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DETERMINATION AND AHP ANALYSIS OF THE WATER PRICE OF DAHUOFANG WATER DIVERSION PROJECT

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ABSTRACT Due to historical reasons, the price of water supplied through the water diversion project is relatively low in our country, which results in the failure of newly constructed projects. Therefore the price has to be determined according to the amount of investment and running situation of the project. The water price also has to accommodate users by being affordable. To make the price of water supplied from Dahuofang reservoir reasonable and operable, it should be determined under the premise of meeting the needs of investment return and achieving normal operation of the project from the view point of the supplier. In this study, the financial capacity of residents and industries to purchase water is analyzed according to the current economic growth rate. Reasonable price is calculated based on AHP and suggestions are made considering the interests of both supply and demand.

Keywords: Dahuofang, water diversion project, price of water, AHP

INTRODUCTION Dahuofang water diversion project aims at transferring water from the eastern areas with ample water supply of Liaoning Province to Dahuofang reservoir, which locates at the upstream of Hunhe river, through the 85.31km water diversion tunnel and re-regulating the water supply through the Dahuofang Reservoir to feed the residents and industries of the six severely short water supplied cities in the middle areas of the Province: Fushun, Shenyang, Liaoyang, Anshan, Yingkou, Panjin. The water diversion flow rate of this project is designed to be 70m^3/s and average annual water diversion amount is about 1.757 billion m^3. This project is divided into two stages: the investment budget of first stage is 5.467 billion, which mainly covers the 85.31km long water diversion tunnel and water intake project; the investment budget of second stage is 6.392 billion, which mainly covers the conduits and costs for companies distributing water from Dahuofang Reservoir to all the six cities receiving the water (Jiang, 2009). In order to make the water supply price of Dahuofang water diversion project accordant with theoretical requirements and also feasible in reality, this study put its aims on: 1. calculating the supplier's water supply price of Dahuofang water diversion project; 2. analyzing the affordability of users; 3. considering the profits of both parties to raise a

reasonable suggestion with regard to the water supply price according to the analysis of the affordability of users and calculation of supplier's cost.

CALCULATING PRINCIPLE OF WATER SUPPLY PRICE As a basic signal of water supply-demand on the market and a key point for water distribution, the price of water plays an important role in the operating management process of water diversion project (Liu, 2004).The reasonable water supply price will not only influence the survival and development of water supply companies, but also affect the rational utilization of water resource and sustainable development of social economics (Tang & Xu, 2009). Nowadays for actual projects the water supply price is normally determined according to only one single point of view: one example is to determine the water supply price on the basis of the calculation of water supply cost according to only the water supplier's point of view, which sometimes might not be accepted by the market because the price is normally too high; the other example is to determine the water supply price on the basis of the affordability of users without considering the water supply cost, which is normally used on agricultural water and can make it difficult to develop a beneficial cycle in the water resource industry. In order to make the water supply price of Dahuofang water diversion project accordant with theoretical requirements and also feasible in reality, this study aims at three points: 1. calculating the supplier's water supply price; 2. analyzing the affordability of users; 3. considering the profits of both parties to raise a reasonable suggestion with regard to the water supply price according to the analysis of the affordability of users and calculation of supplier's cost.

CALCULATION OF SUPPLIER'S WATER SUPPLY PRICE The supplier's water supply price should be composed of three parts: engineering price, environment price and resource price. The calculation of the water supply price should be carried out from the three parts mentioned above (Li et al, 2004).

Calculation of engineering water supply price Engineering price= project cost + tax payment + profit)/actual annual sales volume of water

The available water supply of Dahuofang water diversion project can reach 1.757 billion m^3 after its completion. According to the predicted water demand, the amount of water required just after the completion of the project will be 30% of the designed annual water demand. According to the principles like the financial internal rate of return is no less than 8%, the payable profit ratio of capital is no less than 4%, and the credit period is 15 years, the water price can be calculated on the basis of three kinds of project loan ratio 30%, 50%, and 70%. The calculation results are as follows: if the water supply price is 1.63yuan/m^3, loan ratio from development bank is 30%, financial internal rate of return is 10.13%, payable profit ratio of capital within the loan period is 4.07%, payable profit ratio of capital within the production period is 11.64%, the engineering water supply price of the Dahuofang water diversion project is identified to be 1.63Yuan/m^3.

