# EXPLORING BUILDING INFORMATION MODELLING FEATURES IN BUILDING CONSTRUCTION

A

PROJECT REPORT

*Submitted in partial fulfilment of the requirements for the award of the degree of*

**BACHELOR OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

*Under the supervision*

*of*

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**MAY, 2023**

# STUDENT'S DECLARATION

I hereby declare that the work presented in this report entitled **"Exploring Building Information Modelling Features in Building Construction "** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Civil Engineering** submitted in the department of Civil Engineering**,** Jaypee University of Information Technology, Waknaghat is an authentic record of my own work carried out over a period from August 2022 to May 2023 under the supervision of **Mr. Chandra Pal Gautam, Assistant Professor(Grade-II) in Department of Civil Engineering.**

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

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# CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Exploring Building Information Modelling Features in Building Construction"** in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Ugyen Phuntsho(191630) & Yeshi Jatsho(191631)** during a period from August, 2022 to May, 2023 under the supervision of **Mr. Chandra Pal Gautam**(Assistant Professor) **& Mr. Kaushal Kumar**(Assistant Professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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This project has been carried out in our best interests and hope it becomes helpful to anyone who refers to it in the future.

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# ABSTRACT

The future of the construction industry will be highly collaborative and digital and many countries around the globe are adopting digital-based technology such as the building information models (BIM) in construction practices. Similarly, there is huge scope for the use and application of such technology and practices to improve the overall performance and productivity in construction projects in our country. There is a need to change the way we build, design, manage and maintain any construction project.

Therefore, the primary aim of this study is to explore the application of Building Information Modeling tools and its features for a case study building construction project in Phuentsholing. The 3D models which included architectural, structural, and MEP models were generated in Autodesk Revit from 2D CAD drawings. In addition, a construction schedule was linked to 3D model elements to virtually simulate the phases of the construction using Autodesk Navisworks by which a concept of 4D BIM was achieved. The 5D BIM concepts were achieved by incorporating the cost estimates with reference to the BSR standard in a 4D model. The building then was designed for sustainability and energy-efficient by optimizing the energy use intensity through Autodesk Insight 360.

The method of collaboration, employing the within-network area option, was used to implement a collaborative approach to work that allows team members of our group to work simultaneously in a single model.

***Key Words: BIM, Architectural , Structural and MEP models, Autodesk Revit,* Autodesk Navisworks, *Autodesk Insight 360,* Collaboration.**

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| | |
|---|---|
| AEC | Architecture, Engineering and Construction |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| BSR | Bhutan Schedule Rate |
| CAD | Computer-aided design |
| DOE | Department of Energy |
| GBS | Green Building Studio |
| HVAC | Heating, Ventilation and Air Conditioning |
| MEP | Mechanical, Electrical and Plumbing |
| LAN | Local Area Network |
| LoE | Low Emissivity |

# CHAPTER 1: INTRODUCTION

## 1.1 BACKGROUND

Construction companies are constantly challenged to satisfy client expectations while remaining competitive. The construction sector, which is expanding rapidly, faces distinct concerns and obstacles. Because it involves several parties from various backgrounds participating in various phases of a building project in order to complete the project on schedule and with the desired conclusion. Due to the multi-organizational character of building projects, issues occur. A high level of collaboration is essential, and communication and information must flow smoothly among the parties involved to reduce lead time and uncertainty (Silas Titus, Jan Brochner, 2005).

BIM is the technology of the future. Only an integrated methodology like BIM can adequately display and handle the complexity in the construction industry. Building Information Modeling is based on the concept of using digital building models continuously throughout the lifecycle of a physical facility, from early conceptual design and detailed design through construction and long-term operation (Borrmann et al., 2018). BIM has recently drawn a lot of interest in the architectural, engineering, and construction (AEC) industries. In the construction sector, it is becoming an inevitable means of delivery and management. The question should no longer be whether we should or not, but rather we must. It is extended of three primary spatial dimensions incorporating information about time (4D BIM), cost (5D BIM), asset management, sustainability, etc. Therefore, it covers more than just geometry (Tsai et al., 2010).

BIM enables us to produce an information model with a digital description of every element of the built assets (Mitchell, n.d.). It also provides a faster and more effective way of exchanging and communication information between concerned project parties (Staub-French et al. 2008; Manning and Messner, 2008). In addition, the majority of the data required for building performance evaluation is contained in BIM, resulting in a higher-performing building during the operational phase. By predicting potential construction disputes, enhancing productivity, cost prediction, and avoiding reworks, time and money were saved.

It's also important to think beyond the physical construction and imagine the concept of a virtual construction system above it to minimize uncertainty, increase safety, solve problems, and simulate and assess potential repercussions. Construction will certainly become progressively more collaborative and digital in the future. BIM allows you to envisage a building as an information database, with drawings, specifications, and contracts serving as distinct representations of the database (Zhang et al., 2016).

## 1.2 Introduction to BIM

### 1.2.1 Evolution of Design Process

The design process had evolved from hand drafting to CAD and now we have BIM. In the first phase, hand drawing or drafting which had lasted at least thousands of years in the construction phase. Since it was so tedious that it was replaced by CAD which was an important transition/ advancement in the construction industry. The CAD or computer-aided design taught designers about the computer, file management, and new organization skills but it did not substantially change the process or the way information was displaced. We were still in the traditional method of delivering things. Therefore, it was when BIM came into the picture. BIM is a digital way of architecting, engineering, and constructing. Though the impact of the BIM is not seen at the moment but as per the many BIM users are confident that it will be the future of construction and long-term facility management.

### 1.2.2 Levels in BIM

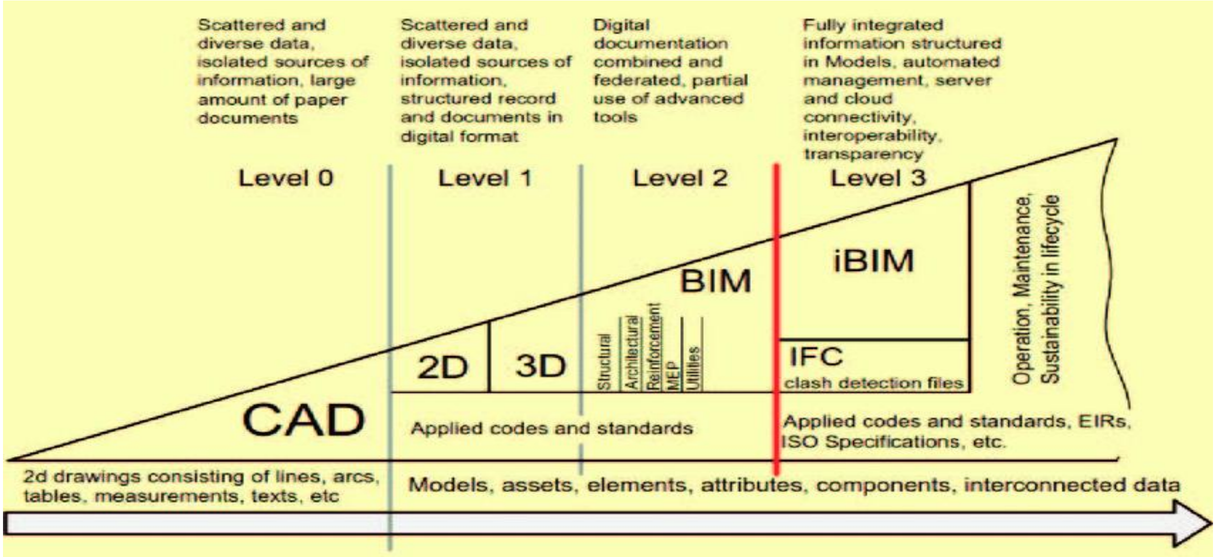



**Figure 1.1** Bew Richards BIM maturity model (Source: Kontothanasis, 2014)

The picture above depicts Mark Bew and Mervyn Richards' UK maturity model, which aids in understanding the various levels of BIM maturity. Building Information Modeling (BIM) maturity levels span from 0 to 3 and beyond, specifying the criteria that must be met in order to be BIM compliant.

BIM Level 0

The level 0 BIM doesn't have collaboration integrated and information exchange is through using 2D CAD drawings. It is rarely in use these days.

BIM Level 1

The BIM Level 1 has low or zero collaboration between the parties since everyone maintains and manages their own data. There is a significant improvement in the management of CAD drawings and compliance with standards. Involves both 2D and 3D CAD for conceptual and production information.

BIM Level 2

Level 2 BIM is upgraded by incorporating a well-managed 3D environment to which data is integrated and developed in a distinct disciplined-based model. And these disparate models are combined to build a federated model while preserving their individual identities and integrity. All the parties work in their local models and synchronize to a central model. Here the data can include construction sequencing (4D), cost (5D) information, and sustainable design data.

BIM Level 3

It is the highest level of BIM, with each model being a collaborative, online project model that includes time and cost sequencing and even the management of construction projects with sustainable design. Level 3 is also known as 'iBIM,' which stands for integrated BIM and is designed to improve business outcomes (Shah, 2021).

### 1.2.3 Dimensions in BIM

For a better understanding of the evolution and the application of BIM, various levels of dimensions are introduced which serve the different features of BIM. It includes 3D, 4D, 5D, 6D, and many more under the process of development. It arose from the necessity to distinguish between modeling geometry in two and three dimensions, as well as being a component of the modeling progression from drawing boards through the first 2D CAD systems to 3D modeling software. The data connected with each dimension improves the model's ability to communicate a deeper understanding of a construction project. Each dimension serves a distinct purpose in determining the cost of a project, its timeframe, when it will be done, and how long it will be sustainable in the future, as well as how to manage the project.

## 1.3 Purpose of study

We should really look beyond and visualize the benefits of the virtual construction system over the actual physical construction system in order to upgrade and adapt to the future of design technology and long-term facility management. BIM is an implementing change across all construction industries but not yet in Bhutan. BIM may be relatively a new technology in an industry typically slow to adopt but many early adopters believe it will become even more important in building documentation (Zejnilović, 2017).

The main purpose of the study is to understand the benefits and advancements in the adaptation of BIM in the construction industry. Furthermore, to digitalize the country's existing construction method in order to achieve considerable cost, value, and energy performance gains through the use of open shareable asset information using BIM technology. With the existing system, our future construction is not at all stable and satisfactory. Therefore, to achieve these purposes, this research implies the exploration of BIM features in the construction industries.

## 1.4 Aims and Objectives

The primary aim of the project is to virtually design, analyze and manage the construction of a building using BIM tools and achieve at least level two of BIM. The objectives of the study are:

- To develop Architectural and structural models using Revit.
- To perform cost estimates using 5-D BIM models.
- To perform energy analysis using 6-D BIM models.
- Coordinate design through collaboration between different models and creating a common data environment (CDE).
- Draw the contribution to the implementation of the BIM model in the construction project.

# CHAPTER 2: STUDY AREA

The study area was located at Phuentsholing, Bhutan. The study area that is the proposed G plus three multifamily residential buildings was taken for the case study of our study. The site plan was generated in the Revit using the massing and site plan tab.

