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Financing Model Decision of Inter-basin Water Transfer Projects

Abstract Inter-basin Water Transfer Projects require the appropriate financing model to attract large amounts of social investment. Therefore, financing model decision becomes the key of engineering construction. In three aspects, such as the subject, the object and the target of the financing model, Grey Target Model is established in this paper. First, the complex financing mode decision problems of Inter-basin Water Transfer Projects are decomposed by using hierarchical decomposition method. Then Analytical Hierarchy Process (AHP) method is used to calculate the comprehensive weight of evaluation index. Experts' opinions financing model are transformed into the evaluation matrix based on the Dephi method. The Weighted Grey Target Model is used to calculate the approaching degree of financing model and assists financing mode decision. In addition, this paper takes the water diversion project from the Han to the Wei River of Shaanxi Province as a verification example for the model. For other water diversion projects, the evaluation results are also reliable and provide theoretical references for the financing model decision of Inter-basin Water Transfer Projects.

Keywords: Inter-basin Water Transfer Projects, financing model, Weighted Grey Target Model, water diversion, Han River, Wei River

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1 Introduction

Inter-basin Water Transfer is a measure to balance the water resources among regions and realize the reasonable utilization of water resources (Ghassemi, & White, 2007). That is, it optimizes the allocation of water resources between areas with abundant water resources and those without enough water by human interference. Inter-basin Water Transfer Projects include principal projects such as water source projects and water diversion projects, and auxiliary projects such as water distribution and sale projects. They have the characteristics of large investment demand, large scale, and large cycle span. Also, project financing problem has become the key problem of engineering construction because of quasi-public welfare of Inter-basin Water Transfer Projects. With the development of China's public utilities, Inter-basin Water Transfer Project in China mainly relies on government investment and a small amount of private capital (Qi, Geng, & Zeng, 2008; Chen, Zhang, & Zhang, 2002). This kind of financing mode has lower risk. However, limited financial capital could not meet the increasing demand for water infrastructure investment. Great efforts should be made to attract private investment to solve the project financing problem (Zhu, Xie, & Ma, 2010). Financing modes, such as Build-Operate-Transfer (BOT) Mode, Build-Transfer (BT) Mode, and Public-Private-Partnership (PPP) Mode, are commonly used in hydraulic engineering. Different financing models have varied characteristics. How to select the appropriate financing model of Inter-basin Water Transfer Project has become a critical factor in the success of the project.

Current studies lay more emphasis on the qualitative comparison of financing model (Feng, & Zhang, 2005; Daube, Vollrath, & Alfen, 2008). Quantitative methods mainly use principal component analysis method, fuzzy comprehensive evaluation method, neural network evaluation method, and gray theory methods. Li and Wang (2012) used triangular number Analytical Hierarchy Process (AHP) method to construct the financing decision model of urban infrastructure project. Wang, Shen and Liu (2014) analyzed financing decision model of Inter-basin Water Transfer Project by applying principle component analysis method. Li and Shu (2014) established financing program evaluation index system according to the Wuli-Shili-Renli (WSR) system methodology and gained fuzzy comprehensive evaluation method. Zhao and Wang (2009) used computer-aided decision support system to select the infrastructure project financing model which is based on Rough Sets (RS) and Gray Correlation Analysis (GCA). Wang and Yang (2008) established financing decision model of infrastructure project which is based on interval entropy. This method evaluated various financing modes through the characteristics of the financing mode and decision makers' subjective judgment.

Although these researches enrich the qualitative and quantitative comprehensive evaluation theories of project financing model, the evaluation index in the above-mentioned researches mainly consider the financing model itself, which means only considering from the object of the financing decision. This paper is on the basis of Grey System Theory, synthesizes the subject, object and target of financing decisions of Inter-basin Water Transfer Project, and establishes the weighted gray target financing decision model. This model overcomes the shortcomings of the traditional one that regards the importance of each index as the same, and ensures the scientific of the evaluation results. Based on the quasi-public nature of Inter-basin Water Transfer Project, this paper analyzed advantages and limitations of hydraulic engineering investment and financing modes. Taking the water diversion from the Han to the Wei River of Shaanxi Province as an example, advantages and disadvantages of each financing mode in project were analyzed with quantitative and qualitative theories. This research will provide theoretical basis for financing mode decision of Inter-basin Water Transfer Project.

