

# Time and Cost Control of Construction Project using 5D BIM process

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**Abstract** - The conventional methods of cost estimation, planning & scheduling and project monitoring are slowly becoming obsolete since the upcoming construction projects are becoming enormous in size and more complex. The market demands a more advanced method which could produce accurate outcome as well as handle the complex nature of the project. Building Information Modelling (BIM) is a new methodology of working which could help bridge the gaps in traditional method. The AEC professionals and researchers are studying its implementation and its impact on the AEC Industry. New tools were developed through the medium of Information Technology. These tools / software's can execute the same work which are done by conventional method, but with more accuracy. BIM can be implemented from the most initial stage of construction i.e. from land acquisition to operational stage to the final stage of demolition. Thus, BIM is not just a tool for 3D modelling but actually a methodology that can be completely incorporated in the construction project and applied from pre-construction stages to post-construction stages. This thesis mostly concentrates on the time and cost aspect of the construction project by implementing Building Information Methodology in the pre-construction phase and determine the advantages and drawbacks of implementing this method with the help of a case study. Further, it provides a methodology to create a 5D simulation model by linking construction schedule and costing data with the 3D model of a G+24 residential project prepared on Autodesk Revit 2020. The data is integrated with the model using Autodesk Navisworks 2020. Time is considered to be the fourth Dimension and Cost is considered as the 5<sup>th</sup> Dimension. Although 5D BIM is a brave attempt on transforming the whole construction process, there are many stakeholders who do not understand the practicability of BIM. This paper reviews and summarizes information relating to BIM and explain the 5D BIM implementation process and the benefits of Scheduling and cost estimation using BIM methodology in construction project. It also determine the benefits of BIM to Architect-Engineers-Contractor-Operator (AECO) Industry all together. It helps AECO industry to achieve more accurate design, reduced clashes, more precise cost estimation and scheduling, integrate design and construction phase and smooth collaboration of different construction participants.

**Key Words:** Building Information Modelling; Cost Estimation; Planning; Scheduling; Modelling; Simulation; 5D Model; 3D Model

## 1. INTRODUCTION

About nine percent of India's GDP is contributed by construction industry. Similar to other business, a construction project is deemed to be a success when the returns on investment (ROI) are maximum. Time consumed and cost incurred are the two most governing factor that influence the success of a project. Therefore, scheduling and cost estimation must be precise and optimum in order to accomplish successful execution of the project and gain maximum profit from the investment without compromising the quality of the construction. Thus time, cost and quality are the essence of a successful project. India being a developing country show massive scope for construction, therefore the future projects are getting massive in size and complex in nature. The current conventional methods are manual and time consuming. Miscommunication leads to 2/3<sup>rd</sup> of problems arising in construction project. The approximate amount of wastage produced by a project is about 30% of the building material delivered on-site (Osmani, 2019). Thus, the conventional 2-Dimensional modelling on today's modern day projects is not a precise solution and only leads to waste of time, inaccuracy and monetary loss. In order to cope with this situation, Building Information Modelling (BIM) comes into action. BIM provides tools that could improve the efficiency of estimating cost and time duration of project. Primarily, BIM uses a 3-Dimensional representation of construction project which gives a visual idea about the project to all the entities involved in the completion of the project. Thus BIM is a process that create a model which consist of both graphical as well as non-graphical information. It allows multiple stakeholders and AEC (architecture, engineering, construction) professionals to collaborate on the planning, design, and construction of a building within one 3D model. Therefore, Based on review of recent research and a case study of a residential building, this article focuses on benefits of using BIM method for cost estimation, scheduling and steps for 5-Dimensional BIM model and obstacles arising during BIM implementation.

## AIM & OBJECTIVE

The study aims at designing 3D model using BIM software and integrating it with scheduling data and cost estimation data as fourth and fifth dimension of the model, hence creating an information rich file which could be used as a central model that could be referred by all the involved participants.

The objectives are as follows:

- To study BIM flow process
- To recognize the difference between BIM process and conventional method
- To state the advantages and limitations of BIM process

## METHODOLOGY

5D BIM process requires learning of three softwares, each plays a different part in modeling.

1) 3D modeling: There are many softwares available for 3D modeling in the market. Autodesk Revit will be the software used for generating 3D model, since this software is the most popular and widely accepted.

