Problem Chosen	2023HSB MCM/ICM Summary Sheet	Team Number
A		MI00181

Yarlung Zangbo River comprehensive development plan based on optimization model

Summary

The Yarlung Zangbo River is the longest plateau river in China and has great development value.In this paper, the development of it is discussed.

For problem 1, discussing the feasibility of constructing Hydropower station on Yarlung Zangbo River, we first selected five sites for analysis based on the feasibility of the five power stations on the Yarlung Zangbo River[1]. Then, according to literature study[2] and theoretical analysis, we screened out dam construction costs, electricity demand, tax collection, and benefits from improving environmental conditions. With a deep covering layer and 11 indicators such as road, railway and other transportation facilities, EWM-TOPSIS model is constructed to find the best dam site. Finally, it is concluded that the feasibility of constructing Hydropower station is the highest in Nang County, and there are no huge problems in the three factors of migrant compensation cost, dam construction project cost and dam operation cost. And the economic benefits obtained under the same circumstances are the most sizable.

For problem 2, in order to explore the number of Hydropower stations that can be built on the main stream of the Yarlung Zangbo River and the potential total power generation that can be generated on the premise of obtaining the maximum energy, this paper adopts the maxmin model, which is established to ensure the maximum output as the optimization objective, and uses matlab to solve the problem through dynamic programming method. To obtain the maximum guaranteed output so as to ensure the functional relationship between output and generation to solve the maximum generation. Finally, according to the scale of selected Hydropower stations, the number of Hydropower stations that can be built on the main stream of the Yarlung Zangbo River is 17, and the potential total power generation is 366.982.2 billion kWh/day.

For problem 3, in order to verify the feasibility of "Hongqi River" project from the perspective of economic benefits, we set up a feasibility model to evaluate the project of "bringing Tibet to Xinjiang". We have learned that the basic goal of the project is to invest 4 trillion yuan to transfer 60 billion m^3 of water to Xinjiang and other arid areas. With the benefit and cost of the project as the goal and technology, ecology and other factors as the constraint, whether the reverse calculation can meet the goal. Based on the annual average runoff of each river, we calculated that the estimated investment amount of the project could not support the completion of the "Hongqi River" project, so the feasibility of the construction of the project is very small.

For problem 4, in order to maximize the value of comprehensive utilization, we establish a multi-objective scheduling optimization model with water transfer, power generation and ecological indicators of hydrological change as objective functions to find a scheme that can maximize economic and ecological benefits. Finally, the scheme of water transfer, higher power generation value, larger WQL and smaller HA is selected.

For problem 5, China's comprehensive development of Brahmaputra River will certainly attract India's attention. In order to consider the influence of India's factors on the comprehensive development plan in this paper, based on the model established in question 4, we take into account the influence of India's factors on the existing indicators, so as to make adjustments to our comprehensive development plan. That is, the scheme with high water transfer and power generation value, high power generation and ecological index WQL and low HA is selected.

Finally, we evaluated the strengths and weaknesses of the model and promoted it. At the same time, we provided a policy recommendation to the Chinese government based on our research and conclusions.

Keywords: Entropy-Topsis method model Maxmin model Multi-objective optimization model

Content

1 Introduction

1.1 Background of the Problem

Yarlung Zangbo River is the highest river in China and even in the world. Its huge drop, the amount of water collected on the plateau and the abundant hydropower resources make it have good value in the development and utilization of water resources and has great potential for exploitation.

China and India are both populous countries in the world, and with the continuous development of their economies, the demand for water resources is increasing. The issue of transboundary water between China and India, located on the upper reaches of the Brahmaputra River and located on the lower reaches of the Brahmaputra River, has resulted in a lack of effective balance between the interests of transboundary water resources of the two countries.

In order to solve the national water problem, China has implemented the South-to-North Water Diversion project and built the first Hydroelectric power station on the main flow of the Yarlung Zangbo River, Zangmu Hydroelectric power station. India has implemented the North to South Water diversion project and the Inland river interconnection project[3].

1.2 Previous Works

At present, hydropower engineering technology has been able to build various types of hydropower projects and giant hydropower projects under very complex natural conditions[4] . At the same time, there are also many research methods on project location optimization at home and abroad. For example, foreign researchers use integrated fuzzy logic and analysis network process (F-ANP)[5] method to select landfill sites. In the optimization of substation location, researchers adopted the hybrid GA-BFGS algorithm[6] to seek the optimal substation location, so as to achieve the most extensive energy distribution. In addition, foreign scholars also adopt Fuzzy-Topsis method[7], NSGA-II evolutionary algorithm[5], etc. From the above point of view, all fields are used to the location problem, through the literature review can be found, used in the actual location methods are more concentrated, such as fuffy-Topsis method and Fuzzy analytic hierarchy process, most scholars choose to use the "combination evaluation" method to select the optimal address.

The hydraulic resources of Yarlung Zangbo River are equivalent to the current power generation capacity of the whole country of India. To deal with the problem of trans-boundary river water resources between China and India with a rational and cooperative attitude, and actively seek new cooperation points, can make the overall relationship between the two countries develop in a good direction . Some scholars have drawn the following conclusions through the dynamic game model of water rights between China and India on the Brahmaputra River: While realizing the common prosperity of the basin, the development cooperation of the Brahmaputra River is also the golden key to the cooperation between China and India, which will promote further exchanges and cooperation between the two countries.

Northwest drought and shortage of water eco-environment led to seriously unbalanced development in our country area, which severely restricted our sustainable development ability. Only by solving the water resource problem in northwest land thoroughly can we guarantee our development space effectively. The "Hongqi River" has a low water intake level, so there is plenty of water. It is expected that the total annual water transfer will reach 60 billion cubic meters, accounting for only 21 percent of the total water intake points of major rivers, and will form about 200,000 square kilometers of oases in the arid region of northwest China[8]. The Hongqi River will communicate with the southwest river, the Yangtze River, the Yellow River and the Northwest River, and affect the Huaihe River, the Haihe River and the Liao River. It is an important infrastructure for the comprehensive utilization, regulation and management of all major river systems, and an important measure to establish the integrity of the Chinese river system[9].

1.3 Our Work

We mainly set up an optimization model to solve the problems in this paper.

In order to solve problem 1, we firstly selected five sites for analysis based on existing power station addresses. Eleven indexes were selected based on literature research and theoretical analysis, and then a new model, entropy weight TOPSIS model, was established by integrating entropy weight method and TOPSIS method to find the best site selection. In the process of analysis, it can be shown that the selected dam site is highly feasible.

In order to solve problem 2, we analyze the number of hydroelectric power stations that can be built on the main stream of Yarlung Zangbo River and their potential total power generation based on the maxmin model of dynamic programming under the premise of maximum energy. Finally, based on the first question, we find that the construction of 17 hydroelectric power stations can generate the maximum energy, and the potential total power generation is 366.982.2 billion kWh/day.

In order to solve problem 3, we built a feasibility model to evaluate the project of "introducing Tibet into Xinjiang" to analyze the feasibility of the project of "Hongqi River". In the end, we calculated that the project had little feasibility for construction.

In order to solve problem 4, we set up a multi-objective optimization model to maximize the comprehensive utilization value of the Yarlung Zangbo River water resources. Finally, on the premise of keeping the water transfer and power generation almost unchanged, the ecological index of the scheme should be as close to nature as possible to maximize the value.

In order to solve problem 5, add India factor to problem 4, so as to adjust the above plan. Finally, we choose the scheme with high water transfer and power generation value, high power generation and ecological index WQL and low HA.

