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A Project Cost Forecasting Method Based on Grey System Theory

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In view of the traditional forecasting methods of project cost, there are some limitations and uncertainties. In the case of the historical data is not complete, and it requires more quickly and accurately the cost of the project. Therefore, with the help of the grey system theory, the paper puts forward a new method of project cost prediction based on Grey System Theory. Firstly, for the problem of GM (1, 1) prediction of single data, GM (1, N) prediction based on grey system theory is proposed; Secondly, by using GM (1, N) model, the dynamic relationship of each factor is found out, and the development and change of multiple behavior variables are predicted. Finally, according to the actual situation of project cost, the GM (1, N) prediction model is established. Compared with the traditional GM (1, 1), GM (1, N) prediction model improves the precision, and it has a certain application value.

1. Introduction

With expanding and continue to standardize the construction market in China, especially after China's accession to the World Trade Organization global competition needs to, China's construction market competition rules also occurred in the great changes, to tender and bid based trading market competition state has been formed (Adeli and Wu, 2014). The construction of the project price is main problems of concern to the construction unit, and for the proposed project, how in the absence of specific construction drawings and scheme (Arafa and Alqedra, 2014), the project to make prediction valuation to determine optimal scheme of engineering and control inputs. Similarly, the construction units pay more attention to the project cost, how to reduce the project cost, increase the profit of the enterprises is their goal (Xie, 2015), which requires them to must master, according to the characteristics and requirements of engineering to predict the project cost, is pre control of project cost. The purpose is to master the various forms of the comprehensive price of the project, in the bidding of the project to control the budget, the final bid at a reasonable price.

There are many commonly used forecasting methods at present. Because of the complexity of the project system, such as the concealment, fuzziness and complexity, so far, there is no mature and effective method to predict the cost of the project. We need through the analysis of a wide variety of engineering cost prediction method, to know its characteristics, weighing the pros and cons, to explore more scientific and effective project cost prediction method.

At present, the application of grey system theory to the project cost prediction is few, and only to the project cost of a single part of the forecast. And we know that the cost of the project is made up of several parts, and they are mutually influenced. Therefore, the method that does not consider the mutual relation of each component of the project cost is not comprehensive. In view of this, this article through the grey forecasting of grey system theory on engineering cost prediction of theoretical research and case analysis, thus obtains the related Grey Prediction GM (1, 1) model and GM (1, n) model, engineering cost prediction.

2. Related works

In recent years, domestic and foreign experts and scholars have studied the highly effective prediction problem of the project, and achieved certain results. A linear regression method is proposed in the paper. In order to quantitatively describe the linear relationship between the two variables, the correlation coefficient is

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usually used to measure the linear relationship between the two variables (Li and Wang, 2015). In addition, we also need to know the difference between the actual value and the predictive value. Literature is presented for multiple linear regression forecasting method (Zhou, 2015). And a linear regression forecast method basic principle is basically the same, but requires independent variables are independent of each other, the calculation process is relatively complex, done with the help of computer. When the independent variable is two, it is called the two element regression (Deng, 2013). Literature refers to the nonlinear regression, the relationship between the independent variables and the dependent variables is not linear, that is, when the nonlinear relationship, to use nonlinear regression method. The nonlinear relation can be transformed into a linear relationship by a certain function, and then the linear regression analysis method is used to solve the nonlinear relationship (Elfaki el al, 2014). Finally, the confidence interval is obtained, and the influence of the environmental conditions of the prediction object is analyzed, and the necessary correction is made for the prediction model. In recent years, it has been applied to the field of Construction Engineering in recent years. Due to its distributed storage, parallel processing and adaptive learning characteristics can directly use sample data to realize the input layer and the output layer between the nonlinear mappings, without the need to establish accurate calculation equation, very applicable to it is difficult to establish a mathematical model but is easy to be collected samples. Engineering valuation is also used in the past, the data of similar projects, and the use of a certain model to calculate (Sun and Su, 2013). However, this method is difficult to achieve satisfactory accuracy due to the influence of many factors, such as the randomness and fuzziness of the collected data.