2) Scheduling-4D: Microsoft Project 2016(MSP) was used for scheduling due to its easy operation and understanding. Considering the size of the selected case study, MSP software proves to be sufficient.

3) Cost Estimating -5D: Cost incurred could be easily calculated if we determine the estimated quantities of the materials & labours that are required. The total cost is then obtained by comparing the quantities with the BOQ (Bill of Quantity). Thus, for estimating the quantities, an Autodesk Revit plugin (software that adds new functions to a host program) was used, named as Areabook : Roombook (ABRB) plugin, which comes under the "quantification" tab in the tool bar. This plugin directly imports all the quantities of the elements used during the 3D modeling in Revit and generates an excel sheet in a format that is self-explanatory.

4) Decision making: In order to prove the benefits of BIM process in decision making, material selection for constructing the partition walls are compared and the most appropriate material is to be selected by using time and cost as elements of comparison.

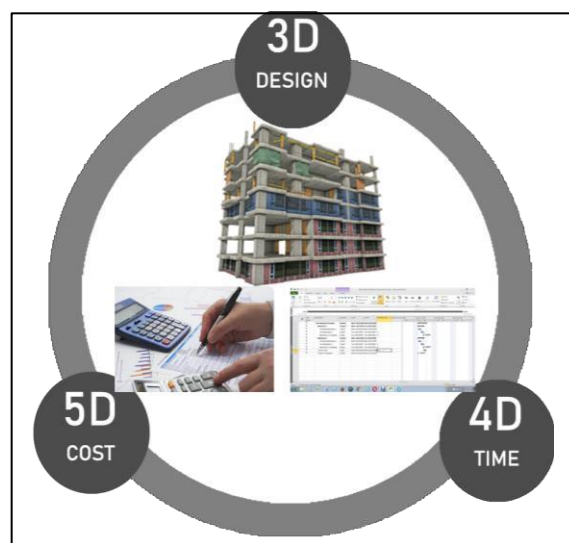


Fig 1: 5D BIM process

## 2. LITERATURE REVIEW

The AEC Industry is slowly shifting from using 2D CAD and paper for designing and are notably accepting three-dimensional approach. The use of technology is becoming trending and positively accepted by many organizations. This technological approach is actually referred to as Building Information Modeling (BIM). The concept of BIM was initially introduced in the year 1960s. The concept of BIM was then studied by researchers which helped them implement working softwares in early CAD programs. In that times BIM actually meant building's graphical three-dimensional model (3D) enriched by additional intelligence (information associated with graphics).

The base of this technology is made up of the Graphical Information Model (GIM), covering the geometrical model building, names and functional peculiarity of its components, its physical properties. The modern definition of BIM has appeared in late 1990's early 2000's, with the emergence on the market of a number of Single Building Model (SBM) realization concepts offered by different CAD software vendors such as Autodesk, GraphiSOFT, Bentley and Revit. The BIM is now considered to be the standard definition for information modeling technology in AEC industry.

According to McGraw Hill Smart Market Report(2014), a survey was conducted in 10 countries which consisted of 727 contractors. The survey concluded that percentage of BIM involvement in construction industry will increase by 50% on an average. A positive ROI (Return on Investment) was reported by three quarters of all the contractors that were surveyed. Most of the surveyed contractors estimated the ROI on their BIM implementation between 10% to 25% and about 60% contractor believed that further advancement in BIM visualization would have most positive impact on BIM ROI. The construction sector is the second largest industry after agriculture accounting for 11% of India's GDP and is demanding for speeding productivity and improving efficiency. This demand gap can be filled with the help of BIM. According to a report by Autodesk, designers across the world have positively implemented BIM technology in their construction project, whereas their Indian counterparts have still not started using BIM to its full potential. Systra, a France based public transport consulting firm was recently awarded a contract of Bangalore metro system, which mandated BIM, but India lacked number of trained people.

### 3. INFORMATION PROCESSING IN BIM

The method of processing the information is different for different users, different phases and different needs, but the flow tends to be the same.

