Application of Building Information Modeling Tool for Building Project

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Abstract: *Building Information Modeling (BIM) is a smart technological tool that allows a project to be built virtually before being built physically. It creates and uses consistent, coordinated, computable information about a building project. This dependable digital information about a building can be used for production of high-quality construction documents, design decision-making, cost-estimating, performance predictions, construction planning and eventually for managing and operating the facility. The purpose of this paper was to see the impact of BIM implementation on the traditional conventional building design methods. The BIM is extends this methodology into three dimensional (3D) drawings in the three primary dimensional width, height and depth with the time as the fourth dimension (4D) and cost as the fifth (5D). 4D model based scheduling simulation can be used to monitor the progress at site without being actually present there. It can also help in monitoring delays in relation to a planned schedule. 5D model based estimating produces accurate quantities for the efficient estimation of architectural, structural and services components. These quantities can be extracted at various stages: at concepts stage for generating budgets, at the end of design development stage for floating tenders, at GFC stage for verifying contractor bills. The BIM tools is to be helps for design, defining the building form and spaces, visualisation to analysing costs, time and energy performance. It is a construction management (CM) tool useful for a real simulation process of the ongoing building project. In the undertaken case study, BIM is useful for increasing total project quality, providing accurate quantity take-offs, improving scheduling timetables, consequently diminishing total project contingencies and costs. The case study presented in this paper suggested contractual arrangement for the building project resulted in improved productivity, better coordination, reduced error and rework of construction.*

Keywords: Building Information Modeling, Construction Management, Global Financial Crisis, 4D Model, 5D Model, Visualisation, Simulation.

1. Introduction

1.1. Overview

Construction planning and scheduling are identified as integral and important part of any construction project. The translation of a design to a construction schedule involves several steps of human interpretation and requires manipulation of data knowledge in the planner's mind. The current planning process is largely manual and time-consuming process. Current practices of construction project planning involve a number of methodologies/techniques that model dependencies and sequencing of project activities. Some of the techniques are bar charts, CPM based network diagrams, and time-changes diagram. None of these techniques have the capability of modeling and visualizing both the sequencing an execution pattern of activities.

A virtual model created using BIM can be put to a wide variety of uses – from recording programmatic data, defining the building form and spaces, to analyzing costs and energy performance. At the same time, the BIM software is perfectly capable of producing conventional drawing, such as plans and 3D renderings, by automatically creating "views" of the model. Therefore, the documents that are required for unambiguous communication and efficient co-ordination between the various design and construction team members, as well as the documents required for obtaining permits etc, are always accurate and updated as and when the design evolves and goes through several modifications. A virtual 3D model is not only graphical design but also a virtual database which required for a building project to be built virtually before being built physically. However, there is uncertainty about the compatibility of the traditional construction management methods. So the construction management (CM) tool can use BIM as a real simulation of the actual project.

1.2. Definitions

Building information modeling is not only used for the maintenance of 3D data but also for 4D and 5D representations. For 3D digital representations, there are some other technologies apart from BIM, such as AutoCAD, CAD, and others. 4D involves time management of the project for scheduling daily and monthly activities and thus, attracts a lot of customers toward the BIM process. 5D involves project's cost management, which can also be handled within the BIM process itself. BIM is a process that involves the maintenance of digital data for communicating project decisions related to different issues such as designing, visualization, collaboration, and simulation of different applications. BIM objects are available in the market for executing the processes during construction. Data that is stored in BIM can be used for managing the entire life cycle of the project with the use of integrated tools for the timely delivery.

1.3. Objective

In this study the building construction project used for basic concepts of the BIM, the planning, and the implementation

processes. It is determined that BIM is effective in the most critical phases of a project's lifecycle. BIM based procedures in real ongoing building project is the main development method used, meaning hands on trials with the state of the art software's, consultations and support by the participating in the organisation, and required data collection from case study projects. After that, a case study of building project in India is presented to quantitatively illustrate the cost and time savings realized by developing and using a building information model. The use of BIM has provided a means for increasing total project quality, providing accurate quantity takeoffs, and improving scheduling timetables, consequently diminishing total project contingencies and costs. The case study presented in the paper suggested contractual arrangement for the project resulted in improved productivity, better coordination, and reduced error, and rework. BIM method has been defined as the process which is implemented with different types of software and services available for various end-users such as contractors, architects, developers, Facilities Managers (FMs), building product manufacturers, and others across different fields such as commercial, residential, educational, healthcare, entertainment, sports, and so on.

