# Water Strategy Impact Evaluation in China based on FUSSY Comprehensive Assessment method

Chunmei Chen [a], Bin Jing [b] and Hui Zhang [c]

College of science, the Second Artillery Engineering University, Xi'an, Shaanxi 710025, China

[a]ccm1977@sohu.com, [b]362437655@qq.com, [c]zhanghui4958@163.com

## Abstract

**This paper aims at formulating a comprehensive water strategy to meet China's water needs at present by taking the economic, social and environment factors into consideration.The paper takes into account the average water resources per capita, possession of waterper unit area, water supplyper capita, million Yuan GDP water quantity, and establishes a comprehensive water resources index. By using analytical processing (AHP), we assess and classify the seriousness of water shortage in different provinces in China. A water strategy impact evaluation system is established based on the economic, social and environmental factors and the fuzzy comprehensive assessment method is employed to evaluate the impact degree of the formulated water strategy. Through the prediction and calculation, we draw the conclusion that the comprehensive impact degree of the water strategy proposed in this paper is grade B now, indicating a strong impact.**

## Keywords

**Water strategy; Evaluation; AHP; FUZZY comprehensive assessment method.**

## 1. Introduction

Water resource is the material basis for all human productive activities and human lives. Without water, there would be no human on the Earth, there is no human. However, water and water resources is different from the concept of natural substances, Water resources are not equal to the water, they account for only three hundred thousandths of water in the Earth system, which is about 47 trillion tons, which as water resources are very limited. So water resources are irreplaceable resources.

The total amount of water resources in China is approximately 2.8124 billion cubic meters, which accounts for 6% of the world's total runoff resources; besides, China stands as the world's most water-consumptive country. In 1993, the amount of water withdrawn( freshwater) is 525.5 billion cubic meters, which accounts for 12% of the world's withdrawn water and is larger than the united states' total amount of withdrawn water in 1995(470 billion cubic meters), freshwater quantity of water, 470 billion cubic meters. Due to the large population, water resources per capita is 2,500 cubic meters, about 1/4 of the world's.[1][2]

Especially in recent years, the sharp increase in the urban population, the deterioration of ecological environment, the backward technology of using water in industry and agriculture, a serious waste and pollution of water, all these factors make the water shortage problem even worse. The economic and social function of water has become increasingly significant.[4]

## 2. Construction of evaluation index system for water strategy

Among the social, economic, environmental and water resources systems are interlinked and interdependent, and interaction, these subsystems form an integral whole, namely water resources system based on macro-economic and ecological environment. Water strategy not only impact on the water resources system itself, but also has a profound impact on the social, economic and environmental subsystem. Therefore water strategy on water resources systems, economic systems, environmental systems, and social systems, we need to establish a comprehensive evaluation index system of comprehensive water strategy.

The fuzzy comprehensive evaluation of the application of the concept of fuzzy set qualitative evaluation index quantified in order to achieve a comprehensive evaluation of the system, commonly used to address issues such as comprehensive evaluation, selection decision programs, estimates and projections , the allocation of inputs and other issues. [3]Therefore, we have chosen the fuzzy comprehensive evaluation method to solve the comprehensive evaluation of the water strategy.

Water strategy considering the impact on water resources systems, social systems, economic systems, and environmental systems, combined with the composition of the various subsystems and influencing factors, to establish as shown in the figure 1 below the water level of strategic influence comprehensive evaluation index system.

