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Research Article

Identify and Assess Hydropower Project's Multidimensional Social Impacts with Rough Set and Projection Pursuit Model

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To realize the coordinated and sustainable development of hydropower projects and regional society, comprehensively evaluating hydropower projects' influence is critical. Usually, hydropower project development has an impact on environmental geology and social and regional cultural development. Based on comprehensive consideration of complicated geological conditions, fragile ecological environment, resettlement of reservoir area, and other factors of future hydropower development in each country, we have constructed a comprehensive evaluation index system of hydropower projects, including 4 first-level indicators of social economy, environment, safety, and fairness, which contain 26 second-level indicators. To solve the problem that existing models cannot evaluate dynamic nonlinear optimization, a projection pursuit model is constructed by using rough set reduction theory to simplify the index. Then, an accelerated genetic algorithm based on real number coding is used to solve the model and empirical study is carried out with the Y hydropower station as a sample. The evaluation results show that the evaluation index system and assessment model constructed in our paper effectively reduce the subjectivity of index weight. Applying our model to the social impact assessment (SIA) of related international hydropower projects can not only comprehensively analyze the social impact of hydropower projects but also identify important social influencing factors and effectively analyze the social impact level of each dimension. Furthermore, SIA assessment can be conducive to project decision-making, avoiding social risks and social stability.

1. Introduction

In the 20th century, human beings have witnessed the rapid development and change of hydropower projects. Policies enacted by US President Franklin Roosevelt, including the New Deal in the 1930s, supported the construction of several multipurpose projects such as the Hoover and Grand Coulee dams, making hydropower account for 40 percent of the country's electricity generation by 1940 [1, 2]. Over the last decades of the twentieth century, Brazil and China became world leaders in hydropower. The Itaipu Dam, straddling Brazil and Paraguay, came into operation in 1984 with a capacity of 12,600 MW, which was enlarged to 14,000 MW [3, 4], second to the 22,500 MW Three Gorges Dam in China [5, 6]. Hydropower had been widely regarded as an important alternative energy source and hydropower engineering grows at an alarming speed. In 2018, International Hydropower Association (IHA) reported in its Annual Hydropower Status Report that worldwide hydropower installed capacity has risen to 1,267 GW, with a record estimate of 4,185 TWh to be generated in 2019. At the same time, as people are increasingly aware of the environmental and social impacts around the world, the value of hydropower and its role in national development needs to be reassessed [7, 8].

Large-scale hydropower projects are characterized by large construction scale, long construction period, complex geographical conditions in hydropower development areas, and great changes in social environment. These are closely related to social and economic level, social environment, and social development of the construction location, which make them produce multidimensional social impact evaluation

problems [9–14]. In view of the problems and new situations faced by hydropower station development, it is necessary to carry out comprehensive evaluation of various social impacts caused by the project before its implementation and reduce all kinds of adverse effects and risks to realize coordinated development of hydropower development and society. China's terrain is high in the west and low in the east. So most of Yunnan, Guizhou, Sichuan, and Tibet in the southwest are mostly located in the upstream of rivers. Hydropower development has unique advantages in these areas. At present, the exploitable volume of hydropower technology in Southwest China is 450 million kilowatt, accounting for 68.2% of the country, of which the undeveloped hydraulic resources account for 52.1% of the total amount in Southwest China. It is estimated that the installed capacity of hydropower plant will exceed 380 million kW by 2020. The hydropower development in the next step will still distribute hydropower development in the West and Middle East reasonably. Sichuan, Yunnan, and Tibet are the main areas in southwest China; large-scale hydropower projects are focused here [15–17]. The particularity of natural and human environment in Tibet, Yunnan, and other areas lies in that they belong to plateau areas, and their natural environment is affected by plateau climate. For example, there is low pressure oxygen deficiency, temperature gradually decreases with the increase of altitude, etc. At the same time, there are many minorities in these areas, so there are also particularities in the human environment. Customs, habits, and religious beliefs of all nationalities have their own characteristics. In these areas, there are social impact assessments including migration, poverty, and religious cultural risks in the construction and operation of hydropower projects.

Large-scale infrastructure construction can drive the economic and social development of backward areas to seek balanced development. This is an important strategy for many countries to reduce regional development gaps. Wongphat and Premrudeepreechacharn took Thanthong Village, Mea-On district, Chiang Mai province, as the research object to evaluate the engineering and economic feasibility of the microhydropower project [18]. Hou-jun emphasizes that the essence of hydraulic engineering is to get along harmoniously with nature on the premise of serving human beings with natural forces. At the present stage, the management of hydraulic engineering construction must be improved. Based on the current economic new normal, people make a brief analysis on the improvement of hydraulic and hydropower engineering construction management [19]. Jordao and Moretto considered that eco-economic zoning is a tool to consider multiple land use patterns. The study focuses on Mato Grosso in the Amazon region. Its purpose is to analyze the "usefulness" of eco-economic zoning for hydropower station site selection before environmental impact assessment [20]. The development of hydropower projects will bring about huge economic and social benefits, but there are also problems in reservoir resettlement and ecological environment protection [21, 22]. The birth of social impact assessment was marked by the National Environmental Policy Act (NEPA) passed by the U.S. Congress in 1969, which required the United States to provide environmental impact reports [23]. Xu et al. and others put forward the principles and methods of landscape ecological corridor construction through discussing the ecological environment problems in disturbed areas of hydropower projects and provided scientific basis for ecological restoration and energy security construction in disturbed area of hydraulic and hydropower projects [24]. Chen considers that the ecological environment impact assessment of hydropower projects is a complex project, which involves natural environment, ecological environment, and social environment. Therefore, the establishment of a complete and accurate evaluation system is an important prerequisite to complete the evaluation work [25]. Li and Jiang proposed that the construction of water conservancy and hydropower projects destroyed the original ecological balance to a certain extent. Therefore, in the process of constructing hydropower projects, environmental awareness should be raised, environmental impact assessment system should be improved, and ecological compensation mechanism should be established [26]. The whole life cycle of large-scale hydraulic and hydropower projects should adhere to the concept of ecological environment protection and harmonious development and combine ecological benefits with engineering construction. In order to guarantee the ecological balance in the area, we need to construct a perfect ecological compensation mechanism to seek a balance between economic development and environmental protection and reduce the impact of engineering construction on the surrounding environment and then improve the overall social benefits.

Social impact assessment (SIA) is a technical means of prepost event analysis and assessment of social impact, consequences of policies, projects, events, activities, etc. [27]. In 2003, the United States formulated the Principles and Guidelines for Social Impact Assessment under the background of NEPA and offered guidance on engineering projects, planning, and policies [28]. At present, the social impact assessment of engineering projects has become an essential link in project implementation. Scholars have carried out research on social impact evaluation of engineering projects before construction, such as design planning and development decision, and emphasized the importance of hydropower projects in the process of project approval to avoid unnecessary social conflicts. Through research on the results of some leading experts, it is found that many Asian countries (Bangladesh, Laos, Nepal, Pakistan, etc.) will use social impact assessment to optimize the project in the project planning stage so as to better promote social development [29]. Mathur and Gonnetilleke evaluated the social impact of research projects from the following four aspects: the Bridge Project in Bangladesh, the hydropower project in Nepal, the hydropower project in Pakistan, and the South Transportation Project in Sri Lanka. Through cross-cultural and comparative studies of these cases, they can provide experience for the design of future large infrastructure projects and sustainable migration [29]. However, some new problems will arise in the process of project construction. Traditional project evaluation has its limitations in both content and method.

