Study of Construction Optimization and Dynamic Management of Building Engineering Based on BIM5D

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Abstract. Traditional building engineering has a large amount of information and lacks communication among professions, so the construction management mode based on BIM becomes the key to engineering construction. According to the characteristics and shortages of the traditional building engineering, and based on the development of BIM technology and the basic idea of BIM 5D technology, As an example in teaching experiment complex building, it is feasible that construction optimization and dynamic management of construction process based on BIM 5D by the analysis of the model integration, construction segment division, schedule optimization, cost monitoring and quality racking. Finally, it summarized and analyzed the existing obstacles of BIM 5D in the process of technology application, and provided reference for the construction enterprises to promote the application of BIM technology.

Introduction

With the development of urbanization in China, the innovation of large scale building is highly demanded, and new type construction, such as green architecture, artistic architecture and intelligent building, has been an important development trend. However, construction enterprises are faced with opportunities and challenges at the same time due to the drawback traditional construction technology, communication barriers among different professionals and low efficiency of construction. Therefore, the new normal development of construction enterprises is the general trend, and these enterprises have urgent demand for transformation and upgrades. With the improvement of information technology, construction enterprises have broken the traditional technology modes, ushering in a new era of “BIM technology”.

BIM is known as the Building Information Model, while the BIM 5D is based on the 3D with “schedule dimension” and “cost dimension”. According to the data investigation of The Business Value of BIM in China, there are 44% of construction enterprises in medium level of application of BIM technology in our country (applied to 15%-30% of the whole project), and 31% of those make use of BIM less than 15% of all projects throughout the year (Xiong, 2016). It proves that the application of BIM technology is still in the early stage in our country. Researching the construction optimization and dynamic management of construction process based on BIM 5D, this paper is beneficial to construction enterprises with examples by introducing the application of “schedule information” and “cost information” based on BIM 5D. Therefore, the application of BIM technology has become an imperative requirement for construction enterprises in order to realize BIM technology serving the life cycle of construction project.
Construction Status of Traditional Buildings

Lack of Cooperation between Different Professionals

Engineering construction is a dynamic process, involving a large number of professionals. There are various problems, such as cross-construction, uncoordinated organization and conflicts detection, caused by point-to-point communication among different professionals. And these problems caused the lack of information transmission and information isolated island phenomenon (Hu, 2015), which has an adverse influence on efficiency of construction.

Unable to Dynamically Control of Construction Schedule

It is difficult to identify the abstract traditional two-dimensional construction drawings, which would affect the whole construction schedule under constructors’ control. At the same time, using the traditional manual compute mode of resource consumption and drawing network diagram, Gantt chart and the forward line would bring about the mass consumption of labor and inexact calculations, and cannot show the dynamic process of construction. Besides, it is difficult to handle and correct the potential conflicts existing in construction schedule, which would lead to research misallocation and schedule delays.

Shortcoming of Construction Cost Management

The engineering project is normally divided into the decision-making stage and the implementation stage, and a large number of costs occurred in the construction stage, which is important in the implementation stage (Hu and Luo, 2011). Due to the long construction cycle, numerous participant enterprises, processing errors by manual handling and complicated cost analysis, etc, it is difficult for constructors to regulate and predict the cost of construction site in time, which would increase the project cost.

Low Controllability of Quality and Safety Problems

Quality and safety problem is the top priority in the construction process, particularly in terms of timely feedback and handling of quality and safety issues at the construction site (Niu, 2016). Traditional construction projects rely on conventional experience to predict a series of problems in projects, and exchange handling suggestion frequently. It can easily lead to rework because of the prediction errors, which would not only delay construction schedule but also increase the cost greatly.

Concept and Development

Development of BIM

In China, with the continuous development of scientific and technological information technology, BIM technology has led to the feature of “BIM +”. Engineering and construction enterprises introduced BIM technology in 2003, which was mainly applied by design enterprises. Although construction enterprises used this technology relatively late, it developed at a high speed (Li et al., 2014). Our country also gives energetic support to BIM technology. During “ the 12th Five-Year Plan”, <The Outline of 2011-2015 Construction Industry Informationization Development> issued by China’s Ministry of Housing and Urban-Rural Construction (MHURC) pointed out that the general goal of the construction informationization development is to realize the popularization and application of the construction enterprise information system, accelerate the application of BIM technology and other new technologies in engineering, and promote the construction of information standards(Pan and Zhao, 2012). Meanwhile, <Instruction on Promoting Application of Building Information Model ([2015] No. 159) published by Ministry of Housing and Urban-Rural Development determined the goal is to realize the integration applications of BIM technology and enterprise management systems and other information technology, which indicates the value of BIM technology in construction field in the future. In addition, BIM technology has been used in
the construction stage of some huge buildings in China, such as the Shanghai Tower, the Guangzhou Pearl River Tower, the Beijing Water Cube, the Concert Hall of Central Conservatory of Music and so forth. In a word, the construction application of BIM technology is still in a low level, which requires in-depth research and promotion.

