

Research on full cycle cost Prediction Model of Construction Engineering based on BIM

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Abstract. The capability of full cycle cost prediction of construction cost and reduce the cost of construction project needs to be improved, a design model of full cycle cost prediction model of construction cost based on BIM is proposed. The game model of full cycle cost prediction of construction cost is constructed, and the balanced control of construction cost is carried out by combining the quality constraint and cost constraint. The information management model of construction cost is designed by using BIM, and the adaptive optimization of the whole cycle cost prediction objective function is carried out by using the method of full sample regression analysis, which combines the method of minimum cost and best balance of quality. The full cycle cost prediction of construction cost under BIM is realized. The software design of the construction engineering cost prediction information management system adopts the Linux2.6.32 kernel design scheme and realizes the software development and design of the full cycle cost prediction model under BIM. The simulation results show that the stability of the model is good, the cost of construction process reaches the minimum, and the quality of information management of construction project is improved.

1. Introduction

With the development of computer technology and building industrialization, building information model and prefabricated architecture emerge as the time require. BIM (Building Information Modeling) has obtained a new concept in the construction industry in recent years. BIM is the core of information sharing. Based on the principle of convenient communication, the efficiency of the project is improved and the project cost is reduced^[1]. The fabricated building is to put the components of the building engineering in the factory after the completion of prefabrication, transport to the construction site to assemble, and finally form the building structure. Fabricated building components are manufactured in the factory and shipped to the site. The construction mode of "production-transportation-installation" requires close cooperation between manufacturers and construction units, and BIM technology can solve this problem. BIM technology is formally applied to the construction industry in 2003, and it has gradually accepted by the construction industry. In terms of cost, at present, the main software used in China has Luban, Wanda, and so on^[2]. These software not only can do 3D manual modeling directly within the software, but also support the import function of 2D drawings drawn by CAD. Although there are many advantages of BIM technology, because operators need to be trained, hardware and software upgrade needs a certain cost, so the promotion of BIM technology is not satisfactory^[3].

Although the application of BIM technology in prefabricated buildings is not very extensive, the popularization resistance is still relatively large. But BIM applications have improved significantly in terms of quality, duration and cost. In this paper, the cost control as the core, the construction project based on BIM full cycle cost prediction model. Traditional cost prediction emphasizes the cost



accounting after the completion of the project. However, due to the lack of cost control goal and no reference comparison, the optimal period of project cost control is missed. In addition, it is difficult for managers to understand the actual situation of engineering cost in real time, and then to correct the deviation of engineering cost in time. At present, the empirical evaluation method is often used to predict the cost of construction engineering^[4]. The related system design and algorithm research is still in its infancy, which leads to low accuracy, poor performance and difficult to control the unreasonable construction cost. At present, single factor grey correlation cost prediction and average mutual information function analysis is mainly used in the cost prediction and control algorithm of construction cost. Based on the quantitative analysis of the target cost and the budget cost of the construction project, the linear relationship of the cost sequence of the project cost is constructed, and the time series analysis algorithm is used to realize the cost prediction and evaluation of the project cost^[5]. In reality, the cost budget model of construction project is influenced by the cross factors such as price, tax, profit, cost management structure of construction unit, real time market price of consumables, etc. Traditional single factor cost prediction algorithm cannot achieve reasonable and accurate cost prediction of project cost, and its application in engineering practice is limited.

In view of the above problems, a design model of full cycle cost prediction model of construction cost is proposed based on BIM, and a game model of full cycle cost prediction of construction cost of construction engineering is built. The balanced control of construction cost is carried out by combining engineering quality constraint with cost constraint, and the information management model of construction cost is designed by BIM. The method of full-sample regression analysis is used to adaptively optimize the objective function of full-cycle cost prediction. Combined with the method of minimum cost and best balance of quality, the full-cycle cost prediction of construction cost under BIM is realized. Finally, the optimal design of the cost prediction information management system is carried out, which shows the superior performance of the whole cycle cost prediction model designed in this paper.

