Chapter 26
Application of Building Information Modeling (BIM) in Site Management—Material and Progress Control

A. Nadeem, A.K.D. Wong, G. Akhanova, S. Azhar and S.N. Wong

26.1 Introduction

Site management plays an important role during the whole construction period of a project. It includes, among other things, progress control, building services design and site layout planning. In a traditional way, all the drawings of above aspects are drawn in 2D on paper with software such as AutoCAD. However, for some aspects relating to time and coordination, it is hard to present these aspects on the paper. In addition, it is difficult to understand the real situation with a 2D drawing only. Although the drawings may provide different views of the structure, it requires imagination which is not easy for all clients or stakeholders to understand. Moreover, if a number of sub-contractors work at the same location, there will be a risk of clashes as they submit their drawings individually. For example, water pipes and electrical wires are required to install on the same part of the roof.

In recent years, invention of new technologies breaks the framework of dimensions. Building Information Modeling (BIM) is an innovative technology which is beneficial to site management in terms of time and coordination. For example, a common database enables different contractors to share their drawings by submitting them onto the same platform. Nevertheless, according to Smart Market Report published by McGraw Hill Construction (2008), contractors are the lightest users of BIM while architects are the heaviest users. Therefore, more

A. Nadeem (✉) · G. Akhanova
Department of Civil Engineering, Nazarbayev University, Astana, Kazakhstan
e-mail: abid.nadeem@nu.edu.kz

A.K.D. Wong · S.N. Wong
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China

S. Azhar
McWhorter School of Building Science, Auburn University, Alabama, USA

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_26

research should be carried out to raise attention from companies in the construction industry.

The aim of this chapter is to investigate the application of BIM to site management in terms of material and progress control. To achieve this aim, the components of site management are first identified. Then the use of BIM in site management is illustrated and the limitations for adopting BIM in site management are identified.

26.2 Literature Review

26.2.1 Building Information Modeling

BIM is a technology that provides a platform, where many parties can get involved, for sharing information and analysis of the building or facility in terms of time, cost and quality (Conocer et al. 2009; Rosenberg 2006; NIBS 2007). The information to be shared in the database not just includes the physical appearance, but also the details of each component of the building. Scottsdale (2009) comments that “BIM represents an evolution from traditional 2D design to a dynamic 3D model build around a database of a project’s physical and functional characteristics”. It means that instead of relying on traditional paper-based 2D design, BIM provides a model constructed from a database containing all the relevant information of the project for discussion.

Moreover, in the Guide for ASHRAE members, Conocer et al. (2009) state that BIM can create a precise model and hence improve productivity, lower construction cost and enhance construction quality. It is because accurate material quantity, scheduling and process control can be derived from information contained in the building model automatically. So, there is increase in productivity and reduction in construction cost as a result of reduction in wastage of time and material. In addition, one of the key findings shown in the SmartMarket report (McGraw Hill Construction 2008) is that 82% of BIM experts believe in the improvement of productivity by adopting BIM. On the other hand, with the help of visualization feature of BIM, clashes and conflicts can be detected and observed from the model. Thus, immediate remedies or changes can be made to have a better construction quality.

26.2.2 Site Management

For traditional site planning, Chau et al. (2005) comment that when planning for resource allocation and site layout, planners rely on their experience, intuition, imagination and judgment with the help of 2D drawings and general schedules, such as bar chart. However, all this information is paper-based. Site planning is required for better site management on time, cost and quality. It is the organizational process of creating and maintaining a plan; and the psychological process of thinking about the activities required to create a desired goal. According to Rodriguez and Walter (1998), objectives of construction site management are as follow:

(i) Support the construction job personnel through efficient material transportation
(ii) Provide flexible work space
(iii) Use available site space effectively
(iv) Reduce capital investment
(v) Provide labour safety and job satisfaction
(vi) Reduce construction time
(vii) Facilitate the construction process
(viii) Reduce "energy consumed" in the construction operation.

In summary, these categories can be grouped into three parts, which are material and progress control (iv, vi), site layout planning (i, ii, iii, vii, viii) and site safety (v). This chapter addresses material and progress control issues of site management.

26.2.3 Material Control

Material cost is one of the major expenditures in a construction project. In current practice, the material quantity is calculated by on-site quantity surveyor (QS) from drawings and bills of quantities manually. Materials are usually ordered throughout the construction period as there may not be enough storage areas for all materials. In case there are changes made to the design, then QS needs to adjust the quantity. However, the drawings on site may not be up-to-date and so there is either overestimate or underestimate of material quantity. Both will lead to increase in material cost.