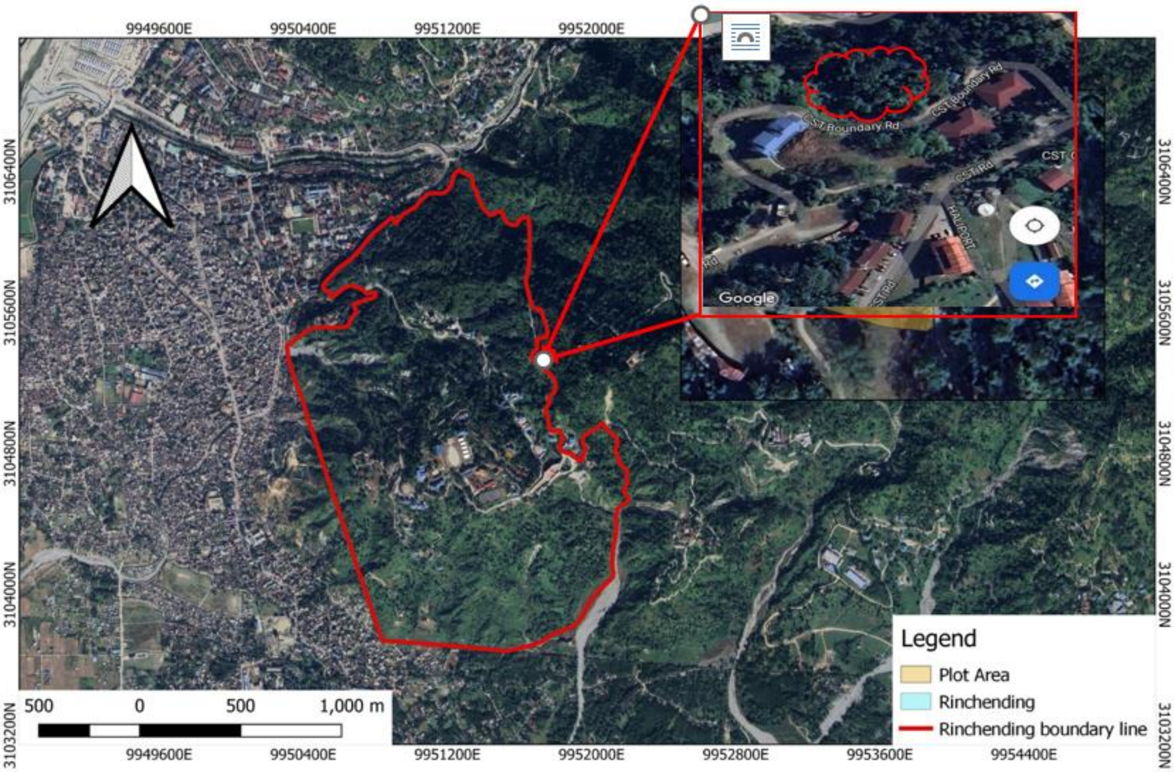



**Figure 2.1** Study Area

# CHAPTER 3: METHODOLOGY

## 3.1 Methods

In the first phase we did the planning and designing concepts and ideas into Architectural, and structural models. The 3D models were created using different templates of the Autodesk Revit. Autodesk Revit essentially has three templates consisting of Architectural, structural and MEP. We used Autodesk Robot structural analysis professional software for the structural analysis. Then the 4D BIM model was completed using the Autodesk Naviswork while the 5D BIM model was generated in Revit itself. Then the 6D BIM model was generated using the Autodesk Insight 360.

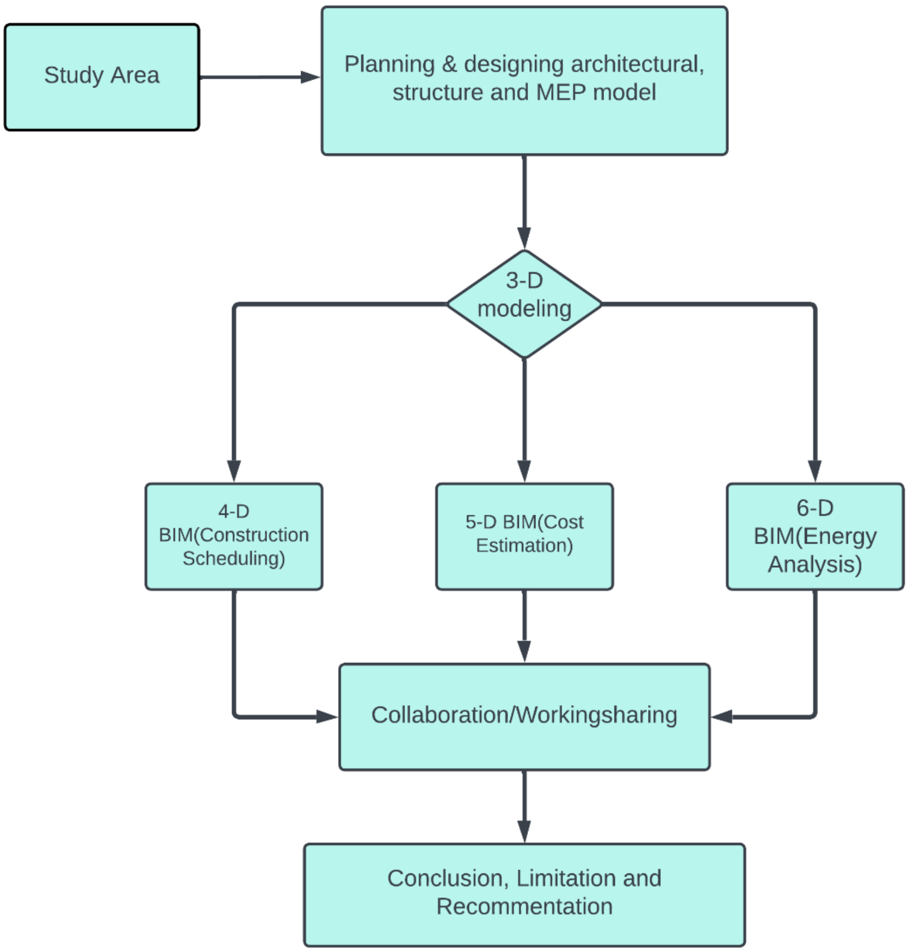



**Figure 3.1** Research Methodology

# CHAPTER 4: 3D MODELLING

## 4.1 Architectural model

Architectural modeling includes all other package diagrams and is the design for the entire system. It is the initial step in the design construction process, and we might develop a digital 3D model of the building using BIM modeling tools, allowing them to see a depiction of what it will look like and how it will function. BIM models are directly modeled as a 3D model without having to produce the building plans.

A multifamily residential building was a G+3 storied with jamthok. The model was created using the architectural template of Autodesk Revit 2018. All the components of the architecture are available on the template. The building plans or the architectural drawings were provided to us by the management. We incorporated those dimensions and the components of the architectural model.

**Table 4.1** Building Components

| **Building Components** | **Description** |
|---|---|
| External Wall | Brick Masonry: 250 mm |
| Internal Wall | Half Brick Masonry: 150 mm |
| Door | Height x Width |
| D1 | 2150x1000 mm |
| D2 | 2150x900 mm |
| D3 | 2150x800 mm |
| Window | Height x Width |
| W1 | 2000x3450 |
| W2 | 1820x2340 |
| W3 | 2000x2250 |
| W4 | 1675x960 |

**Figure 4.1** Architectural Model

## 4.2 Structural model

The structural model was generated in the Revit itself using the link Revit file option. The architectural model was extracted in a structural template in Revit and all the structural components like beams, columns, slabs, etc. were added to the architectural model. The main advantages of using BIM tools were that we could visualize the structure model, especially the type of reinforcements used. It has been usually observed at site, a lot of people have trouble placing reinforcement at beam column junction and other complex regions. Therefore, BIM tools provides this facility to navigate and visualize in 3D to have a clear picture on how to place rebar. It also has an integrated software to perform the other analysis like structural, scheduling, etc. After creating frames and defining section properties in Revit the model was exported to Autodesk Robot Structural professional (RSA) which is also an integrated tool for the structural analysis for Revit. The material property and selection of the proper codes for the design and analysis were added in the RSA.