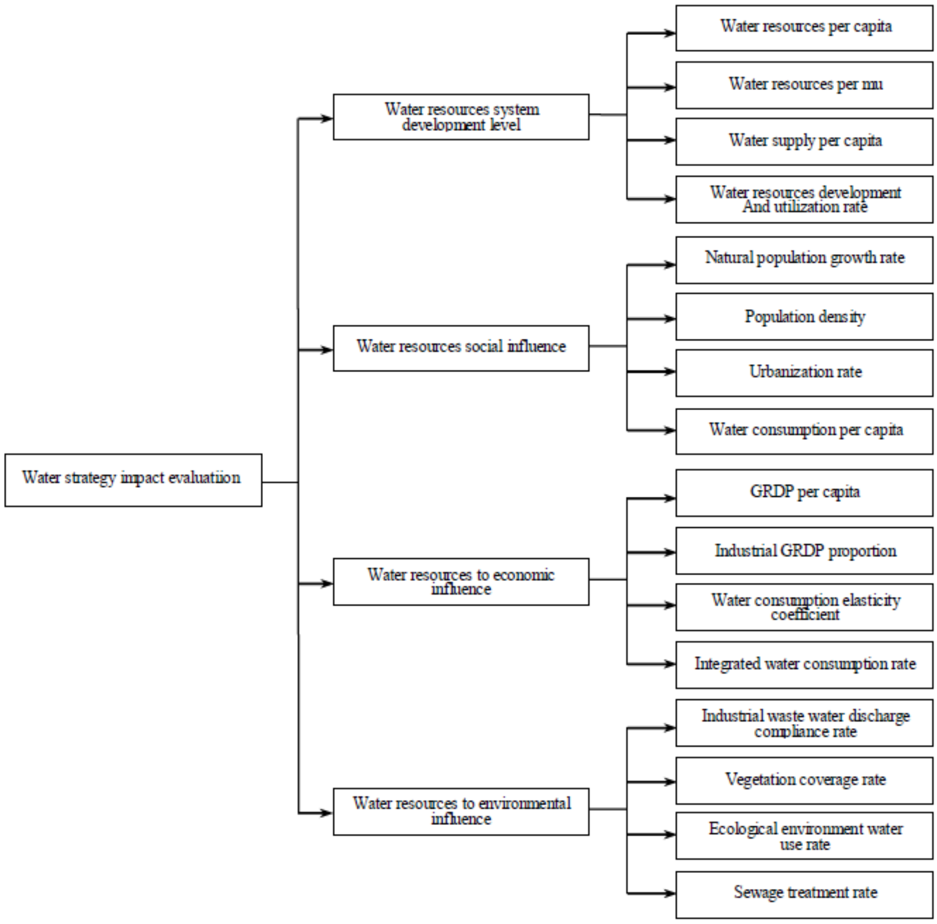


Fig. 1 Water strategy impact evaluations

## 3. Analysis of Data

### 3.1 Data sources

From the State Statistics Bureau official website (http://www.stats.gov.cn ) ,we get the data of different areas in China from the year 1990 to 2014, and by calculating we get the values of Water resources per capita,possession of waterper unit area,water supplyper capita,million Yuan GDP water quantity, as shown in Table 1.

### 3.2 Water Shortage Degree Analysis in different Areas

The comprehensive indicator of water resources in the various provinces of China is calculated according to Formula (1).

$$H = aX_1 + BX_2 + cX_3 + dX_4 \qquad (1)$$

Where $X_1$, $X_2$, $X_3$, $X_4$ respectively indicates water resources per capita, possession of water per unit area ,water supply per capita and million Yuan GDP water quantity ; $a$, $b$, $c$, $d$ is respectively the weight of each element. We use Analytic Hierarchy Process (AHP) to determine weight of the four elements, and employ numbers 1, 3, 5, 7, 9 to measure the degree in importance of two adjacent indicators, which respectively indicates the following 5 cases: the former and latter are equally important, the former is slightly more important, obviously more important, highly more important and extremely more important than the latter. The numbers 2, 4, 6, 8 represents a transition between the two degrees. [3]We can get the judgment matrix by using expert evaluation method, and then obtain the weights by calculating and checking. The weights are showed in Table 2.

Table 1 current status of provincial (regional) water resources

| Area | Water resources per capita | Possession of water per unit area | Water supply per capita | Million Yuan GDP water quantity |
|---|---|---|---|---|
| Beijing | 329.03 | 242857.14 | 326.37 | 225.4 |
| Tianjin | 153.2 | 129203.53 | 225.91 | 117.7 |
| Hebei | 363.06 | 126212.04 | 346.77 | 599.17 |
| Shanxi | 456.86 | 91987.17 | 185.51 | 969.5 |
| Inner Mongolia | 2178.41 | 42831.78 | 669.77 | 4629.42 |
| Liaoning | 877.41 | 247580.09 | 346.88 | 1040.66 |
| Jilin | 1484.01 | 208110.99 | 396.88 | 2695.39 |
| Heilongjiang | 2068.24 | 168652.17 | 843.45 | 2864.35 |
| Shanghai | 184.62 | 426984.12 | 784.76 | 80.05 |
| Jiangsu | 455.23 | 317153.99 | 587.45 | 487.1 |
| Zhejiang | 2022.77 | 881237.72 | 460.31 | 1934.13 |
| Anhui | 1104.61 | 485509.32 | 289.89 | 2534.87 |
| Fujian | 3560.93 | 957166.25 | 523.97 | 3895.19 |
| Jiangxi | 3427.46 | 853781.51 | 491.68 | 8293 |
| Shandong | 381.33 | 213784.3 | 294.39 | 503.75 |
| Henan | 441.09 | 244131.73 | 252.39 | 999.44 |
| Hubei | 1670.69 | 523585.91 | 396.37 | 2843.86 |
| Hunan | 2516 | 774571.42 | 500.12 | 5434.68 |
| Guangdong | 2672.81 | 1054616.67 | 633.73 | 2576.17 |
| Guangxi | 4057.84 | 671428.57 | 626.91 | 9329.09 |
| Hainan | 3358 | 735988.2 | 644.41 | 6087.44 |
| Chongqing | 2574.62 | 950485.43 | 177.25 | 5801.05 |
| Sichuan | 3613.99 | 628683.45 | 239.64 | 9176.2 |
| Guizhou | 2870.21 | 586734.69 | 238.49 | 13052.03 |
| Yunnan | 5425.01 | 563705.58 | 357.98 | 13507.84 |
| Tibet | 180725.8 | 373500 | 661.29 | 58229.15 |
| Shaanxi | 1237.81 | 18114.51 | 220.05 | 3332.47 |
| Gansu | 1099.83 | 60418.5 | 486.64 | 3510.63 |
| Qinghai | 12525 | 86827.5 | 541.12 | 30992.32 |
| Ningxia | 186.79 | 14909.63 | 1829.05 | 469.37 |
| Xinjiang | 5138.53 | 55175 | 2615.89 | 8406.49 |
| China | 2275 | 292958 | 442 | 3761 |

