Hydropower Plant Siting Based on 5G Risk Benefit Assessment

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Abstract. In this study, a comprehensive evaluation model based on TOPSIS planning and multi-objective planning for hydro power plant siting problem is proposed. First, several factors such as economic, environmental and social are identified. Through the study of the hydropower plant siting problem, these factors are quantified as evaluation indicators and input into TOPSIS to select a number of candidate plant sites. Then, risk assessment is performed using 5G technology. The risks as well as benefits of each selected finger point are obtained through a multi-objective planning algorithm to comprehensively evaluate the candidate sites and optimize the score of multi-objective sites to achieve the best site selection plan. The experimental results show that the proposed comprehensive evaluation model achieves good results in terms of accuracy and feasibility of the site selection scheme. In addition, the application of 5G technology for multi-source data collection can also improve the accuracy of the model, which provides strong support for the research and practice of the model.

Keywords: 5G Technology Assessments · Multi-objective planning · TOPSIS

1 Introduction

The hydropower plant siting problem refers to the selection of an optimal site for hydropower plant construction among several potential sites. It is a typical multi-criteria decision problem. Previous work has mainly evaluated the siting of hydropower plants through a single Topsis model [1] or single optimization model [2], and the risk assessment applied in the model is not objective enough, and this approach can lead to a lack of accuracy of the model. With the widespread application of emerging technologies such as 5G and artificial intelligence, the application of 5G technology has led to significant improvements in risk assessment, data processing, calculation and optimization of siting problems. In this paper, ten site selection points are formulated on the Yarlung Tsangpo River [3, 4], and firstly, a TOPSIS model is used for preliminary site selection, and the five highest rated sites are selected from the ten sites considering factors such as

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hydrological [5, 6] and geographical [7, 8] conditions. Finally, a multi-objective planning model is used to select the best site among the five points, and 5G technology is applied to evaluate the risks and benefits of each site. After substituting into the multi-objective planning model, the tenth site is selected as the optimal site, and its stability and accuracy are tested to be higher than that of a single TOPSIS model.

2 Related of Basic Concepts

In order for the reader to better understand the content of this paper, we first introduce some basic concepts about the factors involved in siting a hydropower plant:

(1) Hydro-meteorological conditions: Hydrological conditions [5, 6] refer to the water level, flow rate, water quality, etc., while meteorological conditions include precipitation, temperature, humidity, wind speed, etc. The uncertainty and variability of hydro-meteorological conditions have a direct impact on the safe operation and power output of hydropower plants.
(2) Topographic and geomorphological conditions: Topography and geomorphology [7, 8] affect hydrological and hydraulic conditions, such as the slope of the river and the shape of the riverbed. During the construction of a hydropower plant, topography and geomorphology also affect the layout and operation of the plant.
(3) Risk factors: including geological terrain risk, natural disaster risk, etc. The complexity of the geological terrain may make construction more difficult, and natural disasters may cause damage to the hydropower plant or prevent it from operating properly.
(4) Benefit factors: including economic benefits, social benefits, etc. Hydropower station construction can promote local economic development, increase employment opportunities and improve people's living standards. Secondly, hydropower station construction can provide convenient living services for local residents, such as providing stable power and irrigation water.
(5) Optimal site for hydropower plant: The most suitable site for hydropower plant [2] among all sites to be measured, taking into account Hydro-meteorological, Topographic and geomorphological, efficiency, risk factors, etc.

3 Modeling the Siting of TOPSIS Hydropower Plants

3.1 Introduction and Calculation Steps of TOPSIS Model

The TOPSIS method is a commonly used evaluation model that accurately reflects the differences between various evaluation schemes based on the information of the raw data. In this paper, we need to use it to obtain the highest scores of several schemes, and then use multi-objective programming to find the optimal scheme.

Firstly, for TOPSIS, we need to process the data by transforming them all into maximization indicator data, then normalize them, and finally obtain the standardized matrix Z after normalization.

$$\begin{cases} \overline{x_i} = \max - x_i, \text{minimization indicator handling} \\ \overline{x_i} = 1 - \dfrac{x_i - x_{best}}{M}, \text{midrange indicator handling} \\ M = \max\{x_i - x_{best}\} \\ i = 1, 2, 3, ...n \end{cases} \tag{1}$$