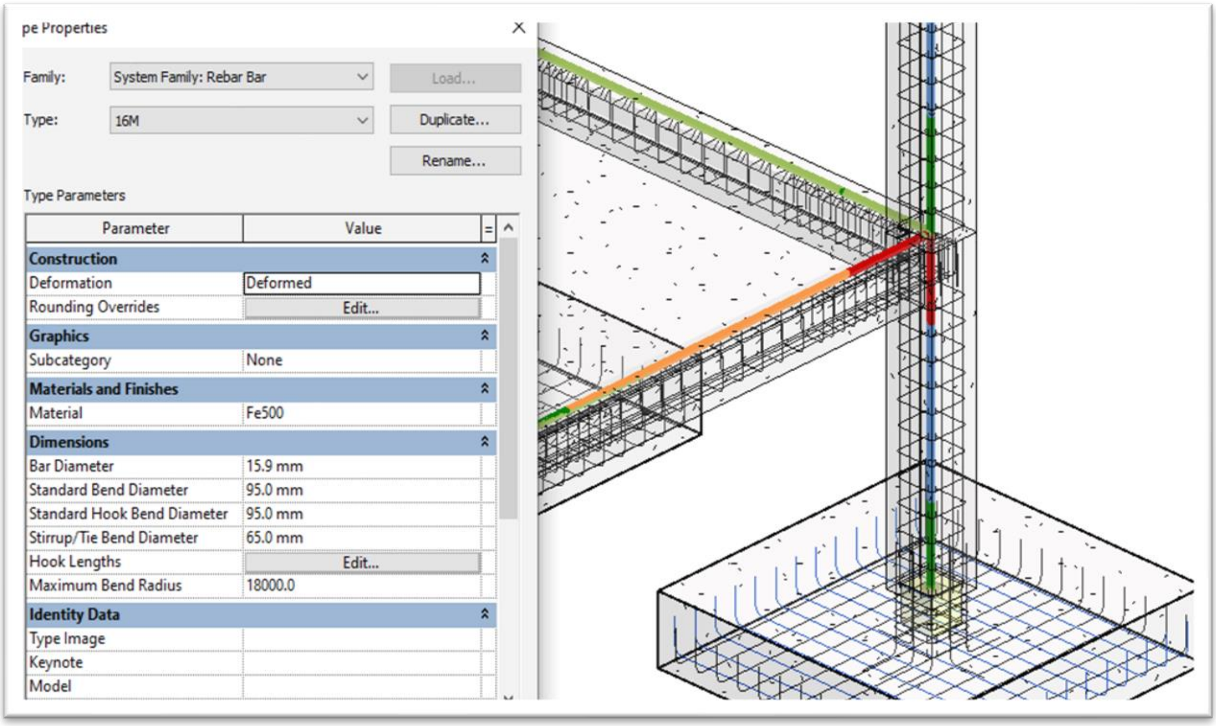



**Figure 4.2** Structure Reinforcement

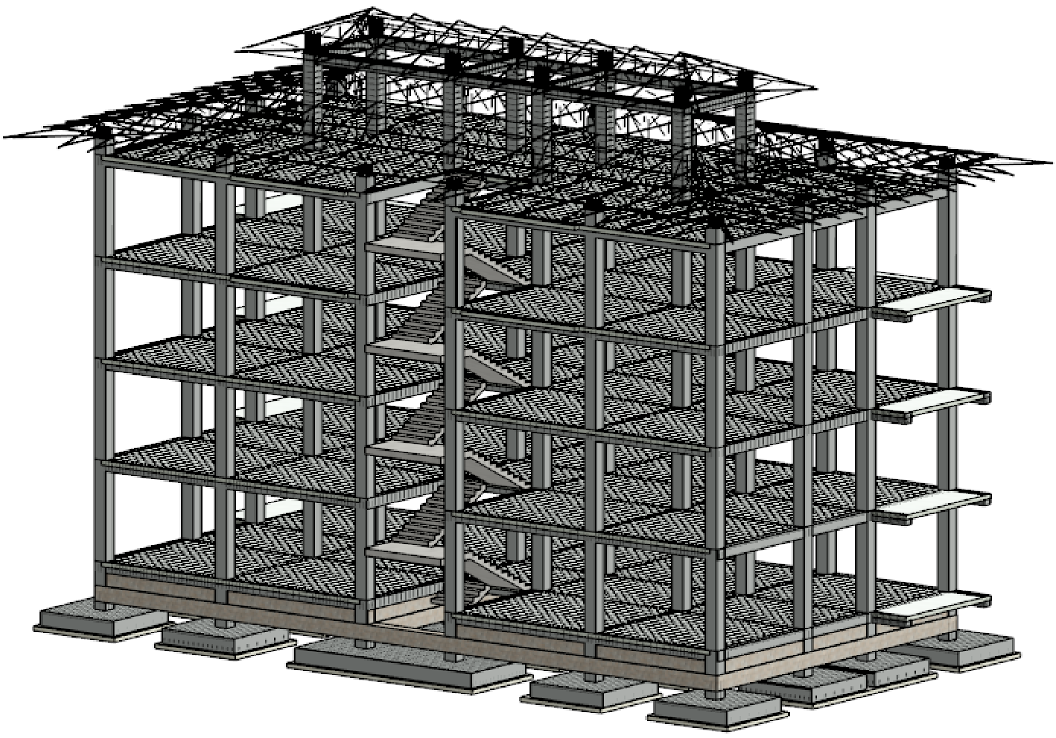


**Figure 4.3** Structural Model

## 4.3 Mechanical, Electrical and Plumbing Model

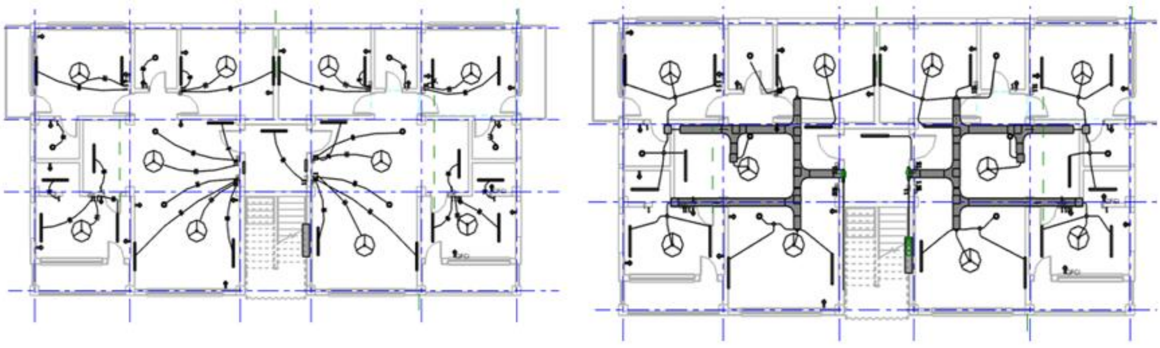
MEP stands for mechanical, electrical, and plumbing systems, which are the living components of construction projects and it can be created using the Autodesk for MEP engineering professionals' templates. It helps MEP professionals in efficient 3D modeling and collision detection. We can even find the accurate estimation of every assigned project items.

### 4.3.1 Electrical system in Revit

Revit provides the facilities to design electrical systems using the system template. We can install electrical components, fixtures, and wiring, as well as design circuits, panel schedules, and load classification. We can use default families by altering the system properties or create new families too. A simple electrical design can be created by linking the architectural model into a system template file. Electrical components include light fixtures that are fluorescent tubesand Compact Fluorescent Lamps (CFLs), ceiling fans, wires, three phase switches, outlets, conduits, cable trays, and panel boards.

#### 4.3.1.1 Benefits of BIM in Electrical System Design

BIM offers all the tools for electrical design and estimation (Jasim Farooq, 2017). In the conventional method of electrical system design, engineers use a combination of applications and produce results in 2D CAD drawings. While using non-BIM applications a lot of information like room dimensions, doors, and window details and material properties, etc., are required from architecture for analysis. The process becomes tedious as it doubles the work and even the probability of making errors increases. However, in BIM-based system design, we can interlink the architecture model and use the same for system design. Whenever there is a change in lighting or power data, automatically updates distribution and panel schedules.



(a) (b)

**Figure 4.4** (a, b) Electrical Floor Plan &Ceiling Plan

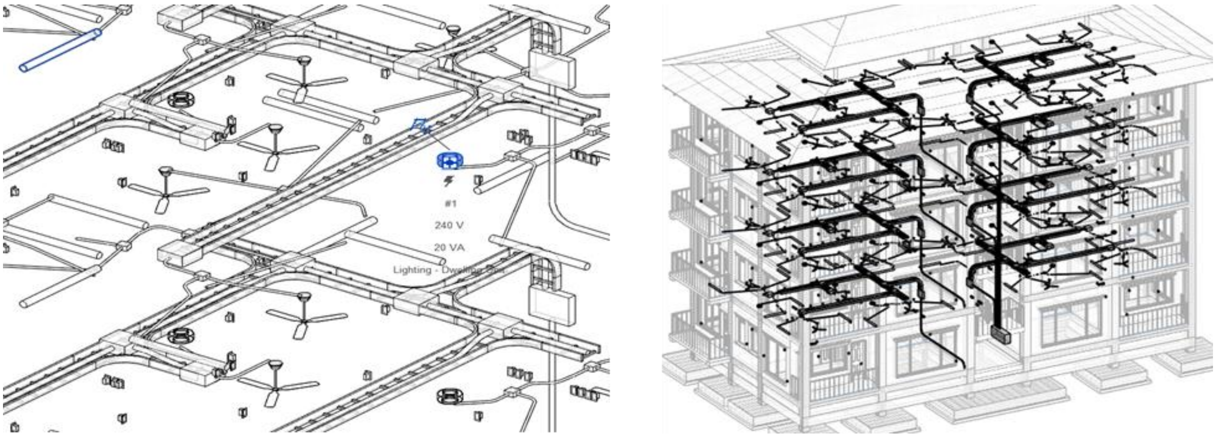



**Figure 4.5** 3D Electrical Model

### 4.3.2 Plumbing Model

The plumbing model is then linked to the initial 3D model. By default, there are three system types for plumbing that are sanitary, domestic hot and cold water in Revit. It comes with a set of view templates that describe many of the view attributes needed to construct specific views automatically. There is a collection of standard components in Revit that may be selected and placed in a project. A separate MEP template for the plumbing model is linked with the architectural model. Then different color codes for the types of system of water have been assigned  for the better understanding of the types of piping system used.

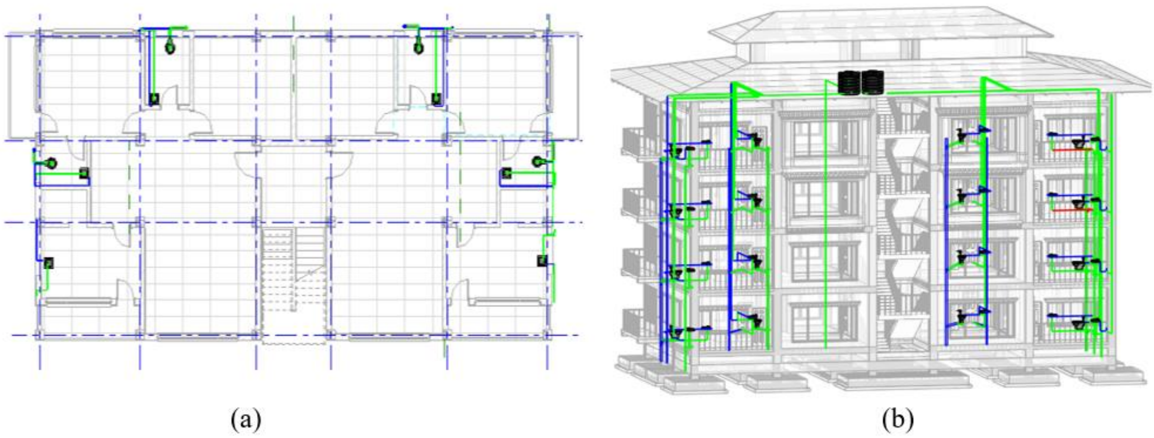


**Figure 4.6** (a, b) Plumbing floor plan and 3D model

### 4.3.2.1 Benefits of using BIM on MEP project

One of the advantages of using MEP Model was that not only it becomes easy during the installation but also during the renovation time. We can figure out the type of material used and the location of each element through improved 3D visualization. The other special benefits are identifying clashes between different model trades. Since Revit has inbuilt capability to run clash detection, all the models are coordinated in a central model and clashes are identified and resolved at the design phase.

# CHAPTER 5: 4D BIM CONSTRUCTION SCHEDULING

For the concept of n-D BIM, firstly a 3D digital model is prepared with all the geometric information of each building element to be called as 3D BIM. While this is quite a progress compared to traditional 2D CAD. However, in AEC projects, relying solely on 3D modeling information is too far removed from the actual building phase, which is heavily reliant on schedule and budget. As a result, the notion of fourth-dimensional (4D) BIM, which incorporates timetable (duration) simulation, was developed.

When you connect a project schedule to a 3D model, you get a 4D sequencing model, which is commonly used to create 4D sequencing animations(Beyond 3D: The Many Dimensions of BIM, n.d.).

## 5.1 Building Scheduling

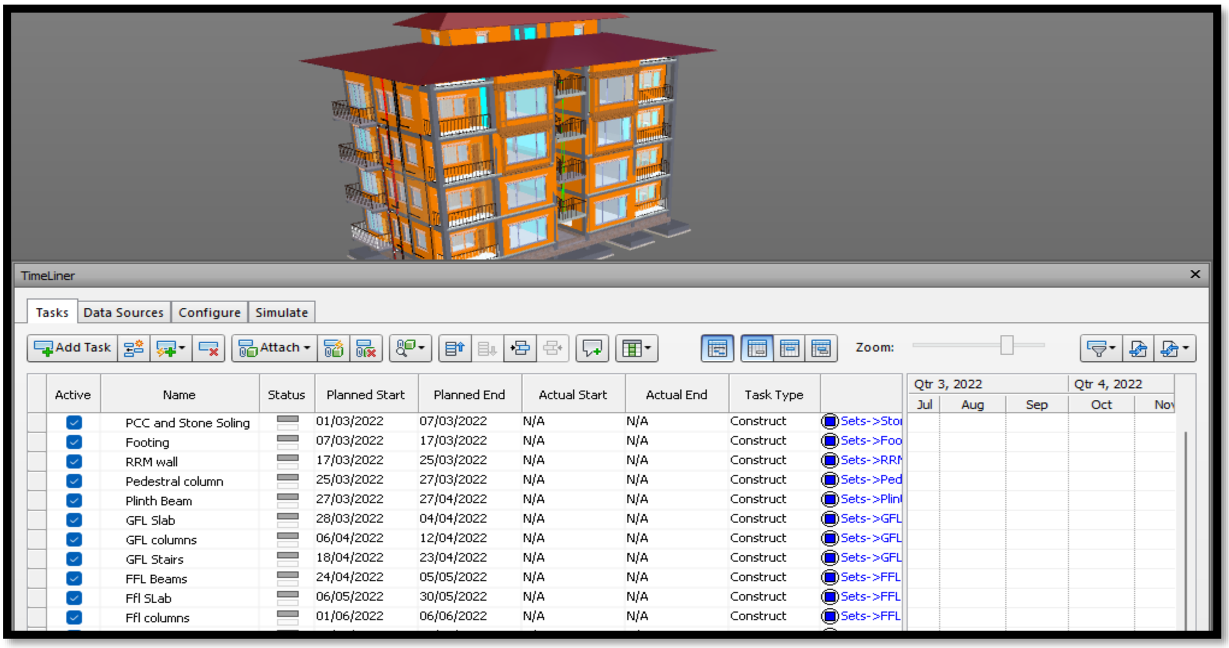



**Figure 5.1** Time liner in Navisworks

The building timetable and development planning are similar to the traditional way. In MS Project, a simple schedule is built and saved as a CSV file. The Revit model was then exported as an Industry Foundation Class (IFC) to allow for model interchange with BIM application program Autodesk Navisworks. The CSV schedule file and 3D model are loaded into Navisworks Manage. BIM-based schedules were created using Autodesk Navisworks.

