Study on Dynamic Control Model of Assembly Construction Cost Based on Piecewise Regression Analysis

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Abstract. Assembly building is still immature, resulting in the higher prefabrication rate of PC components, the higher the cost of assembly building. In order to improve the cost control ability of assembly building, a dynamic cost control model of assembly building based on piecewise regression analysis is proposed. A multi-parameter constrained cost control model with quality, efficiency and cost as the control object is obtained by constructing the mathematical model of control. The statistical parameters of characteristic information of assembly building consumption are analyzed, and the dynamic explanatory variable of assembly building cost is analyzed by descriptive statistical analysis method, and the piecewise regression analysis method is used. The cost control test of assembling building is carried out, the prediction model of building cost is established, the panel data analysis of building cost is carried out by combining the correlation analysis and regression analysis method, and the cost dynamic control of assembling building is carried out by using the piecewise statistical method. The simulation results show that the cost prediction of prefabricated construction cost by this method is accurate, the control convergence is good, the global optimization ability of dynamic control of construction cost is strong, and the cost of engineering cost is effectively reduced. Improve the efficiency and quality of construction.

1. Introduction
China's real estate industry is currently in a high-speed development stage, while building quality and safety requirements are increasingly high. On this basis, by virtue of easy control, energy-saving, short construction cycle and other characteristics of the assembled concrete structure in China's environmental protection policy, with a high degree of competitive advantage. However, compared with other developed countries, the fabricated buildings in China have many problems, such as imperfect management, inadequate construction site control, duplicate work among working procedures, which seriously affect the stability and safety of buildings, and are not conducive to our country. With the continuous development of social economy in China, assembly building has gradually begun to be popularized in China. However, compared with other developed countries, China started late, there are many non-standard, do not pay attention to details, there are a variety of problems in the construction cost control [1].

The prefabricated architecture in our country starts later than other developed countries. Because it is in the process of development and the prefabricated building in our country is not mature, there is
not much research literature on the cost of prefabricated building in our country. Most of them are at the technical level, and very few involve cost research [2]. By comparison, it can be found that the cost of prefabricated building is higher than that of traditional cast-in-place mode, which seriously restricts the rapid development of prefabricated building. Therefore, we need to strictly control the cost of prefabricated building. The cost and cost composition of prefabricated building is obviously different from that of traditional cast-in-place mode [3]. Compared with the traditional cast-in-place mode, the prefabricated building has more parts in production and transportation, and the design stage and construction stage are different from the traditional cast-in-place stage. From the point of view of the composition of the full cycle cost of the prefabricated building, the cost of the prefabricated building is mainly divided into the pre-planning stage, the design stage, the production stage, the transportation stage, the construction stage and the operation and maintenance stage. At present, assembly building is still immature, leading to the higher prefabrication rate of PC components, the higher the cost of assembly building [4]. However, the state is vigorously promoting prefabricated construction, giving a lot of preferential terms on tax, finance and credit policies, which can reduce some taxes, low interest rate loans and lower construction costs. It has great significance to study the dynamic control model of prefabricated building cost and to improve the economic benefit of prefabricated building [5].

This paper presents a dynamic control model of assembly construction cost based on piecewise regression analysis. The mathematical model of dynamic cost control and control of prefabricated construction cost is constructed, and the variable of cost dynamic explanation of assembly building is analyzed by descriptive statistical analysis method. The method of piecewise regression analysis is used to examine the cost control of prefabricated buildings, the prediction model of construction cost is established, the panel data of construction cost is analyzed by correlation analysis and regression analysis, and the piecewise statistical method is adopted. Dynamic cost control of prefabricated construction cost. Finally, the simulation results show that the proposed method can improve the cost prediction and control ability of prefabricated buildings.

2. Construction and problem analysis of dynamic control model of assembly construction cost

2.1. Multi-parameter constrained control model for quality-efficiency-cost control

In this paper, the cost dynamic control and prediction model of prefabricated building cost is designed. Firstly, the mathematical model is constructed, and the cost control model with multi-parameter constraints of quality-efficiency-cost control is designed. The accurate project budget can provide a good guidance function for the construction and evaluation of the whole project and provide a reference and basis for the construction of the project under the optimal cost performance ratio [6]. The prefabricated building is assumed to be a series system consisting of interconnected and relatively independent projects. The optimization problem of dynamic cost control of prefabricated construction cost can be evaluated by three quantitative indexes of quality level, efficiency and cost of prefabricated building construction. Construction of engineering cost model is:

\[
x_{j} = \begin{cases} 
0 & x_{j} \leq 1 \\
0 & \text{else}
\end{cases}
\] (1)

