Problem Chosen	2023HSB	Team Number
A	MCM/ICM Summary Sheet	MI00779

The Song of Water and Electricity in the Yarlung Zangbo River

Summary

In November 2020, the Central Committee of the Communist Party of China (CPC) put forward the "implementation of hydropower development in the lower reaches of the Yarlung Zangbo River" in its proposal for formulating the 14th Five-Year Plan for National Economic and social Development and Vision 2035.In order to better exploit its hydropower resources, this paper has done a series of studies on the construction of hydropower station in Yarlung Zangbo River and the development of Hongqi River project.

Several models are established：Model Ⅰ：Feasibility of hydropower station establishment based on **AHP-TOPSIS**; Model Ⅱ：Maximum power generation based on 0-1 Programming & **Nonlinear Programming**; Model Ⅲ：Comprehensive evaluation of ecological and economic benefits of oasis;Model IV：China-India water rights game,etc.

Before all the models are established, We clean and **visualize** a large amount of data with high reliability,which is of great help to our subsequent indicator selection work.

For problem 1,a **three-tier** evaluation index system with geological conditions, economic benefits, environmental factors and water level meteorology as criteria was established.We constructed Model 1 to analyse the Data of 30 preparatory construction sites (x1-x30). By sorting the comprehensive benefits of each preliminary construction point, 17 suitable preliminary construction points are obtained.The results are shown in section 4.

For problem 2,we used Model Ⅱ with the number of hydropower stations and the Yarlung Zangbo River runoff as the constraint conditions, and the maximum total energy generation as the objective function.The result is as follows: on the basis of problem 1, two hydropower station sites x4 and x10 are removed, and 15 power stations are set up in other 15 sites. At this time, the potential total generating capacity is at its maximum, 44.55 billion KWH per year.

For problem 3,We discussed the economic benefits of Hongqi River project from three aspects. Model 3 is used to calculate the **ecological** value and **socio-economic** value under different scenarios.The results showed that it lost about 500 billion yuan in the initial stage of construction.The economic benefit of Hongqi River Project in the next 50 years is analyzed by the economic benefit cost ratio, whose **EBCR** value is -0.99, indicating a serious loss.

For problem 4,we improved the programming model of problem 2.We changed the objective function to maximum value.The core of constraint conditions is the restrictive relationship between Hongqi River project and hydropower station on the utilization of hydropower resources.The results are shown that when the Hongqi River project water diversion is **17.3%** of the Yarlung Zangbo River runoff, the total benefit of the development planning of the Yarlung Zangbo River is the largest.

For problem 5，We measure the dispute between China and India over the Yarlung Zangbo River through Model IV.Adjust our development plan according to the results of the **game**.The result shows that: the two countries can negotiate and consider the hydropower stations related to the main stream in India, and the hydrological information can be shared.

In addition, our model has strong **adaptability** because of the rich scenarios and emergencies discussed in the above model.

Finally, sensitivity analysis of the index weight shows that our model is not sensitive to changes in them.Afterwards, a proposal letter on the comprehensive development planning of the Yarlung Zangbo River has been written for Chinese government.

Key Words：Site selection; AHP-TOPSIS; Nonlinear Programming; Game theor

Content

1.Introduction

1.1 Background

Yarlung Zangbo River, in ancient Tibetan language called Yangchabu Zangpo, means the water flowing down from the highest peak. Yarlung Zangbo River is the longest plateau river in China and one of the highest rivers in the world. Its water level has dropped greatly and its water energy reserves are rich, second only to the Yangtze River in China. Therefore, the sustainable development goal of "carbon neutrality" and "carbon peak" can be achieved if a series of hydropower stations can be built to increase hydropower generation by taking full advantage of the large water level difference of the main stream of the Yarlung Zangbo River.

1.2 Restatement of the problem

In this article, we need to consider the next fifty years and address the following questions:

1. Select suitable sites on the main stream of Yarlung Zangbo River for hydropower station construction and discuss the feasibility of hydropower station construction there according to the factors to be considered in hydropower station construction.
2. Calculate the maximum power generation capacity of the hydropower station when the number of hydropower stations is built, and calculate the power generation capacity at this time.
3. Comprehensively consider different factors and analyze whether the "Hongqi River" water diversion project is feasible from the perspective of economic benefits.
4. Design the comprehensive utilization plan of the Yarlung Zangbo River water resources, so that the Yarlung Zangbo River can not only provide hydroelectric power, but also transport water resources to the west, so as to maximize the value of the Yarlung Zangbo River water resources.
5. Consider the possible impact of Brahmaputra River development on India-China relations and adjust the comprehensive development plan according to the impact.
6. Provide no more than one page of policy recommendations to the Chinese government based on the research conclusions.

1.3 Literature Review

Scholars at home and abroad have done a lot of research on water resources development and site selection of hydropower station, and achieved a lot of important results. Wang Yunhui et al.[1]analyzed the environmental impact and economic benefits of hydropower station construction projects, estimated the long-term economic benefits and costs, and provided a reference for decision-making in the development and construction of hydropower projects. Liu Peng et al.[2] took the Yarlung Zangbo River as an example, analyzed the interest demands of China and India on trans-boundary rivers, and dealt with the problem of trans-boundary rivers by binding negotiations on trans-boundary rivers and boundary issues, and binding negotiations on hydrological information sharing and water resources development and utilization.

In this paper, based on previous studies, the feasibility of constructing hydropower stations at different locations on the main flow of the Brahmaputra River is discussed by considering various factors such as inputs and benefits, geological and hydrological conditions, environmental costs, etc., a coordinated plan of constructing hydropower stations and transferring water to the northwest is designed, and a development plan that does not harm Sino-Indian relations when the lower reaches of the Brahmaputra River flow into India is analyzed.

1.4 Our work

To avoid complicated description , intuitively reflect our work process, the flow chart is show as the following Figure 1：

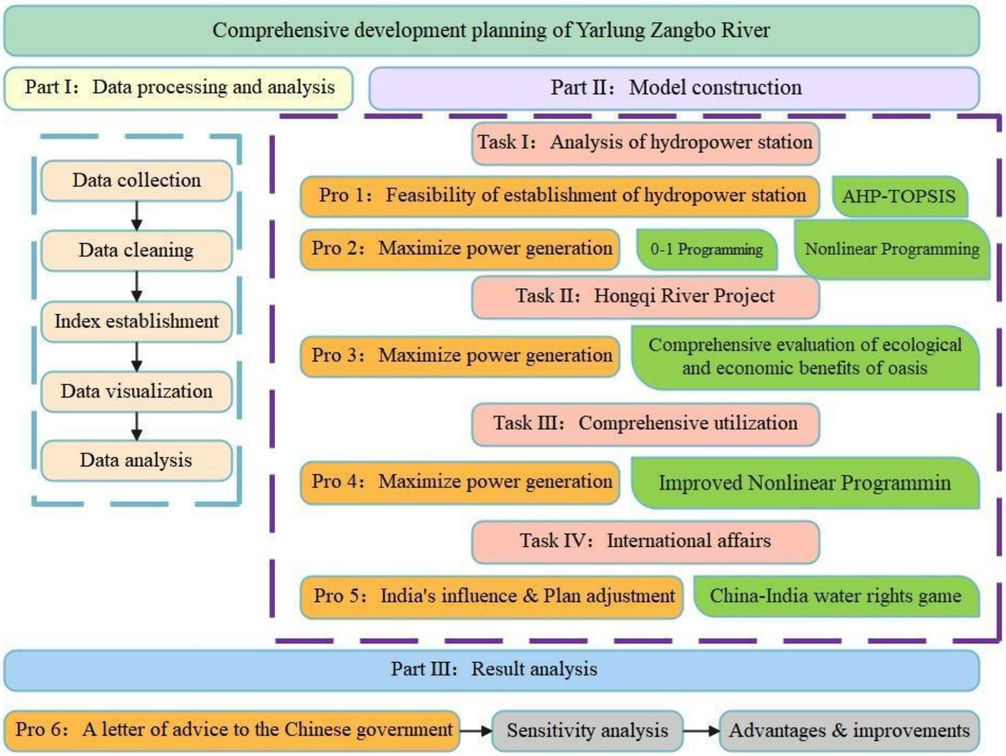


Figure 1 Flow Chart of Our Work

2.Assumptions and Justifications

To simplify the problem, we make the following basic assumptions, each of which is properly justified.

