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T1 ________________	**20045**	F1 ________________
T2 ________________		F2 ________________
T3 ________________		F3 ________________
T4 ________________	Problem Chosen **B**	F4 ________________

2013 Mathematical Contest in Modeling (MCM) Summary Sheet
(Attach a copy of this page to your solution paper.)

Problems and Related Strategies of Available Water in China

Summary

The main purpose of this paper is to develop strategies of the sustainable development of water resources in China from 2013 to 2025 and keep guarantee of water supply in the use of daily life and production.

China now faces up to deficiency of water in some regions for the uneven distribution and too big population and too fast speed in growth of economy. In order to solve those problems, we would like to consider the provinces located in the mainland of China separately.

Firstly, we'd predict the increase of population in respective provinces in China during 2013-2025 by using *Model 1—ARIMA*. Then, we predict the requirement of production water in 2025 by using *Model 2—Grey Prediction GM (1,1)*. The results show that there are 16 provinces facing the problems of water shortage.

Next, the *Model 3—Regulation Model* is designed by us to provide solutions for provinces with the deficiency of water related to the *South-to-North Water Transfer Project*. The *Model 4—Iterative Optimization Allocation Model* is designed by us to regulate water resources in those provinces which are not related to the *South-to-North Water Diversion Project*.

Then, we make use of *Model 5—AHP* to analyze the impacts bring by the water strategy to the economy, physical and environment of China.

And then, we evaluate those models. The models predict the volume of water needed in China during the years till 2025. Compared the economic and environment benefit brought by different strategies, we strongly believe our strategy is feasible, cost-efficient water strategy.

Finally, we provide a position paper to the government about the situation of water problems and related strategies. Further more, we discussed the feasibility and total cost.

Contents

1. Background

The water resources of China are affected by both severe water quantity shortages and severe water quality pollution. A growing population and rapid economic development as well as lax environmental oversight have increased water demand and pollution. China has responded by measures such as rapidly building out the water infrastructure and increasing regulation as well as exploring a number of further technological solutions.

China's water resources include 2,711.5 cubic kilometers of mean annual run-off in its rivers and 828.8 cubic kilometers of groundwater recharge. As pumping water draws water from nearby rivers, the total available resource is less than the sum of surface and groundwater, and thus is only 2,821.4 cubic kilometers. 80% of these resources are in the South of China.

Total water withdrawals were estimated at 554 cubic kilometers in 2005, or about 20% of renewable resources. Demand is from the following sectors: 65% agriculture，23% industry and 12% domestic.

2. Restatement and Analysis

With the development of science and economic, the human civilization get a huge improvement. Compared with the living standard 1000 years ago, there is no doubt that people living in this era are more beatific, at least in some fields. Coins always have two sides. When civilization gets a huge development, at the same time, we ignore the latent problems even at this minute. Water problem is a representative. 70% of the earth is covered by sea, and that may be the reason why people ignored this kind of problems. People can find water everywhere, but few of us do know how much of them can be used by human being.

One purpose of this paper is written to figure out the situation of the available water that people will meet in China in 2025 if we do not take any steps right now. Author will do research for relative data, make our own computing and predict the result logically. On the other hand, if the problem is serious, author will come up with some methods or solutions in order to ameliorate the situation. Of course, at this point, author will show the new result after people adopt those methods or solutions provided by us after using mathematic process and discussion.

Firstly, we think the requirement of water is made of domestic water and production water, then, we use the $ARIMA$ Model and the $GM(1,1)$ Model to predict the requirement of water. Those problems are solved in 4.1. Secondly, according to the different geographical situation of each province, we prepared different methods to solve the problem. Those methods are found in 4.2. Thirdly, in a province or a region, we build the model called iterative optimization allocation model to solve how to transport water resource inside. Those methods are found in 4.3. Finally, we use the method of AHP to discuss the economic, physical and environmental implications of our strategy. Those methods are found in 4.4.

3. Assumptions

- From 2013 to 2025, China would not experience any factors, such as war, disasters, that can cause massive fluctuations in population.
- Residents from the same distract use the same amount of water.
- For different regions, spending for desalinating a unit is the same
- For transporting fresh water, expenses is consistent even in distinct areas.
- We use water prices of capital cities to represent the ones of their provinces, even
- Due to lack of data for Hong Kong, Macao and Taiwan, this thesis only concentrate on water strategy in Mainland, China.
- Assuming, currently, water supplies can balance demands for every province in China.
- Large-scale transfer of population will not happen in China.

4. Models

4.1 The predict of the water shortage of China in 2025

According to the water using situation that the China Statistical Yearbook([3]) gives, while the yearbook hasn't given the data since 2011, we carefully investigate the situation before 2010.we think the shortage $Q(billion\ ton)$ in 2025 should be the difference between the whole supplement $T(billion\ ton)$ and the whole requirement $G(billion\ ton)$ at that time, namely:

$$Q = T - G. \tag{1}$$

If $Q > 0$, it means the supplement is very sufficient; $Q < 0$,it means the supplement is insufficient; $Q = 0$,it means that the supplement is balanced.

For every province of China, we have:

$$Q_i = T_i - G_i, \tag{2}$$

since there are 31 provinces on the mainland of China, we obtain that:

$$Q = \sum_{i=1}^{31} Q_i \ , G = \sum_{i=1}^{31} G_i \, , T = \sum_{i=1}^{31} T_i \ . \tag{3}$$

4.1.1 The prediction of the water requirement of each province in 2025

We consider a province's requirement of water is consisted by two parts, the first one is household water G_{i1} which is used by people for living requirement, the second one is production water G_{i2} which is used to meet the development demand of the province. So we obtain that each province's requirement G_i can be expressed as:

$$G_i = G_{i1} + G_{i2} . \tag{4}$$

Ⅰ.The prediction of the requirement of domestic water G_{i1}

Set $g\left(ton\ per\ human\right)$ as the standard level of the water per human need to live which The United Nations give and N_i as the population of each province, we can take G_{i1} as:

$$G_{i1} = g \times N_i \times 10^{-9} . \tag{5}$$

The population of China is still increasing now, namely each province's population will increased until 2025. It is reasonable for us to predict that the water requirement of each province will also increase. Therefore, first of all, we use the *ARIMA* Model ([6]) to predict the population of China from 2013 to 2025.

The *ARIMA* Model was put forward by BOX and Jenkins in the 1970s .Since this model considers not only the condition that population's increasing relies on the time , but also the random fluctuation in the process of population's increasing, it has high precision to predict the increasing of population. For Beijing as an example, we use the population of Beijing from 2000 to 2011(Table 1) and the *ARIMA* Model and obtain:

$$X_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \cdots - \theta_q \varepsilon_{t-q} , \tag{6}$$

while, $\phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p}$ is the autoregressive part; $\varepsilon_t - \theta_1 \varepsilon_{t-1} - \cdots - \theta_q \varepsilon_{t-q}$ is the moving average part; $\phi_1, \phi_2, \cdots, \phi_p$ is the autoregressive coefficient; $\varepsilon_1, \varepsilon_2, \cdots, \varepsilon_q$ is the moving average coefficient, $\varepsilon_t \sim N\left(0, \sigma^2\right)$.