Then, we calculate the distance to the ideal solution z+ and the distance to the negative ideal solution z- separately. For Z_{nm}, here refers to the standardized rating matrix Z of the data, where the n-th scheme to be evaluated has m indicators. The standardized matrix is shown as follows:

$$z = \begin{bmatrix} z_{11} z_{12} \cdots z_{1m} \\ z_{21} z_{22} \cdots z_{2m} \\ \vdots \\ z_{n1} z_{n2} \cdots z_{nm} \end{bmatrix} \tag{2}$$

$$\begin{cases} z^{+} = [\max\{z_{11}, z_{21}, ...z_{n1}\}, \max\{z_{12}, z_{22}, ...z_{n2}\} ... \max\{z_{1m}, z_{2m}, ...z_{nm}\}] \\ z^{-} = [\min\{z_{11}, z_{21}, ...z_{n1}\}, \min\{z_{12}, z_{22}, ...z_{n2}\} ... \min\{z_{1m}, z_{2m}, ...z_{nm}\}] \end{cases} \tag{3}$$

$$\begin{cases} D_i^{+} = \sqrt{\sum_{j=1}^{m} (z_j^{+} - z_{ij})^2} \\ D_i^{-} = \sqrt{\sum_{j=1}^{m} (z_j^{-} - z_{ij})^2} \\ s = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \end{cases} \tag{4}$$

The i represents ith data, i=1,2,3..., n. With the ideal and negative ideal solution vectors, we can obtain the distance to the ideal solution D_i^{+} and the distance to the negative ideal solution D_i^{-} and then calculate the overall score s.

4 Model Solving

After TOPSIS, we obtain the following results, The specific results are shown in the table below:

The reason for selecting ten pre-selected points above is because the pre-selected points of hydropower stations are usually evaluated by geologists, so there are not many pre-selected points.

The approximate locations of these data on the Yarlung Tsangpo River are as follows:

Table 1. TOPSIS score result

Number	Latitude North	East longitude	Score
U1	29°16′	91°27′	0.763949613
U2	29°15′	91°44′	0.769922118
U3	29°14′	92°15′	0.77600181
U4	29°20′	92°37′	0.782171229
U5	29°20′	92°53′	0.788412913
U6	29°07′	93°8′	0.794709404
U7	29°09′	93°29′	0.801043239
U8	29°11′	93°58′	0.80739696
U9	29°27′	94°41′	0.813753105
U10	29°23′	95°19′	0.800236873

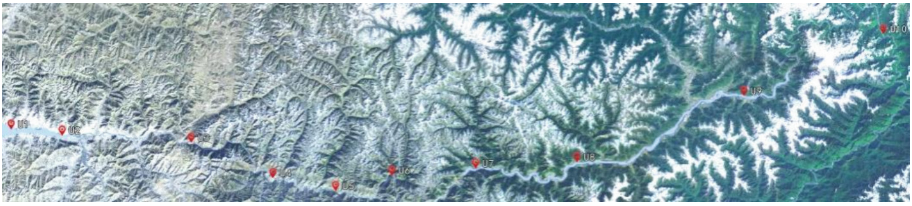

Fig. 1. Specific position of the point to be measured

5 Sensitivity Analysis of the Model

After the weight of each index is determined in model 1, we conduct sensitivity analysis, change the weight, and check the difference between the results and the original data. Here, we will respectively vary the weights of the features, namely water conditions, economic impact, human factors, and natural environment, and set them as situation1, situation2, situation3, and situation4. We will set the perturbation value as 0.1 and observe the effects in the model.

In the graph, the human factors show higher perturbations compared to other features, but the difference is only around 0.03. In reality, factors such as population density and population relocation due to the construction of hydropower plants can indeed have a significant impact on the site selection of hydropower plants. However, using this model can greatly enhance the robustness of the model and achieve better practical results. Overall, the overall changes in the results are not significant, and the overall regression effect is better, indicating better stability of the model.

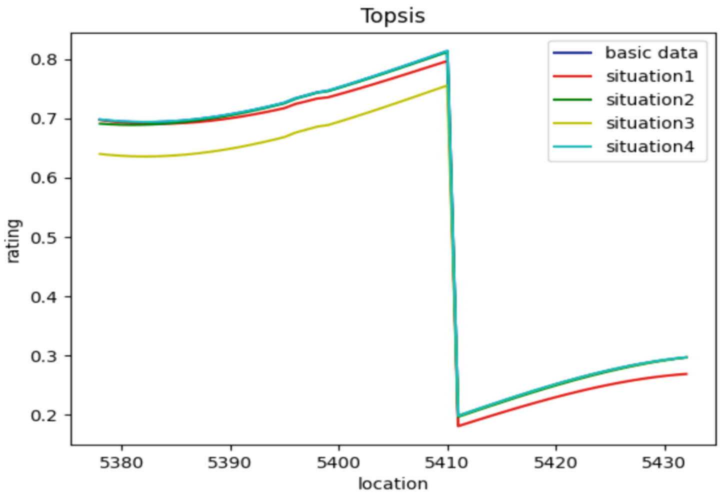

Fig. 2. TOPSIS sensitivity analysis results

6 Multi-Objective Planning Model to Solve for Optimal Location

6.1 Introduction and Steps of the Multi-Objective Planning Model

Multi-objective planning is a mathematical planning method that seeks to solve problems with conflicting objectives among multiple objectives. In multi-objective planning, there are usually multiple objective functions, which may be contradictory or interrelated, which require trade-offs and balances among multiple objectives to find the best solution.