Grey number, grey element and grey relation are the main research objects of grey system. Therefore, grey number and its operation, grey matrix and grey equation are the basis of grey system theory. Analysis, modeling, prediction, decision making and control of industrial control and social, economic, agricultural, ecological and other systems are the main research tasks of grey system. System analysis includes grey correlation analysis, grey statistics and grey clustering and other aspects; modeling system mainly through number generation or the sequence operator to find the rules, and then complete the modeling system according to the five step modeling thought in grey theory. The five step modeling is the first step language model, the second step network model, the third step quantization model, the fourth step dynamic quantization model, and the fifth step optimization model; Grey prediction is based on GM (1, 1) quantitative prediction, according to their functions and characteristics can be divided into sequence prediction, interval prediction, disaster prediction, season disaster forecasting, topology prediction and system prediction five; Grey decision includes grey target decision, grey incidence decision, grey statistics, clustering decision, grey situation decision, grey hierarchy decision and grey programming, etc.; The main content of grey control includes the control problem of the system and the control of grey system method, such as grey incidence control and GM (1, 1) predictive control.

With the rapid development of science and technology, in the modern social economic activities, research activities and people's daily life, the exchange of information has become increasingly important, indispensable. How to effectively extract, select and process information has attracted people's attention. Grey system theory is a new subject that arises at the historic moment. Through probability and mathematical statistics, to solve the problem of large sample size, but the lack of obvious regularity of the data, that is, large sample uncertainty problem (Hegazy and Ayed, 2013). The grey system theory is proposed for neither experience, uncertainty and less of the data.

In the case of the historical data is not complete, and it requires more quickly and accurately the cost of the project. Therefore, with the help of the grey system theory, the paper puts forward a new method of project cost prediction based on Grey System Theory (Kim et al, 2013). Firstly, for the problem of GM (1, 1) prediction of single data, GM (1, N) prediction based on grey system theory is proposed; Secondly, by using GM (1, N) model, the dynamic relationship of each factor is found out, and the development and change of multiple behavior variables are predicted. Finally, according to the actual situation of project cost, the GM (1, N) prediction model is established. Compared with the traditional GM (1, 1), GM (1, N) prediction model improves the precision, and it has a certain application value.

3. Grey system theory model

Grey modeling is to use the original data sequence to generate a number of differential equations (Hwang, 2014). Due to the system by the noise pollution, so the original data sequence showing a Diasporas, the Diasporas series is also a grey sequence, or gray process, the grey process model has become grey model. The theory of grey system is able to establish the model of differential equation, which is based on the following concepts, ideas and methods.

1. The behavior of the system data series is often no rules, is a random variable, random variables and stochastic process, the grey system theory will be all random variables as the grey weight change in a certain

range, stochastic processes as varied in a certain range, and time related grey process (Sonmez, 2014). Grey quantity is not from the point of view of statistical law, through the large sample size, but with the method of data processing, the chaos of the original data into a regular pattern of the formation of a strong. Grey theory that the behavior of the system, although it is hazy, the data is messy, but it is orderly, there is a whole function. So chaotic data behind (Tas and Yaman, 2014), inevitably lurks some rules, and the generation of grey number is from untidy original data to explore, discover, searching for the inner rules (Touran and Wiser, 2013). This is a reality of the law, not a priori rule.

2. Gray theory after the original data is generated without the law, so that it becomes more regular sequence re modeling, so the GM model is actually generated sequence model.

3. Grey theory according to the topology of open sets defined sequence of time measurement (Trarek and Amr, 2014), and then defines the concentration information, defines the grey derivative and grey differential equation.

4. Grey theory by grey numbers of different generating mode, data of different trade-offs and staggers the GM model to adjust, modify, and improve the accuracy.

5. Grey theory model based on the concept of correlation degree and the principle of correlation degree convergence.

6. In the model of grey theory, three kinds of test methods are adopted, namely, residual size test, posterior difference test, correlation degree test. The residual size test is a kind of visual inspection of the accuracy of the model, which is a kind of visual inspection; After the test, is in accordance with the probability distribution of the probability distribution of the test, a statistical test, correlation test, is based on the model curve and the behavior of the curve of the geometric similarity of the test, is a geometric test.

7. For higher order system modeling, the grey theory is solved by GM (1, N) model.

8. Grey theory is not the original data model, but the data model. Therefore, the prediction data of the gray theory is not directly obtained from the model, but the data after reduction. Or the predicted value obtained by the GM model of the generated data must be processed by inverse generation.

The GM (1, N) model and the related formulas are as follows:

The whitening differential equation is:

$$\frac{dx^{(1)}}{dt} + ax_1^{(1)} = b_1 x_2^{(1)} + b_2 x_3^{(1)} + \cdots + b_{N-1} x_N^{(1)} \tag{1}$$

The timing unit has sufficient density and Δt is 1 units, Δt is close enough.

