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Construction of Construction Project Budget Estimation Model Based on Grey Markov Chain

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Abstract: Aiming at the unreasonable problem of current construction project budget, this paper puts forward the construction method of construction project budget estimation model based on grey Markov chain. The content system of construction project budget is optimized, and the risk evaluation algorithm of construction project budget is optimized combined with grey Markov chain, so as to accurately identify the construction budget risk, and simplify the steps of construction project budget estimation. It is confirmed by experiments. The experimental results show that the construction project budget estimation model based on grey Markov chain has high practicability and fully meets the research requirements.

1. Introduction

The traditional construction budget preparation process requires that the budgeter must be familiar with the relevant budget quota, charging standard, various drawings and regional charging regulations. The traditional construction project budget compilation work consumes more manpower, the calculation time is long, the calculation speed is slow, easy to make mistakes, and the work efficiency is low[1]. Therefore, manual budgeting has gradually failed to meet the increasingly fierce demand of the construction market. With the continuous development of information technology, the construction market has put forward new requirements for the preparation of construction project budget: randomness, timeliness and accuracy. At present, in the business activities of the construction market, in order to meet the needs of project bidding, it is necessary to calculate the budget price of the project in time, quickly and accurately, and determine the base bid price or quotation strategy[2]. This will increase the work intensity of the budget staff. Construction enterprises urgently need to reform the original budget management system. The budget work urgently needs the addition of new technical forces, and the development of information technology has made it possible. It can be said that at present, the real estate development enterprises, design units, construction units, supervision units and audit units engaged in engineering construction urgently need a set of intelligent, standardized and integrated construction project budgeting system with powerful functions, efficiency and practicality, in order to help the enterprises in the system complete the construction project budgeting work efficiently[3]. At present, China's research on the field of construction project budgeting and management is not yet in-depth. There are not many mature construction project budgeting software in the market, and the budgeting software used by real estate construction and development enterprises is not the same. In addition to regional and policy differences, there are great differences in the functional development of new products among enterprises, and the technical level is also uneven. Some newly launched budgeting software has not been used for a long time, maturity cannot meet the requirements of most enterprises[4]. In the foreign market, due to the great difference between the standard valuation method of engineering project quota and that of China, foreign products in this field cannot be applied to domestic enterprises. There is still great market potential and broad market prospect in the development and research of domestic construction engineering budget system. Therefore, a construction method of construction project budget estimation model based on grey Markov chain is proposed.

2. Construction Budget Estimation Model

2.1 Construction Project Budget Content System

The construction project budget refers to the technical and economic documents that pre calculate and determine the total project cost of the construction project according to the specific contents of the design documents in different design stages and the relevant quotas, indicators and charging standards stipulated by the state[5]. Due to the multiple characteristics of project cost pricing, the determination of project cost is compatible with the depth of phased work of project construction[6]. Specifically, it is necessary to use investment estimate price to control the selection of design scheme and preliminary design estimate cost, and use estimate cost control technology to design and revise estimate cost; Use the estimated cost and revised estimated cost to control the construction drawing design and estimated cost, that is, the project cost at the upper level controls the project cost at the next level, so as to reasonably use human, material and financial resources and achieve better investment benefits.

Based on the above analysis of the characteristics of new construction project cost and cost control, in order to realize the budget of project cost and the design of cost control algorithm, it is necessary to design the project cost prediction algorithm[7]. The dynamic cost of multiple construction projects with different initial conditions is evaluated online. In the process of movement development, there is exponential separation with the process of time. In the time series estimation of the project budget growth index, the estimation of the project budget growth index is realized by obtaining the activation function characteristics of the nonlinear large-scale bridge cost impact factors in the time series[8]. Markov chain is a discrete event random process with Markov property in mathematics. In this process, given the current state or information, the past (that is, the historical state before the current moment) is irrelevant to predicting the future (that is, the future state after the current moment). Suppose in probability space (F,P) has a random process $A(x)$ (x represents the time set), assuming that the value of the random variable e_t is taken from the state space $I=\{i_1,i_2,i_3,\dots,i_t\}$, when $x(t_0)$ is the system t_0 is the state of time, for any number of non negative integers:

$$\begin{cases} P\begin{cases} A(x)\le x|\ x(t_n) \\ x_n = I\{e_t \le I|\ x(t_n)=I\} \end{cases} \\ F = x_l,\dots,x(t_0)=t_0 \end{cases} \tag{1}$$