In the construction of assembling building, the cost control model is divided into the optimal and the worst benefit level, and the cost-cost-benefit index and the economic index are recorded as \( B_{e} \) and \( B_{p} \). The production quality-efficiency-cost control model can be expressed as follows:
In the research of cost control estimation of prefabricated construction engineering, many consumption prices of consumables in the current market seriously affect the current market engineering situation. It is necessary to adopt the method of piecewise regression analysis to emphasize the key influencing factors and obtain the results [7]. The practical benefit calculation method of cost control coefficient \( S_i \) after optimized scheme by using piecewise regression analysis is expressed as follows:

\[
B_i = \sum_{k=1}^{M} \sum_{j \in N_j} x_{jk} B_{jk}
\]

Furthermore, the cost control model with multi-parameter constraints for quality-efficiency-cost control in prefabricated construction engineering is expressed as follows:

\[
\max \quad \Theta_\phi = \frac{a_\phi}{a_\phi + c_\phi} \quad \max \quad \Theta_e = \frac{a_e}{a_e + c_e} \quad \max \quad \Theta_c = \frac{a_c}{a_c + c_c}
\]

\[
S.t. \quad Q_i \geq Q_{\alpha} \quad E_i \geq E_{\alpha} \quad C_i \leq C_{\alpha}
\]

\[
Q_{\mu} \geq 0, E_{\mu} \geq 0, C_{\mu} \geq 0
\]

\[
\sum_{j=1}^{N_j} x_{jk} = 1, \forall i, 1 \leq k \leq M, 1 \leq j \leq N_j
\]

In the upper formula, \( \Theta \) is called the closeness degree, and the relation between the engineering cost and cost set of prefabricated building \( \{F, E, C\} \) is shown as follows:

\[
\mu_{\phi} = a_{\phi} + b_{\phi} \Delta + c_{\phi} \Phi
\]

Where, \( a_{\phi} = \frac{B_{\phi}}{B_{\phi} + B_i} \), \( b_{\phi} = \frac{(B_{\phi} - B_i)(B_i - B_{\phi})}{(B_{\phi} + B_i)B_i} \), \( c_{\phi} = \frac{B_{\phi}B_i}{(B_{\phi} + B_i)B_i} \), for the large construction of prefabricated building, the cost is regarded as the economic index, and the evaluation standard is opposite to the benefit index. For the efficiency index, the SPA decision model is used to control the cost of the prefabricated construction cost dynamically. In order to establish the model foundation for the next step to realize the dynamic control of project cost and the design of forecasting model [8-10].

2.2. Variable analysis of dynamic cost explanation for assembly building

The method of piecewise regression analysis is used to predict and control the construction cost, and the statistical parameters of the characteristic information of the influence of prefabricated building consumption are analyzed, and the dynamic solution of the cost of the prefabricated building is carried out by using the descriptive statistical analysis method [11]. Based on piecewise regression analysis, the dynamic cost control model of prefabricated construction engineering cost can be divided into two parts: the degree of quality antagonism, the same degree of efficiency, the degree of opposition of
efficiency, the equilibrium design of cost dynamic control and quality benefit control is carried out in several aspects, such as the degree of cost antagonism, and the covariance matrix $C$ of which the cost of prefabricated construction project is incorporated into the data of influence factors is calculated.

$$C = \frac{1}{N} [X - \bar{X}] [X - \bar{X}]^T$$  \hspace{1cm} (7)

Where

$$\bar{X} = \frac{1}{N} \sum_{k=1}^{N} x_k$$  \hspace{1cm} (8)

$$X = [X_1, X_2, \ldots, X_m]$$  \hspace{1cm} (9)

According to the cost reduction of prefabricated construction project is equal to the project budget cost-project objective, and according to the statistical parameters of the influence information of the production capacity of the construction unit itself, the piecewise regression score is obtained. The cost characteristic equation is expressed as follows:

$$(\lambda I - S)U = 0$$  \hspace{1cm} (10)

The dynamic overhead of multiple prefabricated construction projects with different initial conditions is evaluated on line. In the process of motion development, the exponential separation is presented with the progress of time. In the estimation of the exponential time series of project budget growth, the characteristics of the activation function of the influence factors of the time series nonlinear prefabricated construction cost are obtained, and the estimation of the project budget growth index is realized [12].

