, this paper combines the advantages of the two methods of calculating the subjective weight calculation method and the objective weight calculation method, and the least square method of the application right to calculate the subjective weight of the evaluation index of the loess landslide treatment plan, and apply the entropy method to calculate the evaluation index of the treatment plan. Objective weight. Because the starting point of the subjective and objective weight analysis method is different, in order to eliminate the difference between the two, the distance function is introduced to optimize the weighting of the evaluation index of the loess landslide treatment plan [1-4].

3.2.1. The least square method of weights calculates subjective weights

The least square method of weight is a relatively new sorting method in the analytic hierarchy process. The least square method of weight overcomes the deficiencies in the traditional analytic hierarchy process, avoids the "consistency test" and greatly simplifies the calculation process. The basic idea of the method is to use the minimization solution $w_\theta = (w_1, w_2, ...w_m)^T$ of the function $J = \sum_{i=1}^{m}\sum_{j=1}^{m}\left(w_i - a_{ij}w_j\right)^2$ as the order weight vector for the judgment matrix (non-uniform matrix) $A = (a_{ij})_{m\times m}$ under the constraint condition.

3.2.2. Entropy method to calculate objective weight

There are n evaluation objects (landslide management plan) and m evaluation indicators (influencing factors), and each indicator value of each plan constitutes a judgment matrix $A' = (a'_{ij})_{m\times n}$ （i=1, 2, …, m； j = 1, 2, …, n）.

$$a_{ij} = \frac{a_{ij}' - \min_j a_{ij}'}{\max_j a_{ij}' - \min_j a_{ij}'} \tag{2}$$

Based on the information entropy theory [5], the entropy values of different evaluation indicators are calculated as follows:

$$H_i = -k\sum_{j=1}^{n} f_{ij} \ln f_{ij} \qquad \text{i=1, 2, …, m} \tag{3}$$

According to the obtained entropy value, the weight value of each evaluation index is determined, and the expression is as follows:

$$\omega_i = \frac{1-H_i}{m-\sum_{i=1}^{m} H_i} \tag{4}$$

3.2.3. Optimization of weighting rules

This paper introduces the distance function and optimizes the weighting of the primary and objective weights to obtain the final evaluation factor weight.

Based on the concept of distance function, the subjective weight of the hypothesis weight is ω_i', the objective weight obtained by the entropy method is ω_i'', and the distance function between the two is $d(\omega_i', \omega_i'')$. The calculation expression is as follows:

$$d(\omega_i', \omega_i'') = \left[\frac{1}{2}\sum_{i=1}^{n}(\omega_i' - \omega_i'')^2\right]^{\frac{1}{2}} \tag{5}$$

The subjective and objective combination weights are ω, and the calculation method is linear weighting of the main and objective weight values. The calculation method is as follows:

$$\omega = \alpha\omega_i' + \beta\omega_i'' \tag{6}$$

In the above formula: α and β are the distribution coefficients corresponding to the weights of two different calculation methods.

3.3. Comprehensive evaluation method

Using the following formula, the multi-index comprehensive evaluation values of various treatment schemes for loess landslides are obtained:

$$y_i = \sum_{j=1}^{m} \omega x_{ij}, i = 1, 2, \cdots, m \tag{7}$$

4. Roject example (Optimization of comprehensive treatment plan for a loess landslide)

4.1. Establishment of evaluation matrix

A loess landslide is a traction landslide. There is not much deformation at the back of the landslide body. To ensure the stability of the landslide as a whole, it is necessary to ensure the stability of the landslide at the front stage. Therefore, the focus of comprehensive treatment is the front of landslide. At the same time, in order to prevent the erosion of the landslide slope by the Chenligou debris flow at the leading edge of the landslide to reduce the stability of the landslide, it is necessary to treat the front edge debris flow ditch.

According to the geological conditions and main controlling factors of a loess landslide, four feasible comprehensive treatment schemes are designed: ordinary anti-slide pile + channel debris flow control project + drainage engineering (referred to as design scheme M1), backfill counter pressure + channel debris flow control project + Drainage project (plan M2), anchor cable anti-slide pile + channel debris flow control project + drainage project (plan M3) and anchor cable frame + channel debris flow control project + drainage project (plan M4).

The comprehensive treatment of a loess landslide should not only ensure the reliability of the treatment effect, but also comprehensively consider the economic and environmental impacts. This paper selects the total investment (k1), the treatment effect (k2), the construction impact on the environment (k3), and the technology. Feasibility (k4), construction difficulty (k5) and construction period (k6) are the six evaluation indicators to optimize the four treatment options. The optimization

problem of a loess landslide comprehensive treatment plan is transformed into a plan optimization problem with 6 evaluation indicators and 4 evaluation objects.

Table 2 provides a comprehensive language evaluation of the objectives of each program by the expert group. The qualitative language can be quantified to define Pn=(P1, P2, P3, P4, P5) = (1,0. 8,0. 6,0. 4,0. 2) , where P1=fine, P2=good, P3=medium, P4= relatively poor, P5=poor.

Table 2. Comprehensive language evaluation of decision makers on each target

target	scheme					
	k1	k2	k3	k4	k5	k6
M1	relatively poor	medium	relatively poor	fine	fine	good
M2	fine	good	fine	fine	good	good
M3	good	fine	good	medium	medium	medium
M4	relatively poor	poor	relatively poor	good	medium	medium

According to Equation 1, the evaluation matrix of the six evaluation indicators of the four programs can be obtained:

$$x_{ij} = \begin{bmatrix} 0.4 & 0.8 & 0.6 & 1 & 1 & 0.8 \\ 1 & 1 & 0.8 & 1 & 0.8 & 0.8 \\ 0.8 & 1 & 1 & 0.6 & 0.6 & 0.6 \\ 0.4 & 1 & 0.2 & 0.8 & 0.6 & 0.6 \end{bmatrix}$$

4.2. Determine weight

The subjective weight coefficient vector ω_i' of the six indicators determined by the least squares method of weights is:

$$\omega_i' = (0.168, 0.327, 0.140, 0.131, 0.121, 0.104)$$

The objective weight coefficient vector A of the six indicators determined by the entropy method is:

$$\omega_i'' = (0.189, 0.213, 0.198, 0.155, 0.129, 0.111)$$

Introduce the distance function and find the distribution coefficient α=0.613, β=0.387

The weighting factor after optimizing the weighting is:

$$\omega = (0.179, 0.291, 0.159, 0.134, 0.123, 0.104)$$

4.3. Comprehensive management plan optimization

The comprehensive evaluation value of the four governance schemes obtained by using Equation 7 is:

$$y_i = (0.244, 0.289, 0.256, 0.211)$$

5.conclusion

The final comprehensive treatment plan comparison results are program 2 > program 3 > program 1 > program 4, that is, program 2 is the best governance program. According to the characteristics of a loess landslide, the erosion of the front edge by the debris flow ditch, the geographical location and the local economic conditions, the front edge backfilling back works + channel debris flow control project + drainage engineering is selected as a comprehensive treatment of a loess landslide. The preferred solution is reasonable.

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