Table 1([3]).The 2000-2011 population of Beijing

Year	Population(million)
2000	13.64
2001	13.85
2002	14.23
2003	14.56
2004	14.93
2005	15.38
2006	15.81
2007	16.33
2008	16.95
2009	17.55
2010	19.62
2011	20.19

By using SPSS_19, we have $p = 2, q = 1$, also the autoregressive coefficient and the moving average coefficient, then the model is as the following:

$$X_t = 1.95154 X_{t-1} - 0.95526 X_{t-2} - 0.9\varepsilon_t \tag{7}$$

On the basis of table 1, now we can predict the population of Beijing from 2012 to 2025(Table 2 and Figure 1):

Table 2. The 2012-2025 population of Beijing(million)

Year	Population(million)	Year	Population(million)
2012	20.73	2019	23.85
2013	21.24	2020	24.21
2014	21.73	2021	24.56
2015	22.19	2022	24.89
2016	22.64	2023	25.21
2017	23.06	2024	25.51
2018	23.46	2025	25.79

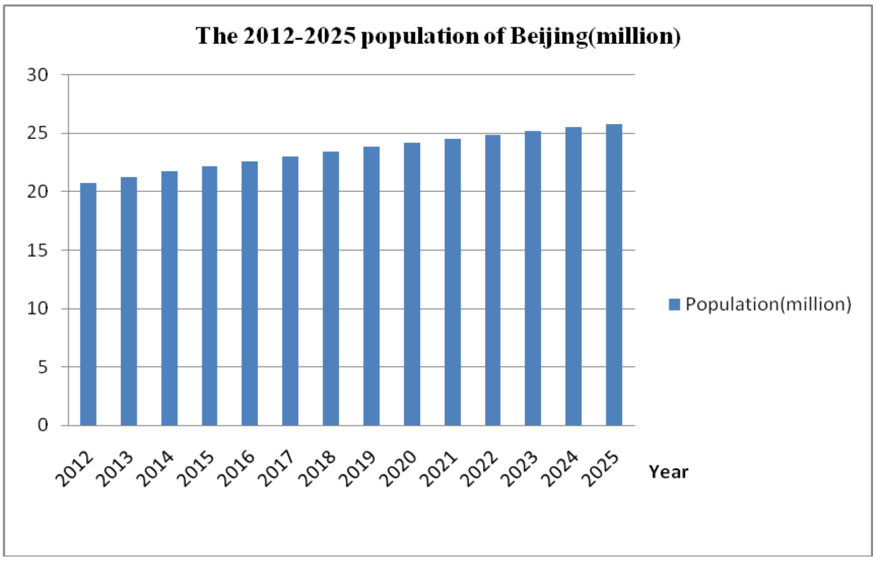

Figure 1. the 2012-2025 population of Beijing

In a similar way, we can predict the population of each province in2025. Following, we give the results of 16 provinces (Table 3):

Table 3 . The population of 16 provinces in 2025(million)

Province	Beijing	Liaoning	Jilin	Heilongjiang
Population	25.79	44.68	27.80	38.44
Province	Shanghai	Jiangsu	Fujian	Jiangxi
Population	27.91	81.98	60.86	39.90
Province	Shanxi	Henan	Hubei	Chongqing
Population	38.20	92.27	60.56	32.61
Province	Sichuan	Guizhou	Xizang	Xinjiang
Population	81.10	33.72	32.90	24.44

Ⅱ.The prediction of the requirement of production water G_{i2}

Here, we use the *GM (1,1)* Model ([7]) to predict the requirement of production water G_{i2} of each province.

a. Accumulate the primary data

Set $x(t)$ as the quantity of production water per year, we have the primary data from 2000 to 2011([3]):

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(11)), \tag{8}$$

then we obtain the increasing sequence (1-AGO):

$$\begin{aligned} x^{(1)} &= (x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(11)) \\ &= (x^{(0)}(1), x^{(0)}(1)+x^{(0)}(2), \cdots, x^{(0)}(1)+\cdots+x^{(0)}(11)) \end{aligned} \tag{9}$$

where

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \quad k = 1, 2, \cdots, 11 \tag{10}$$

and $x^{(1)}(k)$ of generating sequence is:

$$z^{(1)}(k) = \frac{1}{2}\left(x^{(1)}(k) + x^{(1)}(k-1)\right), \quad k = 2, \cdots, 11 \tag{11}$$

Set $\sigma^{(0)}(k)$ ([8]), then we have

$$\sigma^{(0)}(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, \quad k = 2, 3, \cdots, 11. \tag{12}$$

Since $x^{(0)}(k) \in (e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})$, $n = 11$, GM(1,1) model can apply to $x^{(0)}$.

b. The model

Based on Step 1, we have the *GM (1,1)* Model:

$$\frac{dx^{(1)}}{dt} + a x^{(1)} = u, \tag{13}$$

where a, u are const. Now, we use the method of Least Squares to estimate them. According to the way the method of Least Squares tells, we have

$$\begin{pmatrix} a \\ u \end{pmatrix} = (B^T B)^{-1} B^T Y_n, \tag{14}$$

Where

$$B = \begin{pmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(11) & 1 \end{pmatrix} \tag{15}$$

and

$$Y_n = (x^{(0)}(2), x^{(0)}(3), \cdots, x^{(0)}(11)) \tag{16}$$

Now we obtain the solution of (13) is:

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{u}{a})e^{-ak} + \frac{u}{a}\ ,\ k = 0, 1, \cdots, 10\ . \tag{17}$$

The solution (17) shows namely is the predict formula of G_{i2}, we can restore it as**:**

$$\hat{x}^{(0)}(k+1) = x^{(1)}(k) - x^{(1)}(k-1)\ \ k = \cdots 0, 1 \tag{18}$$

c. The test of the residual error of $x^{(0)}(k)$ and $\sigma^{(0)}(k)$ ([8]).

Set $\varepsilon(k)$ is the residual error of $x^{(0)}(k)$ and $\lambda(k)$ is the residual error of $\sigma^{(0)}(k)$, we have:

$$\begin{cases} \varepsilon(k) = \dfrac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)}, k = 1, 2, \cdots, 11 \\ \lambda(k) = 1 - (\dfrac{1 - 0.5a}{1 + 0.5a})\sigma^{(0)}(k) \end{cases}, \tag{19}$$

where $\hat{x}^{(0)}(1) = x^{(0)}(1)$, if $\varepsilon(k) < 0.2, \lambda(k) < 0.2$, we can think that the prediction is comparatively accurate, if $\varepsilon(k) < 0.1, \lambda(k) < 0.1$, we can think that the predict is very accurate. Based on the data of production water of each province, we do the test and have the result that all of $\varepsilon(k)$ and $\lambda(k)$ meet $\varepsilon(k) < 0.2, \lambda(k) < 0.2$, and most of them meet $\varepsilon(k) < 0.2, \lambda(k) < 0.2$,so we think our model is accurate.

Now we use Shanghai as an example to predict the requirement of production water of Shanghai showing in the table and figure below (Table 4 and Figure 2):

Table 4. The 2012-2025requirement of production water of Shanghai(billion ton)

Year	2012	2013	2014	2015	2016	2017	2018
Requirement of production water	10.16	10.22	10.28	10.35	10.41	10.48	10.54
Year	2019	2020	2021	2022	2023	2024	2025
Requirement of production water	10.61	10.68	10.74	10.81	10.88	10.94	11.01

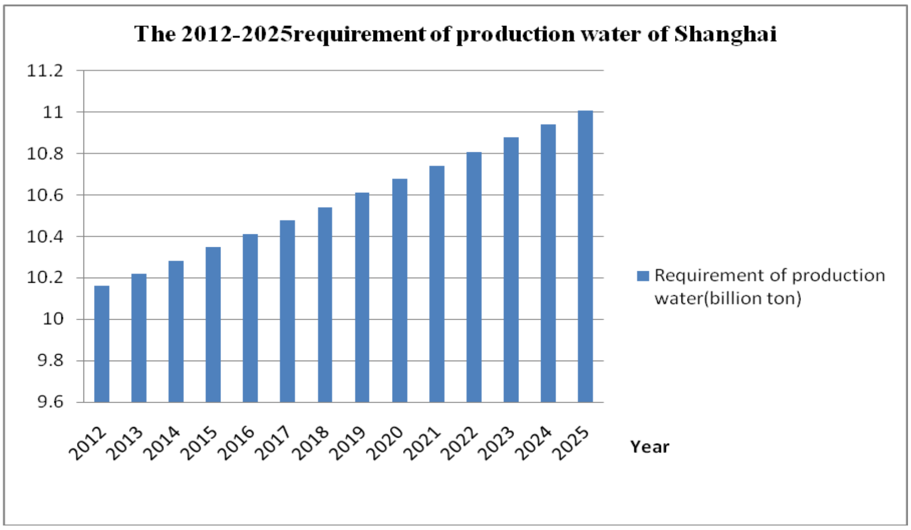

Figure 2. The 2012-2025requirement of production water of Shanghai

In a similar way, we can predict the requirement of production water of each province in2025. We give the results of 16 provinces below (Table 5):