Traditional project evaluation points out that social impact assessment should consider the elderly and other vulnerable groups [30]. When evaluating the social impact of public projects invested by the government, we should focus on four aspects: positive benefits, residents' lives, natural environment, and special groups [31]. In terms of methods, some scholars have systematically analyzed the social impact of dam by means of literature analysis method [32]. Other scholars use the dynamic simulation method of system dynamics (SD) to evaluate the social impact of large-scale development projects [33]. Based on the above research, we can find that social impact ranges vary greatly among different types of planning and projects. Depending on the existing social factors, research studies' focus will be different. We can adjust them according to the specific conditions of actual projects, which can better reflect the social problems caused by major projects.

Social impact assessment is a complex and huge system; it is difficult to define which changes in regional society are directly caused by social development. The social impact of hydropower projects is a complicated problem involving many indexes in a high dimension. There is no systematic evaluation standard yet. Liu Jian and others used case study methods to study the sustainable development of the Three Gorges Dam Project. The research shows that the project has achieved certain benefits in economy, environment, society, and other aspects [21]. Philip Newsome conducts a comparative assessment of sustainability standards in terms of economic efficiency, social equity, ecological sustainability, and governance. Large-scale hydropower projects are available for sustainable development in ecologically important areas such as the Amazon and Mekong River basins [34]. Risako Morimoto proposed the use of sustainability indicators for hydropower projects to study the relationship between the economic, environmental, and social impacts of hydropower development [22]. From the above analysis, we can see that social impact assessment is a process assessment, focusing on the process results of the project rather than just quantitative indicators. The core is to promote the comprehensive awareness of project social impact by government, society, and audiences and put forward measures for improvement or avoidance. On this basis, our study no longer simply measures the economic and environmental benefits of the project. It extends the assessment scope to the multifaceted impacts of the project on the sustainable development of local communities, residents, and social resources and establishes a multidimensional social impact assessment index system.

The index system of our study is to comprehensively evaluate the social impact of hydropower projects from all aspects as much as possible. However, for a specific hydropower project, the social impact may focus on several aspects. Too many reserved indexes tend to lead to too scattered weight; thus the importance of key impact indicators is covered up. The rough intensive reduction can be achieved through multiple indexes, and system reduction keeps important indexes to ensure the objectivity and integrity of social impact assessment of hydropower projects [35].

AHP, fuzzy comprehensive evaluation, DEA, and other index evaluation methods often have the problem of subjective judgment weight or empirical judgment weight, so the results are not scientific and not objective and the robustness is poor [36]. In 1991, the projection pursuit learning network model is constructed by combining the projection pursuit model with an artificial neural network, which can effectively solve the mathematical problems of smoothing nonlinear functions and functions [37]. At present, this method is mostly applied in the field of natural science. In 2011, the projection pursuit model is used for clustering analysis of time-series images of the West Coast environment to automatically classify them [38]. Based on multiple regression analysis, a projection pursuit regression model is established and applied to deal with problems in the economic field [39]. In the study of water resource safety assessment, a projection pursuit model based on information entropy to determine the weight and optimized by the accelerated genetic algorithm is established [40]. To solve the problem of cultivated land security in urban suburbs, a projection pursuit with a genetic algorithm to build a RAGA-PP (Real-coded Accelerating Genetic Algorithm-Projection Pursuit) model based on real-coded accelerated genetic algorithm optimization to solve this multiobjective and multifactor comprehensive evaluation problem is proposed [41]. As far as we know, the RAGA-PP model is seldom used in the social impact assessment of hydropower projects [42–44].

Based on the above analysis, our paper uses a hydropower project as the main research object to carry out in-depth research and analysis on its social impact assessment. The innovations lie in the following: (1) We consider the characteristics of social impact of large-scale hydropower projects. The complex social impact system of hydropower projects is divided into four dimensions: social environment, social economy, social security, and social equity. We select evaluation indexes while considering hydropower characteristics and build evaluation index system of social impact of large-scale hydropower. (2) A new, effective multiobjective dimension reduction method is proposed in our study by combining rough set and RAGA-PP (Real-coded Accelerating Genetic Algorithms-Projection Pursuit). We identify and evaluate the comprehensive impact of each dimension on local society, together with potential positive or negative social impact of large-scale hydropower projects, providing theoretical guidance for the construction and management of hydropower projects.

2. Materials and Methods

2.1. Study Area. The project example Y hydropower station is located at the end of the Panzhihua section of the middle reaches of the Jinsha River. Its main development tasks are power generation and improvement of urban water landscape and water extraction conditions. The construction period of the project is 2005–2017 and 2017–2019 is the impact period after the completion of Y hydropower station. Y power station harnesses 259800 cubic kilometers of the river basin, which enjoys an annual average flow of 1870

cubic meters per second, an annual runoff of 59 billion cubic meters, a total storage capacity of 59 million cubic meters, and a regulating storage capacity of 1.8 million cubic meters. It is a runoff type power station. The installed capacity of the power station is 390 megawatts, with a maximum dam height of 73 meters and an annual average power generation of 1.655 billion kWh. The climate and local ecological environment of the dry-hot valley can be improved after completion of the project. Creating conditions for the development of shipping in reservoir area has irreplaceable far-reaching impact.

2.2. Data. The period of our study, from 2005 to 2019, covers more than 10 years of well-documented data, during which the social impact of hydropower projects in China had been gradually expanding. There are 12 quantitative indicators in the evaluation system. Among them, there are 7 indexes: employment effect of people, resettlement effect of resettlement, energy saving, emission reduction, power generation benefit, tourism benefit, and contribution of regional GDP and financial income. The calculation results can be further corrected according to the feasibility study report, other relevant report data of Y hydropower station, and the calculation formula of quantitative index.

The other five types of quantitative index data were obtained from the Chinese Yearbook Network. The qualitative index of our study adopts the expert scoring method by employing 80 experts to grade the evaluation index. The expert panel shall consist of personnel from design sectors, management positions, and operation and maintenance departments related to Y hydropower station. Considering the difficulty of hiring qualified experts, our paper directly simulates experts' assessments based on substantial data of Y hydropower station to fit the actual situation of the project and verify the feasibility and effectiveness of the social impact assessment model (see Appendix A for expert scoring results).

2.3. Comprehensive Evaluation Index System for the Social Impact of Hydropower Projects. Hydropower project has the characteristics of complex geographical conditions in the development area, great changes in social environment, large construction scale, long construction period, and many stakeholder groups. As a result, the construction of hydropower projects has a wide social impact, with a long, deep, and wide impact [45]. From the perspective of impact content, the construction and operation process of the project is closely related to the social and economic level, social environment, and social development of the construction location. Therefore, compared with other large-scale projects, social impact assessment of hydropower projects involves many indicators, such as resettlement effect, satisfaction of farmers' quality of life, and protection of national interests.

Based on the existing evaluation index system of hydropower projects and the development level of hydropower projects in China [33, 46–49], the social impact evaluation system of hydropower projects is established with four primary indicators of the social environment, social economy, social equity, and social security (see Table 1).

2.4. Methods. Rough set reduction theory is used to process the index data to get the importance degree of each index and then to calculate the weight of each index, which lays the foundation for the objectivity and integrity of large-scale hydropower social impact assessment [50, 51]. Projection pursuit (PP) is a statistical method for analyzing and processing high-dimensional observation data, especially for nonlinear and nonnormal high-dimensional data problems. It has the advantages of good robustness, strong anti-interference, high accuracy, and wide applicability to many fields [52, 53]. Even though a solution to optimal projection direction is a highly complicated nonlinear optimization problem, there are multiple mature algorithms to deal with this problem [54–57]. In our paper, a relatively mature genetic algorithm is selected as the basic algorithm to solve the best projection direction (RAGA: Real-coded Accelerating Genetic Algorithm). The main purpose of the algorithm is to compress the optimization interval of SGA to decrease the time of the algorithm and improve the speed of operation to obtain the optimal solution [58].