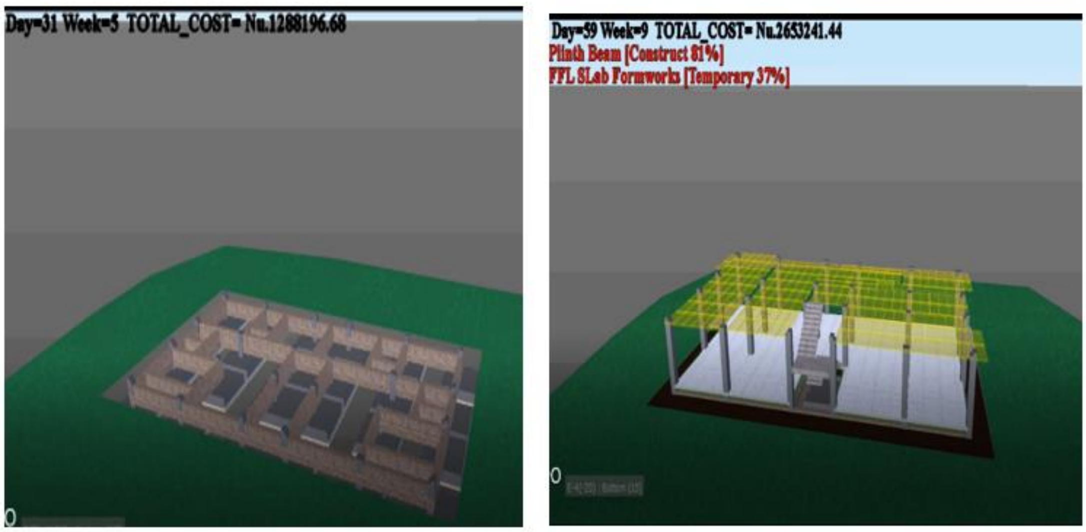
The model's elements are chosen from the selection sets and attached to scheduled activities. Once connected, a simple 4D model in the form of animation or simulation can be exhibited.

## 5.2 4D Construction Process Animation

A simulation of 4D BIM with time in days was prepared as shown in the figure11. While in the 4D simulation we can also add material costs, labor, and equipment costs which will be displayed according to the schedule prepared. Unlike the conventional method, every building element present must be associated with a task and time. However, if the elements are not assigned any task, it doesn't appear in the simulation and if any task is wrongly scheduled it can be visualized in the simulation.

The purpose of creating animation is to visualize the construction process, site layout plan, and temporary equipment, which is constantly varying. It also serves as a visual verification of the schedule and logistic sequence in a comprehensive manner to all the participants involved.

While 4D BIM is not just limited to building elements, we can have logistic planning for space utilization at the site. It includes temporary components such as cranes, mixers, carrier vehicles, fences, lifts, excavators, etc. BIM-based planning improves site safety, space coordination, and product information (Hergunsel, 2011).



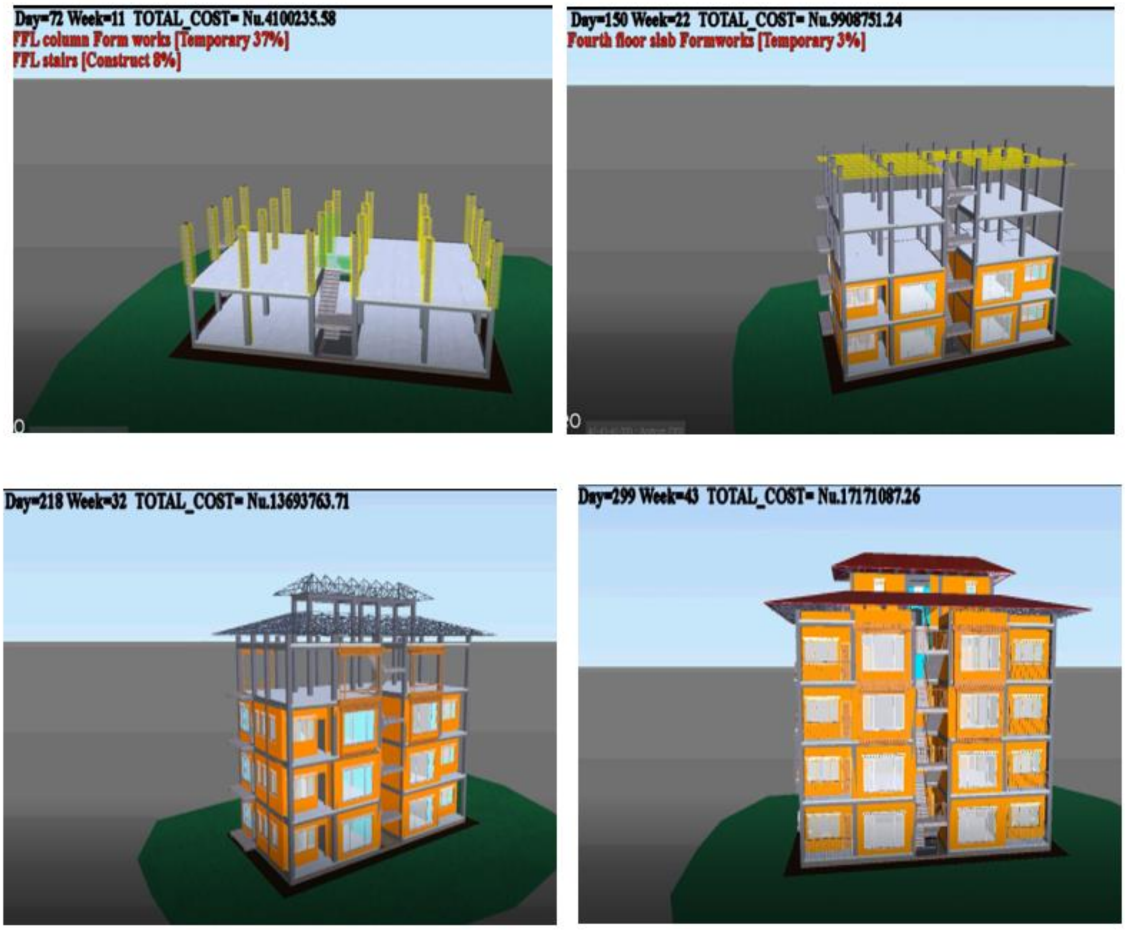



**Figure 5.2** 4D time scheduling

# CHAPTER 6: 5D COST SCHEDULING

The budget of the project is proportional to its timeline. It depends on how many work hours each phase requires and how design modifications and delays affect the cost. Owners and general contractors may exert pressure on the cost schedule as well. Exploring how 5D BIM may be used to further integrate estimation and scheduling within the project team in order to achieve cost accuracy. Cost management operations include planning, estimating, budgeting, financing, funding, managing, and controlling costs to ensure that the project is completed within the allocated budget. As a result, accurate estimating and costing become critical components of the success of a building project (Muhammad Tariq Shafiq, April, 2013).

The method of adding the cost dimension to the 4D BIM model is known as 5D BIM. It is simply a 4D plus cost. Here, we link the cost data to support cost planning and even generates estimate. This 5D modeling helps us to integrate cost, schedule, and design in 5D. In the traditional method, the design and estimation are executed separately, which consumes more time and increases the chance of error. With the 5D BIM, it gives the Engineer new opportunities to make cost estimation more accurate and detailed which increases the efficiency and productivity of the work. Since the Revit has all of the information about building components, and the numbers are correctly identified from 3D models. This enables us to produce a solid cost estimate for the entire project from the start. Therefore, reducing the chances of risk and loss due to mismanagement and communication.

## 6.1 Benefits of Using 5D BIM

i. It allows for the extraction or construction of building components in real time within a virtual model.

ii. Integrates the design with estimation, scheduling, and costing

iii. It allows the client to experiment with various situations, such as demonstrating how a change in design affects both the program and the budget.

iv. Helps perform accurate costing as it includes all the information related to the building and its components.

## 6.2 Material and quantity takeoff

In Revit, there is an option to perform material takeoff, quantity takeoff, and even a list of components with pricing and then the overall schedules. These are the methods used for the estimation as per the result we want to display. The material takeoff offers more information about a component's assembly with lists of sub-components or material whereas the quantity takeoff measure different categories of elements and their parameters.

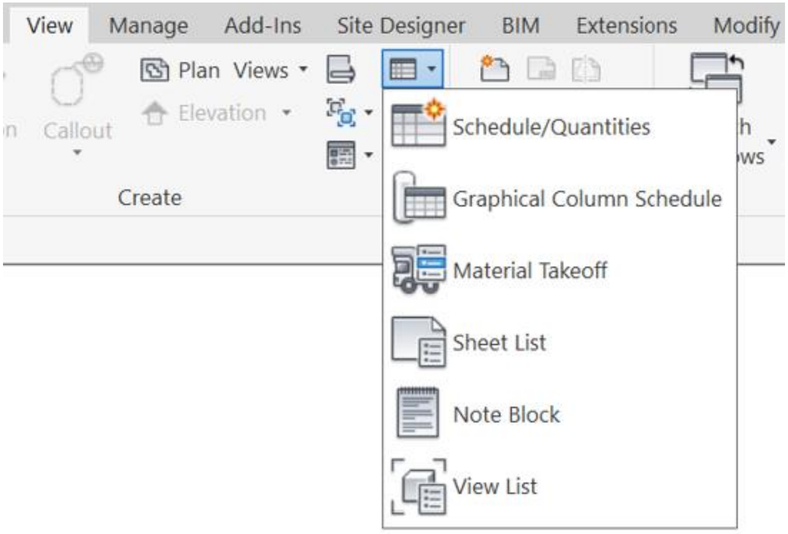



**Figure 6.1** Schedule Option in Revit

For example, if we perform a wall schedule using quantity take-off, various categories of walls can be sorted based on thickness, height, length, etc. Whereas wall schedule using material takeoff, various material of wall i.e., paint, plaster, bricks etc., will be scheduled.

## 6.3 The method of 5D scheduling

At the initial stage of the design phase, we added the price of the material as per the BSR (Bhutan Schedule Rating) in the Revit. This was done to keep updated with all the material that we used and it saved time while performing the scheduling.

For the scheduling, we selected the schedule option from the view menu and there we choose the option for scheduling that is by material and quantity take off as per our preferences. Then the schedule properties tab was displayed where we segregated all the necessary parameters like length, count, description, volume, etc. that we wanted to display in our schedule. We even added the new parameters and formulate them with their unit and properties. Then an automated schedule was generated. The results of the schedule will be exported in the report form or in excel.

