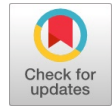


Time and Resource Management of Residential Apartment Construction using Building Information Modeling



Gaurav S. Narlawar, N. B. Chaphalkar, Sayali Sandbhor

Abstract: To complete a project under the complicated situations, it is important to follow effective ways to use available tools and methods, taking into account present technology and management. Also, it is challenging to prepare accurate and achievable plans in large construction projects. Visualizing forms at an early stage in building design improves the ability of designers to deliver ideas and the capability to inspect and assess the methods helps to predict and optimize the actual presentation of the construction project. These different features form the basis for Building Information Modeling (BIM). The archetypal problems like budget overflow, lack of communication, cost overruns, overtime delays, rework can be minimized with the use of Building Information Modeling (BIM) tools for building design & resource management. In this paper, the concept of Building Information Modelling (BIM) is used for 3D modeling, which involves 4th dimension as Time (4D), 5th dimension of Cost (5D) of the project. A case study of G+5 residential apartment is presented for 3D BIM modeling and quantity take-off with the commercial software Autodesk Revit 2019. The 4D BIM carried out using Primavera P6 is explained with methodology for a case study. Further, Autodesk Navisworks Manage 2019 is used for 5D BIM, which includes a graphical presentation of the construction schedule and cost estimation of the case study.

Keywords: Building Information Modelling (BIM), Construction Management, 3D BIM, 4D BIM, 5D BIM.

I. INTRODUCTION

BIM integrates various areas through effective communication, analyzes project system configurability, estimates project cost, and time whenever using quantitative take-off, draws a large picture of projects using visualization and creates a joint team. The BIM technology popularization is stimulating its application at every stage of the construction project life cycle. Construction managers or general contractors utilize BIM to comprise workloads to make cost estimates. Besides, they can create persuasive 3D renderings. Additionally, schedule integrated BIM known as 4D BIM is used for safety analysis, animations and to prepare logistic

site plans. To coordinate the work with subcontractors efficiently, construction managers can use BIM. Also, project schedules of construction managers can have BIM updating. In conclusion, construction managers can provide an integrated BIM model to the maintenance team of the possessor.

A. Scope of the Study

The metropolitan cities in India have a large population with limited space for the construction of houses. The increasing demand for houses in the city can be minimized by the construction of residential apartments using advance techniques. The residential building projects find the subsequent problems during construction such as calculation of constructiveness and recognition of design conflicts before construction, inherently more complex nature due to errors in certification and approval, archetypal issues like budget overflow, lack of communication, cost overruns, overtime delays, rework. These problems can be minimized with the use of Building Information Modeling (BIM) tools for building design & resource management. So, the study on the schedule optimization of a resource-constrained construction project with BIM tools such as Autodesk Revit, and Autodesk Navisworks Manage is accomplished on a residential apartment in this research. The objectives of the proposed work are:

- To understand the importance of resource management in residential apartment construction.
- To study the features and benefits of Building Information Modelling (BIM) tools such as Autodesk Revit and Autodesk Navisworks Manage.
- To analyze the time & cost required for residential apartment construction with the 3D model using Autodesk Revit & Autodesk Navisworks Manage.

B. Methodology for research

The project work is started with the collection of data of residential apartment such as site details, drawings, schedule of works, etc. The following stages are involved in the work methodology of the research as shown in fig. 1:

Manuscript published on 30 August 2019.

*Correspondence Author(s)

Gaurav S. Narlawar, Civil Engineering Department, Government College of Engineering, Karad, Maharashtra, India.

Dr. N. B. Chaphalkar, Civil Engineering Department, College of Engineering, Pune, Maharashtra, India.

Dr. Sayali Sandbhor, Civil Engineering Department, SIT, Symbiosis International (Deemed University), Pune, Maharashtra, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

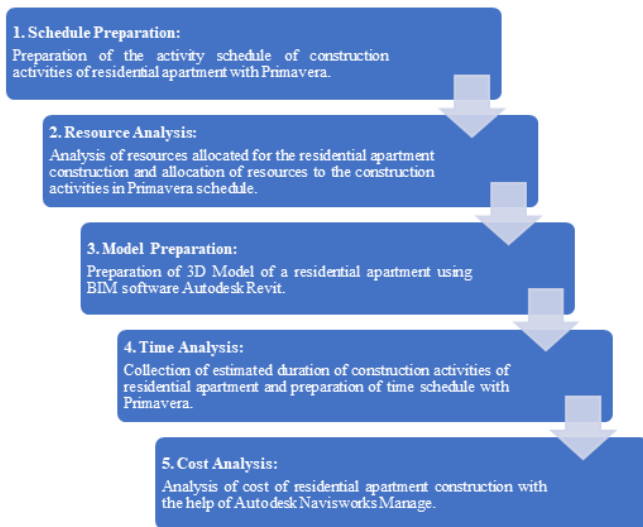


Fig. 1. Flowchart of Work Methodology

II. LITERATURE REVIEW

A. Use of Primavera P6 Software in Construction Management

Kastor A. and Sirakoulis K. [1] evaluated the practicality of Microsoft Project 2007, Primavera P6.0 and Open Workbench 1.1.6, which three prevalent resource-leveling tools with leveling two actual construction projects. Lack of resources is a common cause of project delays. Other methods had been applied to resolve the Resource-Constrained Project Scheduling Problem (RCPSP). The purpose of the methods is to minimize the duration of the project, taking into account both the priority and resource constraints. The results implied that Primavera P 6.0 is widely appreciable software since it permits users to outline an infinite criterion as rules of priority in principle.

Nagaraju S., Reddy B. and Chaudhari A. [2] assessed resource scheduling of speedy construction project having restricted duration. A schedule of Primavera software projects has been prepared for various works on the construction of a commercial building, and the resource-constrained analysis was done by resource leveling for different activities through reducing resources with increasing duration to examine the effects of time. The study concludes that the project schedule presented is constrained with time owing to the user's requirements. The only way to increase the time in the schedule is possible with the resource leveling since whole schedule activities are critical with total float zero. The planned schedule increases daily expenses owing to unexpected labor requirement, which consequently affects the total cost of the project to a very great extent.

