WATER PRICING IN THE HOUSEHOLD SECTOR IN SHANGHAI, CHINA ——A FUZZY MODEL AND ITS APPLICATION

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Abstract:

This paper is based on the author's research on water resources value evaluation and pricing, and focuses on establishing a water pricing model using fuzzy mathematics. The Fuzzy Quantitative Analytical Method with a case study using this model are studied. The author hopes to achieve a representative water pricing method to support the Water Authority in Shanghai to establish appropriate water pricing policies which can help to ensure efficient use of water and to protect water resources.

Key words: *water resources value water pricing, fuzzy mathematical model*

1 INTRODUCTION:

Water resources are one of the most important resources in the world. Many problems have emerged during the process of utilization of these water resources. How to balance the economic and social benefits during the process of water utilization is an urgent and important issue. People all over the world pay great attention on how to form consensus on the following fundamental problems:

(1) The State is required to control the power and to coordinate or balance the relationship and benefits among the people, businesses, enterprises and various organizations, especially to maintain the sustainable use of water, to support waterworks, and to guarantee the poor have a minimum amount of quality water.

(2) Households and organizations should cherish the use of water, and be " willing to pay " for this commodity and the services they receive.

(3) The water management authority should use their revenues, try their best to pay for a portion or a large portion of the operation and maintenance (O & M) costs and gain the support from the government.

Unquestionably water is scarce in China, per capita water resources are only one-fourth world averages, at least 400 of more than 600 cities face water shortages, either in quantity or in quality, in most cases both. For example: (1) in 1997 the Yellow River failed to reach the sea for an astounding 226 days, (2) annually the Beijing groundwater table is dropping at an average rate of 1.5 meters, and (3) the current Shanghai local per capita water resources amount has fallen below $200m^3$ and lacks good quality water in which the most water quality cannot reach Grade □ standard and even grade □ standard although the mighty Yantze River passes through the Shanghai municipality.

It is commonly believed that solutions to water scarcity are often discussed in terms of three different facets:

(1) making water related regulations and policy. (2) developing water management systems and (3) raising awareness of water scarcity and water conservation. Fortunately the economy acts as a lever to drive the three facets. Water pricing reform and its related research has been promoted by both academics and policy analysts as one of the key measures for easing and resolving water scarcity that touches on all the above three facets.

So the people understand that the value of water resources takes an important place in sustainable utilization of water resources. Many researchers have studied and contributed towards water evaluation and pricing.

There are some mathematical models for valuing water resources available such as the Shadow Price Model, Marginal Opportunity Cost Model and Supply-Demand Price Model, each has its own merits and demerits owing to the limitation of practical application and cannot completely reflect the value that water resources specialists perceive for water resources.

The whole water resources valuing system is complicated and ambiguous. It is a complex system composed of three main interactive parts: society, economy and environment.

