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Research on Civil Engineering Project Management Efficiency Improvement Based on BIM Technology

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ABSTRACT

For building construction enterprises, civil engineering project schedule assurance is the embodiment of project performance ability, and project cost control is the root of project profitability. This paper researches the cost-schedule control method based on BIM and critical path earned value method, and establishes a complete set of dynamic cost-schedule analysis and control method including plan preparation, process evaluation and result correction. This paper takes Project F as an example, integrates project management in the BIM platform and optimizes the plan through construction simulation, so that the construction plan is closer to the actual demand, establishes the Earned Value Method for distinguishing the critical path and embeds it into the BIM platform, reflects the progress with the Earned Value parameters of the critical path, reflects the cost with the Earned Value parameters of the whole project, analyzes the problems of the critical path and the project and proposes cost-schedule corrective measures in a targeted way. The critical path and project problems are analyzed, and cost-schedule corrective measures are proposed, so as to realize the fine management of project cost-schedule. Through the case study, it is proved that based on BIM critical path earned value method can achieve schedule and cost coordination and dynamic control and realize 91.8% cost reduction, good civil engineering project management efficiency and change the status quo of civil engineering project cost management.

Keywords: project management efficiency, critical path earned value method, civil engineering, BIM technology

1. Introduction

With the development of social economy and the improvement of technology level, the scale of construction projects is getting bigger and bigger and the complexity is getting higher and higher. Civil engineering project management is an important link to ensure the successful completion of civil engineering projects [1]. However, there are some problems in traditional project management

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methods, such as poor information transfer and inefficient communication. To solve these problems, the construction industry has started to adopt building information modeling (BIM) technology as an advanced digital tool to improve civil engineering project management [2]. The technology uses computer software to carry out three-dimensional simulation modeling of civil engineering, engineering project design, construction and operation of the whole process of information integration management, prompting changes in the traditional project management methods, to promote the management of engineering projects more efficient, high quality [3-4]. The use of BIM technology in civil engineering project management is of great significance, and BIM technology is used to optimize and improve the quality of civil engineering project management, and to improve the social, economic and other comprehensive benefits of civil engineering [5-6]. In this regard, an in-depth discussion of the efficiency of civil engineering project management based on BIM technology is expected to play a certain role in the development of construction project management, thus promoting the development of civil engineering project management in the direction of modernization and intelligence [7-8].

With the rapid development of science and technology, engineering project management faces unprecedented opportunities and challenges. Literature [9] discusses the concepts and application trends of building information modeling/management (BIM) technology, proposes a procurement framework based on building information/management (BIM) implementation, and verifies the effectiveness and practicality of the framework through actual case studies, which can improve the productivity of complex construction projects with better coordination and minimization of errors and duplication of work to achieve the "optimal outcome". Literature [10] highlights that the civil engineering industry is under pressure to improve efficiency and productivity and points out the potential of building information modeling in civil engineering to improve the management of the building lifecycle by dealing with building information modeling issues, providing civil engineering professionals with an overview and tools for effective planning, building blueprints, construction management and infrastructure. Literature [11] emphasized the importance of understanding building information modeling through a systematic review of the literature and used Surabaya construction work as a case study, which was analyzed by a questionnaire to conclude that parametric components are the technical support for the implementation of BIM, the benefit of BIM is the reduction of construction costs, and the main challenge of BIM is the different brands. Literature [12] designed a seven-dimensional building information model and verified through empirical analysis that the implementation of the model can save cost and time in project management, improve the quality and efficiency of the project, and can be used to help engineers/project managers in clash detection, structural design, modification, equipment installation, 3D project management and post-construction maintenance. Literature [13] used multiple regression analysis to assess the impact of building information modeling on project performance and showed that the level of BIM Execution Plan (BEP) participation was a significant predictor of BIM adoption and that there was a significant relationship between speed of delivery, perceived quality of the facility, and group cohesion within the project team and the adoption of BIM, controlling for project complexity. Literature [14] points out the importance of knowledge management in the construction field for the success of construction projects, proposes a conceptual model that combines the fundamentals of knowledge management with the contemporary principles of BIM in the design phase, and validates the proposed conceptual model through a hypothetical case study, which demonstrates strong competence and high efficiency in the improvement and development of knowledge management in the design phase of buildings and projects.

In addition, literature [15] systematically reviewed the integration of BIM and project management throughout the project lifecycle and proposed a BIM competency framework aimed at facilitating the integration of BIM and project management throughout the project lifecycle in order to improve the efficiency of project management in construction projects. Literature [16] developed a 3D model simulation of a three-storey residential building for evaluating the effectiveness of using Building Information Modeling (BIM) tools in project management, and the results showed that BIM can improve the performance of the entire project management process, optimize the project management schedule, and reduce the uncertainty, structural deficiencies, and costs of overall project management. Literature [17] proposed a quality management model based on cloud computing, mobile devices and Autodesk BIM 360 Field software and verified the effectiveness and feasibility of the model through actual engineering and construction projects, which can efficiently manage the construction process of an engineering project so that the project can be completed on time and within the project budget. Literature [18] proposes a project management framework that aims to utilize building information modeling to improve the productivity of construction projects in Singapore, and confirms the scientific and practicality of the proposed framework through a case study of a local residential project, which provides the project team with a valuable tool that can improve productivity performance. Literature [19] aimed to study construction project management using building information modeling, and empirical analysis found that building information modeling can optimize the quality of design throughout the full cycle of a construction project, improve the efficiency of construction work, and help managing contractors to improve their management. Literature [20] used the Mombasa port area development project as a study to examine the impact of building information modeling on the cost management of construction projects using a mixed methodology combining a literature review and a questionnaire survey, the results showed that building information modeling can improve the accuracy of cost estimation of construction projects, and it has a positive impact on items such as construction decision making, collaboration, performance, and delivery time.

