

A Critical Appraisal of Integrating 4D and 5D BIM into Construction Practice

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Abstract

Building Information Modeling (BIM) is the application of concept and principles of interoperability, used for information exchange. It uses efficient business models to control the construction operations in a most significant way that reduces multiple errors. BIM maintains feasibility of all designs and processes by collaboration of information procured from diverse departments operating within a firm. This paper reviews the application of 4D and 5D BIM in construction industry. It also focuses on softwares which can be effectively used to integrate the 3D visualization of building with time and cost element. This study aims at exploring the project management issues related with time and cost overruns, which can be overcome by using 4D and 5D BIM.

Keywords: AEC, BIM, Cost Overruns, Project Management, Time Overruns

Introduction

BIM is a collaborative concept that uses using coordinated and rational softwares effectively running in various formats ranging from 3D to 7D to improve efficiency, reduce time and cost in all phases of construction [1].

BIM is an integrated process used by built environment professionals, which can be executed by a range of softwares. It is an assimilation of technology and management to execute construction projects successfully [1, 2]. It is a set of advanced tools that has changed the way a building is planned, designed and constructed.

BIM is the assemblage of whole building data created into a configured database easy to handle in a digital and practical way [2, 3]. The term BIM was introduced by Prof. Eastman in early 1970's and it got admired in mid 1990's. Construction industry started to implement BIM practically a decade ago. USA is the first nation to implement BIM on large scale chased by UK, Australia and Canada. Nowadays BIM has been effectively used in many countries around the world such as India, China, UAE, Australia, Canada [2, 6].

BIM is used as a project management tool, but fundamentally it is an unmatched novel concept. The perception of three terms i.e. Building, Information, and Modeling is described below [4] and also shown in figure 1.

- Building: The absolute phases of any type of building.
- Information: All unique data received from each construction process and activity.
- Modeling: The built-in tool which creates and controls the information supply, which can be of many types like structural modeling, architectural modeling, MEP (Maintenance, Electrical, Plumbing) modeling, etc.

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B	I	M
Building	Information	Modeling
Residential	Spatial	Site
Commercial	Element	Architectural
Industrial	Process	Structural
Educational	Activity	MEP
Healthcare	Quantity	HVAC

Figure 1. Description of BIM Notion

BIM in Project Management

Project teams in the construction sector are being constantly stressed to deliver successful projects despite of fixed finances, insufficient resources, overrunning time and cost plans and unreliable data [5].

The main facility such as structural, architectural and MEP works should be well coordinated. BIM helps in clash detection due to better 3D visualization of any two colliding elements (such as rebar clashes) and finds the exact location of inconsistency during construction [2].

The BIM model allows simulated construction of a facility in 2D and 3D manner before its real execution, sequentially, to reduce uncertainty, increase safety, reform problems and analyze potential effects. Contractor from any expertise can put vital information in the BIM model prior to construction and gives liberty to prefabricate and pre-assemble some structures offsite. BIM modeler can be appointed to create feasible BIM model and BIM manager for monitoring the whole BIM process in all stages.

Through BIM, construction ravage can be minimized on-site and facilities are conveyed in time, which helps in better inventory management, also the nature and scope of work can be made clearer by accurate design and scheduling. Structures, activities and processes can be shown in a computer-generated figure with all the facilities. It also avoids errors by allowing deviation detection whereas the virtual model visually demonstrates where components of the structure are incorrectly organized [2, 6].

Project managers need to set up a BIM-focused model for communication of information and should know feasibility and benefits of project management through BIM. For new projects, BIM is the core process for communication of information to all members of project teams with multiple disciplines. The use of BIM has changed the way; the project manager works and communicates with different parties.

Hence, the project manager should be aware of some vital problems caused by BIM [6, 20].

For example:

How to include matter related to BIM in an agreement?

- How to deal with risks caused by BIM?
- How to handle extra costs of BIM?
- How to manage changes in the workforce structure?