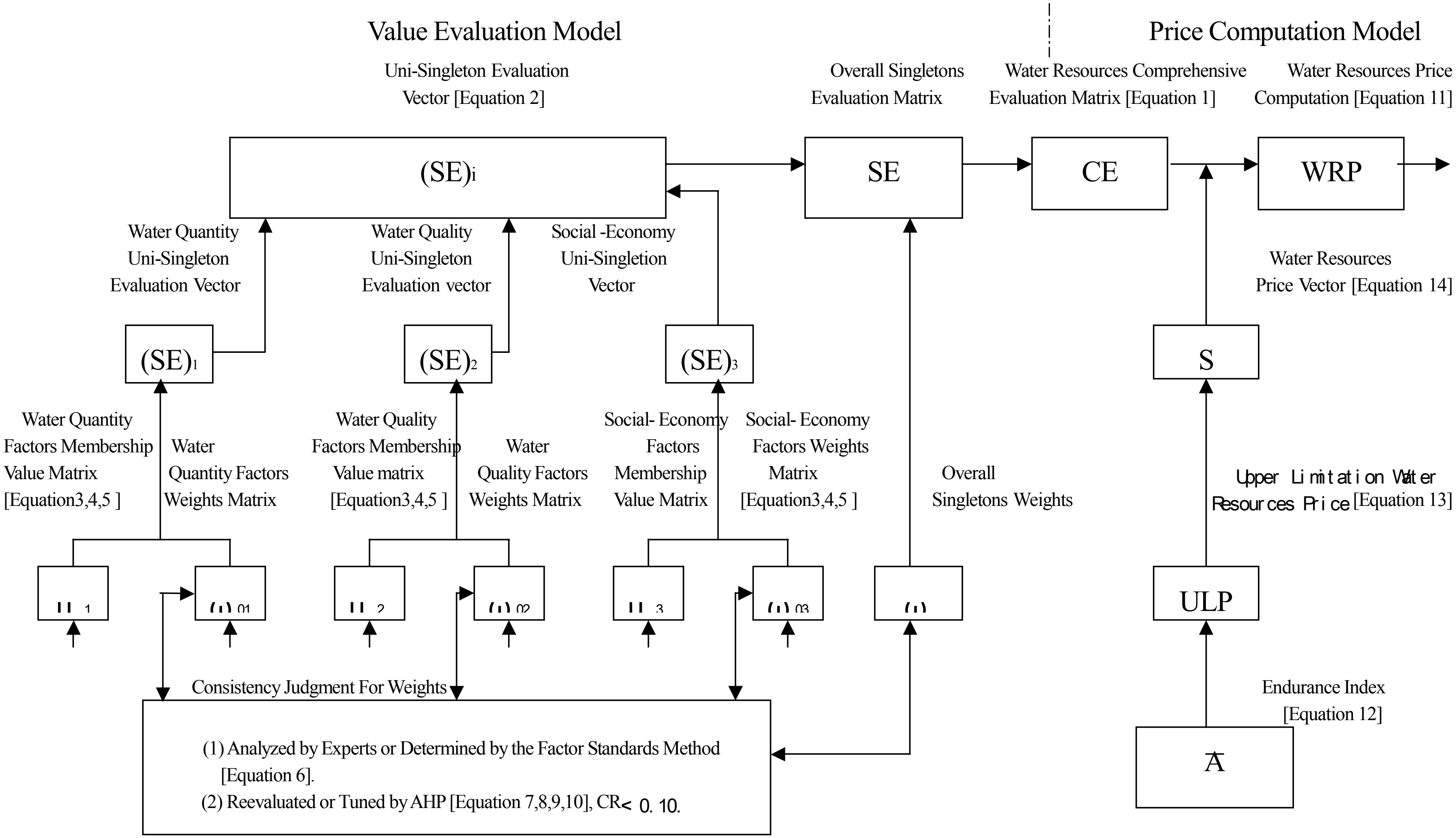
In this paper A Fuzzy Mathematical Model is implemented to solve the computation for valuing water resources.

In the 1970's, a fuzzy theory was proposed by Professor Lotfi Zadeh from the University of California at Berkeley. Fuzzy Theory focuses on uncertainty, often called fuzziness, where a boundary is ambiguous, and cannot define it as yes or no. About Fuzzy Zadeh said: "As the complexity of a system increases, our ability to make precise and significant statements about its behavior diminishes until a threshold is reached beyond which precision and significance become mutually exclusive characteristics".

As we know, there are many uncertainties such as problems in society, economy and environment all over the world. Fuzzy Theory is NOT a fuzzily defined theory. It is a mathematical theory to deal with ambiguities using quantified descriptions in exact methods. Although the object is uncertainties, but the method is not uncertain. The definition of Fuzzy Theory is done in a rigorously scientific way.

In the fact, Fuzzy Theory is so essential and is also applicable to the computation for valuing water resources as in other fields, such as automation, control, and even for washing machines.

For convenient reading, the following flow chart for the computation of Fuzzy Mathematical Model is listed (fig.1). It is a summary of this paper.



The Flow Chart of Fuzzy Mathematical Model for Price Computation of Water Resources

fig.1

2 Fuzzy Model Computation

2.1 The main singletons and factors in computing water resources value Evaluation

We use following main singletons and their evaluation factors in the determination of the water resources value (Table 1).

Table 1

Singletons	Factors
Water Quantity	Local Per Capita Water Resources Amount, Average Area Water Resources Amount and Run-off Coefficient.
Water Quality	DO, BOD_5, COD_{Cr}, NH_3-N, TP, TN and Volatile Phenol.
Social -Economy	Population Density, Per Capita GDP Water Demand for 10□000 RMB YUAN and Irrigation Water Usage Coefficient.

These factors display the main value characteristics of Water Resources. Everybody recognizes that plentiful and high quality water is a tremendous wealth for human beings. The very existence of mankind on earth and its abuses against the earth and industrial production causes water scarcity in the world.

2.2 Fuzzy comprehensive evaluation

Let U, universe of discourse, represents a set of singletons for valuing water resources, where: U =□water quantity, water quality, social-economy□.

V is an evaluation set, which is composed of evaluation grades of the value of water resources (standards or setting levels), and V=□high(1), medium-high(2), medium(3), medium-low(4), low(5) □.

