BIM Application in Owner and EPC Contractor Collaborative Management of a Large-Scale Public Building Project

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Abstract
This paper describes a detailed BIM application in a large-scale public building project which is under EPC (Engineering Procurement Construction) contract. This paper firstly introduces the basic information about this project and owner's unique demand. The owner of this large-scale building project sets up its own PM (Project Management) system, and wants to directly monitor general contractor's daily management activities. Secondly, the authors propose a cooperative mode for owner and general contractor (GC) collaborative management. Data synchronization between GC and owner is the key for the collaboration. Thirdly, two PM systems are developed for owner and GC respectively. At last, applications of this large-scale public building project show that: owner can keep the control ability while transfer risks to GC. Thanks to owner's deep involvement during construction phase, data transfer from construction phase to operation phase can go smoothly.

Keywords: BIM, Collaborative management, Data integration.

1 Introduction

This large-scale public building (Building X) project locates in Shanghai, a complex building with three different towers, of which the heights are 200 m, 180 m, and 160 m, respectively. The three towers are connected by one basement below the surface and a corridor at the middle. A theater is inside the basement. Its ground area is about 55,000 m^2, the floor area is nearly 520,000 m^2 (Figure 1). The construction of the building started at November, 2011, and will finish in 2017.

Building X is a large project with lots of facilities, it not only contains many office rooms, but also a lot of auxiliary rooms, such as computer rooms, meeting rooms, even a theater is inside the basement. Usually, a large project like this one will involve lots of different participants, a complex supply chain, a high cost and a long duration, etc. The construction organization and management of schedule, cost, safety and quality is very difficult. The owner of Building X is a financial enterprise, which knows little about AEC industry. Owner cannot manage the project itself, so owner signed an EPC contract with a large construction enterprise to make sure the success of this project.

Although there are various types of project contract modes, the importance of EPC mode (Ranjan, 2009; Towler and Sinnott, 2008; Yeo and Ning, 2002) is widely recognized in the fields of construction, because of its high efficiency of integrating diverse design, procurement, and construction processes simultaneously (Hale et al. 2009; Guo et al. 2010), which meets owner's increasing requirements for reduced project cost and for a shorter duration. As the single entity

responsible for all project activities, a GC needs to achieve objectives on optimum design, cost-effective procurement, and punctual construction (Yeo and Ning 2002; Galloway 2009). Thus, GC replaces owner's role to promote the construction process whiling securing the quality and saving the cost.

Figure 1 The view of the Building X

Under EPC mode, owner can transfer most risks to GC at the expense of a higher contract amount. But owner's ability in controlling the project decreases due to its little involvement. At the case of this project, owner is also the operator, it still wants to have deep involvement during the construction phase, so that the operation phase can be easier. Thus, owner does not want to transfer the control to GC completely. Besides the EPC contract with GC, owner wants to continuously monitoring the project's overall situation as well as GC's daily activities. Only details of management activities are left to GC. In a word, owner just wants to transfer risks to GC while keeping the control of the project as much as possible. Important issues of the project, including key nodes (such as milestone nodes, nodes required by owner, etc.) of the schedule, major changes, total amounts of materials, total cost, etc., must be sent to owner as quickly as possible.

To realize owner's unique purpose, a possible way is to set up two PM systems for owner and GC respectively, one for GC's daily management; the other for owner to manage the project itself, but with a lower level compared to GC's management . To help its management, owner decides to adopt the latest BIM technology to assist its management and requires GC to do the same thing. BIM can effectively integrate, store, and retrieval data during the construction process, so that both owner and GC can visually supervise the project to avoid waste of time and money. To help its monitoring of the project, owner asks GC to synchronization important data to owner. Thus, data synchronization between owner and GC's PM systems is proposed to connect owner and GC, so that collaborative management of the project can be possible and feasible.

2 Collaborative management

Some modification is made to conventional EPC mode to suit owner's special demands. So, over this project, both owner and GC take part in PM process. A special collaborative management involving both owner and GC is formed.

2.1 Collaborative management network

Over this project, both owner and GC set up their own network systems. On the owner side, it has its own complete management system devices, including server, clients, hubs and switch. Data is input by its stuff at their offices. The owner's PM system is for surveillance in most cases. On the GC side, it put all its data on cloud server, installs Ethernet on the site to input data generated during the construction process before upload the data to cloud server. GC's PM system even supports handheld device, so workers on the site can input data too. Its stuffs then download the data from the cloud and do some daily management work. Both these two PM systems can connect

to the Internet for the convenience of different kinds of use cases and date exchange. Figure 2 shows the network situation of the two PM systems.