This paper combines the BIM technology and the critical path earned value method to establish a complete set of dynamic cost analysis methods including plan preparation, process evaluation and result correction. The method of establishing the cost-schedule model of BIM5D is elaborated, and the scientific and reasonable construction schedule is obtained through process analysis and construction simulation of key project determination, which lays the foundation for the efficient utilization of the earned value method. On this basis, the Earned Value Method is constructed to distinguish the critical path, and the specific factors affecting the progress and cost of the construction process are analyzed, and the indexes can effectively reflect the actual situation of the project. On the basis of precise analysis of the causes of deviation, targeted corrective measures are proposed to realize the construction of the whole chain evaluation and corrective system of the Earned Value Method. Finally, taking the F project as an example, the BIM-based schedule optimization and the Earned Value Method evaluation method of distinguishing the critical path proposed in this paper are applied to project management.

2. Civil engineering project management model based on BIM technology

2.1. General idea of BIM-based cost-schedule control methodology

The general idea of the cost-schedule control method based on the BIM platform is shown in Figure 1. The overall idea is to combine the information technology with the critical path earned value method, and the whole idea can be divided into several pieces of content:

1) BIM-based cost costing: for the existing drawings, a three-dimensional BIM model is established, which integrates the material and information parameters of the sub-projects, and when the modeling is completed, it is able to export all the engineering quantities of the whole project. According to the exported quantities can complete the cost calculation of each sub-project, so as to realize the integration of cost in the BIM model.

2) Scientific and reasonable plan planning: the establishment of BIM model provides the basis for the formulation of schedule plan, combined with the sub-projects, through the WBS work decomposition, according to the experience of engineers on the corresponding sub-projects for the scheduling of the work period, and find the critical path. Among them, the critical path practically

affects the cost and schedule of the project, while the non-critical path does not affect the overall schedule under certain conditions. Based on the established construction plan, the BIM platform is used to simulate the construction process, find unreasonable nodes and optimize them to achieve the final construction plan. Combined with the aforementioned 3D modeling and engineering costs it forms the BIM5D model.

3)Accurate information collection: Collect and enter the information of each sub-component in the process of project implementation, including key parameters such as actual cost, incurred cost, actual progress, etc., to provide a basis for the evaluation of the earned value method.

4) Parameter analysis of the integrated platform: establish the evaluation system of the earned value method that distinguishes the critical path and evaluate it, and give the corresponding evaluation results according to the size of different evaluation indexes.

5) Targeted corrective measures: According to the numerical size of the evaluation indexes of the Earned Value Method, combined with the evaluation of the critical path links, analyze the important reasons for the deviation of each link and summarize them. Then, targeted corrective measures will be proposed for the critical links with significant impacts.