Water resources value can be computed by following equation for its comprehensive evaluation.

$$CE = \omega \circ SE \qquad \text{Equation(1)}$$

Where: CE — Comprehensive Evaluation Matrix

ω — Overall Singletons Weight Allocation Matrix

SE — Overall Singletons Evaluation Matrix .It represents the fuzzy-logic relationship between the set of Singletons U and the Set of Evaluation V.

o — Complex operator for fuzzy matrices, it operates as follows:

Let $A = (a_{ij})_{m\times s}$, $B = (b_{ij})_{s\times n}$ are fuzzy matrices

$$AoB = (C_{ij})_{m\times n}, \quad C_{ij} = \bigvee_{k=1}^{s} (a_{ik} \wedge b_{kj}) \text{ i.e,} \quad C = A\mathbf{o}B \Leftrightarrow C_{ij} = \bigvee_{k=1}^{s} (a_{ik} \wedge b_{kj})$$

2.3 Uni-singleton evaluation matrix

Singletons evaluation matrix SE is composed of three uni-singleton evaluation vectors $(SE)_i$ (i = 1, 2, 3)

$(SE)_i$ is defined as $(SE)_i = \omega_{0i} \circ \mu_i$ Equation (2)

here: $(SE)_1$ — Uni-singleton Evaluation Vector for Water Quantity Factors

$(SE)_2$ — Uni-singleton Evaluation Vector for Water Quality Factors

$(SE)_3$ — Uni-singleton Evaluation Vector for Social-Economy Factors

ω_{0i} — Evaluation Factor's Weight in a given uni-singleton

μ_i — Membership Values Matrix. It is obtained from the membership function of each evaluation factor in a given uni-singleton.

Following linear membership functions with one unknown quantity are used in this paper.

$$\mu_{i1}(v_i) = \begin{cases} 1 & v_i \le S_{i1} \\ \dfrac{S_{i2} - v_i}{S_{i2} - S_{i1}} & S_{i1} < v_i < S_{i2} \\ 0 & v_i \ge S_{i2} \end{cases} \quad \text{Equation(3)}$$

$$\mu_{ij}(v_i) = \begin{cases} \dfrac{v_i - S_{i,j-1}}{S_{ij} - S_{i,j-1}} & S_{ij} \le v_i < S_{i,j+1} \\ \dfrac{S_{i,j+1} - v_i}{S_{i,j+1} - S_{ij}} & S_{i,j-1} < v_i \le S_{ij} \\ 0 & v_i \le S_{i,j-1}, v_i \ge S_{i,j+1} \end{cases} \quad \text{Equation (4)}$$

$$\mu_{in}(v_i) = \begin{cases} 1 & v_i \ge S_{in} \\ \dfrac{v_i - S_{i,n-1}}{S_{in} - S_{i,n-1}} & S_{i,n-1} < v_i < S_{in} \\ 0 & v_i \le S_{i,n-1} \end{cases} \quad \text{Equation (5)}$$

where: v_i — practical value for the Evaluation Factor

$S_{i,j-1}, S_{i,j}$ — two standards or grade setting levels between the adjacent evaluation grades. Here is the grade number of a Evaluation Factor, j = 2, 3,…, n, if n = 5, the set of evaluation is composed of five grades. i.e. V={high(1), Medium high(2), medium(3), medium low(4), low(5)}.

μ_{ij} — Membership Value for Evaluation Factor i, here j = 1, 2,…n.

2.4 Allocation matrix of weights

In water resources value comprehensive evaluation we can determine comprehensive evaluation matrix CE from the equation (1). **ω** in the equation is the Overall Singletons Weight Allocation

Matrix. In this paper we let **ω**= (0.4 0.4 0.2)^T after the experts' Analytic Hierarchy Process (AHP) analysis and evaluation according to Shanghai's practice. These weights of **ω** represent the contribution of water quantity, water quality and social-economy to the results of Water Resources value comprehensive evaluation.

In uni-singleton evaluation we can also obtain vector matrices $(SE)_1$, $(SE)_2$ and $(SE)_3$ separately for water quantity, water quality and social-economy from equation (2), in which the weights ω_{oi} represent the effects among different factors in a given uni-singleton. They also gain by comparison.

In the vector matrices $(SE)_1$ and $(SE)_3$, we still allocate weights according to the experts' AHP analysis and evaluation for two uni-singletons factors. In the vector matrix $(SE)_2$ we use factor standard value method, i.e. we use the following equation (6) to determinate the weights (a_i) of the second uni-singleton's 7 water quality factors.

$$a_i = \frac{v_i}{U_{ij}} / \sum_{i=1}^{n} \frac{v_i}{U_{ij}} \qquad \text{Equation (6)}$$

where: v_i — Water Quality Factor test value.