2 Methodology

2.1 Confirm weight by using AHP

The weight is calculated by AHP method. Operational research experts Saaty (1990) of the University of Pittsburgh in the 1970s proposed AHP. It is a system analysis method combined with qualitative and quantitative analysis.

Using AHP to clear problem, establish the hierarchical structure model, structure judgment matrix, order in single level and whole level, the comprehensive weights of the constituent elements of each level can be worked out. In this paper, the financing model of inter basin water transfer project is presented. The other four steps are as follows.

2.1.1 Confirm weight

(1) Establish the hierarchical structure model.

Hierarchical structure model is the foundation of the evaluation index system, and it is generally divided into the target layer, the criterion layer and the index layer, which are the basic structure of evaluation index system.

(2) Structure judgment matrix.

Judgement matrix reflects the relative importance of each factor in each level to upper level. Judgment matrix is constructed by Delphi using questionnaire. Let A be the target layer, u_i and u_j ($i, j = 1, 2, \ldots, n$) are factors. Experts score with 1–9 scale method. u_{ij} indicates the relative importance of u_i to u_j. The judgment matrix of A-U is composed of u_{ij}.

$$P_{A\text{-}U} = u_{ij} = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n1} & u_{n1} & \cdots & u_{nn} \end{bmatrix}, i,j = 1,2,\ldots,n. \quad (1)$$

(3) Hierarchy single sorting and consistency check.

Hierarchy single sorting is the importance ranking of the factors in this level to the upper layer. The maximum eigen value λ_{max} of the matrix and its corresponding feature vector ω_i ($i = 1,2,\ldots,n$) are calculated in MATLAB software. And ω_i is the relative weight of each factors in this layer to the upper layer.

2.1.2 Consistency check

(1) Compute consistency index CI,

$$CI = \frac{\lambda_{max} - n}{n-1}. \quad (2)$$

(2) The choice of the average random consistency index RI is shown in Table 1.

(3) Calculate random consistency CR of the judgment matrix.

If $RI \leqslant 0.10$, the judgment matrix is consistent with the consistency test. It means hierarchical single ranking is effective. On the other hand, if $CR > 0.1$, it indicates that the judgment matrix does not conform to the requirements of the consistency check. Judgment matrix need to be

Table 1

Corresponding Value Table of RI

Order judgment matrix	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

reconstructed.

$$CR = \frac{CI}{RI}. \tag{3}$$

(4) Hierarchy total sorting and consistency check.

Hierarchical total ordering is a sort of weight value that determines the relative importance of all factors for a certain level to general objective. If all the indicators B_1, B_2,...,B_m of layer B have finished hierarchy single sorting, the weight value of the layer index is $\alpha_1,\alpha_2,...,\alpha_m$. Single layer index weight of indicators $C_1,C_2,...,C_n$ of the layer C which is lower than the layer B is $\omega_{i1},\omega_{i2},...,\omega_{in}$ $(i = 1,2,...,n)$. If C_j is independent of B_i, $\omega_{ij} = 0$. Hierarchy total sorting is calculated according to Table 2, where $\sum_{j=1}^{n}\sum_{k=1}^{m}\alpha_k\omega_{kj} = 1$. Consistency checking is the same as that of the hierarchical single ranking.

2.2 Decision model of the weighed grey target theory

According to grey target theory (Deng, 2002; Liu, Dang, Fang, & Xie, 2004), a gray target should be set up and the bull's-eye in the absence of standard should be found, and the degree of evaluation object near the bull's-eye or the approaching degree should be calculated. The optimal scheme could be selected from the calculation results. Here are the steps

2.2.1 Construct evaluation index matrix

Suppose there are n alternative financing options, m evaluation indexes. They construct an evaluation index matrix named X.

$$X = x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix},$$

$$i = 1,2,...,n,\ j = 1,2,...,m\ , \tag{4}$$

where $x_{ij}\,(i = 1,2,...,n;\ j = 1,2,...,m)$ is the evaluative value of the ith financing model under the jth evaluation index.

2.2.2 The canonical transformation of matrix

Each index dimension is different. Decisions are hard to compare directly. The original decision matrix needs to be standardized by the exchange operator. Here is the basic idea: if the indexes are better than the average for the evaluation objects, they will be given positive value 0 to 1. Others will be given negative value −1 to 0. The normalized decision matrix R can be calculated by this method.