2.4.1. Reduction Index Based on Rough Set

(1) Continuous Data Discretization. Our paper chooses the method of constant width discretization [59]. Condition indicator C_{xy} discrete value interval is

$$l_{xy}^{*} = \frac{\max\left(l_{xy}\right) - \min\left(l_{xy}\right)}{m}, \tag{1}$$

where l_{xy}^{*} represents the length of the interval, $\max(l_{xy})$ represents indicator C_{xy} maximum value, $\min(l_{xy})$ represents indicator C_{xy} minimum value, m represents the set number of discretization intervals.

(2) Building a Decision Table. Decision table $S = \{U, A, V, f\}$ to represent the results after the data is discretized, use $U = \{U_1, U_2, \cdots, U_m\}$ to represent the collection of evaluation objects, and use $C = \{C_1, C_2, \cdots, C_z\}$ to represent condition attribute evaluation index set, whereas $C_x = (1, 2, \cdots, z)$ as a first-level indicator attribute; if the first-level indicator contains the second-level indicator attribute, $C_{xy} = \{C_{x1}, C_{x2}, \cdots, C_{xy}\}$ is available to describe; otherwise, use $R = \{r\}$ to represent the decision attribute set.

(3) Attribute Reduction. Assume that $r_0 \in R$, in case $\mathrm{IND}(R - \{r_0\}) = \mathrm{IND}(R)$ attribute r_0 in R is redundant, and r_0 are redundant attributes; otherwise, r_0 in R is necessary. If every attribute $r \in R$ is absolutely necessary in R, then the attribute set R is independent; otherwise, R is reductive. The set of all absolutely necessary attributes in R is called attribute core and recorded as core (R). Let P and Q be two equivalent relation clusters on the domain, and $Q \subseteq P$. If $\mathrm{IND}(Q) = \mathrm{IND}(P)$ and Q are independent, then Q is an absolute reduction of P and recorded as red (P).

Table 1: Social impact assessment indicators of hydropower projects.

Target layer	First-level indicator layer	Secondary indicator layer	Indicator description and calculation method	Indicator type
Comprehensive social impacts of hydropower projects	Social environmental impact B_1	Population impact b_{11}	Demographic changes caused by hydropower project construction	Quantitative
		Employment effect b_{12}	Total number of people employed × (annual investment in power stations/total investment in engineering) (unit: person)	Quantitative
		Infrastructure b_{13}	Before large-scale hydropower projects officially start, local infrastructure needs to be transformed	Qualitative
		Resettlement effect b_{14}	Resettlement effect = resettlement completion rate + resettlement stabilization rate	Qualitative
		Ecological and environmental impact b_{15}	Possible reductions in biodiversity, vegetation coverage, and wetland area	Qualitative
		Cultural influence b_{16}	Impact on local minority culture and religious culture	Qualitative
		Energy-saving and emission reduction b_{17}	Energy-saving and emission reduction benefits = reduction of co_2 emissions × co_2 emission reduction transaction price (unit: 10,000 yuan)	Quantitative
	Socioeconomic impact B_2	Power generation benefit b_{21}	Power generation benefit = power grid electricity power × grid benchmark electricity price (unit: 10,000 yuan)	Quantitative
		Flood prevention benefit b_{22}	After the power station is completed, compared with the annual average before the completion of the construction, the losses caused by floods and floods are reduced, and the annual average flood prevention investment is reduced	Qualitative
		Water supply (irrigation) benefit b_{23}	Water supply (irrigation) benefit = new or improved irrigation area in the project area/total population in the project area (unit: mu/person)	Qualitative
		Shipping benefits b_{24}	Shipping benefit = annual transport capacity with project waterway-transport capacity without project waterway (unit: t/year)	Qualitative
		Tourism benefit b_{25}	During the operation period of the power station, related tourism projects can be carried out at the same time, bringing tourism benefits to the project	Quantitative
		Regional GDP contribution b_{26}	The increase of GDP in the current year's power station investment = annual direct investment in the power station + annual direct investment in the power station × current year's investment multiplier; the rate of increase of GDP in the project affected area = (with project GDP-no project GDP)/no project GDP × 100%	Quantitative
		Industrial structure b_{27}	Bring the optimization of the regional economic structure and promote the rational distribution and coordinated development of industries between regions	Qualitative
		Financial revenue contribution b_{28}	Bring a large amount of tax to the local finance, open up new tax sources, and increase local fiscal revenue	Quantitative
	Social equity impact B_3	Poverty alleviation effect b_{31}	Help poverty-stricken areas get rid of poverty and become rich, promote the leapfrog development of poverty-stricken areas, help change the income distribution pattern, and reduce the income gap of residents	Qualitative
		Income distribution effect b_{32}	Effect of state (local, enterprise, and individual) income distribution = state (local, enterprise, and individual) income distribution benefit from the project/total national income of the project × 100%	Qualitative
		Gini coefficient b_{33}	Measure the relationship between population and income	Quantitative
		Compensation measures for damaged people b_{34}	Take corresponding compensation measures for the people whose interests are damaged according to the degree of damage	Qualitative
		Protection of national interests b_{35}	Considering the protection of national culture and national ecological compensation	Qualitative
		Urban and rural residents' income ratio b_{36}	Urban and rural residents' income ratio = urban residents' disposable income per capita/rural residents' disposable income	Quantitative
	Social security impact B_4	Property dispute event b_{41}	Probability of hydropower project property disputes	Qualitative e
		Engel coefficient b_{42}	Engel's coefficient = total food expenditure/total household or personal consumption expenditure × 100%	Quantitative
		Residential stability b_{43}	Residents' stability in the project area	Qualitative
		Natural disaster event b_{44}	Geological hazards such as landslides, mudslides, and earthquakes caused by large-scale hydropower construction and flood disasters reduced due to construction	Qualitative
		Immigration group incident b_{45}	Propose reasonable solutions to disputes, quickly resolve conflicts, ensure local social stability, and improve social security	Qualitative

(4) Calculate Attribute Importance. The presence information system $S = \{U, A, V, f\}$, $X \subseteq A$ is a subset of attributes, and if $U/X = \{X_1, X_2, \cdots, X_n\}$, $x \in X$ is an attribute, then X, the amount of information, can be defined as

$$I(X) = 1 - \frac{1}{|U|^2}\sum_{i=1}^{n}\left|X_i\right|^2. \tag{2}$$

For attributes x, the importance in the attribute set is recorded as

$$\mathrm{sig}_{X-\{x\}}(x) = I(X) - I(X-\{x\}). \tag{3}$$

In the above formula, only the importance of the attribute to the entire attribute set is considered and the importance of the attribute is not considered. Because in actual applications the importance of the information quantity attribute may appear to be zero, in this case, improved calculation method for the importance of attributes based on the amount of information is used here; that is, the importance of the attribute itself is added to the original calculation method, and the formula is as follows:

$$\mathrm{sig}_{X-\{x\}} = I(X) - I(X-\{x\}) + I(x). \tag{4}$$

(5) Attribute Weights Obtained by Normalization. According to the normalized operation i, the weight coefficient of each condition indicator is expressed by the following formula:

$$\omega_i = \frac{\operatorname{sig}(x_i)}{\sum_{i=1}^{m} \operatorname{sig}(x_i)}. \tag{5}$$

2.4.2. RAGA-PP (Real-Coded Accelerating Genetic Algorithm-Projection Pursuit) Model. How to find the most projection direction? The optimal solution to projection objective function is the key to model validity and problem-solving. The projection pursuit model based on the accelerated genetic algorithm with real number coding is exactly an effective way to address this kind of high-dimensional, nonnormal, nonlinear complex problem. Therefore, the two methods are combined to construct a projection pursuit model (RAGA-PP) based on real-coded accelerated genetic algorithm optimization for hydropower engineering. The RAGA-PP model can not only prioritize the comprehensive evaluation objects but also estimate how much an evaluation index impacts the comprehensive evaluation results through the optimized projection direction, which proves to be a great advantage. The flowchart of the construction of the RAGA-PP model is shown in Figure 1 (where the genetic algorithm is shown in the attached table).