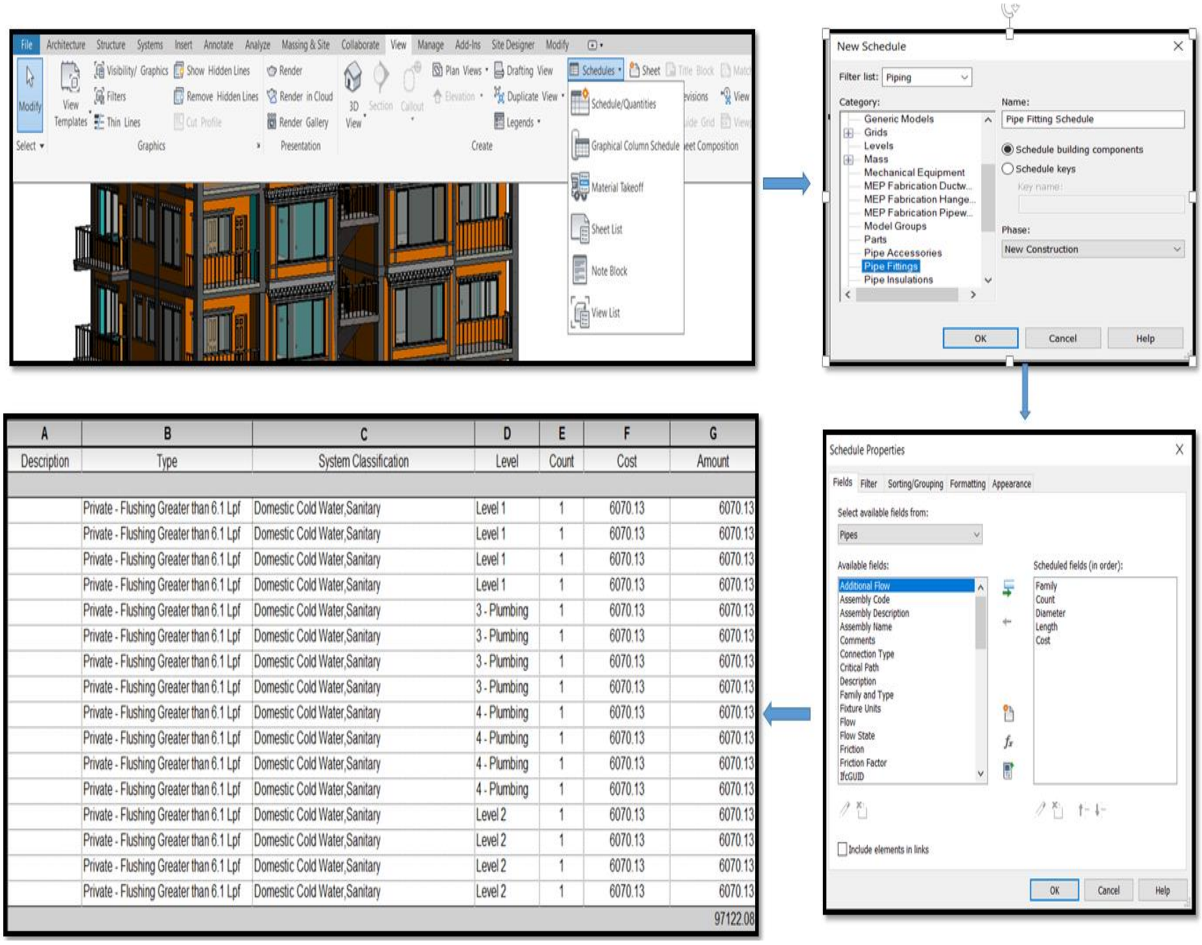



**Figure 6.2** Process for cost estimation

# CHAPTER 7: 6D SUSTAINABLE DESIGN

The natural and technical system are integrated by the concept of BIM into architectural designs ( Anju Ebrahim, A. S. Wayal, 2020). BIM in sustainable design holds a plus point for accurate analysis because it enables us to interactively test, analyze, and update design ideas. The prediction for the thermal and better performance building comfort are made possible through the application of features of 6D BIM. And the point that it has essential part to model buildings and ability to analyze it before the buildings can be erected on site virtually. It is also one of the most important strengths of BIM.

The classification of energy usage by the building is broadly divided into embodied and operating energy. The energy that has been spent in the life of the building is known as embodied energy. It takes into account from the initial amount of energy in the building material, to the installation at the time of technical works and even during erection or construction till the stage of renovation. Whereas, the energy that is required to keep buildings comfortable and maintain them on a daily basis is known as operating energy. It includes HVAC and all running appliances like lighting, domestic water etc. Even the duration of the thermal comfort, types of operating time and climatic changes are necessary to be maintained.

## 7.1 Energy Analysis Workflow

Both conceptual mass and comprehensive building element information can be used for energy analysis. The 3D model which was created earlier in Revit software was used to generate an energy model from the rooms and spaces, and the necessary energy setting and the location were set. Revit supports an internet mapping service which helped us to add the project location. Revit supports an internet mapping service which helps us to add project location. The project location is necessary to read the nearest weather station for climate and weather data. The rooms, spaces, or zones were assigned to their respective spaces or room in the 3D model. The project location was necessary to read the climate and weather data. Then an automatic energy model was generated in the Revit itself. The energy model was then used for the energy analysis in the Autodesk Insight 360 by using the energy optimization option in the Revit. For our study, we used both the energy tools to get the as much information as we could for the better performance building.

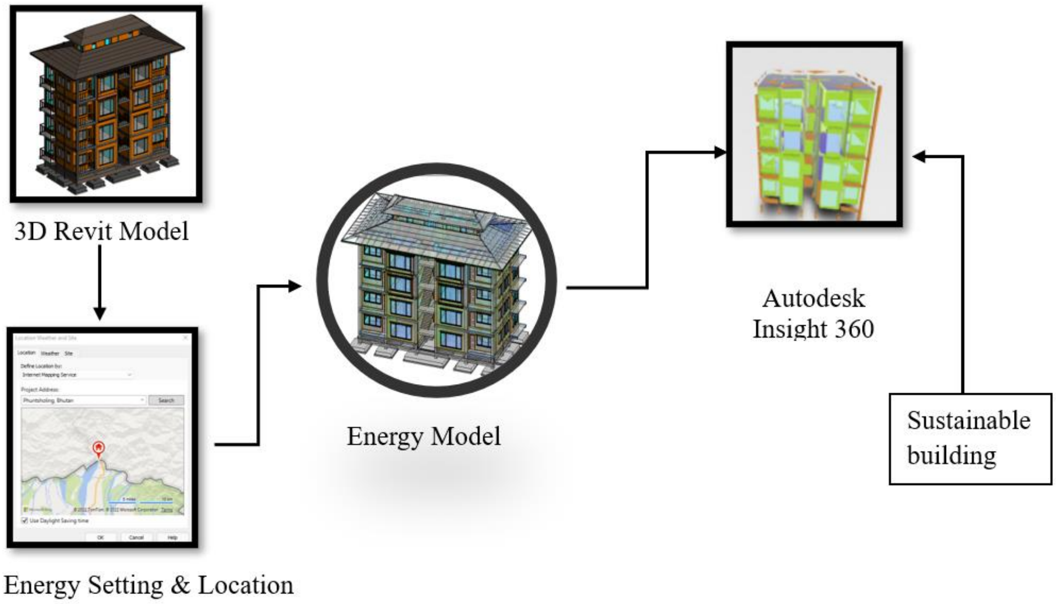



**Figure 7.1** 6D workflow

## 7.2 Autodesk Insight

The web-based platform which allows the designers to monitor and interface with key performance energy driver to optimize, standardize in the range throughout the entire lifespan with real-time cause and effect (Autodesk, 2018).

It has the potential to perform the solar, and daylighting analysis, and calculate the heating and cooling load of the building. The energy optimization was also done using Insight to produce a better-performance building in the pre-construction phase.

### 7.2.1 Solar Analysis

Before the solar analysis, we found the sun path of our project location. The clear picture of the sun's position during the interval between the sunrises to sunset at any range of its movement throughout the year is possible using the sun path. By positioning the sun at any place at along its daily route can be used to understand the full potential of solar research. The sun path for our study is shown below in figure 7.2.

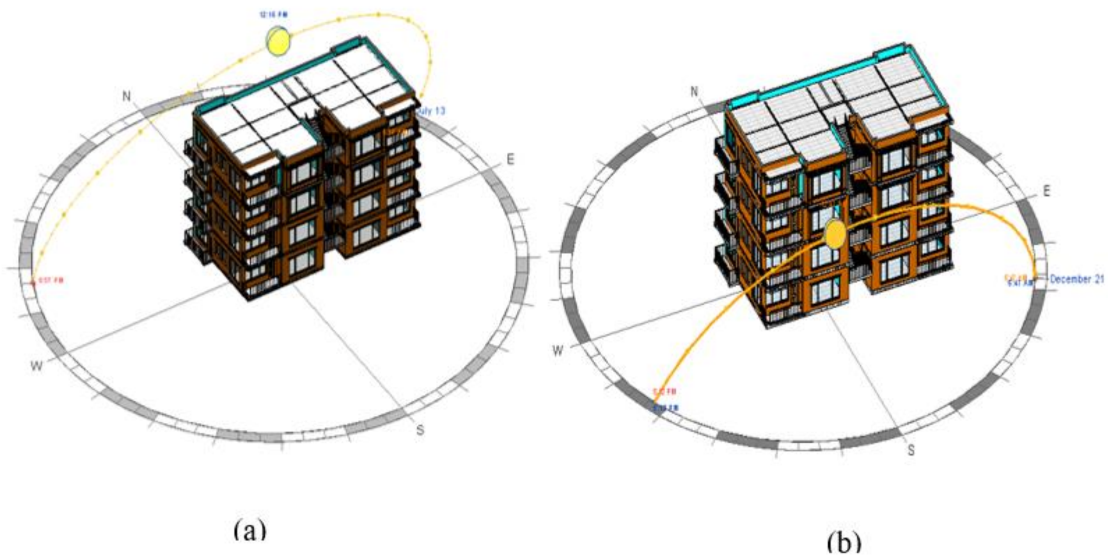



**Figure 7.2** (a, b) Sun path during summer and winter

Solar analysis was performed in the Revit using the Insight plugins of solar analysis. The building surfaces like walls, floors, roofs, and ceilings were selected for the analysis. By implementing a solar system, designers can improve the building's energy efficiency, comfort, and energy savings by analyzing the sun's impact. The model shows the overall solar distribution on the building. The yellow, green, and purple color indicate the maximum, normal and minimum solar experiences respectively.

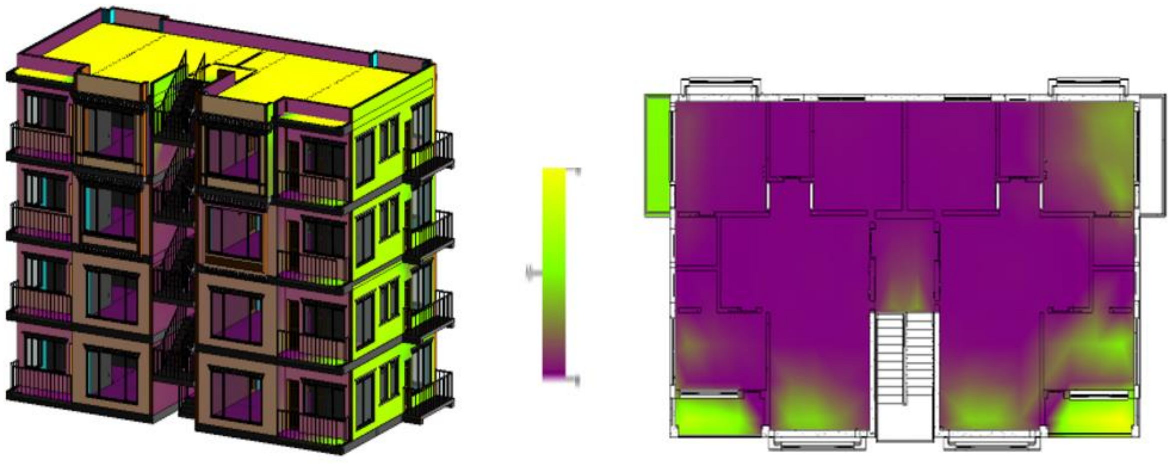


**Figure 7.3** Solar analysis model

### 7.2.2 Day light analysis

Similar to the solar analysis, daylight analysis was also performed to understand if the room or space gets enough sunlight during daytime. A single room was selected to see the daylight distribution. It was observed that the wall having the windows or the opening experienced the maximum daylights. Both solar and daylight analysis are performed in the Revit itself.

