Evaluation approach of water source based on Analytic Hierarchy Process

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Abstract. From the geographic view, rivers or lakes in America often run through several states or even across the half country which makes it difficult to categorize by their natural locations, let alone to allocate them. In an economist's perception, economy in states can have huge discrepancy which directly leads to a rugged graph in water-demanding chart or water use table.

Our main goal is to figure out the ideal weight ratio of various uses of water by addressing the storage and movement, de-salinization and conservation in water process, covering the economic, physical and environmental benefits.

We first divide the whole American region into 3 parts according to the location of its main river basins. Then the Analytic Hierarchy Process (AHP) Model is adopted to filter all the influential factors and extract the final 10 criteria which determine the water uses in those 3 sections. With their weights come out, the abstract problem is successfully transferred into a mathematical one.

We conclude with a series of recommendations to the Water Management Department in the U.S., for how best to allocate water resources due to the current natural distribution of river basins. The outcome of our paper we get about the ratio of water supply quantity in domestic water, process water and water for ecological environment is 5:80:15.

1 Introduction

The quality and availability of water is becoming critical for a specific area's development and prosperity. An effective an economical method to distribute that fresh water from the Artificial river or natural river flowing through the area to quench whatever industrial or domestic need is demanded. Plenty of researches are made and a number of notable papers are addressed to get a reasonable method.

Guaimei Cheng (2004) used improved Analytic Hierarchy Process (AHP) to identify the critical factors that have phenomenal impact on sustainable use of water. Then she employed multi-objective decision analysis aiming maximize integral benefit of economical environmental and social efficacy. After applied Constraint conditions such as the carrying capacity of regional water resources, a model concerning sustainable use of water is emerged. Mingyan Zhao (2005) using standard Hamming distance and standard Euclidean distance, under the intuitionistic set, established a model that could applied to the alternatives selection problem of water supply subject. In his theory, every alternative, every criterion, and every criteria weight are expressed by intuitionistic fuzzy number. Those two distance calculating methods are applied to calculate the alternative index of decision model. Then he compared the results with those AHP yields. And it is proved that his model can describe the fuzzy characteristics of engineering problem exquisitely.

The water resource allocation problem is a muticriteria decision problem. Despite the allocation theory has been studied to different extent with different approaches, the researchers' work usually focus on one aspect. Meanwhile, their proposals did not take their Statistical data as time varied. Therefore, their research may not appropriate to the future needs. We need to develop a model to look for a 'best water strategy choice' that could applied from 2013 to 2025, what's more, the model should be problem-oriented.

The three proposed problems are:

- Develop a model to look for the weight of each criteria of water allocation;
- Develop a model to look for each states' priority concerning water allocation;
- Present a water allocation scheme for America in 2013 that could yield the most favorable outcome in 2025.

2 AHP Model

2.1 Establish a Hierarchy Model

The evaluation criterion of the distribution of river or lake valleys covers many aspects among which economy, water resource itself and the environment are the 3 most significant factors due to their paramount status in establishing a city's working system. For these being necessary prerequisites of how America is divided according to the natural basins, we have figured out social economy condition, development and utilization degree of water resources and state of ecological environment as the 3 swordsman.

Social economy condition

To further segment this economy aspect, we see Gross Domestic Product(GDP), modulus of agricultural output, hydropower production and urbanization level. Each of these four is essential to build an economical pattern.

- GDP
- Modulus of agriculture output
- Hydropower production
- Urbanization level

Development and utilization degree of water resources

The economy condition is an obvious index of these basins' distribution like a born fruit yet it depends on the development and utilization of water resources as it plays a role of gardener. The latter one is subdivided into 4 more portions—proportion of the number of people by water resources(self-sustaining), average temperature, precipitation and percentage of brine.

- Proportion of the number of people by water resources(self-sustaining)
- Average temperature
- Precipitation
- Percentage of brine

State of ecological environment

Say the 2 indexes above are the obvious reflections of whether the distribution of basins in America is successful, the appropriate development and utilization of water resources is also vital without which we would never achieve a balance between the pace of cities thriving and the speed of depletion of natural resources. Thus we regard the environmental factor as the third indispensable element, modulus of soil and water loss, industrial sewage emission and ratio of underground water in water use.

- Modulus of soil and water loss
- Industrial sewage emission
- Ratio of underground water in water use

2.2 Comparison Matrix

Tab.1 shows the weights of the social economy condition, development and utilization degree of water resources and state of ecological environment.

Table 1. Pairwise comparison matrix of hierarchy Ⅰ-Ⅱ

Comprehensive Impact	Social economy condition	Development and utilization degree of water resources	State of ecological environment	weight
Social economy condition	1	1/3	5	0.2746

Development and utilization degree of water resources	3	1	8	0.6571
State of ecological environment	1/5	1/8	1	0.0683

By computing the weights of the 3 main factors, we get the final maximum eigenvalue λ=3.0444, consistency ratio=0.0383.