Table 5.The 2012-2025 requirement of production water of 16 provinces (billion ton)

Province	Beijing	Liaoning	Jilin	Heilongjiang
Requirement	0.80	14.26	14.80	55.11
Province	Shanghai	Jiangsu	Fujian	Jiangxi
Requirement	11.01	57.55	23.54	32.76
Province	Shanxi	Henan	Hubei	Chongqing
Requirement	8.40	38.93	38.75	13.99
Province	Sichuan	Guizhou	Xizang	Xinjiang
Requirement	21.06	10.60	4.69	60.14

4.1.2The prediction of the supplement and shortage of each province

Figure 3. The South-to-North Water Transfer Project

Even though Chinese has taken the South-to-North Water Transfer Project and there is still much storage of fresh water in China. Especially when we analyse the data from China Statistical Yearbook. We find that, in 2010, the supplement and requirement are balanced in each province ([4]). Therefore, we make the assumption that, in 2010, the supplement of water is equal to the requirement in China. For example the requirement of Shanghai in 2010 is 10.16 billion tons, so we assume that the quantity that Shanghai can supply is also 10.16 billion tons. Further more, we assume that the ability of supplying water of a country do not change in the period from 2013 to 2025, the water supplement of Shanghai is still $T_s = 10.16$ billion tons. In this way, according to (1) and (2), we can get the result and the shortage of water in Shanghai Q_s can be judged. Based on this method, we predict Q_s (Table 6 and Figure 3) as the following:

Table 6.The 2012-2025 shortage of water of Shanghai (billion tons)

Year	2012	2013	2014	2015	2016	2017	2018
Q_s	-0.40	-1.44	-2.47	-3.48	-4.47	-5.46	-6.43
Year	2019	2020	2021	2022	2023	2024	2025
Q_s	-7.40	-8.35	-9.29	-10.22	-11.15	-12.07	-12.98

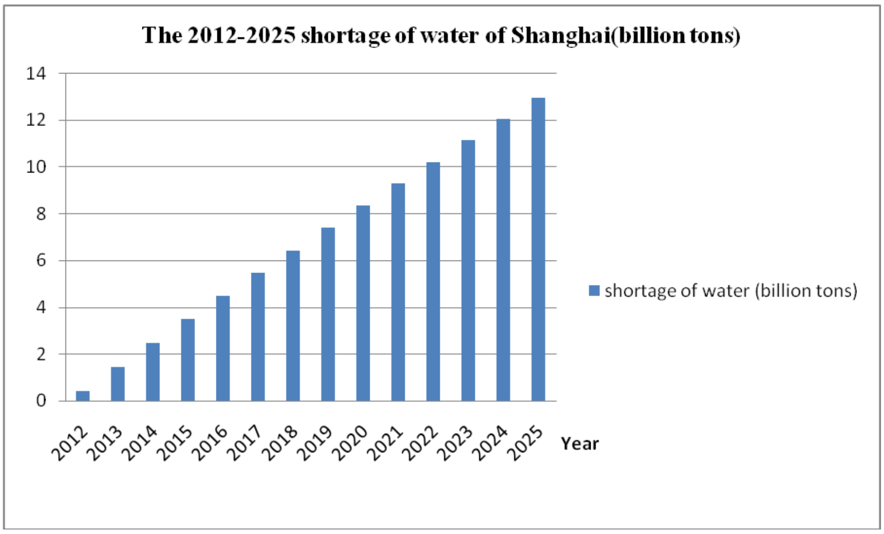

Figure 4.The 2012-2025 shortage of water of Shanghai

In a similar way, we can predict that the shortage of water in each province in 2025. We show the results of 16 provinces below (Table 7):

Table 7 .In 2025 shortage of water of 31 provinces (billion tons)

Province	Beijing	Liaoning	Jilin	Heilongjiang
	0.31	-15.58	-4.83	-24.55
Province	Shanghai	Jiangsu	Fujian	Jiangxi
	-1.30	-8.16	-7.16	-11.62
Province	Shanxi	Henan	Hubei	Chongqing
	-1.67	-20.74	-13.59	-7.50
Province	Sichuan	Guizhou	Xizang	Xinjiang
	-2.07	-2.13	-1.39	-10.71
Province	Tianjin	Hebei	Shanxi	Neimenggu
	0.03	1.81	-0.09	0.31
Province	Zhejiang	Shandong	Hunan	Guangdong
	12.11	0.08	1.65	1.17
Province	Guangxi	Hainan	Yunnan	Gansu
	2.54	0.35	0.50	1.12
Province	Qinghai	Ningxia	Anhui	
	2.79	1.20	0.01	

4.2 The water strategy to solve the water shortage problem

According to the computing result above, we predict the shortage of water in each province. Now, we are going to come up with some solutions and methods for those provinces that may lack of available water according to our prediction. Based on the South-To-North Water Transfer Project (we call it SNWTP for simplification). We list those provinces and their specific situation (Table 8):

Table 8.These provinces with water shortage problem and their situation

Inland	On the line of SNWTP	Henan, Sichuan, Hubei, Shanxi
	Not on the line of SNWTP	Jilin, Heilongjiang, Jiangxi, Chongqing, Guizhou, Xizang, Xinjiang
Coastal	On the line of SNWTP	Jiangsu
	Not on the line of SNWTP	Liaoning, Shanghai, Fujian

After China takes the SNWTP, here we stress whether the provinces with water shortage problem are on the line. SNWTP is a great project which solves some serious problems of water shortage in some regions of China. Such as Shanxi, We assume that the problems of the provinces on the line can be solved. In this way, we only need to consider whether changing (increasing or decreasing) the quantity on the level controlled before. However, there is 12 years between 2013 and 2025, the period is so long that we divided it into four parts and we treat them in Four Strategic Periods. In this way, it is more convenient for us to supply the right quantity and storage to use sustainably.

There are some provinces with water shortage problem which are not on the line of the SNWTP, such as Jilin, so those provinces have no chance to get benefit from the SNWTP. However, if these provinces are in the coastal, such as Liaoning they can use the technique like desalinize the saline water which refers to any of several processes that remove some amount of salt and other minerals from saline water in order to solve the water shortage problem. On the other hand, if these provinces are inland, such as Heilongjiang, those provinces can purify the sewage or build wastewater recycling to solve the problems. The rest are in remote regions where has small population and the development of industry is low. Then, we will discuss how to solve the water shortage problem in the different regions by using different strategy one by one.

4.2.1 The adjustment of SNWTP

In 2025, there are five provinces with water shortage problem related to the SNWTP and they are Henan, Hubei, Sichuan, Shanxi and Jiangsu. While Hubei and Sichuan are providers of the water and Henan, Shanxi and Jiangsu are the main beneficiaries of SNWTP. Therefore Hubei and Sichuan use excess water to support Henan, Shanxi and Jiangsu, then the problems can be mitigated.

When take the cost into account, we ignored the transportation cost happened in the China's economic system and treat all of the transportation cost as the water price in each province. We provide the price of water in each province which includes both providers and recipient (Table 9):

Table 9. The water price in the five provinces

Province	Price(Yuan per ton)
Henan	1.90
Hubei	1.60
Sichuan	2.66
Shanxi	2.48
Jiangsu	1.88

Notes: The water shortage problem of Jiangsu can be solved by both desalinizing the seawater and SNWTP, but the former one costs more, so we take the latter one.

We decide to divided 12 years into four strategic periods and each period has three years. We assume that the transport quantity of each year in a period by SNWTP is all the same. In this way, we are facing other problem which is water storage. After calculation, we set Henan province as an example and provide a related transport method (Table 10):

Table 10. The transport method of Henan province(billion ton)

Period	Transport quantity	Storage of each year
The first Period	10.41	0.80
		0.80
		0
The second Period	12.92	0.87
		0.88
		0
The third Period	15.65	0.95
		0.95
		0
The forth Period	18.62	1.03
		1.03
		0

In addition, according to the principles of economics, we know that the worth of money will increase with the time goes by. In China, we assume that the worth of RMB increase at the rate of 10% per year. Set A_0 as the worth of RMB in 2013 and A_T as the worth after 2013, we have:

$$A_T = A_0\left(1+10\%\right)^T \tag{20}$$

Based on the method in the above, after calculation, we obtain the cost of each province per period before 2025, and there are showing below. (Table 11):

Table 11.The cost of each province every period (million Yuan)

Henan	7.64
Hubei	2.93
Sichuan	0.56
Shanxi	0.68
Jiangsu	2.37

4.2.2 Desalinate the seawater

SNWTP only solves the problems of those provinces related to this project, but there are some provinces with water shortage problems which are not related. Some of them are in the coastal or very close to the area in the coastal(such as Heilongjiang, Jilin and Liaoning), we decide to use the technique of desalinizing the seawater to solve those problems.

