SIMULATE CONSTRUCTION SCHEDULES USING BIM 4D APPLICATION TO TRACK PROGRESS

[1,2]SAGAR M MALSANE, [2]DR. AMEY Z SHETH

[1]Assistant Professor, National Institute of Construction Management & Research, India
[2]phd Researcher, Northumbria University,UK,
[3]Phd, Loughborough University, UK
E-mail: [1]smalsane@nicmar.ac.in, [2]sagar.malsane@northumbria.ac.uk, [3]Sheth_amey@yahoo.com

Abstract- the architecture, engineering and construction (AEC) industry is shifting from 2D CAD drawings to more semantically rich building information models (BIM). The arrival of BIM concept emphasises on adopting an approach of defining a building in a single building model with enough information to meet its various demands instead of defining it in disparate document. Further BIM is a tool which not only stands as a 3D geometric modelling tool, but also supplies useful information, data about several aspects throughout the life-cycle of a project such as design and development of a facility, construction process, quantities and scheduling, fabrication process, and information required for facilities managers, stakeholders. A BIM based approach assists professionals during the conception and designing of building but the same approach can also help in monitoring construction execution and maintain a control over it. This piece of research explores role of BIM methodology in the area of tracking schedules and monitoring of work progress by developing a building information model for a residential building, linking it with project planning systems and tracking it's on site progress. This work is carried out using a simulation tool Navisworks Manage which helps simulate construction schedules in 4D to visually communicate and analyse project activities, and helps reduce delays and sequencing problems.

Index Terms- BIM standards, progress tracking, 4D simulation, visual communication1

1. The authors gratefully acknowledge the support provided for this research by National Institute of Construction Management & Research, India. The authors would like to express sincere gratitude to Intento Associates, project planning and logistic consultant, Mumbai for providing valuable information.

I. INTRODUCTION

The Indian construction industry has experienced a relatively slow progress and gradual decrease in productivity in relation to complex projects. Hence it always faces the problem of not being able to complete projects on time. In the meantime the manufacturing industry has increased its productivity with adoption of right type of technology. The main causes of the lack of progress of the construction industry are related to its fragmented nature due to traditional project delivery approach, use of 2D Computer Aided Drafting (CAD) technology (Teicholz, 2004). The conventional construction project delivery approach fragments the roles of participants during design and construction phases and discourages collaboration amongst the main participants like consultants, general contract, construction manager, etc.

The use of traditional two dimensional CAD drawings lacks a collaborative approach. Architects and engineers produce their own fragmented CAD documents for owners and contractors. These drawings are not integrated and usually pose conflicts of information which result in errors, complexities and delays. The quantity surveyors need to count and generate quantity take offs based on the produced CAD documents. Moreover, the 2D CAD approach does not promote the integration of the drawings with schedule and cost.

This indicates that construction industry is lacking in adopting the right kind of technology which will be responsible for increased productivity as well as reduced project time line. Construction industry has come to a point to realize the true benefits of technological advancement;

adoption of BIM is one such example. Therefore, it is the intention of this research to study BIM and its tool to determine benefits and setbacks it poses to construction execution. This piece of research presents information about BIM gathered from extensive review of literature and a qualitative questionnaire survey. The key focus of this research is to demonstrate how 4D scheduling can be adoptedby construction industry and utilised to reduce delays. Here, the uses of BIM which include visualization, 3D coordination, prefabrication, construction planning and monitoring, cost estimation and record model were discussed in detail. Further Worli Mixed-Use Tower project in Mumbai was presented as a case study to realize the actual uses and benefits of BIM focussing mainly on 4Dsimulation

II. DEVELOPMENT OF CAD TOOLS

Over the past 10 years, design tools in the AEC industry have been improved from 2D modelling to 3D modelling, a situation that is encouraging in terms of the uptake of BIM (Greenwood et al., 2010).

