Analysis of County Industrial Water Demand Forecast Based on the GM(1,1) Model

Bingbing Zhou[1,a], Qingjun Du[2,b,*], Mingqi Sang[2,c], Xinchao Qi[2,d]

[1]Agriculture and Rural Bureau of Qiantang District, Hangzhou, China
[2]Zhejiang Keteng Engineering Consulting Co., LTD., Hangzhou, China

[a]zhoubingbing@qt.hz.gov.cn, [b*]ugrr1u1@dingtalk.com, [c]smq1720@dingtalk.com, [d]qxc0625@dingtalk.com

Abstract. Water resources are a fundamental strategic resource and the basis for national economic and industrial development. This paper conducts a county-level industrial water demand forecast, (Using Qiantang District as a case study). Based on survey data, the industries within the county are categorized, and the industrial water demand is analyzed by sector and administrative region using the GM(1,1) model. This analysis provides a critical technical foundation for future water resource management and water efficiency improvements.

Keywords: Water resources; Industry classification; Industrial water demand

1 Introduction

Industry is a vital sector of the national economy, the scale of industrial water demand is directly related to the formulation of urban planning. Therefore, at the present stage of China's economic and social development, industrial water demand prediction is still an important content of water resources planning and management. Only by constantly exploring the practical technology and management mode of industrial water conservation can we ensure the sustainable development of the industry and the growing demand for urban domestic water. Reasonable water demand prediction is the basis of strengthening the maximum rigid constraint of water resources, the fundamental need of implementing "spatial balance" and "water demand" from the perspective of water resources, and an important tarting point for realizing local conditions and scientific management.

The research on the prediction of water demand (water consumption) originated in the 1960s and went through about three processes. From the 1970s to the early 1980s, scientific statistical methods were mainly adopted, the principle of which was to predict the water demand (water consumption) in the future period based on the known statistical data of water use, analyze the law of its existence, and extrapolate it to predict the water demand (water consumption) in the future period, including time series method, gray prediction method, system dynamics method, etc.Since the late 1980s, due to the uncertainty of influencing factors and the limitations of simulation methods, scholars

Y. Zhang et al. (eds.), *Proceedings of the 2024 10th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2024)*, Advances in Engineering Research 259,
https://doi.org/10.2991/978-94-6463-658-1_49

from various countries have proposed a variety of new research methods, but most of the studies are conducted for a certain basin or a certain province and city, and the analysis results are not universal and can be extended.

2 Basic Background

According to the Water Resources Bulletin of Qiantang District, the total water consumption in Qiantang District for 2023 will be 306 million m3, of which industrial water consumption was 119 million m3, accounting for 38.89% of the total. There were 416 enterprises with annual water consumption exceeding 10,000 tons, including 24 enterprises consuming over 1 million tons. and the annual water consumption of water users with the largest water consumption reached 13.2716 million tons.

According to the "Notice on the Issuance of the '14th Five-Year Plan' Dual Control Indicators for Total Water Consumption and Water Intensity" issued by the Hangzhou Forestry and Water Bureau and the Hangzhou Development and Reform Commission, the annual target total water use control index of Qiantang District in 2023 is 336 million m3, and the water consumption per ten thousand yuan GDP in 2023 is 10.54% lower than the target in 2020. The decrease rate of water consumption per ten thousand yuan of industrial value added compared with the 2020 target is 3.66%. Among them, in 2022, Qiantang District's high-quality development and water consumption index assessment of ten thousand yuan of industrial added value are at the lower level of Hangzhou. Therefore, pilot work on efficient water incentive mechanism reform of "Ton production hero" in water resource conservation and intensive use is carried out, and the forecast of industrial water demand by classification of pilot reform industries in Qiantang District is studied to further improve the intensive use of water resources and optimize the allocation of water resources. It is necessary to allocate and use water resources scientifically and rationally, form water-saving production and life style, optimize business environment, and promote high-quality and green development of Qiantang District.