According to the data, the cost of desalinate seawater is 0.55 dollars per ton ([1]). Moreover, in 2012, the dollar and RMB exchange rate is1:6.23. For instance, in Shanghai, we obtain the quantity of the seawater that need to be desalinized per period after calculation and show them in the table below (Table 12):

Table 12. The quantity of desalinate seawater of Shanghai (billion ton)

Period	the quantity of desalinating	Storage of each year
The first Period	0.78	0.1
		0.1
		0
The second Period	1.64	0.098
		0.098
		0
The third Period	2.50	0.095
		0.095
		0
The forth Period	3.35	0.092
		0.092
		0

Considering to the change of value of money, we can finally obtain that Shanghai need invest 10.8 billion Yuan per period to desalinize seawater.

In a similar way, we can obtain that Fujian need put into 41.66 billion Yuan per period and Jiangsu need put into 43.19 billion Yuan per period. Now, we can comparing the cost between SNWTP and desalinize seawater. For Jiangsu, the cost of desalinizing seawater is greater than the cost of transporting and that is why we choose SNWTP to solve the water shortage problem happened in Jiangsu.

For the three provinces located in the northeast of the China-Liaoning, Jilin and Heilongjiang, some of them are inland and there is no efficient way to solve the problems. But Liaoning is near to the Bohai Bay, and we consider it is possible to establish a large desalination plant in Liaoning to meet the demand of those three provinces. According to the data, when build SNWTP, China pipelayed 3884 km and cost 48.6 billion Yuan, if we assume the price of commodities increases at the rate of 10%, after we find we need pipelay 690.6 km if we only pipelay to the capital of each province(Transporting in a province can be seen at 4.3), we obtain the quantity of desalinate seawater per period of Liaoning is as the following(Table 13):

Table 13. the quantity of desalinate seawater of Liaoning(billion ton)

Period	The quantity of desalinating	Storage of each year
The first Period	19.98	2.17
		2.49
		0
The second Period	25.64	2.08
		2.10
		0
The third Period	32.26	2.31
		2.34
		0
The forth Period	39.63	2.57
		2.61
		0

Considering the change of the value of the money, we finally obtain that Liaoning need invest 285 billion Yuan per period to solve the water problem of the three provinces.

4.2.3 Build waste water recycling system

There are some provinces with water shortage problem are neither on the line of SNWTP, nor in the coastal, they are Chongqing, Guizhou and Jiangxi. We can't use the way as above to solve the problem. However, we find that these provinces can purify the sewage. Those provinces has already build sewage treatment plant, at this point we only need to account the cost of increase the quantity of water that need to be purified. According to the data, we find that the cost to purify sewage is 6.7 yuan per ton. We classify these three provinces into a category and obtain the quantity of purifying the sewage in each period as the following (Table 14):

Table 14. the quantity of purifying the sewage in each period(billion ton)

<table>
<tr><th>Period</th><th>The quantity of desalinating</th><th>Storage of each year</th></tr>
<tr><td rowspan="3">The first Period</td><td rowspan="3">15.38</td><td>1.22</td></tr>
<tr><td>1.23</td></tr>
<tr><td>0.00</td></tr>
<tr><td rowspan="3">The second Period</td><td rowspan="3">26.95</td><td>1.34</td></tr>
<tr><td>1.35</td></tr>
<tr><td>0.00</td></tr>
<tr><td rowspan="3">The third Period</td><td rowspan="3">39.66</td><td>1.47</td></tr>
<tr><td>1.49</td></tr>
<tr><td>0.00</td></tr>
<tr><td rowspan="3">The forth Period</td><td rowspan="3">53.67</td><td>1.63</td></tr>
<tr><td>1.64</td></tr>
<tr><td>0.00</td></tr>
</table>

Considering the change of the value of the money, we finally obtain that Chongqing, Guizhou and Jiangxi need invest 195.77 billion Yuan per period to solve the water shortage problem.

4.2.4 Using snow melt

There are two special provinces-Xizang and Xinjiang which don't have large population and large scale of industry, so we think the shortage problem focus on the requirement of household water. Therefore the people living there can use snowmelt to solve the problem because there are many snow mountains in these two provinces. Because the requirement of household water is not as huge as production requirement, if the environment can be protected well then government of China do not need to invest a lot of money to solve the water shortage problems there.

4.2.5 Conclusion

Based on 4.2.1 to 4.2.4, We obtain that China need put into 718.16 billion Yuan per period namely 239.39 billion Yuan per year to solve the water shortage problem of the country.

4.3 Iterative optimization allocation model for regional water resources

Many effective ways we has discussed on above to solve the problems of water shortage are being implement by Chinese Government. An iterative optimization allocation model for regional water resources is set up and the allocation results are obtained. On the basis of analyzing the composition and structure of a water resources system, a multi-objective optimal allocation model is established for regional water resources system by applying large-scale system optimization theory. The model contains three components: the water source optimal operation model, the water quantity optimal allocation model, and the iterative operation-allocation model. The solution of the water source optimal operation model can be obtained using the iterative method of alternating reservoirs and the dynamic programming approach. The water quantity optimal allocation model is solve with the DW decomposition method of large-scale decomposition coordination theory([2]).

The model contains three components: the water source optimal operation model, the water quantity optimal allocation model, and the iterative operation-allocation model. The function of water source optimal operation model is regulating the source of water with the effect of operate and storage until meeting the needing process of water, thus it can determine the whole area available water supply. The function of water quantity optimal allocation model is fully considering the urban economic development, people's life, food security, ecological environment and other requirements in the case of short supply, and allocating the water source with the most reasonable way. In the optimization allocation model for regional water resources, we use the pre-evaluation iteration method to connect the water source optimal operation model to water quantity optimal allocation model, thus it can optimize the goal of operation and allocation synchronously ([2]).

4.3.1 The water source optimal operation model

We assume that the whole study area is made up of M partitions. According to the characteristics of water, water supply source is divided into the all-region public water source and single partition water source. All-region public water source provide to random partition water source. Single partition water source only provide to themselves. Simplified water supply network is displayed in Figure 4**.**

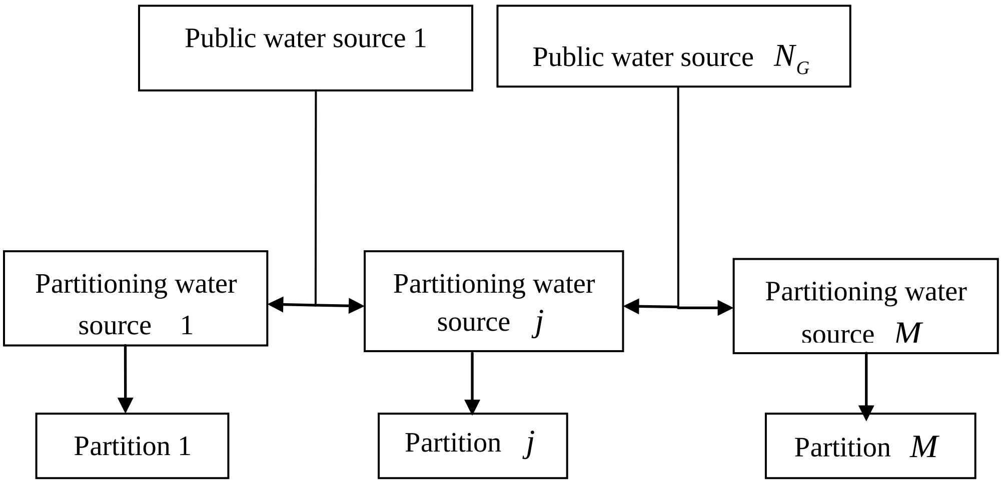

Figure5. The water supply network of the water quantity optimal allocation Model

Ⅰ.Objective function

All-region minimum sum of the square water shortage rate in each time interval is the objective. That is,

$$\min \sum_{t=1}^{T} [(\sum_{j=1}^{M} S_{j,t} - \sum_{i=1}^{N} Q_{i,t}) / \sum_{j=1}^{M} S_{j,t}]^2 \tag{21}$$

In expression: $S_{j,t}$ means water demand in the partition j and time interval t; $Q_{i,t}$ means water supply in the partition i and time interval t. the period of adjustment of water source optimal operation is $1a$, the period of adjustment is divided into T individual time interval, the number of partitions are M; the number of water sources are N.