Sajad M., Sadiq M., Naveed K. and Iqbal M. [3] examined the selection of the appropriate software project management tool out of the list of Primavera, MS Project, GanttProject, Redmine, BaseCamp, dotProject, and Assembla. Since most software development is now carried out on a cloud basis, the trend of web-based software development is growing very rapidly. The web-based management tools utilized to manage cloud basis sort of software development. The study overviewed that Primavera is a complete multi-project planning and control software that is the best project management module.

Ragavi S. and Uma R. [4] made the comparison of MS Project and Primavera software with the help of a case study

of an apartment building. The investigation was made owing to their analogous technical characteristics and evaluation based on the project management function. In this research, the authors looked at the case of an apartment building to demonstrate how to use Primavera and MS Project to plan and schedule appropriately. The author concludes that Primavera is superior to MS Project in several performance characteristics, functionality, and technical characteristics. Primavera offers the best secure tools for retrieving project files and baseline plans. In addition to resource costs, primavera allows to plan, remaining, and activity expenses to enter at the activity level whereas Microsoft project does not have this capability.

B. Building Information Modelling (BIM) in Construction Management

Azhar S. [5] described trends, benefits, potential risks, and upcoming challenges of Building Information Modeling (BIM) in the AEC industry. The results of the study offer beneficial information for AEC industry professionals who would like to introduce BIM technology into their projects. The results illustrate that average BIM Return on Investment (ROI) for projects was large which depicts its potential economic benefits and firms implementing BIM should be very vigilant with legal errors such as data ownership, asset problems, and risk-sharing.

Rokooei S. [6] illustrated the relevance of the roles of BIM & project manager in construction projects and the requirements of the project manager's BIM knowledge and experience. The results found that BIM can be viewed as a management tool, not a technical tool for construction projects.

Migilinskas D., Popov V., Juocevicius V. and Ustinovichius L. [7] considered the stages and trends in the development of the BIM concept, where elements of the BIM technology present four real-time projects case studies accepted by the project participants and make recommendations for future BIM applications. The study found that for more satisfactory implementation of BIM, you need to prepare an adequate level of compatibility and standardization of work practices for project team members and contributors. While BIM technology and tools are evolving speedily, in practice, their active and rapid use is limited to prevailing contractual agreements.

Czmoch I. and Pekala A. [8] summarized the history and advancement of the traditional design in civil engineering. The concept of BIM with benefits like collision detection, dimension approach of BIM, the conceptual design has been discussed. Authors have also elaborated drawbacks of BIM such as high cost of implementation triggered by massive hardware and software prices, designer's education cost, impossibility of hundred percent accuracy in model, need of alteration in contractual relations and documentation, only complete model is useful to follow laws and regulations, conflicts in paying cost for BIM model and gaining benefits from it and lack of legal regulation. Moin Uddin M. and Khanzode A. [9] explored that BIM technology and training help BIM professionals to improve their design and construction processes as well as expand their careers in the field by providing projects more rapidly and economically.



The study aims to determine the BIM contribution for the enrichment of career in the construction industry with the provision of explicit illustrations. The author explained the effect of BIM on traditional roles in the AEC industry and personnel of projects such as designers, estimators, schedulers, managers, engineers, and supervisors. The study found that BIM has transformed the mode in which industry experts around the world can apply technology to building design, construction, and management. Chen L. and Luo H. [10] described and explained the benefits of 4D BIM for building Product, Organization, and Process (POP) data structure. The purpose of this study was to generate a comprehensive, revealing and real-world application based on 4D BIM for the construction quality control and to examine how application based on 4D BIM could be applied to existing construction procedures. The study detected and resolved problems that may arise when using BIM technology with modern quality control measures. The study revealed the BIM implementation in quality control and specified a unified solution to develop the existing quality control methods using BIM work environment. Fazli A., Fathi S., Enferadi H., Fazli M. and Fathi B. [11] analyzed the use of Building Information Modeling (BIM) as a great tool for modeling project situation to evade unnecessary work and loss of time & money. The study determined that it is usually difficult for project managers to view applications because they have lesser knowledge of BIM. The research shows that BIM supports project managers to complete projects effectively and offers a better provision for decision making compared to traditional methods. Smith P. [12] addressed universal problems associated with project cost managers in the execution and development of Building Information Modeling (BIM) in the construction industry. The study reviewed the existing business trends and BIM implementation issues with comprehensive interviews with Australian quantitative survey companies. The research reveals the need for integrating project cost managers at every stage of a project.

Chang-liu C., Wei-wei K. and Shuai-hua Y. [13] showed that it fully appreciates the value of BIM if it develops a practical BIM project implementation plan, defines BIM requirements, specifies level of development, determines BIM quality control plan and clears the content of the BIM application at each stage and provides an integrated method for project stakeholders, appreciates the entire life cycle of construction projects and provides the desired exchange of information in the construction project.

III. CASE STUDY

The aim of the present case study is to implement Building Information Modelling (BIM) using Autodesk Revit and Autodesk Navisworks Manage in residential apartment construction. To get more conversant with the concept of Building Information Modelling (BIM), a conceptual case of construction of residential apartment (G+5) is considered.

The general flow of work of the project comprises the following steps:

1. Create a 3D model in Autodesk Revit 2019.
2. Produce the quantity take-off schedule from the building model using Autodesk Revit 2019.
3. Define specification for each item of work in the project and assign a cost per unit to each item of work according to PWD Schedule of Rates 2018-2019.