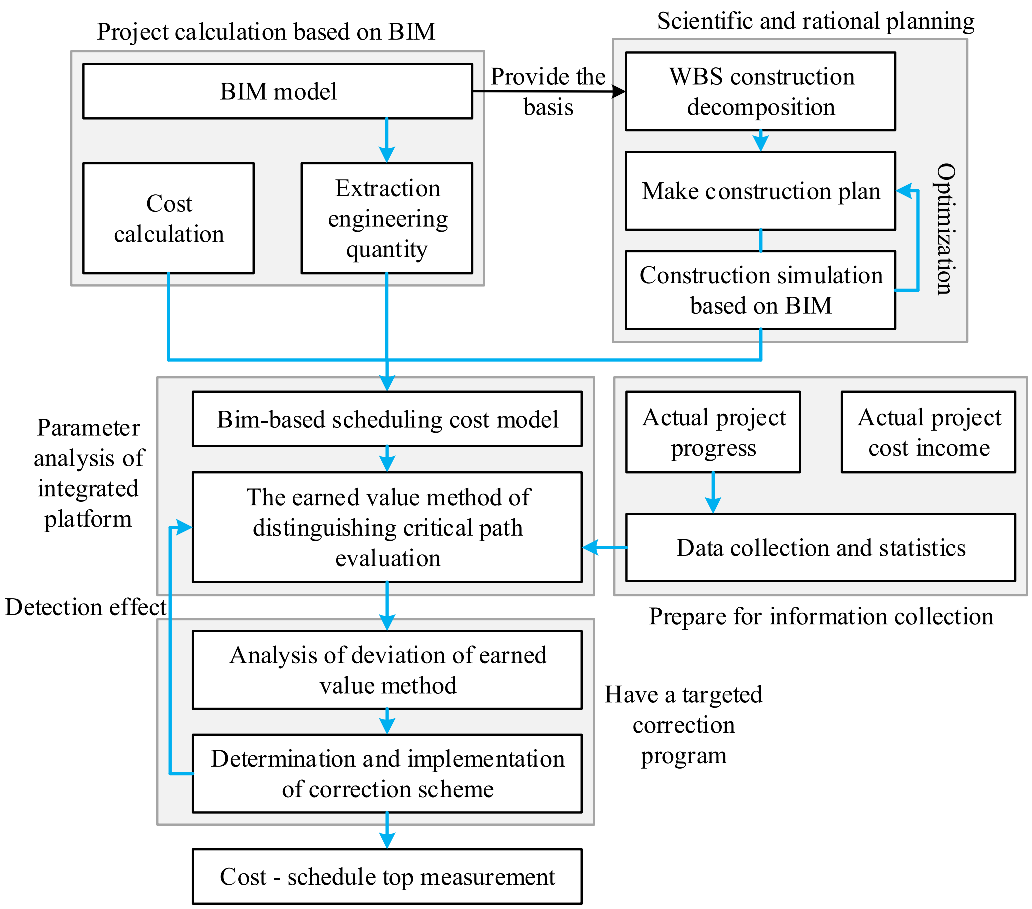

Fig. 1. The overall idea of the cost of BIM platform

Therefore, the whole idea is to establish a cost-schedule control method of “cost-schedule model based on BIM5D, cost-schedule evaluation based on the earned value method, and corrective analysis and measures considering multiple factors”.

2.2. *BIM5D platform model*

2.2.1. Theory and realization of the BIM5D platform. BIM5D platform is based on the original three-dimensional model, integrating two dimensions of project cost information and schedule information. The BIM5D platform not only integrates all the information of the architectural design process, but also integrates the information of the project implementation process, which can be combined with the information technology to rationally organize and control the construction plan, construction cost and resource deployment.

The BIM5D model can be associated with cost budgets, contract budgets, etc. The process of creating the BIM5D model is shown in Figure 2:

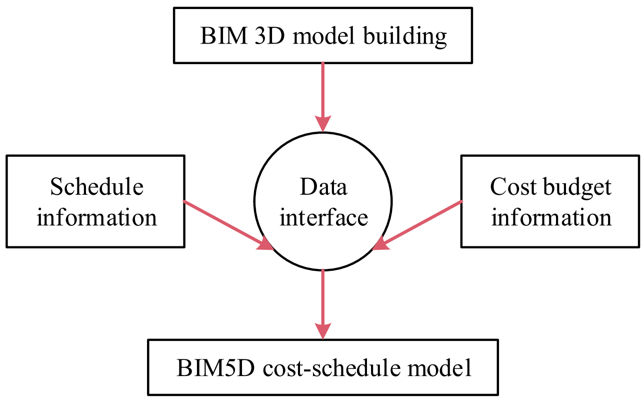

Fig. 2. The bim5d model creation process

2.2.2. Establishment of BIM 3D models. First of all, import the drawings in Revit software, and organize and analyze the drawings, especially to unify the datum coordinates of each profession, etc., so as to facilitate the synthesis of the models of each profession afterwards. Then, start the modeling process including civil model, electromechanical model, curtain wall model, steel structure model, etc. The modeling process is mainly through the identification of building components (including columns, walls, beams, panels, windows, doors), and imported into the corresponding family library modeling. Each layer of the model is built one by one until the whole building model is completed and can be formed into a rendering.

In the process of creating the model, add relevant information such as material material, model, and dosage. After the BIM 3D simulation is completed, the project's quantity can be exported through the BIM model, which provides convenience for cost estimation and eliminates the work of engineers who calculate the quantity according to the drawings in the traditional practice. At the same time, the 3D model can also facilitate the establishment of a digital twin of the smart building in the operation and maintenance phase of the building.

2.2.3. BIM model-based schedule construction. The creation of schedule plan based on BIM model contains three parts: 1) decompose the construction process and flow segments to determine the required manpower, machinery, materials, and duration; 2) determine the critical paths and non-critical paths, and prepare the schedule plan; and 3) import the BIM for construction simulation, and complete the adjustments and refinements to the project schedule plan.

2.2.4. BIM information collection during the construction process. Data collection and analysis in the design phase, construction phase, and operation and maintenance phase during the whole life cycle of a building can be realized on the BIM platform. In the research scope of this paper, only the information collection in the design phase and the information collection in the construction phase are involved.

The information collection in the design phase is actually the information collection of the model, and the relevant information collection has been completed in the process of modeling. The collection in the construction phase includes construction progress, budget cost, quality and safety. During the construction process, the different information mentioned above is imported in a timely manner, and the built-in calculation and analysis module in the BIM software will classify and analyze the entered information. In the actual process, the progress is often easy to get out of the plan and can not be accurately executed, the application of BIM technology for progress control to provide more timely and effective information support, prompting the engineering staff to drawings, programs, engineering characteristics of the understanding of a more intuitive and clear.

2.3. Critical path earned value method model

2.3.1. Earned value method:

1) Three parameters of the earned value method

(1) Budgeted Cost of Planned Work. The budgeted cost of planned work, abbreviated as BCWS, i.e., the cost target, needs to be derived from a pre-estimate of the total cost required at each point in time according to a running program. The formula is shown in (1):

$$BCWS = \text{Planned workload} \times \text{Estimated unit price} \tag{1}$$

(2) Budgeted Cost of Work Performed. The budgeted cost of completed work is abbreviated as BCWP, which is also commonly known as earned value. Refers to the actual operation of the process of a point in time has been completed, according to the ratio of actual workload and budgeted workload, the total amount of funds should be spent to calculate the budget as a standard when the work has been completed. The formula is shown in (2):

$$BCWP = \text{Completed work} \times \text{Estimated unit price} \tag{2}$$

(3) Actual Cost of Work Performed (ACWP). Actual Cost of Work Performed, or ACWP for short, is the total amount actually spent on completed work by a certain point in time. The formula is shown in (3):

$$ACWP = \text{Completed work} \times \text{Actual unit price} \tag{3}$$

2) The four evaluation indicators of the earned value method:

$$CV = BCWP - ACWP \tag{4}$$

Based on the above three parameters, four evaluation indicators of the earned value method can be defined, and the four evaluation indicators are as follows:

(1) Cost deviation indicator. Cost deviation, abbreviated as CV, is used to indicate the difference between the target cost quota and the actual cost spent. The calculation formula is shown in (5):

$$CV = BCWP - ACWP \tag{5}$$

When CV is negative, the actual cost is higher than the budget, indicating cost overrun; when CV is positive, the actual cost is lower than the budget, indicating cost savings.

