4D BIM Implementation for Construction of Multi-Storeyed Residential Building

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Abstract- *Building Information Modelling(BIM) has recently emerged as a highly efficient solution for information management in Architecture, Engineering and Construction(AEC) industry. Clash detection tool is an application of BIM which is used for the coordination of building systems within 3D building models. This paper gives a brief introduction about Clash detection in BIM. The prime objective of this research is to identify the extent of cost optimization and time optimization for the construction of residential building using BIM Coordination (Clash Detection). This research involves the case study of a residential building constructed using conventional methods of building information management. The scope of utilization of BIM Coordination for the project under consideration was identified from the acquired data. This research also focuses on simplifying and standardizing the process of BIM coordination using Autodesk Navisworks.*

Keywords- AEC, BIM, 4D, Coordination, Clash Detection, Monitoring, Cost optimization,Methodology, Scope

I. INTRODUCTION

BIM:

Building Information Modelling (BIM) is process that supports virtual design and construction methodologies putting all team members together throughout the entire design and construction process and beyond to the operations in maintenance of the building, during its working life. Typically, BIM is one holistic process using real-time, intellectual modelling software effectively working in 3D, 4D (3D + time), and 5D (4D + cost) to improve productivity, to save money and time in the design and construction phases, and to reduce operating costs after construction.

Necessity of BIM:

It is also important to highlight the increasing necessity of BIM, and its overall cost-effectiveness. When it comes to the decision-making process, no tool outperforms BIM in clarity of purpose and scope. Each week in the owners' meeting, we observed a communication process that was primarily dependent on oral exchange among meeting participants supported by 2D text and graphics. When the digital drawings are brought out though, a decision is often made in only minutes. As projects become increasingly complex, BIM becomes more and more necessary for all participants to understand what is taking place. It could also be argued that the financial savings of efficient decision-making and fewer project changes will cover the cost of maintaining an accurate model. It is likely that complete BIM services will pay for itself over the life of a project. It is for these reasons that this major qualifying project recommends a gradual investment in BIM technology for all applications in Construction Project Management.

II. 4D BIM

This study aims to shift the focus on the opportunities of BIM for its use in project management functions and to consequently improve the fulfilment of the time constraint. Hence, a separate section is considered necessary to cover all the related issues. This chapter provides the basis for the 'Practical Part' of the present work regarding the 4D environment of BIM.

i. Time: The 4th dimension

The addition of the time attribute to a 3D (x,y,z) environment results in what it is broadly known as 4D (x,y,z,t) environment. This extra feature provides the model with more dynamism in terms of representing the behaviour of the building elements along time, extending in this way its usage for other purposes. Introducing time in the BIM environment is seen by the author to make the time constraint more likely to be fulfilled and at the same time to address some of the problems previously mentioned.

In principle, BIM and 4D technology are separate concepts and have had different progression from their conception. Nevertheless, it is believed that their combination in the same working methodology could help enhance certain processes and it seems especially interesting for contractors (Eastman et al., 2011).

It is believed that advanced ICT can ease the on-time delivery of projects to the project team by the introduction of geometry in traditional construction schedules. In the following section, the application of 4D technologies to the AEC sector is to be analyzed.

III. 4D TECHNOLOGY IN CONSTRUCTION

At the time of representing a building, traditional design tools usually present its final and completed state without paying attention to its variation over time. Thus, one of the main limitations of 3D models is their incapability to display the precise status of the construction progress (Wang et al., 2004). However, planners require of a more dynamic view of the sequence to be able to visualize intermediate stages. Apart from that, the traditional tools employed for planning, such as bar-charts and diagrams do not facilitate the visualization of the process because they do not display spatial features and require of a high level of abstraction to create a mental representation (Koo & Fischer, 2000; Chau et al., 2003 & 2004). Even though experience is a strong point for planning there is a need to reduce risks by leaving less space to improvisation and consequently to possible inadequate interpretations. 4D technology came to light to address all the problems, leading static models towards a more dynamic context by the introduction of the time variable: 3D + time
4D models have several uses throughout the whole project life cycle and they offer opportunities within different project phases. 4 different stages can be distinguished regarding possible utilization of 4D models to assist construction projects (GSA, 2009): (1) pre-design stage, (2) design development, (3) tendering phase and (4) construction stage.

1. Pre-design stage: at very early design or drafting stages, 4D technology is useful for the analysis of possible construction alternatives. It allows comparing several solutions with the interaction between the basic construction schedule and very general parts of the building, such as levels and spaces, but not at the element level yet.

2. Design development: as the design advances on and more details are to be included, this technology is valuable to carry out constructability analysis. Whilst project planning attains importance, 4D models are truly helpful to check whether the planned schedule and construction sequence make sense. Apart from that, they are of good use to compare and select construction methods and processes.
3. Tendering phase: 4D models can be used by contractors to communicate the different construction phases to the client, as well as the way in which the building is to be constructed. In part, it could serve to convince the client about the ability of the general contractor to carry out the project. Simultaneously, they are also mentioned by the U.S. General Services Administration (GSA) to be useful to optimize the bidding process in requests for proposals. Therefore, 4D technology would not only work as a selling tool, but also to gain accuracy in the estimations by means of a better understanding of the construction sequence.