4. Prepare Work Breakdown Structure (WBS) in Primavera P6 and assign time to each activity.

5. Assign resources & cost to each activity and arrive at duration & cost of the project in Primavera P6.

6. Further export 3D model and Primavera P6 schedule to the Autodesk Navisworks Manage 2019 and create a visual simulation for planned schedule and actual schedule.

7. After that, add time parameter and cost parameter to the 3D model to develop 4D and 5D models respectively in Autodesk Navisworks Manage 2019.

A. Collection of Basic Data of Residential Apartment

The project work is based upon input data of the project, namely 'Anand Prestige' situated in Nagpur. It consists of two flats on each floor except the ground floor. The ground floor has three shops and space for the parking purpose. The basic AutoCAD drawings essential for the preparation of Autodesk Revit 3D model includes ground floor plan, typical floor plan, working drawings, etc. The basic schedule of activities is prepared in MS Excel through appropriate consultation with the developer. The general details of the residential apartment are as shown in table I.

Table- I: General Details of Residential Apartment

Project Title:	Anand Prestige [G+5]
Owner:	Yashshree Developers, Nagpur
Plot Size:	21m X 25m [5643.75 sq. ft]
Total Built-Up Area:	1008.228 sq. M [10846 sq. ft]
Number of Flats:	10
Area of Each Flat:	970 sq. ft

B. Use of Primavera P6 for Time Scheduling

The data interpretation in Primavera P6 includes creating Work Breakdown Structure (WBS), assigning duration of each activity, connecting activities with relationships, allocating resources to all the activities which give total construction duration and cost.

C. Use of Autodesk Revit 2019 for 3D Modelling

1. Preparation of Integrated 3D Model in Autodesk Revit 2019

Autodesk Revit software is built for supporting the Building Information Modeling (BIM) process. We can export 2D plan from AutoCAD and then trace the plan by the objects or otherwise can create the plan directly in the Autodesk Revit. An integrated 3D model of the residential apartment is prepared in Autodesk Revit 2019. The 3D view of the model in Autodesk Revit 2019 is as shown in fig. 2.



Fig. 2. 3D View of Model in Autodesk Revit 2019

The all four side elevations viz. East, West, North, and South of 3D model in Autodesk Revit 2019 are as shown in fig. 3.

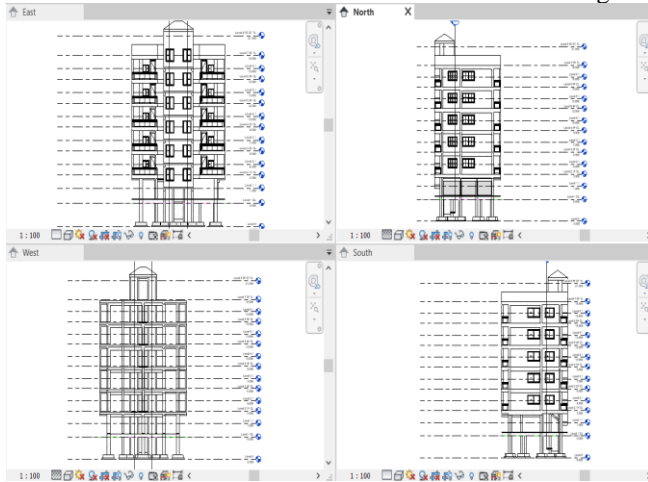


Fig. 3. East, West, North and South Elevation of 3D Model in Autodesk Revit 2019

2. Schedule and Material Take-off from 3D Model in Autodesk Revit 2019

It is possible to extract quantities from the 3D model in Autodesk Revit 2019. For the present case study, the quantities of following items are directly extracted from the model: PCC, column footing, column, beam, floor, slab, wall, plaster, door, and window. For an item like excavation, partial information is extracted from the model, and calculations are done in MS Excel to find out quantities. Initially, the quantities from the model are exported in the Notepad and then into MS Excel. The quantity sheets of the residential apartment are extracted from the Revit 3D Model as 'Schedule' and 'Material Takeoff' in the Autodesk Revit 2019.

D. Use of Autodesk Navisworks Manage 2019 for 4D & 5D Modelling

In the present research, Autodesk Navisworks Manage is used for visualization of the actual and planned schedule. The 3D model is developed in Autodesk Revit 2019 and linked with the time schedule of Primavera P6 in Autodesk Navisworks Manage 2019.

1. Importing 3D Model to Autodesk Navisworks Manage 2019

To import Revit 3D model in Autodesk Navisworks Manage, the file of Revit is exported as NWC file using export utility. After that, the 3D model is imported in Autodesk Navisworks Manage 2019, as shown in fig. 4.

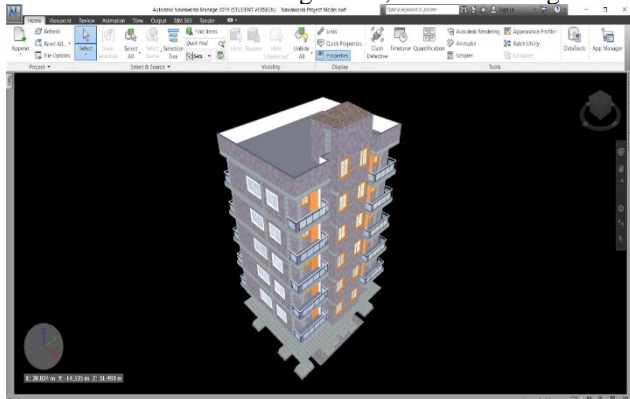


Fig. 4. Importing 3D Model in Autodesk Navisworks Manage 2019

2. Importing Primavera P6 Schedule to Autodesk Navisworks Manage

The schedule prepared in Primavera P6 is imported in TimeLiner as schedule and Gantt chart in the Autodesk Navisworks Manage 2019, as shown in fig. 5.