The differential equation of the background value is:

$$a^{(1)}\left[x_1^{(1)}(k+1)\right] = -a\chi_1^{(1)}(k+1) + b_1\chi_2^{(1)}(k+1) + \cdots + b_{N+1}\chi_N^{(1)}(k+1) \tag{2}$$

The basic relationship:

$$\begin{aligned} a^{(1)}\left[x_1^{(1)}(k+1)\right] &= a^{(0)}\left[x_1^{(1)}(k+1)\right] - a^{(0)}\left[x_1^{(1)}(k)\right] \\ &= x_1^{(1)}(k+1) - x_1^{(1)}(k) \\ &= x_1^{(1)}(k) + x_1^{(0)}(k+1) - x_1^{(1)}(k) \\ &= x_1^{(0)}(k+1) \end{aligned} \tag{3}$$

$$\chi_1^{(1)}(k+1) = \frac{1}{2}\left[x_1^{(1)}(k) + x_1^{(1)}(k+1)\right] \tag{4}$$

$$\chi_1^{(1)}(k+1) = x_1^{(1)}(k+1) \tag{5}$$

The parameter columns are defined as:

$$\hat{a} = \left[a, b_1, b_2, \cdots, b_{N-1}\right]^T \tag{6}$$

The parameters of formula:

$$\hat{a} = \left(B^T B\right)^{-1} B^T y_N \tag{7}$$

$$B=\begin{Bmatrix} -\frac{1}{2}\left[x_1^{(1)}(1)+x_1^{(1)}(2)\right] & x_1^{(1)}(2) & \cdots & x_N^{(1)}(2) \\ -\frac{1}{2}\left[x_1^{(1)}(2)+x_1^{(1)}(3)\right] & x_2^{(1)}(3) & \cdots & x_N^{(1)}(3) \\ -\frac{1}{2}\left[x_1^{(1)}(n-1)+x_1^{(1)}(n)\right] & x_2^{(1)}(n) & \cdots & x_N^{(1)}(n) \end{Bmatrix} \tag{8}$$

$$y_N=\left[x_1^{(1)}(2),x_1^{(0)}(3),\cdots,x_1^{(0)}(n)\right]^T \tag{9}$$

Namely:

$$y_N=B\hat{a} \tag{10}$$

y_N is the type *N*-1 vectors, B is (*N*-1)*N matrix, α is N vectors.

According to the size of N and N, there are three possible situations when the equations are solved:

(1) (*N*-1)=*N*, the number of equations is equal to the number of unknown quantity.

(2) (*N*-1) >*N*, the number of equations is more than the number of unknown quantity, that is, *n*-1 has more than the required number of N conditions, this type of equation is called the over determined equation.

(3) (*N*-1)<*N*, the number of equations is less than the number of unknown quantity, which is called the underdetermined equation.

4. System evaluations

In order to prove the thinking and mathematical models of rationality, and prediction model in the actual engineering application value, according to the Changsha City real estate projects in recent years increased the actual situation, combined with similar types of building structures cost historical data, using the actual project forecast test, inspection standard reference table 1.

Table 1: Scale Model of Accuracy

Model accuracy level	P	C
1 level	0.95≤P	C＜0.35
2 level	0.80≤P＜0.95	0.35≤C＜0.5
3 level	0.70≤P＜0.80	0.5≤C＜0.65
4 level	P＜0.70	0.65＜C

Experiment: Experimental environment is WIN XP; RAM 2G, Dual-core CPU 1.7 G. The cost of labor, materials, machinery, and total costs are considered, as shown in Figure 1 to 4.