Table 2 the weight of evaluation items

| *Items* | *Normalized value* | *Weight* |
|---|---|---|
| Water resources per capita ($m^3$/capita) | $X_1$ | 0.473 |
| Possession of water per unit area ($m^3/km^2$) | $X_2$ | 0.284 |
| Water supply per capita ($m^3$/capita) | $X_3$ | 0.17 |
| Million Yuan GDP water quantity ($m^3$million Yuan) | $X_4$ | 0.073 |

Based on the state of water resources in different areas, we divide the 30 provinces into four levels: Abundant water resources area ($H$>0.2), Fragile areas (0.15<$H$<0.2), Water shortage area (0.08<$H$<0.15) and Serious water shortage area ($H$<0.08). The result is shown in Table 3.

Table3 Each Province Integrated Water Resources Index

| Level | Area | H | Level | Area | H |
|---|---|---|---|---|---|
| | Tibet | 0.6895 | | Jiangsu | 0.1248 |
| | Guangdong | 0.3325 | | Ningxia | 0.1234 |
| | Fujian | 0.3016 | | Heilongjiang | 0.106 |
| | Chongqing | 0.2749 | | Qinghai | 0.0954 |
| Rich area | Zhejiang | 0.2727 | Shortage area | Liaoning | 0.0916 |
| | Jiangxi | 0.2718 | | Beijing | 0.0874 |
| | Hainan | 0.2496 | | Jilin | 0.086 |
| | Hunan | 0.2483 | | Henan | 0.0834 |
| | Guangxi | 0.2333 | | | |
| | Xinjiang | 0.1993 | | Shandong | 0.0777 |
| | Sichuan | 0.1954 | | Shaanxi | 0.0766 |
| | Yunnan | 0.1909 | | Inner Mongolia | 0.0613 |
| Fragile area | Guizhou | 0.1826 | Severe shortage area | Hebei | 0.0575 |
| | Hubei | 0.1714 | | Gansu | 0.0512 |
| | Shanghai | 0.1664 | | Tianjing | 0.0498 |
| | Anhui | 0.1527 | | Shanxi | 0.0381 |

Table 3 indicates that Abundant water areas are mainly distributed in some southeast provinces as Guangdong, Guangxi, Fujian, Zhejiang, Jiangxi, Hunan, Hainan, and southwest provinces as Chongqing and Tibet; Fragile area are mainly distributed in some southwest provinces as Yunnan, Guizhou, Sichuan and Shanghai, Anhui, Hubei and Xinjiang. Water shortage areas are mainly distributed in Heilongjiang, Jilin, Liaoning, Ningxia, Qinghai, Beijing, Jiangsu and Henan. Serious shortage areas are mainly distributed in the northern area as Shandong, Shanxi, Shaanxi, Gansu, Inner Mongolia, Hebei, Tianjin and so on. The result is shown in Figure2.