Due to these complex problems, some intensive research is required and project managers should keep an eye on such problems.

Project Management Issues

Time Overrun

Time overrun is considered as one of the main critical issue in construction diligence at present and has a great impact on construction cost as well. With increase in time of the project, the cost also increases, which can never be recovered for some projects. Time overrun can be defined as a variation in the estimated project time and actual time to finish the project.

It is represented mathematically as [7]:

$$Net\ Duration = Date\ of\ Project\ Commencement - Date\ of\ Project\ Approval$$

$$Time\ Overrun = Net\ Duration - Project\ Duration$$

Time overruns can be due to internal or external causes; the internal causes include delay from contractors, client or consultant’s side. External causes include delay due to natural calamities, government action or material suppliers.

Table 1 shows the top 10 factors responsible for time overruns [7]:

Table 1. Factors affecting time overruns in construction project

S.No	Causes of Time Overrun
1	Tradition of conveying contract to the lowest bidder
2	Inefficient site management
3	Contractor’s financial problems
4	Poor planning, scheduling and estimating
5	Managerial issues with sub-contractors
6	Insufficient work experience
7	Resource allocation and management problems
8	Inaccurate estimate of project duration
9	Unskilled designers
10	Shortage of manpower

4D BIM can be an effective tool, which can actually help to prevent time overruns in construction projects as for any construction project; time is the most critical factor.

Henry Gantt in 1990’s developed the first ever bar chart for projects, commonly known as Gantt Charts and after some years Milestone Charts and CPM were evolved. With the beginning and advancement of 3D BIM in early 2000’s, 4D BIM is the next step in the world of construction schedulers [8, 9].

4D BIM presents a 3D design that is incorporated with the construction schedule; the 4th dimension is time, which is added to the 3D process. The outcome of 4D BIM process is the advance construction mock-up that was never possible earlier. At times Gantt charts become very complicated to analyze and demonstrate within a short duration so their effectiveness can be increased by the 4D BIM by providing a rapid visualization of the project schedule.

The creation of the 4D models allows the diverse members (engineers, architects, designers, contractors and clients) of a construction project, to envisage the whole period of a sequence of construction events and demonstrate the development of activities through the life span of the project [10]. This BIM-enabled strategy towards project management has a very bright prospective to improve the project management and possession of construction project of any size or intricacy.

After creating a model, the scheduling data about different components can be easily linked to generate an accurate program and permits step by step visualization of project’s progress.

Construction progressions can be analyzed as a sequence of setbacks using 4D BIM, facilitating users to search alternatives, administer solutions and optimize the outcomes thereby helping in diversification of construction projects [11, 12].

4D BIM permits product development, collaborative execution, transparent management and improves supply chain management. It maintains a continuous delivery of components/modules by eliminating waste of time, thereby providing value to the customers. The particular activities and processes within those plans can be clearly connected to their graphical illustrations. The addition of time-related quality data allows the 3D illustrations of a project to be nicely created, by showing how the building will be constructed and how it will appear with enclosed surroundings at every stage of the project. This is greatly useful in terms of scheduling work in a secure and rational way that make best use of efficiency on site [8, 13].

4D BIM is employed in colossal construction projects like tall structures, expressways, tunnels, bridges, mills, hospitals, hotels, dams, power plants, mines, etc. 4D BIM has conventionally been used for superior projects in US, UK having high coupled costs. But due to technological advancements 4D BIM has been started to be used in simple but vital processes such as manufacturing.

There are many BIM softwares available online depending upon the necessity, budget and applications. BIM software is integrated with project management software for the purpose of 4D modeling as shown in figure 2. Many types of software are available for 4D BIM process as mentioned below:

- Synchro Professional
- Vico Software
- VIATechnik
- Asta Powerproject
- Constructech
- Engworks
- AcePLP
- Innovaya
- MS Projects
- Primavera

Process of 4D BIM Using MS Project and Naviswork

Example below shows a six step process, how a person can integrate MS Project (Project Management Software) with Naviswork (BIM Software).

