Cluster Evaluation Method of Building Decoration Cost Rationality Based on BIM Model

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Abstract. In view of the low efficiency of traditional cost rationality evaluation methods, this paper designs a cluster evaluation method of building decoration cost rationality based on BIM model. BIM model is used to collect the data of architectural decoration, and the reasonable threshold interval is set. Then the decoration data and threshold parameters are clustered to complete the construction of the evaluation method. After setting the classical domain of quantitative indicators, we prepare the evaluation data set for the experiment, and call two traditional evaluation methods and the evaluation method designed in this paper to carry out the experiment. The results show that the evaluation method designed in this paper is more efficient.

Keyword: BIM model · Building decoration cost · Rational clustering · Evaluation method

1 Introduction

The rapid growth of the market is bound to attract fierce competition from enterprises, the core of the competition is how to maximize the profit, how to maximize the profit is the current stage of the construction decoration enterprises facing the need to urgently solve the key problem. The background in the same environment, in addition to the combination of market demand changes to adapt to the product development, in the process of implementation of project construction, which enterprises can guarantee under the premise of construction schedule, quality, cost of the project's development have enough attention, to control the cost in a reasonable manner, with the lowest cost, realize own benefit and social benefit as much as possible, Then the enterprise can grasp the initiative of market competition more, and realize the survival and development [1–3]. The implementation of architectural decoration has a complete periodicity. First of all, in the investment stage, how to grasp the accuracy of investment directly determines the profit and loss of the later project. In the design stage, controlling the design standard can avoid too many changes and claims in the later stage. In the bidding stage, the false quotation of the contractor will also lead to the difficulty of real estate cost control [4]. In the process of construction, how to combine with the actual situation of construction, reasonable preparation of cost scheme, will also affect the final profit to a greater extent.

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Therefore, in view of the above background, this paper designs a cluster evaluation method of building decoration cost rationality based on BIM model. This paper uses the BIM model to collect architectural decoration data and sets the reasonableness threshold interval. Then the decoration data and threshold parameters are clustered to complete the construction of the evaluation method.

2 Method Design

2.1 Using BIM Model to Collect Building Decoration Data

When using BIM model to collect architectural decoration data, during the whole construction cycle of the project, different stages of work are completed by different participants, and different objectives and interests of each participant will produce different types of cost management methods. At this time, the owner who is in the leading position of project management is particularly important to the management of the overall project cost. The owner's project cost management runs through the whole process of the project, including investment decision-making stage, design stage, bidding stage, implementation stage and completion stage [5, 6]. Under the control of BIM model, the data collection model formed is shown in Fig. 1.

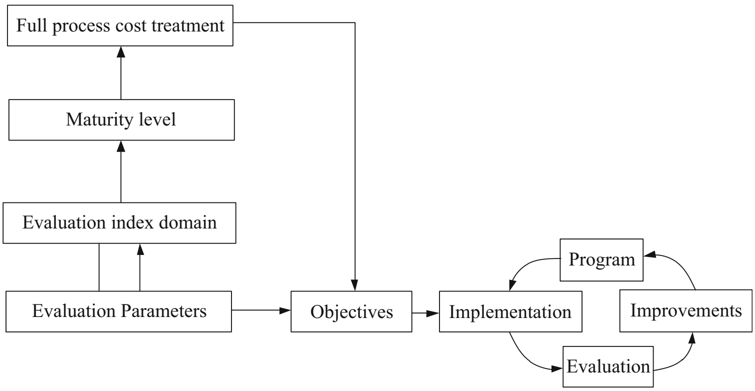

Fig. 1. Data collection process of BIM model

In the data collection process shown in the figure above, the maturity level corresponding to each stage of the whole process of project cost management is gradually decomposed into evaluation index field, which contains several evaluation parameters that can be operated in practice. The basic logic of project cost management maturity model is to calculate the maturity level of each evaluation parameter:

$$g = p\frac{Z}{\alpha} \tag{1}$$

Among them, g is maturity level, p is evaluation parameter, Z is numerical parameter and α is basic parameter [7, 8]. Under the control of the above numerical relationship, the maturity level of project cost management is comprehensively calculated. By setting goals for the evaluation parameters of each stage, the cost management is refined into the basic activities of each process. The maturity model of project cost management specifies the objectives for each evaluation parameter, and the objectives summarize the content of basic activities, and can be used as the judgment standard of whether an organization or project has effectively implemented basic activities. By measuring the evaluation parameters of each stage, the maturity level is obtained [9, 10].