Put random sequence W_{t+n} is called the basic property of Markov chain, x_t is the value has no correlation with the state transition from time t to time j; The probability distribution can only be predicted by the state at time I, and has no correlation with the state before time I. This also fully shows the characteristics of Markov chain: no aftereffect. That is "Markov". The transition probability matrix is shown when the step size of Markov model is n:

$$P_{ij}^{(n)} = PF\left\{W_{t+n} - jx_t + na_i\right\} \tag{2}$$

State k experience m the probability value of changing into state j after step. In state space e, if G is homogeneous Markov, there is a constant independent of I for any hypothesis, and the Markov chain is ergodic at this time. In other words, as long as the transition step U is large enough, no matter which state the project starts from, the transition probability of state I to state j is about, and then the state of the item will become more and more stable at this time, which is specifically expressed as:

$$\varpi = P_{ij}^{(n)} - k_m\left(e\sum_{i=1}^{n} s - Gjm\right) - dU_{ij} \tag{3}$$

Where, ϖ is called the steady-state probability vector, that is, the eigenvector value of the transition probability matrix, which represents the average value of the probability of each state when the project state is gradually stable, and the sum of the probability values here is equal to 1, In order to transfer the probability matrix, the different number of states of the research project will lead to the difference of the predicted results[9]. After adding new historical data later, the prediction process will also change. If we want to predict the results more and more accurately, we need to add more data. After obtaining the nonlinear eigenvalues of the principal components of the construction cost impact factors, the time series estimation method is used to estimate the time series of the project budget growth index[10]. Using the cost control method based on linear model or equivalent approximate linear model, for the new construction project cost growth index time series C. Using the phase space reconstruction method of cost control economic index, the phase space reconstruction vector trajectory matrix of engineering budget growth index is obtained as follows:

$$L = \begin{bmatrix} l_1^{\tau} \\ l_2^{r} \\ \vdots \\ l_N^{r} \end{bmatrix} = \begin{bmatrix} l_1 & l_{1+\tau} & \cdots & l_{1+(m+1/\tau} \\ l_2 & l_{2+\tau} & \cdots & l_{2+(m-1)r} \\ \vdots & \vdots & \ddots & \vdots \\ l_{N-1} & l_{N-1+\tau} & \cdots & l_{N-1+\{N-1)r} \end{bmatrix} \tag{4}$$

If the project budget growth refers to the embedded dimension in the phase space of cost control, and the collected value of market consumables price is r, the budget estimation model of the project is constructed, and R singular value decomposition, using single factor gray correlation prediction for feature decomposition, feature decomposition matrix H and B Is an orthogonal matrix, and:

$$C = Lc_n - Emw / \prod H - RB \tag{5}$$

If σ_n It is singular value. For redundant information related to buildings, the information filtering process meets the following requirements:

$$S = CL\,\mathrm{diag}\left(\sigma_1, \sigma_2, \cdots, \sigma_n\right), \sigma \times \sigma_2 \times \cdots \times \sigma_n \tag{6}$$

Construction budget refers to the preparation of construction budget in the construction stage under the control of construction drawing budget, according to the construction quota, combined with the plane layout, construction methods, construction technical organization measures and the actual situation of construction phenomena in the construction organization design[11]. It is the standard for the internal compilation of labor, materials, construction machinery shift consumption and indirect costs of unit projects or subdivisions by the construction unit. Construction budget generally has the following functions: construction budget is the basis for construction enterprises to arrange labor, materials and organize construction of various types of work[12]. The construction budget is the basis for the construction unit to issue the construction task list and the quota material requisition. The construction budget is the basis to ensure the completion of the plan of technical measures to reduce costs; The construction budget is the basis for the enterprise management department to compare the "two calculations", study business decisions, and implement various forms of economic responsibility system[13].