(2) Progress Deviation Indicator. Progress deviation, abbreviated as SV, is an indicator to measure the actual running progress. The calculation formula is shown in (6):

$$SV = BCWP - BCWS \tag{6}$$

When SV is negative, the actual running progress is lower than the planned progress, indicating that the progress is lagging behind; when SV is positive, the actual running progress is higher than the expected progress, indicating that the progress is ahead of schedule.

(3) Cost Performance Indicator. Cost performance is abbreviated as CPI, which can reflect the actual efficiency of cost utilization. The calculation formula is shown in (7):

$$CPI = BCWP / ACWP \tag{7}$$

When CPI is equal to 1, the actual consumption cost is equal to the projected cost and there is no savings or cost overrun; when CPI is less than 1, the actual consumption cost is greater than the projected cost, indicating cost overrun; when CPI is greater than 1, the actual consumption cost is less than the projected cost, indicating cost savings.

(4) Progress Performance Index. Progress performance, abbreviated as SPI, reflects the actual running progress. The calculation formula is shown in (8):

$$SPI = BCWP / BCWS \tag{8}$$

When SPI is equal to 1, the actual running progress is consistent with the expectation, and the progress is neither ahead nor behind; when SPI is less than 1, the actual running progress is slower than the expectation, indicating that the current progress is lagging; when SPI is greater than 1, the actual running progress is faster than the expectation, indicating that the current progress is ahead.

3) Earned value method predictor variables. According to the basic parameters and indicators of the earned value method, the cost and duration of project completion can be estimated.

(1) Estimated Completion Cost. Estimated Completion Cost, abbreviated as EAC, represents the estimated completion cost of the project when the project runs according to the current status until the project is completed and the project is finished. The calculation formula is shown in (9):

$$BAC = BAC / CPI \tag{9}$$

where BAC is the total planned cost of the project.

(2) Estimated Days to Completion. The Estimated Days to Completion, abbreviated as ETTC, represents the estimated number of days to completion when the project runs according to the current status until the project is completed and the project is closed. The formula is shown in (10):

$$ETTC = OD / SPI \tag{10}$$

where OD is the planned duration of the project.

4) Advantages and disadvantages of the earned value method. Earned value method has the advantages of real-time reflection of operation and simultaneous control of schedule and cost, but also has the disadvantage of not distinguishing the critical path. Earned value method is based on the overall research and analysis, so it ignores the consideration of the individual work packages and their interrelationships, and the progress of the individual work packages can not be faithfully reflected, and the core of the cost control lies in the deviation of the critical path, which will have a direct impact on the subsequent operation, and the Earned value method does not focus on the control of the deviation of the critical path, which may result in inappropriate corrective measures, affecting the operation [21].

2.3.2. Critical path method:

1) The basic model of the critical path method. The most optimistic time, the most pessimistic time, and the most probable time are the three critical factors to be applied in this estimation process, which we record as a, b, and m, respectively, and then the expected completion time of the activity is calculated as follows:

$$ET(i,j)=\frac{a+4m+b}{6} \tag{11}$$

The variance is:

$$\sigma^2=(\frac{b-q}{6})^2 \tag{12}$$

There is no correlation between the durations of each activity, so the sum of all the critical activity times on the critical path is the total project duration.If there are n critical activities in the project, the total project work is expressed as follows:

$$T_s=\sum_i^N \frac{a_i+4m_i+b_i}{6} \tag{13}$$

Expression that satisfies the variance expression of:

$$\sigma_E^2=\sum_i^N (\frac{b_i-a_i}{6})^2 \tag{14}$$

So the total project hours T is a random variable. The probability that the project will be completed on time can be calculated by integrating the normal distribution:

$$P(T\le SD)=\int_{-\infty}^{SD} N(T_E,\sigma_E^2)dt=\int_{-\infty}^{SD-T_E} N(0,1)dt \tag{15}$$

2) Steps of the critical path method

(1) Draw a network diagram, events are labeled using nodes, and operations are represented by arrows, so that the entire project can have an overall overview, and in general, the project starts on the left and ends on the right [22].

(2) The duration (T) of each job is labeled above the arrows.

(3) Starting from the left, for each job the earliest finish time (EF) is calculated, which is the sum of the earliest possible start (ES) and the duration of the job.

(4) After all the calculations are done, the final calculated time is the time needed to complete the entire project.

(5) Starting from the right, the latest finish time (LF) for each job is determined based on the duration of the entire project.

(6) From the right, the latest finish time (LF) for each job is determined by the duration of the entire project.

(7) The latest start time (LS) is equal to the latest finish time minus the duration of the job.

(8) The time difference for each job is the difference between the latest and earliest end time or the difference between the latest and earliest start time for that job.

(9) If the time difference of a job is zero, it means that the job is on the critical route.

(10) The route where the time difference of all operations is zero is the critical route of the project.