Based on the on-site investigation of architectural decoration cost staff and consulting units, and interviews with industry experts and experienced management personnel, the initial evaluation index system is sorted out by analyzing the logical relationship between each index based on the extensive collection of key influencing factors. The index system is shown in Table 1.

Table 1. Index system

Decorative criteria layer	Index name	Evaluation parameters
Investment decision stage	Project decision preparation	Adequacy of decision making preparation
	Investment estimation	Preparation of investment estimation documents
		Deviation rate of investment estimation
	Risk management	Risk identification
		Risk evaluation
		Risk prevention measures
	Investment and financing	Capital ratio
		Financing cost ratio
Design phase	Preliminary design	Preparation of design budget estimate documents
		Deviation rate of Budget Estimate Compilation
	Construction drawing design	Preparation of construction drawing budget document
		Deviation rate of budget compilation and review
		Quota Design
	Design Management	Standard design degree
		Comparison and selection of design schemes

(*continued*)

Table 1. (*continued*)

Decorative criteria layer	Index name	Evaluation parameters
Bidding stage	Bidding management	Standardization of bidding management
	Tender documents	Preparation of bidding documents
		Preparation of bill of quantities
	Preparation of the base price	Rationality of base bid preparation
	Contract signing	Contract preparation
		Deviation rate of contract price
Implementation phase	Engineering change management	Adequacy of change basis
		Changes caused by bidding documents
	Claim management	Claim cost ratio
		Claim compliance
	Contract management	Contract management compliance
		Validity of performance of contract documents
	Project settlement	Preparation of settlement documents
		Settlement price deviation rate
		Preparation of final account documents for completion
Project Acceptance	Final account of completion	Deviation rate of final accounts

Corresponding to the index system constructed in Table 1, the collected data are corresponding to different building decoration stages. After collecting cost data, the reasonable threshold range is set.

2.2 Set Reasonable Threshold Range

After using BIM model to collect data, when setting reasonable threshold interval, the method divides the time series into equal length segments, and uses the average value of data points in the segment to represent the time series. The longer each segment is divided, the larger the dimension reduction is, but the more information is lost. If each segment is too short, the effect of dimension reduction will not be obvious. In order to further retain the key information of time series, it is sorted into a standard series. After processing, dimension reduction is used to process the information into a piecewise function:

$$\bar{x} = \frac{w}{n}\sum_{j=n+1}^{w} x_j \tag{2}$$

where w is the piecewise value, n is the dimension reduction parameter, and x_j is the piecewise function [11–13]. According to the specified letter set size, the Gaussian distribution table is used to find the interval split point. The time series is divided into equal length segments, and the middle point of each segment is selected. Then, the selected data points will be converted into a binary sequence, where 1 represents above the average value of the data points and 0 represents below the average value of the data points. The numerical distribution is shown in Fig. 2.

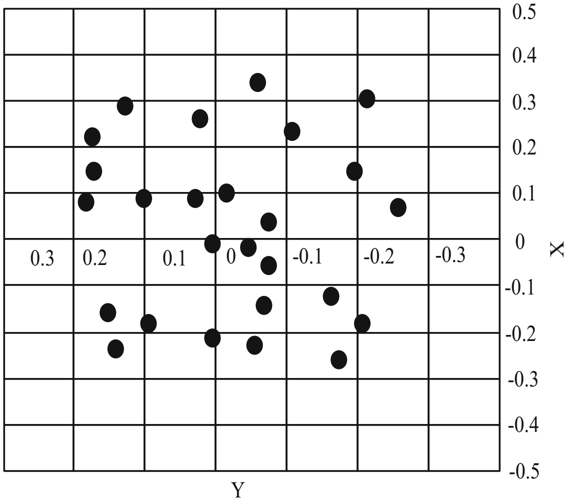

Fig. 2. Numerical distribution

Under the numerical distribution shown in the figure above, and the values in the time series are converted into binary series, it can be expressed as:

$$b_i = \begin{cases} 1 & if\ t \geq \mu \\ 0 & otherwise \end{cases} \tag{3}$$

where t is the conversion period and μ is the average value of the time series. In the calibrated interval, the calculation formula of the numerical point distance in the conversion sequence can be expressed as:

$$D = \frac{\sqrt{\sum_{i=1}^{N} w_i + \sum_{j=1}^{t} d_j}}{b_i} \tag{4}$$

where w_i is the partition function, d_j is the numerical point function, and N and t are the sequence mean. In time series fitting, abnormal data will cause residuals do not conform to the normal distribution, so the analysis of residual series can determine the outlier model. The fitting residual is defined as:

$$\pi(B) = \frac{\theta(B)}{\varphi(B)} \tag{5}$$

where, $\theta(B)$ is the normal residual value, $\varphi(B)$ is the abnormal residual value, and the meaning of other parameters remains unchanged. In order to eliminate the abnormal data in the fitting residuals, the matrix method is used to expand the residuals:

$$\begin{bmatrix} e_1 \\ \vdots \\ e_n \end{bmatrix} = \omega \begin{bmatrix} 0 \\ \vdots \\ 1 \end{bmatrix} + \begin{bmatrix} a_1 \\ \vdots \\ a_n \end{bmatrix} \tag{6}$$

Among them, a_n is white noise sequence, e_n is fitting value after expansion processing, and ω is migration operator. In the process of fitting, the deviation is mainly caused by the outliers, and the values in the noise points are integrated into the test statistics of the noise points. The change of test statistics is shown in Fig. 3.

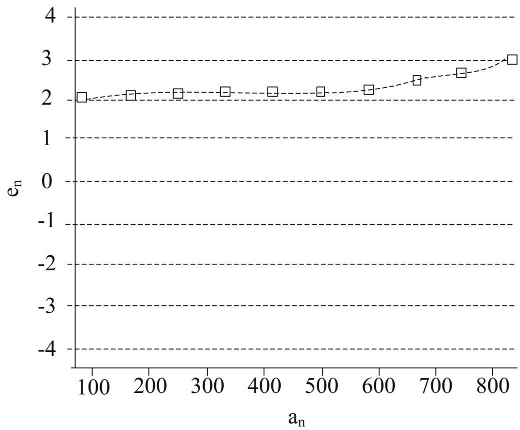

Fig. 3. Test statistics

Under the change of test statistics shown in the figure above, if the test statistics at any time exceeds the limit value, it is judged that there are noise points at that time. The value is taken as the final rationality threshold, and the limit value is taken as the control condition. Clustering process the relationship between decoration data and threshold parameters, and finally build the evaluation method.

2.3 Clustering Processing Decoration Data and Threshold Parameters

In the reasonable threshold interval, the cluster vectors in the interval are calibrated, and the labeling process can be expressed as follows:

$$AC = \frac{1}{N}\sum\nolimits_{j=1}^{t} \max_{k}|\omega_k| \tag{7}$$

Among them, k is the cluster vector parameter, AC is the tag function, and the meaning of other parameters remains unchanged. After label processing, corresponding to different mutual information, intersection processing can be expressed as mutual function:

$$H(c) = \frac{|\omega_k \cap c_j|}{N} \tag{8}$$

where $H(c)$ is the mutual function and c_j is the cluster function. In this information measurement process, the correlation between decoration data and threshold parameters is defined, and the RAND index formed by numerical clustering is calculated:

$$LD = \frac{2(a+b)}{n(n-1)} \tag{9}$$

Among them, a and b represent information entropy, and the meaning of other parameters remains unchanged. At this time, the index changes as shown in the figure below.