3. Optimization of dynamic control model of construction cost

3.1. Cost controllable inspection of assembly building

On the basis of constructing the mathematical model of the dynamic control and control of the cost of prefabricated construction engineering, this paper presents a dynamic control model of the cost of prefabricated construction based on piecewise regression analysis, and obtains the model of the dynamic control of the cost of prefabricated construction [13]. The solution of the optimal economy $F_U$ and the worst economy $F_V$ of construction is obtained by the following formula calculation:

$$F_U = \sum_{j=1}^{M} \min_{j \in N_j} (F_{jk})$$  \hspace{1cm} (11)

$$F_V = \sum_{j=1}^{M} \max_{j \in N_j} (F_{jk})$$  \hspace{1cm} (12)

According to the contribution degree of cumulative variance, the number of principal components is selected. Only when the cumulative contribution rate reaches a certain amount, the corresponding $m$ principal components can be regarded as the necessary principal components, and the actual economy of the optimized scheme $s_i$ is expressed as follows:
\[ F_i = \sum_{k=1}^{M} \sum_{j \in N_j} x_{jk} F_{jk} \]  

(13)

By using the simulated binary crossover operator, the cost set pair of the set pair connection degree of the benefit index and the economic index is obtained. The connection degree \( \{F_i, F_j\} \) of the dynamic control model of the cost of prefabricated construction project is expressed as follows:

\[ \mu_{F_i} = a_{F_i} + b_{F_i} \Delta + c_{F_i} \Phi \]  

(14)

Where, \( a_{F_i} = \frac{F_{iU} F_{i}}{(F_{iU} + F_{i}) F_{j}} \), \( b_{F_i} = \frac{(F_{i} - F_{i})(F_{i} - F_{iU})}{(F_{iU} + F_{i}) F_{j}} \), \( c_{F_i} = \frac{F_{i}}{F_{iU} + F_{i}} \).

These parameters must satisfy the constraints of the minimum production quality reliability threshold \( Q_\alpha \), the minimum efficiency threshold \( E_\alpha \) and the maximum budget cost threshold \( C_\alpha \). Based on piecewise regression analysis, the dynamic cost control model of prefabricated construction project is realized.

3.2. Cost control and cost prediction

Assuming that the historical data of prefabricated construction project budget are expressed as \( \{x_i\}_{i=1}^{N} \), to remove the dimension of the original data and the bad factors such as the excessive amplitude of the data, the raw data is normalized and the principal component is determined. The selected principal component can include all the state information parameters provided by the original data, and the number of principal components is \( m \). After obtaining the nonlinear eigenvalue of the principal component of the prefabricated building cost influence factor, the time series of project budget growth exponent is estimated by the method of interval series estimation [14]. By means of adaptive fuzzy system learning control method, the classification rate of prefabricated construction budget estimation data is mapped into a set of corresponding probability density functions of engineering budget consumables, and the probability of construction budget consumables is obtained through this set of engineering budgets. The density function assigns the use probability of each consumable point:

\[
\begin{align*}
\dot{m}_i(t) &= -m_i + \frac{\alpha^{op}}{1 + p_i^{\tau}(t-\sigma)} \\
\dot{p}_i &= -\beta^{op} (p_i - m_i(t-\tau))
\end{align*}
\]  

(15)

Where \( i = lacl, tetR; j = cl, lacl, tetR \). The cross-balanced model of dynamic control of building cost and cost can be obtained as:

\[
\begin{align*}
\dot{m}_i(t) &= -m_i - \alpha^{op} p_i^{\tau}(t-\sigma) + \alpha^{op} \\
\dot{p}_i &= -\beta^{op} (p_i - m_i(t-\tau))
\end{align*}
\]  

(16)

The prediction model of construction cost is established, and the panel data analysis of construction cost is carried out by means of correlation analysis and regression analysis.

\[ A = \text{diag} \{1,1,1\}, C = \text{diag} \{\beta, \beta, \beta\}, D = \text{diag} \{\beta, \beta, \beta\} \]  

(17)
\[ W = \begin{bmatrix} 0 & 0 & -\alpha \\
-\alpha & 0 & 0 \\
0 & -\alpha & 0 \end{bmatrix}, \quad u = [\alpha \quad \alpha \quad \alpha]^T \] (18)

The prefabricated building shell, metal wiring frame and other facilities are included in the cost forecast scope, as follows:

\[
\max_{p_{1n}, p_{2n}, p_r} \pi^{4}_{DR} = (p_{1n} - w_{1S})q_{1n} + (p_{2n} - w_{2S})q_{2n} + (p_r - w_{rS})q_r
\] (19)

\[
\max_{w_{1S}, w_{2S}, w_r, q_r} \pi^{4}_{M} = (w_{1S} - c_n)q_{1n} + (w_{2S} - c_n)q_{2n} + (w_{rS} - c_r)q_r - B\theta^2 - A\theta q_{1n}
\] (20)

Taking all the influencing factors into account, these real-time data are taken as input variables, the redundant information is removed, the project budget is efficiently and accurately evaluated, and the method of piecewise statistics is adopted to dynamically control the cost of prefabricated construction cost [15].