3 Forecast Methods

Industrial water demand forecast is a complicated work. Due to the variety of industries, the water demand situation is very different, which brings a lot of inconvenience to the analysis and calculation. Under the joint efforts of water experts and scholars from all over the world, the research on the theory and method of water demand prediction has made great progress, and it has been continuously developed and improved in the process of rapid development of social economy and science and technology, and has achieved a lot of valuable results. These achievements not only play an important role in improving economic and social benefits, but also have many innovations in theory and application.

3.1 Quota Method

The quota method can be divided into ten thousand yuan industrial added value water quota method and product water quota method [1]. Water quota refers to the water consumption per unit time, per unit product, per unit area or per capita life (that is, the two parameters of output value and water quota are used to predict the medium and long-term social water demand), which gradually changes with the progress of society, science and technology and the development of national economy. In the past, "quota method" was generally adopted to forecast water demand at home and abroad.

3.2 Grey Forecasting Method

The core of grey system theory is the establishment of a grey model (Grey Model, abbreviated GM) [2]. It is a system approach that skips the structural analysis of the system and instead looks for general trends by accumulating raw data and building exponential growth models. This method is particularly suitable for medium- and long-term forecasting. Grey system theory is effective even when data is scarce or incomplete, making it highly useful when water consumption shows an exponential growth pattern.

3.3 Summary of Methods

The quota method is intuitive and simple to implement, with wide applicability, but it must account for changes in influencing factors and policy adjustments that can affect the quotas [3] [4]. The grey forecasting method identifies the developmental trends of system factors by examining the differences in trends and uses these to predict water demand. It has relatively low data requirements and is particularly effective for handling small data sets with nonlinear characteristics, but it may struggle with volatile data series[5] [6] [7].

The water quota method of ten thousand yuan industrial added value and the grey forecasting method are both suitable for long and short term forecasting, and the above two methods are selected for water demand forecasting in this topic. The first is the comparative verification of the two methods. Then it is compared with the actual water consumption in 2022, and finally the method with the least error in water demand prediction is selected.

4 Forecast Analysis

The grey forecasting method uses the water consumption data of various industrial enterprises from 2017 to 2021 to construct the model. The specific principles are as follows.

4.1 Establishment of the GM (1,1) Model

The GM represents the grey differential equation model of the grey theory. GM (1,1) is a gray differential equation model of one variable.

GM (1,1) prediction model is the most commonly used grey dynamic prediction model, and its modeling principle is as follows:

With a set of raw sequences:

$$x^{(0)} = \left(x^{(0)}(1),\ \ x^{(0)}(2)\right),\ \ \cdots x^{(0)}(n)) \tag{1}$$

Add the original sequence, get

$$x^{(1)} = \left(x^{(1)}(1)\ ,\ \ x^{(1)}(2)\ ,\ \ \cdots x^{(1)}(n)\right) \tag{2}$$

Where:

$$x^{(1)}k = \textstyle\sum_{i=1}^{k} x^{(0)}(i) \quad k = 1{,}2,\ \ \cdots\cdot n \tag{3}$$

Then make the first order mean generation, get

$$x^{(1)} = \left(x^{(1)}(1)\ ,\ \ x^{(1)}(2)\ ,\ \ \cdots x^{(1)}(n)\right) \tag{4}$$

Where:

$$x^{(1)}k = \textstyle\sum_{i=1}^{k} x^{(0)}(i) \quad k = 1{,}2,\ \ \cdots\cdot n \tag{5}$$

constitutes a gray module, the gray model can be established, the general formula of GM (1,1) model is:

$$x(k) = -1/2(x^{(1)}(k-1) + x^{(1)}(k)) \tag{6}$$

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{7}$$

Solve this differential equation in:

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{u}{a}\right)e^{-ax} + \frac{u}{a} \ \ (k = 0{,}1,\ \ \cdots) \tag{8}$$

The parameters a, u can be obtained by the least squares method:

$$\hat{a} = \begin{bmatrix} a \\ u \end{bmatrix} = (B^T B)^{-1} Y_N \tag{9}$$

among:

$$B = \begin{bmatrix} -X(2)1 \\ -X(3)1 \\ -X(n)1 \end{bmatrix} Y_N = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ x^{(0)}(3) \end{bmatrix} \tag{10}$$

The prediction model obtained by reduction reduction is x(0),

$$\hat{x}^{(0)}(k+1) = (1-e^{a})(x^{(0)}(1)-\frac{u}{a})e^{-ak} \quad (k=1,2, \cdots) \tag{11}$$

4.2 Model Test

The GM (1,1) models usually adopt the residual test method. The so-called residual test method refers to a method of calculating the cumulative sequence according to the built model, then reducing by the subtraction method, comparing it with the original sequence, and the difference between the two sequences is the residual difference, and calculating the relative accuracy to determine the degree of model accuracy.

