

# Research on Construction Schedule Control Based on Critical Chain Method and BIM

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**Abstract:** Construction progress management is the core part of project management, but the effectiveness of construction progress management is still not satisfactory at present. Due to the large amount of computation, the lack of stereoscopic and visual management platform, the traditional progress control method is often deviated and lagged from the collection and sharing of the project information, which leads to the progress control work to be the weak point in the whole progress management. Based on BIM-4D technology and critical chain method, the paper constructs an information, visualization and dynamic construction schedule control system. The system includes three modules of 4D actual model management, key chain buffer zone monitoring and progress early warning, and innovating the method of construction project construction schedule management. It provides a good platform and technical support for the management and control of construction progress.

**Keywords:** BIM, Critical Chain Method, Buffer, Progress control

## INTRODUCTION

Construction progress management is the core link of project management, and plays a vital role in the success or failure of construction management. Although the theory and prevention of progress management are becoming more and more mature, the effectiveness of construction progress management is still not ideal. At present, the main methods of the project progress plan are the key path method, the plan evaluation technology and the key chain method. The first two methods only take into account the time factor of project schedule, while the key chain technology based on constraint theory takes into account human behavior factors and resource constraints. The buffer zone is established, which solves the problem of project schedule delay to a certain extent. The problem of project delay is solved to some extent [Wang, et. al., 2012]. In terms of progress control, the traditional control methods include S curve method, banana chart method, forward line method and horizontal road map method. The process is in the whole process of construction, the actual progress of the project and the schedule of the project is compared, if there is any deviation, it is necessary to take measures to adjust in time. In the past, the collection and sharing of project information often deviates and lags due to the large amount of computation, the lack of stereoscopic and visual management platform, which makes the progress control work a weak point in the whole progress management. With the development and wide application of information technology in construction industry, BIM-4D brings new opportunities for the management of construction progress.

However, at present, BIM-4D simulation is limited to pre construction planning stage, which is mainly used for simulation demonstration of construction plan and visual analysis tool for schedule planning. This restricts the application of 4D simulation in the construction phase. Therefore, based on the BIM-4D model that can run through the whole construction process, this paper proposes a BIM-4D actual model, which is different from the plan model, and simplifies the comparison between the actual progress and the schedule of the construction process in the construction process [Fang, et. al., 2017]. Then combined with the key chain technology, a construction project construction schedule control system, which includes three modules of 4D real model management, buffer zone monitoring and progress warning, is created [Wang, et. al., 2018].

## THE CREATION OF THE ACTUAL MODEL OF BIM-4D

The BIM-4D model consists of two parts: the 3D model and the critical chain schedule. A detailed and detailed activity partition and schedule is a key factor in implementing 4D simulation. The subdivided activities will be displayed in the 4D simulation, and the whole progress plan is the whole content that 4D simulation needs to show. In the preparation of the schedule, various factors such as the working space and working time need to be taken into consideration in order to compile the schedule which is in accordance with the logical order and the requirements of the construction process [Ji, et. al., 2014]. In addition, the activities of the progress plan correspond to the component objects of the 3D construction model. The process of assembling the

model components into the whole building according to the time information in the 3D visualization environment is the 4D simulation process by linking the completed schedule plan with the construction model.

BIM-4D actual model is a three-dimensional model that is consistent with the actual construction status of the construction project. The plan model is completed before the project construction, and the actual model is a dynamic development model designed to keep in sync with the actual progress of the project and requires continuous updating of the model in accordance with the actual progress of the project [Liu, et. al., 2013]. Along with the progress of the project, the information generated and gained is growing. New information needs new models to integrate and express. The actual model meets this requirement well, dynamically monitoring and updating the project implementation, so that it can accurately reflect the actual status of the project.