2. Benefit quantity and cost parameter model of the whole cycle cost of construction engineering

2.1. Quantitative evaluation parameter model of the whole cycle cost of construction cost.

In order to design the full cycle cost prediction model of construction cost under BIM, it is necessary to construct the benefit quantification model of full cycle cost prediction of construction cost, combining with the optimization method of quantitative evaluation parameters and cost parameters. Under the restriction of the total contract cost, the quantitative evaluation parameters of the full cycle cost prediction of the construction cost are given, including the level of cash reserve, the amount of financing, the leverage ratio and the profit, etc^[6]. By using descriptive statistical analysis method, the standardized function of full cycle cost prediction of construction cost is constructed as follows:

$$V_i = \frac{X_{\max}^i - X^i}{X_{\max}^i - X_{\min}^i} \quad (1)$$

When the capital structure and industrial structure are combined and regulated, the optimal decision function of the cost quantity is given as follows:

$$\min Z(\tilde{\mathbf{f}}, \hat{\mathbf{f}}, \mathbf{q}^w) = \sum_{a \in A} \int_0^{x_a} [t_a(x_a) + v_a] dx + \frac{1}{\hat{\theta}} \sum_{w \in W} \sum_{k \in K^w} \hat{f}_k^w \ln \hat{f}_k^w + \frac{1}{\tilde{\theta}} \sum_{w \in W} \sum_{k \in K^w} \tilde{f}_k^w \ln \tilde{f}_k^w - \sum_{w \in W} \int_0^{q^w} D^{-1}(w) dw \quad (2)$$

Under the optimal regulation of capital structure of construction enterprises, the quantitative game function of cost prediction of construction cost of construction engineering is described as follows:

$$\sum_{k \in K^w} \tilde{f}_k^w = (1 - \eta^w) q^w, w \in W \quad (3)$$

$$\sum_{k \in K^w} \hat{f}_k^w = \eta^w q^w, w \in W \quad (4)$$

$$C = (1 - \lambda + \lambda t) t^3 \quad (5)$$

The cost, construction material cost and labor cost under the quantitative equilibrium game control are represented by the above expressions^[7]. Combining with the financing adjustment method, the leverage ratio adjustment level function of construction control is obtained as follows:

$$b_{ni}(0; \lambda) = \begin{cases} \frac{1}{2}, & i = 0, 1, \\ 0, & i \neq 0, 1, \end{cases} \quad (6)$$

$$b'_{ni}(0; \lambda) = \begin{cases} -\frac{3+\lambda}{2}, & i = 0, \\ \frac{3+\lambda}{2}, & i = 1, \\ 0, & i \neq 0, 1, \end{cases} \quad (7)$$

$$b''_{ni}(0; \lambda) = \begin{cases} 3 - \frac{\pi^2}{4}(n-2) + 3\lambda, & i = 0, \\ \frac{\pi^2}{4}(n-2) - 3 - 3\lambda, & i = 1, \\ 0, & i \neq 0, 1, \end{cases} \quad (8)$$

Under BIM, the DCC-MVGARCH model is used to construct the quantitative evaluation parameter model of the full cycle cost of construction cost, which provides the input basis of the original parameters for the whole period control of the construction cost^[8].

2.2. Quantitative recursive analysis of engineering cost prediction panel data

Based on the quantitative recursive analysis of panel data of full cycle cost control of project cost under BIM, combined with the internal asset structure of construction enterprises, the profit adjustment and cost prediction are carried out. The results of statistical regression analysis of panel data are expressed as follows:

$$\hat{p}_k^w = \frac{\hat{f}_k^w}{\hat{q}^w} = \frac{\exp(-\hat{\theta} c_k^w)}{\sum_{k \in K^w} \exp(-\hat{\theta} c_k^w)} \quad (9)$$

$$\tilde{p}_k^w = \frac{\tilde{f}_k^w}{\tilde{q}^w} = \frac{\exp(-\tilde{\theta} c_k^w)}{\sum_{k \in K^w} \exp(-\tilde{\theta} c_k^w)} \quad (10)$$

$$q^w \{ [\lambda_w \eta^w + \mu_w (1 - \eta^w)] - D^{-1}(q^w) \} \geq 0 \quad (11)$$

The game model of cost prediction of engineering cost is obtained by solving the distribution S of the total cost quantified control sequence of engineering cost and finding the maximum eigenvalue λ . The game model is defined as follows:

$$\min_{z_b^{bw}, z_d^{cp}, z_{a,p}^{dm}, z_{a,b}^{\alpha}, z_{a,d,p}^{\beta}} \sum_{b \in B} z_b^{bw} K_p^{bw}(S) + \sum_{d \in D} z_d^{cp} K_d^{cp}(S) + \sum_{a \in A} \sum_{p \in P} z_{a,p}^{dm} D_{a,p} + \sum_{a \in A} \sum_{b \in B} z_{a,b}^{\alpha} M \alpha_{a,b} + \sum_{a \in A} \sum_{d \in D} \sum_{p \in P} z_{a,d,p}^{\beta} M \beta_{a,d,p} \quad (12)$$