(1) Let the sample set to be evaluated be $\{x^*(i,j)|i = 1,2,\cdots,n, j = 1,2,\cdots,p\}$, where $x^*(i,j)$ denotes first i sample and j index values, and n and p denote the number of samples (sample capacity) and the number of indicators, respectively. To eliminate the dimensions of each indicator and unify the range of changes in each indicator value, the following formula can be used for normalization of extreme values.

For larger and better indicators, use formula (1):

$$\begin{cases} x(i,j) = \left(\dfrac{x^*(i,j) - x_{\min}(j)}{(x_{\max}(j) - x_{\min}(j))}\right), \\ x(i,j) = 1, \quad x^*(i,j) \geq x_{\max}(j). \end{cases} \tag{6}$$

For smaller and better indicators, use formula (2):

$$\begin{cases} x(i,j) = \left(\dfrac{x^*(i,j) - x_{\min}(j)}{(x_{\max}(j) - x_{\min}(j))}\right), \\ x(i,j) = 0, \quad x^*(i,j) \geq x_{\max}(j). \end{cases} \tag{7}$$

$x_{\max}(j)$ and $x_{\max}(j)$ denote j maximum and minimum values of each indicator; $x(i,j)$ denotes eigenvalue normalized sequence.

(2) Construct a projection function $Q(a)$.

The high-dimensional data information is transformed into a low-dimensional space through the projection method; the data is observed from different angles to find the optimal projection direction that can reflect the characteristics of the data to the greatest extent and fully dig the data information. This method is intuitive and easy to apply, and the conventional method is used for analysis and processing. Therefore, the projection pursuit model integrates the P-dimensional data $\{x(i,j)|j = 1,2,\cdots,p\}$ with the one-dimensional projection value $z(i)$ which takes $a = \{a(1), a(2),\cdots,a(p)\}$ as the projection direction, which is

$$z(i) = \sum_{j=1}^{p} a(j)x(i,j), \quad (i = 1,2,\cdots,n). \tag{8}$$

a is a unit length vector.

When calculating the comprehensive projection index value, the projection value is required $z(i)$ the walking feature should be as follows: the local projection points are as dense as possible, the projection point clusters are scattered as much as possible as a whole, even if the multivariate data is walking between classes in a one-dimensional space S_z intra-class density D_z at the same time, the maximum value is obtained. Therefore, the indicator function will be projected $Q(a)$ defined as the product of the distance between classes and the density within the class, it can be expressed as:

$$Q(a) = S_z \cdot D_z. \tag{9}$$

Distance between classes S_z calculate the standard deviation of the eigenvalues projected from the sample sequence; that is,

$$S_z = \sqrt{\frac{\sum_{i=1}^{n} (z(i) - E(z))^2}{n-1}}, \tag{10}$$

$E(z)$ denotes sequence $\{z(i)|i = 1,2,\cdots,n\}$ average of S_z; the bigger it gets, the more it spreads out.

intraclass density D_z the calculation formula is

$$D_z = \sum_{i=1}^{n}\sum_{j=1}^{n} (R - r(i,j) \cdot u(R - r(i,j))), \tag{11}$$

R is the window radius of the local density, which should be selected so that the average number of projection points included in the window cannot be too small. To avoid the moving average deviation being too large and not to make it follow$n$ increase too high, the general value of R is $2p$.

$u(t)$ is unit step function, when $t \geq 0$. When its value is 1 when $t < 0$ the function value is 0.

(3) Optimize the projection index function.

When the evaluation index classification standard sample data set is given, the projection index function changes only with the change of the projection direction. Different projection directions reflect different data structure characteristics and the best projection direction is the largest possible

exposure of certain types of high-dimensional data. For the projection direction of the structure, according to the above analysis, it can be seen that when formula (4) reaches the maximum value a^* it is the optimal projection direction vector. Therefore, the optimal projection direction can be estimated by solving the projection index function maximization problem.

That is, maximize the objective function:

$$Q(a) = S_z \cdot D_z. \tag{12}$$

Restrictions are

$$\sum_{j=1}^{p} a^2(j) = 1. \tag{13}$$

This is a complex nonlinear problem with optimization variables, which is difficult to handle with traditional optimization methods. Our paper uses an accelerated genetic algorithm based on real number coding to solve its high-dimensional global optimization problem. See the attached table for the molding process.

(4) Evaluation value calculation.

The best projection direction is obtained in step 3a^* substituting formula (3); the projection value of each experience level sample point in the level standard table can be obtained as $Z_s^*(i)$; normalize the sample of water ecological carrying capacity in the evaluation area; the best projection direction is obtained in step 3a^* and normalized index samples are substituted into formula (3) and the projection values of the samples to be evaluated can be obtained as $Z^*(i)$. $Z^*(i)$ projection value with evaluation criteria is $Z_s^*(i)$; by comparison, you can get the level of each dimension of the social impact of hydropower engineering.

3. Results

The weights of 26 indexes are calculated by rough set theory, among which 12 indexes with higher weights are selected to be substituted into the projection pursuit model. The model is solved by accelerating a genetic algorithm based on real number coding. According to formulas (1)–(13), we use the software of Matlab 2018b to process data, population size $N = 400$, crossover probability $p_c = 0.8$, mutation probability $p_m = 0.2$, number of optimized variables $n = 12$, the random number required for variation direction $M = 10$, and acceleration times are 7. The best projection direction is $a^* = (0.4169, 0.4168, 0.1565, 0.0379, 0.4358, 0.4210, 0.0948, 0.1205, 0.3533, 0.0943, 0.1798, 0.2642)$.

The significance of obtaining the best projection direction in the projection pursuit model refers to the weight of the index. Therefore, the importance of each evaluation index in the social impact assessment of hydropower project can be seen by sorting the projection direction of each evaluation index (Figure 2). At the same time, projection value of social impact assessment of hydropower projects can be obtained. That is, the large-scale hydropower projects' procedural evaluation of the social impact is made by using the projection direction values of each index (Table 2).

From the result of index reduction, the impact of Y hydropower station construction on regional resource conditions is generally positive. After temporary land use is completed, part of the lost vegetation and plant resources can be restored by means of vegetation restoration measures. The project itself does not produce pollution and will not have a significant impact on the water quality of the river. Replacing thermal power with hydropower will not cause obvious damage to local ecological environment. Reservoir resettlement is small and will not have a great impact on the surrounding water environment, atmosphere, sound environment, and ecological environment. Negative impacts of national and religious cultures are also not evident. At the same time, we can see that the Y project has little impact on the population.