2. Project Delivery Methods & BIM for Construction Management

The traditional design-bid-build project delivery method is based on an owner requirement design is prepared with the help of architect and consultants. Construction Management at Risk, Design/Build and Integrated Project Delivery (IPD) methods are the most common project delivery approaches that the industry currently practices. No matter which delivery approach is chosen, the general contractor or the construction manager can use BIM. Construction managers or general contractors can use BIM to extract quantities of work to prepare cost estimates. Furthermore, they can provide powerful 3D renderings. Moreover, schedule integrated BIM known as 4D BIM can be used for animations, safety analysis, and to prepare site logistic plans. Construction managers can use BIM to coordinate work with subcontractors. They can also update schedule and costs with BIM. Lastly, they can turn over an as-built building information model to the owner's maintenance team.

3. Motivation of Present Work & Problem Statement

Building Information Modeling (BIM) is an intelligent 3D model-based process that enables accurate, accessible and actionable insight for better-informed decisions across the project lifecycle. The motivation in doing better understand and communicate project risk, intent and options before a project is built. Streamline design tasks with discipline-specific tools that incorporate parametric controls, support engineering standards, and provide design validation rules. Evaluate constructability and identify design conflicts before construction begins. Over budget, delays, rework, poor communication, cost overrun, time overrun are typical problems faced by construction industry. These problems can be tackled through increasing the building information

exchange efficiency. Research in India has shown that rework can be reduced by as much as 30% where BIM is used. Moreover construction projects are becoming complex in nature due to error in documentation and co-ordination. BIM can be a solution to the above problem.

4. Building Construction Simulation in 4D & 5D Modeling

4.1 Defining 4D modeling

The construction planning involves the scheduling and sequencing of the model to coordinate virtual construction in time and space. The schedule of the anticipated construction progress can be integrated to a virtual construction. The utilization of scheduling introduces time as the 4th dimension (4D). There are two common scheduling methods that can be used to create 4D Building Information Model. These are critical path method (CPM) and line of balance. In the Critical Path Method, each activity is listed, linked to another activity, and assigned durations. Interdependency of an activity is added as either predecessors or successors to another activity. Moreover, the duration of the activities are entered. Based on the dependency and duration of the activities, the longest path is defined as the most critical path.

4.2 Defining 5D modeling

The two main elements of a cost estimate are quantity take-off and pricing. Quantities from a Building Information Model can be extracted to a cost database or an excel file. However, pricing cannot be attained from the model. Cost estimating requires the expertise of the cost estimator to analyze the components of a material and how they get installed. If the pricing for a certain activity is not available in the database, cost estimator may need a further breakdown of the element for more accurate pricing. For instance, if a concrete pour activity is taking place, the model may account for the level of detail for the rebar, wire mesh, pour stop, formwork, concrete etc., but not include it as part of the quantity take-off extraction.
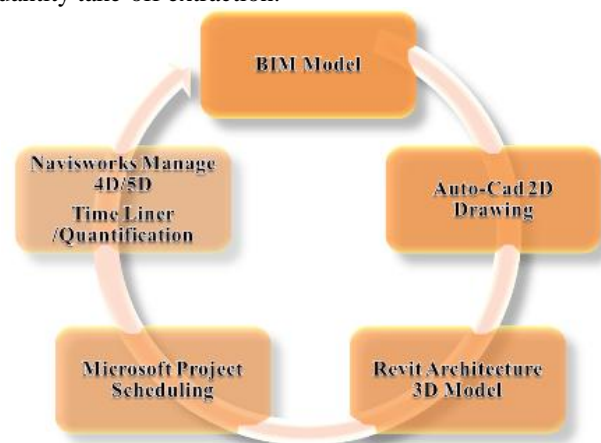