2.2 Budget Risk Assessment Based on Markov Chain

In Markov chain, the system changes from one state to another, which is called state transition. The possibility of starting from a certain state and transferring to other states at the next moment is expressed in probability, which is called state transition probability, and is expressed in matrix form. Mathematically, let p_{ij} is the transition probability, which represents the probability of the system transferring from state I to state j, with ΔP the matrix of elements is as follows, which is called the transition probability matrix:

$$\Delta P = \begin{bmatrix} p_{00} & p_{01} & p_{02} & \cdots \\ p_{10} & p_{11} & p_{12} & \cdots \\ p_{20} & p_{21} & p_{22} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix} = \left(p_{ij}\right) \tag{7}$$

The state transition probability is positive according to its practical significance. The risk factors affecting the construction project budget have been listed in the above special research and reference documents, and the questionnaire has been distributed. Now it is necessary to make statistics on the data contained in the questionnaire, calculate the weight coefficients of various factor indicators, and make a basic evaluation of the cost and risk index system of municipal projects. The risk occurrence probability score is:

$$\delta_i = \frac{P\sum_{n=1}^{5} \lambda n\, G_1}{40 S \tau(x_n)} - f_i \tag{8}$$

If λ is the score the probability of risk occurrence, n is therate risk G_1 is the number of people scoring the probability of risk occurrence. Suppose that the sample series can be divided into index value series τ status, then the sample sequence x_n is the number of times that state n becomes a state after one-step transition is recorded as f. Number of transfers by f_{ij} The matrix formed is called the number transition matrix, and the ratio of the result of the sum of each value in column I of the number transition matrix to the total number of occurrences of all States is defined as "marginal probability":

$$\varepsilon = \frac{\sum_{i=1}^{m} f_{ij}}{\delta_i \sum_{i=1}^{m} \sum_{j=1}^{m} S\tau(x_n)} \tag{9}$$

If the sample space is large enough, the statistics:

$$\chi^2 = 2\sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij} \left| \log \frac{\sum_{i=1}^{m} f_{ij}}{\varepsilon} \right| \tag{10}$$

The degree of freedom of obedience is distribution of d_k, $A_i^{(k)}$ When the transition probability value is given the significance level a, the statistics can be calculated according to the formula K_{ij} is the value sample sequence of has Markov property through Markov property test. On the contrary, the sample sequence cannot be predicted by Markov chain and its related methods. According to the initial state value of the index and calculate the transition probability matrix, we can get the probability of the current state of the index value we want to predict as:

$$v_i = \chi^2 \sum_{k=1}^{m} d_k A_i^{(k)} - K_{ij} \tag{11}$$

This paper selects the classification law of the standard deviation of the sample mean to grade the index value sequence of risk factors to determine the sample status. Applying the classification method of standard deviation of sample mean means to classify samples by using sample standard deviation and sample mean, and set the sequence of index values as sample mean, and set the standard deviation of sample mean as:

$$\phi = \sqrt{\frac{1}{v_i - 1} \sum_{i=1}^{n} \left(x_i - 1\right)^2} \tag{12}$$