With the increase of support from local government and local migrant cadres, the method of combining direct subsidies with employment promotion is adopted to improve the income level of migrants. Combining the implementation of resettlement planning and the actual situation of the construction and requisition area, the government could improve the infrastructure of resettlers and increase the investment of public services. As far as possible, the production and living conditions of the resettlers have been greatly improved by letting the farmers live in the original way.

From the projection of the indicators, the employment effect and infrastructure forecast are 0.3918 and 0.3804, respectively. It is shown that the Y hydropower station does provide convenience for local employment, infrastructure, communication facilities, farmland, irrigation, and so forth. After its completion, it can provide 3.485 billion kWh of clean power each year, which will play a leading role in curtailing emissions of CO_2, SO_2, and nitrogen-oxygen.

In terms of social benefits, the selected key indicators are power generation benefits, regional GDP contribution, and industrial structure, with projection values of 0.0419, 0.4232, and 0.3962, respectively. According to the prediction direction of each index in Figure 2, it can be seen that the contribution to regional GDP and industrial structure is essential. Moreover, it is shown that local economic development can significantly benefit from power generation and further exert positive effects on the optimization and adjustment of industrial structure in the region. According to the evaluation model of the regional economic impact of hydropower investment, every 100 million Yuan of hydropower investment can yield another 97.6 million Yuan for Sichuan's GDP. The construction of the Y project makes it impossible for residents to shift away from their sole dependence on the first industry, containing contain animal husbandry and agriculture to seek prosperity in the second and third industries.

The main influence dimension weight of social equity is the highest, which is 0.3259. It shows that the Y project boosts income within a brief period, but poverty alleviation

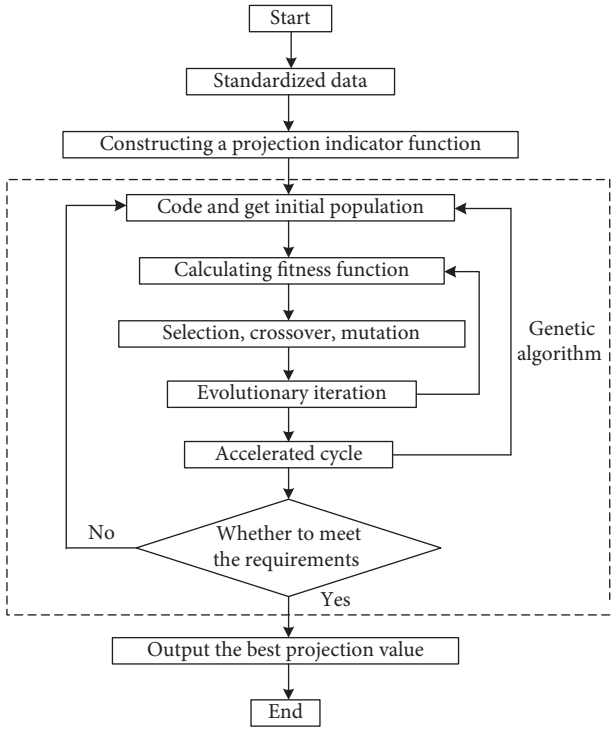

Figure 1: RAGA-PP model flowchart.

can hardly get instant results, since bridging the gap between rich and poor will take time. At the same time, we should also focus on safeguarding national interests.

The important indicators of social security impact are Engel coefficient, natural disaster events, and immigrant group events. According to Figure 2, the importance of natural disaster events and immigrant group events is slightly higher. Due to the complex geological conditions, abundant precipitation, long flood season, abnormal climate, and frequent natural disasters in Sichuan, the prevention and control of natural disasters should be given close attention during the project's development. Y project will undoubtedly serve as a catalyst for employment promotion, income rise, and consumption growth, leading to a decline in Engel coefficient and an increase in social stability, since the lower Engel coefficient is, the more well-off the residents will become. At the same time, we should pay more attention to the major friction among immigrant interest groups, considering that disharmony may pose a direct threat to regional social stability.

The projection data of the top three evaluation indexes from 2005 to 2019 are analyzed and the projection values of each evaluation index increase year by year. It can be seen from Figure 3 that the contribution to regional GDP growth is obvious, with an increase in projection value from 0.0235 to 0.9788 and an average annual growth of 28.22%. It demonstrates that the Y project is a huge stimulus to the regional economy and the optimization of industrial structure, which plays a major part in the national western development strategy.

Since the projection values of social impact in each dimension during the construction period from 2005 to 2013 do not change significantly, our paper analyzes the projection values of the construction period in recent 4 years and 2 years (2014–2019) after completion (see Table 2).

It can be seen from the data in Table 2 and the trend line in Figure 4 that the projection value of the social comprehensive impact assessment of hydropower projects increases year by year, indicating that the comprehensive impact level of hydropower projects from 2014 to 2019 steadily grows except for a slight drop in 2016. The high level of social comprehensive impact explains that Y project has exerted a positive social impact. From 5.3311 in 2014 to 7.0377 in 2019, it has increased by 0.32 times, with an average annual growth rate of 9.32%, indicating how the Y hydropower station will reshape the development of Panzhihua city and create a booming economy.

4. Discussion and Policy Recommendations

From each dimension, the indicators of each dimension of hydropower projects are significantly improved with the improvement of the overall level (Figure 5). In terms of four important dimensions of social impact assessment of hydropower projects, environment, economy, and safety, all of above three have a positive impact on the projection value of comprehensive social impact assessment in the study period, and only the projection value of equity dimension shows a downward trend.

(1) From the projection value curve of environmental dimension, the larger the projection value, the better the environmental condition of hydropower projects. At present, the whole society pays more and more attention to the complex ecological environment problems of large-scale hydropower project construction. Requirements for ecosystem quality are getting higher and higher. Construction and operation of large-scale hydropower projects have an impact on social environment. The construction of Y hydropower station can greatly reduce the consumption of nonrenewable oil and coal carbon resources. It can replace the thermal power plant of the same scale about 400 MW and reduce annual carbon dioxide emissions by 1.3 million tons, sulfur dioxide emissions by 0.4 million tons, and nitrogen oxide emissions by 0.4 million tons. It is beneficial to improve the environmental air quality in Panzhihua city. Because the indicators in this dimension are all using the mean data, it shows that the impact on the environment is showing a trend of rapid improvement. It helps to increase the proportion of nonfossil energy and reduce greenhouse gas emissions. It can support national policies of energy-saving and emission reduction, which could further promote the construction of resource-saving society [60].

(2) The largest growth rate and magnitude from 2014 to 2019 are in the economic dimension, which indicates that the social and economic benefits of hydropower projects increase year by year. When the Y hydropower station is put into operation, it will generate

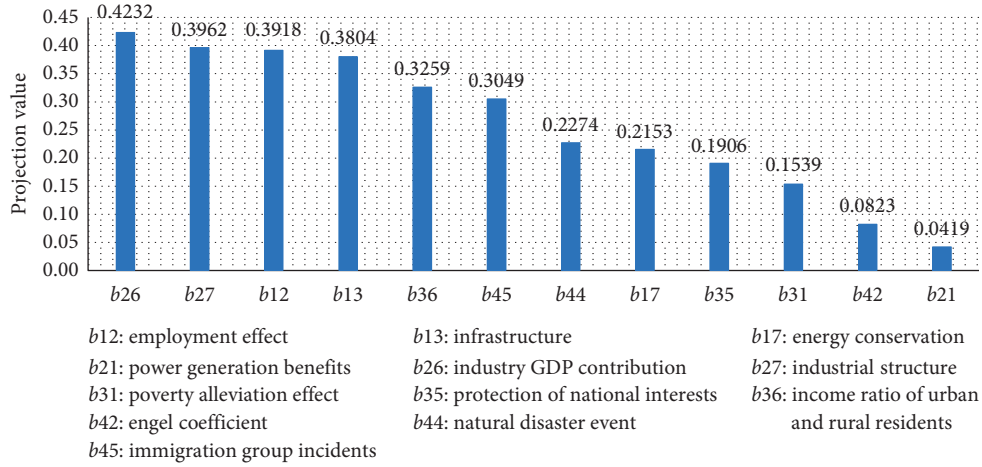

Figure 2: Projection direction of evaluation indicators.