A. The adoption of CAD At first the technology of CAD was not as popular as it is nowadays. However, with the popularization of personal computers, the use of CAD became commonplace. During the 1970s and 1980s, two-dimensional (2D) computer aided design was developed and deployed by the 'early adopters' for construction design practices. By the end of the 1990s, 2D CAD was used in the majority of construction design activities and 3D design systems were available, although their use was limited (Greenwood et al., 2010; Yan & Damien, 2008). One of the main reasons for the resistance to the use of 3D CAD in construction was the lack of perceived benefits. Essentially, this generation of software tool was drawing-oriented, i.e. the underlying representation in the tools was graphical (in terms of lines, arcs, points, etc.). For instance, a door represented in this way would therefore 'behave' like a series of graphical objects and not a door. For example, changing the opening width of the door meant making a line or arc shorter or longer. Whilst this was acceptable in 2D CAD (being no different to a traditional paper-based drawing procedure), in 3D CAD the amount of graphical change required was significantly greater. Thus, although 3D CAD brought great potential benefits (such as clash detection and visualisation) the overheads associated with the authoring of models rendered these benefits too costly.

The end result was that most design practices used 3D for presentational purposes and disposed of the model once this was complete in favour of traditional 2D drawings (Azhar, Brown, & Farooqui, 2009; Lockley et al., 2013). The initial response of CAD vendors to resolve this was parametric object design: rather than the user having to define the lines and arcs of the door they would be automatically generated from a set of parameters, such as height and width. As these parameters were altered, so were the resulting graphical representations. This approach effectively accelerated the process of authoring the graphical representation of the building, but essentially the resulting model was still a graphics-oriented model designed to produce output as drawings.

The development of object oriented CAD resulted in BIM (Greenwood et al., 2010; Krygiel & Nies, 2008). Traditional construction processes (with CAD participation) involve numerous documents at different stages maintained separately, resulting in overlap and inconsistency of information. Various project participants store information at several locations without sharing with other participants, making building design and its execution a complex process and resulting in the late delivery of projects. The BIM concept was introduced to tackle this issue; it was about providing a shared podium which can hold information, including building regulations. BIM is expected to drive the construction industry towards a "model based" process and gradually move the industry away from a "2D Based" process (Foster, 2010).

III. WHAT IS BIM ?

In the AEC industry, there is a misconception by some that BIM is only a piece of software. It is partly due to inadequate knowledge about BIM and partly due to aggressive marketing strategies of some software vendors, selling their piece of software as BIM software. Although software is a necessary part of the process, it is much more than an application. "Building Information Modelling is defined as the creation and use of coordinated, consistent, computable information about a building project in design-parametric information used for design decision making, production of high quality construction documents, prediction of building performance, cost estimating, and construction planning" (Krygiel & Nies, 2008). BIM is interpreted differently by project stakeholders, but more commonly it gets ssociated with 3D graphical modelling of an architectural design. However, any piece of information related to a project can be considered BIM and it needs not to represent geometry all the time (Hamil, 2011). In fact, the actual start point of BIM is the client requirements or project brief; geometry comes later in the scenario in the form of floor plans, elevations and 3D views. As compared to 3D modelling, BIM is a powerful technology. It possesses all the functions of 3D CAD. BIM has an advantage over 3D CAD systems, as it stores information in the form of a collection of objects with associated properties. While 3D CAD can be described as a collection of points, lines, 2D shapes and 3D volumes, the BIM concept comprises geometric entities which have symbolic or abstract significance, as well as quantitative or qualitative data. BIM is fully acknowledged by architects for its versatility in developing design solutions and 3D visualizations. However, so far it is not well recognised as a construction tool which can be used by various stakeholders for different objectives, such as generating costs and scheduling savings etc. (Beetz, 2009; Foster, 2010; Niemeijer et al., 2009). A BIM methodology seeks to add new or additional layers of information by allowing new methods of data exchange and communication amongst all stakeholders in a project. This can be the design team, builders and owners. Each of these teams needs a methodology with which to share information about a project in greater quantities and more efficiently than their current method (Dix, 2009). For any project, BIM acts as a podium which can hold information related to ductwork, electrical installation, fire protection, occupancy, energy consumption, CO2 emissions or any information that needs to be collected regarding a site or building. This collection of information can be fed along with geometry into a BIM authoring tool to enhance the model. The goal of a BIM methodology is to allow an overall view of the building or project by including everything in a single-source model (Eastman et al., 2008).