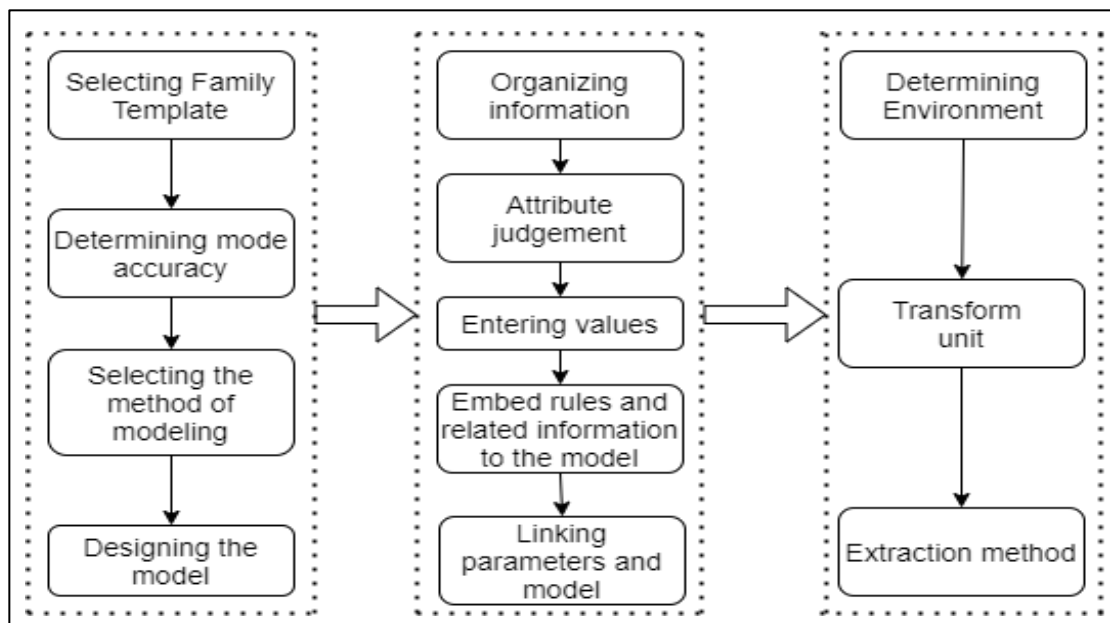


Fig 2: Flow of Information processing

## 4. MODELING

### 4.1 Elevation

The initial step in BIM modeling is defining the elevations. By defining the elevations, the software establishes planes on which we can work. Their accuracy directly influences the model's success. Each elevation must be named to the respective floor. Import the AutoCAD file to the designated elevation. For instance, the elevation level defined for the first floor should be opened in view and the AutoCAD floor plan for the same floor should be imported on that plan view. Initially we design columns by using column family, secondly we define the beam by using beam family and then design the slab. Each and every element designed in the plan can be detailed. For example, the name of the contractor who is going to construct the wall can be entered in the comment section of that element. The designing is done w.r.t imported AutoCAD drawings. Provision of doors, windows, plumbing, HVAC, electrical system and so on is the next step.

#### 4.2 Quantity statistics

Whenever an element is created in the Revit software, the volume, surface area, length, cross-sectional dimension are automatically calculated and be easily obtained, as well as the type of material to be used while constructing can be defined. This data can be directly used for quantity estimating. The accuracy of the quantity obtained depends upon the preciseness of the designed model. Revit software also provides schedule for any type of family used in the model. The family can also be further distinguished by their other properties and a separate schedule can be obtained. These schedule is then imported in the Excel files which becomes handy for quantity estimator to determine the final quantity.

#### 5. 5D BIM CONSTRUCTION PRINCIPLE

All the attributes of construction project information can be integrated in a BIM model. It creates a platform where all the stakeholders involved in the project can work simultaneously and make well discussed decision and reduce clashes. Thus, BIM technology helps create a simulation model which determines the clashes visually and helps avoid disassembly; rework waste in construction phase. The BIM value chain is as shown below.