The actual construction needs to monitor the construction progress of the project site, collect the related data of the project progress, and update the BIM model on this basis, and integrate the actual progress information into the existing models to ensure the consistency of the current BIM model information and the growing project information. The creation of the actual model involves two processes: collecting field data and updating building models. Dynamic updating of real-time construction models is a difficult task. Although advanced technology tools provide a great deal of convenience for field data acquisition, data acquisition requires extra workers or ready-made workers to stop work on their hands. This process requires additional resource input. From the collection of field data to the transformation of BIM model is still a difficult task. The creation of BIM model is a monotonous, time-consuming and error prone work. Due to the actual construction information of the reaction project and the needs of the model based 4D simulation, the components of the real time construction model need to have enough detail, and the components need to be refined so that the progress activities can be linked, so the model is more complex. In addition, the construction of real time construction model is a dynamic process. It is necessary to integrate the collected field data into the model in time. It is necessary to continuously update the model. The process of artificial updating of the model needs more resources and manpower.

The 4D simulation application framework based on the actual model is shown in Figure 1. Unlike the 4D simulation based on the planning model, 4D simulation based on the actual model is a dynamic cycle process. The automatic updating technology of BIM model is used to complete the data acquisition of the completed construction site and update it to the BIM actual model automatically. Through the view of the real-time construction model in the three-dimensional view, it can be traced to the completed construction part and the implemented schedule in a

timely manner, and the completed construction part is considered as the constraint condition for the subsequent construction operation; then the construction model part of the construction is linked to the non execution schedule. The following construction operation 4D simulation is carried out with the completed construction part as the constraint condition, and the 4D simulation is used as a tool to analyze the follow-up schedule and guide the follow-up field construction operation. Generally speaking, the construction model is created before the construction of the project. The 4D simulation based on the three-dimensional model is also a visual simulation before the project is launched. The real time construction model needs to update the completed building part to the model, and the 4D model which is constrained by this model is closer to the current state of the project, thus making the 4D simulation more accurate and more instructive. At the same time, through the BIM real time construction model, the project manager can track the construction situation of the project in time and intuitively, find the existing problems and understand the actual situation of the project. Based on this, the 4D simulation of subsequent activities can more accurately predict and analyze potential problems as an effective tool for project management control.

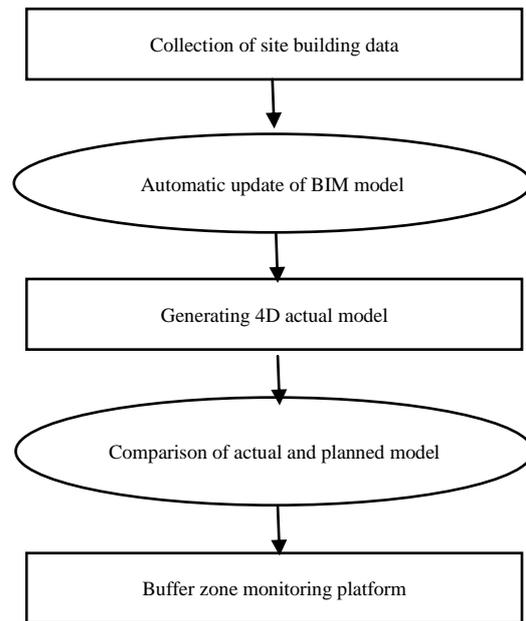


Chart 1 BIM-4D practical model application framework

### **BUFFER ZONE MONITORING**

The buffer is inserted into the network plan as a new time -consuming task , and the buffer element is created in the BIM model. According to the three color buffer monitoring method proposed by Goldratt, the buffer area is divided into three parts, namely in green, yellow and red [Guo, et. al., 2017]. During the execution of the project, when the buffer consumption is lower than the 1/3 of the total slow

impulse, that is, in the green area, the buffer consumption is in good condition, and the project schedule is executed as planned. When the buffer consumption is between 1/3 and 2/3, that is, in the yellow area, the project schedule may be damaged at any time. It is necessary to find out the reasons and set up the measures to strengthen the monitoring and management. When the buffer consumption is more than 2/3, the buffer reaches the red alert area, which indicates that the state of the buffer consumption is serious and the project schedule may be seriously damaged. It is necessary to find out the cause immediately and take relevant measures to avoid further delay in the progress.