Ⅱ. Constraint condition

Each water supply balance and associate constraints of water yield:

$$V_{i,t+1} = V_{i,t} + U_{i,t} + X_{i,t} - P_{i,t} - Q_{i,t} \tag{22}$$

$$X_{i,t} = \sum_{k=1}^{N} C_{i,k} Z_{i,k,t} \tag{23}$$

In the expression:

$V_{i,t+1}$: the stagnant water storage capacity of water supply i in the end of period t.

$V_{i,t}$: the stagnant water storage capacity of water supply i in the early of period t.

$U_{i,t}$: region input water yield of water source i during the period t.

$X_{i,t}$: input water yield of water source i during the period t from other water supply.

$P_{i,t}$: output water yield of water source i during the period t to other water supply.

$Q_{i,t}$: output of supplying water of water source i during the period t.

$c_{i,k}$: linear coupling coefficient between each water supply.

$Z_{i,k,t}$: input water yield of water source i during the period t from the water supply k.

In addition, there are the bound constraints of total water supply, the ceiling binding of single partition water source supply, ability constraints of each water supply(water delivery), effective storage capacity constraints of each water source , water transport direction constraints of ditch or pipeline, and so on([2]).

4.3.2 The water quantity optimal allocation model

After optimizing by the water source optimal operation model, single partition supply water source for themselves partition directly. However,

it need consider the water shortages and water supply benefit of each partition in allocating all-region public water source. Four levels optimal allocation model for water resources is set up by applying large-scale system hierarchical control idea. That is, the first level, it is based on the water supply benefit function and optimal allocation process of single user(crop), solving the stages of water supply process when the users(crops) is under deficit irrigation.

The second level, it is to solve optimal allocation of water resources between all the users (crops), basing on optimization net benefit of industry (agriculture).

The third level is coordinate level of each partition, it is to solve the optimal allocation of water resources in the four sections industry, agriculture, the domestic water supply and the natural environment, basing on maximum comprehensive benefits of each section in partition.

The forth level is all-region coordinate level, it is to solve optimal allocation of water source between the each partition, basing on maximum comprehensive benefits of all-region([2]).

The system organization of water quantity optimal allocation model show in figure 5:

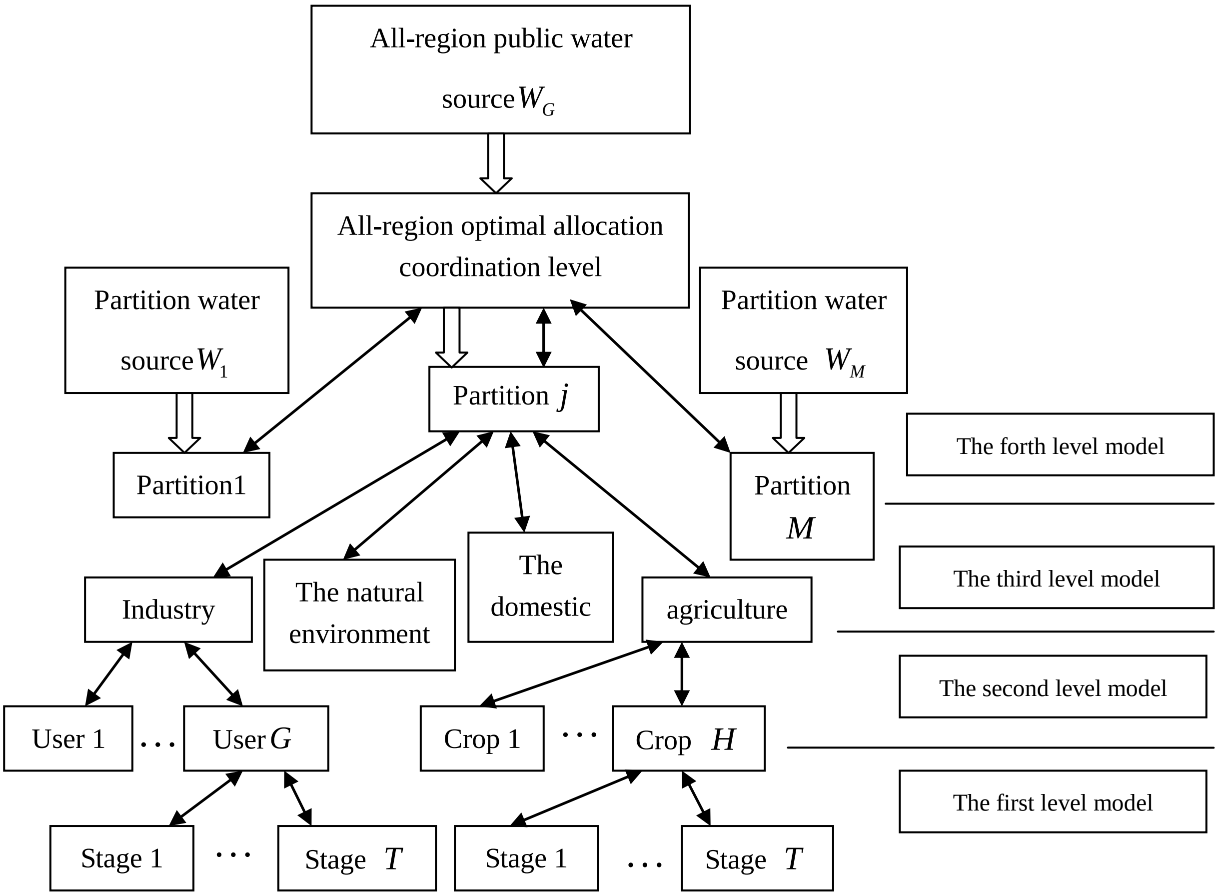

Figure 6. The system organization of water quantity optimal allocation model figure

Ⅰ.Water quantity optimal allocation model between each partition(the forth model)

the effect of the forth model is to allocate the water source of optimal operation between the each partition, and the allocation scheme is transmit to the third level, at the same time, accepting the the information of the third level and coordinated optimization, maximum comprehensive benefits of all-region is the optimal objective.

a. Objective function

maximum comprehensive benefits of all-region is the optimal objective, that is,

$$\max \sum_{j=1}^{M} F_j(Q_j) \tag{24}$$

In the expression:

Q_j:the sum of allocation water source of partition j and single partition .

$F_j(Q_j)$: comprehensive benefits function of partition water source.

b. Constraint condition

constraint condition contains equilibrium allocation constraints of all-region public water source, the bound constraints of water demand in each partition, water transportation ability of channel or pipeline is limit.

Ⅱ.The water quantity optimal allocation model of partition between each sections.(The third level model)

a. Objective function:

$$\max F_j(Q_j) = \max[\omega_{j,g} f_{j,g}(Q_{j,g}) + \omega_{j,n} f_{j,n}(Q_{j,n}) + \omega_{j,s} f_{j,s}(Q_{j,s}) + \omega_{j,h} f_{j,h}(Q_{j,h})]Q_j \tag{25}$$

In the expression:

$Q_{j,g}$ 、 $Q_{j,n}$ 、 $Q_{j,s}$ 、 $Q_{j,h}$ respectively mean allocated water supply of industry, agriculture, the domestic water supply in the partition j .

$f_{j,g}(Q_{j,g})$、 $f_{j,n}(Q_{j,n})$、 $f_{j,s}(Q_{j,s})$、 $f_{j,h}(Q_{j,h})$ respectively mean water supply benefits of industry, agriculture, the domestic water supply in the partition j .