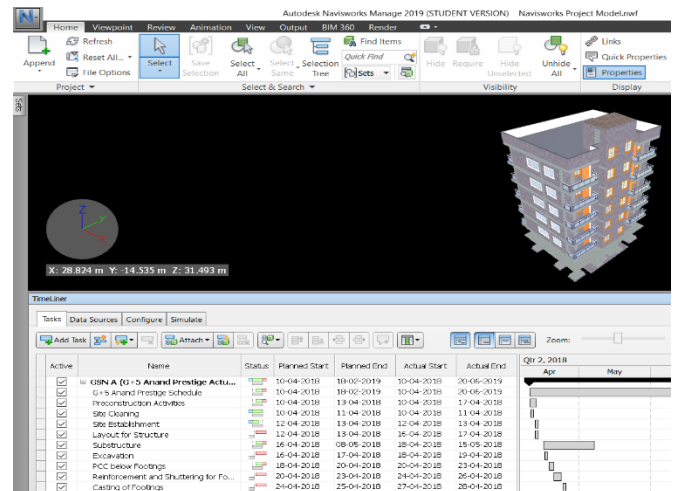


Fig. 5. Importing Primavera P6 Schedule in Autodesk Navisworks Manage 2019

3. Linking Autodesk Revit Model to Primavera P6 Schedule

The object sets are prepared and linked with respective activities in the Autodesk Navisworks Manage 2019, as shown in fig. 6.

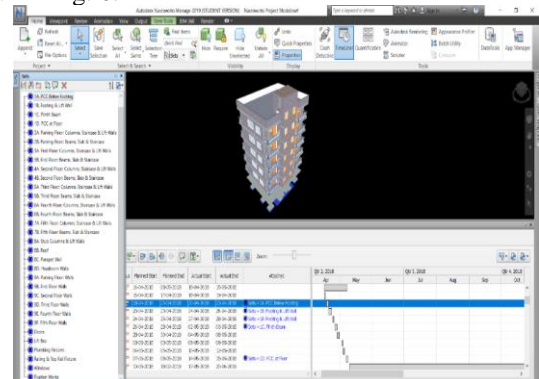


Fig. 6. Linking Activities to 3D Model in Autodesk Navisworks Manage 2019

IV. RESULTS AND DISCUSSION

Review of the case study shows that BIM technology provides plentiful innovative construction management skills for project scheduling and construction management cost estimation. The working out of quantities accurately from 3D BIM-based model which created in Autodesk Revit 2019, planning and scheduling the project activities with the help of Oracle Primavera P6, cost estimation from Autodesk Navisworks 2019 for this project from a construction manager's perspective. Through Navisworks Manage visual, outputs of the project schedule and cost estimation is obtained.

A. Autodesk Revit 3D Model

1. Architectural & Structural Model

Autodesk Revit comprises three modules of Revit viz. Structure, Architecture, and MEP (Mechanical, Electrical, and Plumbing) depending on functionality. The structure module covers the structural modeling of the building with consideration of structural elements such as columns, beams, slabs, etc. Fig.7. shows the structural model of the building in Autodesk Revit 2019. In Revit architecture module, the 3D model of the building can be simulated from the architectural point of view encompassing the architectural elements such as walls, doors, windows, fixtures, etc. as shown in fig. 8.

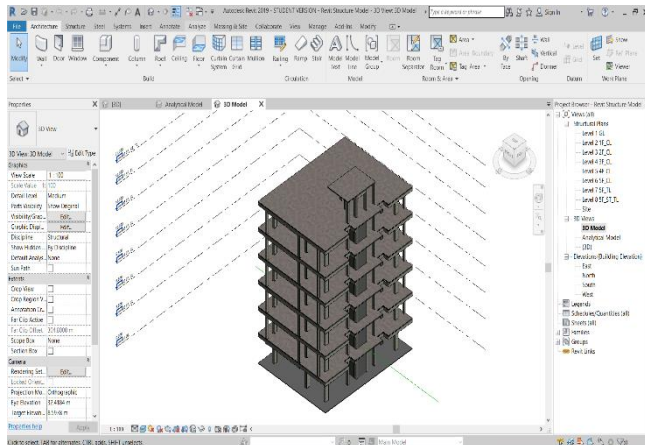


Fig. 7. Structural Model of 'Anand Prestige' in Autodesk Revit 2019

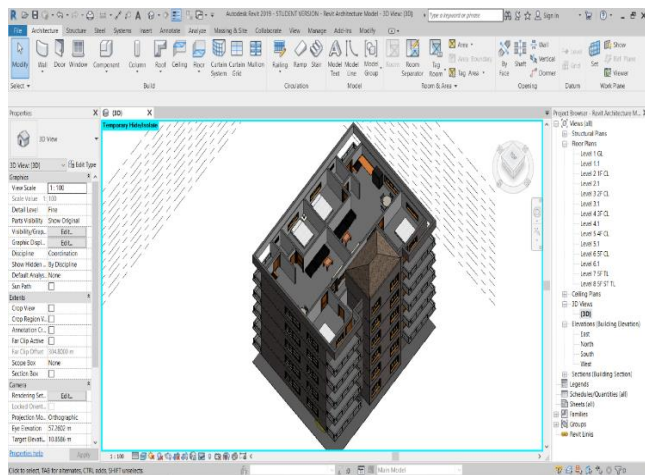


Fig. 8. Architectural Model of 'Anand Prestige' in Autodesk Revit 2019

2. 3D Visualization

Revit 3D Model helps in better visualization, understanding, easier way to construct a 3D model and also gives various options for better designing of the building. We need a thought process that combines a variety of traditional 2D views to create a detail 3D view. These features allow designers and contractors an organized work to offer a remarkable visualization tool to detect and solve complications through models earlier going the field. In the event, a building owner asks for a physical model. Accordingly, they can visualize, well comprehend, come up with options to determine the aesthetics and functions of the objects before construction starts. This is an additional provision of project documents in electronic form. It concerns the use, reuse, and exchange of information, of

which the digital presentation is only a small fraction. BIM modeling allows to create and test virtual layouts at a low cost. Fig. 9. shows the integrated 3D model of the building.