U_{ij} — the grade value of water quality standard for the factor.

i — Water Quality Factors, i = (1, 2, 3,…7).

j — the determined grade of water quality standards .

here j=1, 2, 3, 4 and 5

2.5 The judgement matrix of weights

Engineers have difficulties in accurately determining the weights and evaluations. In this case, with the help of Analytic Hierarchy Process (AHP) engineers can judge the weights allocated whether they are right or wrong. AHP was developed by Thomas L. Saaty and published in his 1980 book, *The Analytic Hierarchy Process.* This process involves pairwise comparisons, which is the key to using AHP. We use the following Table 2 for pairwise comparisons.

In this paper there are five steps for AHP Analysis:

The First Step: determine the target G and the set of evaluation U.

G represents the comprehensive evaluation target for water resources value.

or, G also represents the fuzziness evaluation target of the overall singletons for water quantity, water quality and social-economy.

U represents the set of overall evaluation singletons for water quantity, water quality and social-economy.

Or, U also represents the set of all evaluation factors in every uni-singleton.

Table 2: The scale of Judgment Matrix and their meanings of pairwise comparisons

scales (U_{ij})	meanings
1	compare U_i to U_j, Equally preferred
2	compare U_i to U_j, Equally to Moderately preferred
3	compare U_i to U_j, Moderately preferred
4	compare U_i to U_j, Moderately to Strongly preferred
5	compare U_i to U_j, Strongly preferred
6	compare U_i to U_j, Strongly to Very Strongly preferred
7	compare U_i to U_j, Very Strongly preferred
8	compare U_i to U_j, Very to Extremely Strongly preferred
9	compare U_i to U_j, Extremely preferred

The Second Step: construct Judgment Matrix. Following equation is Judgement Matrix.

$$J = \begin{matrix} U_1 \\ U_2 \\ \vdots \\ U_m \end{matrix} \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1m} \\ u_{21} & u_{22} & \cdots & u_{2m} \\ \vdots & \vdots & & \vdots \\ u_{m1} & u_{m2} & \cdots & u_{mm} \end{bmatrix} \qquad \text{Equation (7)}$$

where: m — the number of factors in the set of evaluation.

U_i — evaluation factor.

U_i □ U (i = 1, 2, …m).

U_{ij} — relative more importance value. (i.e. scale), it gains by comparison between U_i and U_j. With Pairwise Comparisons, we can get a G-U Judgment Matrix J.

The Third Step: compute the characteristic vector $\overline{w}$, normalize every column in G-U Judgment Matrix first, then sum the values over the rows; finally normalize into a single column matrix, to obtain $\overline{w}$ **, (** also called weighted sum vector).

The Fourth Step : calculate Maximum Characteristic Value $\lambda_{max:}$

$$\lambda_{max} = \frac{1}{m} \sum_{i=1}^{m} \frac{(J\overline{w})_i}{\overline{W}_i} \qquad \text{Equation (8)}$$

The Fifth Step: Determine the Consistency Ratio (CR). If $\lambda_{max,}$ is attainable, we can compute Consistency Index (CI) before the final Consistency Ratio (CR) can be computed.

$$CI = \frac{\lambda_{max} - m}{m - 1} \qquad \text{Equation (9)}$$

$$CR = \frac{CI}{RI} \qquad \text{Equation (10)}$$

where: RI — the Random Index, which is determined from the following.

Table 3. The computation of RI is based AHP Theory.

m	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Judgment Rule: When CR□ 0.10, the Judgment Matrix has satisfactory Consistency. For a Consistency Ratio that is greater than 0.10, we should seriously consider reevaluating or tuning scales during the pairwise comparisons.

2.6 Water resources price computation model

In order to compute water resources price economically, A proper price vector is introduced. Through the following equation (11), we can shift from the vector function of membership to the related amount of water resources price.

$$WRP = CE \times S \qquad \text{Equation (11)}$$

where: WRP — Water Resources Price.

CE — Water Resources Comprehensive Evaluation Matrix.

S — Water Resources Price Vector.

2.7 Computation to determine the Endurance index for the water fee.

Endurance Index for water fee represents the tap water users' endured ability to get the water commodity and receive water services for which they are "willing to pay".