- **Assumption 1: All data sources in this paper are true and reliable.**

Justification: We need to rely on the historical data of the Yarlung Zangbo River and northwest China to analyze its trend and study the feasibility of building the power station and Hongqi River project. Therefore, the reliability of data is very important.

- **Assumption 2: The tributaries of the Yarlung Zangbo River have a negligible effect.**

Justification: Since the Yarlung Zangbo River has many tributaries, its runoff is very small compared to the main stream. Less impact on power station output.

- **Assumption 3: Multiple power stations are being built on the main Yarlung Zangbo River with the same raw materials, equipment and unit labor.**

Justification: This assumption does not change the nature of the model and simplifies our calculation of the cost of the plant.

- **Assumption 4: No major natural disasters will occur in the Brahmaputra River basin and Hongqi River areas in the next 50 years.**

Justification: Earthquake, debris flow and other natural disasters are force majeure factors, and we cannot accurately predict or quantify their impact on the stability of our model. In addition, hydropower stations should be built with a life of at least 50 years.

➢ **Assumption 5: Each hydropower station has the same interception capacity for the main flow of the Brahmaputra River.**

Justification: For problem 2, the interception capacity of hydropower station can be regarded as an objective parameter. This hypothesis helps us to simplify the constraint conditions based on displacement of each hydropower station.

• **Note**: Relevant assumptions of game theory model will be shown in section 8.2.

3.Notations and data

3.1 Notations

Table 1 Notations

Notations	Description
Q	Total flow of generator set
N	Total electric power of generating set
E_i	Power generation of the I-th hydropower station
NPV	Net present value of Hongqi River Project in the next 50 years
EBCR	The economic benefit cost ratio of Hongqi River project
ESV	The annual total value of ecosystem services in the region

• **Note**: Some variables are not listed. Their specific meanings will be introduced below.

3.2 Data

3.2.1 Data Overview

The question did not provide us with data directly,so we need to consider which data to collect in the model building.Through the analysis of the problem,we need to collect the data of the Yarlung Zangbo River basin,such as geological conditions, environmental factors, hydrological conditions,etc. In the process of determining the power generation of hydropower stations, we need some necessary physical data.In addition, there is information about the Hongqi River project: potential costs and economic benefits.

Due to the large amount of data,it is not convenient to list them all,so visualizing the data for display is a good method.

3.2.2 Data Collection

We collected lots of useful data from the references.Other data sources are shown in Table 2.

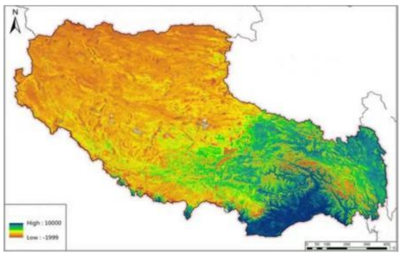
Table 2 Data and Database Websites

Database Names	Database Websites
Meteorology	http://data.cma.cn/
Topography (altitude; longitude)	http://www.gisrs.cn/applists
	https://www.xihe-energy.com/#climate
Investment & Income	http://www.stats.gov.cn/

• **Note**: Data sources that are not listed will be marked when referenced.

3.2.3 Data Screening & Visualization

We made statistical analysis on the collected data and eliminated the outliers.The following figures show our visualization of boring data.



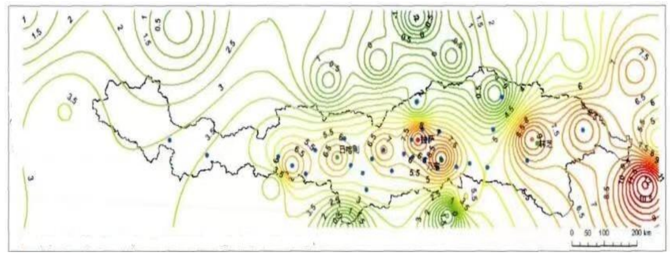


Figure 2 Distribution Map of Tibet Autonomous Region in 2020(Left)

Figure 3 Spatial distribution of average annual temperature over the YR basin(Right)

From the picture, we can clearly observe the geographical distribution of temperature and vegetation in the Yarlung Zangbo River basin.The visualization of other data will be shown below.

4.Problem1

4.1 Problem analysis

For problem 1, we will establish an evaluation model. We will first take input and income, geological and hydrological conditions, environmental costs and other factors as evaluation indicators, then evaluate and score several possible hydropower station sites, and finally get the most appropriate hydropower station construction site. The detailed steps are shown in the flowchart.

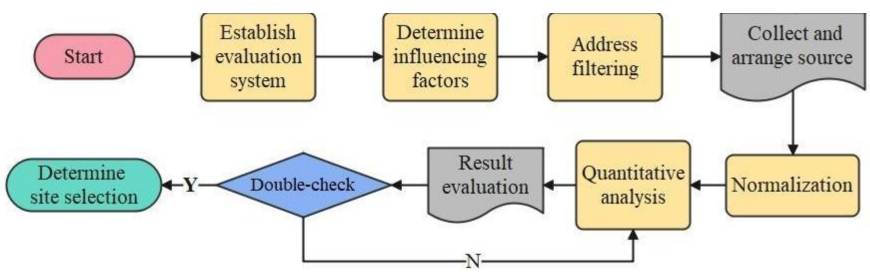


Figure 4 Technology Roadmap

4.2 Establishment of model

4.2.1 Selection of index

The site selection of hydropower station should fully consider the geological conditions, construction conditions, traffic, power grid access and regional natural conditions. In addition, it should also ensure that the original water system is not damaged, and reduce the excavation of earth and stone, house demolition and population relocation.

By referring to relevant data, the site selection characteristics of some current hydropower stations[4] are analyzed. The site selection characteristics of some existing or under construction hydropower stations in China are summarized as shown in Table 3：

Table 3 Site selection characteristics of some existing or under construction hydropower stations

Name	Characteristic
Hongshan hydropower station	There is little difference in geological conditions. Right bank is steep bank, bedrock outcrop; The left bank is a gentle slope with thick cover.
Hupangang hydropower Station	The valley shape is "U", the rock integrity, the regional geological structure is basically stable.
Longjiang hydropower station	The upper and lower dam site is 400m apart, the valley is a wide "V" shape, the two sides of the terrain is basically symmetrica.
Kok Mutang hydropower Station	Most of the river reaches are deep "V" shaped narrow valleys. The bedrock is buried deep, the structure is loose, the construction excavation volume is large, and the stability of the high slope formed by excavation and dam abutment is prominent.
Dongping hydropower station	The lower dam site on both sides of the mountain strong, steep slope. The layout of the upper dam site is flexible and diverse. The main disadvantage of the lower dam site is poor construction conditions.
Hefeng power station	The riverbed rock surface of the upper and lower dam site is mainly weak weathering.
Meixi River ferry Dam hydropower station	The upper, middle and lower dam sites are all located in the monoclinic middle-low canyon topographic area. The two sides of the upper and lower ridge site have symmetrical topography, while the middle dam site has poor symmetry.
Changzhou hydropower station	The terrain is gentle and the river valley is open, which is convenient for the layout of the hub.