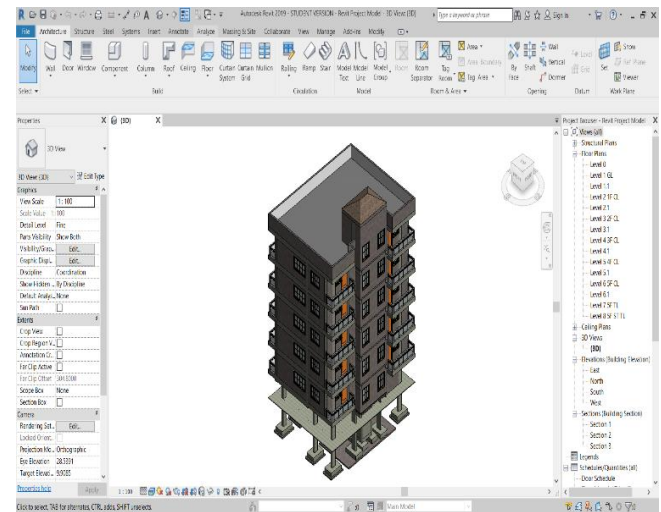


Fig. 9. Integrated 3D Model of 'Anand Prestige' in Autodesk Revit 2019

3. Energy Analysis

BIM tools can perform Energy analysis and LEED evaluation. The Autodesk Revit model can perform very sophisticated analyses such as solar analysis, thermal diffusion, heat transmission, cold draft, etc.

In Autodesk Revit 2019, by defining the location of the building site, date and timing in sun setting option the solar path of the site location can simulate the effect of the sun over the year and about the location of the site. It requires a lot of information for each building element such as materials with the accurate synthesis of material layers, etc. Mostly, the purpose of Autodesk Revit is to simulate the impact of the sun on outer parts of the 3D model. Energy analysis is an efficient technique to envision the shadow pattern of a particular location for days as well as years.

The functionality of Autodesk Revit helps optimize the placement of solar collectors. Fig. 10. shows the sun path for the building in Autodesk Revit 2019.

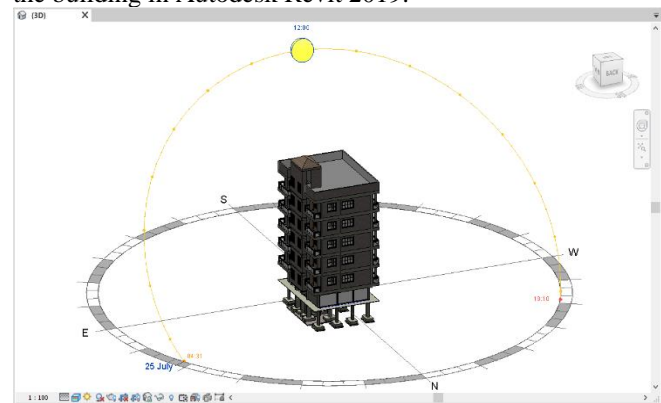


Fig. 10. Sun Path for 'Anand Prestige' in Autodesk Revit 2019

4. Structural Analysis

As we prepare the 3D structural model of the building, Autodesk Revit software simultaneously prepares the analytical model of each floor and 3D analytical model.

Revit 3D analytical model can be exported to structural analysis software like Staad-Pro. The structural analysis function of Autodesk Revit software minimizes the time required to prepare a separate analytical model for structural analysis purpose. The 3D analytical model in the structural model of the apartment building developed in Autodesk Revit 2019 is as shown in the following fig. 11.

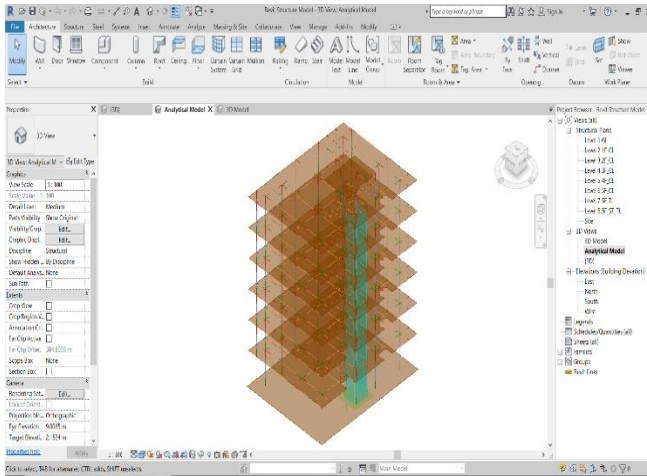


Fig. 11. 3D Analytical Model of 'Anand Prestige' in Autodesk Revit 2019

5. Quantity Takeoff

The quantities of the building are taken out from Autodesk Revit 3D model as schedules and material takeoff reports. The extracted quantities of 'Anand Prestige' apartment is shown in table II.

Table-II: Quantities of 'Anand Prestige' Apartment

Particulars	Quantity
Excavation Quantity	88.56 m ³
PCC work below the footing	10.86 m ³
RCC Column Footing	16.3 m ³
Hard Murum	35.85 m ³
RCC Column	64.52 m ³
RCC Beam	101.85 m ³
RCC Slab	145.08 m ³
RCC Staircase	12.24 m ³
RCC Roof	5.37 m ³
Brickwork	148.249 m ³
Internal Cement Plaster [12mm thick]	1577.626 m ²
External Cement Plaster [20mm thick]	692.852 m ²
European Type Glazed WC Pan	20 Units
Doors	70 Units
Windows	77 Units

B. 4D BIM Model

For this case, the study 4D model is created, which is beneficial BIM application in construction scheduling. A BIM 4D model is developed by linking of schedule activities with the corresponding 3D elements in Autodesk Navisworks Manage. In Autodesk Navisworks Manage, the 'Task Type' are of four categories as Construct, Demolish, Temporary and Early app with the color use to represent the 'Activities Status' i.e. Start, End, Early and Late Appearance which is beneficial to analyze plans, monitor physical activity, perform tasks, sequence the construction activities and simulate construction schedules for construction site

planning. For the present case study, according to planned schedule on 31st August 2018, the casting of the beam, slab, and staircase of the fourth floor should be completed, but actually, the electric conduiting of the third floor was completed till the date as shown in fig. 12 and fig. 13.