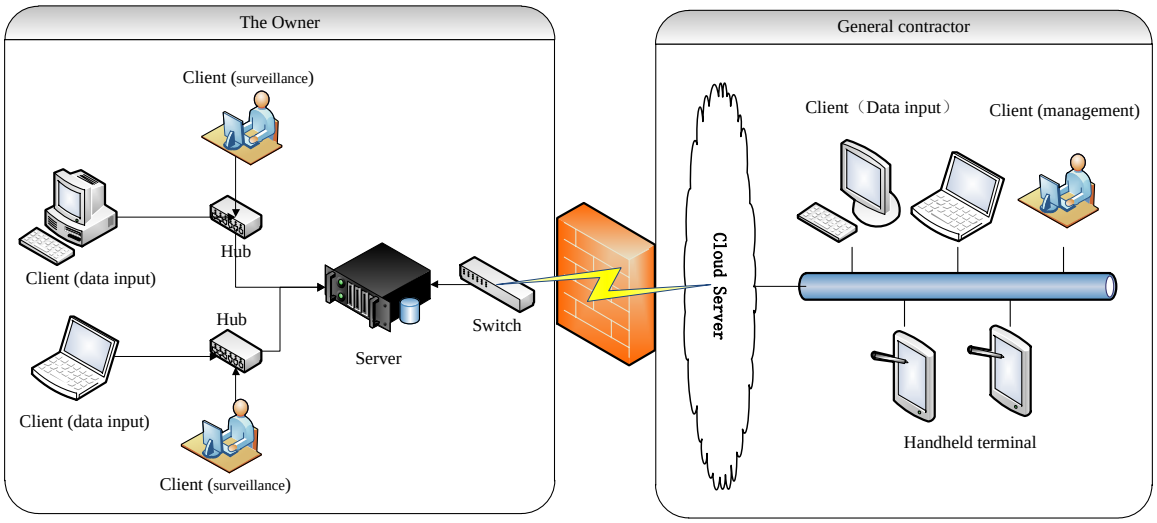

Figure 2 Network of owner and GC's PM systems

Both the owner and GC's PM systems are C/S-B/S integrated platforms, The C/S client is capable for BIM technology capabilities, such as model display, schedule simulation, etc. The B/S client is used for data input and display.

2.2 Collaborative management mode

At the case of this project, owner is also the operator after construction. Owner takes part in all the life-cycle phase of building X. Owner has the willingness to drive the collaborative management. This factor suits the BIM application, because BIM needs all participants to take part in the information collecting, integrating and sharing process. Only owner can coordinate all participants through direct or indirect contracts. Due to lack of knowledge about BIM, the owner hires Tsinghua University as the consultant to assist its management.

Figure 3 shows the actual mode of this project. Owner first signs a consulting contract with consultant at the beginning, the consultant can assist owner on the preparing EPC contract with GC, developing PM system for owner, 3D modeling, data processing, etc. Owner then signs the EPC contract with GC, and asks GC to sign a similar consulting contract with consultant. The consultant can also assist GC on developing PM system, synchronizing its data to owner PM system, etc. Under the EPC contract, GC is also responsible for asking suppliers, design institutes and sub-contractors to submit their rare data to its PM system. These data includes design drawings and documents, building components (piles, foundation, walls, etc.) data, schedules, safety and quality data, materials data, equipment data, etc. GC then integrates and utilities these data to fulfill its duty and synchronize selected data (such as real schedule, safety and quality data, estimated cost, etc.) to owner. Consultant is also responsible for integrating these rare data, as well as maintaining the two PM systems and the synchronization process between them.

Under this mode, EPC mode's advantage is kept, owner still only needs to make a few decisions, such as total contract amount, duration, etc., leaving most details to GC. With the help of consultant, two PM systems are developed in coordinate with each other, owner can be reminded of the key issues of GC's activities, but without too much intervention. Thus, owner can notice important deviations in time, so as able to correct them before they cause serious financial lost or time delays.

