Research Article

Cost Control Method and Software in Bidding Process Based on Gray System Forecast

Xi-Liu Zhou

School of Mathematics and Computer Sciences, Xinyu University, Xinyu 338003, China

Correspondence should be addressed to Xi-Liu Zhou; zhouxl2999@126.com

Received 18 June 2014; Accepted 5 July 2014; Published 17 July 2014

Academic Editor: Xiaofei Zhao

Copyright © 2014 Xi-Liu Zhou. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

With the fast development of social economy, the competition between enterprises in construction projects becomes more and more serious. The cost control method is proposed to the bidding process of enterprises based on the gray system forecast. At the same time, the cost control software is also constructed to the bidding process of enterprises. Experimental results suggest that the proposed approach is feasible and correct.

1. Introduction

With the fast development of social economy, the competition between enterprises in construction projects becomes more and more fierce. As a result, the low bid has become the major trend and the profit space is smaller and smaller. In this situation, enterprises pay more attention to the cost control of construction projects, regarding the cost control object as an important assessment indicator and improving their core competence through internal management. The coming information era has a revolutionary impact on manufacturing, electronics, and so on. In manufacturing industries, it is a long history since the digital model has acted as a crucial production instrument, and technologies such as numerical control and 3D software have played a prominent role in improving production efficiency.

Nowadays, with the construction installation developing toward the low-energy and low-pollution sustainable direction in such a fierce international competitive environment, the operation mode and technologies in traditional CAD era cannot meet various challenges any more, and information technologies have become the main development trend of current construction installation industries in China. The emergence of BIM has just catered for the demand of information technologies, with prominent value advantages in

information exchange and sharing, improving the decision-making speed and accuracy, lowering cost and increasing production quality et al.

2. Literature Review

Unlike China, western countries pay much attention to the cost control involved in economic development very early. This is mainly determined by their unique social and economic conditions. Similarly, the concept of cost control of construction projects forms gradually as the economy develops [1, 2].

Early in the 20th century, the father of production plan progress chart, also the forerunner of scientific management, Henry Lawrence Gantt, founded “Gantt chart” (also called “Bar chart”), which has opened the door of project planning and scientific control and laid a solid foundation for the development of network planning [3–5].

In 1955, the US navy established a special project management office (SPO) in their Polaris program, ready to develop new PERT (program evaluation and review technique). Later, the Dupont company combined their planning management technique and the developed PERT and proposed the famous critical path method (CPM). The application of NASA-PERT

technique in Apollo missions has made PERT famous all over the world, thus making great contributions to perfecting the CPM [2].

In order to balance the progress, expenses (investment and operation cost) and performance (technical parameters or investment benefits), experts proposed the venture evaluation review technique (VERT) in 1973 [6–8]. The book “*Accounting Control Method*,” designed and formulated by the Business Administration Research Institute of Harvard University, first proposed the concept of cost control. Its connotation is to control and reduce the cost [9].

In 1998, Jim first put forward ten principles for cost control and then proposed the cost control system model for a closed cyclic project from the aspect of global cost management [10]. Then in 1999, Froese stressed that an integrated method should be used to manage the project cost. Obviously, the computer software is the best instrument to realize and strengthen the integrated management of project cost [11].

In 2003, Peter and Love developed a project management quality cost information system which can help to identify the drawbacks in the project management so that appropriate measures can be taken to avoid mistakes and remedy limitations in future project management [12].

In 2006, Lurie developed an engineering tool to control project cost [13]. Later in 2011, Pajares and López-Paredes made improvements and extension on the earned value management and then proposed the Cost Control Index and Schedule Control Index to control project cost [14].

Later, more and more countries began to pay attention to the cost control of construction project. Organizations and institutions specialized in relevant researches are set and relevant project contractors also assigned experts for cost control management. For example, the Cost Planning Branch in Japan and the Cost Engineer Association in USA et al. have set special research institutions. Among them, the system cost control method proposed by Harold Kerzner, a famous American project administrator, is comparatively advanced. Nowadays, the widely used methods in western countries are network planning technique, cost optimization, and cost dynamic control.

3. Cost Control in Bidding Process

The bidding process is the source where enterprises obtain construction projects. In this stage, cost control is implemented to make a competitive tender offer. First predict and control the target cost before construction projects, then determine the expected cost, and finally determine the tender offer considering proper profits. Decompose the project until processes according to construction drawings and then predict the cost, actually the expected cost of construction enterprises, based on gray prediction theory model. Finally determine the tender offer considering proper profits based on technology, management level, and bidding techniques of competitors. This tender offer has reflected the performance of construction enterprises. If the predicted expected target cost is lower, more flexible space exists in profits, which

means stronger competitiveness of the enterprise. Besides, once winning the bid, it will enjoy considerable profits and great economic benefits. Therefore, a good beginning in bidding process is very important. Most of the current vast methods for tender offer are rather general and cannot serve for certain stage specially, while the gray theory can specially predict the bidding cost to make it more approximate to practical work.