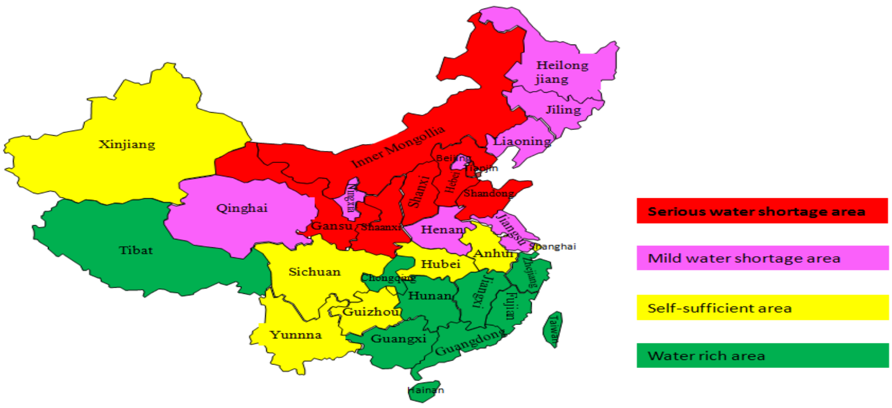


Fig. 2 Schematic diagram of water levels in the various provinces

Analysis of the assessment results:

(1)Water shortage area and Severe water shortage area

Most of Water shortage area and Severe water shortage area are located in the northern China, but different region has different situation. The water shortage state in Qinghai, Jiangsu, Shandong, Liaoning and Tianjin can be relieved by desalination because of the salt water lakes and coastal situation.

Shandong belongs to severe water shortage area, desalination only is not enough to solve the water shortage crisis, and water diversion becomes necessary. As Beijing is located in the territory of Hebei, We take Beijing as the representative of Hebei.

(2)Fragile areas

For the seven provinces of the fragile area, they can basically achieve self-sufficiency in water resources, and further efforts in water conservation and reuse can prevent the scarcity caused by economic development and population increase.

(3)Water-rich area

In addition to Taiwan, Tibet is the richest water resource area in China, but due to the high altitude and complex terrain, the cost of the water diversion from Tibet is too high. So is Hainan. Except for Tibet and Hainan, water diversion can be conducted in the other 7 rich water resources areas.

## 4. Evaluation Model Introduction

### 4.1 Weight

The index system of comprehensive evaluation of the degree of influence of the water strategy is a multi-level, multi-criteria decision - making problems. This article used AHP method to determine the evaluation index weight, first of all, through the experience of law and consulting experts' judgment matrix, by policy makers to judge the relative importance of the elements of each level, constitutes a comparison matrix. Judgment matrix, single level sort and consistency checking. Final stratified operation, and evaluation of all levels weight calculation results are shown in Table 4, remember to evaluation the water strategy affect the extent of the right to ownership of weight index weighting coefficient $A=\{p_1, p_2, p_3, \cdots, p_n\}$

Table 4 Water strategy impact evaluation index weight

| Target layer | Domain layer | Weight | Index layer | Weight |
|---|---|---|---|---|
| Water strategy impact evaluation | Water resources system development level | 0.2 | Water resources percapita | 0.06 |
| | | | Water resources per mu | 0.04 |
| | | | Water supply per capita | 0.06 |
| | | | Water resources development and utilization rate | 0.04 |
| | Water resources to social influence | 0.2 | Natural population growth rate | 0.025 |
| | | | Population density | 0.01 |
| | | | Urbanization rate | 0.025 |
| | | | Water consumption per capita | 0.14 |
| | Water resources to economic influence | 0.3 | GRDP per capita | 0.08 |
| | | | Industrial GRDP proportion | 0.08 |
| | | | Water consumption elasticity coefficient | 0.04 |
| | | | Integrated water consumption rate | 0.1 |
| | Water resources to environmental influence | 0.3 | Industrial waste water discharge compliance rate | 0.05 |
| | | | Vegetation coverage rate | 0.12 |
| | | | Ecological environment | 0.02 |

| | | |
|---|---|---|
| | water use rate | |
| | Industrial GRDP | 0.11 |

## 4.2 Evaluation Criteria

The optimal allocation of water resources strategy evaluation index system , the division of basic indicators of scoring criteria , in accordance with the size of the impact , the index is divided into the influence of "very strong" , "strong" , "medium" , "weak" and "very weak" five score , formation evaluation accordingly set $V=\{A,B,C,D,E\}$ , corresponding score set $G=\{100,80,60,40,20\}$ Reference to the relevant literature and standard literature, combined with the actual situation of the country to determine the evaluation criteria for each index .