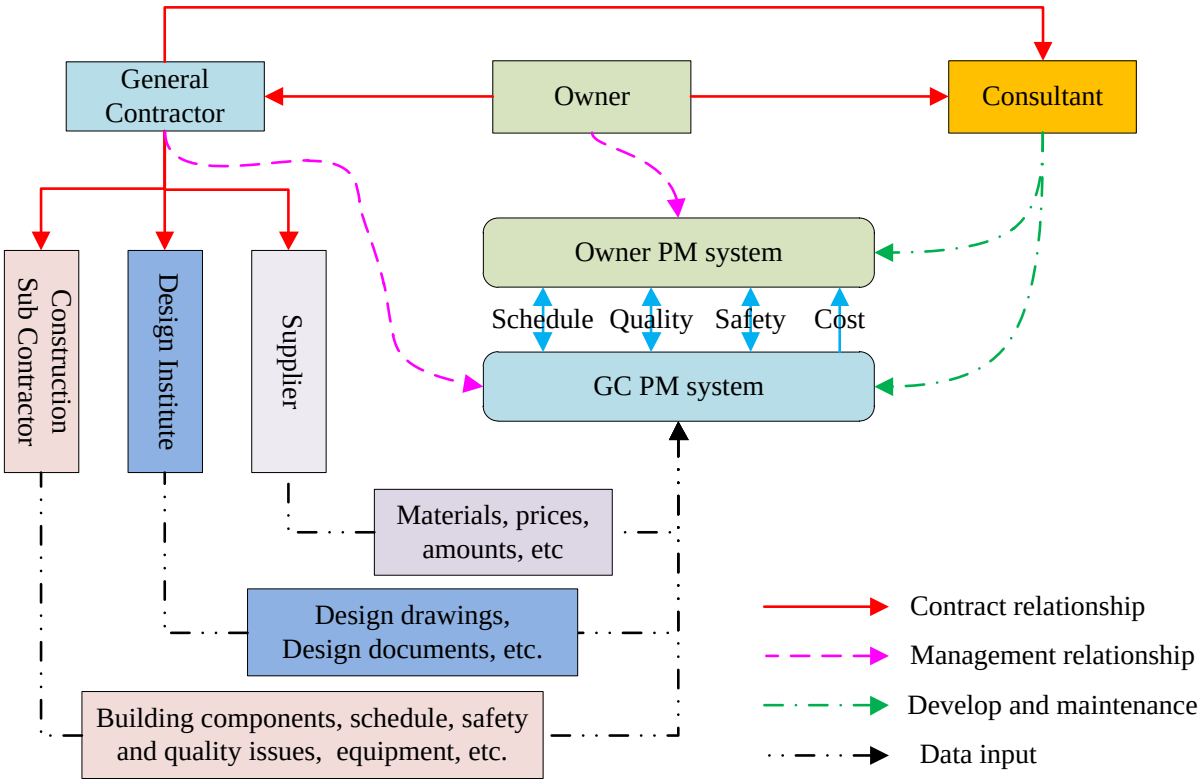

Figure 3 Collaborative management mode

2.3 Data integration and utilization

Both the owner and GC's PM systems are C/S-B/S integrated platforms. Different kinds of data is collected and integrated in different ways: the C/S client is capable for large amount of data, such as 3D models, schedule, etc.; the B/S client is very convenient to daily data input both at office and on the site side. Daily data includes actual schedule, equipment's actual arrive and depart time, etc. These daily data can update the schedule data input beforehand, so the management can be accurate and effective. Figure 4 shows the data flow for both the two PM systems.