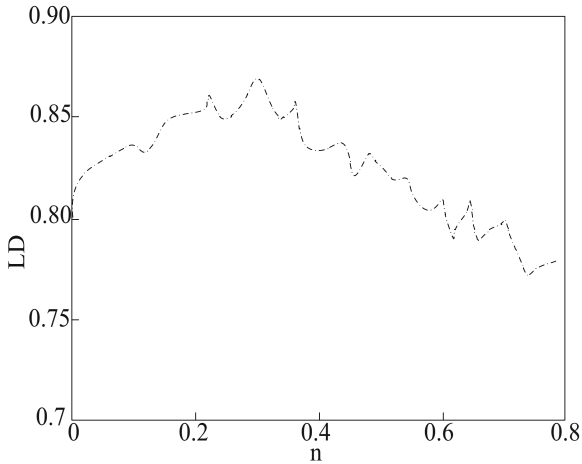

Fig. 4. Change of index value

Under the change of the value shown in the figure above. The introduction of an automatic encoder, the automatic encoder has a strong nonlinear expression ability, which may also fully describe the unique characteristics of individual samples, which results in the over fitting of input data. However, the structure of high-dimensional data is different, and there are many special features. If the automatic encoder is directly used in high-dimensional data for dimensionalization. The possible low dimension eigenvectors can not reflect the public distribution characteristics of high-dimensional data, which leads to the poor generalization ability of the model obtained by training, and it is impossible to popularize it on other data. In order to reduce the weight amplitude and prevent over fitting, L2 norm regular term is added. The numerical relation can be expressed as follows:

$$J(w,b) = \frac{\lambda}{2}\sum\nolimits_{j=1}^{t} n_j \tag{10}$$

where, n_j is the weight amplitude parameter, and the meaning of other parameters remains unchanged. Corresponding to the above numerical relationship, corresponding to the clustering parameters formed by different parameters, the parameters are shown in Table 2.

Table 2. Cluster parameters formed

Index name	Evaluation parameters	Cluster parameters
Project decision preparation	Adequacy of decision making preparation	0.316
Investment estimation	Preparation of investment estimation documents	0.266
	Deviation rate of investment estimation	0.338
Risk management	Risk identification	0.246
	Risk evaluation	0.258
	Risk prevention measures	0.205
Investment and financing	Capital ratio	0.282
	Financing cost ratio	0.239
Preliminary design	Preparation of design budget estimate documents	0.314
	Deviation rate of Budget Estimate Compilation	0.336
Construction drawing design	Preparation of construction drawing budget document	0.343
	Deviation rate of budget compilation and review	0.234
	Quota Design	0.282
Design Management	Standard design degree	0.334
	Comparison and selection of design schemes	0.334

(*continued*)

Table 2. (*continued*)

Index name	Evaluation parameters	Cluster parameters
Bidding management	Standardization of bidding management	0.317
Tender documents	Preparation of bidding documents	0.293
	Preparation of bill of quantities	0.318
Preparation of base price	Rationality of base bid preparation	0.268
Contract signing	Contract preparation	0.301
	Deviation rate of contract price	0.316
Engineering change management	Adequacy of change basis	0.266
	Changes caused by bidding documents	0.338
Claim management	Claim cost ratio	0.246
	Claim compliance	0.258
Contract management	Contract management compliance	0.205
	Validity of performance of contract documents	0.282
Project settlement	Preparation of settlement documents	0.239
	Settlement price deviation rate	0.314
	Preparation of final account documents for completion	0.336
Final account of completion	Deviation rate of final accounts	0.343

Corresponding to the parameters set in Table 2, the calculated clustering parameters are used as the numerical relationship between decoration data and threshold parameters, and the evaluation method is constructed on the basis of the numerical value.

2.4 Complete the Construction of the Evaluation Method

Under the above numerical relationship, when estimating the cost of building decoration, the risk of cost estimation is easy to occur. The threshold value of cost risk is preset. Assuming that the construction period is $t_1, t_2, \ldots, t_n$, when the construction is in period t_i, the planned cost of period i is C_i^*, and the actual cost is C_i. the cost of the prevention and control works of the completed project is calculated as $EV(t_i)$ and the actual cost of the prevention and control works completed is $AC(t_i)$:

$$\begin{cases} EV(t_i) = \sum_{j=1}^{i} C_j^* \\ AC(t_i) = \sum_{j=1}^{i} C_j \end{cases} \tag{11}$$

On the basis of formula (6), the difference between the actual cost and the planned cost of the prevention and control project is calculated, and the cost deviation value $\Delta C_c(t_i)$ is obtained:

$$\Delta C_c(t_i) = AC(t_i) - EV(t_i) = \sum\nolimits_{j=1}^{i} C_j - \sum\nolimits_{j=1}^{i} C_j^* \tag{12}$$