- To begin with, make a schedule in MS Project and save it.
- Open the file in Naviswork, where we wish to import the schedule.

- Under the TimeLiner tab, select Add Task by right clicking to it.
- Under the Links tap in TimeLiner, right click and Add Link; choose the schedule file to be imported.
- After selecting the Link, right click on the link and select Rebuild Task Hierarchy from Link. Now Tasks tab should list the schedule under it.
- Link (Integrate) the elements of the model to their respective parts of the schedule.

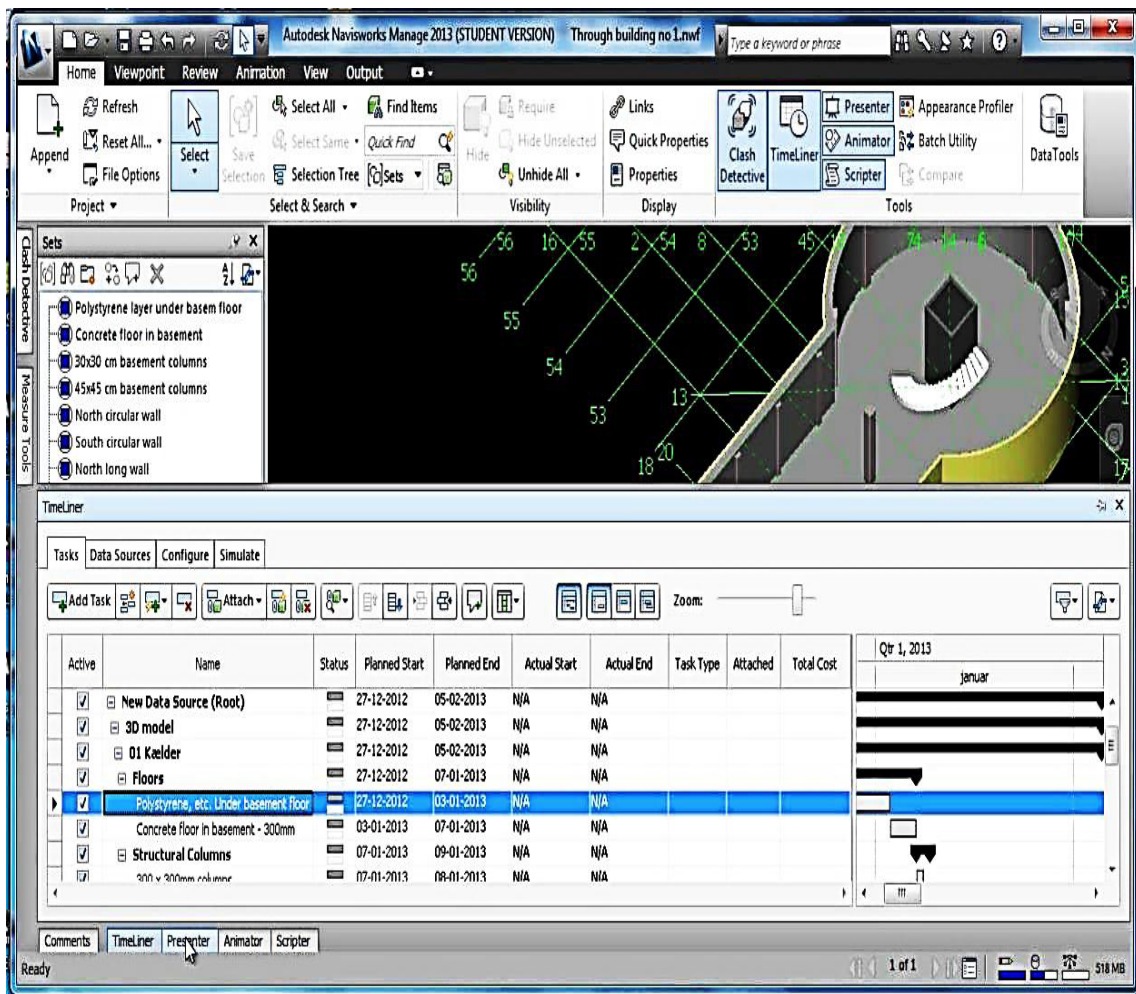


Figure 2.4D BIM process (Source: www.i1.ytimg.com)

Cost Overrun

Cost is always considered as the most dominant factor for the success of a project. Due to poor cost management, firms are facing various problems these days, as projects are rarely completed within the assigned budget.