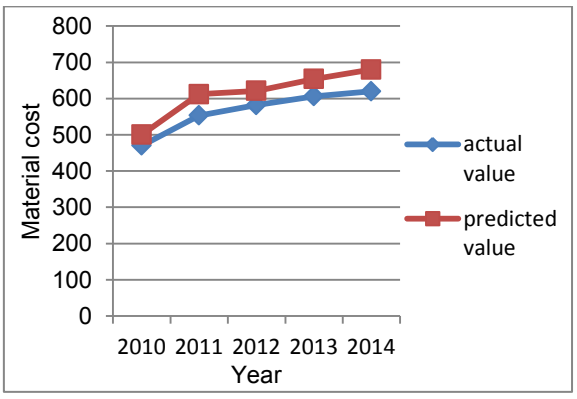

Figure 1: Predict material costs of GM (1, 1) model

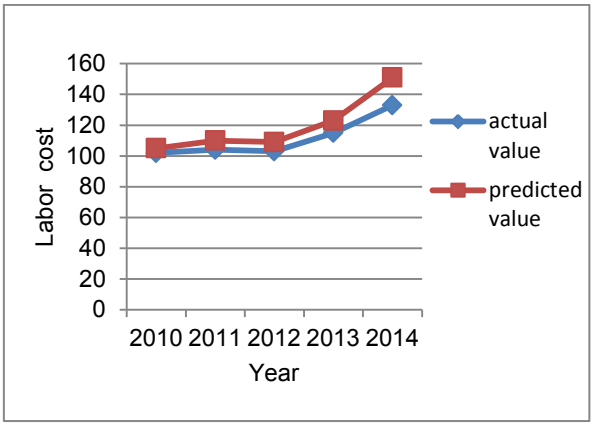

Figure 2: Predict labor costs of GM (1, 2) model

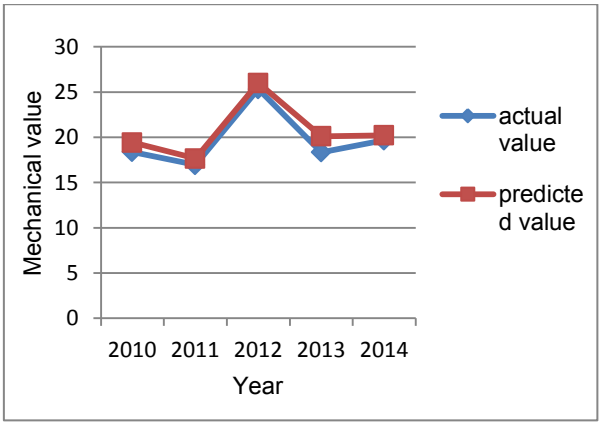

Figure 3: Predict mechanical costs of GM (1, 2) model

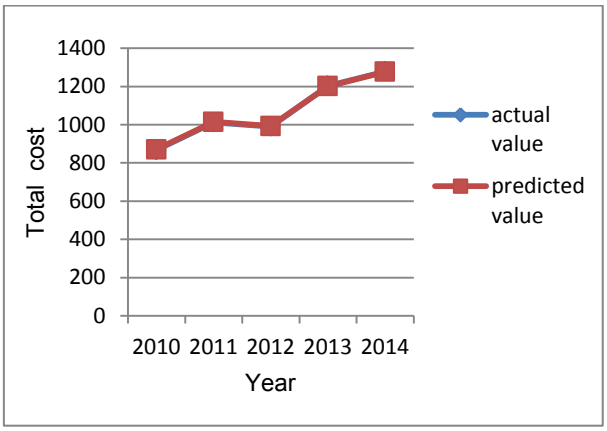

Figure 4: Predict total costs of GM (1, 4) model

Through the analysis of the 1 to 4 prediction model, the real estate data of Xi'an area in the last 5 years of 2010-2014, according to the results of GM (1, N) prediction, the error in 5%, to meet the accuracy requirements. The main reason is that the grey system prediction is a branch of the system, which considers the problem more systematic and comprehensive. Firstly, considering the single material cost, the GM (1, 1) model is established to predict the material cost. Secondly, considering the labor cost, it is related to the cost of materials, in addition to its own technological innovation, that is, the impact of its own, therefore, the establishment of the GM (1, 2) model forecast. Thirdly, considering the mechanical cost, it is related to the consumption of material and the efficiency of its own, so the GM (1, 2) model is established. Finally, we

predict the total cost, the cost of materials, labor costs, machinery costs and the total cost of the project to consider the impact of the relationship between the four, more in line with the actual situation, so the prediction accuracy is very high. The project cost forecasting model is applied to the actual project, the test results meet the accuracy requirements, which shows that the model is reasonable and feasible, and has a certain application value.

5. Conclusions

In view of the traditional forecasting methods of project cost, there are some limitations and uncertainties. In this paper, the basic concept of grey system theory is introduced in detail by using the grey system theory, and the modeling process of GM (1, N) is described in detail. Based on the grey system theory, this paper establishes the GM (1, N) model of the total cost of the project, one by one to test the material costs, labor costs, machinery costs and total cost of the project prediction error, fully meet the accuracy requirements. It shows that the model is reasonable and feasible, and it has a certain application value to the engineering cost prediction. In the future, the focus of the work is the residual model theory of gray theory, hoping to further improve the accuracy of prediction.

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