Different CAD packages have their own internal BIM products. The number of such BIM products in the market is increasing due to its popularity. As these BIMs are owned by different proprietors, they all store information in their respective proprietor's format (Bailey, Brodkin, Hainsworth, Morrow, & Simpson, 2008). This leads to compatibility issues and data sharing difficulties among these models. This issue of interoperability has led to the formation of IFCs (Niemeijer et al., 2009). However, the benefits of BIM will materialize only through the sharing of information across organizations, departments, IT systems and databases. To achieve the benefits, the IFC standards is key to facilitating this cost-ffectively and without relying on any particular product or vendor specific file formats (Conover, 2009; Niemeijer et al., 2009; Solibri, 1999).

IV. BUILDING MODELS LACK INFORMATION

Traditionally, designs have been represented in 2D format in drawings, with an emphasis on making them graphically and visually as correct as possible to enable professionals to understand and interpret them for necessary building information (Eastman et al., 2009; Hiekkila & Blewitt, 1992; Jeong & Lee, 2008; Nguyen & E., 2006). To create a BIM, a modeller uses semantically rich objects to build a virtual prototype. The resulting 3D integrated model is a far more rich representation of a building project than the traditional 2D drawings. The ability to attach 'properties' to objects means that the use of BIM is potentially a far more convincing instrument in communicating building designs in terms of obtaining sanction from the rule checking authorities (Davies & Raslan, 2010; Holzer, 2009; Sullivan, 2007). Recent developments in both software and hardware have resulted in a significant sophistication in representing building models. However, even today building models do not typically include the detailed level of information required at times. This research explores whether BIMs contain enough information required for schedule tracking using 4D applications. The full benefits of BIM will materialize only through sharing of information across organisations, departments, information technology systems and databases (Bernstein & Pittman, 2004; Love et al., 2014). The IFC standard is the key to facilitating this interoperability in a cost-effective way and without relying on any particular product or vendor specific file formats (Conover, 2009; Solibri, 1999). IFC adds a common language for transferring information between different BIM applications, while maintaining the meaning of different pieces of information in the transfer (Ding et al., 2006; Eastman et al., 2009; Holzer, 2009).

V. BIM FOR CONSTRUCTION PROJECTS

The data presented in this section is collected using questionnaire protocol which was developed on the principal of qualitative data. During the investigation, a question about implementation of BIM and simulation based tools was posed to the 42 participants. The responses varied from 'adapting slowly' to '100 per cent of the projects are using BIM'. Also, many BIM users are using the maximum strengths of BIM for various simulations, for example, scheduling, costing, planning, and to calculate end users travel distance. Often, BIM based tools are used for larger and complex projects. The investigation revealed that various tools are adopted throughout life-cycle of a construction project. More often parametric tools are employed for visualisation, energy analysis and improved coordination, and assessment tools to assess a building performance, especially from energy or carbon emissions point of view. Figure 1 shows the applications of BIM based tools for various purposes in the construction industry as revealed during the primary data collection.

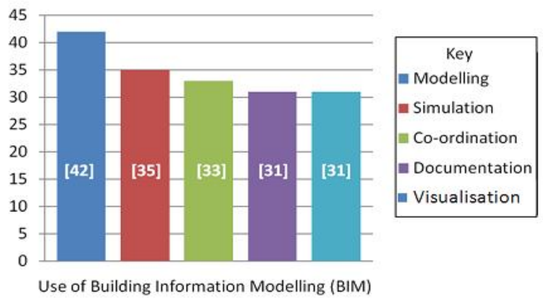

Figure 01; Applications of BIM in construction projects

Considering the characteristics of various BIM based software, they can be used during any stage of the project, including operation and maintenance. BIM can save a significant amount of money and time avoiding a need for physical mock-up by providing virtual mock-up.

VI. 4D SIMULATION FOR EFFECTIVE MONITORING AND TRACKING

The construction planning involves the scheduling and sequencing of the project activities for the smooth execution. Gantt charts have long been one of the most utilised representation tools for project planning but they leave something when it comes to visualizing a project schedule. (Autodesk) Planning and monitoring is an extremely important part of the construction. The construction manager can use various 4D BIM enabled tools to enhance the quality control process. Overall, construction planning and monitoring with 4D BIM is a great process to build a facility per the designed model. But this research evaluate whether only integration of schedule with building model is enough for effective monitoring. To verify this, in this research, the schedule of the Worli Mixed-Use Tower project was integrated to the developed building information model in Revit. The utilization of scheduling introduces time as the 4th dimension (4D). There are plenty of BIM authoring tools such as Revit Architecture, Structure, MEP, AutoCAD Civil 3D, ArchiCAD, MEP Modeller etc. Some of these softwares are also capable of scheduling and cost estimation. Various BIM construction management and scheduling tools that support coordination available are Navisworks Manage, ProjectWise, Digital Project Designer, and Vico. Furthermore, Vico, Navisork's Timeliner, Innovaya and Synchro support BIM and schedule integration. Autodesk Navisworks Manage is well known for its clash detection feature. However it also includes a Timeliner feature, using which a simulation is carried out.

