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Research on the application of BIM technology for cost controlin construction

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Abstract. The cost control of construction projects directly determines the profitability of construction projects. Building information modeling (BIM) technology came into being with the development of modern science and technology, through BIM technology can effectively solve the problem of cost control of construction projects, therefore, the specific application of BIM technology in the cost control work of construction projects is a topic worth studying. This paper mainly outlines the main points of BIM technology and cost control of construction projects, and sets the evaluation indexes of RM, PM and CCD according to the key processes of sub-parts of projects, and evaluates which sub-parts of projects are used in combination with BIM technology as the key processes of cost control of construction projects through the coupling relationship between them, which can significantly reduce the construction cost of construction.

1. Introduction

Building Information Modeling (BIM for short), is an important product of the construction industry in the rapidly developing informationization and digitalization era.The application of BIM technology largely solves the problem of high energy consumption, heavy pollution and low efficiency of the construction industry in the past [1]. Development of technology and digital technologies, modern approaches to construction, automation and dispatching of real estate objects can ensure the development of territories according to the standards of “Smart Buildings” and“Smart Cities” [2]. According to statistics, the average profit margin of the construction industry in China is about 3.5% of the output value [3], the cost efficiency is low, and the effect of cost control in the construction process is not obvious, but the application of BIM technology solves the problem of cost control in the construction process Liu Jingna [4] for the construction stage of the existence of construction cost management problems, put forward in the construction stage based on the solution of the BIM technology construction enterprises to the problem of cost management on the The reduction of construction project costs and the improvement of cost management level have played a significant role. According to the Stanford University Center for Integrated Facilities Engineering's summary of 32 projects, the use of BIM technology can reduce the contract price by 10% through the discovery and resolution of conflicts; control the cost estimate within 3%, and reduce the estimation time by 80%; eliminate 40% of the extra-budgetary changes; shorten the duration of the project by 7%, and can realize the return on investment as early as possible [5]. This paper analyzes the problems of traditional construction cost control, combines the advantages of BIM technology such as information sharing, simulation and visualization, and analyzes the cost of the project in construction through a coupled model with 10 variables, in order to support the evidence of which key processes in the sub-projects are the core of cost control.

2. Application of BIM technology in cost control of construction projects

BIM technology in recent years from 3D-4D-5D is now a breakthrough in the development of software technology also gradually tends to improve, evit, Rhino, Bentley, ArchiCAD, Tekla [6], and through the visualization of the drawing, BIM in the cost control shows a huge advantage, respectively, manifested in the following three aspects.

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2.1Resource management control of costs

The control of building construction cost depends on whether the arrangement of labor, materials, machinery and equipment and capital use plan is reasonable or not, so it is necessary to make a reasonable construction organization plan in the construction, and make effective control of the consumption of materials and the arrangement of personnel, although nowadays there is a sound limitation of the cost control of the project and the procedure approval system, but the management personnel manage the effect only by the experience is not ideal. The BIM-5D technology based on BIM3D+schedule+cost can prepare the material requirement plan, and the management personnel can extract the material consumption information from the model according to the needs of each stage, and then combine with the Internet of Things technology to implant the two-dimensional code or RFID tags into the materials, which can realize the transparent and real-time management in conjunction with the data of the BIM model, so as to realize the limit of receiving materials and better control the cost. The technical flow chart of BIM is shown in Figure 1.

2.2 Cost control by progress management

BIM-5D technology can provide construction progress and resource information at any time, managers can analyze the construction progress and cost of any time period, according to the results of the analysis of construction costs and construction progress for reasonable management. At the same time, the project quantity and budget information obtained through BIM5D model can be timely progress payment by report, which can better strengthen the control of construction process cost [5]. When the schedule is rushed, BIM-5D technology can simulate the construction progress in advance, and take corresponding measures for the construction difficulties and key points. At the same time on the staff, funds, materials and machinery and equipment, etc. to adjust and rationally organize the arrangements for the development of the plan, to do in the actual construction of the cost, progress in a timely manner to deviate from the analysis of heh. The use of BIM technology on the construction progress plan, labor, etc. for repeated optimization, to reduce the construction of winter species encountered in the construction of conflict. The application of BIM technology can improve the collaborative work between each other, to ensure accurate control of the construction progress, reduce the risk of schedule delays [7], and accelerate the process of construction progress.