4. Empirical analysis

In order to test the performance of the algorithm in this paper, the empirical data analysis and simulation experiment are carried out. In the simulation experiment, according to the cost plan of prefabricated construction project, the construction cost of the construction unit mainly includes the cost of materials needed to carry out the project. Salary of construction personnel, cost of machinery and equipment, management cost of construction site, cost management structure of construction unit, The contribution weights of cross-influencing factors such as the price of consumables in real time market to the construction cost are \( \alpha = \frac{4}{7}, \beta = \frac{2}{7}, \gamma = \frac{1}{7} \). The piecewise regression analysis algorithm designed in this paper is used to carry out the optimal scheduling of the production project to realize the dynamic cost control of the project cost. The quality-efficiency-cost control of multi-parameter constraint cost control model is designed, the quality level of assembly building is obtained, efficiency level, the parameter range of unit cost are shown in Table 1.

| Engineering code | Quality level (100%) | Efficiency level (100%) | Unit cost / $10,000 |
|------------------|----------------------|------------------------|---------------------|
| 1                | [0.817 1.00]         | [0.871 1.11]           | [44.2 49.4]        |
| 2                | [0.814 1.00]         | [0.864 1.15]           | [33.1 40.3]        |
| 3                | [0.843 1.00]         | [0.843 1.14]           | [52.7 62.5]        |
| 4                | [0.824 1.00]         | [0.851 1.15]           | [40.5 43.6]        |
| 5                | [0.817 1.00]         | [0.864 1.04]           | [13.0 48.0]        |

The quantitative data of the corresponding engineering quality level, efficiency level and unit cost of each production group are analyzed by using the algorithm and the traditional method, and the optimal solution of the dynamic control result of the construction cost is obtained as shown in Table 2. Taking the first two projects as an example and comparing them with the traditional method, we can obtain the dynamic control of the cost of the prefabricated construction project Q1 and Q2 and the dynamic control of the cost of the corresponding project by using the algorithm in this paper and the simulation experiment, taking the first two projects as an example and comparing them with the traditional methods. The distribution of the predicted optimal solution set is shown in Figure 1.
Table 2 Optimal solution set of dynamic control results of construction cost

| Production group | Quality level (100%) | Efficiency level (100%) | Unit cost / $10,000 |
|------------------|----------------------|-------------------------|---------------------|
| $X_{11}$         | 0.72                 | 0.64                    | 22.6                |
| $X_{12}$         | 0.78                 | 0.74                    | 37.0                |
| $X_{13}$         | 0.76                 | 1.28                    | 36.6                |
| $X_{21}$         | 0.74                 | 0.64                    | 36.0                |
| $X_{22}$         | 0.74                 | 1.24                    | 62.0                |
| $X_{23}$         | 0.78                 | 0.73                    | 44.0                |
| $X_{31}$         | 0.64                 | 0.64                    | 61.0                |
| $X_{32}$         | 1.12                 | 0.78                    | 67.0                |
| $X_{33}$         | 0.78                 | 1.24                    | 67.0                |
| $X_{34}$         | 0.70                 | 1.06                    | 63.0                |
| $X_{35}$         | 0.74                 | 1.27                    | 66.0                |
| $X_{41}$         | 0.78                 | 0.73                    | 20.6                |
| $X_{42}$         | 0.98                 | 1.04                    | 23.0                |

Figure 1. Optimal solution set distribution for dynamic control of building cost

Comparing with the results of Figure 1, it can be seen that this method can achieve the goal of high quality and efficiency level, low unit cost, and achieve the goal of cross-balancing dynamic control of project cost. The comparison results are shown in Figure 2. The analysis shows that this method can improve the accuracy of cost prediction and the ability of dynamic cost control.
5. Conclusion
In this paper, a dynamic cost control model of assembly building based on piecewise regression analysis is proposed. A multi-parameter constrained cost control model with quality, efficiency and cost as the control object is obtained by constructing the mathematical model of control. The statistical parameters of characteristic information of assembly building consumption are analyzed, and the dynamic explanatory variable of assembly building cost is analyzed by descriptive statistical analysis method, and the piecewise regression analysis method is used. The cost control test of assembling building is carried out, the prediction model of building cost is established, the panel data analysis of building cost is carried out by combining the correlation analysis and regression analysis method, and the cost dynamic control of assembling building is carried out by using the piecewise statistical method. The simulation results show that the cost prediction of prefabricated construction cost by this method is accurate, the control convergence is good, the global optimization ability of dynamic control of construction cost is strong, and the cost of engineering cost is effectively reduced. Improve the efficiency and quality of construction. This method has good application value in prefabricated construction cost prediction and dynamic control.

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