Table 5 Scoring Standard

| | Very Weak | Weak | Medium | Strong | Very Strong |
|---|---|---|---|---|---|
| Water resources percapita (m3/capita) | <500 | 500-1000 | 1000-2000 | 2000-4000 | >4000 |
| Water resources per mu (m3/mu) | <400 | 400-1000 | 1000-2000 | 2000-4000 | >4000 |
| Water supply per capita (m3/capita) | <200 | 200-400 | 400-600 | 600-1000 | >1000 |
| Water resources development and utilization rate (%) | >50 | 35-50 | 25-35 | 10-25 | <10 |
| Natural population growth rate (%) | >12 | 11-12 | 9-11 | 5-9 | <5 |
| Population density (person/km2) | >400 | 200-400 | 100-200 | 20-100 | <20 |
| Urbanization rate (%) | <20 | 20-35 | 35-50 | 50-70 | >70 |
| Water consumption per capita (m3/capita) | >1000 | 600-800 | 400-600 | 200-400 | <200 |
| Industrial waste water discharge compliance rate (%) | 40 | 50 | 65 | 80 | 90 |
| Vegetation coverage rate (%) | 20 | 30 | 40 | 50 | 60 |
| Ecological environment water use rate (%) | 1 | 2 | 3 | 4 | 5 |
| Sewage treatment rate (%) | 20 | 40 | 60 | 80 | 100 |
| GRDP per capita (Yuan/capital) | 5000 | 8000 | 10000 | 30000 | 50000 |
| Industrial GRDP proportion (%) | 1.0 | 2.0 | 2.5 | 3 | 3.5 |
| Water consumption elasticity coefficient | 1 | 0.8 | 0.5 | 0.3 | 0.1 |
| Integrated water consumption rate (%) | 20 | 30 | 50 | 70 | 80 |

## 4.3 Calculation

According to either the positive or negative effects that the various rating indicators have on the water strategy,its membership function values were calculated by the various evaluation criteria and the factual indicator value. This reflects the fuzzy relationship between indicators universe and the Evaluation universe [3]. The fuzzy matrix $R$ is as follows:

$$R=\begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1m} \\ f_{21} & f_{22} & \cdots & f_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ f_{n1} & f_{n2} & \cdots & f_{nm} \end{bmatrix}$$

In the equation: $f_{ij}$ stands for the degree of membership of i to the j th filed. Thus we can get the water strategy influence degree fuzzy comprehensive evaluation matrix $Y=A\times R$. If you follow the "checklist" your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

### 4.4 Evaluation

Applying weighted averaging to process the vector results from fuzzy comprehensive evaluation. Suppose "1, 2,…, $m$" stands for each of the grades, and call them the ranks of the grades. Then weight averages the corresponding ranks in $Y$, we get the relative position of the assessed things, the integrated rating is as follows:

$$E=\sum_{j=1}^{m} Y_j \times K_j \tag{2}$$

In the equation: $Y_j$ stands for membership of grade $j$; $K_j$ stands for the rating of grade $j$. Grading criteria is determined according to the threshold of the impact degree of the water strategy. By calculation:

When $E<30$ the result is grade $E$; when $30\le E<50$, the result is grade $D$; when $50\le E<70$, the result is grade $C$; when $70\le E<90$, the result is grade $B$; when $E\ge 90$, the result is grade A.

## 5. Conclusion

Through the established fuzzy comprehensive evaluation index system, we can make a comprehensive assessment of the water strategy we have made. Analyzing the established Indicators system, its specific target values can be improved and optimized during the implementation of the water strategy. On this basis, combined with statistical data in recent years, we can predict the individual index values, and assess the degree of influence by using fuzzy comprehensive evaluation method. According to the assessment, the comprehensive rating for the water strategies is 85.3, grade B,indicating its strong economic, natural and environmental impacts.

## References


[1] Information on http://www.stats.gov.cn

[2] Information on http://www.nianjianku.com

[3] Shoukui Si, Xijing Sun: *Mathematical Modeling*(National defence industry press,China 2011), p.368-381.

[4] Daniel.Hellstrm: A framework for systems analysis of sustainabIe urban water management, Environmental impact Assessment Review, Vol.20(2000) No.2, p.311一321.

[5] Annelies.J.Balkma: Indicators for the sustain ability assessment of wastewater treatment systems, Urban Water, Vol.18(2002) No.4, p.153一161.

[6] Chen Chuanyou, Wang Chunyuan, Dou Yisong: *Water Re-sources and SustainableDevelopment* ( Science Press, Beijing 1998), p. 12-40.

[7] Guodong Qu: *Study on rational regional water resources allocation and its program comprehensive benefits evaluation*(Ph.D., Zheiiang University,China 2013),p. 23-38.

[8] Yao Zhong Yang: *The analyse to the cost of the desalinization*( China Academic Journal Electronic Pubulishing House, China 2011),p. 135-143.