2.3 Cost control of engineering changes

Use BIM5D dynamic cost management model in construction, associate the model with drawings, when the project changes, input the changed information into the model, the related project quantity will change, then according to the change of project quantity, find the corresponding components in the model, you can determine the price after the change [8]. The application of BIM5D technology does not need to calculate the price after change and change of project quantity in accordance with the traditional manual way, make codes for the components when constructing the building model, it can realize the dynamic linkage of project quantity and cost information, simplify the workload of budget personnel. The application of BIM5D technology does not need to calculate the change of project quantity and the price after the change according to the traditional manual way, and it can realize the dynamic link between the project quantity and the cost information when building the building model, which simplifies the workload of the budget personnel by creating the code for the components.

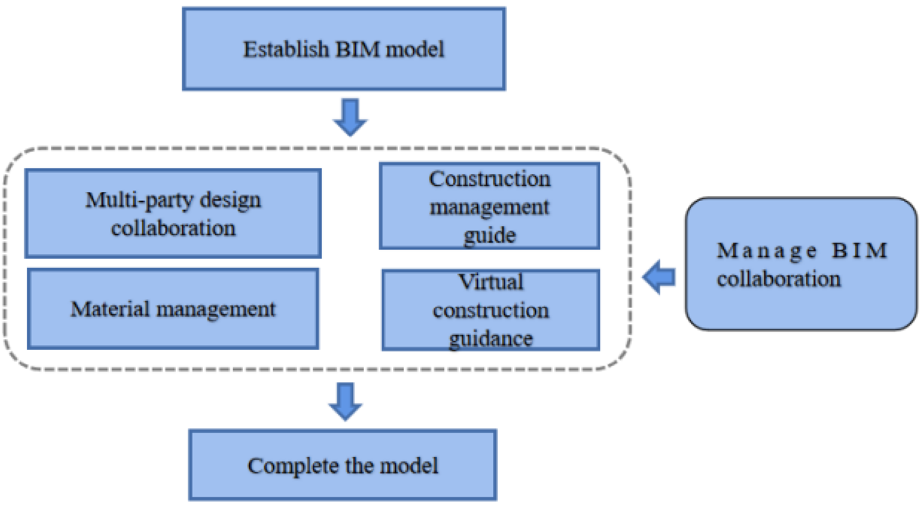

Fig. 1. The technical flow chart of BIM

3. Models and Methods

3.1 Relationship between the selection of RM, PM and PC variables

The cost control subsystem of construction economy mainly refers to its all-round building model system formed by BIM visualization 5D model, in order to better estimate the construction cost pricing. Resource management (RM), progress management (PM) and project changes (PC) are the three main cost control directions, each with its own characteristics, and each with its own structure, function and development rules, but so far RM and PM cost control methods are often used in combination with BIM technology on various construction sites, while PC is often used in combination with BIM technology. Resource management (RM), progress management (PM) and project changes (PC) are the three main cost control methods, each with its own characteristics, and each with its own structure, functions and development rules, but so far, RM and PM cost control methods are often used in combination with BIM technology on various construction sites, while PC is only used on mega projects that have their own design institutes and have on-site design from time to time. Therefore, at present in the BIM technology system and the current construction cost control combined with the main control model for RM and PM, the two interlaced with the BIM technology combined with the coordinated, synchronized development, synergistic and progressive construction is now the implementation of the cost control, reduce the cost of construction costs, improve the effectiveness of the construction economy, promote the real estate economy's rate of return on investment to attract more investment in construction, reduce energy consumption, and promote the real estate economy's return on investment to attract more investment in construction. Reduce energy consumption and promote the potential development of the real estate economy.

