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**Research Article**

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# The overview of prediction methods of urban domestic water consumption

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**ABSTRACT**

*This paper summarizes the prediction method of urban domestic water consumption. Some typical methods of time series, structural analysis, the gray prediction method, artificial neural network and the status quo, to point out the advantages and disadvantages of each method, predicting urban water should be selected according to the actual situation prediction method.*

**Key words:** city, domestic water consumption, prediction methods, overview

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## INTRODUCTION

It is of great significance for the urban construction and development in the future by studying the urban domestic water consumption in planning period and making it approaches to the actual urban development. Due to the complexity of water-consuming system, we still couldn't build a certain mode which can predict it. Many scholars have carried out relevant research, mainly divides into three aspects: namely method of time series, structural analysis and system approach [8].Then the contents of the aspects will be discussed as follows.

## TIME SERIES METHOD

Regardless of the weather and the other factors which affect the system running, method of time series [19] regard the system as a "black box", and the prediction process mainly depends on the historical data and data model. The common method of time series analysis include methods as follows: moving average, trend prediction, markov method and exponential smoothing method [7], et al. Jianhua Zhou [5] and Hongjuan Lan [4] not only made a deep research on time series analysis, but also applied it in the prediction of urban daily water, which obtained a good result.

**Method of moving average.** Method of moving average, using a weighted average of the past years, predictsthe future water demand. For example, if we regard the Vn as the predicted annual water demand, water consumption in the past m years are$V_{n-1}$、$V_{n-2}$、……$V_{n-m}$, and the prediction model is:

$$V_n = (\alpha_1 \cdot V_{n-1} + \alpha_2 \cdot V_{n-2} + \ldots\ldots + \alpha_m \cdot V_{n-m})\ /m$$

Among the model above, the weighted coefficient of data in each year are $\alpha_1$、$\alpha_2$、……$\alpha_m$. This method is appropriately for the swing condition, which has the advantages of simple and accuracy for the recent results. But as for the foreword prediction, it will make a biggish deviation because it's completely built on the predicted data.

**Trend prediction method.** Firstly we should ascertainthe variation tendencyof the historical data, such aslogarithmic, index or s-shaped curve, then estimate the unknown parameter, and finally get the curvilinear equation, used in prediction. This calculation is simple, with a certain accuracy. But the result is not stable. The model equations are: $Vt=at^b+c$、$Vt=ae^t+c$、$Vt=ae^{-be-ct}$, in which a, b and c are unknown parameter, t is for years and $V_t$ is forannual water demand.

**Markov method.** Markov method is a kind of prediction techniques which draw a trend line with the methods above and get the direction of the wave in the future and modify the trend value, according to the probability distribution of data fluctuation. Although the Markov method is used to "filter", which can rule out certain random factors But the result is unstable [9].

**Exponential smoothing method.** This method tells that the historical statistical data are suitably weighted according to time sequence, and smoothed roughly. And then predicting the water demand based on change rule. According to different requirements, smoothing can be divided into one time, two times or even several times. In general, the more times, the higher precision, also the bigger amount of calculation. So this method is generally suitable to nonlinear trend, which has a inferior effect for long prediction. The mainly models are as follows:

$$V_{n+t}=a+bt \text{ or } Vn+t=a+bt+ct^2$$

Where $V_{n+t}$ is for the predicted water demand in the year t, a, b and c are smoothing parameters, and t is for the forecast period.

**STRUCTURAL ANALYSIS METHOD**

This method analyses the different factors affecting prediction, starting from the study of the relationship between the objective things and influencing factors so that setting up the model of relationship between the forecasting objectives and influencing factors. This method is given priority to regression analysis method, including indicators of analysis method, et al., which belongs to the method of cycle prediction. We can get more cycle prediction, which is very effective for the long-term forecast.

**Method of regression analysis.** This method lists model equation containing unknown parameters after approximately judging the relationship between urban water and some influencing factors selected, and then put the actual data into the model equation to get the parameters like population, GDP, et al. This method is for medium- and long-term water demand forecasting with higher accuracy. But the factors should be fewer due to a certain limitation of the mathematical method. Corresponding to different regression, we get different regression equation. For example , the linear regression equation:

$$V_t=a_0+a_1x_1+a_2x_2+\ldots\ldots+ a_nx_n$$

In which $V_t$ is for annual water demand prediction, $a_0 \sim a_n$ are unknown parameters and $x_1 \sim x_n$ are related factors.