Through the statistics of data states with different steps, the transition probability matrix of asynchronous length is calculated. Calculate the M-step transition probability matrix:

$$P_{ij}(s) = \mathrm{D} - \frac{M_{ij}^{(s)}}{\phi M_i} \tag{13}$$

Where is status s passed $M_{ij}^{(s)}$ steps transferred to ij; M_i is the number of occurrences of state I. Risk event D is divided into four levels, and the result is one of 1, 2, 3 and 4. In order to simplify the calculation of the results, the risk event samples are also graded by the standard deviation of this mean. Finally, according to the final result of the prediction, the corresponding coping style risk events are selected D_1 is the first-class risk, we adopt risk-taking measures. Risk bearing refers to taking risks, which refers to a certain degree of risks that must be borne by the company or enterprise. After weighing, it is felt that it is within the range of tolerance, and there is no need to organize excessive costs to eliminate or reduce these risks. If the price of the predicted dangerous event is very small or the degree of loss is very small after the occurrence, the risk-taking strategy will be adopted according to the prediction results D_2. When it is a secondary risk, we adopt risk transfer measures. Risk transfer is a measure to deal with the risk that the unit bearing the risk transfers the risk to other individuals or units by legal means or methods. Converting project development funds into limited certificate risk events D_3 is level 3 risk, we adopt risk hedging or risk compensation measures. Risk hedging is used by the company to reduce the risks of engineering projects on the premise of grasping various risks and assuming various risks, which offset each other. Risk compensation is used to take preventive measures before the danger occurs, formulate the compensation mechanism in advance, and improve the courage and confidence of departments and individuals to deal with risk events D_4 is level 4 risk, we adopt risk control and risk avoidance measures. After identifying the risk, once there is a risk, the investor will exceed the ability of the unit bearing the risk. Or directly reduce the possibility of occurrence and turn it into a controllable risk event. D is just the predicted result. Imagine in advance what measures the company should take to avoid panic when an accident occurs. Of course, there are many positive and negative risk strategies, which need to be determined according to the actual situation in the actual construction process of the actual project. Here, the score of risk event D is divided into four ratings, as shown in the following Table 1:

Table 1 Coping Strategies for Budget Risks of Construction Projects

Number	Risk level	Countermeasures
A	Level 1 risk	Risk bearing
B	Level 2 risk	Risk transfer
C	Level 3 risk	Risk compensation, risk hedging
D	Level 4 risk	Risk control and risk avoidance

There are many kinds of risk events in the construction project budget. The risks generated in the process of project investment cannot be measured by simple data, nor can they be simply handled according to the predicted data. When dealing with risk events in practice, we should make a judgment according to the actual situation and choose the most appropriate risk response when choosing the response measures for risk events.

2.3 Optimization of Construction Project Budget Evaluation Process

According to national regulations, from the perspective of meeting the investment plan and investment scale of construction projects, the estimation of construction project investment includes fixed asset investment estimation and initial working capital estimation. From the perspective of meeting the economic evaluation of construction projects, its total investment estimation includes fixed asset investment estimation and working capital estimation. Therefore, no matter from which angle to make an eye-catching investment budget, it is necessary to estimate the investment in fixed assets and working capital. According to the regulations, the cost that should be included in the total investment of the construction project refers to the total investment amount from the beginning of project approval and financing to the completion acceptance and delivery, including single investment, other costs of engineering construction and preparatory costs. The specific composition is shown in Figure 1.

Budget quota is a quota that calculates the project cost and the material requirements of labor and machinery shifts in the project when preparing the construction budget. Budget quota is a kind of pricing quota, which plays a very important role in engineering construction quota. From the perspective of preparation procedure, construction quota is the preparation basis of budget quota, while budget quota is the preparation basis of budgetary estimate quota or estimation index. Budget estimate quota refers to the quota used to calculate and determine the estimated cost of the project and calculate the labor, mechanical equipment and material requirements when preparing and expanding the preliminary design budget. It is generally prepared on the basis of budget quota, which is more comprehensive than budget quota, and its project division is coarse and fine, which is suitable for expanding the depth of preliminary design. Budget estimate quota is an important basis for controlling project investment and plays an important role in the investment management of engineering construction. The function of the budget editing module is to apply formulas, adjust, edit and other operations according to the needs of the project and the content in the quota library. The menu setting is divided into four operations according to the function: file, edit, table and setting. It should be noted that although there are many function options in the menu list, most of the functions in the table editing process can be directly completed through mouse operation, which is more convenient. The menu form of the budget editing function is shown in the Table 2.