The method of quantitative regression analysis and the method of full sample regression analysis are used for adaptive optimization of the objective function of full cycle cost prediction, which combines the methods of minimum cost and best balance of quality. The cost function of cost prediction is expressed as follows:

$$S.t. \quad z_b^{bw} R_p^{bw} + z_d^{cp} R_p^{cp} + z_{a,p}^{dm} + z_{a,b}^{\alpha} + z_{a,d,p}^{\beta} \geq V_p, \quad a \in A, b \in B, d \in D, p \in P, \quad (13)$$

$$z_b^{bw}, z_d^{cp}, z_{a,p}^{dm}, z_{a,b}^{\alpha}, z_{a,d,p}^{\beta} \geq 0, \quad a \in A, b \in B, d \in D, p \in P. \quad (14)$$

The cost function is optimized globally, and the cost constraint is carried out with Simunic model^[9].

3. Cost prediction model optimization

3.1. Full cycle cost prediction

The information management model of construction cost is designed by using BIM, and the adaptive optimization of the objective function of full cycle cost prediction is carried out by using the method of full sample regression analysis. The investment level and construction cost are selected as the constraint ontology parameters, and the fuzzy cost function of cost prediction is obtained by using the benefit optimal constraint method:

$$\partial L(\hat{\mathbf{f}}, \tilde{\mathbf{f}}, \mathbf{q}^w, \lambda, \mu) / \partial \hat{\mathbf{f}} = 0, \quad \partial L(\hat{\mathbf{f}}, \tilde{\mathbf{f}}, \mathbf{q}^w, \lambda, \mu) / \partial \tilde{\mathbf{f}} = 0, \quad \partial L(\hat{\mathbf{f}}, \tilde{\mathbf{f}}, \mathbf{q}^w, \lambda, \mu) / \partial \mathbf{q}^w = 0 \quad (15)$$

Where, $\lambda_w \eta^w + \mu_w (1 - \eta^w)$ can be understood as the interpretation and control variable of the fitness function of the full cycle cost prediction of construction cost, the fuzzy cost prediction method, the method of minimum cost and the best balance of quality^[10]. The full cycle cost prediction of construction cost under BIM is realized, and the control optimization function is obtained as follows:

$$\left\{ \begin{array}{l} v_s = \|X_s - \sum_{i=1}^n \omega_i X_i\|_2^2, s = 1, \dots, n \\ \omega_s = \frac{\frac{1}{\sum_{j=1}^n v_j} + \lambda}{\sum_{j=1}^n \frac{v_s}{\sum_{j=1}^n v_j} + \lambda}, s = 1, \dots, n \end{array} \right. \quad (16)$$

Combined with the method of minimum cost and best balance of quality, the full cycle cost prediction of construction cost under BIM is realized. The investment level is selected as dependent variable, and the objective function of project cost prediction is obtained, which is based on empirical evaluation and structural life prediction^[11]. According to the derivation of the optimal decision game model of prefabricated construction engineering cost prediction under the management of building information, which are expressed as:

$$\pi_R^{A_1} = \frac{(\beta c_n - c_r)^2}{16\beta(1-\beta)} + \frac{(1-c_n)^2}{16} + \frac{4B^2(1-c_n)^2}{(A^2-8B)^2} \quad \pi_{MD}^{A_1} = \frac{(\beta c_n - c_r)^2}{8\beta(1-\beta)} + \frac{(1-c_n)^2}{8} - \frac{B(1-c_n)^2}{A^2-8B} \quad (17)$$

A parameter control model of the benefit and cost of the prefabricated construction cost under the management of building information is constructed, and the cost control and the prediction and evaluation of the construction cost are carried out under the benefit coordination mechanism.