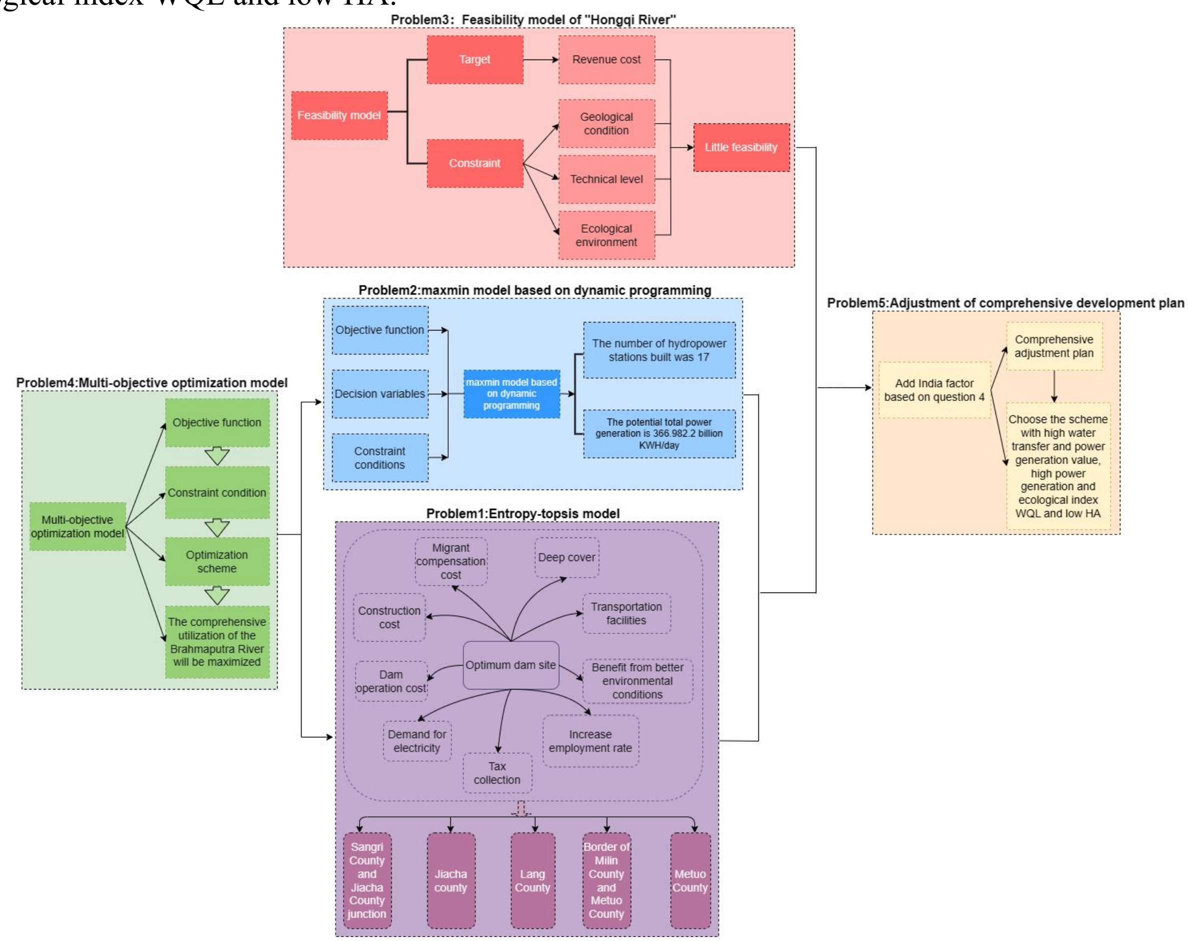


Figure 1 The workflow

2 Symbol Description

Symbol	Definition
C	The number of functions
m_c	Function weight
φ_c	The c function
$(X_t)_j$	Normalized status value
Q	Number of decision factors
Q_t	Time interval in period t
D_t	Time conversion factor
D	Comprehensive output coefficient of power station
$R_{L,t}$	Generation flow in time period t

3 Model Hypothesis

- **Assumption 1**:Assume that the five selected regions have the same internal geological conditions and installed capacity.

Justification: Because the terrain around the Brahmaputra River basin is complex and limited by practical conditions, we cannot conduct field survey.

- **Assumption 2**:Assume that the dam construction cost is determined according to the total installed capacity of the power station[10], and the known dam construction cost in Gyaca County is used to calculate the project construction cost in other locations.

Justification:Because the construction of the Hydroelectric power station on the Yarlung Zangbo River is still in the preliminary stage, the actual cost estimate is lacking.

- **Assumption 3**:It is assumed that all power stations continue to generate electricity, and the total power generation reaches 80% of the maximum total power generation[11].

Justification:Since the potential generating capacity and the number of power stations are calculated from the perspective of maximum energy, the maximum possible value of each index is selected based on the actual situation.

- **Assumption 4**:It is assumed that all hydroelectric power stations are regulated in seasons, years and years, and the ratio of working capacity to guaranteed output of hydroelectric power stations is 4 times.

Justification:Since the seasonal, annual and multi-year regulated Hydroelectric power station can operate above the waist of the load curve, the ratio of its working capacity to guaranteed output will be more than 3 times[12].

- **Assumption 5**:Assuming that the evaporation and leakage of water in the process of water transfer are not taken into account, 60 billion m^3 of water transfer completely reaches the water demand area.

Justification:When considering the evaporation and leakage of water in the process of water transfer, there are too many influencing factors to make an objective analysis. Therefore, in order to simplify the problem, only farmland and green belt water use is considered to estimate the rationality of water transfer.

4 Models and Solutions

4.1 Site selection and feasibility of Hydroelectric power station

4.1.1 Problem analysis

In order to discuss the feasibility of building hydroelectric power stations on the Yarlung Zangbo River, we first selected the junction of Sangri County and Gyaca County, the junction of Gyaca County, Nang County, Milin County and Medog County, and the five locations of Medog County for discussion and analysis based on the locations of five hydroelectric power stations that have been selected on the Yarlung Zangbo River[1]. As shown in the picture below:

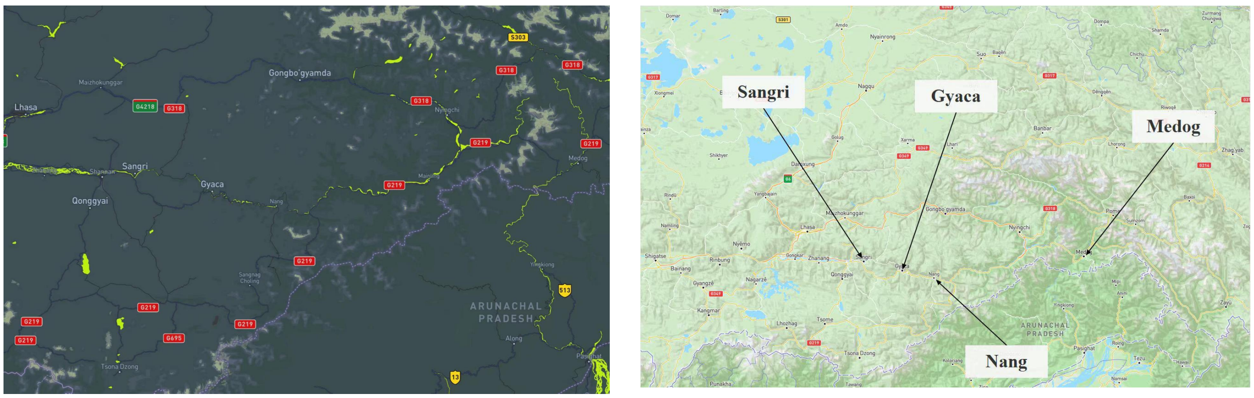


Figure 2 Yarlung Zangbo River and Preliminary site selection of Hydroelectric power station