4. Construction stage: during the construction stage one of the challenges for contractors is to coordinate trades or subcontractors on site to avoid time- space conflicts. This is another capability of 4D models along with the help they provide for visual site management. Another utility for this stage would be the 'as- built vs. as-planned' comparisons for project monitoring functions. This is also the phase where it can be combined with the LPS seen in Section 2.2.4 for short-term look-ahead meetings (Eastman et al., 2011), since the time for meetings can be reduced up to a 30% using 4D technologies (Dawood &Sikka, 2009). Hence, the use of 4D can be extended to work as a tool to improve field productivity through an enhanced coordination and communication between disciplines and project participants. Especial attention is to be paid to these functionalities since this is the most relevant phase for the present research

5. A construction sequence to the client in an animated manner the information and scheduling criteria used for such animation would not be vital. Nevertheless, if it is going to be used for management purposes by contractors and project managers, the model would be much more demanding in order to satisfy the flexibility needs of planners. This is the key factor where BIM has something new to offer.

IV. METHODOLOGY

This Master Thesis includes both theoretical and practical research. For the development of the theoretical part, an extensive literature review is performed mainly based on primary sources of information from scientific databases as well as other reliable electronic and paper-based sources.

The present work consists of 4 different phases to accomplish the aims and objectives set as illustrated by 'Figure 1.1'. Phase 1 represents the literature review and the completion of the theoretical part of the study. The practical part involves Phase 2 and Phase 3. In Phase 2 the original BIM model is implemented in one of the available commercial BIM platforms:

Autodesk Revit ® 2016. A time schedule is also produced in Microsoft ® Office Project 2010. In phase 3 the 4D BIM model is implemented using a commercial BIM tool by the same firm: Autodesk Navisworks Manage ® 2016. The time schedule and the BIM model from Phase 2 are merged to produce the 4D BIM model (Figure 1.2). This practical part also includes the assessment of the selected 4D BIM application by means of a series of simple examples showing its capabilities and paying special attention to the workflow and communication with the rest of employed tools. Finally, Phase 4 is the phase when conclusions are drawn up and opportunities and limitations presented as a result of the previous assessment.

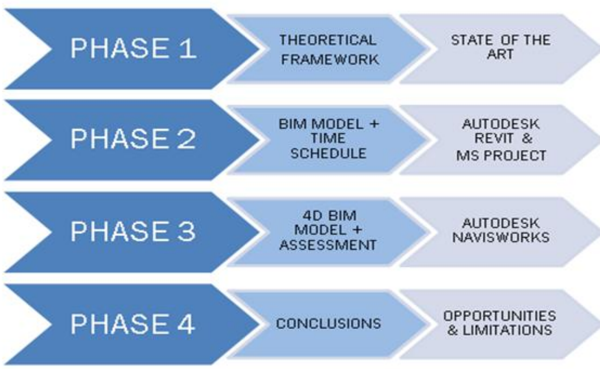

Figure 1.1 – Different phases of the Master Thesis

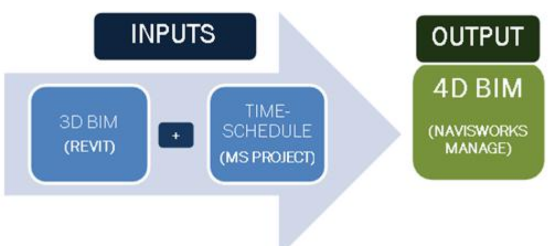

Figure 1.2 – Practical Part: From conventional BIM model to 4D BIM model

V. CASE STUDY

Site: EWS(Economically Weaker Sector) Housing Scheme under BSUP(Basic Services for Urban Poor) JNNURM(Jawaharlal Nehru National Urban Renewal Mission) on sector 17+19(P) Nigdi, Pune.

The site consists of 160 buildings. Each building consists of 7 floors with 4 flats each. The main highlight of this construction in the aluform technology that has been used for construction. Construction cycle for each floor was 7 day.

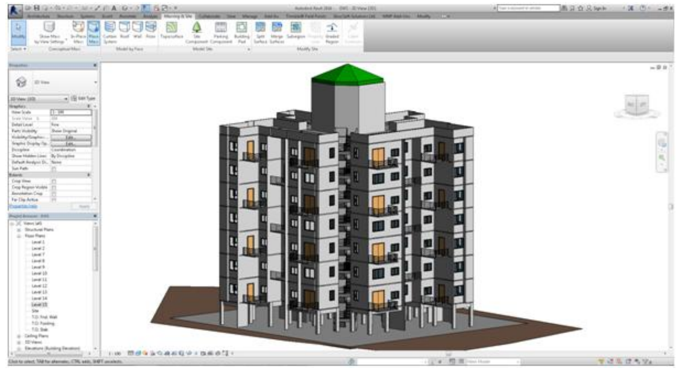

Figure 5.1 – Original BIM model created in Revit 2016

'Figure 5.1' shows the original BIM model generated in Revit. The next step would be to import it into Navisworks as well as to create the construction schedule.