Table 2. Pairwise comparison matrix of hierarchy Ⅱ-Ⅲ

Comprehensive Impact	**GDP**	**Modulus of agriculture output**	**Hydropower production**	**Urbanization level**	**Weight**
GDP	1	6	4	2	0.5125
Modulus of agriculture output	1/6	1	1/2	1/4	0.0743
Hydropower production	1/4	2	1	1/2	0.1377
Urbanization level	1/2	4	2	1	0.2755

Based on calculation of the weight of the 4 factors of social economy condition, the maximum eigenvalue λ=4.0104, consistency ratio=0.0039.

Table 3. Pairwise comparison matrix of hierarchy Ⅱ-Ⅲ

Comprehensive Impact	**Proportion of the number of people by water resources**	**Average temperature**	**Precipitation**	**Percentage of brine**	**Weight**
Proportion of the number of people by water resources	1	1/2	3	5	0.2963
Average temperature	2	1	5	8	0.5351
Precipitation	1/3	1/5	1	2	0.1085
Percentage of brine	1/5	1/8	1/2	1	0.0601

After ciphering the weight of the 3 elements of the development and utilization degree of water resources, the maximum eigenvalue λ=4.0104, consistency ratio=0.0039.

Table 4. Pairwise comparison matrix of hierarchy Ⅱ-Ⅲ

Comprehensive Impact	**Modulus of soil and water loss**	**Industrial sewage emission**	**Ratio of underground water in water use**	**weight**
Modulus of soil and water loss	1	1/2	5	0.3258
Industrial sewage emission	2	1	8	0.6039
Ratio of underground water in water use	1/5	1/8	1	0.0703

When it comes to the final 3 branches of the state of ecological environment, the maximum eigenvalue λ=3.0055, consistency ratio=0.0048.

From the 4 tables above, we have confirmed that the entire consistency ratio is correct.

2.3 Explanations of the Ten Criteria

Data of social economy condition

GDP in this section is the dominant index as it is the most obvious direct reflection of the economy. Modulus of agriculture output and urbanization level cannot be precisely calculated as these are vague conceptions only can be perceived by human beings. And though hydropower production is an accurate number, the way it affects the economy and its decision power is not that strong as the GDP does. Reversely, the reason GDP can weigh over half of the economy factor lies in the sequent processes after hydropower and agriculture produce.

Data of development and utilization degree of water resources

Among all the 4 elements, average temperature plays a leading role. This is intelligible as the self-sustaining quantity given to human of rivers and lakes are largely affected by the characters of four seasons whose main reason is the temperature. During winter, basins in certain area cannot provide a single water drop in a frozen state. And things go even worse in summer when temperature in some desert-like area is extremely high to vaporize and dry the whole water stream where development and utilization of water resources is no way to be discussed. As to other factors like proportion of the number of people by water resources, precipitation and percentage of brine, the data and impact of them cannot be neglected as well.

Data of state of ecological environment

In recent years, the environment issue has become an inevitable factor in almost every situation. According to Tab.1, the state of ecological environment overweighs its other 2 partners. And among the environment family, industrial sewage emission occupies the main position. This can be referred as the pollution factor for the sewage arbitrarily emitting phenomenon can be seen anywhere nowadays. With the lack of certain government regulation and law and public morality, this reprehensive behavior has further caused side effects like reducing underground water use or losing soil and water.

3 Multi-objective Decision Analysis Model

To those time series which have the linear trend components, each predictive variable has a value corresponding to a certain period which in other words we call it dependence. The relationship between water discharge capacity and their periods can be expressed as:

$$Y_i = a + bX_i + \varepsilon_i \qquad i = 1, 2, \ldots, n \tag{1}$$

$$Y_i = a + bX \tag{2}$$

Coefficient a and b can be determined based on the principle of minimizing mean square error (MSE) so that we can acquire the straight line trend equation. And in this way, every single predictive value corresponding to its own X_i can be obtained.

$$\hat{Y}_i = a + bX_i \tag{3}$$

Through this method, we forecast every years river discharge capacity in 2013-2025, river discharge capacity in 2013 is 655 billion cubic meter, in 2020 is 698, in 2025 is 674.

References

[1] Guaimei Cheng. Research of regional water sustainable use based on multi-objective analysis [D]. Yunnan: Kunming University of Science and Technology, 2005

[2] Hongbo Zhang, Allocation model of Yellow River and method discussions [J]. Yellow River, Vol 28, No 1, Jan 2006

[3] Zhengfa Wang, Water resources distribution models on the river [J].Water Resources and Hydropower Engineering, Vol 31 No 9, Sep 2000

[4] Lei Li, Game analysis of allocation of water resources [J]. Commercial Research Vol 390 Dec 2009

[5] Brun S. E, Band L. E. Simulating run off behavior in an urbanizing watershed. Computers, Environment and Urban Systems, 2000, 24: 5-22