$\omega_{j,g}$、 $\omega_{j,n}$、 $\omega_{j,s}$、 $\omega_{j,h}$ respectively mean benefits weight coefficient of industry, agriculture, the domestic water supply in the partition j .Weight coefficient is obtained by the Analytic Hierarchy Process (AHP). one evaluation index is compared to another, the number one to nine is applied to express the importance of one evaluation index to another, the number is greater, the more importance the evaluation index is. After that, it can obtain the judgment matrix, then according to the expression (26),

$$\omega_i = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}} \tag{26}$$

we can calculate weight coefficient of each evaluation indexes.
In the expression:

ω_i: the weight coefficient of the evaluation index i;

a_{ij}: the ratio of the importance of evaluation index i to evaluation index j.

b. Constraint conditions

constraint conditions contain equilibrium constraints of the water allocation in each partition, the bound constraints of each section water demand, the constraints of each section water supply damage degree , and so on.

Ⅲ.The water quantity optimal allocation model of partition between each users(crops).(The third level model)

The second level model is to the water quantity optimal allocation question of industry and agriculture. water using benefit comes from calculation of the first level in each user of industry and crop agriculture.

a. Objective function

The objective of water quantity optimal allocation in each partition industry section is maximum gross industrial output value. The objective of water quantity optimal allocation in each partition agriculture section is maximum total agricultural output value.

That is,

$$\max f_{j,g}(Q_{j,g}) = \max \sum_{g=1}^{G} f_{j,g,g}(Q_{j,g,g}) \tag{27}$$

$$\max f_{j,n}(Q_{j,n}) = \max \sum_{h=1}^{H} f_{j,h,n}(Q_{j,h,n}) \tag{28}$$

In the expression:

$Q_{j,g,g}$:water source of the partition j allocate to user g of industry.

$Q_{j,h,n}$:water source of the partition j allocate to crop h of agriculture.

$f_{j,g,g}(Q_{j,g,g})$:water using benefits of user g of the partition j industry.

$f_{j,h,n}(Q_{j,h,n})$:water using benefits of crop h of the partition j agriculture.

G :the number of industry user.

H : the type number of agriculture crop.

b. constraint conditions

constraint conditions contain equilibrium constraints of the water allocation in each section, the bound constraints of each user(crop) water demand,and so on.

Ⅳ.The water quantity optimal allocation model of single user(crop).(the first level model)

The water quantity optimal allocation model of single user(crop) is a very complicated problem actually. The water supply benefits of the industry users is showed by the linear function, which is expressed by the sum of benefits and water source in each phase. The industry users allocation apply the representative water demand process. However, water supply benefits and optimal allocation for water source in each process of the agriculture crops apply the production function, Jensen Model.

a. Water using benefits of single industry user:

$$f_{j,g,g}(Q_{j,g,g}) = \alpha_{j,g,g} Q_{j,g,g} \tag{29}$$

In the expression:

$\alpha_{j,g,g}$: Water using benefits coefficient of the industry user g in partition j.

b. Water using benefits of the agriculture crop:

$$f_{j,h,n}(Q_{j,h,n}) = b_{j,h,n} y'_{j,h,n} \prod_{t=1}^{T} (Q_{j,h,n,t} / Q'_{j,h,n,t}) \lambda_t \tag{30}$$

In the expression:

$f_{j,h,n}(Q_{j,h,n})$: Water using benefits coefficient of the agriculture crop h in partition j. (It is converted to the agricultural yield of main agricultural production in the area)

$b_{j,h,n}$: Water supply coefficient of agriculture crop h in the partition j.

$Q_{j,h,n}$: Total water supply of agriculture crop h in the partition j.

$Q_{j,h,n,t}$: Output of supplying water of agriculture crop h in the partition j during the phase t.

$Q'_{j,h,n,t}$: The most output of supplying water of agriculture crop h in the partition j during the phase t.

$y'_{j,h,n}$: Production peak of the agriculture crop h in the partition j.

λ_t: Sensitivity Index of the agriculture crop yield during the phase t.

4.3.3 Iterative operation-allocation model

Optimal operation model base on water need process to operate the income water process, so that it can obtain possible water supply W and water supply process

$Q_1, Q_2, \cdots, Q_T$ .Optimal allocation model base on the the principle of optimal all-region comprehensive benefits to optimize possible water supply W in the area, at last, it can obtain the optimal allocation water source process $Q_1^*, Q_2^*, \cdots, Q_T^*$ (optimal allocation water source process of all the single user and crop repeat addition, and then which is synthesized with water movement process of the domestic water supply and the natural environment , above all, it can obtain optimal allocation water source process of all-region partition). After the careful analysis, we can conclude that it is different between the optimal allocation water source process $Q_1^*, Q_2^*, \cdots, Q_T^*$ with the output of supplying water process of optimal operation $Q_1, Q_2, \cdots, Q_T$ .The amount of additive is still the possible water supply W . The reason is that optimal allocation of water source project consider the water need process of all-region, and the water need process of all-region is make up of the water need process of the industries in each partition, all the weighting coefficient is 1. However, optimal allocation process consider water using benefits of the industries in each partition, allocation water source of the industries in each partition is not all equal. From point of fair and efficient, optimal allocation water source process is more significance actually. Therefore, we must question that whether the water source operation contents the optimal allocation water source or not, it is the tenet of the iterative operation-allocation model.

All of the iterative operation-allocation model is divided into two parts:

The first part is to check out the feasibility of operation-allocation. It checks out whether the water source optimal allocation contents the result of optimal allocation $Q_1^*, Q_2^*, \cdots, Q_T^*$. Concrete steps: $Q_1^*, Q_2^*, \cdots, Q_T^*$ as water need process resume load the water source of optimal allocation model, the result is $Q_1', Q_2', \cdots, Q_T'$. If the difference between $Q_1', Q_2', \cdots, Q_T'$ and $Q_1^*, Q_2^*, \cdots, Q_T^*$ is minor, it can consider the water optimal process contents the result of the optimal allocation $Q_1^*, Q_2^*, \cdots, Q_T^*$, otherwise, possible water supply W' input the water source of optimal allocation model with replacing $Q_1', Q_2', \cdots, Q_T'$, loop iteration until the inspect is qualified.

The second part is to check out surplus ability of optimal allocation. Actually, when the first part pass the checkout in the first time, it occurs another possible condition, there is surplus ability of water supply in water source optimal operation for $Q_1^*, Q_2^*, \cdots, Q_T^*$ (it occurs available removed water), at this time should make $Q_1^*, Q_2^*, \cdots, Q_T$ a slight increase, and then resume load the water source of optimal allocation model, If the difference between possible water supply W'' and original possible water supply W is large, it indicates that water source operation occurs surplus water supply ability, at this time, the new possible water supply W'' input the water quantity optimal iterative model,if the difference is is minor, it can pass the checkout and model optimizing finish.

4.3.4 Solution method for model

The solution of water optimal operation model is a cascaded reservoir optimal scheduling problem. This paper apply the iterative method of alternating reservoirs. Keeping the objective is invariable in solving, ever water source takes turns in optimal operation, and repeating iteration, until operation result of each water source reach to the requirement of model' objective.

Dynamic programming approach (DP) is applied to solve optimal operation of single water source. At first, optimum strategy of each reservoir condition during the each time interval to the last of the time interval is reversely calculated, and then ascertaining the optimal operation way from the first to the end of time interval.

4.3.5 Case study

Ⅰ.Study area and water resource general situation

This paper collects the data of the Lianyungang urban district in Jiangsu Province. we take it for a case study. The city proper water supply of Lianyungang relys on the Huaihe River seriously. It is a representative water shortage city. Because of the water shortage, economic growth is restricted.

Study area is divided into three parts, they are Donghai agricultural area, Xinhai district and Lianyun district. Donghai agricultural area is irrigated by the Qiangwei River and Huaishuxin River. The city proper of Lianyun is made up of the Xinhai district and Lianyun district. The study area has been generalized as following figure 6.(In the figure, Qiangwei River the main water supply at the present, the partition water source contain dam impoundment, Rainwater resources, wastewater reuse and so on).