**Concept of BIM 5D Technology**

Building Information Model was first proposed by Dr. Chuck Eastman of the Georgia Institute of Technology 30 years ago, he said, “The building information model synthesizes all of the geometric model information, functional requirements and building performance, and integrates all the information of a building’s entire lifecycle into a single building model, including construction progress, building process, maintenance management and other process information (He and Han, 2011).” The BIM technology developed from 1D to 5D gradually. BIM 1D refers to the original hand-painted stage; BIM 2D is an electronic simulation of hand drawing by using computer and currently design and construction drawings in the construction enterprises are used in 2D; BIM 3D is a three-dimensional information architecture model, including geometry, physics, function and performance; BIM 4D is based on the 3D with the addition of “schedule information”, presenting the formation process of the model by 3D, and optimizing and controlling the entire changing process (Wang et al., 2004); Based on BIM 4D, BIM 5D is combined with “cost information” to achieve real-time monitoring of the entire engineering cost and avoid the loss of benefits.

In conclusion, BIM 5D technology is the sum of 3D (solid model), 1D (schedule information) and 1D (cost information). It is the most complete information model of the construction stage and makes the pre-guiding construction come true. Compared with traditional BIM 3D technology, BIM 5D technology can meet the demand for engineering construction and management better and has brought unprecedented changes for construction enterprises. The building principal of BIM 5D is shown in Figure 1.

![Figure 1. Construction principle of BIM 5d.](image)

**Advantage of BIM 5D Technology**

**Multi-specialty Model Integration and Convenient Management.** Constructional engineering includes construction, structure, installation and other different professionals, and BIM 5D carries the information of those professionals and integrates a whole set of construction documents into databases. Building collaboration platform of different professionals by making use of BIM 5D technology can eliminate the incompatibilities of information from different professionals and realize information sharing among various professionals (Ren et al., 2011), which is convenient for unified management.

**Division of Construction Section and Convenient Operation.** According to the structural characteristics of the building and the site conditions, the model can be divided by using Glodon BIM 5D software. It is more convenient and efficient to calculate engineering quantities because component quantities and bill quantities can be extracted at any time. At the same time, decreasing the number of workers who divide sections can also avoid failed flow construction caused by inaccurate work of workers, unreasonable cross-process and other problems.
Schedule Optimization and Shorten the Construction Period. BIM 5D technology has great advantages in terms of controlling scheduled plan. Through capital curve and resources curve, the reasonability of scheduled plan can be illustrated more easily and it is more convenient to optimize and adjust unreasonable allocation. Meanwhile, we can control the construction progress, actual working conditions and the deviation between planning schedule and actual schedule through the dynamic simulation of construction, and take control method of dynamic loop to optimize and adjust scheduled plan and shorten the construction period.

Control Dynamically Cost and Improve Efficiency. Making use of information technology to integrate information into database accurately, BIM 5D technology creates the cost management platform and address the problem of cost summary. In addition, BIM 5D technology combines three-dimensional model with cost information in engineering project and is able to identify automatically and extract the cost of building components. During the construction simulation, realizing the dynamic control of engineering construction progress and cost is conducive for construction units to allocate the capital plan in real time.

Dynamic Management Application of BIM 5D in Construction

The paper takes a teaching comprehensive laboratory building as a project case, modeling and calculating the quantities by using Revit modeling, reinforcement calculation and civil engineering calculation, making bill of quantities by using Glodon Software, designing the layout of construction site by making use of three-dimensional site layout software and realizing the value of the whole project by using BIM 5D technology. The application process of software is shown as Figure 2 and this paper focuses on comprehensive application of BIM 5D software.

![Figure 2. The process of software application.](image-url)

The structure of the main building is a frame system with an area of 12998m², an east-west length of 95.20m, a north-south width of 57.05m, a six-story floor and a three-story local floor. This project has a long east-west span, a narrow work-yard and numerous participant units, which leads to chaotic management, difficulty in controlling cost and complex scheduling and many other problems. In order to implement the project successfully, the project mentioned above applied BIM 5D technology in the construction stage, gave priority to application together with model, and simulated construction in advance to achieve optimal control and dynamic management in construction stage. The main application is as follows.

Model Integration

The model integrated part of BIM 5D covers two modules: the one is the site model, including the site layout of foundation, the main body and the simple decoration these three stages; the other is entity model, namely, Revit three-dimensional information model, Glodon civil engineering calculation model and Reinforcement calculation model. Using BIM 5D technology to integrate the site model and entity model information is able to avoid the inconsistency among different professionals and realize information connection. The result of integrated model is shown as Figure 3.
Division of Construction Section

This project is divided according to the construction joints of the structure, takes the whole base layer as a construction section, and 1-3 layer is divided into three construction sections respectively, 4-6 layer is divided into two construction sections. The sequence of construction is from Area A → Area B → Area C, as shown in Figure 4.

On the basis of model integration, the model is divided into manageable working surface according to the division of flowing sections. On the one hand, there is no need to separately calculate the civil quantity and reinforcement quantity of area A, B and C, these three different areas, so it avoids the repeated calculation of engineering quantity caused by the conflicting flowing sections. On the other hand, showing visually the components quantity, the bill of quantity, quota of labor, goods and materials, etc. Each flowing section in this teaching experiment building is convenient for choosing the model components of construction section quickly in next step, which is related to scheduled plan, so it can help project staffs arrange construction plan reasonably and save time considerably.