We can compute Endurance Index as following equation:

$$\overline{A} = \frac{WF}{E} \qquad \text{Equation (12)}$$

where: $\overline{A}$ — Endurance Index for Water Fee.

WF — Household Water Fee (RMB YUAN/year).

E — Per Capita Disposable Income (RMB YUAN/year).

2.8 Computation to determine the upper limitation of water resources price.

The Upper Limitation of Water Resources Price (ULP) is Water Resources Price at which the Endurance Index for Tap Water Fee goes maximum, when the users complain and are not "willing to pay".

We can compute ULP with equation (13)

$$ULP = A \bullet \frac{E}{C} - D \qquad \text{Equation (13)}$$

where: ULP — Upper Limitation of Water Resources Price (RMB YUAN) .

A — Maximum Endurance Index for Tap Water Fee (%).

E — Per Capita Disposable Income (RMB YUAN/year).

C — Per Capita Household Water Consumption (m^3/year).

D — Unit O & M Cost and Profits for Tap Water (RMB YUAN /m^3).

2.9 Determining price vector

As mentioned above, the actual water resources price should be between ULP and 0, i.e. (ULP, 0). Different area has different water price, which depends geographical location, different nature and human ecology characteristics and different social-economy.

In this paper we use iso-differential method to find the price interval.

We get related water resources price vector at intervals of iso-differential between ULP and 0. thus, we have

$$S = (ULP, P_1, P_2, P_3, 0) \qquad \text{Equation (14)}$$

where: S — Water Resources Price Vector

and let $P_1 = \frac{3}{4} ULP$, $P_2 = \frac{1}{2} ULP$, $P_3 = \frac{1}{4} ULP$

So we can have Water Resources Price from the equation: $WRP = CE \times S$

3 THE POSITIVISTIC ANALYTICAL CASE OF WATER RESOURCES VALUE IN SHANGHAI

Some important values and standards/setting levels about water resource value evaluation singletons are arranged in table 4. These factors are related to water characteristics, reflect water quantity, water quality and social-economy development in Shanghai. They come together to form the computation fundamentals of water resources value in Shanghai.

3.1 Computing SE

According to equation 1, 2, 3, 4 and 5, we obtain a singletons evaluation matrix SE.

$$SE = \begin{bmatrix} 0.67 & 0 & 0 & 0.22 & 0.11 \\ 0.25 & 0.125 & 0.25 & 0.25 & 0.125 \\ 0.30 & 0.30 & 0 & 0.2 & 0.20 \end{bmatrix}$$

Table 4: **Shanghai Water Resources Value Evaluation Singletons Values And Standards/ Setting Level (2001)**

Singletons	Factors	Value	Standards / Setting Levels				
			High(1)	Midium-high(2)	Medium (3)	Midium-low(4)	Low(5)
Water Quantity	Local Per Capita Water Resources Amount ; m^3	193	400	800	1200	2000	3000
	Average Area Water Resources Amount ; m^3/sq.km	403. 280	100.000	200. 000	300. 000	400. 000	500. 000
	Run-off Coefficient	0. 49	0. 05	0. 20	0. 30	0. 40	0. 50
Water Quality	DO: mg/l	3. 9	8	6	5	3	2
	BOD5: mg/l	2. 8	3	4	5	6	10
	CODcr: mg/l	23	15	18	20	30	40
	NH_3-N: mg/l	0. 62	0. 15	0. 5	1	1. 5	2
	TP: mg/l	0. 218	0. 02	0. 1	0. 2	0. 3	0. 4
	TN: mg/l	2. 98	0. 2	0. 5	1	1. 5	2
	Volatile Phenol ; mg/l	0. 001	0. 001	0. 002	0. 005	0. 01	0. 1
Social Economy	Population Density ; person/sq.km	2093	3000	150	50	10	5
	Per Capita GDP:	37382	5000	3000	2000	1000	500
	Water Demand For RMB YUAN 10,000 GDP ; m^3	215	3500	3000	2500	2000	1000
	Irrigation Water Usage Coefficent	0. 68	0. 30	0. 40	0. 50	0. 60	0. 80

3.2 Computing CE

The overall singletons weight allocation matrix$\boldsymbol{\omega}$=(0.4 0.4 0.2)^T and the other weights about vector matrices $(SE)_1$,$(SE)_2$ and $(SE)_3$ are all determined by AHP Analysis as well as equation 6. From comprehensive evaluation matrix we get CE = (0.308 0.154 0.192 0.192 0.154) .