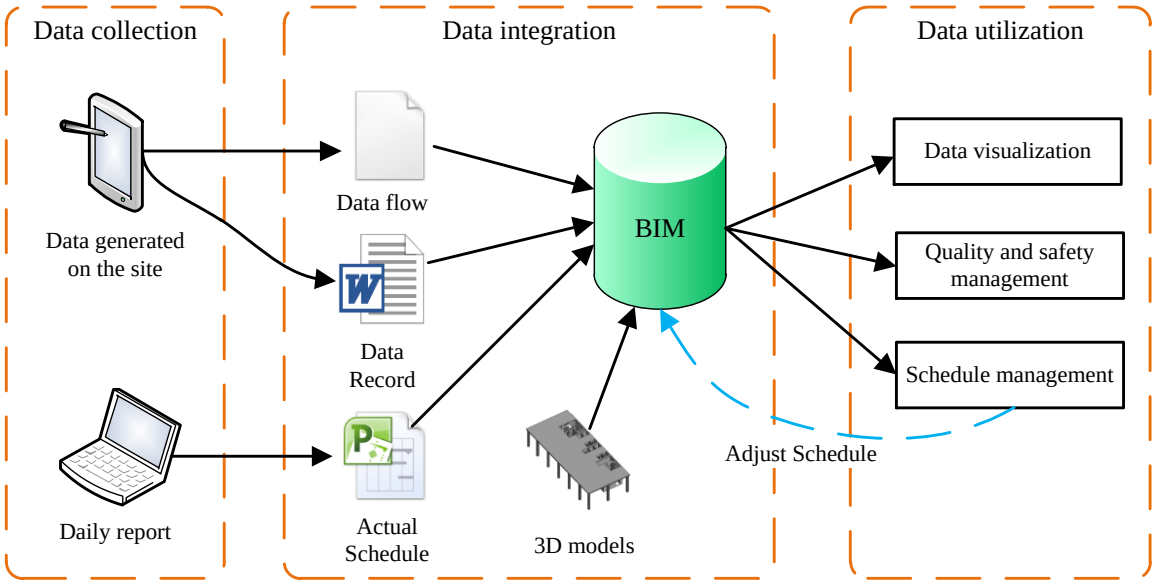

Figure 4 Data flow for management

At the case of this project, the synchronization data can be divided into two categories: real data and modified data. Real data are the ones which GC can send to owner immediately after collecting, this kind of data will not cause any kind of loss to GC, such as real schedule, equipment's parameters, etc. Modified data are the ones which GC doesn't want to publish, this kind of data may

connect to GC's business secrets, patents, etc., such as the real cost, details of its contracts with sub-contractors. GC has to make necessary modification before sending them to owner.

Base on the actual situation, a collaborative mechanism between owner and GC is proposed up. Since both owner and GC have their own PM systems, a feasible way is directly connecting the two databases for data synchronization. Firstly, owner and GC mush make an agreement about the data to be synchronized. Secondly, database design on both sides must consider the synchronization so as the fields of the synchronization data must be the same type. To make the synchronization process more smoothly, the names, types of the fields can be the same for both sides. Thirdly, choose suitable technologies to accomplish the synchronization process. Different technologies are used to suit these two cases: for real data, database technology, such as trigger, is employed; for modified data, web service technology, which must be fired manually, is used. The synchronization flow uses the Internet as the transform medium. At last, a simple communication system based on text is developed for necessary feedbacks and responses between owner and GC. Figure 5 shows the synchronization flow.