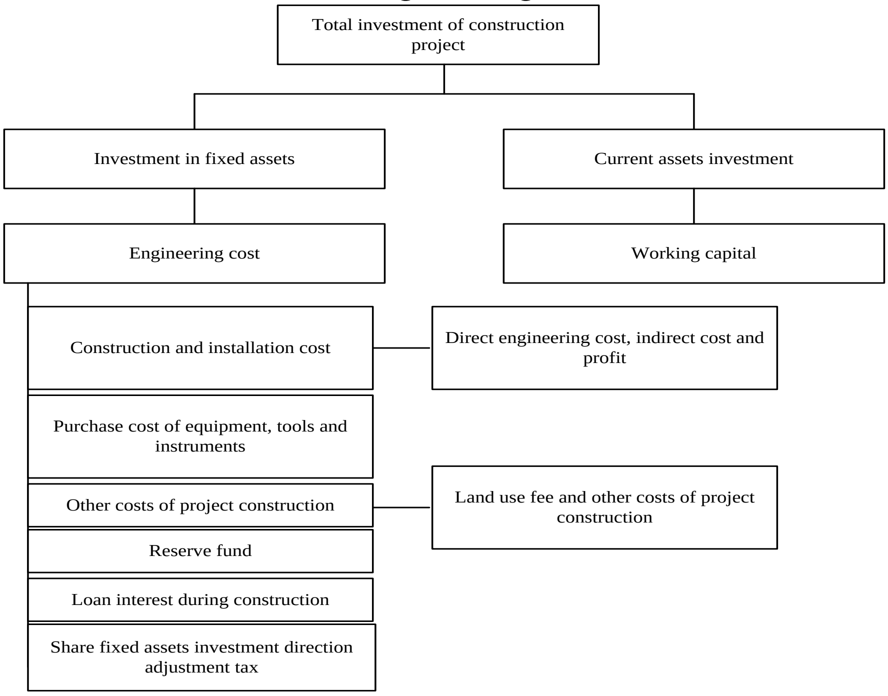

Fig.1 Cost Composition of Construction Project Budget System

Table 2 Project Budget Editing Function Menu Setting Table

File	Edit (total table)	Edit (material list and equipment list)	Set up	Form
Import excel	Copy, add, insert, delete, empty, find replace	Copy, add, insert, delete, empty, find replace	Material system	General budget table, total project amount table, equipment table, material table
Import, export			Rates and adjustments, discounts, and retargeting rates	
Print preview				
Return	Merge, sort, unit rounding, reset material category	Man day adjustment factor, discount, insert subtotal	Update and send back basic library by basic library	
	Replace with budget price, search by keyword	Enter quota in Chapter mode	Make/update template	

The construction cost plan is to prepare the production cost, cost level, cost reduction rate and the main measures and plans taken to reduce the cost of the construction project within the planning period in the form of currency. The construction unit can use the progress data of similar projects built or under construction in the gray Markov chain information integration platform and the project information in the historical database to specify a detailed schedule and material procurement schedule to calculate the corresponding cost, and draw the cumulative curve of time and cost. The preparation of grey Markov chain cost plan before construction is based on the grey Markov chain engineering database platform. It is a process of sorting and reusing internal and external data. In this paper, the grey Markov chain engineering database platform is divided into two parts: historical database and current engineering database. The former extracts and sorts out the previous engineering information, and the latter collects and sorts out the cost information of the current project. Through the comparison of available information and the similarity analysis of main construction parameters, the current project is simulated by substitution, that is, according to the statistics of engineering data in the grey Markov chain platform. Establish the overall progress and resource plan of the target project, cost influencing factors, control measures, etc. In this process, grey Markov chain can optimize the schedule of cost plan, the most appropriate construction scheme, the balance of resource demand as much as possible, and the optimization of capital demand through progress simulation, construction simulation, resource optimization and other work. Based on the above analysis, this paper establishes the cost planning flow chart based on grey Markov chain as shown in the Figure 2.