Since there are many comprehensive factors to be considered in site selection, we use literature study[2] and theoretical analysis to select the index system as shown in the following table:

Table 1 Evaluation indexes of site selection of Hydroelectric power station

Target layer	Criterion layer	Scheme layer
Evaluation index of site selection of Hydroelectric power station	Input costB_1	Migrant compensation costB_{11} Dam construction costsB_{12} Dam operation costB_{13}
	IncomeB_2	Demand for electricityB_{21} Tax collectionB_{22} Benefit from better environmental conditionsB_{23} Increase employment rateB_{24}
	Geological conditionB_3	Rock fractureB_{31} Deep coverB_{32}
	Construction conditionB_4	Highway, railway and other transportation facilitiesB_{41} Construction difficulty degreeB_{42}

The geological conditions were studied according to the above table. The branch of Yarlung Zangbo River at the junction of Sangri and Gyaca County has a plateau and wide valley form, a lot of swamps and lakes, and a lot of rapids and jiangxinzhou. Barchan dunes were the main terrapins at both sides of the river channel, which were heavily weaved and thin. In the middle reaches of Nang County, the canyons are alternately wide and narrow, in the shape of beading, which is a wide valley reach with thick covering layer. In the reach of Medog County, the riverbed beach reef is spread, many canyons, both sides of the canyons are densely covered with forests, and the covering layer is thicker.

The construction conditions are studied according to the following figure: At the junction of Sangri and Gyaca County, Gyaca County is far from the national highway, so the construction of

Hydroelectric power station has little impact on traffic; Nang County and Medog County are close to the national highway, the construction of Hydroelectric power station has a great impact on traffic.

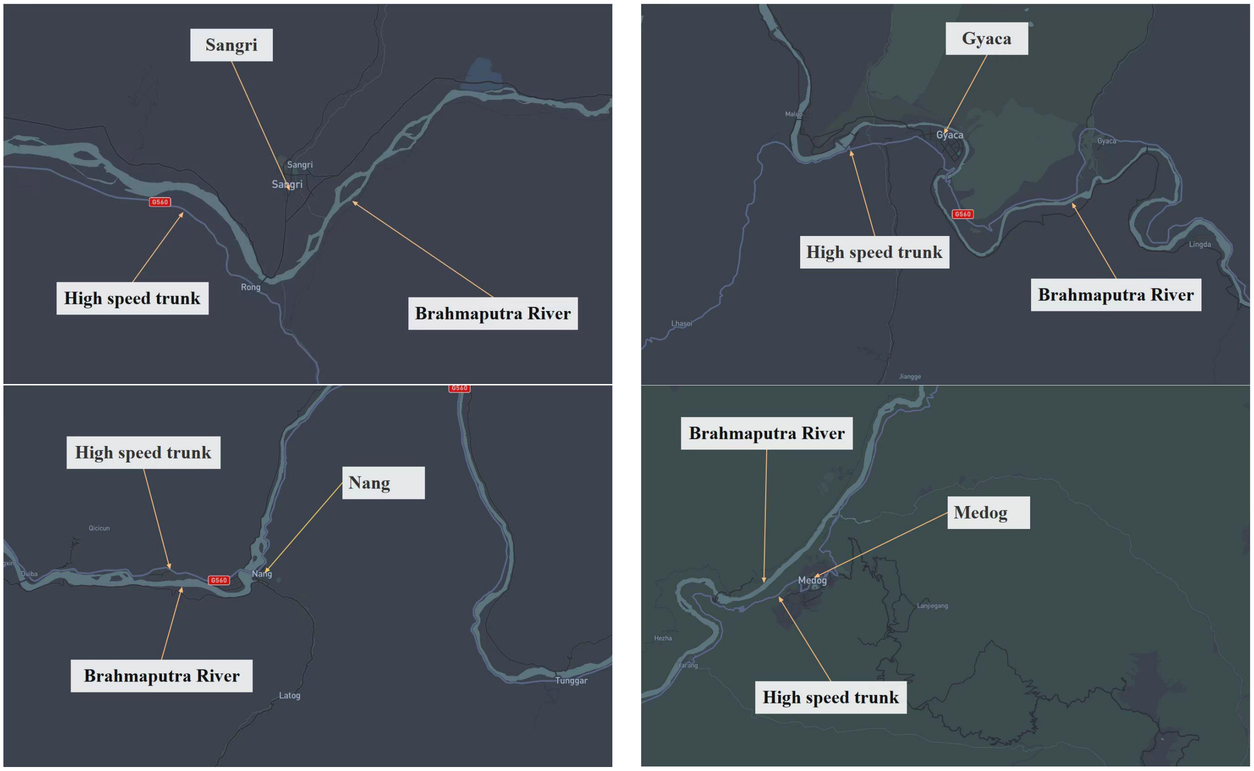


Figure 3 The distance between the five locations and the National Highway

Based on the above analysis and collected data[13], 11 evaluation indicators are summarized, as shown in the following table:

Table 2 Summary of evaluation indicators

index	Sangri County and Gyaca County junction	Gyaca	Nang	Border of Milin County and Medog County	Medog
Migrant compensation cost B_{11}	1.8	2.38	2	2.4	1.5
Dam construction costs B_{12}	8×10^9	8.443×10^9	5.2976×10^9	5.6287×10^9	1×10^{13}
Dam operation cost B_{13}	5.1	5.1	3.2	3.4	7
Demand for electricity B_{21}	4	5	4.5	4.6	3.7
Tax collection B_{22}	7	3	5	7	1
Benefit from better environmental conditions B_{23}	5	5.2	4.5	4.8	7
Increase employment rate B_{24}	7	5	6	4.9	8
Rock fracture B_{31}	3	4	4.2	5	5.5
Deep cover B_{32}	4	5	5.5	7.2	7.6
Highway, railway and other transportation facilities B_{41}	3	3.5	6	6.3	6.5
Construction difficulty degree B_{42}	4.4	4.8	5	5.2	7

*Migrant compensation, dam operating costs, earnings, geological conditions and construction conditions were assigned using the expert scoring method

Then, according to the data in the table above, EWM-TOPSIS model is established to analyze the feasibility of the construction of Hydroelectric power station.

4.1.2 Model establishment

(1) Construct the original decision matrix

According to the data in Table 2, the original decision matrix is defined as:

$$S_{5-11}=\begin{bmatrix} 1.8 & 8\times10^{9} & 5.1 & 4 & 7 & 5 & 7 & 3 & 4 & 3 & 4.4 \\ 2.38 & 8.443\times10^{9} & 5.1 & 5 & 3 & 5.2 & 5 & 4 & 5 & 3.5 & 4.8 \\ 2 & 5.2976\times10^{9} & 3.2 & 4.5 & 5 & 4.5 & 6 & 4.2 & 5.5 & 6 & 5 \\ 2.4 & 5.6287\times10^{9} & 3.4 & 4.6 & 7 & 4.8 & 4.9 & 5 & 7.2 & 6.3 & 5.2 \\ 1.5 & 1\times10^{13} & 7 & 3.7 & 1 & 7 & 8 & 5.5 & 7.6 & 6.5 & 7 \end{bmatrix}$$

(2) Standardized decision matrix

The original decision matrix is changed into standardized decision matrix by vector norm method:

$$S'_{5-11}=\begin{bmatrix} 0.55 & -0.08 & 3.00 & 6.82 & 2.61 & 4.47 & 4.85 & 2.47 & 2.09 & 1.33 & 3.72 \\ 0.82 & -0.08 & 3.00 & 9.00 & 0.89 & 4.70 & 3.17 & 3.63 & 2.83 & 1.66 & 4.16 \\ 3.12 & -0.09 & 1.63 & 7.91 & 1.75 & 3.91 & 4.01 & 3.87 & 3.20 & 3.34 & 4.38 \\ 0.83 & -0.09 & 1.77 & 8.13 & 2.61 & 4.25 & 3.09 & 4.80 & 4.46 & 3.54 & 4.61 \\ 0.41 & 2.41 & 4.38 & 6.17 & 0.03 & 6.74 & 5.70 & 5.38 & 4.75 & 3.67 & 6.61 \end{bmatrix}$$