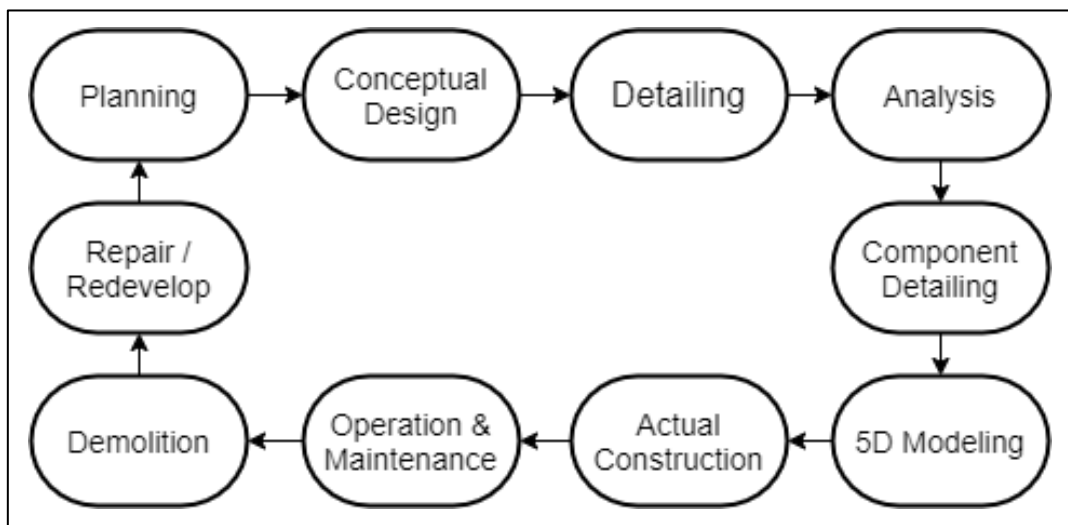


Fig 3 : BIM Flowchart

During the construction of a project, many entities are involved in the phase, such as site engineers, contractors, plumbing contractor, electrical contractor and so on. BIM creates a single source of information that is assessable by all the involved entities, hence any changes made are immediately uploaded on the main server and conveyed to all the contractors and site engineers simultaneously.

There are many kinds of BIM softwares available in the market. Bentley and Autodesk are the two leading companies in providing BIM software. The Revit + Navisworks combination is the most popular in civil buildings and both products are owned by Autodesk. Revit software is used for modelling while Navisworks is used for 3D model integration, data collaboration, simulation and calibration.

5D BIM helps timely sharing and transmission of information to all the involved participants, and also provide timely data-information required for construction management. In design stage 5D BIM helps detects the changes to be made in drawings in advance. The overall project is in control and accurate completion of the scene of staff and resource allocation. It minimizes the loss caused by workers and also guide us in preparing maintenance and repair plan during operational phase. However, this study mainly discusses on application of BIM 5D in construction phase of project management. The application of 5D BIM construction management platform in construction phase include site layout simulation and optimization, virtual construction, visualization, progress control and cost control.

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### **5.1 Virtual visualization**

Visualizing a project before even its construction makes the BIM technology important to use. 5D BIM creates a simulation, an animated video that help visualize the construction stages of project i.e. from site management to operational stage.

### **5.2 Clash detection**

A project consists structural components, architectural components as well as MEP (Mechanical, Engineering & Plumbing) components. Each component is designed by different participants and hence more prone to errors. BIM helps merge all the data together and create a simulation model. This model helps determine clashes that might occur even before the actual construction has initiated and determine changes to be made in design drawing, thus avoiding rework, construction cost and saving time.

### **5.3 Construction simulation**

According to the construction organization, initially the model is simulated by using different construction process, then the most optimum construction sequencing and construction method is selected and an optimal construction plan is implemented. Construction scheduling includes schedule simulation, construction program simulation, site layout and so on. This helps complete the project on time and also maintain the quality of construction.

### **5.4 Model updating**

As the construction commence, many problems arise during modelling since the site conditions are different from each other. Thus changes in BIM model need to be made in real time. Thus, model need to be modified by project management personnel and the same central model is referred by other participants and the decision making process becomes more easy.

### **5.5 Design visualization**

Autodesk Revit is used to create a 3D model of the structure which includes RCC structure, walls, windows and doors. It helps determine pre-construction problems and optimize the design. Traditional construction process causes many issue due to poor communication. So the Park Mist Residency project will be planned with the help of BIM technology and create a visual process to construct the building. A simulation video will define the construction process and visualize the complex part of the structure which will be easy to understand by all the participants. Any errors in the drawings will be known in advance and a lot of time will be saved. A 5D BIM model has three important components i.e. the schedule procured by planning engineer and the estimated cost procured by cost estimators. Navisworks then helps integrate this data together to finally create a 5D model rich with information which can be easily interpreted by any participants.