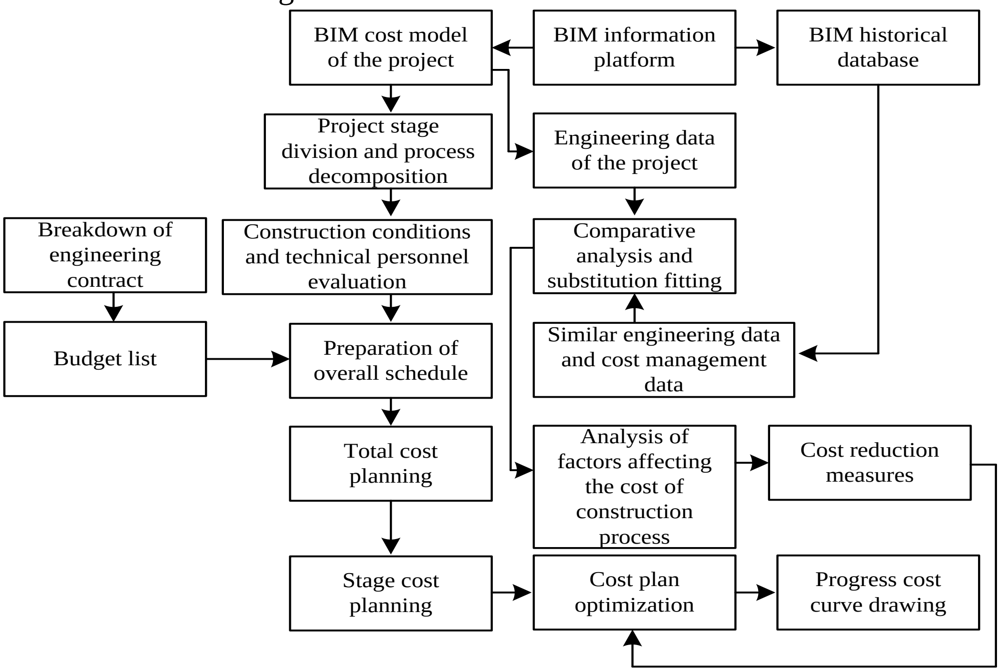

Fig.2 Flow Chart of Cost Planning Based on Grey Markov Chain

Construction cost control refers to strengthening the management of various factors affecting the cost during the construction process, taking various measures to control the actual consumption and expenditure within the scope of the cost plan, timely feeding back and strictly reviewing whether the expenses meet the standards, calculating and analyzing the difference between the actual cost and the planned cost, and then taking a number of measures to eliminate the loss and waste in the construction. the basic principle of cost control based on grey Markov chain can be summarized as follows: Based on the project contract, according to the formulated cost control objectives and cost control measures, regularly use grey Markov chain to quickly generate multi calculation comparison documents, compare the actual cost value with the target value, and take effective measures to dynamically control the cost.

3. Analysis of Experimental Results

Autodesk series software and Luban series software are used as the main software of grey Markov chain modeling application, and Pathfinder and fuzor are selected as safety evacuation simulation and animation simulation software. Cloud platform is the supporting condition of gray Markov chain information sharing platform. The specific software scheme is shown in the Table 3.