Let $Z_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$, $j = 1,2,...,m$, for positive indicators, the bigger, the better:

$$r_{ij} = \frac{x_{ij} - z_{ij}}{\max\left(\max_{1\leqslant i\leqslant n}\{x_{ij}\} - z_j, z_j - \min_{1\leqslant i\leqslant n}\{x_{ij}\}\right)}. \tag{5}$$

For reverse indicators, the smaller, the better:

$$r_{ij} = \frac{z_{ij} - x_{ij}}{\max\left(\max_{1\leqslant i\leqslant n}\{x_{ij}\} - z_j, z_j - \min_{1\leqslant i\leqslant n}\{x_{ij}\}\right)}. \tag{6}$$

Then the normalized decision matrix R is:

$$R = r_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix},$$

$$i = 1,2,...,n, j = 1,2,...,m\ . \tag{7}$$

Table 2

Calculation Table of Hierarchy Total Ranking

Layer C	Single layer index weight				Hierarchy total sorting of C layer
	B_1 (α_1)	B_2 (α_2)	$\cdots$	B_m (α_m)	
C_1	ω_{11}	ω_{21}	$\cdots$	ω_{m1}	$\sum_{k=1}^{m}\alpha_k\omega_{k1}$
C_2	ω_{12}	ω_{22}	$\cdots$	ω_{m2}	$\sum_{k=1}^{m}\alpha_k\omega_{k2}$
$\vdots$	$\vdots$	$\vdots$		$\vdots$	$\vdots$
C_n	ω_{1n}	ω_{2n}	$\cdots$	ω_{mn}	$\sum_{k=1}^{m}\alpha_k\omega_{kn}$

2.2.3 Determine the bull's-eye and the approaching degree

Let $r_j^0 = \max\{r_{ij} | 1 \leqslant i \leqslant n\}$ $(i = 1,2,...,n,\ j = 1,2,...,m)$, and $\gamma = \{r_1^0, r_2^0, ..., r_m^0\}$ is the optimal effect vector of multi objective gray target decision model, also called the bull's-eye. Let $r_i = (r_{i1}, r_{i2}, ..., r_{im}) \in R^{(m)}$ $(i = 1,2,...,n)$, $\omega = (\omega_1, \omega_2, ..., \omega_m), \omega_j > 0; \sum_{j=1}^{m} \omega_j = 1$ $(j = 1,2,...,m)$ is the weight worked out by AHP. And the approaching degree ζ_i of effect vector r_i:

$$\zeta_i = |\gamma_i - \gamma_0| = (\omega_1(r_{i1} - r_1^0)^2 + \omega_2(r_{i2} - r_2^0)^2 + ... + \omega_m(r_{im} - r_m^0)^2)^{1/2}. \quad (8)$$

The approaching degree ζ_i can reflect the effects of the pros and cons of vector r_i. The smaller the approaching degree is, the better the scheme. When the approaching degree is too big, the scheme will not be suitable.

3 The establishment of decision index system of financing mode

3.1 Project financing model

Project financing is a way to raise funds. It can promote the construction of public utilities in a country (Daube, Vollrath, & Alfen, 2008; Yan, & Du, 2010). In recent years, there have been a variety of financing models in order to obtain a wide range of market investment. Each of these methods has its own characteristics and different scope of application. The main characteristics, advantages and limitations of each model are shown in Table 3.

3.2 The establishment of decision-making index system

Different financing models have different characteristics. The decision makers need to consider the advantages, limitations and feasibility of each model to make a strategic decision. At present, China's financing system of Inter-basin Water Transfer project is mainly based on government-led investment and construction, and it is necessary to attract commercial loans and social funds actively. It has gradually established multiple investment and financing system which is composed of government investment, social investment and bank loans (Li, 2013). This paper argues that the financing mode decision should be made from three aspects: The subject (the investor), the object (Inter-basin Water Transfer project), and the target (financing mode).

Based on the quasi-public nature of Inter-basin Water Transfer Project, 16 sub-decision indexes have been selected to form the decision index system (Zhu, Zhou, Yu, & Zhai, 2015), which is shown in *Figure 1*.