### **5.6 Decision making**

To understand the benefits of BIM process, the material selection for the construction of partition walls was considered. Initially the partition walls were created in the Revit model and the schedule was then imported from the model into Microsoft Excel which includes volume, surface area, thickness, length and height. This data obtained helped reach the final decision more quickly. Partition walls material includes material for plastering, type of brick and the bonding material between the bricks.

### **5.7 Schedule Management**

BIM helps plan ahead of schedule to coordinate the construction of human, material, machine and make the construction process smooth and in orderly fashion. The BIM process thus help in quality tracking, real time tracking. BIM provides with live cost plan that can help make early cost decisions.

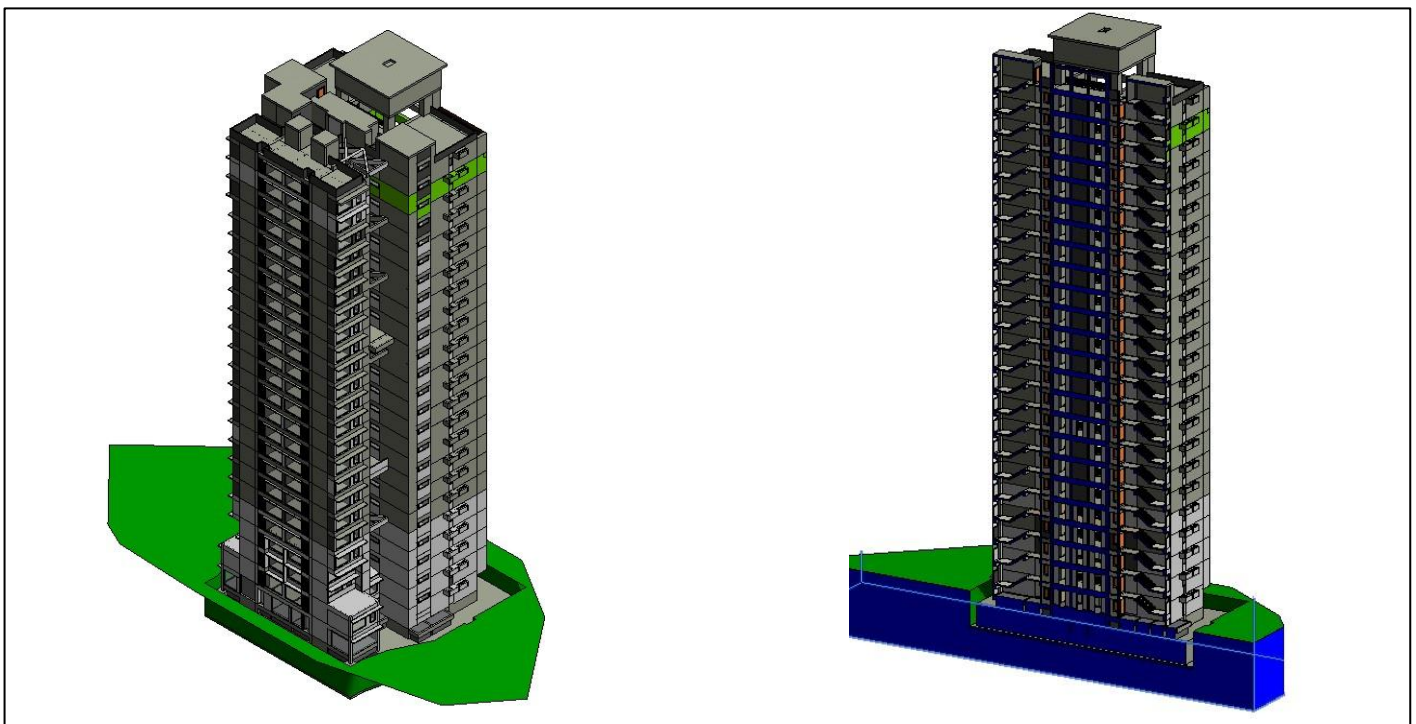
## **6. BIM IMPLEMENTATION - CASE STUDY**