3.2 Constructing the evaluation index system

The evaluation index system should comprehensively and realistically reflect the relationship between the control of cost by resource management and the control of cost by progress management on the development of construction economy, as well as how to integrate the use of each method with BIM technology. Therefore, in this paper, based on the principles of scientificity, rationality, operability and representativeness, and in combination with the main contents of cost control of construction economy, we designed an index system containing 10 indicators to evaluate the development of BIM technology with PM and PM in 30 construction sites (Table 1). The indicators we chose were selected according to the Pricing Regulations of the Fixed-Price Pricing Code of the People's Republic of China [9]. Therefore, it should be scientifically sound, widely acceptable, and based on affordable monitoring or statistical data. We have standardized the use of indicators with relative significance to reflect the real situation and to eliminate the effect of scale. Indicators of buildings with geographical characteristics of the site need to be deleted because our aim is to conduct a comprehensive study on cost control of construction works, and our study has also considered the availability of data on the cost of all construction works. We referred to the official website of the Ministry of Housing and Urban-Rural Development of the People's Republic of China, and selected five indicators for evaluation of the bill of quantities pricing method (component project cost, measure project cost, other project cost, fees and taxes) and five standard components of the unit project cost of the quantity-fixed pricing method (direct project cost, comprehensive management fee, construction measure cost, other costs, taxes) [10]. For details, see Table 1.

Table 1. Evaluation of the bill of quantities pricing method

Level 1	Level 2	Data sources	Building level
Bill of quantities pricing	Sub-component costs	Official website of the Ministry of Housing and Urban-Rural Development of the People's Republic of China, construction project cost information network	Grade A, B, C
	Measurement project costs		
	Other project costs		
	Regulatory fee		
	Taxes		
Quantity-fixed pricing system	Direct engineering costs	Official website of the Ministry of Housing and Urban-Rural Development of the People's Republic of China, construction project cost information network	Grade A, B, C
	Comprehensive management fee		
	Cost of construction measures		
	Other expenses		
	Taxes		

Before assessing the level of real estate socio-economic and BIM technology application and the degree of its coupled and coordinated development, it is necessary to assign reasonable weights to the indicators in the evaluation system. Since the real estate economic system is a complex system composed of many factors and the development of RM and PM is influenced by many indicator factors, most evaluation methods show some limitations in evaluating the development of RM and PM. In view of this, this study introduces the coefficient of variation method to determine the indicator weights. The coefficient of variation can objectively reflect the relative importance of the evaluation indexes, avoid the preference of expert assignment, and weaken the influence of extreme value indexes on the evaluation results The higher the coefficient of variation is, the higher the weight of the index is.There are differences in real estate economy and the development of the application of BIM technology in 30 projects.
Therefore, the weights of the indicators were calculated on the basis of the coefficient of variation. The detailed steps are shown as follows: firstly, the indicators should be standardized by using standardization methods because of the differences in the measurements and magnitudes of different data. In this paper, we need to standardize the raw data by using the extreme value processing method (Eq. (1) and Eq. (2)).

$$Y_{ij}=\frac{X_{ij}-\min\{X_j\}}{\max\{X_j\}-\min\{X_j\}} \tag{1}$$

$$Y_{ij}=\frac{\max\{X_j-X_{ij}\}}{\max\{X_j\}-\min\{X_j\}} \tag{2}$$

Where X_{ij} is the actual value of the jth indicator for construction project i; max{X_j } denotes the maximum value; min{X_j } denotes the minimum value and Y_{ij} shows the normalized value. Equation (1) will be used when the RM and PM levels of a construction project increase in tandem with the indicator values. Equation (2) will apply when construction project RM and PM levels increase with decreasing construction project RM and PM levels when indicator values, equation (2) will apply. If a coefficient of variation exists, then equations (3) and (4) will be taken into account for the calculation.[The coefficient of variation is the ratio of the standard deviation to the mean (average)].

$$\bar{x}_j=\frac{1}{m}\sum_{i=1}^{m}x_{ij},\ j=1,2,\ldots,n \tag{3}$$

$$s_j=\sqrt{\frac{1}{m}\sum_{i=1}^{m}(xij-\bar{x}j)^2}\ _j=1,2,\ldots,n \tag{4}$$

Therein, the coefficient of variation and weight for each indicator can be calculated by Eqs. (5) and (6) as follows.