Bidding decision should be made according to practical project profile and bidding documents. Since loss risks exist in construction projects, full preparations should be made before the bidding decision to manage the cost to guarantee expected profits. The cost control in bidding process should be made based on a serious analysis on the economic development, technology, management level, and feasible project management measures as well as the forecast and judgment for future construction environment. It aims to save labor expenditure, estimate the cost practically, and finally make a realistic target cost. Just as the analysis in the instance does, the bidder tendered without consideration of the complicated reality and made a low estimation on the tender cost, which finally led to the risk of losses. This is very common in construction, so an overall analysis on projects before bidding is definitely necessary.

3.1. Modeling. Gray forecast is the quantitative forecast based on GM (gray model), which can be classified into several types according to its function and features such as sequence forecast, interval forecast, calamity forecast, seasonal calamity forecast, wave forecast, and system forecast. The gray system forecast theory can make up defects of traditional cost forecast theory in forecasting the construction project cost due to its uncertainty with requirements on information and the complicated data in the construction process. It has no requirements on the quantity of forecast data, neither need it get rid of incomparable factors, and the forecast result is reliable as long as the established model has reached the required precision.

Establish the mathematical model through gray forecast theory. Suppose that

$$X^{(0)} = \{X^{(0)}(P)\} \quad (P = 1 \sim m) \quad (1)$$

is a set of time sequence collected in the system. Make an accumulation on $X^{(0)}$ and the following sequence forms

$$X^{(1)} = \{X^{(1)}(P)\} \quad (P = 1 \sim n). \quad (2)$$

Here, $X^{(1)} = \sum_{j=1}^P X^{(0)}(j)$, $(P = 1 \sim n)$ which can be solved by the first-order differential equation. It is the GM(1,1) model in gray forecast.

Establish the following model through GM(1,1) model:

$$\frac{dx^{(1)}}{dt} + aX^{(1)} = u. \quad (3)$$

Here, a is the development gray number and u is the gray action. Solve the equation through $a = [a, u]^T =$

$(G^T G)^{-1} G^T Y_N$. Further estimate parameters a and u , get the forecast model of time sequence accumulation and forecast model of original sequence, then substitute the involved data into models, and finally obtain the forecast cost. Here

$$G = \begin{bmatrix} -\frac{1}{2} [X^{(1)}(1) + X^{(1)}(2)] & 1 \\ -\frac{1}{2} [X^{(1)}(2) + X^{(1)}(3)] & 1 \\ \vdots & \\ -\frac{1}{2} [X^{(1)}(n-1) + X^{(1)}(n)] & 1 \end{bmatrix}, \quad (4)$$

$$X_n = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{bmatrix}.$$

3.2. Solution Method

(1) Forecast model of time sequence accumulation:

$$\widehat{X}^{(1)}(k+1) = \left(X^{(0)}(1) - \frac{u}{a} \right) e^{-ak} + \frac{u}{a}, \quad k = 0, 1, 2, 3, \dots \quad (5)$$

(2) Forecast model of original sequence:

$$\begin{aligned} \widehat{X}^{(0)}(k+1) &= \widehat{X}^{(1)}(k+1) - \widehat{X}^{(1)}(k) \\ &= \left(X^{(0)}(1) - \frac{u}{a} \right) \times (1 - e^a) e^{-ak} = A e^{-ak}. \end{aligned} \quad (6)$$

Here, $A = (X^{(0)}(1) - (u/a)) \times (1 - e^a)$, $\widehat{X}^{(0)}(1) = X^{(1)}(1)$, $k = 1, 2, 3, \dots$

(3) Accuracy test of the model (construct the variance ratio and small error probability to test the model).

Forecast error:

$$e(k) = X^{(0)}(k) - \widehat{X}^{(0)}(k). \quad (7)$$

Forecast error mean:

$$\bar{e} = \left(\frac{1}{n} \right) \sum_{j=1}^n e(j). \quad (8)$$

Original data mean:

$$\bar{X}^{(0)} = \left(\frac{1}{n} \right) \sum_{j=1}^n x^{(0)}(j). \quad (9)$$

Standard deviation of original data:

$$S_1 = \sqrt{\frac{1}{n} \sum_{j=1}^n (X^{(0)}(j) - \bar{X}^{(0)})^2}. \quad (10)$$

TABLE 1: Cost statistics of similar projects.