Table 3 List of Grey Markov Chain Software Configuration

Software name	Software purpose
Revit2021	Modeling of project structure, electromechanical and architectural disciplines
Navisworks2021	Overall model integration, verification and collision inspection of the project
AutoCAD2020	Plan drawing processing
Luban Trans Revit	BIM model output and transformation
Luban stcel	Quantity statistics
Luban MC	Count the detailed quantities of a certain area and form a comparison table of quantities
Luban BE	Find details of any component, etc
Office 2020	Document generation software
Pathfinder	Safety evacuation simulation
Modeling workstation	Cpui7, 16G memory, 1TB hard disk

According to the data related to weekly progress cost, the progress cost curve is automatically drawn by using 5D gray Markov chain model to visually and intuitively show the corresponding dynamic trend of weekly cost of each month. The horizontal axis of the curve represents the time schedule, and the vertical axis represents the construction cost. This chapter takes the progress cost curve of each week from June to September as an example, as shown in the Figure 3 below:

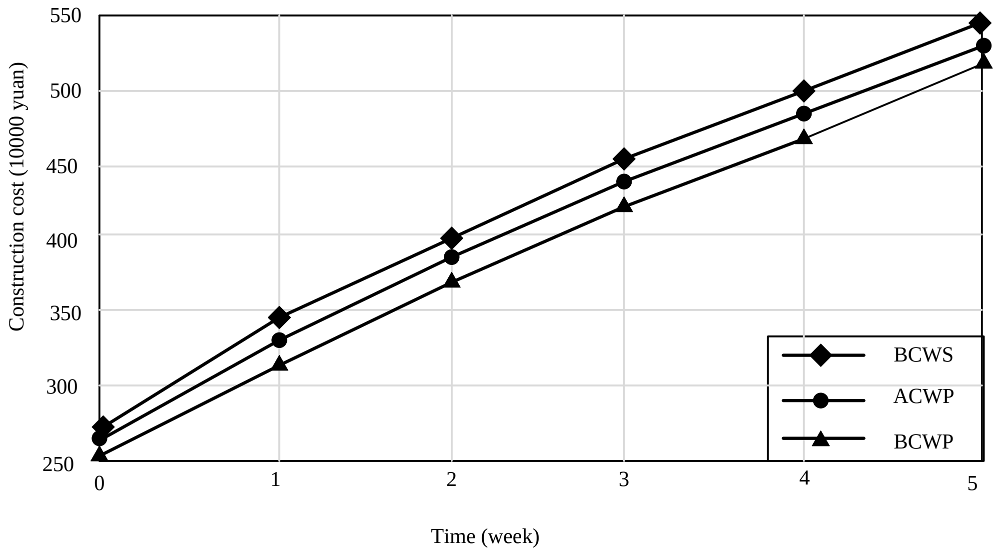

Fig.3 Progress Cost Curve Analysis Chart

Figure 3 intuitively shows the trend of three progress cost earned value curves in June within the original design scope of project a, in which BCWS>BCWP and ACWP>BCWP. From BCWS>BCWP, we can see that the actual progress of project a is not controlled within the planned progress range, and the gap between them is becoming larger and larger. The actual progress in June is obviously lagging behind, and the management personnel need to take corresponding measures to correct the deviation. It can be seen from ACWP>BCWP that the actual cost of project a is not controlled within the planned cost, but the gap between them is constantly narrowing. The ACWP curve is gradually approaching the BCWP curve, and the cost control has a trend of developing in a good direction. In order to verify the effectiveness of the design model in this paper, the traditional estimation model and the estimation model in this paper are used to estimate the building respectively. Assuming that the structure of the grey Markov chain building information model is 10*22*2, the detailed comparison results of complex building cost estimation are shown in the Table 4.