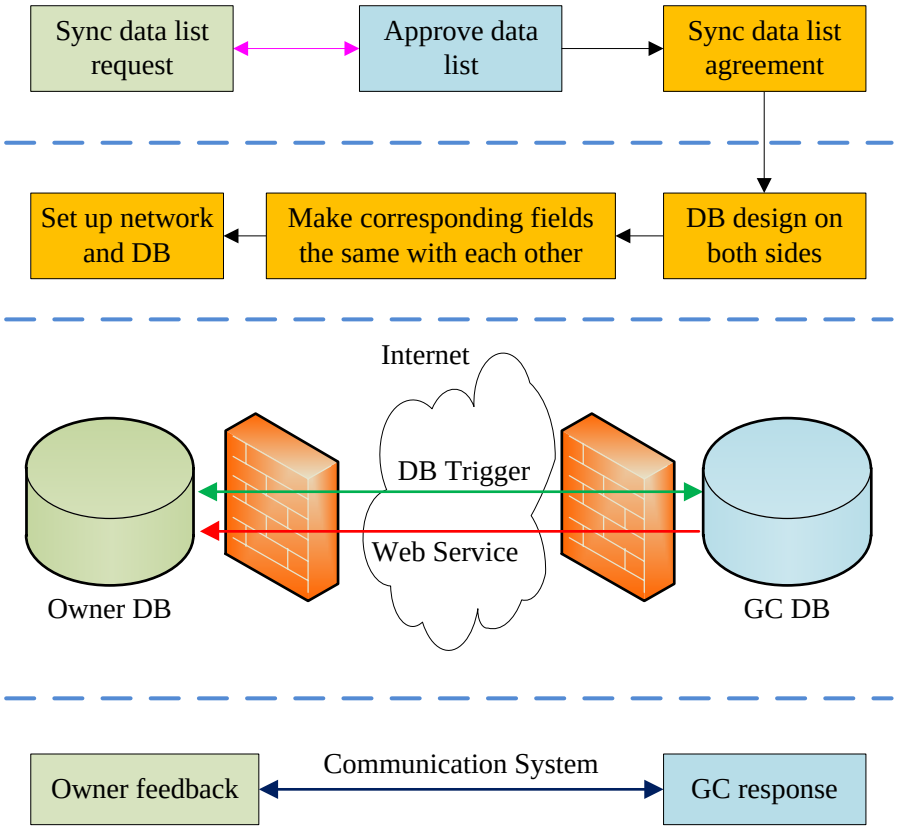

Figure 5 Data synchronization flow

3 BIM-based project management

The authors have developed two PM systems for each of the owner and GC. The C/S clients of these two systems are almost the same, Figure 6 is the screenshot of the C/S client for owner, and the one for GC is similar. The B/S clients are much different, due to different use cases, Figure 7 and Figure 8 shows the B/S clients for owner and GC respectively.

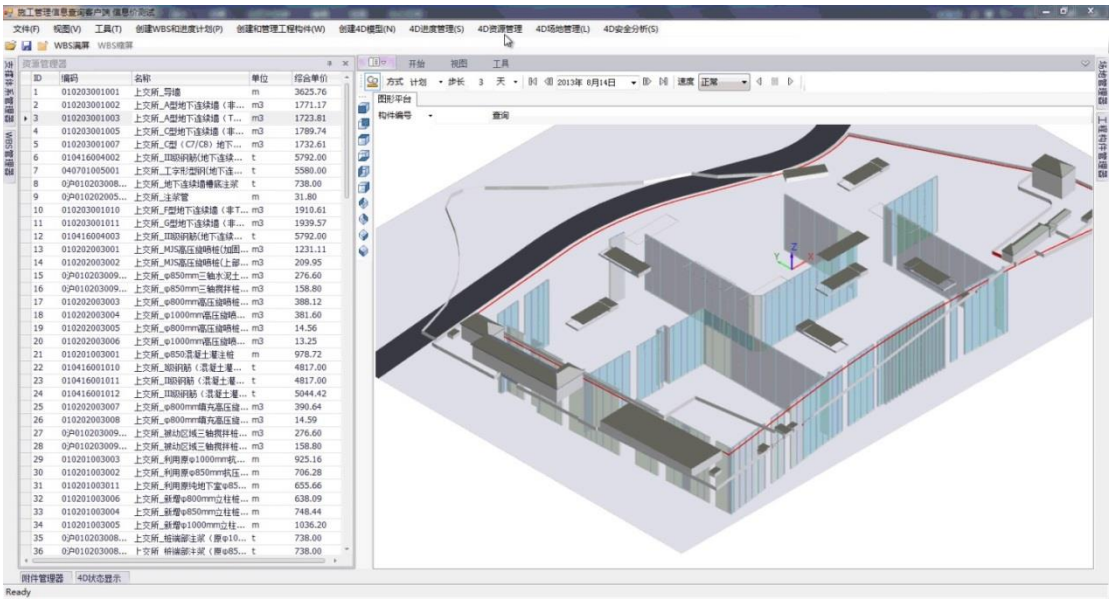

Figure 6 C/S client for the owner

Figure 7 B/S client for the owner

Figure 8 B/S client for general contractor

For these two PM systems, some important works must be done. In brief, these works contains the following categories.

3.1 Model and schedule auto mapping

Before using Autodesk Revit to build 3D models, consultant and GC have set up a simple rule for mapping the models to corresponding task items of the schedule: add task name to the corresponding 3D models as a property. After importing 3D models and schedule to the C/S client, comparing this string to match the models and task items to establish the mapping. Figure 9 shows the auto mapping process.