4 Case analyses

4.1 Background of the water diversion from the Han to the Wei River

The water diversion from the Han to the Wei River of Shaanxi Province is in south central of Qinling Mountains, stretching across the Yangtze River and the Yellow River,

Table 3

The Characteristics of Project Financing Mode

Modes	Main characteristics	Advantages	Limitations
Build-Operate -Transfer (BOT)	Infrastructure management rights is limited mortgaged	BOT is conducive to improving the operational efficiency of the project and the government risk is small	The cost of pre-bidding is relatively large; the government has lost control of the project during the concession period
Build-Transfer (BT)	Owners pay the total investment and reasonable return to the investment side	Does not increase the government's external debt, does not affect the ownership of the government	The government is less involved in the project; the final repurchase price is difficult to determine
Transfer-Operate -Transfer (TOT)	Investors operate of public facilities projects that have been put into operation	Within a short period of time to recover the funds to ease the financial pressure	Financing scale is limited; the final transfer price is difficult to determine
Private-Finance -Initiative (PFI)	Government purchases of services from the private sector	Through the purchase of services of the private sector, the full use of private capital resources	It is difficult for the government to coordinate of forms of cooperation
Asset-Backed -Securitization (ABS)	ABS raises money by issuing bond staking the project anticipated income as the guarantee	Low financing costs, a wide range of financing	Limited by the local capital market and related regulations, policy
Public-Private -Partnership (PPP)	Public sector cooperates with private enterprises to participate in the construction of infrastructure	Public and private complementary advantages, reasonable risk allocation	The contract structure is complicated, and the operation experience is not mature

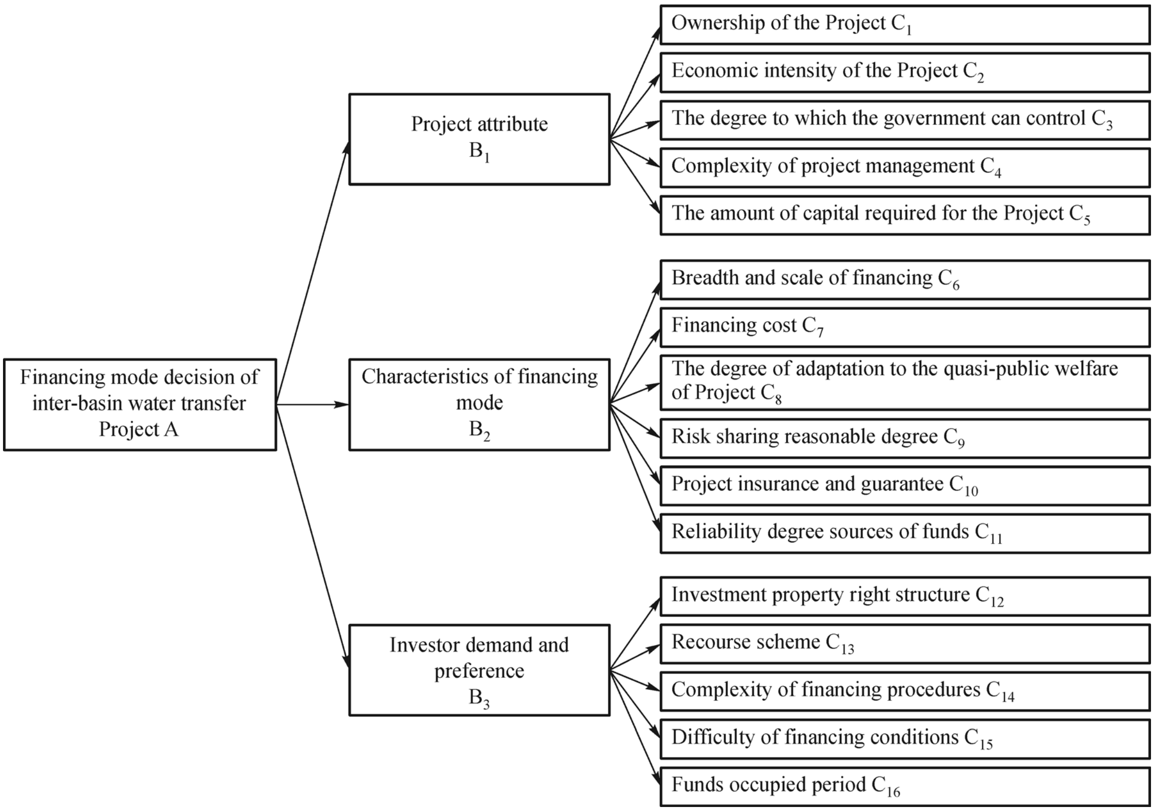

Figure 1. Inter basin water transfer project financing mode decision evaluation index system.