$$v_j=\frac{s_j}{x_j},\ j=1,2,\ldots,n \tag{5}$$

$$w_j=\frac{v_j}{\sum_{j=1}^{n}v_j},\ j=1,2,\ldots,n \tag{6}$$

3.3 Coordinated assessment of weight coupling

This study invokes the concept of coupling in physics to express the degree of coupling between RM and PM development in construction engineering [11]. It mainly refers to the coupling coordination model to study the relationship of coordinating the mutual influence of real estate cost control and BIM technology and the level of application of BIM technology in real estate economy, so as to assess the degree of CCD coupling more comprehensively. (7)- (9)

$$C=E_{SE}{}^{K}\times E_{EE}{}^{K}/(\alpha E_{SE}+\beta E_{EE})^{2K} \tag{7}$$

$$T=\alpha E_{SE}+\beta E_{EE} \tag{8}$$

$$CCD=\sqrt{C\times T} \tag{9}$$

4. Results and Discussion

The evaluation results and evaluation methods of 30 construction projects in China using BIM technology for cost control are shown in Table 2.

Table 2. Variable results of BIM technology on cost control

Itemized Work	Grade Of Work	RM	PM	CCD
Concrete	Excellent	0.662	0.419	0.624
Ground Treatment (e.g. Of a Building)	Excellent	0.389	0.285	0.468
Slope Support Works	Excellent	0.237	0.292	0.509
Pile Foundation Works	Excellent	0.331	0.408	0.601
Masonry	Excellent	0.345	0.259	0.618
Earthwork	Excellent	0.284	0.295	0.538
Roofing And Waterproofing	Excellent	0.229	0.319	0.509
Doors And Windows	Excellent	0.19	0.31	0.471
Reinforced Concrete Works	Excellent	0.73	0.446	0.698
Decoration Of Secondary Structures	Excellent	0.535	0.335	0.544
Mean:		0.393	0.326	0.558
Concrete	Second Rate	0.517	0.499	0.663
Ground Treatment (e.g. Of a Building)	Second Rate	0.238	0.389	0.527
Slope Support Works	Second Rate	0.278	0.461	0.573
Pile Foundation Works	Second Rate	0.221	0.474	0.521
Masonry	Second Rate	0.421	0.385	0.542
Earthwork	Second Rate	0.332	0.477	0.66
Roofing And Waterproofing	Second Rate	0.385	0.316	0.583
Doors And Windows	Second Rate	0.22	0.21	0.494
Reinforced Concrete Works	Second Rate	0.552	0.489	0.697
Decoration Of Secondary Structures	Second Rate	0.4	0.25	0.51
Mean:		0.356	0.395	0.577
Concrete	Third Class	0.359	0.453	0.574
Ground Treatment (e.g. Of a Building)	Third Class	0.271	0.402	0.564
Slope Support Works	Third Class	0.254	0.294	0.521
Pile Foundation Works	Third Class	0.288	0.414	0.549
Masonry	Third Class	0.271	0.39	0.556
Earthwork	Third Class	0.175	0.57	0.505
Roofing And Waterproofing	Third Class	0.282	0.294	0.536
Doors And Windows	Third Class	0.165	0.29	0.422
Reinforced Concrete Works	Third Class	0.316	0.483	0.615
Decoration Of Secondary Structures	Third Class	0.22	0.35	0.448
Mean:		0.260	0.394	0.529

4.1 Analysis of results and evaluation of Class A, B and C works

Table 2 shows that in class A project the RM value is maximum 0.73, minimum 0.19 and mean 0.393, PM maximum 0.446, minimum 0.259 and mean 0.326, CCD maximum 0.698, minimum 0.468 and mean 0.558. In class B project the RM value is maximum 0.552, minimum 0.22, mean 0.356, PM maximum 0.499, minimum 0.21 and mean 0.395, CCD maximum 0.697 and minimum 0.51, CCD maximum 0.697, mean 0.395, and CCD maximum 0.395. The mean value is 0.356.PM maximum value is 0.499,minimum value is 0.21 and mean value is 0.395.CCD maximum value is 0.697,minimum value is 0.51 and mean value is 0.577.RM value in class C project is maximum 0.359,minimum value is 0.165 mean value is 0.260.PM maximum value is 0.483,minimum value is 0.29 and mean value is 0.394, CCD maximum value is 0.615, minimum value is 0.422 and mean value is 0.529.Thus no matter at which level of project, it shows that RM value of reinforced concrete project is highest, concrete project is closely followed by the second one, and RM value of windows and doors project has the lowest result. And the same is true for PM and CCD values. Therefore, in Class A large-scale projects, project personnel tend to mainly control the reinforced concrete works and concrete works in the subsections for better cost control of construction works. This is followed by piling, earthworks, masonry, roofing and waterproofing. Finally, there are doors and windows and secondary structure decoration works. This shows that the control of construction materials is the important part of cost control, followed by the control of progress and quality. Therefore, this highlights the importance of modeling construction with BIM 5D technology. The fewer collision overlaps, the less material depletion, the fewer changes, and the more efficient the schedule.