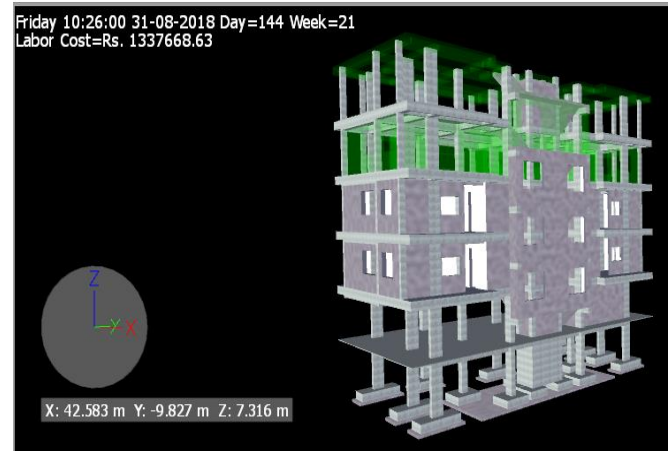


Fig. 12. Planned Work on 31st August 2018 in Autodesk Navisworks Manage

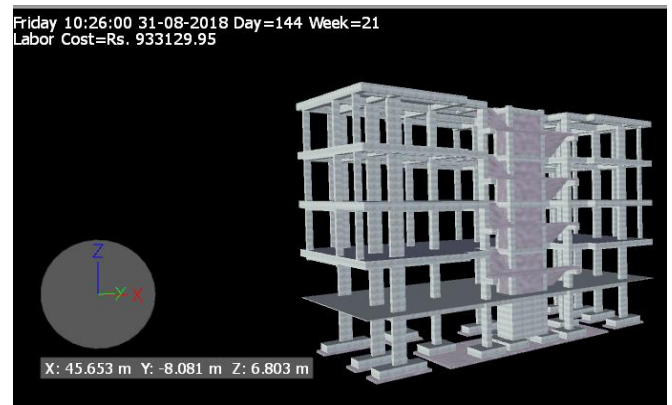


Fig. 13. Actual Work on 31st August 2018 in Autodesk Navisworks Manage 2019

Following are some advantages of 4D BIM model for project planning:

1. Comprehensive and Precise Work Plan

With 4D BIM, project stakeholders can create accurate and detailed work plans that are more problematic to accomplish with conventional methods of planning. The conventional method may not be able to cover entire construction activities in the construction schedule because of poor visualization.

In contrast, 4D BIM model offers a very efficient tool for visualizing construction projects and identifying all construction tasks that can lead to correct and comprehensive work planning. The 4D model feature of the BIM tool schedules projects more accurately, including the planned schedule and actual schedule of projects. Fig. 14, fig. 15 and fig. 16 show activity bars of planned and actual Gantt charts.

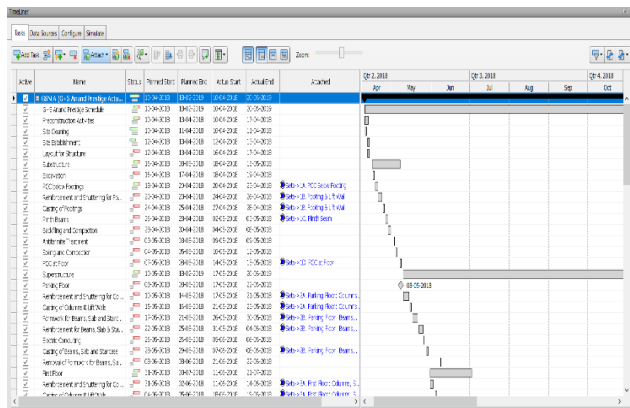


Fig. 14. Planned Gantt Chart in Autodesk Navisworks Manage 2019

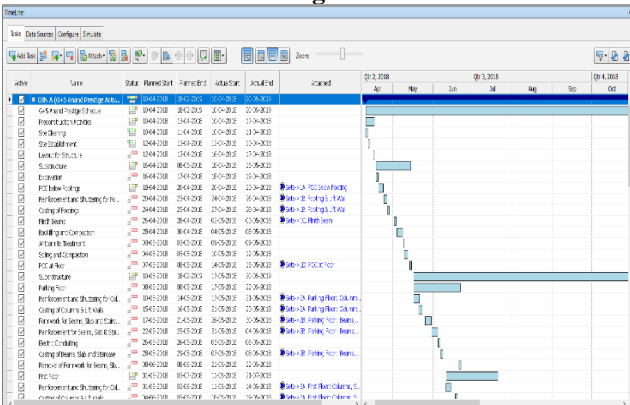


Fig. 15. Actual Gantt Chart in Autodesk Navisworks Manage 2019

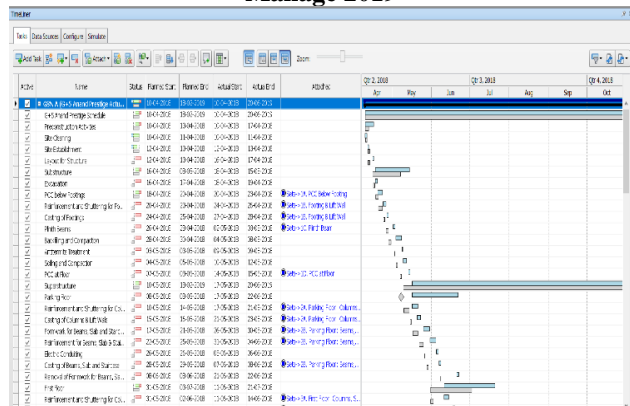


Fig. 16. Actual and Planned Gantt Charts in Autodesk Navisworks Manage 2019

2. Improves Occupational Safety of Construction Project

Construction site safety hazards are one of the major reasons for unanticipated extra costs because the construction industry's accident rates and accidental deaths are still high. Project managers can use 4D modeling to detect areas where accidents can happen and take preventive actions such as introducing warning signals, access restrictions, or providing security tools.