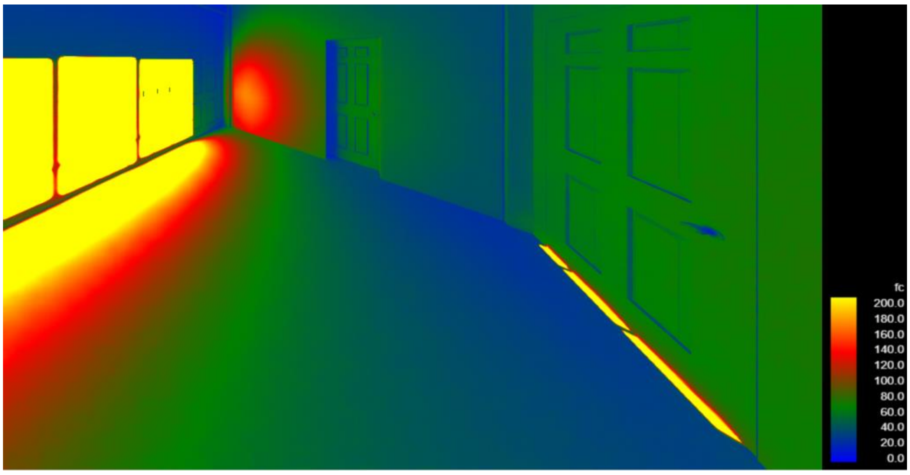



**Figure 7.4** Daylight analysis

### 7.2.3 Energy optimization using Autodesk Insight 360

At Autodesk Insight, energy optimization is the method of changing the material of the building envelope to get the optimum energy. It is one of the most important features of insight. We created different design scenarios selecting the most efficient material in each phase. For our study, we selected 8 scenarios to make the high-performance building from a current state.

#### 7.2.4.1 Current Building State

The initial state of the building was assessed without a single change. The current states of the building were 41% of the window to wall ratio, main entrance is located on the south side of the building excluding the building shades. There was also no insulation in the walls, floors, or roofs. Based on the energy setting of the project, the energy usage of the building was determined as energy use intensity or EUI measured in kWh/m2 per year. The EUI is computed by dividing the total energy spent by the entire gross floor area of the building over a year. For our current building, the energy use intensity of the baseline building was 158 kWh/$m^2$/yr which is less than the energy consumption of a typical multifamily residential building according to the ASHRAE 90.1 standard. But still exceeds the benchmark of Architecture 2030.

**Figure 7.5** Energy Model in Insight

The various scenarios were added to the current building state in order to obtain the optimum energy. The main scenario selected were building orientation, window wall ratio, the glass type of window, wall and roof construction. And also, the operating period and HVAC system.

The outputs were produced by altering the various construction components and scenarios in the Autodesk Insight. The above figure shows the model in Insight and the graph below showing energy use intensity versus scenario that was chosen.

# CHAPTER 8: COLLABORATION

Construction project collaboration is directly related to communication and the efficient sharing of information among stakeholders (Hughes et al., 2012). According to the National BIM Standard (NBIMS), fully utilizing BIM technology necessitates an industrial paradigm shift in which information is transferred, shared, and coordinated electronically across organizational boundaries (Homayouni et al., 2014). It involves the process of undertaking by the two or more individuals sharing the data involved in the project. Collaboration in BIM facilitates communication and mutual understanding among different stakeholders and construction teams.

Collaborative working approaches, which involve all design team members earlier in the design process and are supported by BIM tools, are predicted to save at least 10% of the cost associated with traditional design-build projects (Egan, 1998 and Allen Consulting Group 2010 as cited in McDonald). The BIM collaboration process can be viewed as a method of identifying various construction phases for a single project. This description also contains an explanation of the process for transferring data and information between construction phases.

The trades of the AEC industry working on the same project with individual goals of completing the required tasks using the traditional method of data, file, and information transfer, creating a haphazard situation such as misplacing, losing data, etc. as many files are needed to be shared among each trade for the project's completion. BIM with collaboration allows each trade in the AEC industry to collaborate on common project goals rather than separate goals, resulting in an excellent manner to complete projects. Building Information Modeling is revolutionizing the present and traditional methods of collaboration, as well as the roles of project members. Aided by the BIM, the whole design team members can be engaged at the earlier design stage process by creating a common data environment.

## 8.1 Method of collaboration

There are two ways of collaboration in Revit:

**i. Collaboration within your networks**

Here the collaboration is possible only on a local area network or wide area network (LAN or WAN). It is an internal method of collaboration and is also known as the working sharing method and allows users on the same local area network (LAN) to collaborate on the same Revit model.

ii. **Collaboration using the cloud**

Collaboration is over any internet using the BIM 360. It is primarily built on a web server or cloud, which creates a common data environment in which several users work on the same model with the same project data, hence improving team activity and communication. Collaboration within the network/working sharing method.

We used a local area network to collaborate for our research because cloud collaboration requires a license.

### 8.1.1 Collaboration using the LAN

Within the network, many Revit models can be linked together to allow team members to collaborate in real-time. Work sharing allows users on the same local area network (LAN) to collaborate on the same Revit model. Working sharing is a creative methodology that enables multiple team members to work on the same project model at the same time. Many projects allocate team members to distinct functional areas to focus on. No additional software is required for the working sharing model.

#### 8.1.1.1 Terminologies

i. Central file: It is the work shared master model of the project and maintains current ownership information for all project pieces and serves as a distribution point for all changes made to the file. It is the Revit file that allows several users to work on its features at the same time.
ii. Local file: A copy of the central model shared to the team member.
iii. Work set: It is the project's element that allows for establishing defined functional areas. It can be used to separate functional areas in building systems, such as HVAC, electrical, plumbing, and piping.

### 8.1.1.2 Demo on Collaboration using LAN

#### 8.1.1.2.1 File sharing using LAN

In the first step, we created the folder that was shared with our team members using the local area network. The folder was made accessible on four different desktops. The folder was named the “Final year project”.

#### 8.1.1.2.2. Creating a central model

We opened the Revit file on which we were working and wanted to collaborate. Then the file was saved as a “Central file” in the folder that we created earlier in our network. After that, we used the “collaborate” tab in the Revit. There were two options for collaboration that were displayed using within the network or cloud. We selected the first option that collaborated within our network. After saving the file again, we were notified that it was the first time saving the central file. It is the most crucial stage that we often overlook and forget to save.

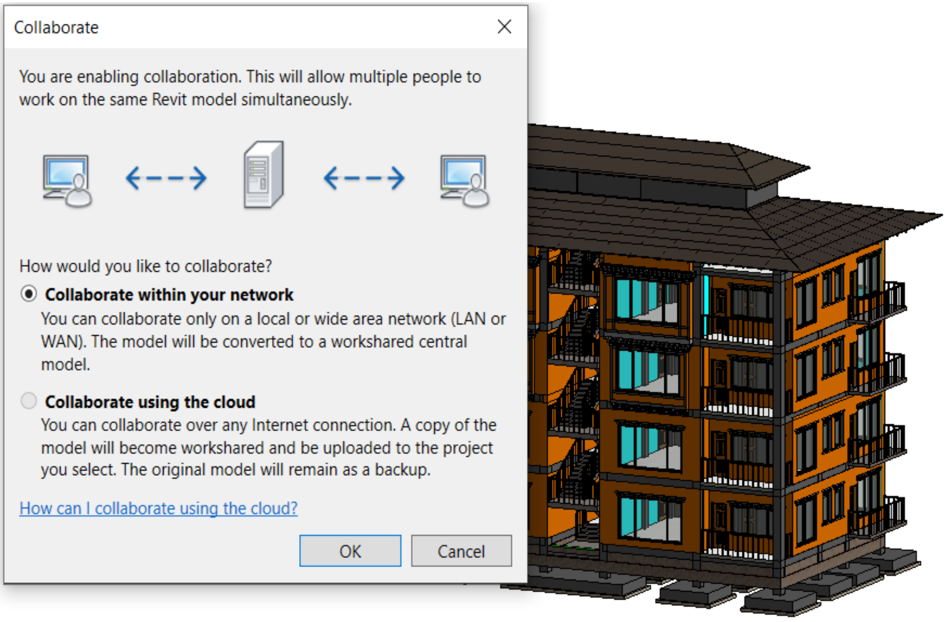



**Figure 8.1** Collaboration in Revit

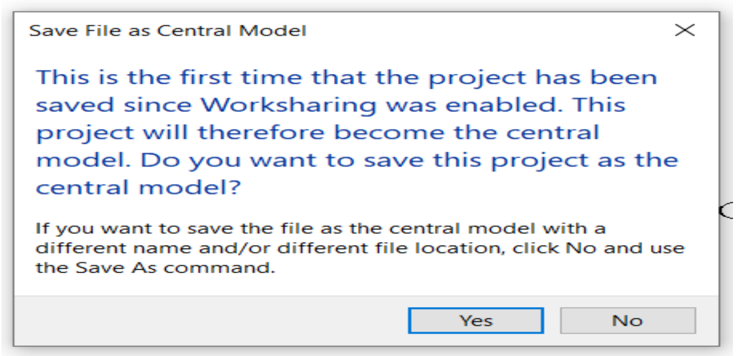



**Figure 8.2** Creating center file

### 8.1.1.2.3 Creating the local file

After the central file was saved, the same file was saved as a "local file" in a different location on our desktop. The file location was on the desktop and was saved in the folder "local model". The central file should not be edited or moved. Similarly, the central file was accessed by the three other desktops and created the local copy of the central file .

### 8.1.1.2.4 Creating Work sets

For our work to be separate, distinct, and functional, we created our own work sets where we all have our own jobs destination like architectural, structural, and MEP.

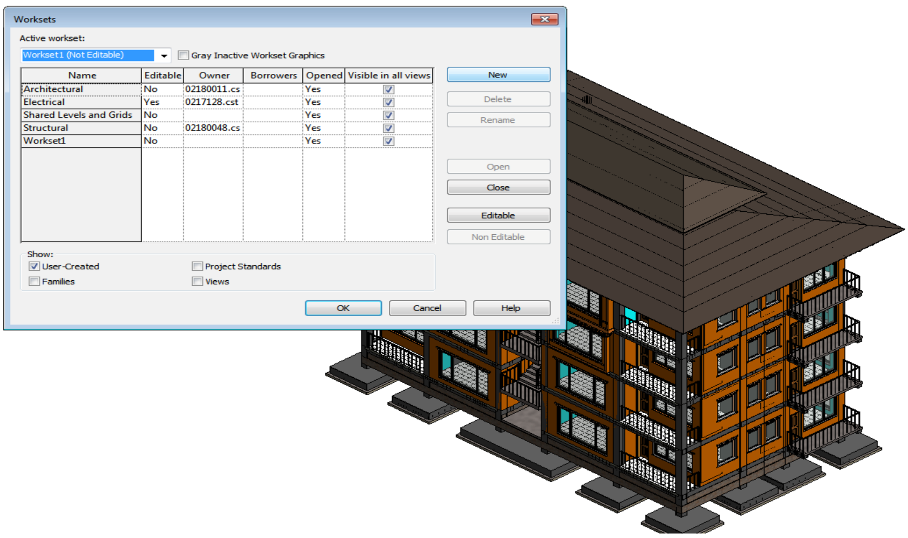



**Figure 8.3** Work sets in Revit

### 8.1.1.2.5 Synchronize with central

Using the Synchronize with Central tool to help us save our local modifications to the central model when working on work shared project. We worked on our own local file using our own work sets or in any of the active work sets. Whenever we made any changes to our local file, we selected collaborate tab where we had the option to "Synchronize with central". There are two options, the first option allows us to leave comments on the changes that we had made. We observed that by synchronizing with central, we were able to keep updated on any changes made to the model by the other team members. We could see the whole history of the changes made to the model by the team members. And to keep updated with the latest changes, the "Reload the latest" tab was used. Any latest changes would be loaded in the local file.