3.2. Software development design and implementation of construction project cost forecast information management system

Based on the design of construction engineering cost prediction information management system, the software development design of the whole cycle cost prediction model of construction cost is carried out, and the above control algorithm is written in the implementation algorithm of program loading module. Firstly, it analyzes the whole design frame of construction cost precision planning, analyzes and introduces the functional module components, and uses EPC analysis technology to process the whole cycle cost transmission information of construction cost. The embedded module scheduling and cross-compiling design of the full cycle cost prediction model of construction cost are carried out under the Linux operating model. The cross compiling method is adopted as the whole cycle control of construction cost in BootLoader. The cross compiling environment is used to output the cost planning result of the whole cycle construction cost of construction project and to operate the interactive operation between man and machine. The software development environment of the full cycle cost prediction model of construction cost is built in the development environment of embedded Linux, and the kernel is configured after transplanting. The hardware transplantation of the whole cycle cost prediction model of construction cost is carried out on LabWindows/CVI platform. VisualDSP++ is used to schedule the whole cycle cost information of the construction cost in the local database. Under the arch/arm/boot directory, the compiling software of the construction cost full cycle cost prediction is generated, and the bus transmission and cross compile control of the construction cost full cycle cost

prediction are carried out by sampling the AD information. The stability of construction cost prediction is improved, and the software development flow of the whole cycle cost prediction of construction cost designed in this paper is shown in figure 1. The optimization design of cost prediction model is realized by debugging the cost prediction model and configuring the target file under the environment of Linux2.6.32 kernel.

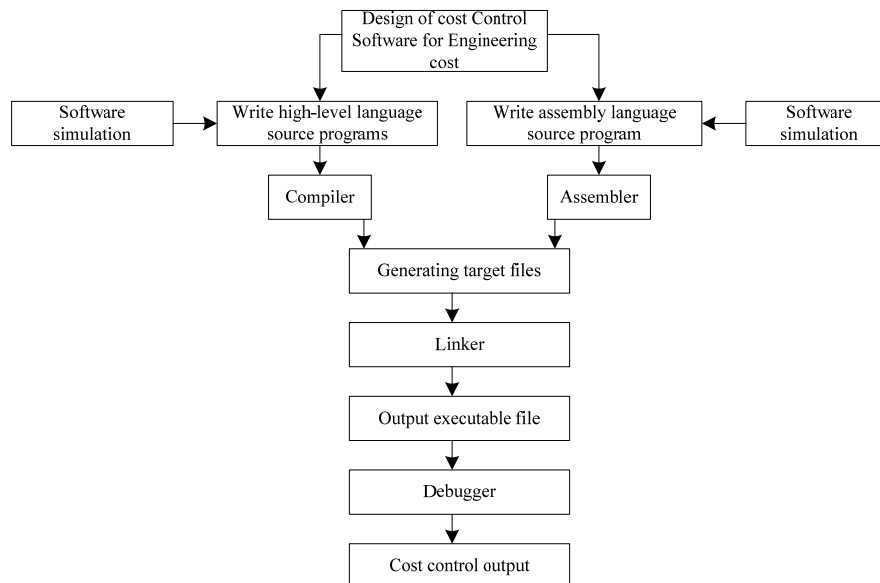


Figure 1. Software development process for full cycle cost prediction of construction cost.

4. Simulation experiment and result analysis

In order to test the application performance of this method in realizing the full cycle cost prediction of construction cost of construction engineering, the simulation experiment is carried out. The experiment is designed by Matlab7, and the cost prediction and statistical analysis are carried out with the combination of SPSS14.0 statistical analysis software. The initial constant of construction engineering cost is set as [0, 0.25, 0.75, 1], the correlation constraint factor of construction facilities is 0.29 and the constraint component factor of credit fund is 0.072. According to the "Construction Project Budget quota", the cost of assembly building based on BIM is obtained. The design of the prediction parameters is shown in Table 1.

Table 1. Contribution weight of construction cost prediction.

p_{1n}	p_{2n}	p_r	w_{1D}	w_{2D}	w_{rD}	w_{1S}
1.87	2.34	0.54	2.11	3.24	1.45	5.33
w_{2S}	w_{rS}	θ	π_R^D	π_D^D	π_M^D	π_T^D
5.43	1.12	0.13	3.76	7.32	24.32	25.21

Table 2. Engineering cost control constraints.

p_{1n}	p_{2n}	p_r	w_{1S}	w_{2S}
3.21	3.23	1.65	5.43	5.56
w_{rS}	θ	$\pi_R^{A_1}$	$\pi_{MD}^{A_1}$	$\pi_T^{A_1}$
1.68	0.25	22.66	21.33	57.221

According to the above simulation environment and parameter setting, the whole cycle cost prediction simulation of construction engineering is carried out. The efficiency closeness degree,

quality closeness degree and cost closeness degree of engineering cost prediction are tested by using the method of this paper and the traditional method. The result is shown in figure 2.