VII. ASSESSING VISUAL SIMULATION APPLICABILITY

The aim of BIM 4D application is to simulate construction schedules with BIM to visually communicate and analyse project activities, and help reduce delays and sequencing problems. The 4D scheduling features have capability to verify building viability by developing construction sequences that link model geometry to times and dates; import times, dates, and other task data from project

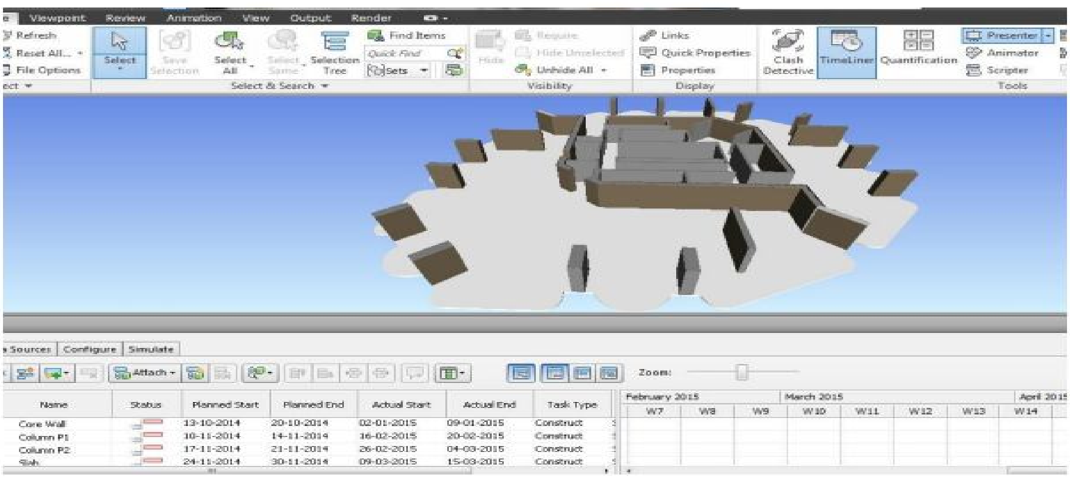

Figure 02: Navisworks 4D typical floor plate Prototype Model

management software to dynamically link schedules with project models; and set up planned and actual times to visualize deviations from the project schedule. To assess visual simulation (4D application), an example in the form of a project Worli Mixed-Use Tower was considered. It is a 142,500sq.m, seventy five storey development with a height of 327 m. This is an ongoing project, located in Worli, Mumbai. To begin with, a building model of the selected project was developed focussing on typical floor plates to restrict the research scope.