3. Improved 4D Simulation by Sequencing Construction Activities

The 4D BIM simulation offers a simulated view of the project progress. As pretend tasks are associated with the construction elements of 3D BIM model, 4D BIM modeling supports to adjust the schedule of the project by changes in the project. In the 4D BIM model, various colors are used to simplify the visualization and understand the construction status associated with the daily activities of the project team.

Construction personnel can track project schedules more accurately by viewing construction progress viz. Planned Start and Actual Start, Planned End, and Actual End. Using the various color pattern to display 3D elements during a schedule simulation, we can see a green transparent color for start appearance activity, red transparent color at late appearance activity and yellow transparent color at early appearance activity as shown in fig.17.

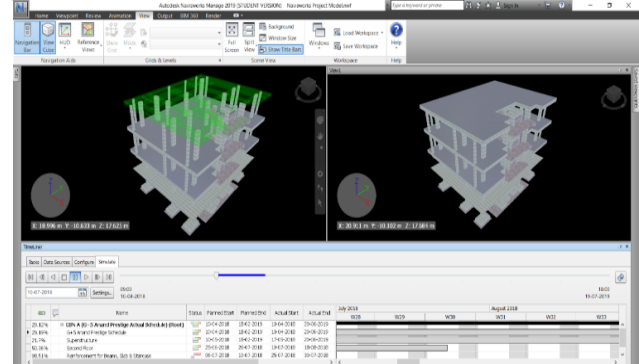


Fig. 17. 4D BIM Scheduling Interfaces of Autodesk Navisworks Manage 2019

C. 5D BIM Model

In 5D model, dimensions can be stimulated directly from the fundamental model which consist of drawings, the take-offs, quantities. A 5D BIM means a 4D model intelligently linked with cost information for a project. Following are some advantages of 5D BIM model in construction management:

1. Improved BIM Based Cost Visualization

BIM visualizes construction projects in the design stage and integrates them with project cost estimation and management. BIM-based model useful for project stakeholders to better understand the project design, detect important coordinate points, and increase their efficiency in managing their projects. The BIM model can be used to support sales and marketing exhibitions instead of 2D representation. Since BIM-based automated visualization useful for early progress cost performance assessments are utmost liable to design changes can be evaluated quickly. BIM-based cost visualization by using Autodesk Navisworks Manage 2019 is shown in fig. 18.

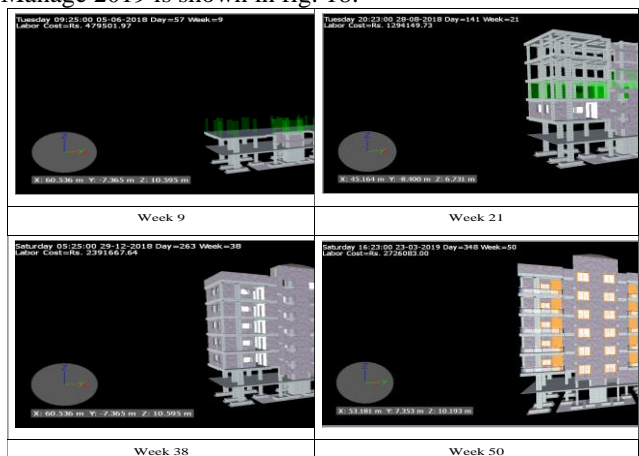


Fig. 18. Project Cost Visualization in Autodesk Navisworks Manage 2019

2. Accurate Cost Estimation

By using the BIM estimation process, cost estimators are much more reliable in terms of accuracy of model and all-inclusiveness. 5D BIM allows cost estimators to enhance the initial stages of scheduling; positions with cost controls are a more precise, error-free, and significant saving of time in quantity take-offs and create cost estimations. So that estimating with BIM-based model for contractors and construction managers to rise productivities in minimum time and optimize the cost-effectiveness of projects.

3. Quick Automated Quantification

BIM tools provide quickly and automatically quantity take-off of project building. Therefore, the easiness and rapidity in the evaluation of a bill of quantities. The calculations are speedy for an automatic bill of material for sets of elements in the model. The bill of quantities for the complete item is finished in some seconds or minutes. As compared to traditional methods of cost estimation, the BIM tools can offer correct, automatic, and restructured quantities without difficulty. BIM can be integrated with proficient cost estimations to enable the take-off and estimating process. BIM tools can link BIM objects to cost estimation objects. Finally, from a cost estimator's point of view, BIM can be seen as the subsequent stage in the development of the quantification method.

4. Coordinated Documentation

There are huge amounts of the document are involved in a cost estimate at a certain point. All project documentation is created from a single BIM model. This allows the user to create accurate and coordinated project documentation. Documentation for revisions or changes that may be required either during design or construction phase can be quickly generated and revised drawings issued.