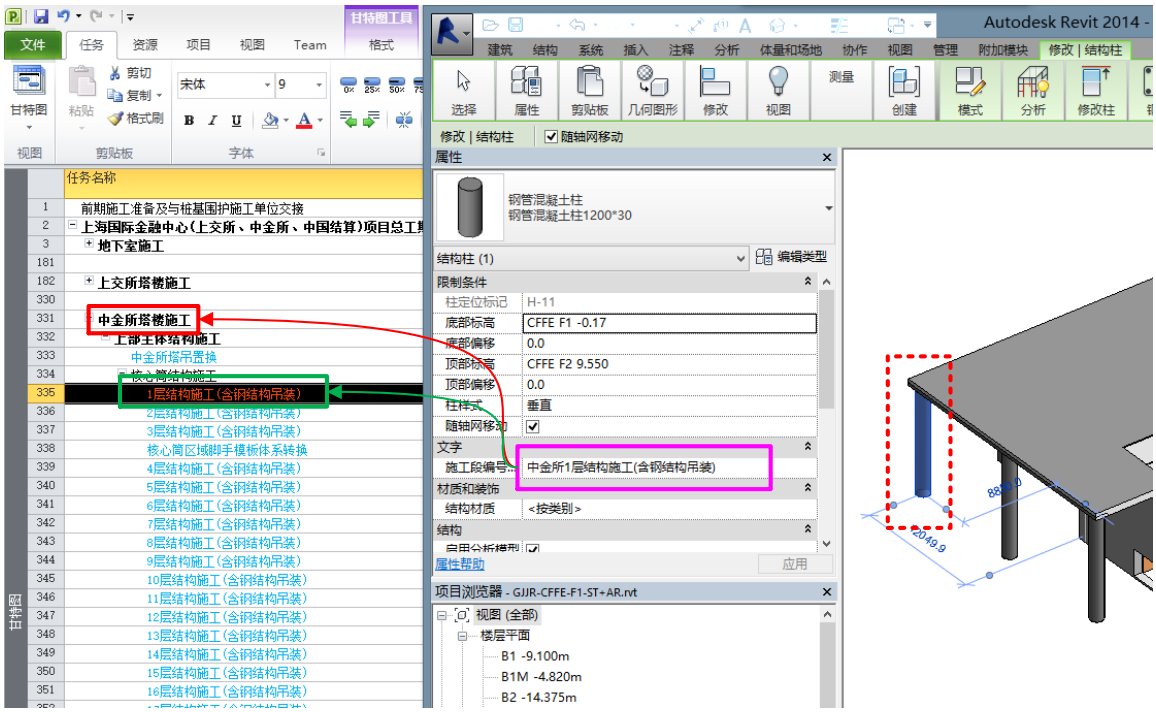

Figure 9 Auto mapping between 3D model and schedule task item

As shown in Figure 9, the string inside the pink rectangle was added to the column inside the red dotted rectangle as a property in Revit. The string consists of two parts: the tower name and the task item name in schedule file. The tower name (red rectangle in Figure 9) is used to tell which tower this column belongs to. And the task item name is used to map this column to task item with the same name (green rectangle in Figure 9). As for this column, both the tower name and the task item name can be found in the schedule file, so this column can be automatically mapped to the task item in the schedule.

3.2 Schedule management

Schedule management is mainly for GC. Daily schedule is input by sub-contractors or GC, including task name, start time, end time, completion, delay reason, reporter and modifier. Figure 10 shows the B/S client for GC's schedule management. This daily input data can be directly updated to C/S client because B/S and C/S clients use a single database.