Table 2: Projected social impact of hydropower projects.

Years	Social environmental impact	Rank	Socioeconomic impact	Rank	Social equity impact	Rank	Social security impact	Rank	Comprehensive social impact	Rank
2014	0.5254	6	0.7556	6	2.0995	1	1.9505	3	5.3311	6
2015	0.9541	5	1.2527	4	1.9766	2	2.0316	2	6.2150	4
2016	1.0432	4	1.3904	3	1.8215	3	1.7176	6	5.9727	5
2017	1.1754	3	1.2144	5	1.8067	4	2.0571	1	6.2536	3
2018	1.7020	2	1.8581	2	1.5475	5	1.7352	5	6.8428	2
2019	1.8936	1	1.9310	1	1.4461	6	1.7669	4	7.0377	1

Table 3: Scoring result of Y hydropower station social impact assessment experts.

Qualitative index	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Industrial structure	5.8	6.3	7.2	6.9	7.8	8.1	8.3	8.5	4.2	3.9	2.7	3	3.2	3.3	3.1
Infrastructure	3.9	4	4.5	5.7	5.9	6.7	7.2	6.4	3.4	3.5	4.2	3.8	3.1	2.5	2.3
Poverty alleviation effect	8.5	7.3	8	7.5	7.1	6.4	6.5	7.2	6.8	5.8	6.2	6.7	6.5	7.5	7.4
Income distribution effect	3.5	4.1	5.4	6.2	6.7	6.5	6.8	7.1	7.3	7.7	7.5	7.4	7.9	7.6	7.8
Flood prevention benefit	1.2	2.1	1.7	2.2	2.3	3	2.8	6.8	7.2	7.4	7.7	7.5	7.3	7.6	7.5
Water supply (irrigation) benefit	5.4	5.8	4.2	3.9	4	4.2	3.7	6.5	7	7.7	7.9	8	8.2	7.9	7.6
Shipping benefits	4.9	5.2	4.8	5.1	5.4	5.3	4.9	6.9	7.8	7.5	7.6	8.1	7.9	7.8	7.2
Compensation measures for damaged people	8.9	8.5	7.8	8.3	7.9	6.7	5.7	5.9	6.1	6.4	5.6	5.4	5.8	6	5.9
Protection of national interests	3.8	2.9	4.6	5.4	6.3	7.4	7.7	7.4	8.4	7.6	8	8.2	7.5	7.9	7.4
Property dispute event	2.3	2.5	3.1	1.9	3.7	4.9	4.3	5.1	6.3	7.9	8.2	8.7	7.8	8.2	7.6
Engel coefficient	1.8	2	1.5	3.4	3.7	5.8	5.6	7.3	8.4	7.8	8.3	8.1	8.6	8.4	8.2
Natural disaster event	3.1	2.9	4.8	5.9	5.6	6.8	7.4	4.1	5.1	3.8	4.5	2.3	1.7	3.2	2.1
Immigration group incident	4.3	2.5	5.1	3.8	4.1	4.5	5.7	6.1	8.4	7.3	6.8	8.6	8.4	8.5	8.6

an annual output value of 460 million Yuan and annual GDP of 67 billion Yuan, constituting a major driving force to economic development in the area [15, 61]. At the same time, the project construction combines with the implementation of the urban environmental renovation project. A good hydrophilic environment will be formed, which is reflected between the power station, Pinghu Lake, and the landscape belt along the coast, thus driving the development of the tertiary industry. Taxes will also be paid to the local government each year to increase fiscal revenues, which can be used for upgrading infrastructure and improving the living environment, so that it could achieve harmonious economic and social development [62, 63].

(3) The only downward trend is the projection curve of the equity dimension, which indicates that the Y hydropower station has a greater impact on local social equity. With the continuous improvement of project capability and the increasing impact of the project on society, the implementation of hydropower projects will inevitably lead to the relocation

Table 4: Qualitative indicator assignment discrete results.

	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}
b_{11}	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
b_{13}	2	2	2	3	3	3	4	3	2	2	1	2	2	1	1
b_{15}	3	3	2	2	2	2	1	3	4	4	4	4	4	4	4
b_{16}	1	1	1	1	1	2	1	3	4	4	4	4	4	4	4
b_{22}	1	1	1	1	1	1	1	3	4	4	4	4	4	4	4
b_{23}	3	3	2	2	2	2	2	3	4	4	4	4	4	4	4
b_{24}	2	3	2	3	3	3	2	3	4	4	4	4	4	4	4
b_{27}	3	3	4	3	4	4	4	4	2	2	1	2	2	2	2
b_{31}	4	4	4	4	4	3	3	4	3	3	3	3	3	4	4
b_{32}	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4
b_{33}	2	2	2	3	2	4	4	4	3	4	4	4	3	4	4
b_{34}	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3
b_{35}	2	2	2	3	3	4	4	4	4	4	4	4	4	4	4
b_{36}	2	1	1	1	1	1	2	2	2	3	4	4	4	4	4
b_{41}	1	1	1	1	2	2	2	3	3	4	4	4	4	4	4
b_{42}	1	1	1	1	3	2	1	1	2	2	4	4	4	4	4
b_{43}	1	1	1	2	2	3	3	4	4	4	4	4	4	4	4
b_{44}	2	2	2	3	3	3	4	2	3	2	2	1	1	2	1
b_{45}	2	1	2	2	2	2	3	3	4	4	4	4	4	4	4

$n1$~$n14$ in the table represent 2005~2019.

of a large number of residents in the reservoir area. Since losses in this change may not be thoroughly measured, there remains a difficulty in guaranteeing national interests and narrowing wealth inequalities [64]. Therefore, instead of being limited to the technology, we would better develop a comprehensive understanding of the pros-cons of hydropower projects and show initiative in assuming different social responsibilities. When it comes to decision-making and conflicts resolution, it is crucial to take all the factors regarding economy, technology, morals, and values into account to meet our obligations of future mankind [63, 65].

(4) Viewed from the projection value curve of the safety dimension, projection value fluctuates greatly but generally tends to rise. Y hydropower station may bring about certain social security problems, but the degree of impact is not particularly large, indicating that the hydropower project has not caused large-scale social conflicts and instability. However, the government should raise the awareness of safety management and control and establish well-rounded safety management and protection system. At the same time, all kinds of risks should be identified and supervision and inspection mechanisms are formulated [8].