If the relative accuracy meets the required accuracy, the model passes the test; if the required accuracy is not met, the residual GM (1,1) model can be established through the above residue sequence to correct the original model.

The GM (1,1) residual model can improve the accuracy of the original model in two ways:

When the GM (1,1) residual model is established with the residues of the generated sequence, the residual sequence is.

$$\varepsilon^{(0)}(t) = \hat{x}^{(1)}(\mathrm{t}) - x^{(0)}(\mathrm{t}) \tag{12}$$

The GM (1,1) model generated by its accumulation is

$$\varepsilon^{(1)}(t+1) = \left(\varepsilon^{(0)}(1)-\frac{dt}{at}\right)e^{-a_z}t+\frac{u_z}{a_z} \tag{13}$$

The derivative is a correction term to the model: $(\hat{x})^{(1)}$

$$\delta(t-i)(-a_z)(\varepsilon^{(0)}(1)-\frac{u_z}{a_z})e^{-a_z}t) \tag{14}$$

Among:

$$\delta(t-i) = \begin{cases} 1(t \geq i) \\ 0(t < i) \end{cases} \tag{15}$$

The corrected model is given as follows:

$$\hat{x}^{(0)}(t+1) = -a\left(x^{(0)}(1)-\frac{u}{a}\right)e^{-a_q t}+\delta(t-i)(-a_\varepsilon)(\varepsilon^{(0)}(t)-\frac{u_\varepsilon}{a_\varepsilon})e^{-a_q}t \tag{16}$$

When the GM (1,1) model is established with the residual sequence of the reduced model, its residual sequence is.

$$q^{(1))}(t) = \hat{x}^{(0)}(1) - x^{(0)}(t) \tag{17}$$

Its cumulative generative model is:

$$\delta(t-i)(-a_q)(q^{(0)}(1)-\frac{u_q}{a_q})e^{-a_q}t \tag{18}$$

To guide the correction term of the model:

In the formula:

$$\delta(t-i)=\begin{cases}1(t\geq i)\\0(t<i)\end{cases} \tag{19}$$

The modified model is$\hat{x}^{(1)}(t+1)$and $q^{(1)}(t+1)$the sum of derivatives, namely:

$$\hat{x}^{(1)}(t+1)=\left(x^{(0)}(1)-\frac{u}{a}\right)e^{-az}+\frac{u}{a}+\left(q^{(0)}(1)-\frac{u_z}{a_z}\right)e^{-az}+\frac{u_z}{a_z} \tag{20}$$

Taking the manufacturing industry of chemical raw materials and chemical products as an example, the model building steps are as follows.

Initialize the modeling of the original sequence

1536.14,1687.99,1735.48,2197.82,2049.83,2075.23

The 1-AGO generation of the original sequence

1536.140,3224.130,4959.610,7157.430,9207.260,11282.490

Next to the mean generation of the 1-AGO generated sequence

2380.135,4091.870,6058.520,8182.345,10244.875

The development coefficient a and the gray action amount b of the gray model are calculated

a=-0.05, b=1615.28

Simulation value and simulation error

The analysis results are shown in Table 1, Figure 1 and Table 2.

Table 1. Simulated values and simulated error table

Order number	**Real data**	**Analog data**	**Residual**	**Relative simulation error**
1	1687.99	1744.78	-56.79	3.36
2	1735.48	1841.48	-106	6.11
3	2197.82	1943.55	254.27	11.57
4	2049.83	2051.27	-1.44	0.07
5	2075.23	2164.95	-89.72	4.32

Calculate the average simulation relative error: 5.09%.

Finally, the water demand of the key water industry in 2022 is calculated by the mode The results of comparing the two methods are shown in Figure and Table.