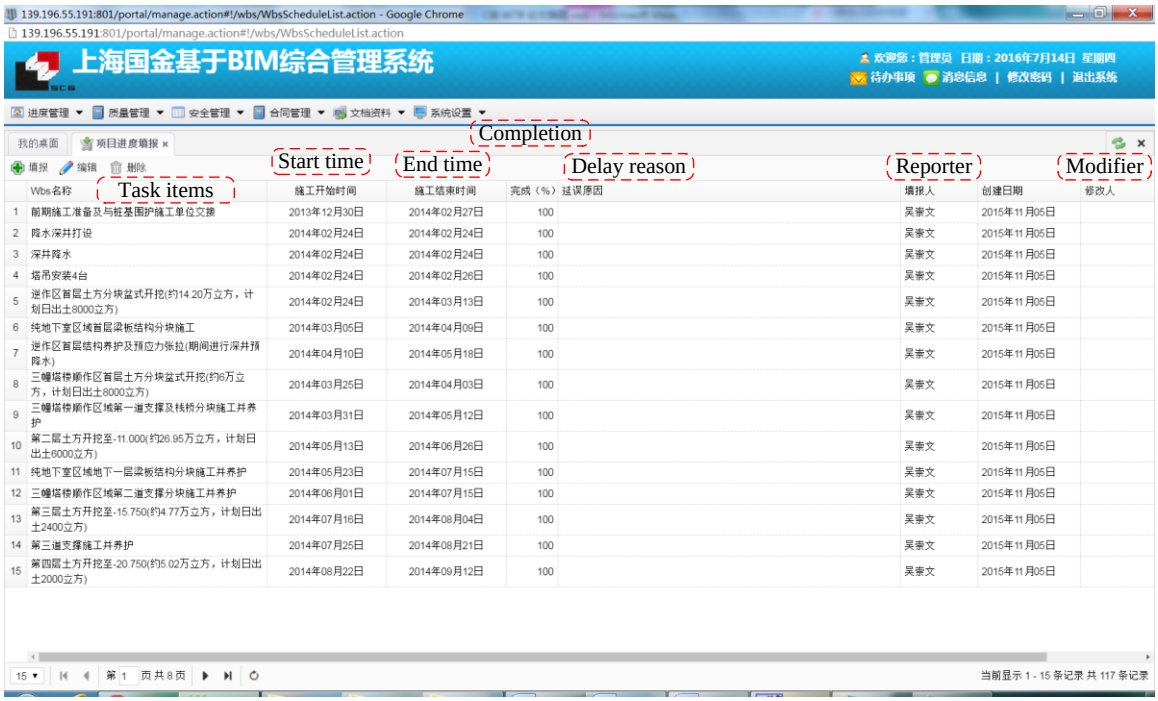

Figure 10 Schedule management for GC

Not all of GC's schedule tasks are synced to owner, but only the key nodes. Key nodes are set manually beforehand.

3.3 Quality and safety management

Quality and safety management is solely for GC, because this is GC's responsibility. Quality and safety management must be through both C/S and B/S clients. Because B/S client's capability for displaying 3D models is poor, quality and safety key points must be labeled to 3D model at the C/S client first. Both quality and safety key points are selected manually by GC beforehand. After labeling them on 3D models, respective records are added to B/S client automatically, so that corresponding data can be collected through B/S client. These data then can display on the C/S client too. Figure 11 shows an example of safety key points labeling: 3 different key points are labeled on the model directly.

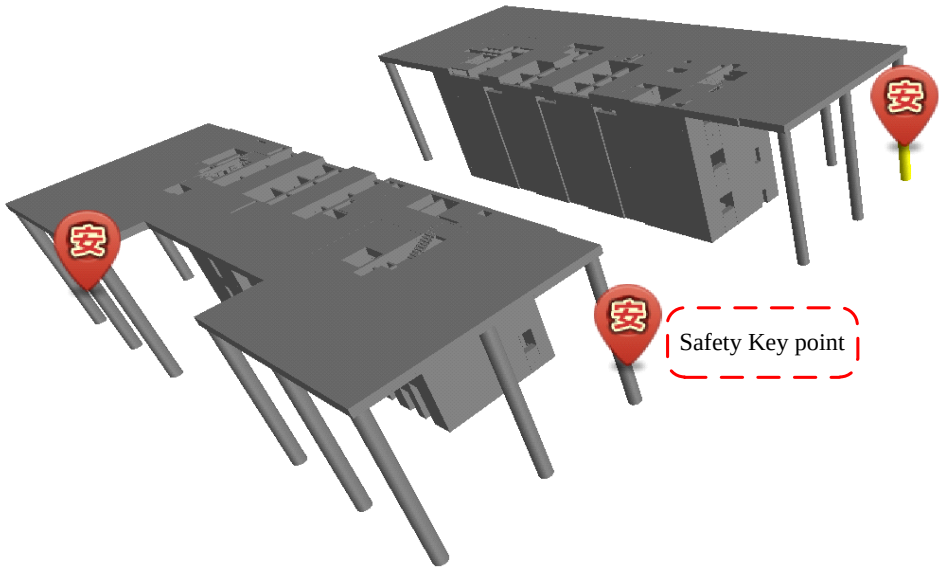

Figure 11 Safety key points labeling on the 3D model

Quality key points management shares the same ways with safety key points. These two kinds of data are not synced to owner if there is no quality or safety problems occurred. Once they do happen, reports must be sent to owner to explain them.

4 Conclusion

Because of EPC mode can transfer risk from owner to GC, when owners know little about AEC industry, this characteristic suits very well. Usually, owners lose the control ability too. At some special cases, owners still want to keep the control ability, this paper showed an example that some modification can be made to conventional EPC mode to suit these special cases. Some important data flowed from GC to the owner side, so the owner could supervise the construction in time. Thus, EPC mode's advantages can be preserved while its disadvantages can be avoided. Thanks to owner's long-term management during the construction phase, the handover between construction phase and operation phase can go through smoothly, making a good foundation for the operation phase.

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