(3) Establish index weights

The calculation results of indicators are shown in the following table:

Table 3 Entropy, difference coefficient and weight of each attribute

Index	Entropy valueE_i	Coefficient of differenceg_j	weightw_j	Index	Entropy valueE_i	Coefficient of differenceg_j	weightw_j
B_{11}	0.8763	3.4784	0.1002	B_{24}	0.9887	0.9606	0.0092
B_{12}	0.0989	9.6670	0.7301	B_{31}	0.9874	0.9927	0.0102
B_{13}	0.9742	1.4503	0.0209	B_{32}	0.9833	1.1544	0.0136
B_{21}	0.9965	0.5260	0.0028	B_{41}	0.9712	1.4771	0.0233
B_{22}	0.9058	2.5352	0.0763	B_{42}	0.9915	0.8521	0.0069
B_{23}	0.9919	0.8310	0.0066				

According to the above results, the dam construction cost occupies the largest weight, followed by the migrant compensation cost and tax collection cost. These factors have an important impact on the feasibility of the construction of hydroelectric power stationss in the five sites. Then TOPSIS method is used to obtain the evaluation results.

4.1.3 Model solution

In this paper, the site selection of Hydroelectric power station is studied from the single attribute and the whole. According to the attribute characteristics of the indicators established above, the indicators are divided into positive indicators and negative indicators. Among them, the positive indicators are: electricity demand, tax use, benefit from improved environmental conditions, increase in employment rate; Negative indicators include compensation costs for migrants, dam construction costs, dam operation costs, rock fractures, deep overburden, transportation facilities such as roads and railways, and construction difficulty.

(1) Calculate the single attribute weighted decision-making matrix S

By organically combining weight data with standardized decision matrix data, the calculated results are as follows:

$$S_1=\begin{bmatrix}0.1625 & 0.4994 & 0.4580\\ 0.2420 & 0.4992 & 0.4580\\ 0.9167 & 0.5008 & 0.2482\\ 0.2448 & 0.5006 & 0.2703\\ 0.1213 & 0 & 0.6677\end{bmatrix} \quad S_2=\begin{bmatrix}0.3976 & 0 & 0.4069 & 0.5070\\ 0.5248 & 0.5345 & 0.4275 & 0.3311\\ 0.4612 & 0.2673 & 0.3552 & 0.4190\\ 0.4739 & 0 & 0.3862 & 0.3223\\ 0.3595 & 0.8018 & 0.6134 & 0.5949\end{bmatrix}$$

$$S_3=\begin{bmatrix}0.2665 & 0.2592\\ 0.3915 & 0.3509\\ 0.4165 & 0.3967\\ 0.5166 & 0.5525\\ 0.5791 & 0.5892\end{bmatrix} \quad S_4=\begin{bmatrix}0.2060 & 0.3463\\ 0.2579 & 0.3877\\ 0.5169 & 0.4084\\ 0.5480 & 0.4291\\ 0.5688 & 0.6155\end{bmatrix}$$

(2) Single attribute evaluation

The comprehensive evaluation results of single attribute are as follows:

Table 4 Results of single-attribute comprehensive evaluation

Index	Sangri County and Gyaca County junction	Gyaca	Nang	Border of Milin County and Medog County	Medog
Migrant compensation costB_{11} Dam construction costsB_{12} Dam operation costB_{13}	0.1823	0.1957	0.3076	0.1771	0.1373
Demand for electricityB_{21} Tax collectionB_{22} Benefit from better environmental conditionsB_{23} Increase employment rateB_{24}	0.0919	0.2798	0.1593	0.0580	0.4110
Rock fractureB_{31} Deep coverB_{32}	0	0.1288	0.1701	0.3204	0.3807
Highway, railway and other transportation facilitiesB_{41} Construction difficulty degreeB_{42}	0	0.0613	0.2493	0.2722	0.4172

(3) Comprehensive evaluation

The comprehensive evaluation results obtained by TOPSIS method are shown in the table below:

Table 5 Statistics of comprehensive evaluation results

Location	Sangri County and Gyaca County junction	Gyaca	Nang	Border of Milin County and Medog County	Medog
Comprehensive valuation	0.1851	0.1612	0.2597	0.2164	0.1776

(4) Result analysis

Through the analysis results, it can be found that if there are differences between the analysis results and the comprehensive evaluation results from the aspect of single attribute, it indicates that the evaluation results are different in different regions under the influence of different factors.

In order to analyze the feasibility of constructing Hydroelectric power station more comprehensively and clearly, the radar map of comprehensive evaluation results is constructed in this paper.

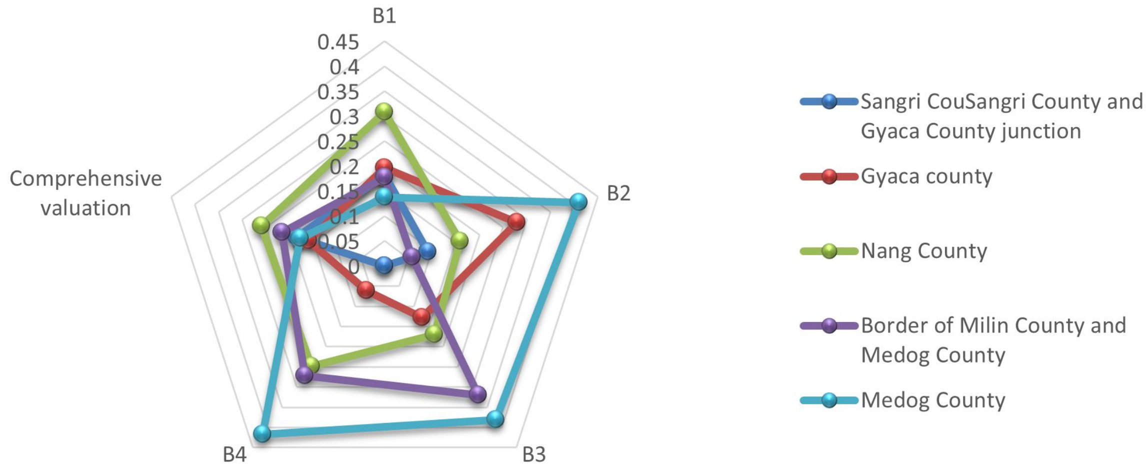


Figure 4 Radar map of comprehensive evaluation results

For comprehensive evaluation, the feasibility of building Hydroelectric power station in Nang County is the highest.

Through the radar map, it can be intuitively concluded that there are no huge problems in the three factors of migrant compensation cost, dam construction cost and dam operation cost in Nang County, and the economic benefits obtained under the same circumstances are the most considerable. Among the five site selection areas, dam construction cost has a greater impact on site selection and plays a leading role in the evaluation. This conclusion is consistent with the above analysis results by entropy weight method, which further proves the rationality of our model.