mainly lying in Southern Shaanxi and Guanzhong Area. Transferring water from Hanjing river basin of southern Shaanxi to Wei river basin of Guanzhong Area alleviates the imbalance between supply and demand of water resources in Guanzhong Area, and improves the ecological environment of the Wei River Basin. This project achieves optimal allocation of water resources in Shaanxi Province and coordinated the development of economy, society and ecology in Guanzhong Area. It is of great significance to promote the economic and social development in Guanzhong Area (Chang, & Jiang, 2011).

In the feasibility study phase, about 16.874 billion CNY was invested in the water diversion project from the Han to the Wei River was invested as static construction funds. According to its loan capacity, its capital fund of designing scheme was 11.542 billion CNY (accounting for 68.4% of the total static investment). When the water price was 1.5 CNY/m^3, its maximum loan capacity was 7.264 billion CNY (including 1.932 billion CNY financing interests of construction period) (Wang, 2014). By the end of January 2015, the management team of the water diversion project from the Han to the Wei River had cooperated with several banks and gradually received credit approval of financing about 15 billion CNY, and had signed a short-term loan contract of 2.95 billion CNY and project loan contract of 2 billion CNY. These funds basically eased the financial burden of Water Transfer Project. But with the start of transporting and distributing engineering, the funding gap is still tremendous and financing task is also very heavy. Solving the financial problems plays a role in improving the construction of projects. Only relying on the central finance cannot meet the tremendous needs of engineering funds.

The experience using financing models in other water resources allocation projects could be adopted to attract social capital for project construction. It may provide a new approach to solve financial problems of the water diversion from the Han to the Wei River.

4.2 Results

First, the weight of each index of financing evaluation index system is calculated by AHP method. Then combining with the score of each financing model for each evaluation index, the approaching degree of each model is calculated by applying the weighted gray target decision model. Finally, the most suitable financing model of the water diversion from the Han to the Wei River is chosen according to the size approaching degree.

4.2.1 Determining the weights of indexes

Ten qualified experts in the field of water resources scheduling, watershed management and financing management of hydraulic engineering are invited to determine the weights of the evaluation index system of financing model. They give scores for the weight and the level of the evaluation index system mentioned above according to the analytic hierarchy process model. The judgment matrixes given by ten experts will be calculated by the weighted average method and operated in MATLAB. Then the comprehensive weights of each index of evaluation index system would be obtained, and shown in Tables 4 and 5.

Table 4

Weight of Influence Factor Layer

Influence factor layer	Weight
Project attribute B_1	0.1294
Characteristics of financing mode B_2	0.3452
Investor demand and preference B_3	0.5254

4.2.2 Calculate approaching degree

First, the positive and reverse indexes in the index system must be determined. Ownership of the project, economic intensity of the project, the degree to which the government can control, breadth and scale of financing, the degree of adaptation to the Semi-commonweal of the project, reasonable risk sharing degree, project insurance and guarantee, reliability degree of funds, investment property right structure and recourse scheme are divided into positive index. Others are divided into reverse index. The comprehensive evaluation index of each financing model is shown in the following Table 6.

According to the comprehensive evaluation index of each financing model, the comprehensive evaluation index of each scheme is solved in MATLAB software. The approaching degree of each financing models is shown in the following Table 7.

4.3 Analysis

According to the approaching degree, there are six financing models, that is, BT, PPP, ABS, BOT, TOT, PFI. From the judgment standard to the results of the weighted gray target decision model, the smaller the approaching degree (ξ) is, the better the scheme. In this case, the BT model is the most suitable model. The PFI model is the most undesirable. The BT model can adapt to the quasi-public welfare of the inter basin water transfer project. It is difficult to recover the cost of Inter-basin water diversion project in the short-term. The BT mode doesn't have operational risk. The BT contractor is only responsible for the fund raising and project construction. This model is widely used in the South to North Water Transfer Project. The result conforms with the actual situation.