Determination of environment water price The environment price is used for compensating the influence of the used water drained by the customer to the nature, which refers to the cost of sewage disposal. In this project, the water are abstracted from the outer basin with abundant water resources in the water diversion area and the diversion volume only holds a small proportion of the riverway runoff volume, therefore it will not affect the environment of land surface. The water diversion area is a

mountainous area containing rare underground water so it will not affect the underground water condition in the water diversion area either. Therefore the environment price in this project does not include the cost for compensating the influence to the environment of the water diversion area, but only counts in the additional sewage disposal cost for the newly increased water supply in the areas introducing the water. According to the No. 19 [2002] of the People's Government of Liaoning Province "Notice on adjusting the standards about collecting water resource fee and sewage disposal fee and water supply price of provincial reservoirs and relevant issues", it is clearly specified that the standard of collecting sewage disposal fee is 0.65Yuan/m^3. The environment price of Dahuofang water diversion project is determined to be 0.65Yuan/m^3 after its completion.

Determination of resource price The economic essence of resource water price is the scarcity of resources, and the resource price is the realistic reflection of the economic ownership of the water resource and social cost for using water other than construction management cost of the water supply project. The resource price appears as the taxes or fees in reality. In America, this price is charged in the way of tax, while in our country it is charged in term of water resource fee. According to the standard for collecting water resource fee from the above document No. 19 [2002] of the People's Government of Liaoning Province, the resource price of Dahuofang water diversion project is determined to be 0.11Yuan/m^3.

Determination of supplier's engineering water supply price Based on the above analysis, the supplier's water price=engineering water price + environment price + resource price. Thereafter, the supplier's water supply price of Dahuofang water diversion project should be: Supplier's water supply price = engineering water price + environment price + resource price =2.73+0.65+0.11=3.49 Yuan/m^3.

ANALYSIS OF USER'S AFFORDABLE WATER PRICE In the Dahuofang water diversion project the affordability of water price is analyzed from two aspects: industrial water consumption and domestic water consumption. The analysis of affordability of industrial water consumption is based on the proportion of water fee to the industrial production cost and the analysis of affordability of domestic water consumption is based on the proportion of water fee to the disposable income of urban residents (Zeng et al, 2006).

Analysis of affordability of industrial water price According to the research of the World Bank and some international loan institutes, the water fees for industrial use should be paid attention to only when it reaches 3% of the gross output value of the industry on average. However it is generally believed in our country that it is too high for the water fee to cost 3% of the gross output value. Therefore in this Dahuofang water diversion project, we use 2% of the gross output value of the industry to be the industrial water fee costs to analyze the expense of industrial water fee, so the affordability of industrial water price is analyzed on the basis that it costs 2% of the gross output value of the industry. The calculation results of affordable industrial water price are shown in Table1.

Table 1 Analysis results of the affordability of industrial water price in Dahuofang water diversion project

Items	Year	Shen-yang	An-shan	Fu-shun	Panjin	Ying-kou	Liao-yang	Whole province
Water consumption quota per 10 thousand RMB turnoverm3/10 thousand RMB	2000	42	135	129	100	102	131.2	111.0
	2010	21.5	72.7	71	48.2	45.1	69.4	56.5
	2020	13.8	45.7	47.6	28.2	26.1	42.2	36.5
Expense for water fee of every 10 thousand RMB turnoverYuan	2000	200	200	200	200	200	200	200
	2010	200	200	200	200	200	200	200
	2020	200	200	200	200	200	200	200
Company affordable water priceYuan/ m3	2000	4.76	1.48	1.55	2.00	1.96	1.52	1.80
	2010	9.30	2.75	2.82	4.15	4.43	2.88	3.54
	2020	14.49	4.38	4.20	7.09	7.66	4.74	5.48

As per Table1 the affordable industrial water price in the year of 2002 is 3.54 Yuan/ m^3, and in the year of 2020 it is 5.48 Yuan/m^3.