C_j^* of the phased planned cost of the prevention and control project is the cost of each phase of the project determined according to the overall profit of the overall construction project. The actual cost in phase i is too high because of the risk factors of the project, which leads to the risk deviation. According to (7) and (8), the deviation threshold of cost risk is obtained,

$$R_c(t_i) = \frac{\Delta C_c(t_i)}{EV(t_i)} \tag{13}$$

Using the obtained threshold value of cost risk deviation, the entropy method is used to determine the weight value of estimated cost risk. At this time, the i-th cost deviation transmitted by the prevention and control project is defined as I_i, and $I_i = -R_c(t_i)np_i$ is obtained, where p_i is the probability of deviation. Suppose there are n deviations at this time, and the probabilities of occurrence are p_i^0 and $i = 1, 2, \ldots, n$ respectively, so the entropy of deviation is:

$$e = -\sum_{i=1}^{n} p_i R_c(t_i) np_i \tag{14}$$

The entropy obtained is used to determine the risk weight of cost, assuming x_{ij} is the observation value of the j index of I prevention and control project (i = 1, 2,…, n). For a given x_j, the greater the difference between x_{ij} and the greater the information content contained in the index, the characteristic specific gravity of the index is calculated: $p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} (x_{ij} \geq 0)$, and the entropy value of indicator x_{ij} is $e = -k\sum_{i=1}^{n} p_{ij} R_c(t_i) np_{ij}$, in which $k > 0$, where $k = \frac{1}{\ln n}$ is obtained. Normalize e_j, so $0 \leq e_j \leq 1$. The difference coefficient of index x_j is calculated as follows: $g_i = 1 - e_j$, and the final cost risk weight value is obtained:

$$w_j = \frac{g_i}{\sum_{i=1}^{m} g_i} \tag{15}$$

where: w_j is the final calculated cost risk weight expression. m is the number of difference coefficients. Then the three-dimensional structure is used to evaluate the risk weight, and the cost estimation function is established. Before establishing the cost estimation function, the risk early warning of the prevention and control project should be evaluated, and the three-dimensional structure chart should be used to early warn the cost risk of the prevention and control project. The three-dimensional structure chart used is shown in Fig. 5

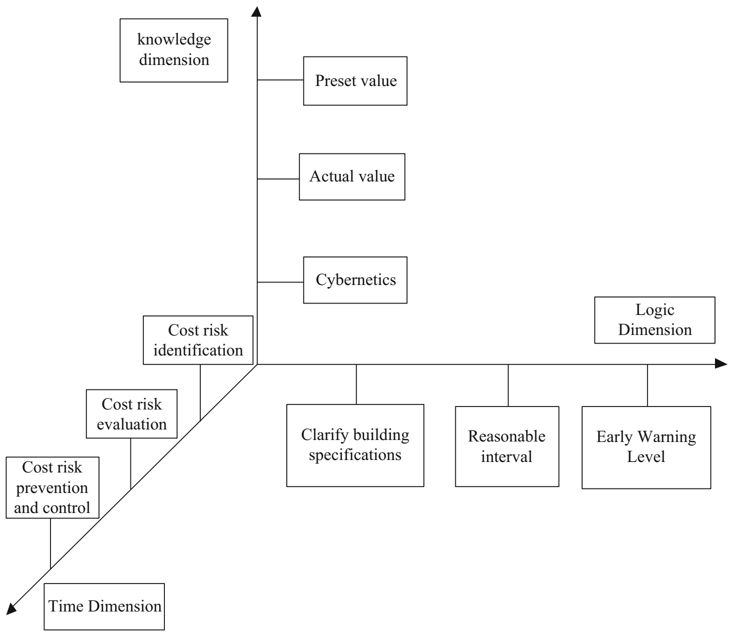

Fig. 5. Three dimensional structure of risk early warning

As shown in Fig. 4 above, cost risk is evaluated according to three dimensions: time dimension, logic dimension and knowledge dimension. In the time dimension, on the basis of equipment depreciation, we use formula (12) to identify and prevent the risk of the project. In the logical dimension, formula (13) was used to calculate the soil pollution concentration, and the logical dimension was evaluated according to the concentration. In the knowledge dimension, formula (14) is used to calculate the difference between the preset value and the actual value, so as to control the size of the preset value more strictly and realize the evaluation on the knowledge dimension.