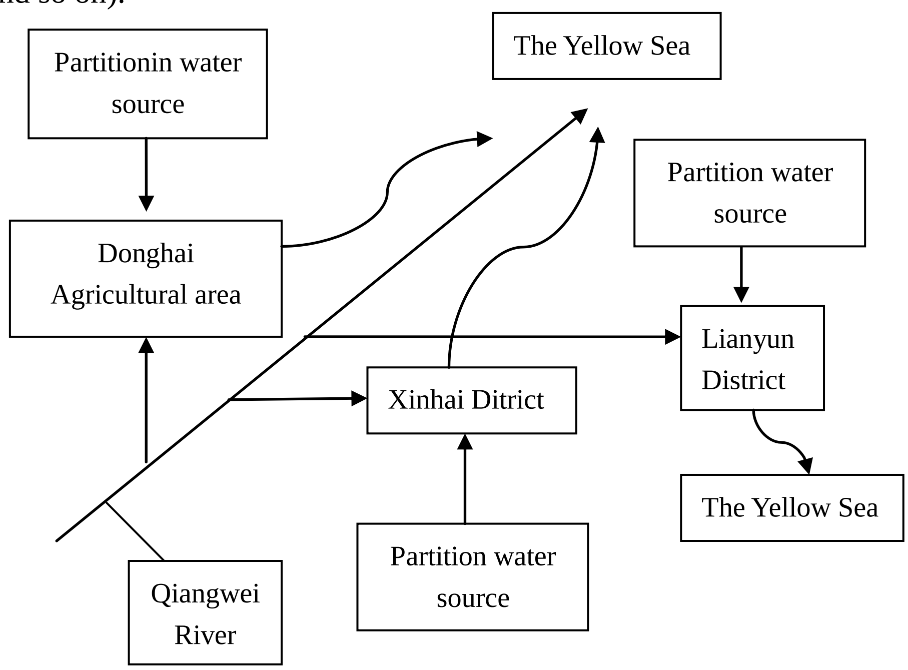

Figure 7. Simplified water resources system in the study area

Ⅱ.The calculation of model parameters

a. The number of time interval in partition

According to the figure 6, there are three water source partition, four water supply(one water supply of all-region and three water supply of partition), twelve time intervals, four water-use sectors, that is, industry, agriculture, the domestic water supply and the natural environment.

b. Muli-objective weight coefficient

Analytic Hierarchy Process (AHP) is applied to calculate muli-objective weight coefficient. the judgment matrix of Analytic Hierarchy Process(AHP) is obtained by the the expert evaluation method. It is showed in Table 15, weight coefficient of four water-use sectors is calculated with the expression (26), that is,

$\omega_g = 0.16, \omega_n = 0.09, \omega_s = 0.47, \omega_h = 0.28$.

Table 15. the judgment matrix of Analytic Hierarchy Process(AHP)

section	Industry	agriculture	The domestic water supply	The natural environment
Industry	1	2	1/3	1/2
agriculture	1/2	1	1/5	1/3
The domestic water supply	3	5	1	2
The natural environment	2	3	1/2	1

c. Water supply benefits coefficient of user (crop)

water supply benefits coefficient contains water supply benefits coefficient of industry user and water supply benefits coefficient of agriculture crop. Water supply benefits coefficient of industry user is obtained by analyzing the several annual value of production date and water supply volume data with the linear regression analysis method.(regression equation pass through the origin) Water supply benefits coefficient of major enterprises is showed in table 16. Water supply benefits coefficient of agriculture crop considers the rainfall frequency, because irrigation norm of agriculture crops is different as to different rainfall frequency. Water supply benefits is calculated basing on the different rainfall frequency (50%,75%,90%), irrigation norm and the crop yield of irrigation quota It is showed in table 17.

Table 16. Water supply benefits coefficient of major industry water-user in study area

User name	Belonging partition	Water supply benefits coefficient/（Yuan ·m^{-3}）
power enterprise	Lianyun partition	922.5
chemical plant	Xinhai partition	146.9
plastics company	Xinhai partition	143.3
beer company	Xinhai partition	37.4
Soda Factory	Lianyun partition	16.9

Table 17. Water supply benefits coefficient of major agriculture crop

Crop name	assurance rate/%	Water supply benefits coefficient/（kg ·m^{-3}）
rice	50	1.55
	75	1.46
	95	1.26
wheat	50	4.12
	75	2.75
	95	1.65
Other crop	50	3.53
	75	2.35
	95	1.76

Note: all the agriculture crops yield is transformed to rice yield by price ratio

Ⅲ.Calculation results and analysis

According to the planning of water supplying for Lianyungang district in Jiangsu province, it should increase the output water source, and dredge the Qiangwei River to improve the ability of storage capacity, thus in this paper, calculating the water supply is in allusion to the water supply ability which water source programming has implemented. On the basis of the above parameter, water demand of two different planned years (2010,2020) and three different assurance rate(50%,75%,95%) are optimized calculation in each study area. In the 2020 year, the result of water resource optimal allocation with the assurance rate 95% is showed in Table 18.

Table 18. the result of water resource optimal allocation with the assurance rate 95%

Unit: ten thousand stere

Partition	Water yield	Donghai agriculture district	Xinhai district	Lianyun district	All- Region
Industry	Water demand	203	73900	116000	190103
	Water supply	181	95771	103240	169192
	water deficit	22	8129	12760	20911
Agriculture	Water demand	64915	2510	206	21541
	Water supply	46090	6801	6280	14960
	water deficit	18825	6665	6154	14661
The domestic water supply	Water demand	1879	6801	6280	14960
	Water supply	1841	6665	6154	14661
	water deficit	38	136	126	299
The natural environment	Water demand	121	1250	655	2026
	Water supply	115	1188	622	1925
	water deficit	6	62	33	101
Summation	Water demand	67118	90606	123645	281369
	Water supply	48227	79769	110520	238517
	water deficit	18891	10837	13125	42852

In the 2020 planned year, industry, agriculture, the domestic water supply and the natural environment inordinate is water shortage with the assurance rate 95%. Water deficient ratio of four sections respective is 11%, 29%, 2% and 5%. Water deficient ratio of three partitions respective is 28%, 12%, 10.6%. Allocation condition is analysed between each section. In the model, under the effect of different water-using section weight coefficient and the bound constraint of water supply, in different planned years, the domestic water and the natural environment water is satisfied preferential with the different assurance rate. In the dry years, agriculture water will be affected first. In especially dry years, agriculture and industry will be water shortage inordinately.

According to analyzing the allocation condition between each water source, in the dry and especially dry years, each partition will be water shortage inordinately. In which， Donghai agriculture district is serious water shortage, however , Lianyun district is not serious water shortage, because the weight of Donghai agriculture water demand is maximum, the weight of Linyun agriculture water demand is minimum. Though programming water supply source of water-supply source will increase on the basis of existing conditions in the model, comparing with water demand is still lesser. In dry year, opening up other water source is solve water shortage problem, such as sea water desalination, wastewater treatment and so on.

4.4 The economic, physical and environmental implications of our strategy

Based on 4.2 to 4.3, we provide our strategies and use them to predict, analyze and solve the water shortage problem of each province in China comprehensively. Now we use the method of AHP to consider the economic, physical and environmental implications of our strategy.

