Study of cost estimation in the project design phase based on the gray system model

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Abstract

With the rapid development and transformation of the construction industry, the construction project cost has been increasing in recent years. It has not only affected mark competitiveness of the construction enterprise, but also consumed the more social resources. Then how to make the construction project cost control precisely and effectively is a key problem, especially in the project design phase. Based on the previous research, the paper summed up that the project managers had a single method of cost control and forecast, and also the accuracy was not high. This paper then explored a fit method for forecasting and controlling the budget in project design phase based on the Gray System Model (1,1).Comparing with several commonly prediction methods on project cost, it summed up their differences and selected a prioritization scheme—Gray System Model (1,1) for testing. In order to control and forecast the budget with a timely and reasonable, this paper lastly applied Gray System Model (1,1) for the project design phase of engineering practice and it proved that the evaluation method was feasible.

Keywords: Project Cost; Estimates for Prediction and Control; Gray System Model

1 Introduction

Project cost control throughout the whole process of project construction, it is beyond doubt. But obviously, the key lies in project cost control investment decisions and pre-construction design phase, and after the project investment decisions, control engineering cost management cost management in the second phase of development [1], so many people generally ignore the pre-construction project cost management session, but often to focus on cost management in the construction phase - Audit construction budget and reasonable settlement construction project cost. Although doing so is also effective, but that is too late. To effectively control the cost of investment in construction projects in advance, we must play an important role in the control design phase of the project costs, earnestly carry out the design of this critical phase [2]. The average construction period of medium-sized construction projects is approximately four to five years, small-scale construction project is about one to two years, if you do not consider the fluctuations in the price of materials within the construction period, the completion of the project cost will be more than the time when the final accounts of the project's investment plans differ widely, so that investment runaway phenomenon will become more prominent.

To avoid these problems occur, we must begin before the project construction project cost estimates and limits. This requires the contracting parties undertake to divert attention from the budget and final accounts to the estimates [3]. Preliminary estimates for system design phase is to determine the maximum amount of investment in the key steps to control and predict the research budget for the phase is the only criterion will determine the cost estimates for phase accuracy (Shown as FIGURE 1).

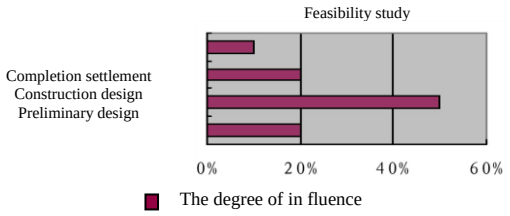

FIGURE 1 Effect of various phases of construction works full cost

For these reasons, the process of forecasting and budget preparation phase of this paper to explore the design phase of the proposed budget by the actual case will GM (1,1) applied at the phase of project cost.

2 The meaning and content of the Study

2.1 SIGNIFICANCE OF THE STUDY

Project cost must be reasonable control, and should be used ever afterwards to control the transition to predict beforehand. From a microscopic point of view, the method can be used to strengthen the capital of operational efficiency and reduce the cost of the project cost to be controlled, the estimates during the design phase of the project cost is a key step prior forecast [4]. Budget for the phase is an important part of the implementation of cost management through cost projections, is conducive to the timely detection of problems, identify construction project

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cost management problems, and to take timely measures to control the cost of the total cost, in order to gain maximum economic benefit. From a macro perspective, to strengthen the design phase of the proposed budget price controls can reduce funds for construction of individual projects, so that state funds utilization increased.