4.2 Analysis of evaluation indicators for both PM and RM

What are the overall cost savings of the two evaluation metrics of PM and RM for cost control of construction projects? The answer to this question is shown in Figure 2. Each item is represented as a point in the figure, where they are sorted in the order of the results of the evaluation of the two indicators PM and RM. According to the scatter diagram it is shown that whether using the bill of quantities method of pricing or the quantity fixed method of pricing, the concrete works and reinforced concrete works in the sub-projects are the main focus of saving construction costs, followed by the dominance of earthworks, piling works, roof waterproofing works, secondary structure works, slope stabilization works. The least important are window and door works located at the lowest end.

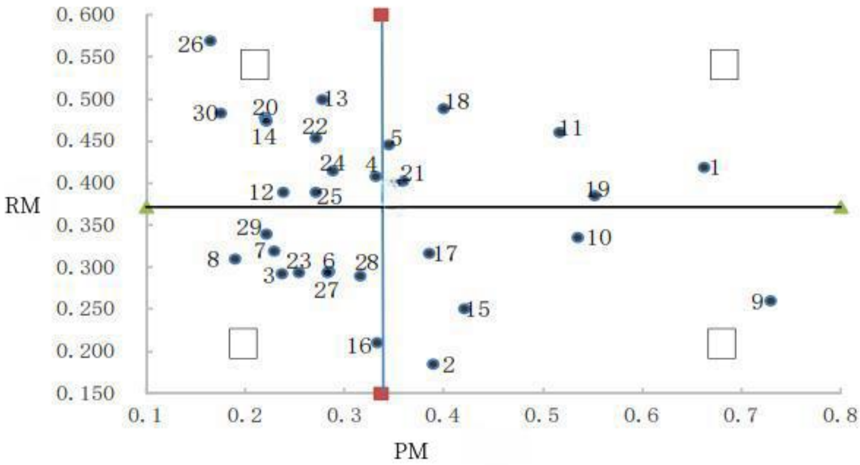

Fig. 2. Scatterplot of the evaluation metrics analyzed for both PM and RM.

4.3 ESDA Space Technology Analysis

According to the spatial analysis of ESDA technology, the closer the concrete and reinforced concrete distribution share the cost control of the project, the higher the value of the CCD using ArcGIS 10.2 to carry out the ESDA analysis, the results of the three-dimensional perspective view shown in Figure 3, in which the X-axis represents the east-west direction, the Y-axis represents the north-south direction, which represents the axis of the CCD. overall, the spatial pattern of the change is very interesting, the X direction is almost an inverted U-shaped In general, the spatial pattern is interesting, with an almost inverted U-shape in the X direction and a decreasing trend in the Y direction. The curve in the XZ plane almost follows a regular inverted U-shaped trajectory, but the end point is higher than the beginning of the curve, which means that the level of development of CCD for resource control in cost control of construction projects is higher than the level of development of schedule control. From the curve on the YZ plane, it can be seen that the decrease of the value is more obvious at the beginning, but in the middle of the curve, the decreasing trend is no longer obvious. This shows the main control project of cost control of reinforced concrete in construction works, pile foundation works, masonry works as auxiliary body control works, secondary structure and doors and windows works not unimportant body control point works.