Analysis of affordability of domestic water price According to the overseas and domestic experiences, it is practicable for the water fee to cost 2%, 2.5% of the disposable income of residents. According to the Statistics Yearbook of Liaoning province, the annual disposable income per person in the year of 2000 is presented in Table3. The annual growth rate of disposable income per person from 2000 to 2010 is 8%, so the annual growth rate of disposable income per person from 2010 to 2020 is predicted to be 8%. The expense of water fee is calculated on the basis that it costs 2% of the annual disposable income per person. Thus the calculation results are shown in Table2.

Table 2 Calculation results of the affordability of domestic water price

Items	Year	Shen-yang	An-shan	Fu-shun	Panjin	Ying-kou	Liao-yang	Whole province
Annual disposable income, Yuan/person·year	2000	5851	6053	5155	4924	5094	4950	5358
	2010	12632	13068	11129	10631	10998	10687	11568
	2020	20576	21286	18128	17316	17914	17407	18842
Domestic water consumption per person, m3/person ·year	2000	80.30	66.43	43.80	50.01	62.05	66.43	63.44
	2010	91.25	71.17	51.10	56.75	70.08	74.83	71.20
	2020	102.20	74.82	58.40	61.32	74.83	79.20	76.13
Annual water fee expense per person, Yuan	2000	117.02	121.06	103.10	98.48	101.88	99.00	107.16
	2010	252.64	261.36	222.59	212.61	219.95	213.73	231.35
	2020	411.52	425.73	362.57	346.32	358.28	348.15	376.85
Residents' affordable water price Yuan/ m3	2000	1.46	1.82	2.35	1.97	1.64	1.49	1.69
	2010	2.77	3.67	4.36	3.75	3.14	2.86	3.25
	2020	4.03	5.69	6.21	5.65	4.79	4.40	4.95

It is clear in Table 2 that the residents' affordable domestic water price in the year of 2010 is 3.25 Yuan/m^3 and in the year of 2020 it is 4.95Yuan/m^3. The degree of residents' affordability of domestic water price, which is figured out on the basis of residents' economic capacity, is lower than the one of industrial water price. The residents' psychological endurance is relatively poor because of long time low water price policy. It will take a long time for the residents to enhance their psychological endurance for water price.

Determination of user's affordable water price Upon the above analysis, the affordable industrial water price in the year of 2010 is 3.54 Yuan/m^3 and the current urban water supply price is 3.23 Yuan/m^3, which means that the water price can be raised. The affordable industrial water price in the year of 2020 is 5.48 Yuan/m^3; therefore the price can be raised for 2.25 Yuan/m^3. The residents' affordable domestic water price in 2010 is 3.25 Yuan/m^3, and it will be 4.95Yuan/m^3 in 2020. Normally the residents' affordable domestic water price is lower than affordable industrial water price. The residents' affordable domestic water price can not be raised too fast.

To sum up, according to the proportion of various water uses and the calculation of weighted average water price, the customer's affordable water price in 2010 is 3.35 Yuan/m^3 and it is 5.06 Yuan/m^3 in 2020, which is affordable to the customers.

DETERMINATION OF INTEGRATED WATER PRICE According to system engineering theory, the water price is determined by integrated processing of an organic system, which is composed of multiple factors and sectors. The determination and implementation of water price will make a great influence on the economy, society, politic, ecologic environment, etc. On the basis of the overall analysis of all the influential factors of water price and considering the interests of suppliers and customers, the determined water price should satisfy the needs of getting returns on investment of

the project and keeping normal operation, and should also be affordable to the users. The analytic hierarchy process is applied in the Dahuofang water diversion project for calculating the integrated water price (Jiang, 2008).

Theory of analytic hierarchy process Analytic Hierarchy Process (AHP for short) was designed in the early 1970s by an American operational researcher professor T·L·Sauty as a simple, flexible and practical multi-criteria solution approach. The basic idea of AHP is to find a mathematical way to convert the comparison of multiple cases into pairwise comparison so as to resolve the problem of multi-case comparison.

In order to reach an agreed standard for multi-cases comparison, Sauty and his colleagues proposed a scaling method with 9 layers. Please see the details in Table 3.