4.2 Construction quantity and generating energy of Hydroelectric power station

4.2.1 Problem Analysis

Relevant studies show that the maximum power generation is equal to the product of installed capacity and working hours[14], and there is a ratio relationship between the maximum installed capacity and the maximum guaranteed output. Maxmin model is mainly used for the compensation adjustment calculation of Hydroelectric power station groups, which can be solved by using POA[15] algorithm or iterative adjustment target[16] method. Therefore, maxmin model can be adopted to ensure the maximum output as the optimization objective, and matlab can be used to solve the problem through dynamic programming method, and the maximum guaranteed output can be obtained to solve the maximum power generation. Finally, the number of hydroelectric power stations that can be built on the main stream of the Yarlung Zangbo River is calculated according to the scale of the selected hydroelectric power stations.

4.2.2 Establishment of model

(1) Objective function

To ensure that the maximum output is the target, the objective function can be written as:maxmin $\{N_t\}$.

(2) Decision variables

The decision variable of this model is set as inflow runoff I_t in time period t and outflow W_t in time period t.

(3) Constraint conditions

The following constraints are mainly considered:

1) Water balance constraints

$$V_{t+1} = V_t + (I_t - W_t)\Delta t \, , t = 1,2, \ldots\ldots, T$$

Where, V_t , V_{t+1} are respectively the water storage capacity of the reservoir at the beginning of time period t and t+1, I_t is the inflow runoff during the period of t, W_t is the downstream discharge in time period t.

2) Flood control restrictions

$$V_t \geq V_{min}\,,\ t = 1,2,\ldots\ldots,T$$

Where, V_{min} is the maximum water storage value of flood control restricted reservoir during t period.

3) Constraints on ecological environmental protection

$$V_t \leq V_{max}\,,\ t = 1,2,\ldots\ldots,T$$

Where, V_{max} :The minimum water storage capacity necessary to maintain the stable development of ecological environment.

4) Shipping constraints

$$W_t \geq W_{min}\,, t = 1,2,\ldots\ldots,T$$

Where, W_{min} :The minimum discharge that must be discharged from the reservoir to meet downstream shipping requirements

5) Constraints on expected output of hydraulic turbine

$$N_t \geq N_{min}\,, t = 1,2,\ldots\ldots,T \qquad N_t \leq N_{max}\,, t = 1,2,\ldots\ldots,T$$

Where, N_{max}:Expected output of turbine， N_{min}:Water turbine technology is minimal

6) Constraint on maximum excess water flow of turbine

$$W_t \leq W_{max}\,, t = 1,2,\ldots\ldots,T$$

Where, W_{max}:Maximum excess water flow of turbine

(4) maxmin optimization model based on dynamic programming

In summary, maxmin optimization model based on dynamic programming is established:

$$\max\min\ \{N_t\}$$

$$\text{s.t.}\begin{cases} V_{t+1} = V_t + (I_t - W_t)\Delta t \\ V_{min} \leq V_t \leq V_{max} \\ W_{min} \leq W_t \leq W_{max} \\ N_{min} \leq N_t \leq N_{max} \end{cases}, t = 1,2,\ldots\ldots,T$$

4.2.3 Solving the model

The time of a year is divided into T periods, and the water balance equation is taken as the state transfer equation, namely:

$$V_{t+1} = V_t + (I_t - W_t)\Delta t\,, t = 1,2,\ldots\ldots,T$$

When sequential sequential recursion is adopted, the index function at the end of time period t is:

$$J_t = max(min_t(N_t))$$

The recursive calculation equation is:

$$J_{t+1} = max(min(J_t, N_{t+1}))$$

The initial condition $J_0 = \infty$ is set, and the boundary condition is the given storage capacity at the beginning and end of the scheduling cycle.

By searching the data, we get the measured runoff of the five Hydroelectric power station construction areas as follows:

Table 6 Measured runoff in the five regions

Region	Gyaca	Sangri County and Gyaca County junction	Nang	Border of Milin County and Medog County	Medog
Measured runoff（m^3/s）	300.02	202.15	290.0	920.31	919.9

* This data was taken from Basic Information of 7 Subbasins of Yarlung Zangbo River[16]

According to relevant information:

$$\text{Installed capacity} = \text{Maximum guarantee force} \times 4$$

$$\text{Power generation} = \text{Installed capacity} \times \text{Working hours}^{[14]}$$

The installed capacity of the selected Hydroelectric power station is taken as the standard installed capacity of the Hydroelectric power station in this region, and the number of hydroelectric power stations to be built can be calculated by combining the maximum total power generation obtained above:

$$\text{Number of hydropower stations} = \text{Maximum installed capacity}/\text{Installed capacity of each Hydroelectric power station}$$

The specific results are shown in the table below:

Table 7 Specific results for five locations

Region	Gyaca	Sangri County and Gyaca County junction	Nang	Border of Milin County and Medog County	Medog
Maximum guaranteed output（$10^4 kW$）	46.59	46.16	46.66	47.9	47.93
Maximum installed capacity（$10^4 kW$）	186.38	184.64	186.64	191.6	191.72
Installed capacity of each Hydroelectric power station（$10^4 kW$）	51	51	32	34	6000
Number of hydroelectric power stations	3	3	5	5	1
Power generation（10^8kWh/day）	7268.82	7200.96	7278.96	7472.40	7477.08

* Because Medog Hydroelectric power station is located in the "Big Bend" canyon section of Yarlung Zangbo River with large drop and large discharge, six large hydroelectric power stations with 10 million kW are laid out along the Qu River valley, so the installed capacity of Medog Hydroelectric power station is large. Therefore, no other hydroelectric power stations can be built in Medog County except Medog Hydroelectric power station.

To sum up, from the perspective of maximum energy, 17 hydroelectric power stations can be built on the main stream of the Yarlung Zangbo River. The maximum total generating capacity is used to describe the potential total generating capacity, that is, the maximum total generating capacity of the 17 hydroelectric power stations on the main stream of the Yarlung Zangbo River is 366.982.2 billion kWh/day.

4.3 Feasibility of Hongqi River Project

4.3.1 Problem Analysis

First of all, the title requires to discuss the feasibility of the construction of "Hongqi River" project from the perspective of economic benefits. Through consulting the materials[17], we have learned two key issues of the water transfer project: one is whether the border transfer area is short of water and how much water under the condition of bearing the water supply cost and paying the water supply price; One is whether the project can provide water at a cost and price that local residents can afford. The two questions are dichotomous, but inseparable. The project aims to transfer 60 billion m^3 of water from the Yarlung Zangbo River, Nu River, Lancang River, Jinsha River, Yalong River and Dadu River to arid areas such as Xinjiang, with an estimated investment of 4 trillion yuan. In order to meet the benefits of adding 200 million mu of farmland in Xinjiang and other areas, transforming 150,000 km^2 of desert into oases, extending more than 1,000 km of shipping lanes, and changing China's climate pattern, The cost of 4 trillion yuan is far from enough. Therefore, we judge the feasibility of this project in the face of multiple severe challenges and great uncertainties in terrain, science and technology, social economy, ecological environment and many other fields, as well as many problems such as market demand, investment benefits and international river water allocation.

4.3.2 A feasibility model to evaluate the project of "introducing Tibet into Xinjiang"

（1）Definition of economic benefits in water diversion projects

By browsing a lot of information[18],We divide economic benefits into four areas:

- First, the quantity and quality of labor force and employment status of the areas through which water is transferred.
- Second, the economic aggregate and industrial structure of the province through which "Hongqi River" project passes;
- Third, the total amount of investment and source of funds for the main project of "Hongqi River";
- Fourth, the "Hongqi River" project to social and economic development may produce advantages and disadvantages.