Schedule Optimization

To realize continuous and balanced construction, according to quantity data provided by every flowing section and consumption quota of housing construction and decoration engineering, this project took technical measures of segmented flowing construction to schedule project progress plan. The workers made use of BIM 5D technology to combine divisory flowing section with the corresponding task items, which is called “attribute association”, and they gave schedule information to each component in the model to promote the link between progress and model.

Capital and resources is an important means to ensure the rational use of resources. On the one hand, this project is mainly based on the gentle degree of capital and resource curve to regulate and control optimized scheduled plan. Plan A schedules to set the duration of 235 working days, 145 people, the overall curve of capital and resources is relatively steep; Plan B schedules to set the duration of 197 working days, 174 people, and the capital and resources curve has a concentrated rise area; Plan C schedules to set the duration of 207 working days, 157 people, and the capital and resources curve keeps steady. In summary, Plan C’s financial and resources arrangement is reasonable and uniform, which saves construction cost and improves the utilization rate of
resources. As shown in figures, Figure 5 is the cumulative curve of planned capital and Figure 6 is the cumulative curve of planned resource. On the other hand, we can compare the construction simulation between plan and actual progress during the work process, which can visually display the project with time changes, find the tasks ahead of schedule and lag tasks and adjust the construction schedule and material arrangement in order to guide the subsequent work arrangements, to realize dynamic management and real-time monitoring of the whole project construction. Figure 7 is the project schedule bar chart.

![Figure 5. The cumulative curve of planned capital.](image1)

![Figure 6. The cumulative curve of planned resource.](image2)

![Figure 7. The project schedule bar chart.](image3)

**Cost Monitoring**

We can realize the real-time tracking comparison of cost through combining the budget results pricing software GBQ with budget and import function of BIM 5D. In this project, 135 matches are automatically matched in the list, among which, the two kinds of reinforced concrete square piles and concrete columns are matched manually so that the budget file can quickly select the component type.

The dynamic information database of cost can be constructed by linking the model nodes with the bill of quantities. It is convenient for the project managers to query the details of the sub-engineering fee, check the budgeted cost, actual budgeted cost and actual consumed cost of each flowing section in the “Capital Curve” according to the schedule and actual progress, and make statistical analysis the bias of progress and cost, to discover errors in time and take preventive measures (Zhang et al., 2011).
Quality Tracking
For the quality and safety problems in the three-dimensional model, we can link the model with the quality and safety problems in the construction site in order to facilitate all participants in to discuss and exchange opinions. In addition, by marking pictures, quality and safety problems and solutions, we can find out the quality and safety issues accurately, and realize real-time tracking of progress until the problem is resolved, which can ensure the construction to achieve high-quality and safe production according to its preset goals.

Obstacles of BIM 5D Technology Application

Need Improvement of BIM 5D Software
BIM 5D software needs to improve the functions constantly and complete the loopholes in order to better promoted and used. BIM 5D software is limited to the use of project in its planning progress, for example, Menglong, Hanwen, Pinming and other software cannot be linked with BIM 5D. BIM 5D software should integrate application with modification. In the construction progress of the simulation, Models of building and civil engineering that the site layout software of Glodon made were the same. It will need the site layout software to delete, which causes a lot of trouble.

High Cost of BIM 5D Software
BIM 5D software that Glodon developed has a high acquisition cost and a genuine software will cost hundreds of thousands of dollars. However, BIM is a unity of more than 10 different kinds of software. They function in BIM through the exchange of information and transmission and neither of them can be neglected. In addition, BIM 5D software has a high requirements on computer configuration, which increases the economic burden of the construction unit.

Change for Traditional View Hardly
The traditional architectural concept has been deeply rooted, but what the BIM 5D technology brought is the information transformation of the construction enterprise. Construction workers are accustomed to the traditional construction management mode. To accomplish the transformation of the mode completely need to relearn the BIM model. Sticking to the traditional way of thinking has become a major obstacle to the development of BIM 5D technology.

Lack of New Talents
BIM 5D technology requires comprehensive talents who have both the construction experience and good learning ability. Talent shortage is a major factor in the slow promotion of BIM 5D technology. Furthermore, the main focus of the domestic construction is on the construction project and the construction of professional personnel training is less, which is another major factor in the slow promotion of BIM 5D technology.

Conclusion
Through the study on the application of BIM 5D technology of the construction units in this research, construction enterprises should focus on the dynamic control of the entire construction schedule and cost, use simulation and optimization of construction and dynamic management by making use of data, and emphasize the application value of BIM 5D technology. It can be predicted that the secondary development of BIM technology is a necessary development trend in the future, facing the entire construction enterprises (Chen and Lai, 2015). This project can help to solve how to use BIM 5D technology for construction optimization and dynamic management. But for now, there are still some problems we need to solve in the process from BIM 3D to BIM 5D, in order to truly usher a new era of BIM 2.0.
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