Nevertheless, accuracy could be improved by adopting BIM technology. There are many different kinds of software to be used for quantification and estimation, such as Automated Estimator (Drogemuller and Tucker 2009), Exactal, Innovaya (Eastman et al. 2008) and Autodesk Quantity Takeoff. The sources of these quantity takeoff tools are the data from various BIM tools, for example, Autodesk Revit, AutoCAD. The special feature of quantity takeoff tools is to link up design data and the 3D model. Quantity and cost are automatically generated from the tools after inputting the unit rate for material and labour.

26.2.4 Progress Control

Since changes to the design do occur, the construction manager has to spend time on reviewing the updated drawings and renewing schedule, which highly relies on the interpretation of drawings by the manager. When there is a mistake in interpretation, it will affect the schedule and may lead to a delay. Thus, BIM is introduced to improve the efficiency with the use of shared database and enhance the accuracy through visualization of a 4D model (Hardin 2009). A 4D model is created by 4D tools or software like Autodesk NavisWorks. The main idea of these tools is integration of BIM model and construction schedule to produce a 4D model (i.e. 3D geometrical model + time).

With the visualization of the end results, the construction manager is able to check whether the sequence is correct and to optimize the construction sequence (Ashcraft 2008). Visualization helps communication between team members so that everyone understands the work in an easier way than just referring to the bar chart. Meanwhile, contractor can check the feasibility of the working schedule through 4D simulations. If there are conflicts or changes of design, adjustments to the schedule can be made immediately before the activity starts.

Koohang et al. (2008) comment that BIM is helping the industry to transform from a paper-based process to an integrated and interoperable way of performance as the shared database encourages more interaction and communication between parties, as well as knowledge capture and management. Regarding the construction process, the database provides information or knowledge for the construction sequence adopted in previous projects for the same task. So they have an idea of how the work is carried out and may either follow the same process or create a new sequence by making adjustment. This is particularly useful for complex task and special building design or structure as they do not have much experience in tackling the problems of these specialties.

26.3 Case Studies

In this section, two case studies are used to show how BIM is applied in different areas of site management in real practice for material and progress control.

26.3.1 Case 1: One Island East

The One Island East (OIE) is a 70 storey office building completed in Hong Kong at about $300 million. In OIE, BIM was implemented throughout the whole development process, including both design and construction phases. With the use of specialized BIM software, the accuracy of material quantity increased as the bills of quantities (BQ) was kept up-to-date before and after tender. The quantity takeoff was automatically generated from Digital Project (DP) software. Construction time could be reviewed in the same table as well. So the on-site QS would know how many materials were required at what time and hence the QS could figure out the reorder point to ensure that materials were ready before construction.

Furthermore, BIM helped in reducing material wastage through counter-checking of the quantity in the model and manual calculations to ensure that there was not a great difference between them. It benefited in the calculation of concrete amount as Grade 60 and 100 concrete were used for outriggers, in which they had very limited experience in using these two high strength concrete. So they were not sure how much of it should be ordered.

Alongside with the construction schedule, BIM helped to reduce part of the construction time. Construction sequences could be visualized in the 4D model so that it allowed contractor to identify problems and resolve them before construction commenced. In this case, BIM was used for planning the erection sequence of outriggers which was complicated. The outrigger zone occupied about four floors, which were non-typical floors. As they had not tackled with such complex situation before, they allowed more time for contingency in case there was error in construction planning.

With the implementation of BIM for clashes identification, about HK $19.9 million, which is about 7% of $300 million, and 254 m^3 of materials were saved. Moreover, it shortened the construction period of the outrigger installation activity by about 20 days. Therefore, lower construction cost was achieved in this case.

26.3.2 Case 2: The Camino Medical Office Building

The Camino Medical Office Building (MOB) project was composed of a main medical building and a parking structure in San Francisco in the US at a cost of $96 million. In this case, BIM was helpful in reducing construction period by 6 months. The project manager decided to adopt a lean approach together with an integrated BIM model.

Camino MOB is different from the previous case, OIE. It allowed not only contractor to design the model, but also allowed subcontractor to provide an input to the model. In fact, every major party were able to add constructability knowledge into the model so as to enhance collaboration and clashes identification within the 3D model. Weekly meetings were also held for sharing information and resolving conflicts found in the model. Therefore, less rework was performed due to reduction in conflicts between installations of precast components.

Besides that, in order to avoid delay due to late delivery of materials, a detailed schedule was produced to show the construction process of each part of the project through visualization of the 3D model. Hence, it would be easy to identify what kinds of materials were required for the completion of tasks and when detailed design was required. Since the most updated quantity would be used for material ordering and sufficient lead time had to be provided for material delivery, detailed design should be produced just before purchasing material. Meanwhile, just-in-time delivery method was applied to this project so that the construction process could run continuously and keep on track.