5. Conclusions

The ultimate goal of the hydropower project is to serve society and human beings. It can yield considerable social benefits but may also cause serious social instabilities. Based on the trend of hydropower development in China, the possible social impact of hydropower projects is analyzed and an evaluation index system of social economy, social environment, social equity, and social security is established. The rough set method is used for index reduction and the projection pursuit method based on real code accelerated genetic algorithm optimization is used for assessment. The evaluation model is applied to specific project cases and its validity is verified. It has certain innovation and operability:

(1) With the rapid development of hydropower, the development of hydropower projects has paid more and more attention to the social impact. The huge benefits of hydropower projects are reflected not only in the economy but also in the environment, fairness, society, and other aspects. Therefore, it is of great practical significance to carry out social evaluation of hydropower projects. The economic evaluation of hydropower projects in China has been very mature. In recent years, there have been more and more researches on environmental assessment, but there are not many researches on social impact assessment of hydropower projects. In the economic evaluation of the project, the social impact assessment and the social impact of the project should be taken into account. Only by analyzing the relationship between the project and social development can we better implement the sustainable development strategy so as to promote the coordinated development of the project and society.

(2) Hydropower projects bring about a range of benefits to society and environment. Except to generating electricity revenues, hydropower projects reduced the reliance on fossil fuels and avoided more heavy pollution. In addition, hydropower projects can support local businesses in creating jobs and improving livelihoods. These projects invest in transportation, education, health services, tourism, and leisure. With that, we will promote national macroeconomic growth and trade opportunities and alleviate the effects of floods and droughts.

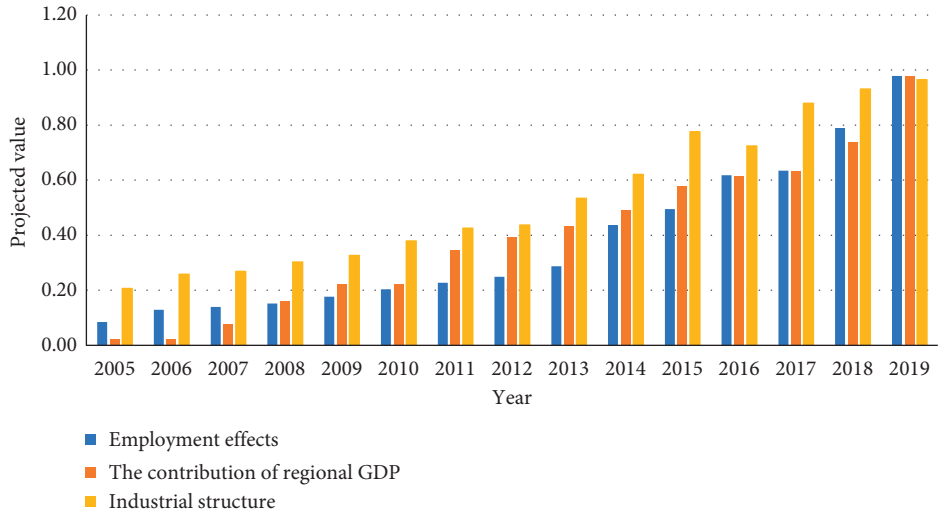

Figure 3: Projection value of some evaluation indexes.

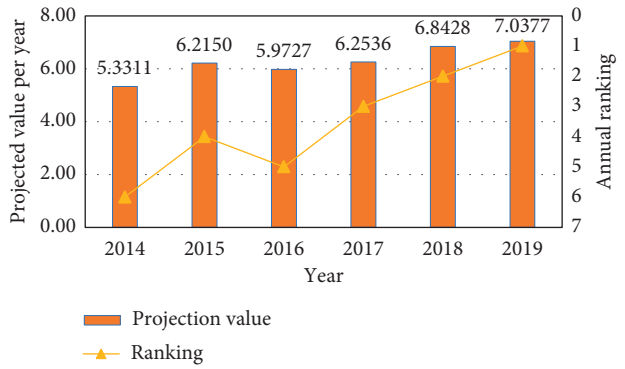

Figure 4: Projected values and ranking of comprehensive social impact assessment.

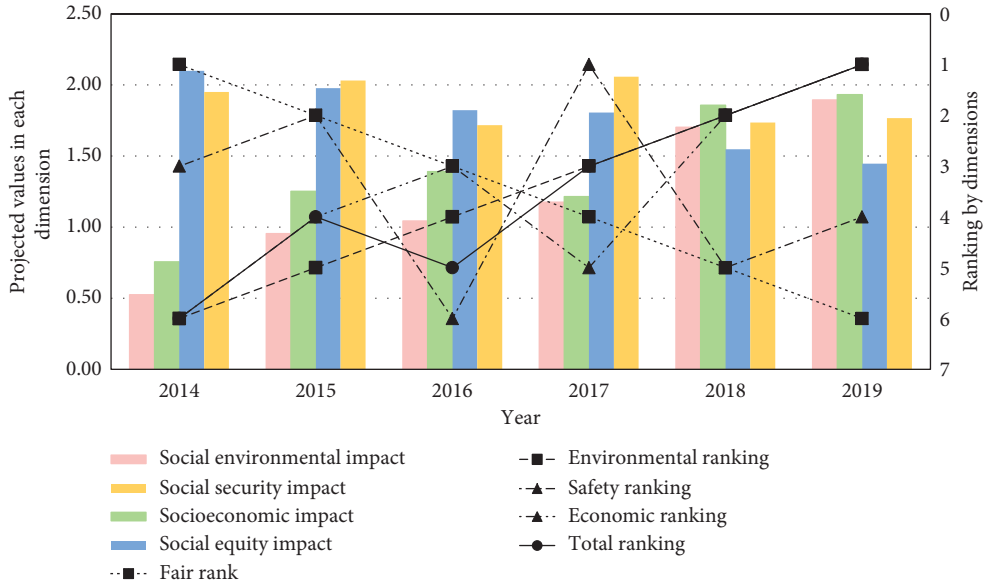

Figure 5: Projected values and rankings in each dimension (the higher the projection value and ranking, the higher the overall score for social impact).

(3) Under the background of sustainable development strategy, social impact assessment of hydropower projects is carried out. Based on the analysis of social impact mechanism of hydropower projects, the evaluation index system and model of social impact of hydropower projects are built. This will not only enrich the theory of social impact review but also verify the rationality of the index system and evaluation model. What is more, identifying positive-negative social impacts of specific hydropower projects can provide corresponding policies and suggestions to improve the rationality of hydropower project implementation.

(4) Resettlement of hydropower projects has attracted wide attention from all walks of life. It not only affects the production and life of the resettles but also induces social conflicts of the resettles. When evaluating and analyzing the migration risk, we should take effective preventive measures against all kinds of possible risks from a high political angle. At the same time, various possible external interference factors should be considered to ensure the smooth implementation of migration work. It is suggested that social impact assessment of large-scale hydropower projects should take the following aspects into consideration: first is reasonable planning for production and living resettlement of resettles; second is that additional budget for facilities with religious significance is recommended by planning units; third is restoration of unique religious and cultural facilities in minority areas.

(5) The degree of technology development in Sichuan and Yunnan areas with rich water resources in the middle and east of China is more than 80%. It is inevitable to expand foreign market by hydropower development in the future. However, evaluating the social impact of foreign hydropower projects, establishing the corresponding social impact evaluation system, and further improving the evaluation system on the basis of the existing social impact evaluation system are facing great challenges.

Appendix

A

Discrete treatment is carried out on qualitative indexes. Based on the fact that all qualitative indexes have the average score given by experts, the intervals of the mean values are on [1, 9]. Isometric division method is used to divide the data in Table 1 equidistantly, [1, 3] is represented by "1," [3, 5] by "2," [5, 7] by "3," and [7, 9] by "4." The results of the discretization of each index are shown in Table 2.

B

Accelerated genetic algorithm based on real number encoding.

This algorithm is mainly for solving equations (7) and (8). The specific modeling process is as follows.