Figure 1: Process for developing BIM model

5. BIM Tools Used

There are plenty of Building Information Modeling tools. BIM tool represents the development and use of computer generated n-dimensional models to simulate the planning, design, construction and operation of a facility. It helps architects, engineers and constructors to visualize what is to be built in simulated environment and to identify potential design, construction or operational problems. BIM has recently attained widespread attention in the Architectural, Engineering and Construction (AEC) industry. The following table no. depicts the BIM authoring tools and their primary functions. The list includes MEP, structural, architectural, and 3D modeling software's. Some of these software's are also capable of scheduling and cost estimation.

Table 1: BIM Authoring Tools

Product Name	Manufacturer	Primary Function
Revit Architecture 2014	Autodesk	3D Architectural Modeling and parametric design.
Revit Structure 2014	Autodesk	3D Structural
Navisworks Manage 2014	Autodesk	Simulate for whole-project review & generate 4D and 5D model base scheduling.

6. BIM Use on Construction Projects Stage

BIM offers innumerable advantages throughout the entire lifecycle of a project – right from the design phase to the construction and operations phase.
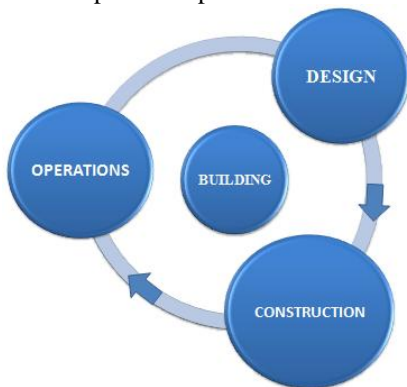

Figure 2: Design to Construction and Operation stage diagram

Table 2: BIM Use on Construction Process Phase

Design Stage	Construction Stage	Operation Stage
Visualization	Visualization	As built
Validation	Clash detection during Execution	Facilities management
Co-ordination	Co-ordination during Execution	
Estimates	Estimates	
	Resource Planning	
	Shop drawings	
	Delay Monitoring	

7. Visualization

BIM helps visualize the architectural design and assists in crucial decision making even at this stage. It is a great visualization tool. It provides a three dimensional virtual representation of the building. During the building phase of the project, the construction manager can provide renderings, walkthroughs, and sequencing of the model to better communicate the BIM concept in 3D. Visualization provides a better understanding of what the final product may look like. It takes away thought process of bringing the different traditional 2D views together to come up with the 3D view of a detail.

8. Validation

Images here show how the various design components can be validated through BIM modeling. Design and construction conflicts can be detected and resolved at a very early stage. Any changes in design can be very easily updated, visualized and implemented. These changes are then accessible to all the concerned team members from the different disciplines of the project.
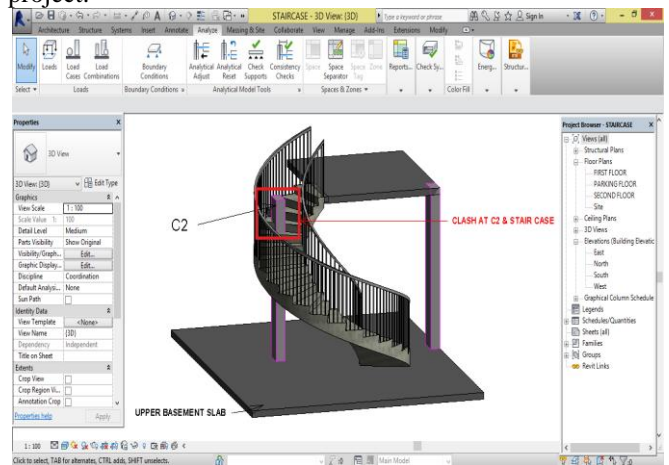