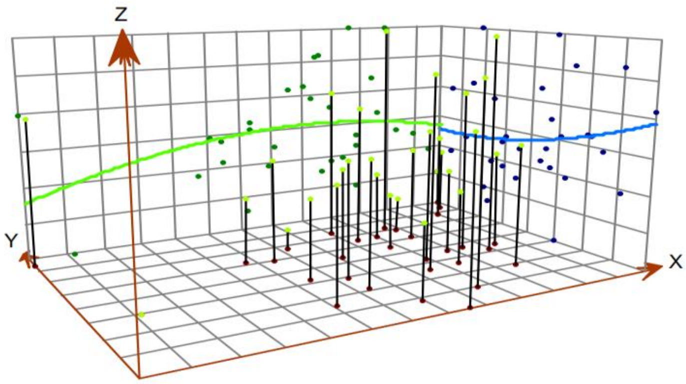

Fig. 3. Analytical chart of ESDA spatial technical analysis

5. Recommendations and Responses

5.1 Recommendations for BIM technology in resource management for cost control

BIM technology can output the project's engineering measurement calculations according to the floor or other classification methods after completing the statistics of the project volume [12], according to the actual construction of the project according to the budget volume, BIM calculations of the amount of materials used on the construction site for accurate control, through the actual amount of poured on-site to compare the statistics of the loss situation, and to find out the parts of the larger amount of loss. It can also provide a variety of data for comparative analysis, so as to carry out overall resource management, in order to achieve the purpose of cost control. For example: a project in the actual construction of the loss rate of the beam plate was found to be larger than the loss rate of the wall column, the technical staff according to this situation developed a special construction program for wall columns, beams and slabs of concrete. The use of special construction program construction found that the loss rate of the beam plate is greatly reduced, reduced by 44.1%; wall column loss rate reduced by 23.4% [13]. By comparing the budgeted quantity, the BIM quantity and the actual quantity, it is found that the quantity extracted by BIM is more favorable for us to control the resources management of the construction project, and it is convenient for us to achieve the purpose of cost saving.

5.2 Recommendations of BIM technology in schedule management for cost control

First of all, the BIM-5D construction model with BIM3D model+schedule+cost should be established during the construction, and the construction process should be simulated by this model. Through the simulation, we find out the operation conflict problems in the construction process and optimize the construction. Among them, the collision problem is an important factor affecting the project schedule, especially in the pipe arrangement; therefore, the application of BIM technology simulation solves the collision problem for the project and avoids the schedule delay caused by the collision problem. Secondly, the collision checking by BIM technology realizes the optimization of the overall schedule, not only can predict the construction overlap of individual sub-projects in advance, but also reduces unnecessary labor waste, solves the collision problem in advance due to the unreasonable design and construction work surface, which can speed up the construction progress to improve the quality of the construction, and also reduces the cost of the construction accordingly.

5.3 Suggestions of BIM technology in engineering change on cost control

Using 5D model of BIM technology, through construction simulation and scheme simulation, we can put forward optimization suggestions on the scientificity of construction organization design and special construction scheme, reduce the occurrence of errors, and upload the change information to the platform for preservation, avoiding the loss caused by the loss of paper documents. Especially for construction projects with large scale, complex engineering and tight schedule involving multiple professional cross-flow construction, we use BIM technology to carry out technical briefing and construction simulation, which not only greatly helps construction personnel understand the construction program and construction technology, avoiding rework during construction, but also reduces the time claims and schedule delays due to changes in the project to save time and improve efficiency and reduce costs. Improve efficiency and reduce costs.

6. Conclusion

Coordinated development refers to the cooperation between at least two parties or two variables with the goal of achieving a win-win situation, and through the analysis, we are able to evaluate the coordinated development of real estate cost control as well as the coordinated development of the application of BIM technology and the coupled coordinated development between PM and RM. Through the 10 evaluation indexes we selected, we comprehensively reflect the relationship between BIM technology and real estate economic cost control in the sub-projects, therefore, the key to solving the cost control problems existing in the actual construction project work of the construction engineering enterprises lies in how to adopt BIM technology to optimize and perfect the cost control work in the project sub-projects of the construction engineering enterprises. From the analysis data of this model, both PM and RM values show that the reinforced concrete project and concrete project are the most important for cost control, followed by piling project and earthwork project, and finally masonry project, secondary structure decoration project and doors and windows project. Therefore, how to reasonably control the quality and cost of construction projects, under the premise of guaranteeing the quality of construction projects to reduce costs as much as possible, so as to meet the market demand for construction projects, enhance the profitability of construction engineering enterprises, promote the efficient and stable development of construction engineering enterprises, and contribute to the enhancement of the overall level of the construction engineering industry is a problem that continues to be worthy of in-depth discussion today.

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