V. DISCUSSION

Traditionally, building imagined by designers is conveyed in 2D drawings which need the experience to imagine how the actual building will be constructed. But if the same design is presented in the 3D model, then it's quite simple to interpret the same to non-technical team members of the project as well. As in the present case study, Autodesk Revit 2019 is used, various views are automatically generated and updated as per updates in a certain view. Autodesk Revit 3D model had decreased manual work and errors with time-saving. Autodesk Revit 3D model makes available quantity takeoff from the project model and can be used for structural analysis, energy analysis, etc. In Autodesk Revit, walkthrough and rendering are better options for the effective presentation of the 3D model. For 4D and 5D simulation, Autodesk Revit 3D model and Primavera P6 schedule are imported in Autodesk Navisworks Manage 2019. The Navisworks software allows linking the schedule to the elements of the 3D model of the project, which helps to interpret the schedule of time by generating visual simulation. Autodesk Navisworks Manage 2019 allowed taking visual simulation outcomes of the planned and actual project schedule. In the present case study, the software tools like Primavera P6, Autodesk Revit 2019 and Autodesk Navisworks Manage 2019 are used, which helped in better understanding the construction progress and design of the building. Also, these tools are beneficial for well-organized transfer of project in time.

VI. CONCLUSIONS

In this paper, BIM tools and scope of BIM application are explained with importance given to model simulation, scheduling, and cost estimating. The concept BIM is tried to elaborate through 3D modeling in Autodesk Revit 2019, scheduling and resource management in Primavera P6 and cost estimating in Autodesk Navisworks Manage 2019. Following are conclusions of the current study:

- BIM provide a systematized work in Autodesk Revit 2019 as an outstanding visualization tool to distinguish and resolve problems through 3D models prior going the field.
- Energy analysis is used to visualize and compute the impact of solar radiation on different construction faces of the 3D model in Autodesk Revit 2019.
- The Indian construction industry is currently large developing in infrastructure, commercial and real estate market which show a large volume of work for the construction industry. Therefore, it is necessary to develop a new project management tool such as 4D BIM to confirm that all projects are complete in within particular time and cost limit.
- The 4D Model helps in line optimization and avoiding manual errors instated of traditional scheduling. So, the construction managers will have more time to coordinate other tasks and the schedule confusion can be moderated via the visualized schedule by linking the 3D model with the desired schedule through 'Visual Simulation' in Autodesk Navisworks.
- 4D BIM model can lead to improving occupational safety.
- The study presented the use of visualization in estimating, which allows an estimator to walk inside a virtual building and select elements for estimating.
- BIM-based Autodesk Navisworks 5D Model increase productivity, more work in the least time and maximize the profitability of construction projects.
- The method for evaluation and visualization of construction work in terms of cost is established and is useful for project members who have a system that allows them to visualize and assess the construction process without difficulty.
- For the more rapid and improved implementation of construction project correct and all-inclusive information is essential which can be achieved using BIM tools like Primavera P6, Autodesk Revit, and Autodesk Navisworks Manage. Precise and consistent data can be extracted as needed and can be rationalized or changed as the project moves forward, improving project management and productivity.

ACKNOWLEDGMENT

The authors wish to thank Dr. Shrikrishna Dhale (Yashshree Developers, Nagpur) for his valuable support.

REFERENCES

1. A. Kastor and K. Sirakoulis (2009). "The Effectiveness of Resource Levelling Tools for Resource Constraint Project Scheduling Problem." International Journal of Project Management, 27, pp. 493–500.
2. S. Nagaraju, B. Reddy and A. Chaudhari (2012). "Resource Management in Construction Projects – A Case Study." Engineering Science and Technology: An International Journal, 2(4), pp. 660-665.
3. M. Sajad, M. Sadiq, K. Naveed and M. Iqbal (2016). "Software Project Management: Tools assessment, Comparison and suggestions for future development." International Journal of Computer Science and Network Security, 16(1), pp. 31-42.
4. S. Ragavi and R. Uma (2017). "Planning and Scheduling of an Apartment Building by Comparison of MS Project and Primavera." International Academy of Science, Engineering and Technology, 6(4), pp. 21-32.
5. S. Azhar, (2011). "Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry." Leadership and Management in Engineering, 11(3), pp. 241-252.
6. S. Rokooei (2015). "Building Information Modelling in Project Management: Necessities, Challenges and Outcomes." International Conference on Leadership, Technology, Innovation and Business Management, Procedia - Social and Behavioral Sciences 210, pp. 87–95.
7. D. Migilinskas, V. Popov, V. Juocevicius, and L. Ustinovichius (2013). "The Benefits, Obstacles, and Problems of Practical BIM Implementation." 11th International Conference on Modern Building Materials, Structures and Techniques, Procedia Engineering 57, pp. 767-774.
8. I. Czmocho and A. Pekala (2014). "Traditional Design versus BIM Based Design." Theoretical Foundation of Civil Engineering (23RSP) Procedia Engineering 91, pp. 210-215.
9. A. Khanzode and M. Moin Uddin (2014). "Examples of How Building Information Modeling Can Enhance Career Paths in Construction." Practice Periodical on Structural Design and Construction (ASCE), 19(1), pp. 95-102.
10. L. Chen and H. Luo (2014). "A BIM-based construction quality management model and its applications." Automation in Construction 46, 64-73.
11. A. Fazli, S. Fathi, H. Enferadi, M. Fazli, and B. Fathi (2014). "Appraising effectiveness of Building Information Management (BIM) in project management." International Conference on Project Management 16, pp. 1116-1125.
12. P. Smith (2014). "BIM & the 5D Project Cost Manager." 27th IPMA World Congress Procedia - Social and Behavioral Sciences 119, pp. 475-484.
13. C. Chang-liu, K. Wei-wei, and Y. Shuai-hua (2018). "Research on the application of BIM technology in the whole life cycle of construction projects." 2nd International Workshop on Renewable Energy and Development 2018, IOP Conf. Series: Earth and Environmental Science 153, pp. 1-6.

AUTHORS PROFILE



Gaurav S. Narlawar is currently pursuing Master's degree in Civil Engineering in Government College of Engineering, Karad, Maharashtra, India.



Dr. N. B. Chaphalkar is Former Associate Professor in Civil Engineering Department in College of Engineering, Pune, Maharashtra, India.



Dr. Sayali Sandbhor is an Assistant Professor in Civil Engineering Department at SIT, Symbiosis International (Deemed University), Pune, Maharashtra, India.