Figure 3: Conflict point detect in structural component

9. Co-ordination/Clash Detection and Resolution

In BIM the coordination between the architectural and structural components as well as various services is smooth and can be carried out well in advance, thus saving time delays during execution. Clashes between various disciplines can be identified prior to construction and delays at site can be eliminated. Clash detection is one of the biggest benefits that BIM offers and has been the largest contributing factor for widespread BIM usage in India.
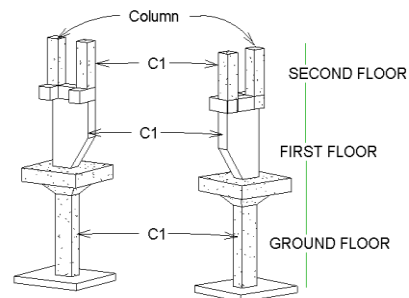

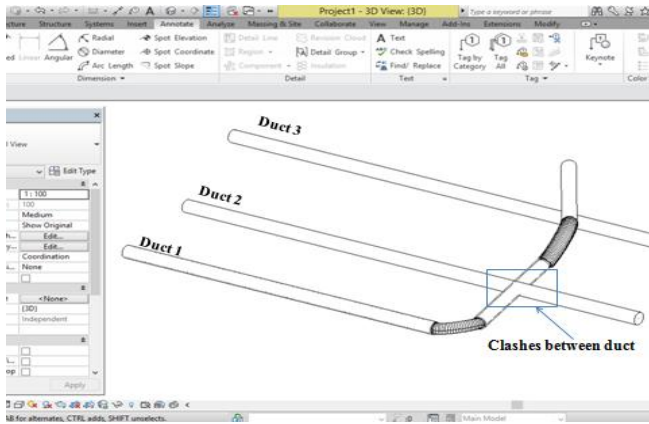**Figure 4(a):** Conflict point detect in structural component

Figure 4(b): Conflict point detect in structural component

10. Methodology

The goal of this project was to examine the uses and benefits of BIM for construction management and analyze BIM based scheduling and costing. There were two case studies presented in this project. The first case study, proposed Ladies Hostel building for Rajarambapu Institute of Technology College, Rajaramnagar. In that case study, building project, included real life examples of BIM uses and benefits. Also in the case study, a prototype building project, examined the 3D, 4D and 5D model by using BIM tools. The second case study, a prototype G+14 storied residential apartment building project for Om Sai Construction, Dhayari Pune generate and analysis of BIM model. Overall, the case study provided an insight on the benefits of using BIM and its applications.

11. Development of 3D, 4D and 5D Model- Overview of Case Studies

11.1.1 Case Study 1:- Rajarambapu Institute of Technology, Rajaramnagar, Islampur.
Proposed Ladies Hostel building project was used as a case study to understand the use and benefits of BIM in detail. The study includes the utilization of BIM for visualization, 3D coordination, prefabrication, construction planning and record model in a construction facility.

11.1.2 Use of BIM Tools
The primary focus of this project was the use of Building information modeling a 3D model, 4D for time integrators, 5D for cost estimation. This section provides results on the use of BIM tools. This includes formation of prototype building information model, interoperability of the model, integration of the model with schedule and BIM based scheduling.

11.1.3 3D Modeling of a Hostel Building
Student licensed version of Revit Architecture 2014 was downloaded from Autodesk's student community website to develop a 3D building model. The creation of a 3D building model using the Revit Architecture 2014 showed the powerful features of BIM. The creation of an element on a view such as floor plan translated correctly to a different view such as elevation view. This saved a lot of time in comparison to if the design were drawn in traditional 2D

view. Furthermore, the parametric modeling detected the conflicts of elements. The use of this feature eliminated duplication or overlapping of elements.

First, a new Revit file was created and saved. Then, the perimeter walls were created. Once the perimeter walls were completed, the interior walls are created. Then, the foundation walls, flooring, doors, windows, roof, stairs, deck were created. Furthermore, the rooms were tagged. Also electrical and plumbing elements were created for this study. The differences of 3D modeling and 2D drafting were reviewed. Furthermore, the granularity of objects including the decomposition of the elements was explored. Figure No.5. Depicts the prototype Revit building model created for this project.