By analyzing the site selection characteristics of the above-mentioned hydropower stations and combining with other reference materials, a three-layer evaluation index system is planned to be constructed, which is mainly divided into three levels: target level, criterion level and scheme level[3]. In this paper, 9 basic indicators are selected from four aspects, and an evaluation index system for site selection of hydropower station is constructed, as shown in Table 4:

Table 4. Evaluation index system and index attribute of site selection of hydropower station

Target layer	Criterion layer	Scheme layer	unit	Index attribute
Index system U	Geological condition U_1	Depth of overburden U_{11}	m	A
		Rock fracture U_{12}		B
		Osmotic stability U_{13}		B
	Economic benefit U_2	Total project investment U_{21}	RMB	A
		Economic benefit cost ratio U_{22}	%	A
	Environmental factor U_3	Vegetation coverage U_{31}		B
		Market demand for electricity U_{32}		B
	hydrometeorology U_4	Annual rainfall U_{41}		B
		altitude U_{42}		B

• **Note:** A-quantitative ; B-qualitative

Because the evaluation index system of the site selection of hydropower station involves quite a lot of evaluation factors, the evaluation of each factor is mostly fuzzy, it is not suitable to use a numerical value to express. Therefore, it is impossible to evaluate the site selection of hydropower station with absolute quantitative evaluation method. However, the completely qualitative evaluation method is not persuasive and pertinence is not strong. If we can adopt a qualitative and quantitative evaluation method, we can better solve the above problems, and more practical. The fuzzy comprehensive evaluation method is one of the methods to satisfy the above conditions. To sum up, the fuzzy comprehensive evaluation method is used in this paper to comprehensively evaluate the candidate addresses of a regional hydropower station.

4.3 Construction of AHP-TOPSIS fuzzy comprehensive evaluation model

First, we need to understand the general situation of the Yarlung Zangbo River, such as the terrain and so on.

Figure 5 Topography map of the Yarlung Zangbo River

As can be seen from Figure 5, the influencing factors in different regions of the Yarlung Zangbo River vary greatly. For the convenience of modeling, we collected the data of 30 preliminary construction sites (x_1, x_2, ..., x_{30}) for analysis.

This question follows the evaluation index system of hydropower dam site mentioned above, normalize the data through the TOPSIS fuzzy comprehensive evaluation model constructed, determine the weight value of each index by using the expert consultation method, determine the positive ideal solution and negative ideal solution by TOPSIS comprehensive evaluation method, and calculate the relative proximity between the evaluation object and the ideal solution. Rank different alternatives, the higher the ranking, the better the comprehensive benefit of the evaluation object. The specific steps are as follows:

(1) Determine the object set, factor set and decision set

Assuming that a hydropower station is to be built on the Yarlung Zangbo River, there are 30 preparatory construction sites to choose from, and the evaluation index set is factor set U, which can be divided into three layers.

The first layer is

$$U=U \tag{1}$$

The second layer is

$$U=\{U_1,U_2,U_3,U_4\} \tag{2}$$

The third layer is

$$\begin{aligned} U_1 &= \{U_{11},U_{12},U_{13}\} \\ U_2 &= \{U_{21},U_{22}\} \\ U_3 &= \{U_{31},U_{32}\} \\ U_4 &= \{U_{41},U_{42}\} \end{aligned} \tag{3}$$

The 30 preparatory construction points are the decision set $V = \{x_1, x_2 ... x_{30}\}$. Through the investigation and analysis of these 30 preliminary construction sites, the corresponding evaluation values of various factors corresponding to each preliminary construction site can be obtained. After data processing, the fuzzy comprehensive evaluation of each single factor can be obtained, as shown in Table 5:

Table 5 Fuzzy comprehensive evaluation results of each region (only six regions are selected for display)

Factor	x_1	x_2	x_3	x_4	x_5	x_6
Depth of overburden	0.91	0.85	0.87	0.98	0.79	0.60
Rock fracture	0.92	0.81	0.93	0.87	0.61	0.61
Osmotic stability	0.88	0.82	0.88	0.64	0.61	0.95
Total project investment	0.90	0.90	0.90	0.94	0.60	0.91
Economic benefit cost ratio	0.90	0.90	0.87	0.95	0.87	0.65
Vegetation coverage	0.60	0.95	0.60	0.95	0.95	0.95
Market demand for electricity	0.60	0.71	0.70	0.60	0.80	0.95
Annual rainfall	0.60	0.71	0.77	0.60	0.82	0.95
altitude	0.92	0.90	0.93	0.91	0.95	0.93

(2) Determine the fuzzy weight vector A of the factor set

In fuzzy comprehensive evaluation, weight will have a great influence on the final evaluation result. In this question, we use the expert consultation method to determine the weight. We consulted the literature on the site selection of hydropower station construction [8] and obtained the scores of experts on the importance of different factors in hydropower station construction. Based on comprehensive expert opinions, the final weight determination results of this model are as follows:

$$\begin{aligned} A &= \{0.1, 0.3, 0.4, 0.2\} \\ A_1 &= \{1/3, 1/3, 1/3\} \\ A_2 &= \{0.6, 0.4\} \\ A_3 &= \{0.3, 0.7\} \\ A_4 &= \{0.7, 0.3\} \end{aligned} \quad (4)$$

(3) Construct the evaluation matrix R

There are 30 evaluation objects and 9 evaluation indexes, and they form a comprehensive evaluation matrix $R = (r_{ij})_{m\times n}$,

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{19} \\ r_{21} & r_{22} & \cdots & r_{29} \\ \cdots & \cdots & \cdots & \cdots \\ r_{301} & r_{302} & \cdots & r_{309} \end{bmatrix} \quad (5)$$

(4) Construct the weighted normalized decision matrix V

$$V = A * R = \begin{bmatrix} A(1)A_1(1)r_{11} & A(1)A_1(2)r_{12} & \cdots & A(4)A_4(2)r_{19} \\ A(1)A_1(1)r_{21} & A(1)A_1(2)r_{22} & \cdots & A(4)A_4(2)r_{29} \\ \cdots & \cdots & \cdots & \cdots \\ A(1)A_1(1)r_{301} & A(1)A_1(2)r_{302} & \cdots & A(4)A_4(2)r_{309} \end{bmatrix} \quad (6)$$

(5) Calculate the relative proximity of each alternative scheme

In the construction of weighted normalized decision matrix, the vector composed of maximum elements in each column is called positive ideal point u^+. Vectors consisting of the smallest elements in each column are called negative ideal points u^-;

$$u^+ = \left(u_1^+, u_2^+, ..., u_{30}^+\right), u_j^+ = \max\left\{u_{ij}\right\}\left(j = 1, 2, ..., 9\right)$$
$$u^- = \left(u_1^-, u_2^-, ..., u_{30}^-\right), u_j^- = \max\left\{u_{ij}\right\}\left(j = 1, 2, ..., 9\right) \quad (7)$$

Calculate the relative proximity of each defined point u_i to the ideal point D_i

$$D_i = \frac{\left\langle \Delta u_i, \Delta u \right\rangle}{\left\|\Delta u\right\|^2}, i = 1, 2, ..., 30 \quad (8)$$

Where, $\Delta u = u^+ - u^-$; $\Delta u_i = u_i - u^-$

$\left\langle \Delta u_i, \Delta u \right\rangle$ is the dot product of the vectors Δu_i and Δu , $\left\|\Delta u\right\|$ is the Euclidean norm of Δu .

$$\left\|u\right\| = \left\{\sum_{j=1}^{m}\left(u^+ - u^-\right)^2\right\}^{\frac{1}{2}} \quad (9)$$

In problem1, topsis method is used to rank the comprehensive benefits of each preparatory construction site. First, each positive and negative ideal solution is determined. Then the relative proximity of each preparatory construction point to the ideal point is calculated according to the basis D_i. The larger the D_i, the better the comprehensive benefit. Also, the smaller the D_i, the worse the comprehensive benefit of the evaluation object is.