(1) Real number coding. Use the following formula for linear change:

$$x(j) = a(j) + y(j)(b(j) - a(j)), \quad (j = 1, 2, \cdots, p). \tag{B.1}$$

According to formula (7), Q for the objective function is to be optimized and p is to optimize the number of variables.

Formula (9) corresponds the j variable $x(j)$ on interval $[a(j), b(j)]$ to interval $[0, 1]$, which corresponds to real $y(j)$ on interval $[0, 1]$, then defines $y(j)$ as the genetic gene in RAGA. The genes corresponding to all the variables of the problem to be optimized obtained according to the above method are serially connected to obtain the useful $(y(1), y(2), \cdots, y(p))$ chromosome represented, and the chromosome represents the code that constitutes the solution to the problem. After the above operation process, ensure that the value range of the variables falls $[0, 1]$ within the interval; then perform the following operations on the genes of each optimization variable.

(2) Define the initial parent population.

First set the number of parent groups to n and then get each p group and each n group in $[0, 1]$ random number on the interval, that is, $\{u(j, i) | (j = 1, 2, \cdots, p; i = 1, 2, \cdots, n)\}$. Definition $u(j, i)$ individual values of the parents of the initial population $y(j, i)$ will $y(j, i)$ substitute into the formula (9) can get the optimized variable value $x(j, i)$. The objective function value obtained by the objective equation $\{Q(i) | (i = 1, 2, \cdots, n)\}$ is sorted from small to large, corresponding to individuals $\{y(j, i)\}$ following the ranking. Because the size of the objective function value represents the strength of the individual's adaptability, the former obtained by the above ranking will be k; each is defined as an excellent individual and is directly credited to the next generation.

(3) Establish a fitness evaluation function.

The fitness evaluation function is used to set the probability of each chromosome in the population to ensure that the possibility of chromosome selection is proportional to its fitness. It is worth noting that the order-based evaluation function (using $\text{eval}(y(j, i))$ (Represented)) is not reallocated based on its actual target value, but based on the order of the chromosomes. $\alpha \in (0, 1)$ given the order-based evaluation, and the function is represented by

$$\text{eval}(y(j, i)) = \alpha(1 - \alpha)^{i-1}, \quad i = 1, 2, \cdots, N, \tag{B.2}$$

$i = 1$ represents that chromosomes are the best; $i = N$ represents that the chromosome is the worst.

(4) Select the next generation of individuals.

By spinning the wheel N seconds, based on the fitness of each chromosome, a new set of chromosomes is selected in each rotation, resulting in the first generation $\{y(j,i)|j=1,2,\cdots,p\}$, and the specific selection process can be expressed as follows:

Per chromosome $y(j,i)$, calculate cumulative probability $q_i(i=0,1,2,\cdots,N)$ for

$$\begin{cases} q_0 = 0, \\ q_i = \sum_{j=1}^{i} \text{eval}(y(j,i)), \quad j=1,2,\cdots,p; i=1,2,\cdots,N. \end{cases} \tag{B.3}$$

From the interval $[0,q_i]$, generate a random number in$r$if $q_{i-1}<r<q_i$; then select the$i$chromosomes $y(j,i)$.

Repeat steps 2 and $3N$ times, with available N duplicate chromosomes to form a new generation of individuals.

(5) Cross the parent population to obtain the second-generation population.

Parameter p_c is defined as the probability of a crossover operation; that is, there will be p_cN chromosome cross operation. $i=1$ to N repeat the following process to determine the parent from the crossover operation: $[0,1]$ random number $r<p_c$; then select $y(j,i)$ as a parent. Use $y_1'(j,i), y_2'(j,i),\cdots$ to represent the selected parents and randomly pair them as shown below, $y_1'(j,i), y_2'(j,i)$, $(y_3'(j,i), y_4'(j,i))$, $(y_4'(j,i), y_5'(j,i))$; if there are odd numbers in the parents, you can delete chromosomes or add chromosomes to ensure pairing. As an example, the arithmetic cross method is used to explain the process of the entire cross operation. $(0,1)$ generate a random arbitrary number in $c$and then in $y_1'(j,i)$ with $y_2'(j,i)$ cross operations between X with Y two offspring, the specific operation process is as follows.

$$\begin{aligned} X &= c\times y_1'(j,i) + (1-c)\times y_2'(j,i), \\ Y &= (1-c)\times y_1'(j,i) + c\times y_2'(j,i). \end{aligned} \tag{B.4}$$

There is premise that the two descendants obtained by the cross operation are feasible, which is that the two parents are feasible and the feasible set is convex. However, the convexity of the feasible set is usually unknown, so it is necessary to check whether each descendant is feasible. The rule is to replace feasible parents with feasible offspring and then repeat the crossover operation. It is important to note that, during the entire crossover operation, the parent can only be replaced by feasible offspring. When a new generation of individuals is not feasible, some improvement strategies can also be adopted to make it feasible. After the complicated operation process above, you can get the second-generation group $\{y_2(j,i)|j=1,2,\cdots,p; i=1,2,\cdots,n\}$.

(6) Mutation to obtain new populations.

Parameter p_m is defined as the mutation probability in a genetic algorithm, indicating that there will be p_mN; each chromosome is subjected to mutation operations. The process of selecting parents through crossover operations is very similar to mutation selection. $i=1$ to N, select interval $[0,1]$ random number r; when $r<p_m$, a chromosome $y(j,i)$ is the parent of the mutation $y_3'(j,i)$ indicating that mutation is performed as follows. Selecting any direction as d in n-dimensional space as the direction of variation, then

$$y_3'(j,i) + Md, \quad i=1,2,\cdots,p. \tag{B.5}$$

Through M for $(0,1)$ random numbers above make the above formula feasible to meet the diversity of the population, in addition to ensuring that M is a sufficiently large number. If there is no feasible solution for a given number of iterations, then set M to 0 to solve it. Always replace $y_3'(j,i)$ with $X=y_3'(j,i)+Md$ instead regardless of M value; repeating this process can obtain a new generation of population obtained by mutation $\{y_3(j,i)|j=1,2,\cdots,p;\ i=1,2,\cdots,n\}$.

It is worth noting that the processes of selection, hybridization, and mutation of SGA are usually performed sequentially. The disadvantage of this is that the previous genetic operation causes the subsequent genetic operation to lose useful information. The selection, hybridization, and variation processes of RAGA are parallel, which means that RAGA generally has a broader search area than SGA, so the optimal solution obtained has relatively more opportunities and higher accuracy.

(7) Evolutionary iteration.

According to the fitness function value, 3n progeny individuals generated by selection, hybridization, and variation will be sorted. Select the first $(n-k)$ individuals as excellent offspring, and repeat step 3 as new parents, i.e., as the beginning of the next stage. Repeat the process of evaluation, selection, hybridization, and variation of the entire parent individual.

(8) Speed-up processing.

By determining the interval between the first and second generations of excellent individuals as the iteration interval for the next generation of optimization variables, too many evolutions will weaken the search algorithm's ability to optimize, so you can turn to step 1 to optimize again. The interval is getting more and more accurate, so the cycle is accelerated. The algorithm ends when the value of the optimal individual's objective function reaches the set value or the set number of accelerations. At this time, the best individual obtained in the current

whole is the optimization result of RAGA. For the model, it is the best projection direction a^*, and the above is the complete RAGA algorithm.

Data Availability

The data used to evaluate the social impact comes from the feasibility study report of the Y hydropower station and other relevant reports. Meanwhile, some social-environmental impact indicators and socioeconomic indicators are calculated based on the prediction results of relevant topics of the hydropower station.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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