2.2 CONTENT OF THE STUDY

Architectural engineering is a complex process designed to forecast project cost estimates are part of the plan for the construction of the expected price was predicted before the implementation of the project, is the basis for the feasibility study of the project. Do predict pre-construction, you can control the price range of the entire project, from the most to the overall cost of the initial phase is controlled, the paper constitutes an analysis of the design phase, the impact of major exploration and research design estimates for construction cost forecasting and control [5]. Through qualitative and quantitative analysis, as well as various elaborate mathematical model analysis and prediction methods gray system theory, for example, to explore its application in the phase of project cost estimates for prediction. Prediction knowledge through the system, and fully consider the interaction relationship between the various components of the total project cost between the combined information and data, drawn gray system prediction GM (1,1) model for the project cost forecasting, prediction aim to achieve more rapid can accurately control the cost of the proposed budget. Gray forecast thought the proposed project cost is commonly used as a model to predict. It was created to provide an accurate reference data for bidding units, so that the project investment to achieve the desired objectives.

2.3 IMPACT AND CONTENTS OF THE DESIGN PHASE

Design phase is the construction project by defining work plans into reality phase, is to determine the major phases of the project value [6]. General project design according to the preliminary design and construction drawing design, this is referred to as the "two phase design". For a complex project, can according to the preliminary design, technical design and construction drawing design of three phases, called "three phase design". Adopt two phase design of construction projects, the preliminary design phase must prepare the budget; Using three phase design of construction projects, must prepare the revised estimate when expanding the preliminary design phase. In different phases of the design phase of the main content and the procedure were shown in FIGURE 2.

The FIGURE 2 clearly shows that in different phases of the design phase content and procedures, and pointed out in this paper, we study the problem: using the method of the design budgetary estimate of projections, focus on the estimates of phase cost control problem.

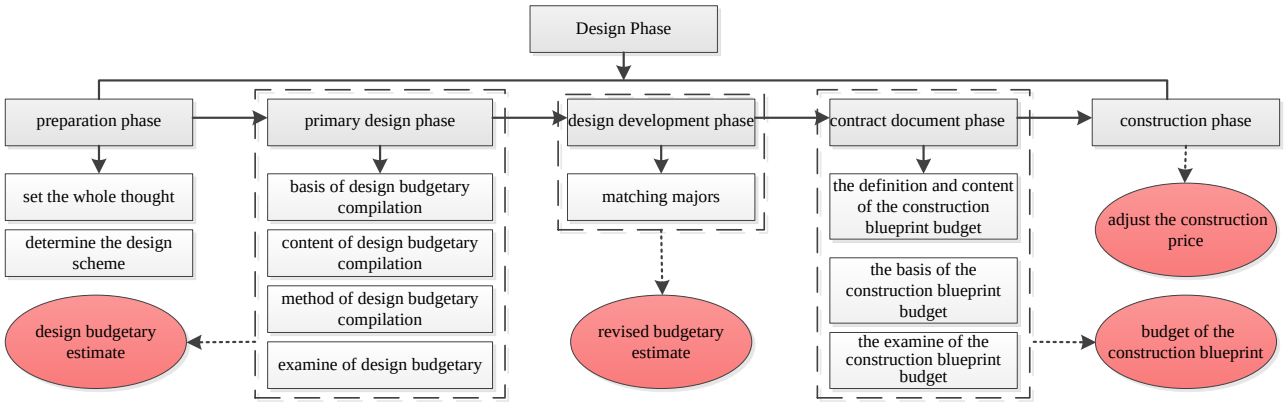

FIGURE 2 The content and process of each design phase

3 Traditional forecasting methods of cost control in project design phase

There are two kinds of traditional budget control methods in design phase basically (shown as FIGURE 3), one is qualitative analysis, the other one is quantitative analysis method.

3.1 QUALITATIVE FORECASTING METHODS

Qualitative forecastings are based on the information and intuitive materials that we already have, with the use of specialists and experts who have substantial experience and the ability of analysis, subjective experience to make inference and estimation on the nature and extent of construction project material cost, market quotation cost [7].