3.3 Computing ULP

It is difficult to determine Maximum Endurance Index (EI) for tap water fee in Shanghai. The average percentage of water fee to household income is about 0.64% (Table 5). The maximum percentage is 1.16% for lowest income household and the minimum one is 0.32% for highest income household. From the sample survey in China, if EI=1%, no impact to water users' perception of pricing; If EI=2%, the users begin to pay attention to conserving water; If EI=2.5%~3%, more impact to household users; When EI is beyond 5%, there is severe impact to the families.

According to the survey by the United Nations, many cities in the Asia Pacific Region have the same conditions as in China. The cities, where EI=0~1%, (the data cited represents "percent water cost per household income", have same concept with EI) are New Delhi,Hanoi, Ho chi minh, Hong Kong, Kuala Lumpur, Madras, Penang, Seoul, Singapore, Suva and Taipei. The cities, where EI=1~2%, are Bangkok, Calcutta, Colombo, Manila and Medan.Dhaka, Jakarta and Vientiane have EI's of 2~5%. And the cities', where EI□5%, are Bombay, Cambodia and Papua New Guinea. In our case we use EI=3% for computing (Table 6). We take into account that the water users in Shanghai can accept an incremental price policy, although the average household income in Shanghai is catching up with some developed cities or countries listed above, such as Hong Kong, Taipei and Singapore, and in most other situations, is beyond them. Shanghaiese should accept and endure EI of 3% for better water quality and sustainable development of their better life.

$$ULP = A \bullet \frac{E}{C} - D \qquad \text{Equation (15)}$$

where: ULP — Upper Limitation for Water Resources Price

A — Maximum Endurance Index (EI) for Tap Water Fee（3%）

E — Per Capita Disposable Income (Per Capita 12883 RMB YUAN in 2001)

C — Per Capita Household Water Consumption (m^3/year) (Table 7: 253 l/d)

D — Unit Cost for O & M and Profits for Tap Water (RMBYUAN/m^3)

Shanghai Urban Household Per Capita Annual Consumer Expenditures

Table 5: (2001,Grouped By Income Level) unit: RMB YUAN

Indicators	Total Average	Lowest Income (First Decile)	Low Income (Second Decile)	Medium-low (Second Quintile)	Medium-Income (Third Quintile)	Medium-High (Fourth Quintile)	High Income (Ninth Decile)	Highest Income (Tenth Decile)
Annual Disposable Income	12883 (0.64%)	6103 (1.16%)	7700 (1.04%)	9170 (0.86%)	11155 (0.67%)	13812 (0.61%)	16935 (0.54%)	30615 (0.32%)
Total Consumer	9336 (0.88%)	6126 (1.16%)	7731 (1.03%)	7647 (1.03%)	8473 (0.89%)	10010 (0.84%)	11997 (0.76%)	15482 (0.63%)
Food	4022	3136	3543	3646	3978	4228	4279	5652
Clothing	577	387	332	427	516	634	810	1105
Household Facilities,Articles and Services	642	261	314	368	422	521	1318	1942
Medicines and Medical Services	558	365	423	499	542	657	623	789
Ttaffic and Communications	875	381	416	599	701	1405	1045	1518
Recreation Education and Cultural Services	1360	868	1706	1141	1203	1299	1942	1804
Residence	733 (11.2%)	514 (13.8%)	662 (12.1%)	616 (12.8%)	647 (11.6%)	653 (12.9%)	843 (10.8%)	1510 (6.5%)
Rent	118	83	142	121	120	107	103	165
Water Fees	82	71	80	79	75	84	91	98
Electricity Fees	269	212	249	247	268	273	312	344
Fuels Fees	156	137	155	148	157	155	166	187
Miscellanecus Commodities and Services	569	214	335	351	464	613	1137	1162

* .Data are obtained from the sample survey on income and expenditures of 500 urban households in Shanghai.
**.Percentage in brackets is the ratio of Water Fee to Income and Expenditures.

Table 6: A real case in Shanghai (Year 2001)

Water revenue	584,000,000 RMB YUAN
Sold water amount	662,230,000 m^3
Total cost	595,128,900 RMB YUAN
Unit cost for O & M	$\frac{595{,}128{,}900}{622{,}230{,}000} = 0.899$ RMB YUAN
Profits rate supposed	10□
D	0.899×(1+0.10)=0.989RMB YUAN

$$ULP = A \bullet \frac{E}{365C} - D = 0.03 \bullet \frac{12883}{0.253 \times 365} - 0.989 = 3.20 \text{ (RMBYUAN)}$$

3.4 Computing S

From ULP=3.20, according to equation (14) we can get S=(3.20 2.40 1.60 0.80 0)^T. The interval is 0.80.