Based on the three-dimensional evaluation results, when establishing the cost, we integrate (11), (12) and (15):

$$C = \lambda \frac{K}{R_i} \tag{16}$$

At this time, (16) is the evaluation function of cost. In actual use, according to the nature of building construction, adjust the calculation index in formula (16), calculate the weight of the index, get the weight value of cost risk, use the result of three-dimensional evaluation of cost risk weight, establish the cost estimation function, so as to complete the construction of the cluster evaluation method of building decoration price rationality.

3 Simulation Experiment

The following experiments are designed to verify the effectiveness of the cluster evaluation method of building decoration cost rationality based on BIM model.

3.1 Experimental Preparation

According to the arrangement of FHC decoration completion acceptance data, combined with the evaluation and weight assignment of each index, the classical domain of each index can be obtained by calculating each single index. This paper analyzes and studies the rationality of architectural decoration cost, and quantitatively and qualitatively deals with the classical domain of quantitative index of architectural decoration cost. The classical domain is shown in Table 3.

Table 3. Classical domain of quantitative index

Index name	Excellent	Second
Amount of contract price change	(0.7, 0.6)	(0.05, 0.1)
Contract dispute rate	(0.7, 0.6)	(0.05, 0.1)
Design change ratio	(0.7, 0.6)	(0.05, 0.1)
Change quantity and amount ratio	(0.7, 0.6)	(0.05, 0.1)
Default ratio of project payment	(0.7, 0.6)	(0.05, 0.1)
Major change ratio	(0.7, 0.6)	(0.05, 0.1)
Budget implementation rate	(0.7, 0.6)	(0.05, 0.1)
Change response rate	(0.7, 0.6)	(0.05, 0.1)
Difference from budget estimate	(0.7, 0.6)	(0.05, 0.1)
Management goal setting	(0.7, 0.6)	(0.05, 0.1)
Organization management mode	(0.7, 0.6)	(0.3, 0.5)
Clarity of responsibility division	(1, 0.7)	(0.3, 0.5)
Qualification examination	(1, 0.7)	(0.3, 0.5)
Evaluation method	(1, 0.7)	(0.3, 0.5)
List settings	(1, 0.7)	(0.3, 0.5)
Contract form	(1, 0.7)	(0.3, 0.5)
Procurement of main materials and equipment	(1, 0.7)	(0.3, 0.5)
Contract form	(1, 0.7)	(0.3, 0.5)
Clarity of contract terms	(1, 0.7)	(0.3, 0.5)

Under the quantitative and qualitative indicators set in the above table, after defining the classical domain, we can obtain the section domain of building decoration cost evaluation matter-element, and organize it into the evaluation data set as shown in Table 4.

Table 4. Evaluation data sets prepared

Dataset name	Dataset size/M	Time series length	Number of categories
1	2125.8	210	66
2	2377.5	170	91
3	2313.8	223	67
4	2378.4	211	88
5	2447.2	132	59
6	2479.6	245	10
7	2454.4	154	89
8	2055.7	249	87
9	2399.8	206	13
10	2487.5	142	7
11	2070.9	227	66
12	2243.3	160	94
13	2431.2	168	14
14	2032.2	179	72
15	2395.7	182	71
16	2204.8	194	75
17	2217.8	133	57
18	2020.7	191	79
19	2056.1	149	20
20	2041.4	180	80

Using the experimental data set shown in Table 4, prepare two traditional evaluation methods and the evaluation method designed in this paper for experiments, and compare the performance of the three evaluation methods.

3.2 Results and Analysis

Based on the above experimental preparation, under the control of the three clustering evaluation methods, the actual running time of the three clustering evaluation methods is counted according to the data set in the table. The results are shown in Table 5.