Project number	1	2	3	4
Cost of each work day	150	130	130	140

Unit: yuan.

Standard deviation of forecast error:

$$S_2 = \sqrt{\frac{1}{n} \sum_{j=1}^n (e(j) - \bar{e})^2}. \quad (11)$$

The first posterior indicator: variance ratio $M = s_2/s_1$.

The second posterior indicator: small error probability $P = p\{|e(k) - \bar{e}| < 0.6745S_1\}$.

Here, $p = m/n$ (m is the number of errors smaller than the above mentioned). The test shows that, the better the model is, the smaller the grade of accuracy is, and models are incompetent when their accuracy grades are more than four.

4. Cost Control Instance in Bidding Process

In bidding process, the cost of mechanical and electrical installation projects is mainly labor cost. Final account materials of four similar recent projects have been collected in this paper and the labor cost worked out is shown in Table 1.

Suppose that the original sequence is

$$X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), X^{(0)}(3)\} = \{150, 130, 130, 140\}. \quad (12)$$

Step 1. Make an accumulation on $X^{(0)}$ and get $X^{(1)} = \{150, 280, 410, 550\}$.

Step 2. Take a test on $X^{(0)}$ about its accurate smoothness: $P(k) = X^{(0)}(k)/X^{(1)}(k-1)$ and obtain

$$P(2) = 130/150 = 0.867;$$

$$P(3) = 130/280 = 0.464 < 0.5;$$

$$P(4) = 140/410 = 0.341 < 0.5.$$

When $K > 2$, the accurate smoothness condition can be satisfied.

Step 3. Verify whether $X^{(1)}$ obeys the accurate index law $Q^{(1)}(k) = X^{(1)}(k)/X^{(1)}(k-1)$ or not and obtain

$$Q(1)(2) = 280/150 = 1.867;$$

$$Q(1)(3) = 410/280 = 1.464;$$

$$Q(1)(4) = 550/410 = 1.341.$$

$\forall k, Q^{(1)}(k)[a, b], d = b - a$, when $d < 0.5, Q[1, 1.5]$, and $X^{(1)}$ obeys the accurate index law, so a model can be established for $X^{(1)}$.

Step 4. Mean generation with consecutive neighbor for $X^{(1)}$: let $Z^{(1)}(k) = 0.5X^{(1)}(k) + 0.5X^{(1)}(k - 1)$ and obtain

$$\begin{aligned} Z^{(1)} &= [Z(2), Z(3), Z(4)] \\ &= (0.5 \times 280 + 0.5 \times 150, 0.5 \times 410 + 0.5 \\ &\quad \times 280, 0.5 \times 550 + 0.5 \times 410) \\ &= (215, 345, 480) \\ B &= \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ -Z^{(1)}(4) & 1 \end{bmatrix} = \begin{bmatrix} -215 & 1 \\ -345 & 1 \\ -480 & 1 \end{bmatrix}, \\ Y &= \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ X^{(0)}(4) \end{bmatrix} = \begin{bmatrix} 130 \\ 130 \\ 140 \end{bmatrix}. \end{aligned} \quad (13)$$

Step 5. Make a least square estimation on $\hat{a} = [a, u]$ and obtain

$$\hat{a} = (B^T B)^{-1} B^T Y = \begin{bmatrix} -0.04 \\ 120.17 \end{bmatrix}. \quad (14)$$

Step 6. Finalize model. Consider the following:

$$\frac{dX^{(1)}}{dt} - 0.04X^{(1)} = 120.17. \quad (15)$$

The time response equation is

$$\widehat{X}^{(1)}(k+1) = \left(X^{(1)}(0) - \frac{u}{a} \right) e^{0.04k} + \frac{u}{a}. \quad (16)$$

Here, $a = -0.04$ and $u = 120.17$. Consider the following:

$$\begin{aligned} \widehat{X}^{(1)}(k+1) &= (150 + 3004.25) e^{0.04k} - 3004.25 \\ &= 3154.25 e^{0.04k} - 3004.25. \end{aligned} \quad (17)$$

Step 7. Solve the simulation value of $X^{(1)}$

$$\begin{aligned} \widehat{X} &= (\widehat{X}^{(1)}(1), \widehat{X}^{(1)}(2), \widehat{X}^{(1)}(3), \widehat{X}^{(1)}(4)) \\ &= (150, 278.3, 409.6, 548.0). \end{aligned} \quad (18)$$