3.5 Computing WRP

WRP = CE × S

= (0.308 0.154 0.192 0.192 0.154) ×(3.20 2.40 1.60 0.80 0)^T

= 1.82 (RMB YUAN/m^3)

4 FURTHER DISCUSSION ABOUT WATER PRICING FRAMEWORK IN SHANGHAI

In order to make water usage more sustainable, we should take into account water pricing policy and methodology and the following essential elements should be obviously further included.

4.1 Increase public awareness and let citizens participate.

With economic development, improvement of people's life and the strengthening of environment protection, acceptance of water pricing schemes and the polluters pay principle by the general public has increased gradually. Construction and control investments are necessary to develop and to implement strategies, which should focus on explaining to users (citizens, industries, commercial services and agricultural organizations) why they need to pay more for their water use and how they can reduce their water bills through more efficient water-saving and pollution control practices.

4.2 Public participation helps to support the integration of different policies involved with water eco-environment protection, construction and improvement and the acceptability of higher water bills.

Shanghai has good experiences in this field. Citizens and representatives from a variety of organizations (industries and water services, etc) held discussions in the People's Congress. Through face-to-face communication they may begin to understand the reasons behind price increases, to understand how to their waste water is going to affect the sewerage system and rivers, and to learn more about water is being extracted excessively and what the consequences for their environment are. This participation increases transparency and is helpful to avoid lack of information exchange between users and water authorities. As everybody knows, the lack of transparency is always an obstacle to implement of new and more efficient pricing schemes.

4.3 Full water pricing has to include enough costs for water resources development and reversing water environmental damages.

The polluter pays and precautionary principles can only be put into practice effectively by inclusion of water resources costs and environment damages into the water pricing system. The full internalization of these costs is a necessary measure to ensure water's sustainable use, and is not just "efficient use" water.

Metering and volumetric pricing schemes are useful "tools" for efficient use and saving of water resources. Despite having reached a high percentage goal of metering for households, industries and commercial services almost have been reached 100% in Shanghai city proper, some work needs to be improved in the suburbs. Furthermore, irrigation in some situations is neither metered nor priced per volume does still exist. With completely implementing metering system, the expensive water price makes people save water for common requirements. It may increase the water demand elasticity to some extent. An Increasing Block Schedule can be used to adjust social equity needs.

As was mentioned above, the social equity can be influenced by proposed water pricing. From Table 5, we can see more wealthy citizens bear less burden. On the other hand, some people still live below the poverty life line. (According to UN's standard for developed countries, the poverty life line is below half the amount of per capita disposable income . In Shanghai's case in 2001, the poverty life line is 4,294 RMB YUAN, i.e.358 RMB YUAN monthly, 12 RMB YUAN daily, is equivalent to 1.45 USD, see Table 8, exchange rate:1USD=8.27RMB YUAN, is almost close to 1USD – the poverty life line standard formulated by UN for developing countries). We suggest 108 liters of water per capita a day as shown in Table 7, be set as a basic daily water usage block to be charged for whom lives below the poverty life line seems to be a good possible solution for the above equity problem. Meanwhile, high water consumption should no longer be encouraging by the charging system.

Shanghai Urban Household Per Capita Water Consumption

Table 7: unit: RMB YUAN

Year	1965	1970	1975	1980	1985	1990	1995	2000	2001	2005	2010	2020
Household Per Capita Water Consumption Xi(L/person.day)	64. 8	86. 2	110	94. 5	83. 8	116	132. 5	141	146	160	170	180
Household Per Capita Comprehensive Water Consumption (L/person.day)								246	253	300	380	350
Per Capita GDP Yi(RMBYUAN)	1042	1446	1898	2738	3855	5910	18942	34547	37382			

Regression Equation: $Yi = A + BXi$

$A = -2832.61$, $B = 61.10$, $r = 0.62$ } 1965~1990, $A = -36825.66$, $B = 450.88$, $r = 0.86$ } 1965~2001

The average (1965~2001) of household per capita water consumption is about 108 l/person·day.