2.3.3. Critical path earned value approach. Critical path earned value method is the optimization of earned value method, which is the cost control method that applies earned value method for cost control while deviation analysis is carried out on critical path and non-critical path respectively [23]. That is to say, the critical path earned value method is based on the earned value method and introduces the critical path method to consider the performance execution status on the critical path for cost and schedule control.

In addition to the three basic parameters of the earned value method, two other parameters are introduced, i.e., BCWPcp and BCWScp, where BCWPcp refers to the total amount of money consumed in terms of the budget for the completed work on the critical path; and similarly BCWScp refers to the budgeted cost on the critical path. The above parameters can be used to calculate the deviation metrics for the critical path schedule. The formula is shown in (16):

$$SVcp = BCWPcp - BCWScp \tag{16}$$

2.4. Steps in applying the critical path earned value method

2.4.1. Preparation of WBS work structure breakdown diagrams. For engineering projects, the vast majority of them are extremely complex, therefore, before the start of the project construction, the first need to make a certain split on the construction content, that is, the construction of the work structure decomposition diagram (WBS). Its role is to achieve a more rationalized division of the project structure, so that the responsibilities of various departments have a clearer division. In the WBS, the corresponding tasks are independent of each other and easy to manage and measure. For the preparation of the work structure, it can be decomposed based on the results or processes.

2.4.2. Establishment of benchmarks for earned value measurements. The analysis of the project progress and the corresponding cost utilization mainly relies on the Earned Value Measurement Benchmark for evaluation. With the help of earned value measurement benchmarks, more scientific and objective data can be obtained, thus making the project construction initial plan investment costs, budgets, and the corresponding actual consumption costs can be better compared, thus realizing the effective management of costs.

2.4.3. Determine the critical path of the operational process. The main methods for solving the critical path are as follows:

1) According to the idea of drawing a network diagram and the relationship between the activities of a project, the network diagram of a project can be obtained;

2) Calculate the node and activity time

The starting time corresponding to each work starting at this node can be expressed using ET(a). Denote the start time at the first node as 0. For the start times corresponding to the other nodes, the calculation equation is:

$$ET(b) = \max\{ET(a) + t(a,b)\} \tag{17}$$

Generally speaking, for nodes at terminals, their corresponding latest start time is in essence the same as the start time, i.e., LT(n) = ET(n). Where n denotes the terminal node. For other nodes at the corresponding latest time is calculated as follows:

$$LT(a) = \min\{LT(b) - t(a,b)\} \tag{18}$$

For the activity, there exists ES(a, b) = ET(a). The earliest end time is denoted by EF(a, b), which is calculated as follows:

$$EF(a,b) = ET(a) + t(a,b) \tag{19}$$

For the latest ending time of the activity, which corresponds to the prerequisite of not being able to impede subsequent work, and LF(a, b) = LT(b), which can be expressed using LS(a, b), the calculation of this value is as follows:

$$LS(a,b) = LT(b) - t(a,b) \tag{20}$$

2.4.4. Calculation of project earned value indicators. Earned value management can be effective if the planned budget, actual budget, and actual construction expenditures for a project are close to each other. However, when evaluating project progress and cost deviations, it is important to look at both the critical and non-critical paths.

2.4.5. Analyzing the factors influencing bias and the level of importance. For managers, it must be able to effectively grasp the extent of the impact of various factors on the deviation, which can help them to enhance the effective control of costs, while contributing to the enhancement of their own management capabilities.

In this paper, the process of analyzing the degree of influence of various factors is as follows:

First, the content to be evaluated for the corresponding split, and then divided into different evaluation indicators. For the same level of indicators, in essence, will be affected by the upper level of indicators, and at the same time, will also be governed by the lower level of indicators. Through this relationship, the corresponding hierarchical model can be constructed.

Next, the relative importance of the indicators is determined: if the corresponding benchmark is M, then for elements x_{k-1} and x_k, the corresponding ratio of importance is w_{k-1}/w_k, denoted r_k, and the corresponding values can be found. Subsequently, the weights of the influencing factors are determined.

2.4.6. Adoption of corrective measures. For the internal management of the enterprise, in order to realize the effective management of the project cost, it is necessary to use the earned value analysis can be realized. According to the earned value analysis, can determine the reasons for the project schedule deviation, and then develop a more feasible solution, so that the corresponding earned value curve and cost curve can be carried out according to plan.

3. Application of the civil engineering project management model

3.1. Basic overview of civil engineering projects

Project F decoration project is a company headquarters office building renovation project, the project is located in Fengtai District, Beijing Fengtai Park Industrial Base, with a total construction area of 15058 square meters. 2021 April 6, started, completed on December 26, 2021, the total construction period of 265 days. The construction area of this project is relatively large, time is tight, the task is heavy, the distribution of functional zones on each level is many, the process is complex and different from other projects, only by adopting advanced cost and schedule control methods can we ensure that the project is successfully completed and reach a certain profit margin under the premise of ensuring the quality of the project.

In order to maximize the profit, the critical path earned value method based on BIM technology is introduced into the F project for cost control, which is intended to solve the following three problems. First, to improve the company's cost management system, and further improve the cost control awareness of all employees, and enhance the cost control level of the enterprise. The second is to construct the company's scientific and effective cost and schedule control methods to save costs in order to improve the company's economic efficiency and competitiveness. Finally, it solves the problem that cost control and progress control of engineering projects are detached from each other, reduces the potential risk of cost and expense control, and proposes reasonable and feasible management means for cost control.