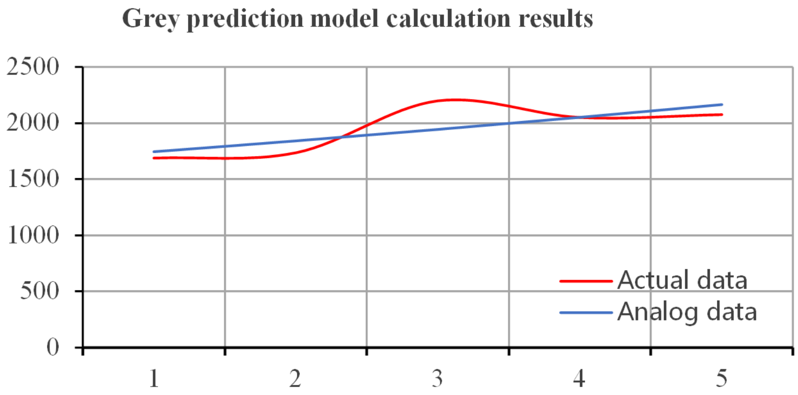

Fig. 1. Prediction results of the grey prediction model

Table 2. Comparison of water consumption in 2022 predicted by ten thousand yuan industrial added value water quota method and grey prediction method

Industry category	Water consumption in 2022(ten thousand tons)			Error	
	Actual water consumption	Predicted value 1*	2Predicted value 2*	Error1* (%)	Error2* (%)
Textile industry	727.92	674.85	718.27	7.29	1.33
Chemical industry	2136.07	2471.2	2418.61	15.69	13.23
Food industry	986.84	870.38	1119.87	11.80	13.48
The other	2087.12	2321.1	2357.96	11.21	12.98
Totel	5937.95	6337.5	6614.71	6.31	11.40

Remark: **Predicted value1***representative Forecast by water quota method of ten thousand yuan industrial added value: **Predicted value2***representative grey prediction method; **Error1*** representative Water quota method of ten thousand yuan industrial added value error; **Error2*** representative Grey prediction method error.

5 Conclusions

Compared with the actual water consumption, the prediction of the water consumption of pilot enterprises in 2022 by the water quota method of ten thousand yuan industrial added value is smaller, with an error of 6.31%, while the error of the grey prediction method is larger, with an error of 11.40%. Therefore, we choose the water quota method of ten thousand yuan industrial added value to forecast water demand.

References

1. Wang Ruxue, Wang Peng. Research on the prediction method of water demand in industrial parks [J]. Inner Mongolia Water Conservancy, 2022, (08): 65-66.
2. Wenjing Yan. Industrial water consumption prediction study [D]. North China University of Water Resources and Electric Power, 2022.DOI:10.27144/d.cnki.ghbsc. 2022.000217:14-14.
3. Fulin Wang Wang. Research on medium and long-term water demand prediction in Liaoning Province based on gray system prediction model and quota method prediction model [J]. Journal of Shenyang Agricultural University, 2013,44 (04): 491-494.
4. Tianmei Feng, Zhang Xin. Prediction analysis of water consumption in Baotou city based on a modified combination model [J]. Journal of Northwest A & F University (Natural Science Edition), 2014,42 (3): 226-234.
5. Tiwari MK, Adamowski JF. Medium-Term Urban Water Demand Forecasting with LimitedData Using an Ensemble Wavelet-Bootstrap Machine-Learning Approach. [J]. JOURANAL OF CES PLANNING AND MANAGEMENT.2015,141(2).
6. Danielle C. M. Ristow, Elisa Henning, Andreza Kalbusch, Cesar E. Petersen; Models for forecasting water demand using time series analysis a case study in Southern Brazil[J]. Journal of Water, Sanitation and Hygie. [J]. Joumal of Water,Sanitation and Hygicne for Devclopment, 2021, 11(2): 231-240.
7. Kashyap P K, Kumar S, Jaiswal A, et al. Towards precision agriculture IoT-enabled intelligent irrigation systems using deep learning neural network[J]. IEEE Sensors Journal, 2021, 21(16): 17479-17491.