This research practice use of Building Information Modeling (BIM) process to control time and cost aspect of a construction project and define its advantages by comparing it with conventional method. Initially, the 2D AutoCAD drawing are to be

procured which includes floor plans and elevation sections of the building and the structural consultant provided the reinforcement details. The research method consists of (1) Literature review and (2) Case study

For Case study, a live project is considered. Data required for 3D modeling was procured from architects and structural consultants. The data for planning & scheduling was acquired from project management consultant. With the help of BIM software, this data is then initially used to design a 3-Dimensional representation of the residential building and then the costing and scheduling data is integrated with the 3D model to obtain a 5-Dimensional (5D) model. The process and model are then analyzed to help illustrate how this new project delivery method can help optimize a project's time and cost.

The case project is a G+24 residential building in Dadar (west), Mumbai. Figure 3 shows the visual representation of the building in Autodesk Revit 2020. The building is a redevelopment project which has provision for vertical parking and built on a plot area of 0.47 acre i.e. 1902 sq. mtr.



**Fig 4: Final 3D view and cross-section view of Park Mist Residency project**

Initially, the 3D model was designed on Autodesk Revit software by using the procured data. First step during the designing is creating the structural components i.e. beams, columns, slabs and stairs. Secondly create walls as per the thickness mentioned in the AutoCAD drawings. Now we add doors and windows to the walls. This three steps helped create a 3D model. Conceptual design, working drawings and material specification were generated from the 3D model.

Initially three types of material combination were considered for partition wall construction and the most optimum material was selected by comparing time and cost aspect:

1) Fly Ash bricks (223x150x100)mm with cement mortar of ratio 1:6 as bonding material

No.	Material	Quantity	Rate(Rs)	Final amount
	Fly Ash Brick	277725	4	11,10,900
	Sand	146.0835	1059.47	154771.086
	Cement	701 bags	350	245350
	Labour cost			2884266
				Total costing = Rs.43,95,287.09/-
				Duration =140 days

2) Autoclaved aerated block with cement mortar of ratio 1:6 as bonding material

No.	Material	Quantity	Rate(Rs)	Final amount
	AAC block	24447 no.	55	13,44,585
	Sand	83.875 cumec	1059.47	88,863.046
	Cement	403 bags	350	1,41,050
	Labour cost			2265222
Total costing = Rs.38,39,720.05/-				
Duration = 107 days				

3) Autoclaved aerated block with AAC block adhesive chemical as bonding material

No.	Material	Quantity	Rate(Rs)	Final amount
	AAC block	34431 no.	55	18,93,705
	Sand	69.105 cumec	1059.47	73,214.674
	Adhesive	400	400	1,60,000
	Cement	332 bags	350	1,16,200
	Labour cost			1884433
Total costing = Rs.40,27,552/-				
Duration = 90 days				

Thus by comparing the time and cost aspect of all the three types, the most optimum output would be “Autoclaved aerated block with AAC block adhesive chemical as bonding material”. Which will cost Rs.40,27,552/- and time consumed will be 90 days. Hence BIM helps in taking accurate and faster decisions

Scheduling of the building was done on Microsoft Project 2016. As per the schedule the final total time required to complete the RCC work, walls and installation of doors & windows was 399 days, which is approximately 14 months.

Task Name	Duration	ROUND OFF DURATION	Start	Finish
▾ Park Mist Residency	398.75 days	399days	Mon 01-04-19	Mon 11-05-20
Receipt of LOI	0 days	0days	Mon 01-04-19	Mon 01-04-19
Satautory & Construction approval	7 days	7days	Mon 01-04-19	Sun 07-04-19
Agreement	15 days	15days	Mon 01-04-19	Mon 15-04-19
Site Handing Over	0 days	0days	Mon 01-04-19	Mon 01-04-19
Receipt of Lineout Drawing	0 days	0days	Mon 01-04-19	Mon 01-04-19
▾ SITE PREPARATION & MOBILIZATION	22 days	22days	Mon 01-04-19	Mon 22-04-19
▾ SUBSTRUCTURE	61 days	61days	Mon 01-04-19	Sat 01-06-19
▾ SUPERSTRUCTURE	397.63 days	398days	Mon 01-04-19	Sun 10-05-20
▾ PROJECT CLOSE-OUT	66.25 days	66days	Sun 10-05-20	Wed 15-07-20