Figure 5: 3D model of RIT Proposed Hostel, Rajaramnagar

11.1.4 4D Modeling of a Hostel Building
The creation of 4D model involved the transition of the model via Industry Foundation Classes (IFC) from Revit Architecture to Navisworks Manage. During the transition, several challenges were found for the building project. Since some of the walls extended from 1st floor up to the roof, the IFC file was exported using Revit's "split walls and columns by level" option for scheduling purposes as depicted in figure no.6

4D modeling required the development of a 3D model as well as the schedule. The 3D model was created in Revit Architecture 2014. A simple schedule with 170 activities generated in MS Project was successfully imported to Navisworks Manage. The elements of the model listed under resources were successfully linked to schedule activities. Once the linking was complete, a simple 4D model was visualized. The visualization at any given time of the project can be enhanced at Gantt view with the drag of the timeline. This helps a better understanding to prepare for sequencing. Figure No.6 depicts the timeline, activities, and model of the project.

The Microsoft Project used the critical path method to create the schedule. Autodesk's Navisworks Manage Simulate for whole project review for 4D BIM tool was downloaded through its website. In this project, it was utilized as the integrator of the Revit model in IFC format and the Microsoft Project in xml format. Once the model and the schedule were imported in to the Navisworks Manage integration tool, the Industry Foundation Classes (IFC) resources which was a list

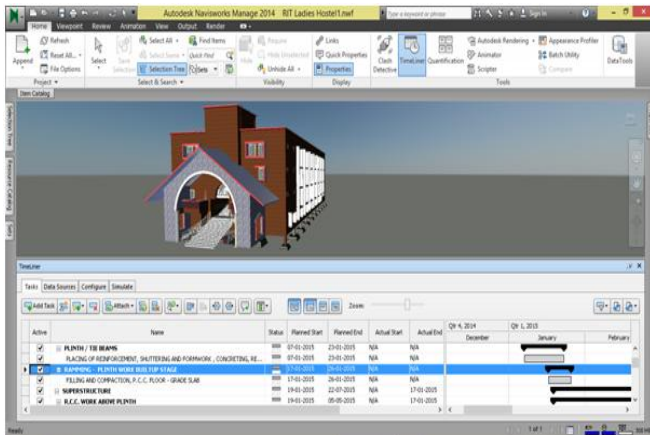of building elements created in BIM was linked to the activities.

Figure 6: 4D model of RIT Proposed Hostel, Rajaramnagar

11.1.5 5D BIM model based estimating of a Hostel Building

BIM produces accurate quantities for the efficient estimation of architectural, structural and services components. These quantities can be extracted at various stages: at concept stage for generating budgets, at the end of design development stage for floating tenders, at Good for Construction (GFC) stage for verifying contractor bills.
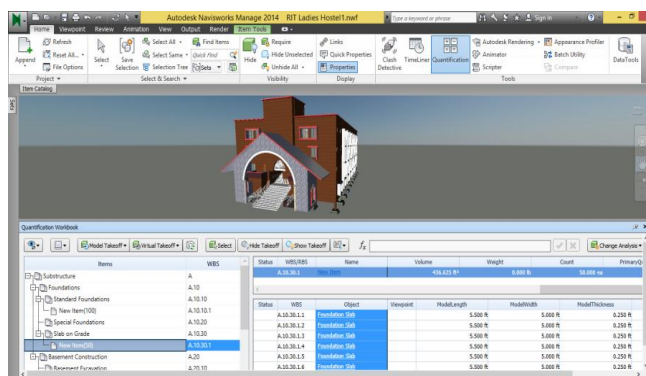

Figure 7: 5D model of RIT Proposed Hostel, Rajaramnagar.

11.2 Case Study 2: Om Sai Construction Dhayari, Pune

11.2.1 3D Modeling of a Residential Apartment

The creation of an element on a view such as floor plan translated correctly to a different view such as elevation view. This saved a lot of time in comparison to if the design were drawn in traditional 2D view. Furthermore, the parametric modeling detected the conflicts of elements. The use of this feature eliminated duplication or overlapping of elements.

The primary focus of this project will be the use of Building information modeling a 3D model of a case study and then after 4D for time integrators, 5D for cost estimation. This includes formation of prototype building information model, interoperability of the model, integration of the model.