4.4.1 Construct a Comparison Matrix

We construct the relationship diagram(figure 7)

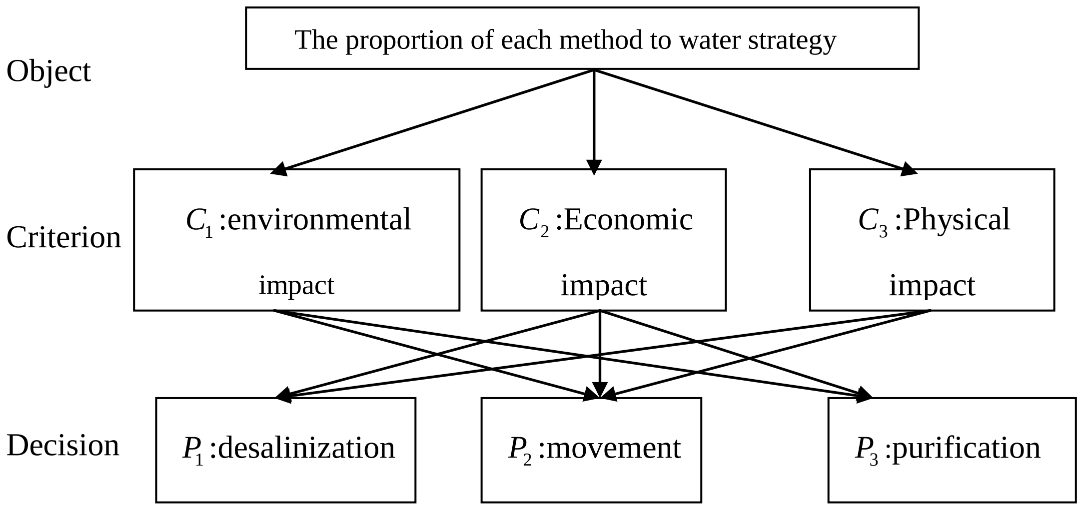

Figure 8. relationship of each level

Set a_{ij} as the ratio of element i and element j ,and $A=\left(a_{ij}\right)_{n\times n}$,

while we define:

Table 19. The comparison matrix

The relative importance degree	The same	A little more important	More important	Much more important	Very much more important
a_{ij}	1	3	5	7	9

Then based on the existing strategy of China, we obtain the comparison matrix as Table 20:

Table 20. Relative importance Matrix

A	environmental C_1	Economic C_2	Physical C_3
environmental C_1	1	4/9	4/7
Economic C_2	9/4	1	9/7
Physical C_3	7/4	7/9	1

4.4.2 Consistency check

To check the rationality of A,we must do the Consistency check.

Step 1. Calculate the max characteristic value of A

Step 2. Calculate the consistency index:

$$C.I. = \frac{\lambda_{\max} - n}{n-1}. \tag{31}$$

Step 3. Obtain the R.I(Table 21).

Table 21. Consistency Ratio

Order number	3	4	5	6	7
$R.I.$	0.58	0.90	1.12	1.32	1.41
Order number	8	9	10	11	12
$R.I.$	1.45	1.49	1.51	1.54	1.56

Step 4. Calculate the consistency ratio:

$$C.R. = \frac{C.I.}{R.I.}, \tag{32}$$

if $C.R. << 0.1$, A has high rationality.

4.4.3 Construct judgment matrix

Based on 4.4.1 to 4.4.2,we can construct judgment matrix:

$$\begin{cases} \begin{bmatrix} C_1 & P_1 & P_2 \\ P_1 & 1 & 1/5 \\ P_2 & 5 & 1 \end{bmatrix} & decision\ to\ C_1 \\ \begin{bmatrix} C_2 & P_1 & P_2 \\ P_1 & 1 & 1/2 \\ P_2 & 2 & 1 \end{bmatrix} & decision\ to\ C_2 \\ \begin{bmatrix} C_3 & P_1 & P_2 \\ P_1 & 1 & 3 \\ P_2 & 1/3 & 1 \end{bmatrix} & decision\ to\ C_3 \end{cases}$$

4.4.4 Conclusion

Finally, by using Matlab_2010 , we obtain the proportion of desalinization, movement and purification is the following(Table 22):

Table 22. Proportion of desalinization, movement and purifying

desalinization	movement	purification
0.2958	0.4042	0.3000

5. Simulation and Analysis of models

5.1 Towards the $ARIMA$ model

We compare predicted value with the actual value, for the Beijing as an example, we can obtain:

Table 23. Relative error table of predicted value with the actual value

Year	actual population (million)	predicted population （million）	deviation %
2000	13.64	/	/
2001	13.85	/	/
2002	14.23	14.05	-1.26
2003	14.56	14.59	0.22
2004	14.93	14.87	-0.37
2005	15.38	15.28	-0.64
2006	15.81	15.81	-0.01
2007	16.33	16.22	-0.68
2008	16.95	16.83	-0.74
2009	17.55	17.54	-0.06
2010	19.62	18.12	-7.64
2011	20.19	21.59	6.93

5.2 Towards the GM(1,1) model

We find that residual error and class-compare verification are all less than 10%, the model meets requirements.

5.3 Towards the processing of water shortage province model

On the basis of the above model, we consider the time value of money in allocation way of water source sufficiently, and our model meets requirements.

5.4 Towards the iterative optimization allocation model for regional water resources

The advantage of model: judgment matrix of Analytical Herarchy Process(AHP) complete consistency check, and $C.R. < 1$, the model meets requirements.

5.5 Towards the analytical hierarchy process model

Identically, judgment matrix of Analytical Herarchy Process(AHP) complete consistency check, and $C.R. << 1$, the model meets requirements.

6. Model Evaluation

6.1 Towards the Model 1 - ARIMA

Strength:

We process the data with the smooth method, and obtain concise expression of population on the basis of former years population. precision of prediction is higher.

Weakness:

Considering the transfer of population is difficult, we do not consider the transfer of population in predicting.

6.2 Towards the GM(1,1) model

Strength:

On the basis of a bit known data, we build the GM(1,1) model, and predict the production water supply in the future years. what's more, the model is concise and feasible.

Weakness:

Production consumption is monotonous in forecasting of our model, it is possible different to the practical situation.

6.3 Towards the processing of water shortage province model,

Strength:

We consider the different practical situation of each province and take different measures to each province. Considering the practical situation of China, we use the market price of water to replace the cost of transport, it makes the model more simplified.

Weakness: the process mode for each province is rough.

6.4 Towards the iterative optimization allocation model for regional water resources:

Strength:

On the basis of analyzing the composition, level and structure of a water resource system, a reasonable and feasible optimal allocation model was established for regional water resources by applying large-scale system optimization theory and multi-objective optimization technique. By finding the solution of the model and the allocation results, the feasibility of the model and its feasibility can be checked.

Weakness:

It is theoretically complete to consider water consumption benefits of each region, department and consumer through different perspective while setting up the optimal allocation model. However, the potential problem of such a large and complete model should be thought deeply while putting into practical use.

6.5 Towards the analytical hierarchy process model

Strength:

On the point of the macroscopic view, we consider that the economic, environment, physical influence the decision comprehensively. We obtain the importance of the three aspects, it is benefit of government's decision.

Weakness:
evaluation matrix has its subjectivityin our model.

7. A Position Paper to Governmental Leadership

To governmental leadership:

Water is an indispensable resource for human being to live. It seems that, on the earth, there are water everywhere, but the truth is completely opposite. In China, water is a limited resource. Because of the geographic conditions in different regions are different, the water distribution is severe uneven. Futher more, the population distribution is also uneven. All those factors cause a huge gap of water resource per capita between different regions. Many provinces may face the water shortage problems in 2025 if there is no improvement measure and some of the provinces has already suffering that kind of problems. Increased population, severe pollution and endless damge to the ecology make the situation worse. The water shortage crisis is not unfounded and it can be seen in our study results: in 2025, the number of provinces with water shortage problem is more than 50%-16 of 31. Futher more, 12 provinces may face terrible water shortage problem hold the proportion of 38.7%. It is time for us to take some actions. According to our research and discussion, we believe that some methods could help us to improve the situation and finally solve the problems. They are provided in the following.

- Enhance the propaganda of water’s role and situation to enhance the consciousness of people to save and protect water.

- Build more water conservancy projects like the great South-to-North Water Transfer Project to transport water to those ereas with water shortage problem.

- Improve the use ratio of water and take actions to deal with waste water.

- Enhance the strength on punishing the behavior that pollutes water resource.

We comprehensively discuss the different water shortage situations. According to those situations we provide related solutions. We strongly believe that our water strategy is effective and feasible. In addition, according to our computing, China only need to invest 239.39 billion yuan (0.5%-1% of the GDP of China) to solve the problem. It is not a huge amount of money when compared with the welfare of more than thousand of people living in this country. Therefore, we believe that is the best water strategy choice. Please think over our advice and water strategies. Thank you!

Yours sincerely,

Team 20045

2013-2-4

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