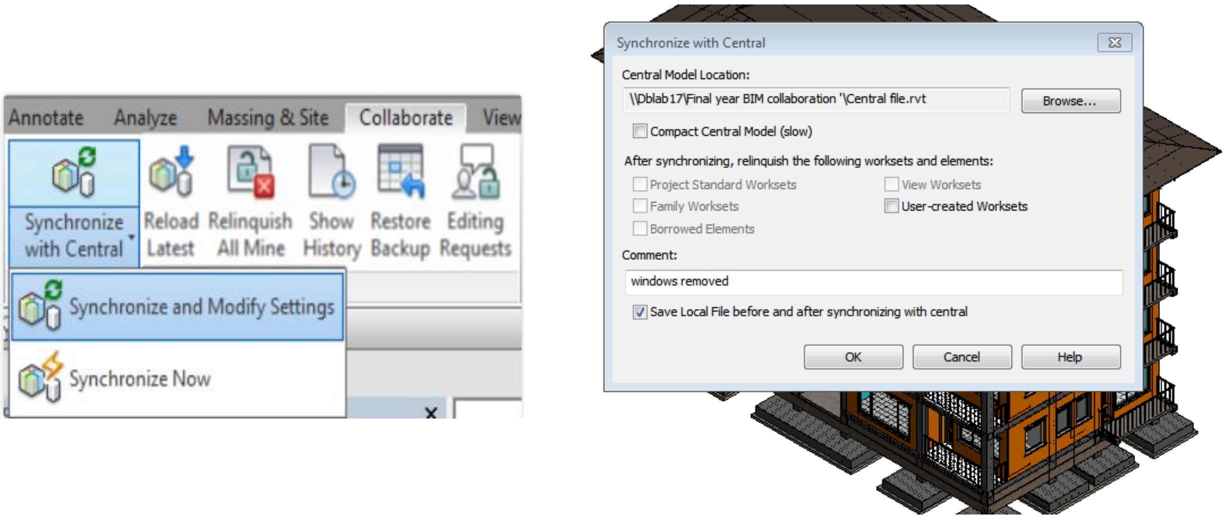



**Figure 8.4** Synchronize with central

Collaboration also helps in the clashes of the works, if one trade had worked on the model and another trade wanted to make changes to that model. We needed to place a request and access for the changes to be made. The other received the notification and as per the genuine, the user can deny or allow. Collaboration makes the data sharing among multiple users effortlessly and smoothly without creating haphazard situations.

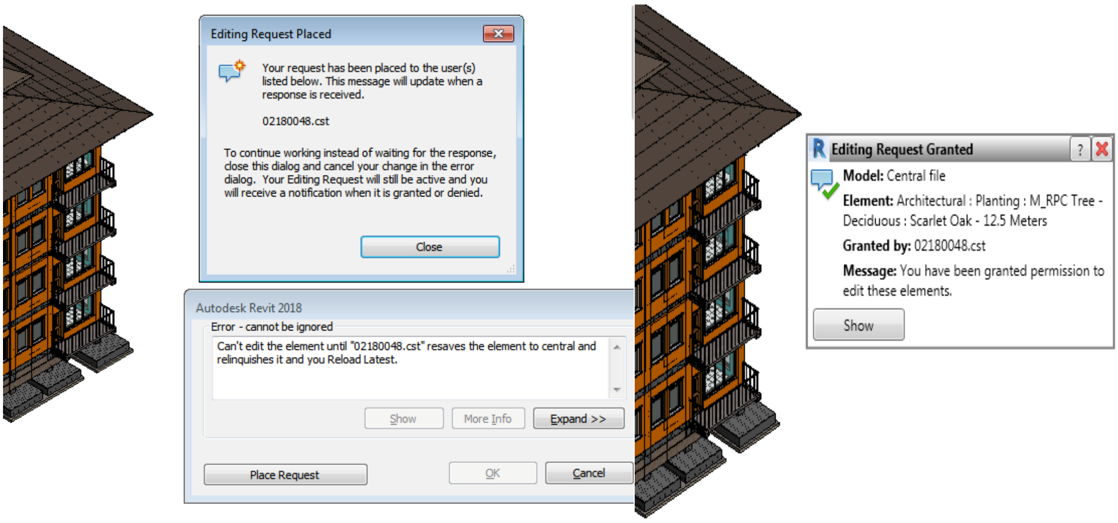



**Figure 8.5** Placing request in Revit

# CHAPTER 9: RESULTS

## 9.1 Estimation summary

### 1. PPGI Sheet

| <PPGI Sheet> | | | | | |
|---|---|---|---|---|---|
| A | B | C | D | E | F |
| Description | Material: Name | Count | Area | Cost | Amount |
| | | | | | |
| | Metal - Steel 43-275 | 1 | 370 m² | 1016.74 | 376221.53 |
| | Metal - Steel 43-275 | 1 | 109 m² | 1016.74 | 111174.06 |
| | | | | | 487395.59 |

**Figure 9. 1** PPGI Schedule

### 2. Brickwork

| B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|
| of Wall | | | | | | |
| Base Constraint | Count | Length | Width | Volume | Cost | Amount |
| | | | | | | |
| GFL | 1 | 22 | 0.250 m | 9.63 m³ | 2500 | 24,080.16 |
| GFL | 1 | 10 | 0.250 m | 3.70 m³ | 2500 | 9,249.23 |
| GFL | 1 | 10 | 0.250 m | 3.51 m³ | 2500 | 8,780.94 |
| GFL | 1 | 7 | 0.250 m | 5.01 m³ | 2500 | 12,527.50 |
| GFL | 1 | 3 | 0.250 m | 2.29 m³ | 2500 | 5,718.75 |
| GFL | 1 | 7 | 0.250 m | 4.82 m³ | 2500 | 12,058.75 |
| GFL | 1 | 5 | 0.250 m | 1.97 m³ | 2500 | 4,930.70 |
| GFL | 1 | 4 | 0.250 m | 2.81 m³ | 2500 | 7,035.00 |
| GFL | 1 | 5 | 0.250 m | 1.69 m³ | 2500 | 4,212.73 |
| GFL | 1 | 1 | 0.250 m | 0.77 m³ | 2500 | 1,925.62 |
| GFL | 1 | 5 | 0.250 m | 1.84 m³ | 2500 | 4,607.88 |
| GFL | 1 | 1 | 0.250 m | 0.86 m³ | 2500 | 2,160.00 |
| GFL | 1 | 5 | 0.250 m | 1.95 m³ | 2500 | 4,883.83 |
| | | | | | | |
| FFL | 1 | 22 | 0.250 m | 9.63 m³ | 2500 | 24,080.16 |
| FFL | 1 | 10 | 0.250 m | 4.07 m³ | 2500 | 10,172.48 |
| FFL | 1 | 10 | 0.250 m | 3.87 m³ | 2500 | 9,680.76 |
| FFL | 1 | 7 | 0.250 m | 5.66 m³ | 2500 | 14,145.81 |
| FFL | 1 | 3 | 0.250 m | 2.55 m³ | 2500 | 6,385.94 |
| FFL | 1 | 7 | 0.250 m | 4.82 m³ | 2500 | 12,058.75 |
| FFL | 1 | 5 | 0.250 m | 1.97 m³ | 2500 | 4,930.70 |
| FFL | 1 | 4 | 0.250 m | 3.14 m³ | 2500 | 7,855.75 |
| FFL | 1 | 5 | 0.250 m | 1.85 m³ | 2500 | 4,614.16 |

| B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|
| TFL | 1 | 14 | 0.250 m | 10.02 m³ | 2500 | 25,055.69 |
| TFL | 1 | 1 | 0.250 m | 0.49 m³ | 2500 | 1,218.75 |
| TFL | 1 | 4 | 0.250 m | 1.69 m³ | 2500 | 4,216.19 |
| TFL | 1 | 1 | 0.250 m | 0.73 m³ | 2500 | 1,828.12 |
| TFL | 1 | 0 | 0.250 m | 0.01 m³ | 2500 | 19.97 |
| TFL | 1 | 1 | 0.250 m | 0.49 m³ | 2500 | 1,218.75 |
| TFL | 1 | 4 | 0.250 m | 1.69 m³ | 2500 | 4,216.19 |
| TFL | 1 | 1 | 0.250 m | 0.49 m³ | 2500 | 1,218.75 |
| TFL | 1 | 0 | 0.250 m | 0.27 m³ | 2500 | 677.63 |
| TFL | 1 | 0 | 0.250 m | 0.39 m³ | 2500 | 975.00 |
| TFL | 1 | 4 | 0.250 m | 2.27 m³ | 2500 | 5,663.43 |
| TFL | 1 | 0 | 0.250 m | 0.39 m³ | 2500 | 975.00 |
| TFL | 1 | 4 | 0.250 m | 2.27 m³ | 2500 | 5,686.13 |
| TFL | 1 | 1 | 0.250 m | 0.64 m³ | 2500 | 1,589.25 |
| TFL | 1 | 0 | 0.250 m | 0.63 m³ | 2500 | 1,584.38 |
| TFL | 1 | 0 | 0.250 m | 0.04 m³ | 2500 | 109.69 |
| TFL | 1 | 4 | 0.250 m | 4.30 m³ | 2500 | 10,749.38 |
| TFL | 1 | 1 | 0.250 m | 0.88 m³ | 2500 | 2,198.62 |
| TFL | 1 | 1 | 0.250 m | 0.64 m³ | 2500 | 1,589.25 |
| TFL | 1 | 1 | 0.250 m | 0.88 m³ | 2500 | 2,198.62 |
| TFL | 1 | 3 | 0.250 m | 1.64 m³ | 2500 | 4,095.81 |
| TFL | 1 | 3 | 0.250 m | 1.64 m³ | 2500 | 4,095.81 |
| TFL | 1 | 3 | 0.250 m | 2.35 m³ | 2500 | 5,862.50 |
| TFL | 1 | 4 | 0.250 m | 3.02 m³ | 2500 | 7,541.69 |
| | | | | | | 477,311.98 |

**Figure 9. 2** Brickwork Schedule

## 3. Steel

| <Rebar Details> | | | | | | |
|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G |
| Bar Diameter | Maximum bar length | Reinforcement Volume | Quantity | Weight kg | Cost | Amount |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1590 mm | 374.63 cm³ | 3 | 2.94 | 77.38 | 227.57 |
| 10 mm | 1310 mm | 10082.94 cm³ | 98 | 79.15 | 77.38 | 6124.71 |
| 10 mm | 1310 mm | 10082.94 cm³ | 98 | 79.15 | 77.38 | 6124.71 |
| 10 mm | 1050 mm | 824.67 cm³ | 10 | 6.47 | 77.38 | 500.93 |
| 10 mm | 1030 mm | 808.96 cm³ | 10 | 6.35 | 77.38 | 491.39 |
| 10 mm | 1050 mm | 824.67 cm³ | 10 | 6.47 | 77.38 | 500.93 |
| 10 mm | 1030 mm | 808.96 cm³ | 10 | 6.35 | 77.38 | 491.39 |
| 10 mm | 1050 mm | 824.67 cm³ | 10 | 6.47 | 77.38 | 500.93 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 mm | 22220 mm | 11259.04 cm³ | 1 | 88.38 | 77.38 | 6839.11 |
| 25 mm | 22700 mm | 11502.26 cm³ | 1 | 90.29 | 77.38 | 6986.85 |
| 25 mm | 22700 mm | 11502.26 cm³ | 1 | 90.29 | 77.38 | 6986.85 |
| 25 mm | 10890 mm | 5518.04 cm³ | 1 | 43.32 | 77.38 | 3351.84 |
| 25 mm | 10890 mm | 5518.04 cm³ | 1 | 43.32 | 77.38 | 3351.84 |
| 25 mm | 10890 mm | 5518.04 cm³ | 1 | 43.32 | 77.38 | 3351.84 |
| 25 mm | 10890 mm | 5518.04 cm³ | 1 | 43.32 | 77.38 | 3351.84 |
| 25 mm | 10360 mm | 5249.49 cm³ | 1 | 41.21 | 77.38 | 3188.71 |
| 25 mm | 10360 mm | 5249.49 cm³ | 1 | 41.21 | 77.38 | 3188.71 |
| 25 mm | 10360 mm | 5249.49 cm³ | 1 | 41.21 | 77.38 | 3188.71 |
| 25 mm | 10360 mm | 5249.49 cm³ | 1 | 41.21 | 77.38 | 3188.71 |
| 25 mm | 22220 mm | 11259.04 cm³ | 1 | 88.38 | 77.38 | 6839.11 |
| 25 mm | 22220 mm | 11259.04 cm³ | 1 | 88.38 | 77.38 | 6839.11 |
| 25 mm | 22220 mm | 11259.04 cm³ | 1 | 88.38 | 77.38 | 6839.11 |
| 25 mm | 22220 mm | 11259.04 cm³ | 1 | 88.38 | 77.38 | 6839.11 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| 25 mm | 21900 mm | 11096.89 cm³ | 1 | 87.11 | 77.38 | 6740.62 |
| | | | 14374 | 47548.18 | | 3653040.62 |