Minimize or maximize the objective function vector F = ($f_1(x)$,$f_2(x)$..., $f_k(x)$), where x=(x_1,x_2,x_3,...,x_n) is the vector of decision variables.

$$Z = F(X) = \begin{bmatrix} \max(\min) f_1(x) \\ \max(\min) f_2(x) \\ \vdots \\ \max(\min) f_k(x) \end{bmatrix} \tag{5}$$

Add the restriction that φ_n (x) is an m-dimensional vector function and G is an m-dimensional constant vector.

$$s.t.\varphi(x) = \begin{bmatrix} \varphi_1(x) \\ \varphi_2(x) \\ \vdots \\ \varphi_m(x) \end{bmatrix} \le G = \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_m \end{bmatrix} \tag{6}$$

However, there is no single optimal solution for the multi-objective planning model, and it needs to be considered according to the actual situation to get the priority order of the objective function consideration and get the optimal solution.

The specific steps are as follows:

Step1: Create multiple objective functions.

Step2: Consider constraints on variables, such as equation constraints, inequality constraints.

Step3: Select the suitable optimization algorithm for solving.

Step4: Analyze the trade-offs between each optimal solution.

Step5: Develop an implementation plan based on the final chosen optimal solution.

7 Model Solving

We considered maximum return and minimum risk as the objective function, and minimum risk was considered as the limiting function to establish a multi-objective planning model.

$$\max \sum_{i=1}^{n} p_i x_i$$
$$s.t. \begin{cases} \sum_{i=1}^{n} R_i x_i = R_{\max} \\ \sum_{i=1}^{n} x_i = 1 \\ 0 \leq x_i 1, i = 1, 2..., n \end{cases} \tag{7}$$

Five sites will be selected and various environmental data such as meteorological, geological and hydrological data will be collected based on 5g technology to assess risks as well as monitoring and analysis of construction and operation costs to help evaluate the economics of the hydropower plant. After substitution into the model.

Table 2. Multi-objective programming results

	P_i	R_i	x_i
U6	0.21	0.74	0
U7	0.44	0.67	0
U8	0.75	0.91	0
U9	0.49	0.78	0
U10	0,51	0.45	1

We arrive at U10 as the optimal site, and after investigation and verification, U10 is an existing hydroelectric plant, which also verifies the accuracy of our model. There is an improvement of model accuracy compared to the base TOPSIS. Therefore, the accuracy of single topsis model site selection is not high, but the site selection considering multiple factors after multi-objective planning is more accurate and more practical.

8 Conclusion

Using the TOPSIS method and a multi-objective planning model, we first selected the five highest rated sites out of the ten sites using TOPSIS, and then considered the trade-off between construction risk and profit using the multi-objective planning model to determine the optimal site for the hydropower plant. By evaluating the construction risk and profit of the sites, we found that site U10 had the highest profit and lowest risk, and therefore we recommended that the hydropower plant be built at site U10. Through sensitivity analysis and evaluation of the model, we confirmed the validity and accuracy of the model and proved the value of TOPSIS method and multi-objective planning model in the hydropower plant siting problem.

References

1. Liangjing, Z.: A study on the model of dam site selection for hydroelectric power plants based on entropy TOPSIS method. North China Electric Power University, Beijing (2020).
2. Qian, Wu., Lei, Z.: Research on solving the location problem of slope hydropower stations based on optimization models. Sci. Technol. Innov. Rep. **12**, 48–49 (2017)
3. Juping, S.: Study on geomorphic features of Yarlung Zangbo River based on DEM. China University of Geosciences, Beijing (2007).
4. Yunfei, G., Furong, Z., Fen, Z., Fang, H.: Benefit analysis of water diversion project in eastern Zhejiang. Water Conserv. Technol. Superv. **11**, 73–77 (2021)
5. Xitao, Z., Lejun, W.: How much water can be transferred from the 'five rivers and one river' in western China? – Two comments on the conception of 'Hongqi River Project.' J. Earth. **3**, 492–506 (2019)
6. Jingjun, Y.: Study on the influence of watershed water transfer project on regional industrial structure and economy. Shanghai Jiao Tong University (2008).
7. Jingjun, Y., Xundi, D.: Analysis on the water supply benefit of the project of diverting the River to the Pacific to Jiaxing City. Water-saving Irrig. **8**, 110–112 (2007)
8. Ruzhou, N.: Estimation of design cost of hydropower station. Water Conserv. Hydropower Technol. (2011).