Step 8. Restore $X^{(0)}$, solve its simulation value according to $\widehat{X}^{(0)}(k) = \widehat{X}^{(1)}(k) - \widehat{X}^{(1)}(k-1)$, and obtain

$$\begin{aligned} \widehat{X}^{(0)} &= (\widehat{X}^{(0)}(1), \widehat{X}^{(0)}(2), \widehat{X}^{(0)}(3), \widehat{X}^{(0)}(4)) \\ &= (150, 128.3, 131.3, 138.4). \end{aligned} \quad (19)$$

The comparison between the original value and the forecast value is shown in Table 2.

Step 9. Accuracy test. Make calculations according to residual equation $e(i) = X^{(0)} - \widehat{X}^{(0)}$ and obtain Table 3.

TABLE 2: Comparison between the original value and the forecast value.

Project number	1	2	3	4
Cost of each work day ($X^{(0)}$)	150	130	130	140
Gray forecast cost ($\widehat{X}^{(0)}$)	150	128.3	131.3	138.4

Unit: yuan.

TABLE 3: Result of accuracy test.

Project number	1	2	3	4
Cost of each work day ($X^{(0)}$)	150	130	130	140
Gray forecast cost ($\widehat{X}^{(0)}$)	150	128.3	131.3	138.4
$e(i)$	0	1.7	-1.3	1.6

Unit: yuan.

Mean value of residual: $\bar{e} = (1/4) \sum_{i=1}^4 e(i) = 0.5$.

Variance of residual: $S_2^2 = (1/4) \sum_{i=1}^4 [e(i) - \bar{e}]^2 = 1.5$.

Practical mean value: $\bar{x} = (1/4) \sum_{i=1}^4 X^{(0)} = 137.8$.

Practical variance: $S_1^2 = (1/4) \sum_{i=1}^4 [X^{(0)} - \bar{x}]^2 = 68.8$.

Posterior error ratio: $M = (S_2/S_1) = (\sqrt{1.5}/\sqrt{68.8}) = 0.15$.

The second posterior indicator: small error probability $P = p\{|e(k) - \bar{e}| < 0.6745S_1\}$ in which $0.6745S_1 = 5.59$, $P1 = |e(1) - \bar{e}| = 0.5 < 0.6745S_1$. Similarly, $P2 = |e(2) - \bar{e}| < 0.6745S_1$, $P3 = |e(3) - \bar{e}| < 0.6745S_1$, $P4 = |e(4) - \bar{e}| < 0.6745S_1$, and $P = (3/4) = 0.75$. According to the accuracy table, we know that this model belongs to ones with the third grade of accuracy, so the corresponding forecast result is reliable.

Step 10. Make forecast according to the forecast model

$$\widehat{X}^{(1)}(k+1) = 3154.25e^{0.04k} - 3004.25. \quad (20)$$

When $k = 4$, $\widehat{X}^{(1)}(5) = 693.7$; when $k = 3$, $\widehat{X}^{(1)}(4) = 550$

$$\widehat{X}^{(0)}(5) = \widehat{X}^{(1)}(5) - \widehat{X}^{(1)}(4) = 143.7, \quad (21)$$

namely, that the forecast cost of each work day is 143.7 yuan. The expected project duration is 12 months (each month contains 22 work days) and 150 operators are in need each day, so the total expected labor cost is 5.69 billion yuan. Other costs can also be forecasted in this way. The forecast results are shown in Table 4.

The forecast cost of the project is 53.5 billion yuan; so it is reasonable to set the tender price to about 53.5 billion yuan.

5. Cost Control Software in Bidding Process

The system contains the following ten modules: login, user management, file, tool, view, construction component management, basic information management, knowledge management, maintenance management, and contingency plan management. Its functional structure is shown in Figure 1. The user main interface, composed of tool bar, build tree,

FIGURE 1: Mechanical and electrical equipment installation management system based on BIM.

TABLE 4: Forecast costs of mechanical and electrical installation project in SN Insecticide Factory.

Number	Project	Cost (billion yuan)
1	Labor cost	569
2	Materials cost	2582
3	Expense of using construction machinery	619
4	Measure fee	357
5	Required fees	236
6	Business management expense	198
7	Profits	403
8	Taxes	386
Total		5350

and main window, will pop up once the system is being logged in. With a component-based open architecture, the system enjoys good reusability and maintainability, which can satisfy different demands and provide individualized service. It also provides IFC file parser and IFC standard data interface engines, so information exchange and sharing between the design, construction, operation, and maintenance stage of the system and other application systems are allowed, which makes contributions to avoiding the

information fault between different stages in the current construction cycle and other application systems. Besides, the system has provided a multidimensional visual work platform based on BIM technique and network environment, which makes the information exchange between different operation maintenance departments and participants possible, thus achieving network maintenance management.