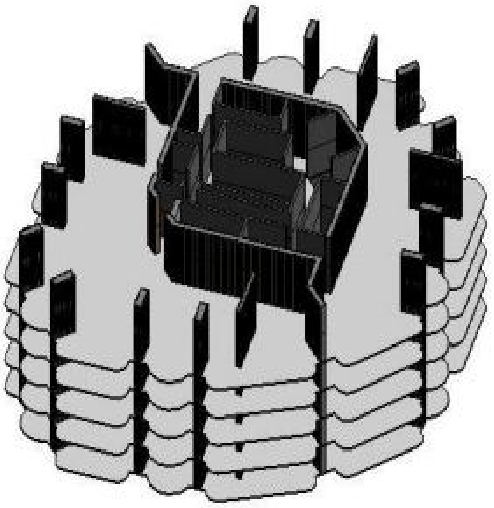

Figure 01; typical floor to floor construction view

The following Revit rendering (figure 01) shows typical floor construction view of the Worli tower project. Further a construction schedule prepared in Primavera was studied and linked to the developed building model using Navisworks. It was linked either by manually mapping the schedule dates from the project plan to the respective model components or schedule generated in Primavera was successfully imported to Navisworks. Using Naviswork's Timeliner feature, a simulation was carried out (see Fig.-02) as part of 4D application. Figure 02 depicts the timeline, activities, and model of the project. Once the model components and schedule activities were interlinked, the advantages of the 4D modelling were realized. As the timeline was selected for a particular day, the planned progress of the virtual construction project was immediately shown in the model. The simulation helped in understanding the flow of construction work through a visual medium. The flow or sequence of work included major activities such as construction of columns in groups (04 numbers), core wall construction and concrete slab construction.From the Primavera schedule, a floor to floor activity cycle flow was understood and noticed that it includes construction of major structural component such as columns (16 numbers), core wall and concrete slab (1900sq.m.). However the study of primavera schedule suggests many more activities than the mentioned above and it was necessary to link those activities to their respective building component. A typical floor to floor cycle process included typical activities (for Core Wall, columns, concrete slab) such as 1) Fixing of Reinforcement, 2) Checking and approval of Reinforcement 3) Fixing of Shutters 4) Checking and approval of Shutter 5) Concreting 6) Formwork stripping 7) Jumping of Formwork. To make 4D simulation responsive to the above mentioned activities, the model needed to include relevant components such as rebar structure, formwork, concrete pour etc. Figure 02 shows customise model which includes components mentioned above.

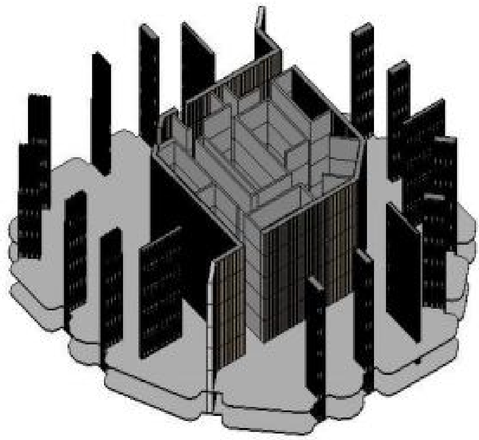

Figure 02; typical floor to floor construction view

4D modelling was an extremely powerful construction planning application for the construction management team but it was concluded that model needs to be author in response to the site execution related strategies or principles. Until the model is not authored in alliance with project planning activities, achieving the real benefits of 4D modelling is not possible.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support provided for this research by National Institute of Construction Management & Research, India. The authors would like to express sincere gratitude to Intento Associates, project planning and logistic consultant, Mumbai.

REFERENCES

[1] Azhar, S., Brown, J. and Farooqui, R. (2009) 'BIM-based Sustainability Analysis: An Evaluation of Building Performance Analysis Software.', 01, pp. 09, Available: CADC 2008 Seed Grant.

[2] Beetz, J. (2009) Facilitating Distributed Collaboration in the AEC/FM Sector using Semantic Web Technologies. PhD Vries, B., Eindhoven University of Technology, The Netherlands., Eindhoven.

[3] Foster, L. (2010) 'Legal Issues and Risks Associated with Building Information Modelling Technology', 01(01), pp. 1-12 [Masters thesis], Available: University of Kansas (Accessed 22.06.2011).

[4] Greenwood, D., Lockley, S., Malsane, S. and Matthews, J. 'Automated Compliance Checking using Building Information Models', Cobra 2010 RICS International Research Conference, Paris. Paris: Journal of Law in the Built Environment, 1-8.

[5] Krygiel, E. and Nies, B. (2008) Green bim:successful sustainable design with building information modelling. Indianapolis,Canada: Wiley Publishing,Inc.

[6] Lockley, S., Malsane, S. and Matthews, J. 'An Object Model Development for the UK Automated Compliance Checking'. The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors, New Delhi: RICS COBRA 2013.

[7] Niemeijer, R. A., Vries, B. d. and Beetz, J. 'Check-mate:automatic constraint checking of IFC models', Managing IT in construction, Istambul,Turkey.

[8] Yan, H. and Damien, P. 'Benefits and Barriers of Building Information Modelling', 12th International Conference on Computing in Civil and Building Engineering, Beijing, Beijing, 16.10.2008.

★★★