5 Conclusions

Project Financing is significant to the Inter-basin Water Transfer Projects which have low Return on Investment and long payback period such as the water diversion from the Han to the Wei River. However, at this stage, a large

Table 5

Comprehensive Weight of Specific Indicator Layer

Specific indicator layer	Weight	Comprehensive weight
Ownership of the project C_1	0.0849	0.0110
Economic intensity of the project C_2	0.3009	0.0389
The degree to which the government can control C_3	0.1306	0.0169
Complexity of project management C_4	0.0409	0.0053
The amount of capital required for the project C_5	0.4427	0.0573
Breadth and scale of financing C_6	0.0697	0.0241
Financing cost C_7	0.1231	0.0425
The degree of adaptation to the Semi-commonweal of the project C_8	0.3504	0.1210
Risk sharing reasonable degree C_9	0.1971	0.0680
Project insurance and guarantee C_{10}	0.1161	0.0401
Reliability degree sources of funds C_{11}	0.1436	0.0496
Investment property right structure C_{12}	0.3806	0.2000
Recourse scheme C_{13}	0.0712	0.0374
Complexity of financing procedures C_{14}	0.1000	0.0525
Difficulty of financing conditions C_{15}	0.1309	0.0688
Funds occupied period C_{16}	0.3173	0.1667

Table 6

Program Evaluation Index Comprehensive Score

Influence factor layer	Specific indicator layer	Comprehensive evaluation index					
		BOT	BT	TOT	PPP	PFI	ABS
Project attribute	Ownership of the project	5.6	6.7	6.3	5.5	6.5	5.3
	Economic intensity of the project	6.5	5.6	3.6	6.9	6.3	4.3
	The degree to which the government can control	5.2	6.1	4.5	4.9	4.3	5.9
	Complexity of project management	7.1	6.2	5.9	6.5	7.3	5.3
	The amount of capital required for the project	5.2	5.3	4.5	4.9	4.3	5.9
Characteristics of financing mode	Breadth and scale of financing	5.8	6.2	4.7	6.8	6.4	7.4
	Financing cost	6.3	5.7	4.3	5.9	3.6	3.4
	The degree of adaptation to the quasi-public welfare of project	5.3	7.5	5.1	7.6	4.8	7.3
	Risk sharing reasonable degree	4.3	4.8	3.9	6.2	5.2	6
	Project insurance and guarantee	6.5	6.3	5.8	6.8	5.3	5.2
	Reliability degree sources of funds	6.8	7.1	5.2	6.7	5.8	6
Investor demand and preference	Investment property right structure	6.2	5.7	5.3	6.8	5.8	4.5
	Recourse scheme	4.3	5.5	4.2	5.4	4.3	4.6
	Complexity of financing procedures	6.8	7.1	6.1	6.7	5.8	5.3
	Difficulty of financing conditions	6.2	5.7	5.3	6.8	5.8	4.5
	Funds occupied period	5.8	5.4	5.3	6.2	6.9	4.9

Table 7

The Approaching Degree of Each Financing Models

Financing scheme	Approaching degree (ξ)
BOT	1.1349
BT	0.8717
TOT	1.2591
PPP	0.8873
PFI	1.2700
ABS	1.1308

number of Inter-basin Water Transfer Projects in China are still mainly dependent on government investment, while the private capital is insufficient. Thus, this is a great burden on government financial fund. With the continuous improvement of investment and financing system of China Hydraulic engineering and the refinement of investment subsidies, finance discount, rice mechanism, water rights system reformation and other supporting policies, the fund-raising mode of Inter-basin Water Transfer Projects will develop diversely. And the financing model will become a focus in the research field of fund-raising for large-scale water transfer project in the future.

This paper uses the weighted gray target model, takes the water diversion from the Han to the Wei River as example, selects relevant evaluation index and adopt AHP theory to determine the weight of each index to research the financing mode of Inter-basin Water Transfer Projects. The actual situations of other water transfer projects show that the calculations are reasonable and feasible. This evaluation model can comprehensively reflect the influence factors of the subject, the object and the target of financing model. It can provide references for the financing model decision of Inter-basin Water Transfer Project.

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