If the schedule is going to be created directly in MS Project, it is of great importance to include two extra columns: "Task ID" and "Task Type". The Task ID consists of a code given to each task (Table 1.1) and the Task Type is introduced with the aim of distinguishing between temporary elements, elements to be constructed, and elements to be demolished'. The figure shows activities categorized under construct type.

Task ID	Task Name	Task ID	Task Name
T01	INITIAL SURFACE	RF01	ROOF
T02	EXCAVATED SURFACE	EW01	EXTERNAL WALLS L0
F01	FOUNDATIONS	EW02	EXTERNAL WALLS L1
C01	COLUMNS L-1	EW03	EXTERNAL WALLS L2
C02	COLUMNS L0	EW04	EXTERNAL WALLS L3
C03	COLUMNS L1	IW01	INTERNAL WALLS L0
C04	COLUMNS L2	IW02	INTERNAL WALLS L1
C05	COLUMNS L3	IW03	INTERNAL WALLS L2
F01	FLOOR L0	IW04	INTERNAL WALLS L3
F02	FLOOR L1	D01	DOORS L0
F03	FLOOR L2	D02	DOORS L1
F04	FLOOR L3	D03	DOORS L2
S01	STAIRS L0-1	D04	DOORS L3
S02	STAIRS L1-2	W01	WINDOWS L0
S03	STAIRS L2-3	W02	WINDOWS L1
R01	RAILING STAIRS L0-1	W03	WINDOWS L2
R02	RAILING STAIRS L1-2	W04	WINDOWS L3
R03	RAILING STAIRS L2-3	---	---

Table 1.1 – Tasks and ID of the elements in the model

VI. SCOPE OF WORK

1. To build a BIM Architectural and structural model, coordinate between all the services, model the interiors and coordinate that with the other disciplines.

2. Prepare the MSP schedule for the project under consideration.
3. Create a 4D simulation in Navisworks using MSP model and Revit model.
4. Calculate Quantities from the prepared Model
5. Calculate Cost of project from the prepared model
6. Prepare reports for project monitoring based on MSP model.

VII. RESULTS

1. Quantity take-offs from the 3D model
2. 4D simulation for monitoring and control of construction.
3. Cost reports generated by MSP
4. Implementation for Indian conditions.

VIII. LIMITATIONS

As well as opportunities, Navisworks has some weaknesses that represent limitations, being the following considered to be the most significant ones:

1. The main limitation of Navisworks comes from its conception of not being able to modify the original files. This is more a design-review-like feature, but it is not as helpful for a 4D BIM environment. Indeed, 4D BIM is not the main utility that it was conceived for, but the 'Timeliner' is rather an additional tool included in its set of tools. Counting with more options for bi-directional data exchange between the model and the schedule would be interesting.

2. In the same lines, planning of re-scheduling operations cannot be processed in the 3D environment. It is necessary to go back to the external scheduling tool and synchronize the 'Timeliner'hierarchy.

3. Parts and zones have to be created beforehand in Revit, which can be considered a weakness, since having elements divided in parts is not handy in the original BIM model. A 4D BIM tool should include a function to split elements like slabs, walls, etc. without modifying the model contained in the originalfile.

4. Although in one way or another Navisworks covers the most of the outlined project management functionalities (Table 4.1), some of them are covered in what it is considered a 'passive' way rather than in an 'active' way (Jung &Joo, 2011). This means that these functionalities are supported by 4D technologies only because they improve visualization. Consequently, a more active role of these tools would be also useful. This is commonly achieved by additional automation

IX. CONCLUSION

The cure for the recovery of the construction industry appears to rely on many different and innovative concepts that are continuously emerging. In fact, important changes are required to improve construction performance because despite of its ancient character, nowadays it lags behind many other industries.

The working methodology presented in this work, which pretends to totally change the information management in construction and is broadly known as BIM, involves the adoption of ICT with its consequent changes in many processes as they were known to date. As a result, it is experiencing a severe resistance to change by construction practitioners although it seems to be finally imposing, at least in some parts of the world. It is believed that BIM can be further optimized if it is accompanied by contracting methods based on IPD and some of the Lean Construction concepts, since all of them look forward to improving the construction sector and encouraging a collaborative environment that has been once and again mentioned throughout the whole study.
Focusing on a branch within BIM, the study was redirected towards 4D BIM for a better management of time, and it was found to be valid for project management functions to mitigate project risks by means of one of the available commercial applications: Navis works Manage 2016. This tool requires of the use of 2 other platforms to make 4D modelling possible: Revit 2016 and MS Project 2010. This workflow was analyzed and it was concluded that it is able to satisfy many of the theoretical functionalities expected from it. However, apart from opportunities some limitations already mentioned in the previous section were alsodetected.

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