Table 3 Scale list

Scale value aij	Definition
1	Factor i and factor j share equal importance
3	Factor i is slightly more important than factor j
5	Factor i is relatively more important than factor j
7	Factor i is much more important than factor j
9	Factor i is absolutely more important than factor j
2, 4, 6, 8	The scale value representing the intermediate state between above two judgments
Reciprocal	Comparing factor j with factor i, the result should be aji/aij, aii=1

The maximum eigenvalue of comparison matrix and its corresponding characteristic vector can be determined by using the scale values of each layer, which indicates the relative value of all the factors in the matrix (i.e. relative degree of importance).

Establishment of ascending hierarchic structure of the water price in Dahuofang water diversion project The water price of Dahuofang water diversion project is determined by considering the purpose of coordinating the effective distribution of resource, promoting the economic development of these areas, achieving the supplier's returns of cost and normal operation and making the price affordable to users. Therefore, the Target layer represents the reasonable water price; principle layer indicates supplier's water price and affordable water price of users; goal layer, which is recognized as restraint layer, is determined by analyzing the above factors used for obtaining a reasonable water price. The layer structural model is shown in Table 4.

Table 4 Layer structural model of integrated water price

A Target layer	P Principle layer	C Goal layer
Integrated water price	Supplier's water price	Promoting the reasonable distribution of water resources C1
		Promoting project construction and financing C2
		Adapting to the requirement of market economy C3
	Affordable water price of users	Encouraging saving and reducing extravagance C4
		Promoting regional sustainable development C5
		Easing the burden of consumers C6

Calculation of weight In this study, the relative importance of each factor in C layer is analyzed and compared by using the Layer structural model and scale values in Table 4 to evaluate the relative importance condition of each related factors in the layer structural matrix. The structure of judgment matrix is established and the conduct weight calculation is accomplished.

According to the structural judgment matrix A-C, formula(3) is obtained.

$$\begin{bmatrix} 1 & 1/2 & 1/3 & 1/5 & 1/7 & 1/9 \\ 2 & 1 & 1/2 & 1/3 & 1/5 & 1/7 \\ 3 & 2 & 1 & 1/2 & 1/3 & 1/5 \\ 5 & 3 & 2 & 1 & 1/2 & 1/3 \\ 7 & 5 & 3 & 2 & 1 & 1/3 \\ 9 & 7 & 5 & 3 & 3 & 1 \end{bmatrix}$$

For consistency test on A-C judgment matrix, the weight vector $\overline{W_i}$ is calculated at first to be:

$W\left[0.03304 \quad 0.05347 \quad 0.08882 \quad 0.15189 \quad 0.23580 \quad 0.43697\right]^T$

According to the consistency index in Table 5, it is identified that the judgement matrix conforms to the requirement of consistency and the calculated weight is reliable.

Table 5 Average random consistency index

Order	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Then construct the judgement matrix of C-P□C1-P□C2-P□C3-P□C4-P□C5-P□C6-P□, the calculated weight vectors, which conform to the requirement of consistency, are shown in Table 6.

Table 6 C-P judgment matrix λ_{max} □ CI□ CR and weight vector calculation sheet

Judgment matrix	λ_{max}	CI	CR	$W[W_1 \quad W_2]^T$
C1-P	2	0	0	$W[0.33333 \quad 0.66667]^T$
C2-P	2	0	0	$W[0.16667 \quad 0.83333]^T$
C3-P	2	0	0	$W[0.87500 \quad 0.12500]^T$
C4-P	2	0	0	$W[0.83333 \quad 0.16667]^T$
C5-P	2	0	0	$W[0.66667 \quad 0.33333]^T$
C6-P	2	0	0	$W[0.66667 \quad 0.33333]^T$

The value of CR in Table 6 shows that the judgment matrix can meet the requirement of consistency.

Calculation of combinational weight The A-P judgment matrix is formed by using the combinational weight calculation in Table7 and the combinational weight is calculated according to the formula of $V^{(2)}$in Table 7. The calculation results of A-P judgment matrix and combinational weight are shown in Table 8.