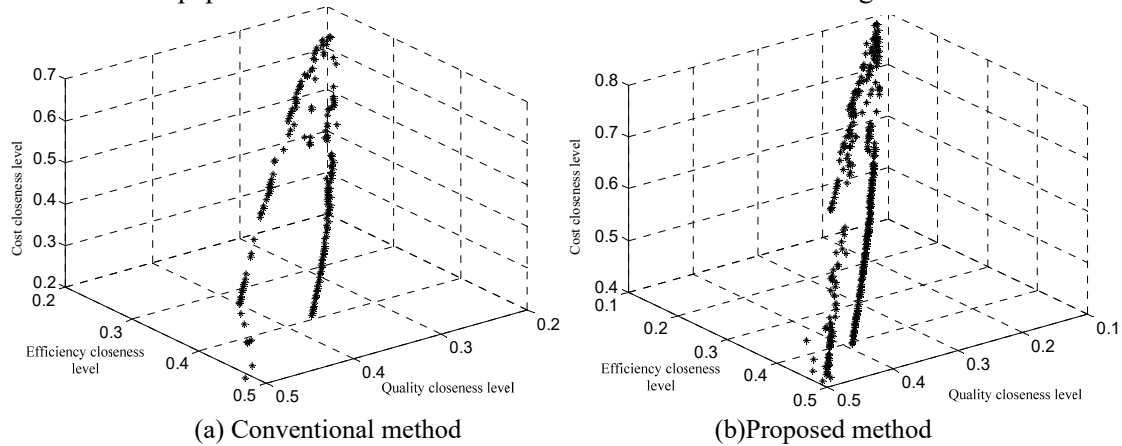


Figure 2. Game relation of project cost prediction.

Figure 2 shows that the proposed method has good convergence and good game equilibrium between cost, efficiency and engineering quality. The quality level and efficiency level of engineering construction are higher and the unit cost is lower. The traditional algorithm needs multi-step iteration to reduce the cost, and the cost dynamic control accuracy is deviated. This is because the method of piecewise regression analysis has constructed a cost control model with multi-parameter constraints of quality-efficiency-cost control, which ensures the cost control ability of construction engineering in the whole cycle. The accuracy of different methods for engineering cost prediction is tested, and the results of comparison of prediction errors are shown in figure 3. Figure 3 shows that the error of the method is lower and the global equilibrium is better.

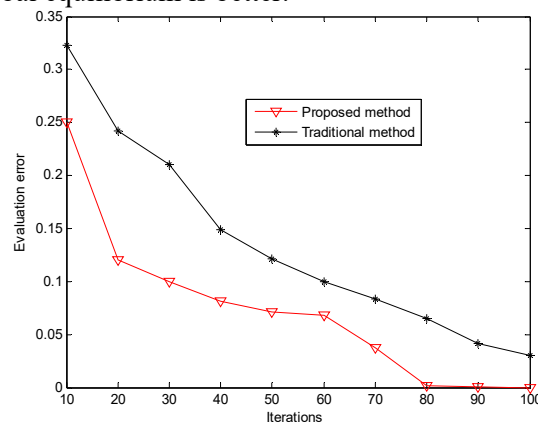


Figure 3. Comparison of cost prediction performance.

5. Conclusions

In this paper, a design model of full cycle cost prediction model of construction cost based on BIM is proposed, and a game model of full cycle cost prediction of construction cost of construction engineering is constructed. The balanced control of construction cost is carried out by combining engineering quality constraint with cost constraint, and the information management model of construction cost is designed by BIM. The method of full-sample regression analysis is used to adaptively optimize the objective function of full-cycle cost prediction. Combined with the method of minimum cost and best balance of quality, the full-cycle cost prediction of construction cost under BIM is realized. The research shows that the method has good equilibrium, low prediction error and strong game equilibrium ability between engineering quality benefit and project cost. This method has good application value in engineering cost prediction.

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