Cost overrun involves the unanticipated costs, when budget exceeds the cost limit, which is prepared during financial planning. Cost overrun is different from cost escalation,

which is used to express the unexpected increase in budget due to inflation.

Cost overruns can be due to three main reasons:

- Technical
- Socio-Political
- Human Related

Figure 3 shows the factors responsible for cost overruns [14]:

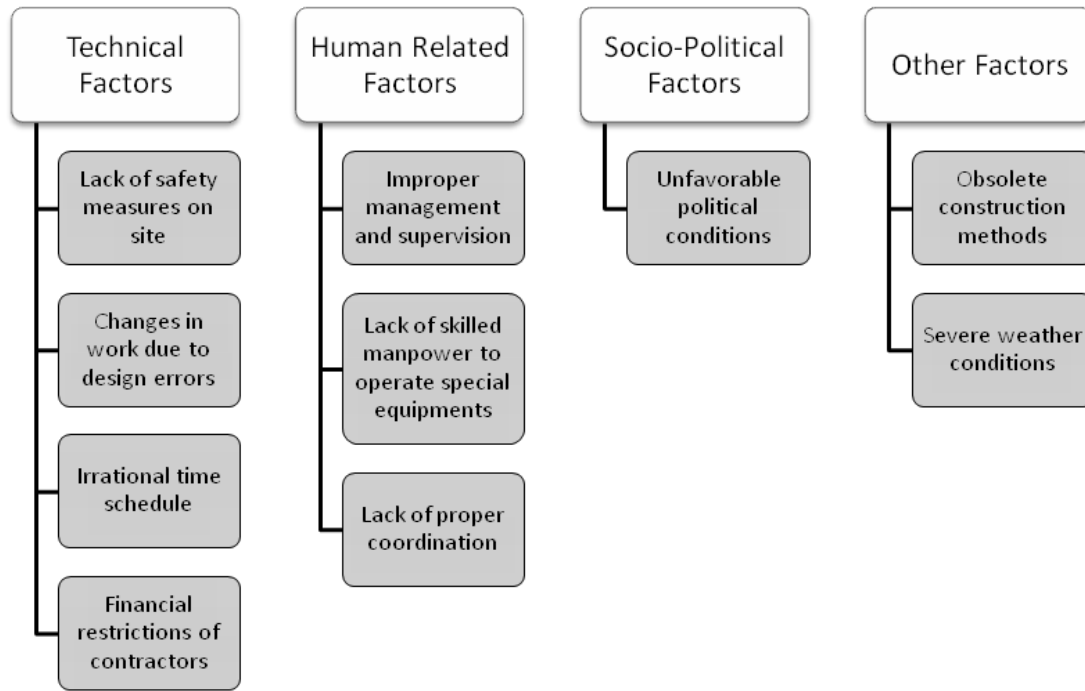


Figure 3. Factors affecting cost overruns in construction project

In this respect, 5D BIM can be an effective tool to prevent cost overruns in construction projects by efficient cost management.

5D BIM is a term used in AEC industry which refers to the integration of 3D components of building with time (4th dimension) and cost (5th dimension).

5D Models enables the project professionals to envisage the progress of construction work and its related costs over time. 5D BIM is the evolution of 4D BIM and it helps the cost managers to prevent cost overruns and costing errors in construction project as cost is one of the prominent factor that affects the performance of the project.