The final evaluation scores of 30 construction sites were obtained by using MATLAB, and the first 17 sites got high scores, which were denoted as $\{x_1，x_2 ... x_{17}\}$.

5.Problem2

5.1 Problem analysis

We analyzed 17 sites in problem 1. From the perspective of maximum energy, the more hydropower stations built, the greater the potential total power generation capacity. But this is not the case in actual construction. Therefore, in this question, we need to take the maximum energy as the objective function and combine the actual water flow situation to establish constraints to determine the total number of hydropower stations that should be built.

5.2 Establishment of model

5.2.1 Determination of constraints

(1) Constraints on the number of hydropower stations

We adopt 0-1 programming to establish constraint conditions, assuming that c_i is variable 0-1, then：

$$c_i = \begin{cases} 1, \textit{when hydropower station } x_i \textit{ should be built} \\ 0, \textit{when hydropower station } x_i \textit{ should not be built} \end{cases} \quad (10)$$

The total number of hydropower stations does not exceed the 17 mentioned in problem:

$$\sum_{i=1}^{17} c_i \le 17 \quad (11)$$

(2) Constraints on runoff

Runoff is the amount of water passing through a section of a river in a certain period of time. We assume that the amount of water flowing through different hydropower stations is divided into two types: the amount of water flowing naturally through the power station from the river, and the amount of water flowing down when the power is generated by the upstream hydropower station, i.e., the generation flow. The calculation formula of power generation flow is as follows:

$$Q=\frac{N}{9.8H\eta} \tag{12}$$

Where, Q is the total flow of the generator set (m^3/s),N is the total flow of the generator set (kW),H is the mechanical energy per unit weight of liquid (m), η is power generation efficiency, According to the numerical simulation in the literature on the power generation efficiency of hydropower station, the value is about 80%[3].

We assume that the direct runoff of the i hydropower station is q_i and the generating flow is Q_i. We consider that the amount of water in the reservoir downstream for power generation and interception should be greater than the amount of water flowing into it, otherwise there may be a flood disaster due to insufficient drainage capacity. After consulting the data, we found that the results of the river closure model test of Jiacha Hydropower Station, which also located on the Yarlung Zangbo River, show that when the water flow into the hydropower station is 1080 m^3/s, the closure flow is 420 m^3/s [4]. It is calculated that about 60% of the original runoff flow passes through the hydropower station after cut-off. For ease of calculation, we assume that other hydropower stations located on the Brahmaputra River have the same interception capacity. We assume that there is a hydropower station x_i, its generating units used to generate electricity have a total flow rate of Q_i. After the closure of the dam through the hydropower station, the total flow of the remaining generating units is 0.6 Q_i, together with the ordinary runoff q_{i+1} flowing into the hydropower station x_{i+1}, it constitutes the water flow into the next hydropower station, which should be less than the outflow of the x_{i+1} hydropower station. According to the above principles, we can draw the following constraints on the runoff:

$$q_{i+1}+0.6Q_i \le (q_{i+1}+0.6Q_i)*0.4+Q_{i+1}+q_{i+1} \tag{13}$$

When the above constraint conditions are established, hydropower station can be built at the corresponding location. Combined with (1), we get the following inequality:

$$c_i=\begin{cases}1, q_{i+1}+0.6Q_i \le (q_{i+1}+0.6Q_i)*0.4+Q_{i+1}+q_{i+1}\\0, q_{i+1}+0.6Q_i > (q_{i+1}+0.6Q_i)*0.4+Q_{i+1}+q_{i+1}\end{cases} \tag{14}$$

5.2.2 Determination of objective function

We need to solve the potential maximum total generating capacity, so the maximum generating capacity is set as the objective function. Considering the different power generation of different power stations, we set the objective function as follows:

$$\max Z=\sum_{i=1}^{17} E_i c_i \tag{15}$$

Where, E_i is the power generation of the I-th hydropower station, and the calculation formula is the integral of the actual power generation over time:

$$E_i=\int_0^t N_i \eta dt \tag{16}$$

Where, N_i is the total electric power of the generator set of the i hydropower station (kW), it is determined by Q and H. The value of H varies according to the topography of the hydropower station. The calculation formula of Q (generation flow) is as follows：

$$Q = vs \tag{17}$$

Where, v is the flow velocity and s is the cross-section area of the hydropower station, which varies according to different river widths of the river area where the hydropower station is located.

5.2.3 Establish the model

From 5.2.1 and 5.2.2, we can know that the nonlinear programming model finally established is as follows：

$$\max Z = \sum_{i=1}^{17} E_i c_i \tag{18}$$

$$s.t.\begin{cases} \sum_{i=1}^{17} c_i \le 17, c_i = 0 \ or \ 1 \\ c_i = \begin{cases} 1, q_{i+1} + 0.6Q_i \le (q_{i+1} + 0.6Q_i) * 0.4 + Q_{i+1} + q_{i+1} \\ 0, q_{i+1} + 0.6Q_i \ge (q_{i+1} + 0.6Q_i) * 0.4 + Q_{i+1} + q_{i+1} \end{cases} \end{cases} \tag{19}$$

5.3 Solution of model

First, we refer to relevant data, and according to the relevant formula in 5.2.2, calculate that if 17 hydropower stations are established at the corresponding 17 locations in Problem1, the annual power generation of different hydropower stations can be obtained as shown in the table:

Table 6 the annual power generation of different hydropower stations

Hydropower station	Annual power generation(kw/h)	Hydropower station	Annual power generation(kw/h)
x1	48 billion	x10	54 billion
x2	56 billion	x11	25 billion
x3	83 billion	x12	27 billion
x4	81 billion	x13	18 billion
x5	50 billion	x14	9.5 billion
x6	15 billion	x15	7.5 billion
x7	19 billion	x16	13 billion
x8	22 billion	x17	14.5 billion
x9	38 billion		

Using Lingo17.0 to solve the nonlinear programming model established in 5.2, it is concluded that the two hydropower station sites x_4 and x_{10} should be removed on the original basis, and 15 power stations should be built at the other 15 sites respectively. At this time, the potential total power generation capacity is the maximum, 44.55 billion KWH per year.

6.Problem3

6.1 Problem analysis

For the problem 3, we need to explore the feasibility of the "Hongqi River" water diversion project from the perspective of economic benefits. First of all, the Hongqi River Project involves five rivers and one river, namely the Yarlung Zangbo, Jinsha, Yalong, Lancang, Nu and Dadu rivers. Therefore, the Hongqi River project cannot only consider the runoff of the Brahmaputra River. We consider the economic factors of the project from the following three aspects:

(1)The economic benefit of improving the water shortage situation in northwest China;

(2)The economic benefits of improving the local natural environment;

(3)The development cost of implementing "Hongqi River" project. Among them, the development cost includes: construction cost, technical cost and ecological loss cost caused by water transfer in the original southwest region.

Figure 6 The route of “Hongqi River” (after S4679 Research Group, 2017; WANG, 2017)

6.2 The economic benefits of improving the local natural environment

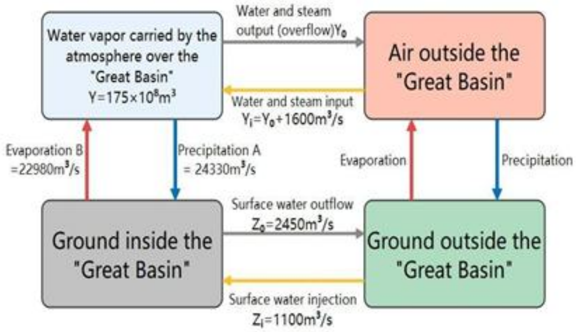
(profit-Environmental improvement，P-ei for short)

We viewed the entire Northwest as a "Great basin" [5]. According to the precipitation distribution map in recent years, the average annual precipitation in the "Great Basin" is estimated to be $A = 24330m^3/s$ (equivalent to liquid water, the same below) , the amount of water pumped into the "Great Basin " from the surface is estimated to be $Z_i = 1100m^3/s$. And the outflow from the "Great Basin" is the sum of four flows which the Yellow River's Sanmenxia station ($1350m^3/s$),Ertysh ($350m^3/s$), Erguna River ($300m^3/s$) , Shilka River ($450m^3/s$) is $Z_0 = 2450m^3/s$, so the net outflow is $Z_n = Z_i - Z_0 = 1350m^3/s$.