3.2. Critical Path Earned Value Methodology for Project Implementation

3.2.1. Decomposition of project work structure. This paper decomposes the work of F project, based on the process of decoration and renovation, according to the construction drawings, construction organization design, construction plan and the organizational structure of the project department, decompose each subsection into several work packages in accordance with the project construction sequence and project construction requirements, and take the original cost of each work package as the accounting data.F finishing project mainly consists of six major parts: indoor decoration work, electrical work, water supply and drainage work, and weak power work. , fire-fighting works, air-conditioning and ventilation works and weak electricity works are composed of six major parts. On this basis, each sub-project is divided into a number of work packages, so that the responsibility of each work package is put in place.

3.2.2. Critical path of the project. Before calculating the critical path of Project F, the detailed planned duration is organized based on the collected information, as shown in Table 1.

Table 1. Planned duration of F engineering project

Specific project (working package)	Planned period
Light steel keel partition	2022.04.06-04.25
Toilet supply and drainage pipeline laying	2022.04.26-05.23
Electrical engineering	2022.05.17-06.23
Fire protection engineering	2022.04.26-05.20
Air conditioning ventilation engineering	2022.05.03-06.09
Weak current engineering	2022.06.07-06.27
Ceiling light steel keel installation	2022.07.01-08.27
Wall top emulsion engineering	2022.06.03-06.23
The toilet is waterproof and the basic level is made	2022.06.10-06.30
The toilet is waterproof and the basic level is made	2022.07.01-07.21
The ground water mud mortar leveling	2022.07.22-08.25
Wall floor glass tile	2022.08.26-09.06
Ceiling erection	2022.08.21-09.10
Wall panel installation project	2022.09.08-09.14
Wooden door installation	2022.06.10-09.22
PVC glue	2022.09.11-10.10
Stainless steel kick installation	2022.09.15-10.05
Air conditioning	2022.10.01-10.14
Fire protection terminal installation	2022.10.15-10.28
Sanitary ware installation	2022.10.29-11.07
Toilet partition installation	2022.11.08-11.18
Electrical switch socket and lamp installation	2022.10.29-11.11

Then, according to the work structure decomposition diagram and construction sequence of F finishing project, the logical relationship of different work packages was considered comprehensively, and the work relationship table of F finishing project was summarized, as shown in Table 2.

Table 2. Work relationship table of project F

Job code	Working package	Tight work	Duration(day)
A	Light steel keel partition		20
B	Toilet supply and drainage pipeline laying		28
C	Electrical engineering	B	38
D	Fire protection engineering	B	25
E	Air conditioning ventilation engineering	A	25
F	Weak current engineering	C	38
G	Ceiling light steel keel installation	C	21
H	Wall top emulsion engineering	D	58
I	The toilet is waterproof and the basic level is made	D	21
J	The toilet is waterproof and the basic level is made	E	21
K	The ground water mud mortar leveling	F	12
L	Wall floor glass tile	G	21
M	Ceiling erection	H	105
N	Wall panel installation project	I	30
O	Wooden door installation	J	14

P	PVC glue	J	14
Q	Stainless steel kick installation	O	30
R	Air conditioning	K	21
S	Fire protection terminal installation	M	14
T	Sanitary ware installation	N	14
U	Toilet partition installation	P	14
V	Electrical switch socket and lamp installation	L, U, S, T, Q, P	38

Through the work relationship table, the duration and logical relationship of each process can be understood in detail, and according to the principle of drawing network plan diagram, the network plan diagram of F project is drawn, and the route consisting of the work with zero time difference is the critical path. Through the network plan diagram of Project F, the critical path of Project F is derived as shown in Figure 3.

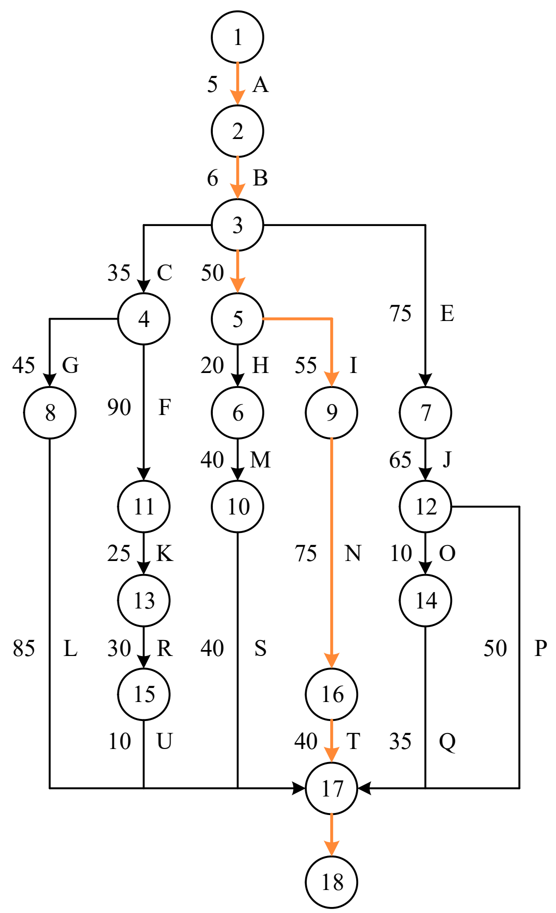

Fig. 3. Project F project network plan

3.2.3. Preparation of project cost budgets. For F finishing project, its budgeted cost consists of direct cost, indirect cost and other expenses. Due to the introduction of the critical path earned value method to implement cost control for architectural decoration projects, it mainly refers to the direct cost control of the project. And the direct cost mainly consists of four parts, which are labor cost, material cost, machinery cost and other costs, and at the same time, the budgeted cost allocated to each work package also consists of labor, material, machinery and other costs. Based on this, the cost budget of Project F is shown in Table 3.