（2）Water demand in the target area

The Hongqi River project aims to divert water from the Yarlung Zangbo, Lancang, Nujiang, Jinsha, Yalong and Dadu rivers to arid areas such as Xinjiang. According to hydrological data from the National Qinghai-Tibet Plateau Scientific Data Center[19], the average annual runoff of the five rivers is 413.9 billion m^3. The annual average water resources of these rivers at the crossing position of Hongqi River are as follows:

Table 8 Average annual runoff of each river

river basins	Average annual runoff（10^9m^3）
the Yarlung Zangbo River	634
Nujiang River	241
Lantsang	164
Upper Jinsha River	116
Gangtuo	130
Ya-lung River	115
Dadu River	160
Total	1444

As can be seen from the above table, combined with the proposed road map of "Hongqi River" (Figure 5), if the lower reaches of the Brahmaputra River flow through India and Bangladesh, the hydroelectric power stations and projects below the Great Bend diversion port, relevant ecological and environmental risks, and related social economy and other factors are not taken into account, the total water transfer capacity of 60 billion m^3 can be theoretically satisfied in terms of water resources. But 60 billion cubic meters of water will not meet the economic targets set by the scheme.

Figure 5 Proposed route of "Hongqi River" project

（3）Assessment of water use for farmland construction and ecological green belt

- **Analysis of water consumption of 200 billion mu farmland construction**

There is no doubt that in the arid Northwest there is no agriculture without irrigation.By looking up information[19],According to the farmland irrigation data of the Tarim River Basin in Xinjiang, we know that the effective utilization rate of canal system water is about 40%. The farmland irrigation area of the Tarim River Basin is 7.87 million mu, and the annual water consumption is 13.205 billion m^3.The amount of water per mu of farmland is calculated according to the above data. The irrigation amount per mu is 1 670 m^3, and the net irrigation amount is 670 m^3. According to the statistics of Xinjiang in recent years, the irrigated area of the whole Xinjiang is 92.66 million mu, and the total water consumption reaches 56 billion m^3, with an average water consumption of 604 m^3 per mu. The net irrigation allowance is about 600 m^3 per mu of land, regardless of leakage and evaporation from the canal system.In all, 120 billion m^3 of irrigation water is needed to develop 200 million mu of agricultural land. Even if water-saving methods such as sprinkling irrigation or drip irrigation are developed in Xinjiang, according to the existing water quota of 400 m^3 per mu of drip irrigation or drip irrigation in Xinjiang, the annual irrigation water consumption of 200 million mu of farmland will be at least 80 billion m^3. Obviously, even if other influencing factors such as farmland channel leakage and surface evaporation are completely ignored, 60 billion m^3 of water can never meet the needs of 200 million mu of farmland. Theoretically, only 150 million mu of modern farmland can be developed. If you take into account such factors as canal leakage and evaporation, the development of 100 million mu at most.

- **Analysis of water consumption of 150000 km^2 ecological green belt**

By finding lots of relevant data[19] We have learned that in order to maintain the existence of the lower reaches of the Tarim River wetland, Xinjiang has transported 7 billion m^3 of ecological water to the lower reaches from 2000 to 2017, with an average of 400 million m^3 per year, and the average annual water demand per mu is about 500 m^3. If calculated according to the above data, the annual total water demand for the construction of 150,000 km^2 ecological green belt is 112.5 billion m^3, and the water demand for the construction of 200,000 km^2 ecological green belt is 150 billion m^3.

4.3.3 Solution of model

- **Only 60 billion m^3 of water transfer is considered for farmland development**

In terms of economic benefits, if evaporation and leakage of water from the Yarlung Zangbo River, Lancang River, Nu River, Jinsha River, Yalong River and Datu River along the 6000km route to Xinjiang and other arid areas are not taken into account, 60 billion m^3 of water can only support the construction of 100 million mu of farmland. According to the official program documents, on the premise that only 4 trillion yuan is spent and 60 billion m^3 of water is transferred, the estimated cost per cubic meter of water from the construction of 200 million mu of farmland and 150,000 km^2 of ecological green belt is 66 yuan. Then, based on the income of 20,000 yuan per mu of farmland, the income of 100 million mu of farmland is 2 trillion yuan, and the loss of water is 3,960 billion yuan. The net income is -1.96 trillion yuan.

- **Only 60 billion m^3 of water transfer is considered for 150,000 km^2 of ecological green belt construction**

In terms of economic benefits, assuming that the economic benefits of water evaporation, leakage and non-artefact loss in the 6,000km route from the Yarlung Zangbo River, Lancang River, Nu River, Jinsha River, Yalong River and Datu River to Xinjiang and other arid areas are not taken into account, the 60 billion m^3 of water can only build an ecological green belt of 60,000 km^2. Based on the cost of 66 yuan per cubic meter of water, the loss of 150,000 km^2 ecological green belt construction is 3.96 billion yuan.

To sum up, although 60 billion m^3 of water is transported by artefact, the use of pipeline to transport water reduces evaporation. With the strong financial support of the state, 150 million jobs have been provided. From the perspective of social and economic development, this has increased the feasibility of the "Hongqi River" project. However, in fact, the "Hongqi River" project transfers 60 billion m^3 of water to Xinjiang and other arid areas every year, and the construction cost far exceeds the expected investment amount of the project. No one can afford the high water bill, and the state cannot pay for it in the long term. Therefore, from the perspective of economic benefits, the construction feasibility of the "Hongqi River" project is very small.

4.4 Seek comprehensive utilization value maximization scheme

4.4.1 Analysis of problem

In order to seek a plan to maximize the comprehensive utilization value of the Yarlung Zangbo River, from the perspective of ecological protection, the establishment of Hydroelectric power station on the Yarlung Zangbo River will destroy the ecological environment. From the point of view of economic input and output, direct water transfer to the west is better. Therefore, when developing Yarlung Zangbo River, ecological protection of the river should be considered on the premise of meeting the needs of flood control and power generation, so as to maximize the ecological benefits. In this case, we select the inflow flow data of the Upper Nuxia hydrographic Station on the Yarlung Zangbo River from 2015 to 2020, and establish a multi-objective scheduling optimization model with water transfer, power generation and ecological index of hydrological change as objective functions for analysis.

4.4.2 Establishment of multi-objective scheduling model

The water transferred from the Yarlung Zangbo River to the west does not participate in power generation. The downstream discharge measured by the Nuxia Hydrographic station includes flood discharge and power generation flow during the flood season. We use Gaussian radial basis function to fit the reservoir scheduling rules[13]. The factors that affect the operation of reservoir are analyzed, including the inflow flow, different time periods and storage volume.The decision factor of radial basis function is set as R_t、t、S_t.In this problem, four radial basis functions are used to describe scheduling rules. Each function has five parameters: $a_{1,c}$、$a_{2,c}$、$a_{3,c}$、b_c、m_c，A total of 20 parameters need to be determined[3].

$$R_{\mathrm{i,out}} = \sum_{c=1}^{C} m_c \varphi_c(X_t)$$

$$\mathrm{t} = 1,2,\ldots,T \qquad 0 \le \mathrm{m_c} \le 1$$

$$\varphi_c(X_t) = \exp\left[-\sum_{j=1}^{Q} \frac{((X_t)_j - a_{j,c})^2}{b_c^2}\right]$$

$$a_{j,c} \in [-1,1] \qquad b_c \in (0,1)$$

C:The number of functions m_c:Function weight φ_c:The c function，$(X_t)_j$:Normalized status value，Q:Number of decision factors，a,b:parameters.

The Yarlung Zangbo River has functions such as water transfer and power generation. Considering the ecological protection, four objective functions are involved, as shown below:

$$M(T) = \max \sum_{t=1}^{T} \left[R_{P,t}\, Q_t\, D_t\right]$$

$$E(T) = \max \sum_{t=1}^{T} (L_t Q_t) = \max \sum_{t=1}^{T} (D\, R_{L,t}\, H_t Q_t)$$

$$R_{L,t} = I_t - R_{P,t} - P_t$$
$$I_{MRN}(T) = \max(\ I_{MRN}\ )$$
$$I_{HA}(T) = \min(\ I_{HA}\ )$$

The function value of the above formula is the water transfer in time T, $R_{P,t}, L_t$:Average water transfer and average output in time period t; Q_t :Time interval in period t, D_t :Time conversion factor, D :Comprehensive output coefficient of power station, $R_{L,t}$:Generation flow in time period t,H_t:Average power generation and clean water head during t period,I_t,P_t:Inlet discharge and discharge discharge in time period t.