Table 5. Operation time of three clustering evaluation methods

Dataset name	Running time/ms		
	Traditional assessment methods 1	Traditional assessment methods 2	Method of this paper
1	36.7	28.6	11.4
2	39.8	20.9	10.6
3	40.5	29.9	10.6
4	34.9	28.6	10.7
5	35.4	20.7	10.8
6	36.9	24.2	11.3
7	31.5	24.7	11.3
8	34.4	29.5	10.1
9	36.5	23.3	11.6
10	41.9	28.2	11.3
11	38.6	24.8	11.7
12	37.9	28.2	11.6
13	32.1	24.6	10.6
14	41.3	23.7	10.2
15	41.5	22.4	10.1
16	35.9	28.6	10.9
17	35.8	24.6	10.3
18	38.9	25.3	11.2
19	39.9	21.1	11.3
20	36.5	21.9	10.9

According to the running time results shown in Table 5, the average running time of traditional evaluation method 1 is about 38S, and the actual running time is longer. The average evaluation time of traditional evaluation method 2 is about 24 s, and the actual running time is short. The average time of this method is about 10 s, compared with the two traditional evaluation methods, the time of this method is the shortest.

In the above experimental environment, the accuracy of three reasonable clustering evaluation methods is defined:

$$C = \lambda \frac{K}{R_i} \tag{17}$$

Among them, C is the accuracy of evaluation, λ is candidate parameter, K is evaluation data set, and R_i is cluster parameter. Under the control of the above numerical relationship, the accuracy results of the final three evaluation methods are shown in Table 6.

Table 6. Accuracy results of three evaluation methods

Dataset name	Accuracy		
	Traditional assessment methods 1	Traditional assessment methods 2	Method of this paper
1	0.5294	0.6955	0.9062
2	0.5673	0.6951	0.9135
3	0.4004	0.7676	0.9337
4	0.4303	0.7465	0.9076
5	0.5209	0.6134	0.9315
6	0.5411	0.6154	0.9083
7	0.5879	0.7711	0.9073
8	0.5194	0.7981	0.9399
9	0.5119	0.7888	0.9378
10	0.5318	0.6187	0.9359
11	0.5689	0.7849	0.9383
12	0.4459	0.6204	0.9388
13	0.4999	0.7934	0.9469
14	0.4279	0.6273	0.9093
15	0.5423	0.6916	0.9141
16	0.4417	0.6137	0.9223
17	0.5281	0.7162	0.9151
18	0.4344	0.6566	0.9141
19	0.5499	0.6299	0.9203
20	0.4949	0.6456	0.9394

Under the control of three evaluation methods, the accuracy relationship constructed above is taken as the accuracy result. According to the numerical results in Table 6, it can be seen that the accuracy of traditional evaluation method 1 is about 0.5, and the actual evaluation accuracy is poor. The accuracy of traditional evaluation method 2 is about 0.7, and the accuracy of the actual evaluation results is higher. The accuracy of this method is about 0.9, and the accuracy of this method is the best compared with the two traditional methods.

The above experimental environment is kept unchanged, and the quantitative classical field in the above table is different gradients. The calculation process can be expressed as follows:

$$G = \frac{T - T'}{H_0 - h} \tag{18}$$

Among them, T is the classical domain acquisition cycle, T' is the ideal evaluation cycle, H_0 is the domain value difference, and h is the number of indicators. According to the above calculation formula, a total of five reasonable gradients are collected. Under the control of the reasonable gradient, three evaluation methods are used for processing. The more data points that can be evaluated in the corresponding gradient, the greater the efficiency of the evaluation method is. Finally, the evaluation efficiency results of the three evaluation methods are shown in Fig. 6.

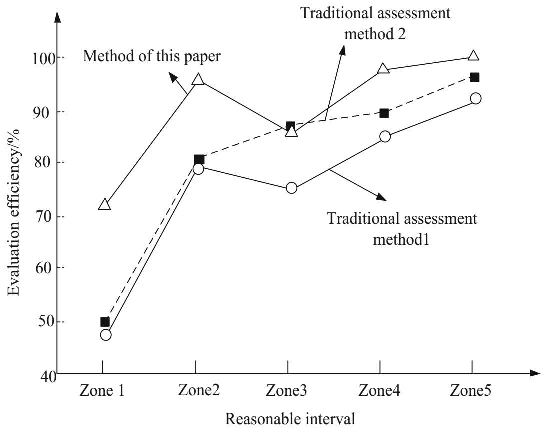

Fig. 6. Efficiency results of three evaluation methods

According to the efficiency results of the evaluation method shown in Fig. 6, after dividing the reasonable gradient of cost, the average efficiency of traditional evaluation method 1 is about 78%, that of traditional evaluation method 2 is about 82%, and that of this method is about 93%, which proves that the efficiency of this method is the highest compared with the two traditional evaluation methods.