Table 3. Budget cost sheet(Unit: yuan)

Project	Labor cost	Materials cost	Mechanical charge	Other expenses	Total
A	73458	0	505490	3492	582440
B	40456	205508	19298	3877	269139
C	435933	0	45856	2780	484569
D	755272	1006990	0	5016	1767278
E	671743	818919	0	7491	1498153
F	1118910	461131	0	4910	1584951
G	561030	190723	0	3834	755587
H	299713	3098374	0	1741	3399828
I	575947	1819887	0	5427	2401261
J	836683	2546954	0	6438	3390075
K	310539	908016	0	2421	1220976
L	1280469	5020343	305736	12399	6618947
M	754438	1082444	38043	3952	1878877
N	1022183	1504458	0	8282	2534923
O	61882	804340	0	772	866994
P	449182	349220	57783	5622	861807
Q	209207	0	165571	3707	378485
R	54354	2478302	301080	3643	2837379
S	576486	1478670	59334	3421	2117911
T	329048	2346858	0	4250	2680156
U	92377	667547	37702	977	798603
V	99531	0	0	1222	100753
Total	10608800	26788700	1535893	95674	39029100

3.2.4. Calculating Earned Value Parameters for Critical Paths. BCWS refers to the calculation of the budgeted cost of planned work. This calculation is mainly based on the previously established project network plan diagram, the entire project according to a certain period of time, such as monthly, weekly and other spans of the amount of work for the calculation of the budget cost. The result of the calculation gets the project cost budget table, through which we can clearly understand which month's workload accounts for how much, which month needs to strengthen the management of the project, etc., and the cost budget table is also the basic data for the later calculation of earned value management.

By reintegrating and calculating the project budget from the cost table in Table 3, and combining the logical relationship of each work package in the network plan diagram in Figure 3 to establish the benchmark for earned value measurement (BCWS), the specific cost budget situation is shown in Table 4.

Table 4. F project 2022.4-2022.november BCWS(Unit: yuan)

Parameter	Working package	April	May	June	July	August	September	October	November
BCWS	A	544712							
	B	246311							
	C	254527	190981						
	D	667651	989762						
	E	355241	591468	591527					
	F		224451	527681	510098	241891			
	G		215984	511674					
	H			3226727					
	I			1178452	1171252				
	J			2197684	1245321	1421634			
	K					743571	440748		
	L				2142208	2287542	1870235		
	M			445121	1521174				
	N				157851	1043228	1109231	221246	
	O			851255					
	P						516893	297842	
	Q						209765	145542	
	R						1947897	737687	
	S					1465432	455792		
	T							1423312	971689
	U							786732	
	V								113583
Accumulated		2068442	2212646	9530121	6747904	703298	6550561	3612361	1085272

BCWP (budgeted cost of completed work) = completed workload * budgeted unit price, decorative engineering projects to determine the completed workload generally use the percentage of completion method, the project manager according to the scientific method of engineering construction statistics and the actual situation of the project, the actual construction workload is accounted for and multiplied by the budgeted amount, the result of the budgeted cost of completed work BCWP.

ACWP (actual cost of completed work) = actual completed workload * actual unit price, the actual project members of the project department rigorous and serious statistics construction team attendance, machinery and equipment utilization, material usage, etc., and from the accounting point of view of the workers' payroll, materials purchase list, materials warehousing list, machinery and equipment purchase and lease documents, etc., based on these original documents and statistical tables to calculate the actual completed workload. The actual amount of work accomplished is calculated from these original documents and statistical forms.

Variance indicators as long as the project cost variance (CV) and project progress variance (SV), cost and progress are the two main indicators of cost and expense control, the specific formula: CV = BCWP - ACWP, SV = BCWP - BCWS), when the CV is greater than 0, indicating that the actual cost exceeds the budgeted cost, the cost of control is poorly executed, and need to be corrected in a timely manner; on the contrary, it means that the effect is good; When SV is less than 0, it indicates that the actual project progress is less than the planned project progress, and it is necessary to pay attention to the causes of progress delay in time; conversely, it indicates that the progress is ahead of schedule. By organizing the data from April to August 2022, the earned value report is now organized as shown in Table 5-Table 8.

Through the comprehensive analysis of several tables, we can see that the cost deviation from April to August is greater than 0, which indicates that the project cost control effect is better, the actual cost is lower than the planned cost, and the project cost management work is in place, but in December there is a cost deviation of less than 0, which indicates that the cost consumption is greater than the cost of the planned budget, which needs to be paid attention to. Through the analysis in the field, it was found that the reason for the increase in cost may be due to the increase in the price of materials, the daily maintenance of machinery and the dispatching of the use of not planned in advance, the low utilization rate of materials and other reasons, for the deviation of the data shown by the project management staff to timely identify the problem and put forward measures to solve it.