Table 4 Estimation Results of Two Models

Model construction cost (yuan/m2)	Actual cost	Traditional model	Paper model
15	1372.6	1463.8	1373.7
16	1408.6	1578.8	1442.2
17	1325.6	1466.8	1325.4
18	1215.5	1356.8	1249.1
19	1487.3	1569.2	1485.4
20	1261.5	1783.5	1266.2

It can be seen from the table that the estimation model designed in this paper is closer to the actual value. With the formulation of different costs, the cost of the traditional model is still higher than the actual cost value, while the estimation model designed in this paper is always close to the actual value. The calculation of cost deviation can be automatically completed through the grey Markov chain information integration platform. The cost deviation percentage refers to the ratio of the difference between the budget cost of completed work and the actual cost of completed work to the budget cost of completed work. The following table counts the cost percentage of the construction project within the original design scope and the cost deviation percentage after engineering changes. The grey Markov chain early warning system automatically processes the cost deviation data according to the deviation area and the setting of early warning color, so that cost managers can propose targeted solutions.

Table 5 Statistical Table of Cost Deviation Data Based on Grey Markov Chain Model

Schedule cost related data (%)	Progress timeline (weekly as the basic unit)							
	June 2021				July 2021			
	1	2	3	4	5	6	7	8
$(BCWP - ACWP) / BCWP$	-3.05	-2.25	-1.97	-1.72	-1.26	-0.57	-0.09	0.18
BCWP−C−ACWP−C-BCWP−C	-2.53	-2.18	-1.85	-1.61	-1.18	-0.52	0.07	0.45

Table 6 Statistical Table of Cost Deviation Data Based on Grey Markov Chain Model

Schedule cost related data (%)	Progress timeline (weekly as the basic unit)							
	August 2021				September 2021			
	1	2	3	4	5	6	7	8
BCWP−ACWP-BCWP	0.69	1.33	1.79	2.37	2.85	3.03	3.57	3.61
$(BCWP - ACWP) - C / BCWP - C$	0.95	1.65	2.19	2.39	2.88	3.08	3.58	3.72

In order to further verify the superiority of the complex construction cost estimation model based on grey Markov chain, on the basis of Table 5 and Table 6, the estimation errors of the traditional model and the model in this paper are compared, and the results are shown in the Figure 4.

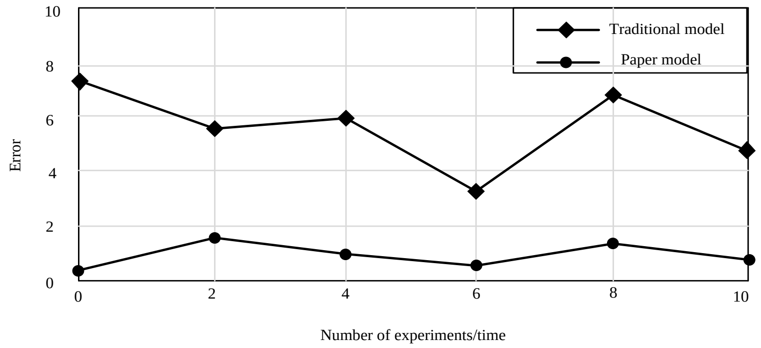

Fig.4 Comparison Results of Estimation Errors of Two Models

It can be seen from Figure 6 that the estimation error of the complex construction cost estimation model based on grey Markov chain for the cost of different construction complexity is lower than that of the traditional estimation model, and the error of the estimation model designed in this paper is basically maintained at about 0.15, while the fluctuation of the traditional estimation error is obvious.

4. Conclusion

At present, the empirical model is used in the construction cost budget, which is difficult to form quantitative prediction and analysis. This paper presents a new construction cost budget and cost control algorithm based on the time series analysis of the growth index of the construction cost budget, which realizes the accurate prediction of the construction cost. The characteristics of the new construction project cost budget are analyzed, then the new construction project cost prediction and control mathematical model is constructed, and the algorithm is improved to improve the prediction accuracy of the project cost. The simulation verification is carried out, which shows the superior performance of the new construction project cost prediction and cost control model designed in this paper. The research results show that the cost control efficiency and project quality are effectively improved by using this algorithm, the construction cost of new buildings is reduced.

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