According to the water storage capacity of the reservoir, the discharge, the flood season operating level, etc., the following constraint conditions are established:

$$S_{t+1} = S_t + (\ I_t - R_{P,t} - P_t\ )\delta_t$$
$$S_{t,\min} \le S_t \le S_{t,\max}$$
$$R_{t,\min} \le R_t \le R_{t,\max}$$
$$L_{t,\min} \le L_t \le L_{t,\max}$$
$$R_{t,ta} \le R_{\max,ta}$$
$$R_{t,qqg} \le R_{\max,qqg}$$
$$Z_{P,\mathrm{t}} \le Z_{P,m}$$

S_t,S_{t+1}:Reservoir capacity at the beginning and end of t period;

$S_{t,max}$,$R_{t,max}$,$L_{t,max}$:The maximum storage capacity of the reservoir guaranteed in time period t, Maximum allowable discharge volume, Maximum output of Hydroelectric power station.

$Z_{P,m}$:The highest allowable water level in flood season.

Then, an optimal scheme is constructed to maximize the comprehensive utilization value of the Brahmaputra River.

4.4.3 Solution of model

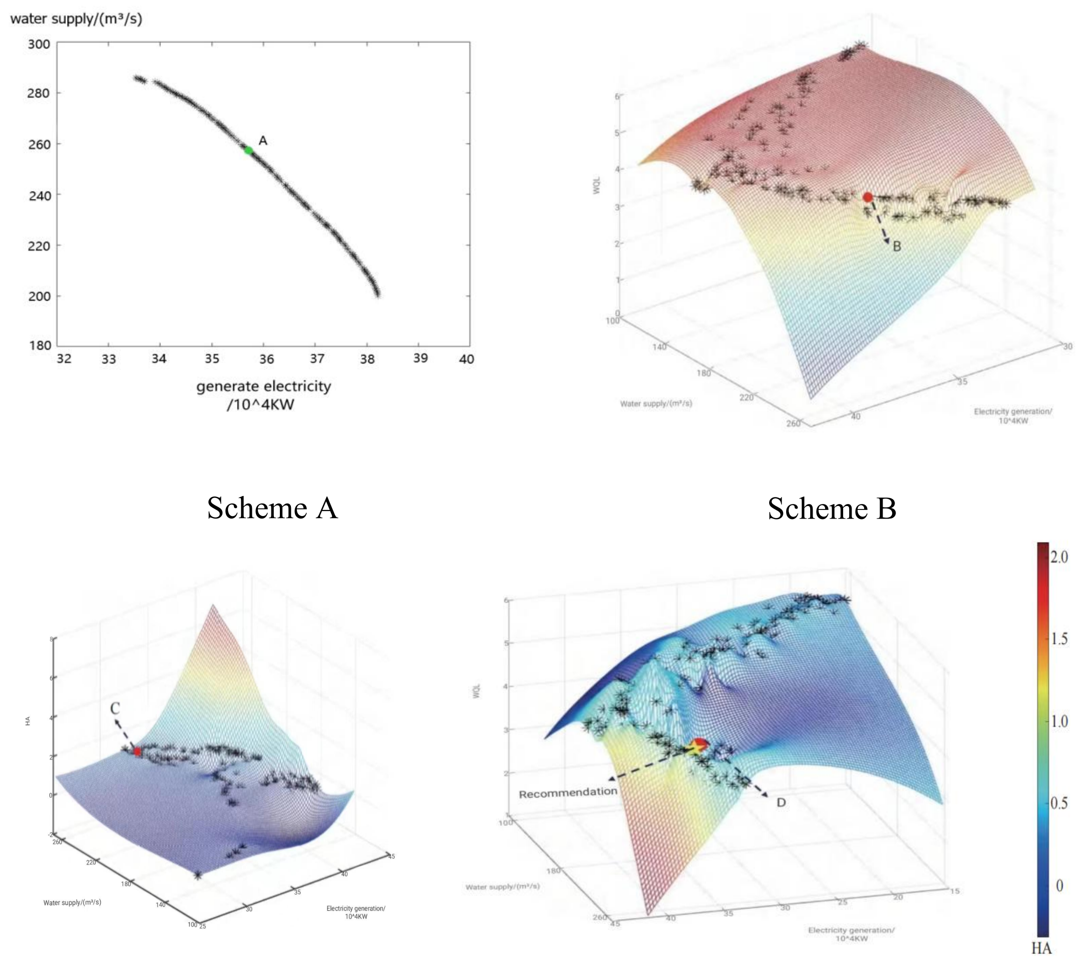
Construction optimization scheme:

In order to find the response relationship among the water diversion, power generation and ecological indicators WQL and HA of the Yarlung Zangbo River, the targets are decomposed into plans A-D, as shown in the following table. Plan A is the optimization of water transfer and power generation that has been realized. Plan B-D considers ecological benefits on this basis and adds indicators WQL and HA.

Table 9 Optimization scheme

prioritization scheme	objective function
Existing scheme A	Water diversion and power generation are the most valuable
prioritization scheme B	The value of water transfer and power generation is larger, and the WQL is larger
prioritization scheme C	The value of water transfer and power generation is larger, but HA is smaller
prioritization scheme D	The value of water transfer and power generation is larger, while WQL is larger and HA is smaller

According to the daily inflow flow data from 2015 to 2020 obtained by Nuxia Hydrological observation Station, NSGA-II optimization algorithm was used to solve the problem, and multi-objective optimal scheduling was carried out to find the optimal scheduling function satisfying the conditions. Pareto optimal frontier under A-D scheme is shown in the following figure:



Scheme A Scheme B

Scheme C Scheme D

Figure 6 Optimization results of four schemes

After comparative analysis, the red point in Figure D is selected to coordinate with "water transfer - ecology - power generation", and its WQL index is increased by 3.1% and HA is reduced by 1.25%. Therefore, this scheme is adopted to maximize the comprehensive utilization value of Yarlung Zangbo River by making water transfer and power generation more valuable, while WQL is larger and HA is smaller.

4.5 Adjustment of comprehensive development plan

4.5.1 Analysis of problem

Runoff from China's southern Tibet into the tributaries of the Brahmaputra exceeds 300 billion cubic metres a year. That is about 50 per cent of the river's runoff into the sea, more than 50 per cent of the river's runoff into the sea, and more than 15 per cent of India's water resources.

China transfers an average of 200 billion cubic meters of river water from the Brahmaputra River to the Yellow River every year, and of India's total hydropower potential, 44.4 percent is located in the Brahmaputra River basin, which India wants to tap to meet its growing energy needs.

Based on the dynamic game model of water rights between China and India, it can be seen that China can not only safeguard its own water rights interests through soft power, but also reach a cooperative game to obtain further long-term benefits through development and utilization[20].

4.5.2 Problem solving

Building the basis and model of cooperation in the Brahmaputra River basin will help form a positive symbiotic relationship in the basin and achieve common prosperity of the countries in the basin.