Table 5. F project 2022.4-2022.8 BCWP(Unit: yuan)

Parameter	Working package	April	May	June	July	August
BCWP	A	623714				
	B	281087				
	C	250087	213219			
	D	664788	105450			
	E	377027	377517	585521		
	F		231093	545213	520212	254565
	G		219466	513462		
	H			3355914		
	I			1310136	1038381	
	J			194253	15807954	1558851
	K					780399
	L				2280145	2456047
	M			465768	1430121	
	N				156631	1017172
	O			855746		
	P					
	Q					
	R					
	S					1631118
Total		2196703	1146745	7826013	21233444	7698152

Table 6. F project 2022.4-2022.8 ACWP(Unit: yuan)

Parameter	Working package	April	May	June	July	August
ACWP	A	610427				
	B	286497				
	C	152687	242043			
	D	654263	102051			
	E	387473	533099	603524		
	F		40390	40097	419942	232591
	G		8628	487060		
	H			3389619		
	I			1283642	937982	
	J			190076	16171627	1536877

	K					758425
	L				2283804	2434073
	M			475374	19509	
	N				54115	995198
	O			838340		
	P					
	Q					
	R					
	S					1609144
Total		2091347	926211	7307732	19886979	7566308

Table 7. F project 2022.4-2022.8 SV(Unit: yuan)

Parameter	Working package	April	May	June	July	August
SV	A	51951				
	B	21147				
	C	0	5738			
	D	5960	-976767			
	E	10643	-10734	-10676		
	F		-1200	12547		
	G		-1083	6799	-512355	-154565
	H			-67215	0	1647864
	I			14687	1160165	110987
	J			0	1.48367E7	1680825
	K			0	-1455292	-716017
	L			0	2401929	1794470
	M			8990	-185888	-2304733
	N				-1134343	1139446
	O				-58324	-938155
	P				-512355	-154565
	Q					
	R					
	S					1578324
	T					-1488571
	U					0
	V					0
Total		89701	-984046	-34868	14540200	2195310

Table 8. The f project is 2022.4-2022.8 CV(Unit: yuan)

Parameter	Working package	April	May	June	July	August
CV	A	14055				0
	B	-4642				0
	C	98168	-30102			0
	D	11293	2121			0
	E	-9678	39923	-16432		0
	F		1176	506687	-1971	-11673
	G		3397	27973	0	0
	H			-32134	0	0
	I			28065	-1842	0
	J			5688	-465914	-14527

	K				0	6741
	L				-105900	-117751
	M			-8035	1308371	0
	N				-7842	-49311
	O			18977		0
	P					0
	Q					0
	R					0
	S					-45312
	T					0
	U					0
	V					0
Total		109196	16515	530789	724902	-231833

3.2.5. Deviation analysis:

1) Analyze the reasons for cost deviations. Through the process of tracking and monitoring of the project, we found that the F work package on the critical path has produced a negative earned value, and we analyzed the F work and found that it was mainly due to the rise in materials, machinery and equipment cost overruns and other reasons. Due to the large demand for stone in the F project, and the need for time is urgent, coupled with the rise in market prices caused by the increase in material costs, and due to the inaccurate grasp of the progress of the project caused by the early leasing of machinery and equipment, but due to the materials and other preparatory work is not done, resulting in the utilization of machinery and equipment is low, resulting in an increase in costs.

2) A brief analysis of progress management deviations. There are different degrees of deviations in both non-critical path and critical path for progress deviation. For the deviation in the non-critical path due to the deviation value is not large, and does not exceed the overall project to its maneuvering time, so you can not do too much attention, but should always pay attention to not delay more than the maneuvering time. For the T-work packages on the critical path, the reason was due to rework because the suppliers of the materials were not up to standard and did not meet the owner's requirements.

3.3. Results of implementing BIM + Critical Path Earned Value Approach

Through the calculation, after the implementation of the critical path earned value method in Project F, there is a significant improvement and enhancement on the cost and schedule of the project, based on the results of the cost comparison between the critical path earned value method and the traditional method as shown in Table 9.

It can be seen from the data that if the management implements corrective measures in time, the cost and schedule can be effectively controlled in time. From the above comparison chart, it can be seen that after the implementation of the critical path earned value method, we have different degrees of cost savings in labor cost, material cost and machinery cost. The actual cost is reduced by 7,969,747.57 yuan compared with the budget, of which the labor cost is reduced by 7,666,697.89 yuan compared with the budget, which is a larger amount. The material cost is reduced by 5753555.48 yuan compared with the budget, the mechanical cost is reduced by 93.9%, and other costs are reduced by about 6%, and the project is completed on time, accomplishing the project cost management objectives, which indicates that the critical path earned value method based on BIM technology can significantly improve the civil engineering project management effect.

Table 9. Cost comparison

	Labor cost	Material cost	Mechanical cost	Other expenses	Total
Cost sheet method	10608800	26788700	1535893	95674	39029100
Critical path earning method	9842102.11	21035144.52	92578.5	89527.3	31059352.43

4. Conclusion

This paper combines BIM technology and critical path earned value method to solve the problems of traditional earned value method applied in civil engineering project engineering, and establishes a complete set of dynamic cost analysis method which contains planning, process evaluation and result correction. Through typical engineering cases, the BIM-based schedule optimization and the earned value method of distinguishing the critical path proposed in this paper are applied to project management. The application results show that the actual cost is reduced by 7969747.57 yuan compared with the budget, of which the labor cost is reduced by 766697.89 yuan compared with the budget, which is a large amount of cost reduction. It confirms that the critical path earned value method based on BIM technology can reasonably and effectively synchronize the cost and schedule control of the project, showing that this method is a scientific and efficient management method. Distinguishing between the critical path and non-critical path has a very important role in cost project management, and is also conducive to project managers to carry out an overall analysis from a global perspective, and quickly make a good understanding of the work priorities of the entire project.

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