Percentage Of Shanghai Urban Households In Total Grouped By Disposable Income (1990~2001)

Table 8: unit: %

Year	Below 2000 RMB YUAN	2000~ 3000 RMB YUAN	3000~ 4000 RMB YUAN	4000~ 5000 RMB YUAN	5000~ 6000 RMB YUAN	6000~ 7000 RMB YUAN	7000~ 8000 RMB YUAN	8000~ 9000 RMB YUAN	9000~ 10000 RMB YUAN	10000~ 20000 RMB YUAN	20000~ 25000 RMB YUAN	over 25000 RMB YUAN
1990	51. 0	43. 2	5. 4	0. 4								
1991	29. 8	54. 2	13. 0	2. 6	0. 2		0. 2					
1992	12. 8	45. 0	31. 2	7. 8	2. 8	0. 2	0. 2					
1993	2. 6	19. 6	32. 2	23. 0	10. 4	6. 6	3. 2	1. 6	0. 4	0. 4		
1994	1. 0	5. 6	15. 4	22. 8	22. 8	11. 2	7. 4	5. 4	2. 4	6. 0		
1995		2. 6	7. 4	17. 0	17. 0	16. 0	12. 6	8. 0	6. 8	12. 2	0. 2	0. 2
1996		1. 0	4. 0	13. 4	15. 0	13. 6	12. 4	11. 8	9. 4	18. 0	1. 2	0. 2
1997		1. 0	2. 8	5. 8	12. 6	14. 2	13. 6	12. 2	9. 6	26. 4	1. 6	0. 2
1998		1. 0	3. 2	4. 4	9. 2	14. 6	12. 4	15. 0	11. 2	26. 8	1. 8	0. 4
1999			0. 4	1. 2	3. 8	10. 6	13. 8	12. 6	11. 6	40. 4	3. 6	2. 0
2000		0. 2		0. 6	2. 4	4. 0	12. 2	12. 2	10. 6	51. 4	3. 6	2. 8
2001			0. 2	0. 6	3. 2	5. 0	9. 0	11. 2	10. 0	53. 4	3. 8	3. 6

5 CONCLUSIONS:

In general terms, overall water pricing should include three facets: water resources price, tap water price and sewage tariff.

(1) Water resources value (price): It is already computed by Fuzzy Mathematical Model. WRP=1.82 RMB YUAN/m^3 (2001).

(2) Tap water price: we can obtain tap water price and per capita GDP data from 1990~2001 in Table 9. Through regression computation, coefficient of correlation r = 0.97, it shows good relationship between yearly water price and related per capita GDP. Tap water price in 2001 is 0.88 RMB YUAN/m^3. Some tap water prices can be predicted by this regression equation.

Shanghai Tap Water Price (1990~2001)

Table 9: unit: RMB YUAN

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Water Price(Xi)	0. 12	0. 18	0. 28	0. 4	0. 5	0. 5	0. 5	0. 68	0. 88	0. 88	0. 88	0. 88
Per Capita GDP(Yi)	5910	6955	8652	11700	15204	18942	22275	25750	28240	30805	34547	37382
Regression Equation: Yi = A+BXi, A = -360.56, B = 37528.25, r = 0.97												

(3) Sewage tariff in Shanghai (1986~2002) is shown in Table 10. This tariff was promoted by the World Bank in the Shanghai Sewage Project. In this project 145 million USD was loaned by the World Bank. Sewage tariff in 2001 is 0.70 RMB YUAN/m^3. It can basically cover O & M costs in Shanghai sewerage system.

Although Shanghai government does not levy for water resources as yet, WRP=1.82RMB YUAN/m^3 is only a theoretical price, it at least remains us sufficient room to gather financial resources for water conservation. If the above three kinds of water fees put in action together, the total price consumption in water represents ca 2.4% of Shanghai's per capita disposable income (12,883 RMB YUAN/year, 253 liters per day). If we are to achieve an EI of 5% target in near future for establishing a reasonable water pricing framework, further study should be continued.

Shanghai Sewage Tariff(1986~2002)

Table 10: unit: RMB YUAN

Year		1986	1994	1996	1998	1999	2000	2001	2002
Tariff	household			0. 12	0. 24	0. 45	0. 70	0. 70	0. 70
	Trade	0. 12	0. 14	0. 34	0. 37	0. 45	0. 70	0. 70	0. 70
	Abstraction charge			0. 14	0. 17	0. 25	0. 50	0. 50	0. 50

As said above, using Fuzzy Mathematical Model to evaluate and compute water resources price is easy and practical. The result of computation coincides in Shanghai's situation.

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上海市两大引水系统图
Shanghai Raw Water Distribution Systems
Chongming Island
Yangtze River
Jiangsu Province
TAICANG(P)
2nd Raw Water Resources
CHENHANG
3rd Proposed Raw Water Resources
QINGCAOSHA
YUEPU
WUSONG
DACHANG
ZHABEI
Huangpu River
1st Raw Water Resources
East China Sea
LEGEND
raw water pumping station
waterworks