As to the BIM-based mechanical and electrical equipment installation management system, the author has designed a cost control software module in bidding process through the mentioned cost control method based on gray forecast.

During the cost control in bidding process, relevant data of some familiar recent projects are used to forecast the corresponding data of the mentioned project. The data that needs forecasting include labor cost, material cost, expense of using construction machinery, measure fee, required fees, business management expense, profits, and taxes. The corresponding calculation interface is shown in Figure 2.

6. Conclusion

This paper has adopted the gray system forecast method to explore the cost control problem in bidding process in installation enterprises and its main contents were as follows: proposed a cost control method in bidding process based on

Cost control software module in bidding process		
Labor cost:	Click to forecast	530
Materials cost:	Click to forecast	2582
Expense of using construction machinery:	Click to forecast	619
Measure fee:	Click to forecast	357
Required fees:	Click to forecast	236
Business management expense:	Click to forecast	198
Profits:	Click to forecast	403
Taxes:	Click to forecast	386
Click to forecast the total offer of the to project to be bid		5350

FIGURE 2: Calculation interface of the cost control software module in bidding process.

the gray system forecast, then provided the corresponding cost control instance of an enterprise, and finally showed the BIM software results of the installation project cost control in a factory.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

References

- [1] Y. A. Olawale and M. Sun, "Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice," *Construction Management and Economics*, vol. 28, no. 5, pp. 509–526, 2010.
- [2] J. S. Shane, K. R. Molenaar, S. Anderson, and C. Schexnayder, "Construction project cost escalation factors," *Journal of Management in Engineering*, vol. 25, no. 4, pp. 221–229, 2009.
- [3] K. M. Nassar, W. M. Nassar, and M. Y. Hegab, "Evaluating cost overruns of asphalt paving project using statistical process control methods," *Journal of Construction Engineering and Management*, vol. 131, no. 11, pp. 1173–1178, 2005.
- [4] J. A. Kuprenas, "Construction project cost performance prediction based on project bid characteristics," in *Construction Research Congress 2005: Broadening Perspectives-Proceedings of the Congress*, pp. 957–965, 2005.
- [5] L. S. Riantini, A. Veronika, and B. A. Firmansyah, "Identification of corrective action recommendation for labor management in project cost control," in *Proceedings of the 4th International Structural Engineering and Construction Conference: Innovations in Structural Engineering and Construction*, vol. 2, pp. 1439–1442, 2008.
- [6] E. Thalheimer, "Construction noise control program and mitigation strategy at the Central Artery/Tunnel Project," *Noise Control Engineering Journal*, vol. 48, no. 5, pp. 157–165, 2000.
- [7] D. Agdas and R. D. Ellis, "Analysis of Temporary Traffic Control cost items in transportation construction bidding process," in *Proceedings of the Construction Research Congress 2010: Innovation for Reshaping Construction Practice*, pp. 1103–1114, May 2010.
- [8] L. Liu and K. Zhu, "Improving cost estimates of construction projects using phased cost factors," *Journal of Construction Engineering and Management*, vol. 133, no. 1, pp. 91–95, 2007.
- [9] G. D. Creedy, M. Skitmore, and J. K. W. Wong, "Evaluation of risk factors leading to cost overrun in delivery of highway construction projects," *Journal of Construction Engineering and Management*, vol. 136, no. 5, pp. 528–537, 2010.
- [10] Z. Jim, "A project cost control model," *Cost Engineering*, vol. 17, pp. 3–6, 1998.
- [11] T. Froese, "Industry foundation classes for: project management a trial implementation," *International Journal of Project Management*, vol. 17, pp. 30–41, 1999.
- [12] E. D. Peter and Z. I. Love, "A project management quality cost information system: for the construction industry," *Information & Management*, vol. 40, pp. 649–661, 2003.
- [13] P. M. Lurie, "Mediation: An engineer's tool to control project cost," *Journal of Professional Issues in Engineering Education and Practice*, vol. 132, no. 4, pp. 322–323, 2006.
- [14] J. Pajares and A. López-Paredes, "An extension of the EVM analysis for project monitoring: the Cost Control Index and the Schedule Control Index," *International Journal of Project Management*, vol. 29, no. 5, pp. 615–621, 2011.