4 Conclusion

Through the analysis of BIM model on the current situation of project cost management, it can be found that the owner's evaluation of project cost management ability stays on empiricism and lacks systematic and scientific methods. Therefore, this paper constructs the construction cost cluster evaluation method, which can evaluate the rationality of the construction decoration cost, evaluate the maturity of the cost management in each stage, and finally get the maturity level of the project cost management, and improve it pertinently, so as to provide a more scientific evaluation method for the construction decoration cost. The current construction project cost prediction model has problems such as complex modeling and ignoring regional differences. The construction cost per unit area is used to cluster the residential construction projects in 30 areas, and the 30 areas are divided into four categories. The next step of the research direction can be to add the area category as an influencing factor to the linear regression model, and obtain the prediction model of the residential building project cost through principal component regression analysis.

Fund Projects

1. Guangxi Vocational Education Teaching Reform Research Project in 2020 "Research and Practice on the Practice Teaching System of "Three Courses and Four Abilities" in Higher Vocational Architecture Majors with Progressive Ability" (GXGZJG2020B122)
2. In 2020, Guangxi Gao School's young and middle-aged teachers' scientific research ability improvement project "Research and Practice of Prefabricated Buildings Based on BIM Technology in Underdeveloped Areas" (2020KY45013).

References

1. Wang, A., Su, M., Sun, S., et al.: Evaluation of BIM application capability of prefabricated buildings based on life cycle theory. J. Civil Eng. Manage. **37**(02), 27–33+40 (2020)
2. Dong, N., Hu, L., Zou, Z., et al.: Application benefit evaluation of BIM based on C-OWA operator and grey clustering. Sci. Technol. Manage. Res. **39**(04), 48–544 (2019)
3. Wang, W., Ma, B., Li, Q., et al.: Clustering of BIM components based on similarity measurement of attributes. J. Graph. **41**(02), 304–312 (2020)
4. Li, P., Xu, J., Duan, Y.: Evaluation method of property right of building information modeling in construction enterprises. Sci. Technol. Manage. Res. **39**(01), 183–189 (2019)
5. Sun, S., Sun, B., Wu, J.: Evaluation on BIM-based synergy degree in design stage of prefabricated buildings. Yangtze River **51**(04), 218–225 (2020)
6. Han, F., Lin, S.: Energy-saving mode assessment method for hydropower building construction based on building information modeling technology. Sci. Technol. Eng. **19**(24), 231–236 (2019)
7. Liu, S., Liu, D., Khan, M., Ding, W.: Effective template update mechanism in visual tracking with background clutter. Neurocomputing (2020). https://doi.org/10.1016/j.neucom.2019.12.143
8. Liu, S., Liu, X., Wang, S., Muhammad, K.: Fuzzy-Aided solution for out-of-view challenge in visual tracking under IoT assisted complex environment. Neural Comput. Appl. **33**(4), 1055–1065 (2021)
9. Bai, J., Lyu, X., Sun, P.: Rapid modeling method of urban rail transit based on BIM API. Urban Mass Transit **22**(08), 170–173 (2019)
10. Zhao, W.: Dynamic integration mechanism of building information modeling technology and low carbon green building evaluation index system. Sci. Technol. Eng. **19**(03), 196–201 (2019)
11. Liu, S., Sun, G., Fu, W.: e-Learning, e-Education, and Online Training, pp. 1–386. Springer International Publishing, USA
12. Hu, Y., Pei, L., Han, C.: A seismic performance evaluation method for masonry structures based on BIM. China Earthquake Eng. J. **41**(01), 221–226 (2019)
13. Chen, H., Xu, G., Wu, X., et al.: Research on information design and green degree evaluation of green building based on BIM. Archit. Technol. **50**(08), 996–1000 (2019)