After creating the 4D BIM model, the next step is to make the precise cost estimates of various components. The estimates include the initial purchasing cost of equipment, installation cost, repair cost, maintenance cost and operation costs associated with the component during its service life and renewal cost after the completion of service. After having the quantities, the production rates are obtained from sub-contractors. The whole project is divided into a number of blocks or segments and unit rates are applied for manpower, material and equipments.

With the help of 3D and 5D model, cost managers can rapidly determine the quantity of any component and by applying unit rate to calculate the overall cost of module [15]. The module costs are then combined to get the overall cost of project. Totaling of cost can be done automatically, thus saving the time. Manager can see clearly in 3D model what the various elements are costing and get notifications automatically whenever changes are made in the design

model; this is how the 3D model works in collaboration with the cost element to create a 5D process.

Just like 4D BIM, 5D BIM is also relevant to the project delivery team. With accurate schedule data and robust cost estimation, one can monitor the project performance. This accurate and fast cost estimation can be helpful for preparing financial statements at the end of month [8, 16].

Cost reporting is the process of reporting the net total cost to the client, the quality of which is directly dependent on the quality of information, which the project team procures. If information provided is inaccurate, then that inaccuracy will effect costing also.

Currently, cost managers might create an analytical cost plan at the beginning of a project and then revise it once or twice as a project progresses. Cost associated with complete design is only obtained after the team finishes designing [17, 18]. In a 5D BIM process, cost managers are engaged right from the beginning and are equivalent participants in the project team. They save their time from meticulous manual estimations to more precise cost reporting at early stage and efficiently sustain an active cost plan that become helpful in serving their teams in budgeting.

5D BIM process is more than model based estimation. It is rather an innovative means of working with project stakeholders, conveying a pool of information to the team in a visually unrestrained manner [19].

Process of 5D BIM using VICO Software

The process can be described as below and also shown in figure 4:

- Provide various estimates to the client for the quick comparison with the targeted cost.
- Achieve, the scope of project in an excellent way with visual data modeling abilities. The costs are calculated with appropriate formulas on the basis of design, materials, specifications, site conditions, legal conditions by keeping in view the clients requirements.
- Achieve the information in real time manner, after the model is created.
- Store, the building data and personnel's data in designed database which can be used from specific departments like plant and machinery, billing, quality etc.

Conclusions and Recommendations

BIM is a growing area of research, integrating multiple information sources within the engineering, construction, fabrication and manufacturing industry. Construction business is rising with proficiency and innovation. Principally, BIM and its all dimensions (3D, 4D, 5D, 6D and 7D) are becoming globally recognized. Following are the conclusions of the study:

Effectiveness of 4D BIM

- 4D models function mainly as communication tool for solving time restrictions and as a technique for increasing collaboration. Contractors can evaluate 4D models to make sure that the plan is practical and effective as much as possible.
- The 4D simulations cover both the chronological and spatial facets of a schedule and interconnect the schedule more efficiently than a customary Gantt chart.
- Planning managers can link diverse schedules easily, and can quickly detect whether the project is on trajectory or behind stipulated schedule.

Limitations of 4D BIM

- To maintain a 4D model, it's quite fussy to collect data throughout a project.
- 4D BIM models requires knowledge of advanced scheduling tools.

Effectiveness of 5D BIM

- Estimators can use 5D BIM tools to smooth the difficult task of quantity takeoff.
- They can rapidly visualize, detect, and evaluate conditions which provide more time to adjust prices from sub-contractors and vendors.

Limitation of 5D BIM

- 5D BIM is simply an initial point for estimating.

No software can provide a complete estimate automatically from a building model. A model can merely deliver a minor part of the information required for a cost estimate. The residual data is taken either from guidelines or physical entries delivered by a cost estimator [19].

Recommendations

- Some of the methods that are used to study time overruns within a 4D model require full automation.
- For the full command on 5D BIM, engineers and planners should synchronize methods to regulate building modules and the features related with those modules for cost estimation.

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