The net input of water vapor Y_n Should be the difference between water vapor input Y_i and water vapor output Y_0, then $Y_n = Z_n = 1350m^3/s$ (equivalent to liquid water, the same below).At the same time, the actual evaporation B in the "Great Basin "should be equal tothe difference of the precipitation A and the net outflow of surface water Z_n ,so $\mathrm{B} = A - Z_n = 22980m^3/s$.

The ratio of precipitation to actual evaporation is 106/100. Based on an average change period of 8.3 days for the amount of water vapor in the global atmosphere, the current amount of water vapor carried by the atmosphere over the "Great Basin" (the multi-year average) is about $175\times 10^8 m^3$.Its water cycle process is shown in Figure 7.

Considering the changes of Hongqi River Project on the "Great Basin", there are two main aspects: First, the increase of water vapor evaporation will make the water vapor above the basin reach saturation, which leads to the increase of rainfall. Second, Hongqi River project will increase the inflow of surface water in the basin. The calculation method of correlation value is the same as above. After relevant calculation, the future water cycle diagram of Northwest China is shown in Figure 8：



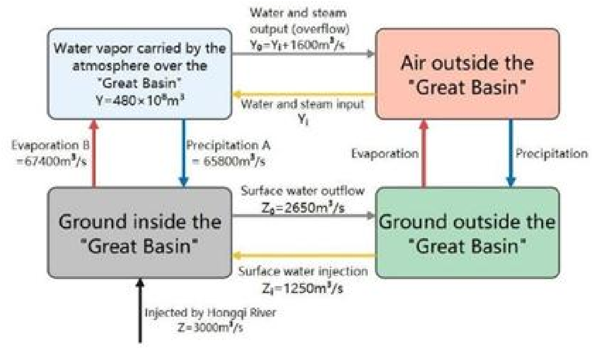


Figure 7 Diagram of current water cycle in Northwest China(left)

Figure 8 Diagram of future water cycle in Northwest China（right）

From the changes in the above two graphs, we can infer that:

The current average annual precipitation in northwest China is about 155mm, some places have almost no precipitation. After the construction of Hongqi River, northwest China will gradually become humid, and the annual precipitation will increase slowly until it reaches stability several hundred years later. It is preliminarily estimated that the stable annual average precipitation will not be lower than 500mm, and the precipitation in the Tarim Basin is 600mm ~ 1000mm. With this precipitation, the area of about 300×104km^2 in northwest China will be changed from "extremely unlivable ~ unlivable" to "basically livable ~ livable".

6.3 Economic benefits of improving water shortage in Northwest China

(profit-water resource, P-wr for short)

Experts envisage that when the Hongqi River project is designed to divert 60 billion m3 of water, it will create a giant oasis about 10,000 km long and 20km wide in northwest China. We set the water transfer to about 54% of the idea. Therefore, the area of oasis actually formed is 1.08×105 km^2. The ecological value and socio-economic value brought by oasis development are shown in Figure 9:

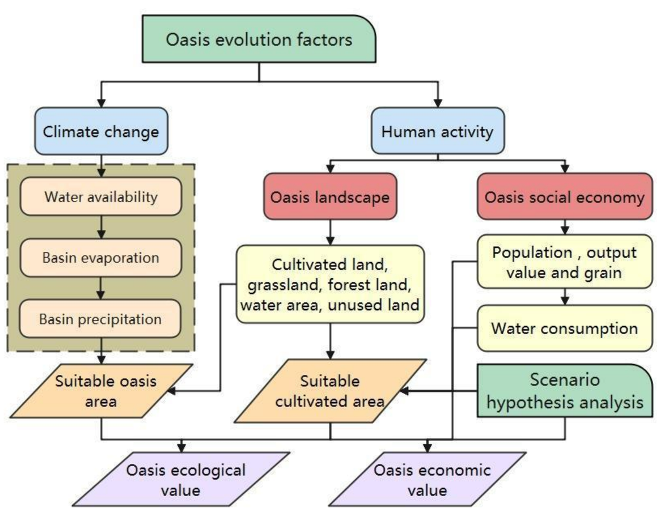


Figure 9 The ecological value and socio-economic value brought by oasis development

Oasis evolution is mainly influenced by climate change and human activities. In 6.2, we have mentioned that factors such as rainfall, evaporation and the corresponding amount of available water resources in the basin are mainly considered in the impact of climate change. The influence of human activities mainly leads to the change of oasis landscape type factors, including the change of land use type area of cultivated land, woodland, grassland, water area and unused land. If we want to know the influence of oases formed through Hongqi River Project on the economy of northwest China, we need to analyze the change indicators mentioned above, so as to obtain the economic benefits brought by oases.

To specifically calculate the ecological value and socio-economic value brought by the oasis, scenario analysis should be carried out first, as follows:

Table 7 Oasis planning scenario design

Scenario	Scenario design
Scenario1	20% reduction in population and agricultural acreage
Scenario 2	20% reduction in livestock production in industrial output value
Scenario 3	20% reduction in livestock production
Scenario 4	20% reduction in livestock production, population, agricultural acreage, industrial output value
Scenario 5	20% increase in population and agricultural acreage
Scenario 6	20% increase in industrial output value
Scenario 7	20% increase in livestock production
Scenario 8	20% increase in livestock production, population, agricultural acreage, industrial output value

Then we need to calculate the ecological value and socio-economic value separately under different scenarios. The socio-economic value is mainly calculated based on the output value of different local industries. We first found data on the output value of these industries in China's National Bureau of Statistics, and then increased or decreased the corresponding output value by 20% depending on the scenario. The formula for calculating land ecological value is as follows:

$$ESV = \sum (S_k \cdot VC_k) \qquad (20)$$
$$ESV_f = \sum (S_k \cdot VC_{fk})$$

Where, ESV is the annual ecosystem service value (RMB) for the region, S_k is the area of the KTH land use type (hm^2),in the study area, VC_k is the annual ecosystem service value per unit area of land use type k (RMB/hm^2), ESV_f is the total value of the annual service functions f of the regional ecosystem (RMB). VC_{fk} is the annual ecosystem service value of item f of the KTH land use type in the study area (RMB/hm^2).

After calculation and analysis, the results are as follows:

When the scenario combination is to increase population, increase arable land, increase animal husbandry and increase industrial combination (scenario 8), the sum of oasis ecological value and socio-economic value reaches the maximum value, which is 189.17×10^{10}RMB.

6.4 The development cost and benefit of implementing Hongqi River Project

6.4.1 Cost and benefit of Hongqi River Project in short term

Although the implementation of Hongqi River project will bring immeasurable economic benefits to northwest China, its high development cost cannot be ignored. Next, we will explain them separately from the development cost, construction cost, loss cost of water source (Yajiang, etc.) and negative impact cost in Northwest China:

(1) Development cost（Cost1）

Hongqi River project needs to pass through Hengduan Mountain area, Qinling Mountains and other numerous mountains and various complex terrain, ravines and valleys. The proportion of aqueducts and tunnels will be very large. The project passes through the second and third seismic zones of China, where strong earthquakes occur frequently. Therefore, the difficulty to solve the seismic problem is higher. We refer to the statistics of national science and technology expenditure in 2020 [6], the development cost is about 5 billion yuan.