Table 7 Calculation sheet of combinational weight

C layer / P layer	Factor □C1□C2□…Cn Weight □W1□W2□…Wn	Combinational weight
P1	$W_{11}^{(2)}W_{12}^{(2)}...W_{1n}^{(2)}$	$V_1^{(2)}=\sum_{j=1}^{n}W_j^{(1)}W_{1j}^{(2)}$
P2	$W_{21}^{(2)}W_{12}^{(2)}...W_{2n}^{(2)}$	$V_2^{(2)}=\sum_{j=1}^{n}W_j^{(2)}W_{2j}^{(2)}$
⋮		
Pn	$W_{k1}^{(2)}W_{k2}^{(2)}...W_{kn}^{(2)}$	$V_k^{(2)}=\sum_{j=1}^{n}W_j^{(k)}W_{kj}^{(2)}$

Table 8 A-P judgment matrix and weight vector calculation sheet

A	C1	C2	C3	C4	C5	C6	Vj
P1	0.33333	0.16667	0.87500	0.83333	0.66667	0.66667	
P2	0.66667	0.83333	0.12500	0.16667	0.33333	0.33333	
Wi	0.03304	0.05347	0.08882	0.15189	0.23580	0.43697	
Wi×P1i	0.01101	0.00891	0.07772	0.12657	0.15720	0.29132	0.67274
Wi×P2i	0.02203	0.04456	0.01110	0.02532	0.07860	0.14566	0.32726

Determination of integrated water price According to the analysis above, the supplier's water price is 3.49 Yuan/m^3; affordable water price to the customer is 3.35 Yuan/m3 (in the year of 2010) and 5.06 Yuan/m^3 (in the year of 2020). According to the calculation results of the weight, the integrated water price in the two design average year is as follows:

Year of 2010: P=3.49×0.6727+3.35×0.3273=3.44 Yuan/m^3□

Year of 2020: P=3.49×0.6727+5.06×0.3273=4.00 Yuan/m^3□

Therefore, the integrated water price of Dahuofang river diversion project is 3.44 Yuan/m^3 and 4.00 Yuan/m^3 corresponding to the two level years 2010 and 2020.

Rationality analysis of the integrated water price The engineering water price can be calculated reversely from the integrated water price determined above, i.e. integrated water price □ environment price □ resource price □ additional price charged by water purification plant. See the following calculation:

Engineering water price in 2010 =3.44-0.65-0.11-1.1=1.58 Yuan/m^3□

Engineering water price in 2020 =4.00-0.65-0.11-1.1=2.14 Yuan/m^3□

According to the above engineering water price and related analysis, the economical evaluation of Dahuofang water diversion project is as follows: the financial internal rate of return of this project is 9.49%; economical net present value is 9272.14 million Yuan; loan repayment period is 15 years. Therefore it meets the financial evaluation index of project and requirement of loan repayment. As to the water price, the integrated water price in 2010 is 3.44Yuan/m^3 and affordable water price to customer is 3.35 Yuan/m^3, which shows that the integrated water price is higher than affordable water price but it is still acceptable to the customers; the integrated water price in 2020 is 4.00 Yuan/m^3 and affordable water price to customer is 5.06 Yuan/m3, which shows that the integrated water price is lower than affordable water price. Thus it is observed that the integrated water price determined in this study can not only meet the financial and loan repayment requirements during the operating period of the project, but also can fit the affordability of water consumers. Therefore the integrated water price determined in this study is feasible.

CONCLUSION Most of the time in actual projects the water supply price is only determined in consideration of one single point of view. However in our study, the water price is determined by calculating many different related aspects and it is a reasonable integrated price based on the comprehensive analysis of those aspects. AHP model is used for determining the integrated water price and the hierarchical analysis model, which is easy to be built up, easy for calculation and quite practicable, is established to make the integrated water price as the target layer, supplier's water price and affordable water price as the principle layer, and coordination of effective resources distribution as the goal layer. Of course, there are still some problems to be further investigated, for example the customer's affordability could not be always the same. Therefore it needs more studies on the way of investigation and analysis for obtaining the water consumers' affordability index.

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