Fig 5: Microsoft Project 2016 schedule

The same schedule was then integrated with 3D model by using Autodesk’s Navisworks software and created a 4D simulation model. The third step is to import quantities from 3D Revit model. Revit helps you import the schedule in Excel too. But in this project, a plugin named Buildingbook: Areabook: Roombook extension was used which directly imports quantity schedule into excel file which is more easy to understand and give distinguished quantities. The schedule can be edited as per your requirement

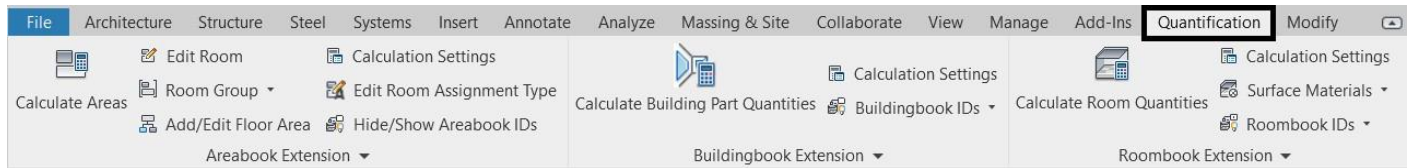


Fig 6: Areabook Roombook plugin panel in Revit (Quantification)

Below is an example of basic walls provided in ground floor. The snap was taken from the automatically generated excel sheet.

Basic Walls										
Level	Type	Structural Usage	Count	Element	Length/Width	Height	Thickness	Area	Volume	
0 Ground Floor	Interior - 250	Non-bearing	1	Basic Wall1250: Basic Wall: Interior - 250						
			1	Layer 1: Main	2200	2100	250	5	1.15	
	<b>TOTAL: Interior - 250</b>		<b>1</b>						<b>5</b>	<b>1.15</b>
	SW 1250	Bearing	2	Basic Wall38: Basic Wall: SW 1250(38), Basic Wall6: Basic Wall: SW 1250(6)						
			2	Layer 1: Main	1050	1550	1250	3	4.07	
			2	Basic Wall1247: Basic Wall: SW 1250(1248), Basic Wall1248: Basic Wall: SW 1250(1249)						
<b>TOTAL: SW 1250</b>		<b>4</b>						<b>6</b>	<b>8.01</b>	
<b>TOTAL: SW 1250</b>		<b>4</b>						<b>10</b>	<b>12.08</b>	

Fig 7: Automatically generated Excel sheet by using ABRB plugin(Shear walls)

Floors											
Level	Type	Structural	Count	Element	+/-	Function	Material	Thickness	Surface	Volume	
-1 Story	1.5m Raft	Yes	1	Floor378: Floor: 1.5m Raft		Interior					
			1	Layer 1: Main	+	Structure [1]	Concrete, Cast-in-Place gray	1500	21	31.72	
	<b>TOTAL: 1.5m Raft</b>		<b>1</b>					<b>Concrete, Cast-in-Place gray</b>		<b>21</b>	<b>31.72</b>
<b>TOTAL: -1 Story</b>		<b>1</b>					<b>Concrete, Cast-in-Place gray</b>		<b>21</b>	<b>31.72</b>	
New Raft	3M Raft	Yes	1	Floor1: Floor: 3M Raft		Interior					
			1	Layer 1: Main	+	Structure [1]	Concrete, Cast-in-Place gray	3000	675	2024.29	
	1	Floor1: Floor: 1.5m Raft	-				1500	0	-0.82		
<b>TOTAL: 3M Raft</b>		<b>1</b>					<b>Concrete, Cast-in-Place gray</b>		<b>675</b>	<b>2023.46</b>	
<b>TOTAL: New Raft</b>		<b>1</b>					<b>Concrete, Cast-in-Place gray</b>		<b>675</b>	<b>2023.46</b>	
Story 1	130	Yes	1	Floor4: Floor: 130		Interior					
			1	Layer 1: Main	+	Structure [1]	Concrete, Cast-in-Place gray	130	12	1.62	
			1	Floor5: Floor: 130		Interior					
			1	Layer 1: Main	+	Structure [1]	Concrete, Cast-in-Place gray	130	11	1.43	
1	Floor6: Floor: 130		Interior								