(2) Construction cost（Cost2）

It is calculated that the river channel size needed to be established for the implementation of Hongqi River project is 100 meters wide and 10 meters deep. By referring to the general contracting scheme of Hongqi River earthwork project phase I, we can see that there are four earthwork projects of 9.32 billion, 3.6 billion, 2.2 billion and 1.6 billion, with the unit price above 140 yuan. A total of 16.72 billion cubic meters. According to this, it can be roughly inferred that the construction cost of Hongqi River project is 2340.8 billion yuan.

(3) Cost of water loss（Cost3）

With the $323 \times 10^8 m^3$ water transfer as the basis, that is to achieve the annual runoff of 20% or 21% of the proportion of annual water transfer. This part of water is not transferred but used for power generation, which can generate 1.404 times the Three Gorges power generation, about 151.2 billion KWH of electricity. At 0.2-0.65 yuan per KWH, the cost of electricity will be 307.8 to 97.2 billion yuan. The loss of a ton of water is 0.54~1.62 yuan, and a ton of water is 2.835 degrees.

(4) Cost of negative impacts in the Northwest Territories（Cost4）

According to the results of comprehensive treatment of saline-alkali land in the past, if the existing saline-alkali land comprehensive treatment can increase grain yield by at least $2250 kg/hm^2$,then the grain loss of saline-alkali cultivated land is 20.7 billion kg/a, and the annual loss of fresh grass of saline-alkali grassland is 121.8 billion kg. Salinized arable land in northwest China accounts for 15% of the total arable land, about 14.87 million hectares.The comprehensive treatment of salinized land in China needs a total investment of about 66 billion yuan.Combined with Hongqi River project, the actual area of oases formed is $108 \times 10^5 km^2$. If these supposed oases are turned into saline-alkali land, the loss will be about 1 billion yuan.

Based on the above analysis, we can calculate that,

Total cost:

$$Cost = Cost1 + Cost2 + Cost3 + Cost4 = 23775.8 \sim 24440 \; Hundred\ million\ yuan \tag{21}$$

The Net-profit-H of Hongqi River project is:

$$\text{Net-profit-H} = (\text{P-wr}) + (\text{P-ei}) - \text{Cost} = (-4858.8 \sim -5523) \; Hundred\ million\ yuan \tag{22}$$

Calculations show that in the short term of the initial completion of the diversion project, the Hongqi River project lost about 500 billion yuan.

6.4.2 Benefits of Hongqi River Project in the next 50 years

First, we need to calculate the net present value of Hongqi River Project in the next 50 years:

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} - CF_0 \tag{23}$$

Where, NPV is the net present value, CF_i is the cash inflow in each period, the earnings in each year, CF_0 is the construction cost of the first year. In addition to the construction input cost of Hongqi River project, there is also the cost of constructing the oasis city. r is the annual interest rate which is 3%.

As mentioned in 6.2 and 6.3, the water diversion of Hongqi River Project will form a $1.08 \times 10^5 hm^2$ oasis in northwest China, which has the greatest social and economic value when it is mainly used for industry, agriculture and animal husbandry. Therefore, we take the sum of the output value of agriculture, industry and animal husbandry as the annual income of this oasis. According to the data, the area of Xinjiang excluding desert is 1229,600hm^2, with a ratio of 15.3 to the oasis. Each year, the output value of industry is 1,359.711 billion yuan, the output value of animal husbandry is 91.53 billion yuan, and the output value of agriculture is 293.633 billion yuan. We assume that the development degree of this oasis in northwest China is roughly the same as that of Xinjiang, then according to the ratio, the annual industrial output value of this oasis is about 88.87 billion yuan, the output value of animal husbandry is about 5.98 billion yuan, and the agricultural output value is 19.19 billion yuan. When the output value of these industries is added together, CF_i is 114.04 billion yuan. And in calculating CF_0, We refer to the data [7] and find that it takes about 15 billion yuan to build a city of 1.22 million square meters, so we estimate that it takes about 1300 billion yuan to build a city in this oasis, which is about 1301 trillion yuan when added to the input cost of Hongqi River project. The value of NPV can be obtained by plugging in the above values.

Next, we calculate the economic benefit-cost ratio, that is, the ratio of NPV to the construction cost in the first year. The calculation formula is as follows:

$$EBCR = \frac{NPV}{CF_0} \tag{24}$$

The calculated value of EBCR is -0.99, and the result is negative. It is considered that the project has a serious loss from the economic perspective.

7. Problem4

7.1 Problem analysis

In the first three issues, we have discussed separately: the feasibility of building hydropower stations on the Brahmaputra; Maximization of power generation; The economic benefits of Hongqi River Project. Obviously, there is a certain restrictive relationship between the hydropower project and Hongqi River project. The core of this question is to describe this constraint relationship, so as to rationally allocate the water resources of the Brahmaputra.

7.2 Model establishment

7.2.1 Preparation and description of the model

(1)In problem 2, we analyzed the maximum power generation capacity of several hydropower stations built on the main stream of the Yarlung Zangbo River. For this question, we need to convert the research center from maximum power generation to maximum economic benefits. Although the research direction has changed to some extent, the previous research methods mentioned above can be used for reference.

(2)The starting point of the Hongqi River project is the "big bend" of the Yarlung Zangbo River. For convenience, we may define this point as point D. The Hongqi River Project diverts water from Point D, and the hydropower resources available to the hydropower station downstream of Point D will be reduced accordingly. The hydropower stations upstream of Point D are not affected. Refer to problem 1, we stipulated that the hydropower stations involved downstream of point D are recorded as：

$$x_{1i}(i = 1,2,...,n') \tag{25}$$

Where, n' represents the maximum number of hydropower stations that can be built downstream of point D.

(3)According to question 2, we can calculate the power generation of each hydropower station, which is denoted as $e_{1i}(i=1,2,...,n')$ .Refer to the price of 0.2-0.65 Rmb/kWh. The specific electricity price used in the calculation process is defined as v_0 .We can infer roughly the economic benefits of each hydropower station. In problem 2, we have defined the relationship between runoff and the amount of electricity generated by a hydropower station. According to the data, the price of hydropower station construction is about 5000-10000 Rmb/kilowatt hydropower station[6]. In this way, we can obtain the approximate cost of building hydropower stations at different locations of the Yarlung Zangbo River, which is defined as $c_{1i}(i=1,2,...,n')$

(4)The total amount of raw water energy resources at point D is : U ; the total amount of hydropower used by the downstream hydropower station at point D is U_1 ; the total diversion amount of Hongqi River project is : U_2

(5)The total economic income of hydropower station is V_1 .The calculation method of economic benefits of Hongqi River project refers to problem 3, which is defined as V_2.And we define the annual average income obtained by solving Problem 3 as V_t . The sum of the economic benefits of the two projects is V. Costs can be similarly defined as: C_1, C_2, C, and $C=C_1+C_2$.