At present, data collection and monitoring of construction progress are mainly based on traditional manual methods, which consume a lot of time and manpower cost. Moreover, due to complex field environment, data acquisition is prone to human errors, and the deviation and lag of schedule data often occur. With the popularization of automatic data acquisition technology in the construction industry, the timeliness and accuracy of data acquisition have been greatly improved, and the increasing maturity of automation technology makes the cost of field data acquisition lower and more efficient. In addition, automated data acquisition technology can integrate well with BIM to meet the BIM based progress warning requirement [Li, 2016].

The size of the buffer consumption computation buffer is related to the uncertainty of the project. With the progress of the project, the uncertainty and the potential impact on the duration of work are decreasing, and the amount of buffer needed for the remaining tasks is also smaller. Therefore, we should dynamically calculate the buffer size needed for the project with the project.

The setting of trigger points will directly affect the behavior of buffer monitoring and the release of warning messages. The conservative setting of trigger points will lead to early action to control project progress and increase management cost. Partial risk will delay the warning of danger signal, so that project progress can not be controlled in time, and even lead to delay in construction period. Since the system takes into account the relationship between the buffer demand and the amount of the project completed, the setting of the trigger point should also depend on the size of the buffer needed for the remaining part of the project. On the basis of the three color monitoring method, the end of the amount of buffer needed in the remaining part is aligned with the initial buffer end. Then the trigger point is set at 1/3 and 2/3, based on the buffer required by the remaining part [Lin, et. al., 2014].

**PROGRESS WARNING**

In each monitoring point, the alarm is determined by comparing the size of the buffer consumption and the size of the trigger point, and the visual function of

the BIM technology is used to visualize the alarm in different colors. The setting of monitoring points should be combined with fixed monitoring points and dynamic monitoring points. The fixed monitoring points include the milestone tasks of the project and the fixed period monitoring points set according to the actual situation of the project. The dynamic monitoring points should take into account the sudden situation in the project execution and the event which has a greater impact on the construction period [Zhang, et. al., 2017]. The alarm is classified as safety, warning and danger, as shown in Table 1.

Table 1 Alarm judgment table

Standard of judgment	Alarm	Display color
Less than first trigger points	security	green
Between first and second trigger points	warning	yellow
Higher than second trigger points	danger	red

Based on the powerful rendering function of Navisworks, the manager can render the progress of different projects in different colors, indicating the progress risk of different grades. Through the visualization of the model interface, managers can focus on analyzing the construction procedures corresponding to the Yellow components, and find out the reasons for the occurrence of the alarm.

**RESULTS AND CONCLUSIONS**

The effective control of the project progress is the key to the implementation of the project progress goal, and the real-time control dominated by information technology has already become an important guarantee for the progress management. The emergence and development of 4D technology has brought huge benefits to construction projects. Using the BIM model, the application of 4D simulation can be extended to the whole construction stage. The 4D simulation based on the real-time construction model enriches and promotes the application of 4D simulation in the construction stage, and further plays the role of 4D simulation, which will bring more benefit to the project. In this paper, BIM technology and critical chain method are integrated into the construction schedule control. This paper draws the following conclusions:

- (1) With the progress of the project, the uncertainty of the project will continue to decrease, and the required buffer will gradually decrease. Therefore, the trigger point should be dynamically set in connection with the construction progress of the project. The actual 4D model monitors the actual construction progress of the project site, collects the related data of the project progress, and updates the data information to the BIM model, thus ensuring the consistency of the model and the project information.
- (2) The buffer zone in the key chain is inserted into the schedule, the buffer zone element is created in the BIM 3D model, and then the consumption of the

buffer is analyzed and calculated using the powerful data processing ability of BIM, so as to realize the effective monitoring of the buffer zone.

(3) By creating the actual BIM-4D model, monitoring the buffer zone in real time and sending out the progress warning in time, it can realize the information, visualization and dynamic of construction progress control, and bring more benefit to the construction project.

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