Table 10 Basic information of the Yarlung Zangbo-Brahmaputra river basin among the four countries

Country	Length of main stream/km	proportion (%)	drainage area/$10^4 km^2$	proportion (%)	annual runoff/$10^8 km^3$	population/10^5
China	2050	70	32.34	62.9	3071	340
India	640	21.8	11.34	22	1586	5080

China's construction of hydroelectric power stations in the Yarlung Zangbo River basin and the implementation of the plan to "divert Tibet to Xinjiang" must not have a negative impact on the runoff of the Brahmaputra River in India and ensure that India's related water conservancy projects in the Brahmaputra River will not be affected.

Based on the optimization model established in Problem 4, considering the influence of India factor on the four existing indicators, the model is re-solved, and the following results are obtained: Plan D is still the best, that is, the value of water transfer and power generation is larger, WQL is larger, HA is smaller, but its WQL index increases by only 2.7% and HA decreases by 1.04%.

4.6 Policy suggestion

Opinions on Hydroelectric Power Project Construction in China

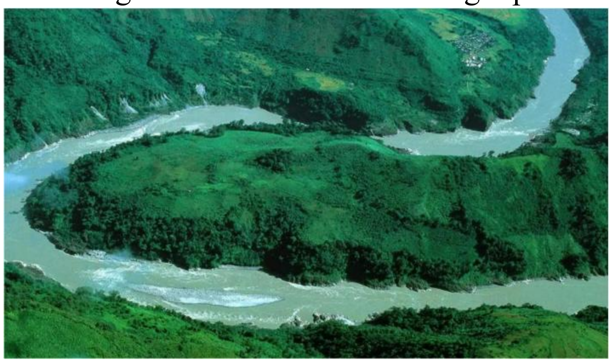
To：Chinese government From：Team#00181

Date：Sunday, February 5, 2023

Subject: Relevant suggestions are put forward for the construction of Yarlung Zangbo River Hydroelectric power station and Hongqi River diversion project

Dear Chinese government:

Based on our own research and conclusions, we will present our thoughts and suggestions to the Chinese government in the following report.



Yarlung Zangbo River Hydroelectric power station construction

- For Tibet, sustainable ecological development is the basis for sustainable development, and the construction of hydroelectric power stations on the Yarlung Zangbo River is based on the protection of the ecological environment. As the ecological environment in Tibet is fragile, any large-scale project construction will greatly affect the stability of the ecological environment. Moreover, the construction of Hydroelectric power station on the Yarlung Zangbo River is one of the largest projects since now, and will have a great impact on the ecological environment of the surrounding areas after its completion. Therefore, we suggest that the Chinese government add more relevant policies. For example, the government advocates the construction of large-scale natural resource development projects, but only on the premise of "respecting, respecting, adapting to and protecting nature".
- In response to the obstruction and objection of India, in order to ensure the peaceful, friendly and smooth progress of the construction of the Yarlung Zangbo River and other transnational river basins between China and India, the stable development of China-India relations and the peaceful development of the China-India junction, it is hoped that the Chinese government can strengthen the countermeasures against such problems in the future and adopt a plan based on the guarantee of the peaceful and stable development of China and India. We also hope that the construction of hydroelectric power stations on the Brahmaputra River can be understood and respected by India.

The construction of “Hongqi River” project of water diversion project

- The "Hongqi River" project has a special landform, rugged terrain and fragile environmental conditions, so as to reduce the "forced through the mountain" and ensure the way of water diversion as far as possible. The water diversion route can also be extended appropriately to increase the feasibility of the "Hongqi River" project.
- If the Hongqi River project is completed, it will not only greatly promote China's development and bring huge economic and ecological benefits, but also improve the ecological environment in Xinjiang and other arid areas. In order to ensure that the "Hongqi River" project can be completed, the government should increase the investment in it and impose preferential policies on the investment enterprises.

In a word, our idea is also to select a more scientific and reasonable optimization plan to promote the comprehensive and detailed planning of the western route of water transfer as soon as possible, and to start the construction of the Western Route as soon as possible. We also hope that our suggestions can help the Chinese government.

Yours Sincerely,
Team #00181

5 Model Extensions

In this paper, a new comprehensive evaluation model -- EWM-TOPSIS model is constructed to make a comprehensive study of entropy-weight method and TOPSIS method, so as to narrow the gap between subjective evaluation and objective calculation and make the evaluation results more scientific, reasonable and accurate.

6 The strengths and weaknesses of the model

6.1 Strengths

1. In order to find the optimal location of Hydroelectric power station construction, we not only analyzed the entropy weight method and TOPSIS method respectively, and found the shortcomings of a single evaluation method, but also studied the effective integration of these two methods to make up for the shortcomings, so as to construct a new evaluation method -- EWM -TOPSIS model.

2. The maxmin model based on dynamic programming can avoid the problems of unsuccessful trial calculation and uncertain calculation time as far as possible, so as to ensure the optimal results. The maxmin model of maximum guaranteed energy can replace the traditional guaranteed output solution method, and the potential total power generation of Hydroelectric power stations can be obtained effectively by dynamic programming.

6.2 Weaknesses

1. Perhaps due to the imperfect query data, the influencing factors of dam site selection and the selection of evaluation indicators are biased.

2. As the construction of hydroelectric power stations in different areas needs to be analyzed according to the actual situation, the model has not taken into account the distribution of water sources and climate conditions in the region, so the accuracy of the model needs to be improved.

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9 Appendix

EWM code

```
clc;clear;close all;
data = xlsread("data1.xlsx");
x=data';
[m,n]=size(x);
aver=zeros(1,m);
for i=1:m;
    aver(i)=mean(x(i,:))/n
end
st=[];
for i=1:m;
    st=std(x,1,2);
end
st=st'
norX=zeros(m,n);
for i=1:m;
    norx=(x(i,:)-aver(i))/st(i)
    norX(i,:)=norx
end

p=[]; P=[];
X=norX;
for k=1:m
    s=0
    s=sum(X(k,:));
    p=X(k,:)/s;
    P(k,:)=p
    p=[];
end;

E=[];
for k=1:m
    s=sum(x(k,:));
    pp=x(k,:)/s;
    s=0.0;
    for i=1:n
        if(pp(i)>0) s=s+pp(i)*log(pp(i)); end
    end
    E(k)=-s/log(n);
    g(k)=st(k)/aver(k);
end;
s=sum(E);
W1=(1-E)/(m-s);
E,g,W1
n=norX’
```

TOPSIS code

```
clc;clear;close all;
  X = xlsread("data2.xlsx");

  [n,m] = size(X);
  disp(['There are 'num2str(n)' evaluation objects, ' num2str(m) 'value index'])
  Judge = input([Whether 'num2str(m)' index needs to be forward processed? Please enter 1 instead of
0: ']);

  if Judge == 1
  Position = input('Please enter the columns where the indicators need to be processed forward. For
example, columns 2,3, and 6 need to be processed, then you need to enter [2,3,6] :');
  disp('Please enter the indicator types for the columns you want to process (1: very small, 2:
intermediate, 3: interval). ')
  Type = input('For example, if column 2 is extremely small, column 3 is interval type, and column 6 is
intermediate type, input [1,3,2] :');

  for i = 1 : size(Position,2)
  X(:,Position(i)) = Positivization(X(:,Position(i)),Type(i),Position(i));
  end
  disp('This is the forward matrix X = ')
  disp(X)
  end

  Z = X ./ repmat(sum(X.*X) .^ 0.5, n, 1);
  disp('Normalized matrix Z = ')
  disp(Z)

  D_P = sum([(Z - repmat(max(Z),n,1)) .^ 2 ],2) .^ 0.5;
  D_N = sum([(Z - repmat(min(Z),n,1)) .^ 2 ],2) .^ 0.5;
  S = D_N ./ (D_P+D_N);
  disp('The final score is:')
  stand_S = S / sum(S)
  [sorted_S,index] = sort(stand_S ,'descend')
```