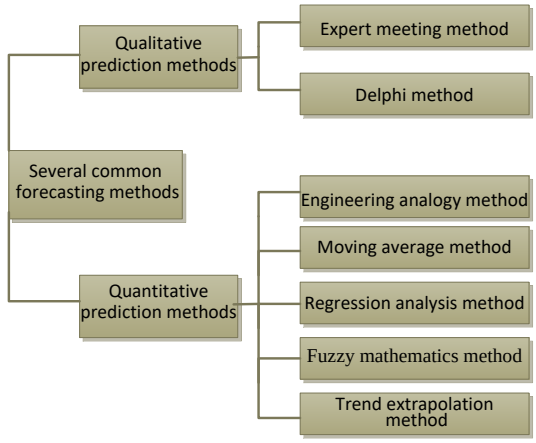

FIGURE 3 Several common forecasting methods

Qualitative forecasting is widely used in construction engineering practice, especially suitable for the situations that are lack of forecasting models' data information (including historical and realistic), or the effective factors are difficult to describe with figures, or the number of the main effective factors are difficult to analyze etc. It mainly includes the following categories: Expert meeting method, Delphi method [8].

3.2 QUATITATIVE FORECASTING METHODS

Quantitative forecasting is a forecasting method which is based on the relatively good historical data that are already have, utilizing certain mathematical methods to conduct scientific processing [9], to reveal the relations among relevant variables for forecasting the future development situation.

Quantitative forecasting methods includes engineering analogy method, moving average method, regression analysis method, fuzzy mathematics method, trend extrapolation method.

We made comparison in advantages and disadvantages of the methods, were shown in TABLE 1.

TABLE 1 Comparison of various kinds of prediction methods

Methods	**Regression analysis method**	**Moving average method**	**Fuzzy mathematics method**	**Trend extrapolation method**	**Engineering analogy method**
strength	simple method and model	Simple respond, quickly to changing	Common and fast Speed	Simple calculation, strong applicability	Estimation with fast speed
weakness	Considered not attentive, and require large amounts of data	Predicted value in behind-time	Hard to drive	Need an assortment of ways to supply	Accuracy is relatively low

3.3 OTHER METHODS

Other common methods are: exponential smoothing, autoregressive moving average method, Markov forecasting method, gray prediction technology. In addition, the uncertainty of probability and statistics commonly used systems research methods [10]. The research objects have some uncertainty, which is the probability statistics and gray, fuzzy similarities between mathematics. Comparison of methods to make these three models, the difference is the study of objects on uncertainty, uncertainty derives three distinctive disciplines. Their different points of comparison were shown in TABLE 2.

TABLE 2. The comparison of three methods of uncertainty

Contents	**Probability Statistics**	**Fuzzy mathematics**	**Gray systems**
research objects	big sample uncertainty	cognitive uncertainty	small sample uncertainty
methods	probability distribution	mapping	overlaying of information
ways and measures	statistical frequency	cut set	gray sequence operator
data requirements	typical separation	degree of membership	arranged in a random
thinking modes	repeated and singleness	epitaxial quantization	different angles
aims	historical statistical rules	recognition and expression	objective reality
characteristics	big sample	experience	small sample

By comparison, it is easy to find that the large sample, uncertainties and more data is available to solve probability and statistics; awareness of the problem of uncertainty, can be fuzzy mathematics to solve; encountered little data, small sample, incomplete information and lack of experience of uncertainty issues, available gray theory to solve. Gray system theory is nowadays a commonly used model, so in this article we choose to affect Gray Forecast Model of the proposed budget for the main analysis, and case studies introduced in the next chapter specific instructions.

4 Gray System Model

4.1 GRAY SYSTEM THEORY

Gray system theory is a theory that is relevant to establishing the model of gray system, controlling model, forecasting, decision-making, optimization and other issues. The theory is that even though the behavior of the system phenomenon is dim, and the data is complex, yet it has order and whole function. Gray forecasting method is an important part of gray system theory. It is a method that forecast the system with uncertain factors. By identifying the dissimilarity among system factors trends to analyse the association, find the change law of system through the generation of processing the raw data, generate strong regularity of data

sequence, and build the appropriate equation model.