7.2.2 Determination of objective function

We need to solve the maximum value of the comprehensive utilization scheme of the Yarlung Zangbo River water resources, so the maximum value was set as the objective function. Considering that value consists of benefits and costs, we set the objective function as follows:

$$\max V = V_1 + V_2 - C \tag{26}$$

7.2.3 Determination of constraints

(1) Constraints on the total amount of water energy

Obviously, the utilization of hydropower for hydropower cannot reach 100%, that is:

$$U_1 + U_2 \le U \tag{27}$$

(2) Each hydropower station planned to be built should maximize its economic benefits:

$$v_{1i} = \max(e_{1i} \bullet v_0 - c_{1i}) \quad i=1,2,...,n' \tag{28}$$

(3) The sum of economic benefits of hydropower station is :

$$V_1 = \sum_{i=1}^{n'} v_{1i}(i=1,2,...,n') \tag{29}$$

(4) Cost of Hongqi River Project: $V_2 = \sum_{t=1}^{50} V_t \bullet \frac{U_2}{U}(t=1,2,...,50)$ (30)

7.2.4 Model establishment and solution

After the above analysis, the final nonlinear programming model is as follows:

$$\max V = V_1 + V_2 - C \tag{31}$$

$$s.t.\begin{cases} U_1 + U_2 \le U \\ v_{1i} = \max(e_{1i} * v_0 - c_{1i}) \\ V_1 = \sum_{i=1}^{n'} v_{1i}(i=1,2,...,n') \\ V_2 = \sum_{t=1}^{50} V_t \cdot \frac{U_2}{U}(t=1,2,...,50) \end{cases} \tag{32}$$

Combining the planning scheme of Problem 2 and problem 3, we used matlab to solve the problem. The algorithm is described as follows:

Algorithm 1: Maximum economic benefit solver

Input: U_1 U_2
Output: V
for i = 1 to n **do**
  for t = 1 to 50 **do**
    According to x_i t , relevant V_{1i} V_1 can be calculated.
    Randomly select U_1 & U_2 from (0,1).
    Calculate the corresponding V_1 V_2 C.
    Then the total income is recorded as V
  end
end

The results show that when the Hongqi River project water diversion is 17.3% of the Yarlung Zangbo River runoff, the total benefit of the development planning of the Yarlung Zangbo River is the largest.

This result is quite close to 21% of problem 3, which proves the accuracy and rationality of the model from the side. At the same time, we can draw a conclusion that the hydropower project has greater economic benefits than the Hongqi River project.

8.Problem5

8.1 Problem analysis

In this problem, we first analyzed the interest appeals of China and India on cross-border rivers, and adjusted the comprehensive development plan according to this. After consulting the literature[9], we found that the interest appeals of China and India are as follows：

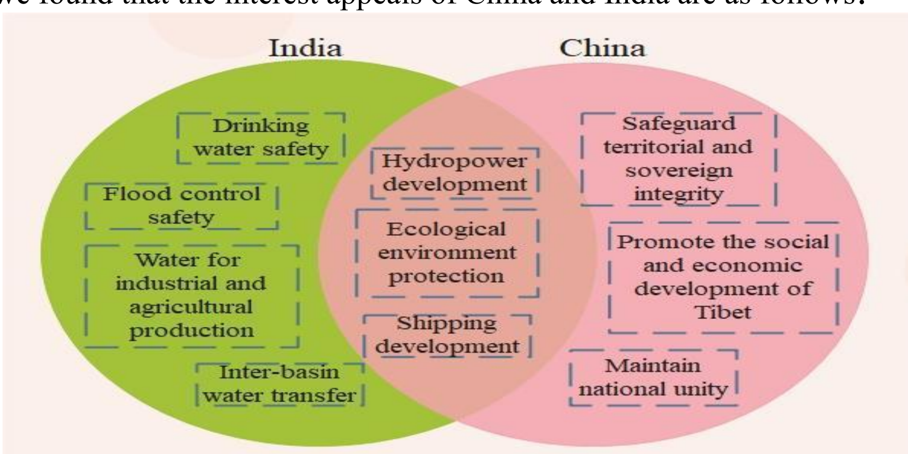


Figure 10 The interest appeals of China and India

It can be seen from the figure that some of the interest appeals between China and India are compatible, such as hydropower development, ecological environment protection and shipping development, while some of them have obvious conflicts, such as sovereignty, territorial integrity, inter-basin water transfer, etc. The compatibility and conflict of interests lead to a complex interdependent relationship between China and India, and this interdependence has a unique impact on the relationship between China and India. Therefore, we build a game model, analyze the game between the two sides, and give China's strategic response to the problem of transboundary rivers.

8.2 Establishment of game model

The Yarlung Zangbo River is a river with water rights in both China and India. The development and utilization strategy between the two sides is based on the respective interests of both countries, and the final distribution of water rights in the river mainly depends on their respective interests game.

We can establish the following game model for research, and the model assumptions are as follows：

✧Hypothesis of game subject: the game participants are both China and India.

✧ The game information environment hypothesis: the game is an imperfect information game. Each participant knows his own type, but not the type of other participants, that is, both parties do not know the strategic choice of the other party.

✧Rational assumption: both sides will take the most favorable actions.

The dynamic game model of China-India water rights in Yarlung Zangbo River is shown in Figure 11：

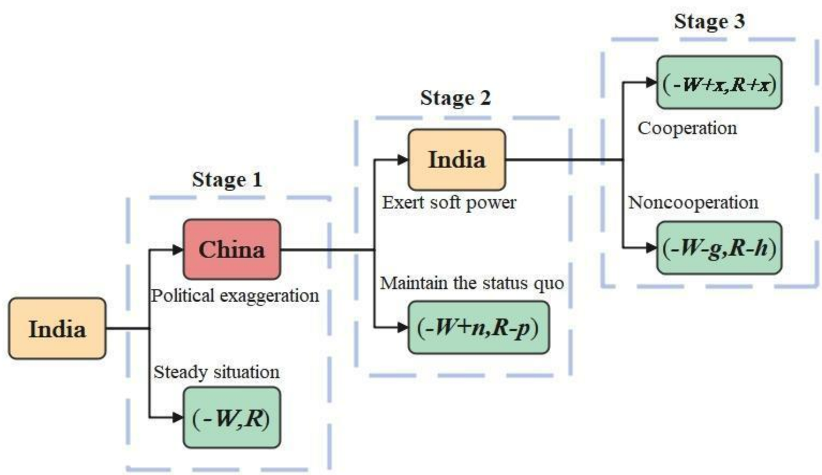


Figure 11 Dynamic Game Model of China-Indian Water Rights

Where,R is the benefit of China's water resources development; $-W$ is the loss suffered by India in China's water resources development; n is the sympathy of domestic and international public opinion gained by India; $-p$ is the loss of China's international image caused by India's political exaggeration; $-g$ is the total loss of India under the strategic choice of non-cooperation; $-h$ is the total loss of China under the strategic choice of non-cooperation;x & y are the respective benefits for India and China after cooperation.

8.3 Analysis of game results

According to the dynamic game model, both sides take the most favorable strategic path choice according to the interest orientation. China can not only maintain its own water rights interests through the role of soft power, but also reach a cooperative game to obtain further long-term benefits through development and utilization.

We analyzed the national conditions of the two countries and put forward some suggestions on China's adjustment of the development plan for the construction of hydropower stations:

✧ Advice 1： The Chinese side can adjust the construction plan and do not build hydropower stations near the Brahmaputra River in India to avoid hindering the normal operation of hydropower stations in India.

✧ Advice 2： China should continue to promote the development and utilization of water resources in the Brahmaputra region. For rivers downstream but still located in southern Tibet, China should also build hydropower stations, but can promise to share hydrological information with India.

9. Sensitivity analysis of the model

Since the fuzzy weight is determined by the expert consultation method in this paper to analyze the feasibility of constructing hydropower station, it is subjective to a certain extent. In order to ensure that the evaluation model is more practical and scientific, we need to discuss the influence of the relevant weight vector on the feasibility of constructing hydropower station.