Fig 8: Automatically generated Excel sheet by using ABRB plugin(Floor slab)

### Final Quantities

- **Concrete** - 8386.17 cum
- **Reinforcement** - 217.64 metric ton
- **Excavation quantity** - 4281.43 cum
- **Doors** - 354 no.
- **Window** - 794 sq.mtr

When all the quantities are calculated, the actual cost of all the material is taken from the BOQ (Bill of Quantity). This information is feed in Microsoft Project (msp) file and called as resource sheet. The resource sheet includes the daily labour wages, equipment rental rates, material cost, etc. Once the resource sheet is loaded, the quantity of the resources and the type of resource is then individually updated for each activity task in "Summary Task Information".

### Total Budget for RCC work , Doors & Windows, partition walls and Plastering

₹ 5,16,65,258.26 /-





## 8. Benefits, limitations, obstacles and problems of BIM process

Visualization of a construction project provide better understanding to all the participants involved. But most importantly it becomes simple to communicate information with the investors. It provides reliable features to architects, engineers, contractors and all the other participants. It creates a single centralized model which is accessible to all the entities and defines each and every element of a building. Therefore any update in the model will be noticed by all. 5D BIM helps avoid costly error during construction. Predetermining the clashes between other elements helps save time, cost and many other discrepancies. Computerized automated model support decision making by evaluating the model with different construction methods, materials and techniques without even actually performing the construction, and select the most optimum process which can save time and money. The 3D model is designed on Autodesk Revit by creating elements such as walls, floors, foundation, doors, windows and so on. These element can also be viewed in cross-section. The quantity of all the elements used during modelling can be imported in excel sheet from Revit software. There are many barriers that are faced by organizations, such as failure of implementation, high initial investment, time consumed during software training, inefficient hardware. But the most common reason for implementing BIM is lack of knowledge about strict BIM implementation standards

## 9. RESULTS

Results shows that the 5D BIM approach have a good potential and many benefits in simplifying the process of monitoring construction activity. The quantities were easy to procure from the model. It made the decision making process more precise and at the same faster. The same model will prove very advantageous during operation and maintenance stage, since the operator will be able to access all the information about the building through the model. Three software were learned during the process, of which Autodesk Revit had the longest learning time duration.

## 10. CONCLUSION

The case study proves that advancement in technology has taken the AEC industry into computer-based age. It has proved to be a promising technique and has caused better changes in entire construction industry. The BIM is applicable throughout the lifecycle from planning stage to the implementation stage to operational stage. BIM provides possibility for optimization of complex projects. As there are many advantages to BIM methodology, there are some limitations too. Initially, software training consumes a lot of time and the computer machines required should also be advanced in order to bear the load of these softwares, which makes the cost of implementation high. Secondly, during the literature review study, it was pointed out that the government plays a major role in the acceptance and success of this methods. For instance, the UK government made it compulsory to implement BIM process to all the government aided projects which lead to acceptance of BIM process by all the construction companies, the same goes with Italy as well as Australia. The BIM process were a success in these countries. There are many upcoming softwares in the market but they are not effectively practiced since there are constraints such as existing contractual arrangement and traditional organizations which flight for their individual benefits rather than searching for better project delivery solution.

## 11. FUTURE SCOPE

BIM is applicable in every aspects of the AEC industry. The scope of this thesis is limited to 5D BIM modeling, which is only applicable for constructing the building, but the level of detailing (LOD) can be increase by integrating Mechanical- Electrical- Plumbing(MEP) works, sustainability(6<sup>th</sup> Dimension), operation & maintenance(7<sup>th</sup> Dimension) and so on to make the model more rich in information. In recent study, safety is also considered to be an important aspect and is considered as 8<sup>th</sup> dimension in modeling. This thesis only considered the time and cost aspect during decision making, whereas there are many other factors that can influence the decision, such as environmental aspect, safety aspect and so on. It would not only help the construction industry but also the environment by using LEED tools for energy efficient designs and to human energy by reducing the use of materials and skilled labour.

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