Differential gray system theory is called GM model, G namely Gray, M namely Model. GM (1, N) means that the order is a type of differential equation model of N variables. GM (1, 1) means that the first-order differential equation model of a single variable type. Gray forecast the development trend is the use of GM (1, 1) model of the system eigenvalues change forecast. The gray forecast is a prediction of gray system theory GM (1, 1) model. This paper mainly in engineering cost estimates for this model in the application example analysis.

4.2 THE RELATION OF PROJECT COST IN DESIGN PHASE AND GRAY SYSTEM

Project cost in design phase is affected by many factors, there are not only macroeconomic factors, micro factors, but also certainty factor, uncertainty factors [11]. Project cost is usually cost by many factors, and the interact of these factors and the impact on the cost are always not clear, there is a great ambiguity and uncertainty on the boundaries of each factors. The relationship of cost system in design phase is gray, as mentioned earlier, the system includes certain, known information and uncertain, unknown information. Based on these considerations, it is totally possible to see cost system as a gray system, using gray theory to study on a significant cost project. In the project implementation process, each phase of the project investment has dynamic characteristics and uncertainty, it is in line with the characteristics of gray system and can be seen as a separate gray system [12].

5 Establish GM (1, 1) model

Gray prediction modeling process GM (1,1) model is erratic raw data accumulate, get stronger regularity modeled after the number of columns generated, the data generated by the model was then cut to obtain the raw data tired the predicted value and the prediction.

Set the original sequence as

$$X^0 = \left(x_1^0, x_2^0, \cdots\cdots, x_n^0\right) \tag{1}$$

To accumulation X^0 once

$$X^1 = \left(x_1^1, x_2^1, \cdots\cdots, x_n^1\right) \tag{2}$$

Among them:

$$x_i^1 = \sum_{k=1}^{i} x_k^0 \tag{3}$$

$$Z^1 = (z^1(2), z^1(3), \cdots\cdots, z^1(n)) \tag{4}$$

Among them:

$$z^1(k) = \frac{1}{2}(x_k^1 + x_{k-1}^1) \tag{5}$$

Then call $x_k^0 + az^1(k) = u$ as GM (1, 1) model.

To establish an albino equation

$$\frac{dx^1}{dt} + ax^1 = u \tag{6}$$

Among them, a, b can have gray differential equation $x_k^0 + az^1(k) = u$ least squares estimate of the parameter list $\hat{a} = (a, u)^T = \left(B^T B\right)^{-1} B^T Y$ obtained,

Among them:

$$Y = \begin{bmatrix} x_2^0 \\ x_3^0 \\ \vdots \\ x_n^0 \end{bmatrix}, B = \begin{bmatrix} -z^1(2), 1 \\ -z^1(3), 1 \\ \vdots \\ -z^1(n), 1 \end{bmatrix} \tag{7}$$

Solve the differential equation to accumulate prediction model

$$\hat{x}_{k+1} = (x_1^0 - \frac{u}{a})e^{-ak} + \frac{u}{a} \tag{8}$$

Then for the derivation, reduction model:

$$\hat{x}_{k+1} = -a(x_1^0 - \frac{u}{a})e^{-ak} \tag{9}$$

The original sequence forecast $\hat{x}_k^0$ as the original sequence x_k^0 residual inspection, finally to make predictions.

6 The gray GM (1, 1) model in the application of the project cost estimation

A Chongqing real estate development company will design a kindergarten building (frame structure, construction area of 6800m^2) under effective control and estimate in 2015. In order to control and estimate the project cost effectively, company selected six buildings (frame structure) which were built in 2014, by the statistics, final dates were shown in TABLE 3.

TABLE 3. Statistics of the similar engineering project cost

Project NO.	Completed monthly	Building area(㎡)	Project cost (Ten thousand Yuan)
1	2014.1	5200	320
2	2014.3	5800	368
3	2014.6	6300	416
4	2014.8	6700	456
5	2014.9	7200	514
6	2014.10	7300	530

Each unilateral project cost was calculated in TABLE 4.