A total of four factors were compared, namely, geological conditions, economic benefits, environmental factors and hydrometeorology. We only need to change the weight of these factors appropriately. In order to ensure the fairness of the experiment, we only change them slightly (up or down no more than 0.1). Here, we tested the case of weight recombination of each factor adjusted higher by 0.09. The result is shown in Figure 12：

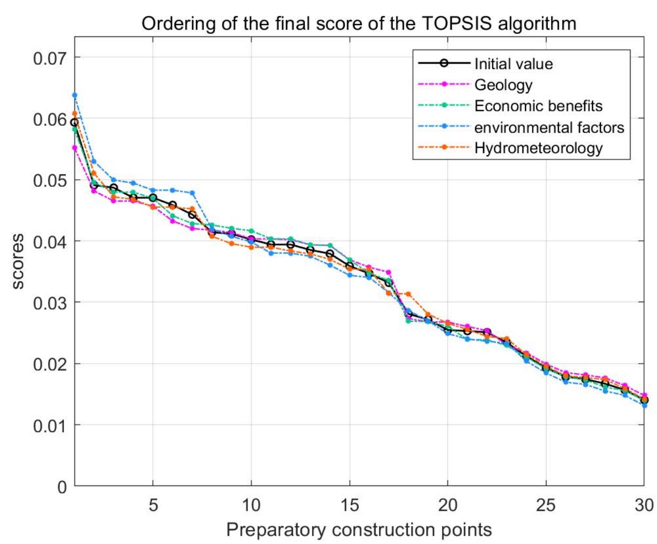


Figure 12 Sensitivity analysis - Weight

We can see that the final result suitable for the establishment of hydropower stations is still dominated by $x_1, x_2, \ldots, x_{17}$. Our model is stable.

Conclusion: The weight of these factors has a small impact on our model, and our model is not affected by subjective factors.

9.Problem6

To promote the "implementation of hydropower development in the lower reaches of the Yarlung Zangbo River" in its proposal for formulating the 14th Five-Year Plan for National Economic and social Development and Vision 2035， we wrote a letter of advice to the Chinese government based on our analysis of the Yarlung Zangbo River development plan.

Dear Chinese Government：

First of all, I would like to express my sincere greetings to you.

The longest plateau river in China is located in the Qinghai-Tibet Plateau. It is the cradle of Tibetan people's culture and has always been called "Tianhe". This river is the Yarlung Zangbo River. The water level in the upper and lower reaches of the Yarlung Zangbo River bed has dropped significantly, and the water energy reserves are abundant, which is a gift from nature.

However, in recent years, the contradiction between the rapidly developing economy and the increasingly scarce resources has gradually intensified. We should make full use of the water resources of the Yarlung Zangbo River, for example, to carry out hydropower or build water diversion projects. They can all alleviate the urgent need. We have studied this and given some suggestions based on the research results, hoping to enlighten you.

1. The construction of hydropower station can comprehensively consider various factors.

Site selection is crucial for hydropower station construction projects. Due to the different flow velocities in different basins, the thickness of bedrock and overburden in the dam site area are different. From the perspective of sustainable development, the impact of the construction of hydropower stations on the ecological environment also needs to be assessed.

Our model comprehensively considers the input and income, geological conditions, hydrological conditions and other factors, constructs 17 suitable locations for the construction of hydropower stations for the Yarlung Zangbo River, and takes into account the corresponding economic benefits and power generation capacity.

2. There is no conflict between the construction of hydropower station and water diversion project.

The construction of hydropower station and Hongqi River project on the Yarlung Zangbo River can be comprehensively considered and coordinated. Our model shows that when the funds are fixed, the water resources at the "big turn" of the Yarlung Zangbo River should be reasonably allocated, and then the value of the water resources of the Yarlung Zangbo River can reach the maximum.

3. The sharing of hydrological information and the development and utilization of water resources should be bound in the Sino-Indian cross-border river negotiation.

As an upstream country, China has the obligation to provide hydrological information to help the downstream country, India, to better flood control and develop and utilize river resources, but hydrological information should be shared in both directions.

Finally, I sincerely wish your country a better and better development.

#MI00779
2023.2.05

11. Evaluation and extension of the model

11.1 Advantages

✧ Our models effectively achieved all of the goals. For the construction of hydropower station and Hongqi River project, we have considered all possible main factors. In addition, we have also made corresponding assumptions and explanations for some extreme cases.

✧ The sensitivity analysis of the model demonstrates the effectiveness of the model under different parameter combinations and prove the robustness of the model;

✧ The visualization work is done very well by us, such as the framework of various research methods, the change trend and distribution of various influencing factors in question 1, and the road map of the Hongqi River project in question 3 etc. Boring data may be able to reflect the law, but not as intuitive as so many images.

11.2 Improvements and Extension of the model

Our model has the following limitations and related improvements:

✧ The analysis of feasibility of hydropower station establishment can be more accurate if we have more complete data;

✧ The Hongqi River Project not only transports the water resources of the Yarlung Zangbo River and other basins to the northwest of China, but also has two branch lines, ending in Beijing and Yan'an.

12.Refernence

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12.Appendix

Appendix 1
Introduce: Tools and software
Paper written and generated via Office 2019. Graph generated and calculation using MATLAB R2021b & Python 3.8. & Lingo17.0

Appendix 2

Introduce: ModelI: AHP-TOPSIS

```
clear all;clc
%% single-factor judging matrix
R1=[0.91 0.85 0.87 0.98 0.79 0.60
0.92 0.81 0.93 0.87 0.61 0.61
0.88 0.82 0.88 0.64 0.61 0.95];
R2=[0.90 0.90 0.90 0.94 0.60 0.91
0.90 0.90 0.87 0.95 0.87 0.65];
R3=[0.60 0.95 0.60 0.95 0.95 0.95
0.60 0.71 0.70 0.60 0.80 0.95];
R4=[0.60 0.71 0.77 0.60 0.82 0.95
0.92 0.90 0.93 0.91 0.95 0.93];
%% Weight
A=[0.1 0.3 0.4 0.2];A1=[1/3 1/3 1/3];
  A2=[0.6 0.4]; A3=[0.3 0.7];A4=[0.7 0.3];
%% Result
B1=A1*R1;B2=A2*R2;B3=A3*R3;B4=A4*R4;
R=[B1;B2;B3;B4];
B=A*R
```

Appendix 3

Introduce：Sensitivity analysis

```
clear all
clc
%% Import data
X=xlsread('data.xlsx');
%% Data preprocessing_forwardization
[n,m] = size(X);
disp(['There are ' num2str(n) 'evaluation subjects, '
num2str(m) 'evaluation indicators'])
Judge = input(['There are' num2str(m) 'Whether the
indicators need to be forwardized, please enter 1
and do not need to enter 0: ']);
if Judge == 1
    Position = input('Please enter a column, for
    example [2,3,6]:'); %[2,3,4]
    disp('Please enter (1: very small, 2: intermediate,
    3: interval) ')
Type = input('For example[1,3,2]：   '); %[2,1,3]
for i = 1 : size(Position,2)% forwardize each
column
X(:,Position(i)) =
Positivization(X(:,Position(i)),Type(i),Position(i));
end
disp('Matrix after forward orientation X = ')
disp(X)
end
%% figure
plot(sorted_S,'k-o','MarkerSize',4,'LineWidth',1)
xmin=1;xmax = size(sorted_S,1);
ymin = 0;ymax = max(sorted_S)+min(sorted_S);
axis([xmin xmax ymin ymax]);
grid on
xlabel('Preparatory construction
points');ylabel('scores');
title('Ordering of the final score of the TOPSIS
algorithm')
hold on;
plot(sorted_S_1,'-.*','MarkerSize',3,'color',[1 0
1],'LineWidth',0.8)
hold on;
plot(sorted_S_2,'-.*','MarkerSize',3,'color',[0 0.78
0.55],'LineWidth',0.8)
hold on;
plot(sorted_S_3,'-.*','MarkerSize',3,'color',[0.12 0.56
1],'LineWidth',0.8)
hold on;
plot(sorted_S_4,'-.*','MarkerSize',3,'color',[1 0.38
0],'LineWidth',0.8)
legend('Initial value','Geology','Economic
benefits','environmental factors','Hydrometeorology')
```