Starting from the characteristics of multiple regress, Yajun Zhang [17][18] analyzed respectively the water requirement of life and the industrial demand in Beijing and determined the final prediction equation, and then applied it to the prediction of water requirement of life and industrial water demandin Beijing 2010, which has a good applicability. The history data of daily water was applied to regression analysis model which uses temperature as variables by Ming Zhao [11], who built nonlinear regression combination forecast model of daily water and applied time series analysis to the regression residual sequence with dour order autoregressive model, which further proved the accuracy of prediction.

**Indicators of analysis method.** The method is based on the comprehensive analysis of historical data of the water system, to formulate all kinds of water quota. Then we can calculate the long-dated water volume according to the water quota and long service population. But because of the generality of water quota, a bigger deviation will come up when predicting the water consumption in particular cities or areas.

The key to predict urban water consumption is determined by reasonably items of index of water consumption, which size directly affects the accuracy of the prediction of urban water consumption. For example, according to the short-and long-dated population of city and comprehensive water consumption per capita in this area over the years, compared to the comprehensive water consumption per capita of similar cities, then determining short- and long-dated comprehensive water consumption per capita in planning area when combined with "Water supply specification", and finally extrapolating short- and long-dated total water consumption of city in the further step [14].

It is hard to make a discussion about the relationship of multi-factor and non-linear within the system because this method can only look for regular pattern from the digital trends. Because of the complexity of urban water system development, it is necessary to continue this kind of work. Most prediction methods existed are simplified such as simplifying it to linear, reducing the number of variables, and using grey box model. As a result, it is rough and the application range is relatively narrow.

## SYSTEM APPROACH

**Gray prediction method.** This method utilizes a grey model of city water requirement based on the gray theory to predict, which is not required to get more knowledge of the system structure and regarded as an opaque "grey box". On the analogy of the past behavior, we can get its future behavior and the result we get is in a certain precision.

Yajun Zhang [20] started from the characteristics of the grey model and the change rule of water requirement itself and verified the water requirement of Tokyo by GM(1,1) model, processing a grey prediction along with water consumption of Beijing City. Yajun Chen [21] utilized gray prediction method to establish GM(1,1) model of water consumption. His prediction was based on the original data sequence coming from the water consumption of Handan City, and he also used a posteriori error method to test the accuracy of the model prediction and the result corresponded to the actual situation well.

**Method of artificial neural network.** Artificial neural network makes a parallel processing for the data based on a large number of input/output given signal and establishes nonlinear input/output model of water consumption. And when given a prospective input case, the computer would judge a due output according to the previous "experience". Artificial neural network has a great potential in modeling of urban water consumption [13]. Yixing Yuan [22], Hongbo Liu [3] and Jinlin Shan [6] make a research on the artificial neural network and apply it into the prediction of monthly water consumption, hourly water consumption and daily water consumption. And the forecasting results have a higher accuracy.

**Forecasting method of combinatorial optimization.** It is an important means to enhance the precision of prediction that improving forecast method of single model or setting up combination forecast model [12]. Aiming at that prediction system of urban water demand has the characteristics of nonlinear and stochastic volatility; Yaping Jing [16] adopted the "based on the combination of gray neural network and Markov chain method" when he forecasted urban water consumption. And he compared analytically the prediction effect between the gray GM (1,1) model, BP neural network model and the linear combination of the prediction model of gray neural networks, to improve the prediction accuracy of the models. For example, the actual data of water consumption of Yulin city from 2000 to 2009 are the main study object, through which we can analyze the prediction precision of models compared by each other. After modification by Markov chain, the prediction precision of the establishment of "combined model of gray neutral network based on the modification of Markov chain" is higher. The absolute value of the prediction error is less than 4% and the mean square error is 1.00, which is less than that of combined gray neural network model and GM(1,1) model, BP neural network model.

Forecast model of water consumption of combined gray neural gray network modified by Markov chain has a better prediction for urban water consumption than models of gray neural network and each single prediction model. Not only does it have a higher prediction precision, but also it can reflect the general trend of development of the data sequence and the inherent law between the each system statue, which is suitable to describe the prediction problems that have larger stochastic volatility. Guiyuan Yang [2] utilized gray model and improved BP neural network to establish the optimal combination model of prediction of urban water requirement; Bohong Zhang [1] introduced the use of prediction of gray Markov chain in modeling method and its application; Xinguo Zhu [15] well applied the prediction model combining the BP neural network and Markov chain to the prediction of water requirement.

## CONCLUSION

The developments of foreign developed urban domestic water demand show that urban domestic water demand is not only a monotone increasing tendency. Extensive researches about the forecast of urban domestic water demand have been conducted at home and abroad at present The application of water demand forecast model in gray model, artificial neural network model and the combined model has become mature and wide day by day.

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