TABLE 4. Similar unilateral project cost table

Time	2014. 1	2014. 3	2014. 6	2014. 8	2014. 9	2014. 10
The cost (yuan / ㎡)	615	634	660	681	714	726

Step1. the original sequence.

$X^0 = (x_1^0, x_1^0, \cdots\cdots, x_6^0)$

= (615, 634, 660, 681, 714, 726)

Accumulated generating operation

$$X^1 = (615, 1249, 1909, 2589, 3303, 4029)$$

Step2. For solving matrix B and Y.

$$B = \begin{bmatrix} -z^1(2), 1 \\ -z^1(3), 1 \\ \vdots \\ -z^1(n), 1 \end{bmatrix} = \begin{bmatrix} -933, & 1 \\ -1580, & 1 \\ -2250, & 1 \\ -2948, & 1 \\ -3668, & 1 \end{bmatrix}$$

$$Y = (634, 660, 681, 714, 726)^T$$

Step3. for solving.

$$\hat{a} = (a, u)^T = (B^T B)^{-1} B^T Y = \begin{bmatrix} -0.035 \\ 604.417 \end{bmatrix}$$

Step4. build GM (1, 1) model and from $\hat{x}_{k+1} = (x_1^0 - \frac{u}{a})e^{-ak} + \frac{u}{a}$, Obtained:

$$\hat{X}_{k+1} = (647,\ 670,\ 694,\ 718,\ 744,\ 770)$$

Step5. residual test. The computed result was shown in TABLE 5.

TABLE 5. Residual error test table

Serial number	calculated value	Original value	Residual error	Relative error
1	647	634	13	2.08%
2	670	660	10	1.54%
3	694	681	13	1.97%
4	718	714	4	0.64%
5	744	726	18	2.43%

TABLE 5 shows: Mean value of the original data

$$\bar{x} = 671.78$$

$$A^2 = \frac{1}{5}\sum_1^6 (x_k^0 - \bar{x})^2 = 1899$$

$$A = 43.58$$

The salvage value e_k^0 mean value $\bar{e}^0 = 11.8$

$$B^2 = \frac{1}{4}\sum (e_k^0 - \bar{e}^0)^2 = 23.62$$

$$B = 4.86$$

The salvage value contrast C=B/A=0.112, the minimum error of frequency $P = \{|e_k^0 - \bar{e}^0| < 0.6745A\} = 1$, control precision rating TABLE 6 shows accuracy for "very good", and the predict unilateral cost results were shown in TABLE 7.

TABLE 6. Prediction accuracy rating table

Grade	P	C
very good	>0.95	<0.35
good	>0.80	<0.45
qualified	>0.70	<0.50
unqualified	≤0.79	≥ 0.60

TABLE 7. Results unilateral cost prediction

Time	Actual building cost (yuan/㎡)	Predicted value (yuan/㎡)
2014.1	634	647
2014.3	660	670
2014.6	681	694
2014.8	714	718
2014.9	726	744
2014.10	—	770

On TABLE 7, obtained the predicted value $T_{c:}$ 6800× 770=5.236 million yuan.

It has proved that the gray system model is feasible in the design phase of the approximate prediction by the analysis of the case study.

7 Conclusion and discussion

In terms of cost control, the value engineering method mentioned in this article is a commonly used method in the selection and optimization of the regimen， it can be controlled in the initial phase of the construction cost. In terms of project cost forecasting, this paper has described the methods which were used to predict the field today, and through comparative analysis by quantitative analysis and qualitative analysis, which has figured out the advantages of gray prediction method. In the budget for the prediction of the design phase of the project cost, it has proved gray system is feasible and easy to use relatively by example calculation, thus it will have an effective control in terms of the price.

Gray theory utilize the method of processing data to find the patterns of know statistical data, making up the defects of mathematical statistical methods which have too much calculation, and expand its scope of application. However, there are still some shortcomings of the model, such as the discretization process of the cost continuous data will cause more errors in the cost that is far short of the actual value; using data mean generation sequence directly is also too casual, there is still room for further improvement in the future cost estimation study.

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