The lean approach and BIM model helped increase the productivity by 10–30% for a couple of reasons, including less rework and safer working environment. At the same time, there was a total reduction in construction schedule for 6 months comparing to traditional design-bid-build method and it led to a great success of the project.

26.4 Findings of Case Studies and Interviews

26.4.1 Case Study Findings

The case studies have shown how BIM was applied in real practice in terms of site management for materials and progress. At the same time, interviews were conducted with three consultant and three contractor representatives for how BIM is applied on site management and their comments on implementation of BIM, including limitations, from various perspectives. The summary of findings from the case studies is presented in Table 26.1.

Table 26.1 Summary of BIM application in two cases

	Case 1: One island East, (Hong Kong, China)	Case 2: Camino medical, Office building project (San Francisco, US)
BIM scope	➢ Utilize BIM throughout the project life cycle (both design and construction phase)	➢ Reduce overall project duration
BIM participants	➢ Owner ➢ Consultant ➢ Architect ➢ Contractor ➢ Quantity Surveyor	➢ Owner ➢ Contractor ➢ Subcontractor ➢ Architect
Application in material and progress control	➢ Focus on accurate material quantity ➢ Check the construction schedule to work out the material reorder point ➢ Optimize construction sequence	➢ Able to know when detailed design is required for material ordering ➢ Keep on tracking the construction schedule to ensure materials delivered on time and reduce conflicts through visualization
Observed benefits	➢ Reduction in construction cost by HK$19.9 million ➢ Reduced construction time of outrigger installation by 20 days ➢ Reduce 254 m^3 of materials	➢ Reduced construction period by 6 months

26.4.2 *Interview Findings*

26.4.2.1 Material Control

For material management, BIM is capable to calculate the accurate quantity of materials by material quantity takeoff from the BIM model, which is one of the BIM usages in the One Island East (OIE) case. However, there is no software which can calculate the amount of materials to be reduced with the implementation of BIM. Instead, all interviewees agreed that it helps to reduce risk of material waste. It is because in most cases, wastage is caused by mistakes, such as wrong calculation of material quantities so that excess materials are wasted and this can be coped with BIM.

26.4.2.2 Progress Control

On the other hand, the consultants suggested that theoretically, if the 3D model is accurate enough, prefabrication can be used as the main construction method because delivering fully arranged components is more preferable than piece by piece because of quality and time. Since the precast element is automatically manufactured in the factory, this helps in controlling the quality of the material and reducing material waste. Therefore, there will be less in situ procedures and hence risk of mistakes as well as rework is lowered.

The visualization of 3D or 4D model helps people understand the real situation. Concerning optimization of construction sequence, interviewees agreed that theoretically, BIM is able to provide "the most optimized situation" that it can guarantee the project to be completed on time if everything is exactly the same as those in the model. However, the technologies used at this moment cannot attain this optimized situation because there must be some changes or something missing during construction so that the project cannot complete on time. Instead, the model just helps planner to optimize the sequence, but not automatically.

26.4.2.3 Limitations of BIM Application for Material and Progress Control

From the point of view of contractor, interviewee mentioned that, sometimes BIM model is different from SMM (Standard Method of Measurement) as BIM has its own measurement method in the software. For example, the dimensions in BIM are always using "mm" as the unit. However, in SMM, it uses "m" as the standard unit. Also, the calculation of area may not be the same. Therefore, when using the quantity provided in the model, it should be taken care of the unit as well as how it is calculated. Otherwise, errors will easily appear in the calculation.

Human attitude towards BIM technology is an obstacle to BIM implementation, which is so-called "black art of planning" by one of the interviewees. He explained that people sometimes do not trust the findings generated from the model. Instead, they prefer do it themselves. For example, some quantity surveyors do not rely on the material quantity calculated from the model and they use their own calculations. Thus, BIM may not be very useful in this case.

26.5 Conclusions

As conditions on a construction site are complex, it is hard to understand the site relying on 2D drawings only, not to mention the site management. Building Information Modeling (BIM) has great potential helping in the interpretation, communication and coordination among involved parties, such as developers, quantity surveyors and contractors. The findings of the case studies and interviews in this chapter show that BIM is useful for material and progress control components of site management, including quantity takeoff, construction sequence optimization and provision of knowledge database. This encourages interaction between parties because an informative BIM model cannot be produced by just one party. It requires various kinds of data to be input into the model to make it as perfect as possible.

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