Figure 8: 3D model of Om Sai Construction, Dhayari Pune

11.2.2 4D Modeling of a Residential Apartment building

The construction of any structure can be visually simulated once the BIM model is built. A Microsoft project or Primavera construction project plan is linked to the various components of the model to generate the simulation. This simulation can be used to monitor the progress at site without being actually present there. It can also help in monitoring delays in relation to a planned schedule. The use of Industry Foundation Class (IFC) was used as the main communication protocol for the exchange of information and the generation of the schedule since it acts an interoperability application between various BIM tools. The IFC provided a breakdown of information that categorized the elements of construction. Navisworks Manage was utilized to generate BIM based schedules. When the model was imported to Navisworks Manage, the option "create tasks and assignments for imported resources" was checked off to create a quick IFC based schedule. The generated BIM based (IFC) schedule was automatically linked to resources as depicted in figure 5. IFC schedule was exported to MS Project to create a more elaborative BIM based schedule as shown below. When the revised BIM based schedule in MS Project was imported back into Navisworks Manage, the 3D elements did not recognize the relationship of the IFC file.
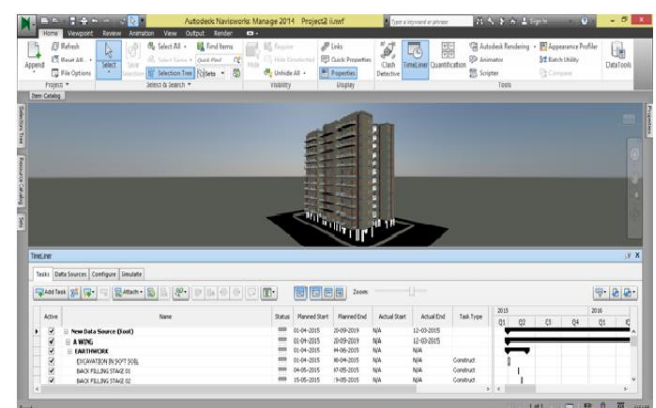

Figure 9: 4D model of Om Sai Construction, Dhayari Pune

12. Limitation of BIM in India

BIM has no limitation but its application can be perceived only because of resistance to adoption and implementation. The BIM is an emerging technology, it is going to have several risks and liabilities that go along with it. Obviously,

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one of the biggest risks a firm takes with BIM is errors in accuracy. BIM model is the core of the project, even a single error in precision can be extremely expensive.

Another setback that can arise is the price tag. BIM technologies, such as training, software costs and required hardware upgrades, are costly and it is very time consuming to implement them into an existing process. Adequate training is needed in different areas and levels of expertise can vary. The problem here is that because such a large amount of data is exchanged among team members, there is the group could endanger the entire project.

These new projects are being fast-tracked and mandates are being issued to include the very latest building technologies such as BIM. India has large and relatively inexpensive labour available which decreases the value of the productivity improvements that BIM offers. Lower cost of employing workers discourages efforts to replace field labour with automated solution. However, BIM offers time savings and competitive advantage and it helps in quick turnarounds in the intense time pressured and competitive environment of India.

13. Recommendations

Following are recommendations based on Revit Architecture 2014 BIM tool:
- The use of BIM in comparison to 2D modeling is strongly encouraged because the parametric model denies overlapping of the elements and there are no errors, omissions or conflicts of information at different views.
- The user should be use currently available elements and alter them to create new elements because Revit Architecture requires time and investment to build brand new elements from scratch.
- Further study is required for the decomposition of elements.
- When a project is being modeled, scheduling activities shall be considered and splitting option shall be used when necessary.

14. Conclusion

During the construction better understand and communicate project risk, intent and options before a project is built. Streamline design tasks with discipline-specific tools that incorporate parametric controls, support engineering standards, and provide design validation rules. Evaluate constructability and identify design conflicts before construction begins. In construction process share and the same consistent data across the project lifecycle. In the building construction project in sequencing and planning can also produce a 4D visualization simulation. By using BIM method 80% reduction in time to generate estimates. 10% saving on construction cost through clash detection. 20% saving through construction process simulation.

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