**Figure 9. 3** Steel Schedule

## 4. Windows

<Window Schedule>

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| Level | Description | Count | Width | Height | Cost | Amount |
| | | | | | | |
| Ground | | 1 | 960 | 1675 | 6000.00 | 6000 |
| Ground | | 1 | 960 | 1675 | 6000.00 | 6000 |
| Ground | | 1 | 960 | 1675 | 6000.00 | 6000 |
| Ground | | 1 | 960 | 1675 | 6000.00 | 6000 |
| GFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| GFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| FFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| FFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| FFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| FFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| FFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| FFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| SFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| SFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| SFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| SFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| SFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| SFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| TFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| TFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| TFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| TFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| TFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| TFL | | 1 | 960 | 1675 | 6000.00 | 6000 |
| 6000: 24 | | | | | | 144000 |
| GFL | | 1 | 2780 | 1365 | 7000.00 | 7000 |
| GFL | | 1 | 2780 | 1365 | 7000.00 | 7000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| GFL | | 1 | 3450 | 2000 | 10000.00 | 10000 |
| GFL | | 1 | 3450 | 2000 | 10000.00 | 10000 |
| GFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| GFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| GFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| GFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 3450 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 3450 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 3450 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 3450 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| FFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| SFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| SFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| SFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| SFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| TFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| TFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| TFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| TFL | | 1 | 2250 | 2000 | 10000.00 | 10000 |
| 10000: 24 | | | | | | 240000 |
| SFL | | 1 | 3025 | 2000 | 12000.00 | 12000 |
| SFL | | 1 | 3025 | 2000 | 12000.00 | 12000 |
| TFL | | 1 | 3025 | 2000 | 12000.00 | 12000 |
| TFL | | 1 | 3025 | 2000 | 12000.00 | 12000 |
| SFL | | 1 | 3450 | 2000 | 12000.00 | 12000 |
| SFL | | 1 | 3450 | 2000 | 12000.00 | 12000 |
| TFL | | 1 | 3450 | 2000 | 12000.00 | 12000 |
| TFL | | 1 | 3450 | 2000 | 12000.00 | 12000 |
| 12000: 8 | | | | | | 96000 |

**Figure 9. 4** Windows Schedule

## 5. Door

<Door Schedule>

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| Level | Description | Count | Height | Width | Cost | Amount |
| | | | | | | |
| GFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
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| GFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| GFL | Internal Single Door | 1 | 2150 | 1000 | 10000.00 | 10000 |
| GFL | Internal Single Door | 1 | 2150 | 1000 | 10000.00 | 10000 |
| GFL: 16 | | | | | | 132000 |
| FFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| FFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| SFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
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| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| SFL | Internal Single Door | 1 | 2150 | 1000 | 10000.00 | 10000 |
| SFL | Internal Single Door | 1 | 2150 | 1000 | 10000.00 | 10000 |
| SFL: 16 | | | | | | 132000 |
| TFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
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| TFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 900 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 800 | 8000.00 | 8000 |
| TFL | Internal Single Door | 1 | 2150 | 1000 | 10000.00 | 10000 |
| TFL | Internal Single Door | 1 | 2150 | 1000 | 10000.00 | 10000 |
| TFL: 16 | | | | | | 132000 |

**Figure 9. 5** Door Schedule

## 9.2 Construction Schedule in MS Project

### a. Estimated Architectural Schedule

| Task Name | Duration | Start | Finish | Predeces |
|---|---|---|---|---|
| **Staff Quarter CST** | **548 days** | **Tue 5/17/22** | **Thu 6/20/24** | |
| start | 1 day | | | |
| **foundation** | **24 days** | **Tue 5/17/22** | **Fri 6/17/22** | |
| excavation | 2 days | Tue 5/17/22 | Wed 5/18/22 | |
| soling and PCC | 2 days | Tue 5/17/22 | Wed 5/18/22 | |
| footing | 10 days | Thu 5/19/22 | Wed 6/1/22 | 4 |
| RRM Wall | 10 days | Thu 6/2/22 | Wed 6/15/22 | 6 |
| **GFL** | **60 days** | **Thu 6/16/22** | **Wed 9/7/22** | **7** |
| Soling and PCC | 6 days | Thu 6/16/22 | Thu 6/23/22 | |
| plinth beam | 10 days | Thu 6/16/22 | Wed 6/29/22 | 7 |
| earth fill in plinth level | 2 days | Thu 6/30/22 | Fri 7/1/22 | 10 |
| Compaction | 2 days | Thu 6/16/22 | Fri 6/17/22 | |
| PCC and Soling | 7 days | Mon 7/4/22 | Tue 7/12/22 | 11 |
| Column | 12 days | Wed 7/13/22 | Thu 7/28/22 | 13 |
| **FFL** | **54 days** | **Fri 7/29/22** | **Wed 10/12/22** | |
| Slab& Beam Shuttering | 10 days | Fri 7/29/22 | Thu 8/11/22 | 14 |
| slab& beam Reinforcement | 8 days | Fri 8/12/22 | Tue 8/23/22 | 16 |
| beam and slab casting | 1 day | Thu 9/22/22 | Thu 9/22/22 | 17FS+21 days |

| | | | | |
|---|---|---|---|---|
| Staircase Shuttering | 2 days | Fri 9/23/22 | Mon 9/26/22 | 18 |
| Column | 12 days | Tue 9/27/22 | Wed 10/12/22 | 19 |
| ◢ **SFL** | **54 days** | **Thu 10/13/22** | **Tue 12/27/22** | |
| Slab& Beam Shuttering | 10 days | Thu 10/13/22 | Wed 10/26/22 | 20 |
| slab& beam Reinforcement | 8 days | Thu 10/27/22 | Mon 11/7/22 | 22 |
| beam and slab casting | 1 day | Wed 12/7/22 | Wed 12/7/22 | 23FS+21 days |
| Staircase Shuttering | 2 days | Thu 12/8/22 | Fri 12/9/22 | 24 |
| Column | 12 days | Mon 12/12/22 | Tue 12/27/22 | 25 |
| ◢ **TFL** | **54 days** | **Mon 12/12/22** | **Thu 2/23/23** | **25** |
| Slab& Beam Shuttering | 10 days | Mon 12/12/22 | Fri 12/23/22 | 25 |
| slab& beam Reinforcement | 8 days | Mon 12/26/22 | Wed 1/4/23 | 28 |
| beam and slab casting | 1 day | Fri 2/3/23 | Fri 2/3/23 | 29FS+21 days |
| Staircase Shuttering | 2 days | Mon 2/6/23 | Tue 2/7/23 | 30 |
| Column | 12 days | Wed 2/8/23 | Thu 2/23/23 | 31 |

**Figure 9. 6** Construction scheduling in MS project

## b. Structural column Schedule

| Structural Column Schedule | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Family Type | Physical: Structural Material | Physical: Assembly Code | Physical: Description | Physical: Base Level | Length | Count | Physical: Cost | Physical: Volume | Amount |
| M_Concrete-Square-Column : 400x400 | Concrete, Cast-in-Place gray | CW0002 | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | Footing Top | 1600 | 24 | 5417.23 | 2.45 m³ | 13262.16 |
| M_Concrete-Square-Column : 400x400 | Concrete, Cast-in-Place gray | CW0002 | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | GFL | 3350 | 24 | 5417.23 | 12.46 m³ | 67488.60 |
| M_Concrete-Square-Column : 400x400 | Concrete, Cast-in-Place gray | CW0002 | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | FFL | 3350 | 24 | 5417.23 | 12.46 m³ | 67490.78 |
| M_Concrete-Square-Column : 400x400 | Concrete, Cast-in-Place gray | CW0002 | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | SFL | 3350 | 24 | 5417.23 | 12.46 m³ | 67488.60 |
| M_Concrete-Square-Column : 400x400 | Concrete, Cast-in-Place gray | CW0002 | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | TFL | 3900 | 24 | 5417.23 | 14.60 m³ | 79085.57 |
| M_Concrete-Square-Column : 400x400 | Concrete, Cast-in-Place gray | CW0002 | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | FourthFL | | 24 | 5417.23 | 5.57 m³ | 30178.25 |
| | | | | | | | | 59.99 m³ | 324993.96 |

**Figure 9. 7** Structural Column Concrete takeoff

## c. Stairs Schedule

| Stairs Material Takeoff | | | | | |
|---|---|---|---|---|---|
| Family | Description | Top Level | Material: Cost | Material: Volume | Amount |
| | | | | | |
| Cast-In-Place Stair | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | FFL | 5417.23 | 2.74 m³ | 14853.64 |
| Cast-In-Place Stair | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | SFL | 5417.23 | 2.74 m³ | 14853.64 |
| Cast-In-Place Stair | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | TFL | 5417.23 | 2.74 m³ | 14853.64 |
| Cast-In-Place Stair | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | FourthFL | 5417.23 | 2.74 m³ | 14853.64 |
| Cast-In-Place Stair | 1:1.5:3 (1 cement : 1.5 sand : 3 graded crushed rock 20 mm nominal size) | GFL | 5417.23 | 0.28 m³ | 1530.02 |
| | | | | | 60944.60 |

**Figure 9. 8** Stairs concrete takeoff

## 9.3 Energy Optimization Results

### a. Scenarios in Autodesk Insight 360

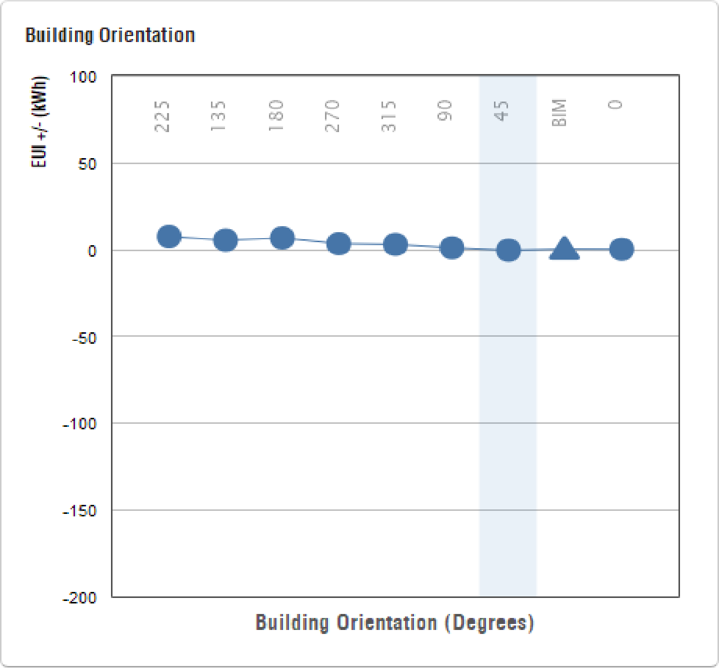


**Figure 9. 9** Building Orientation

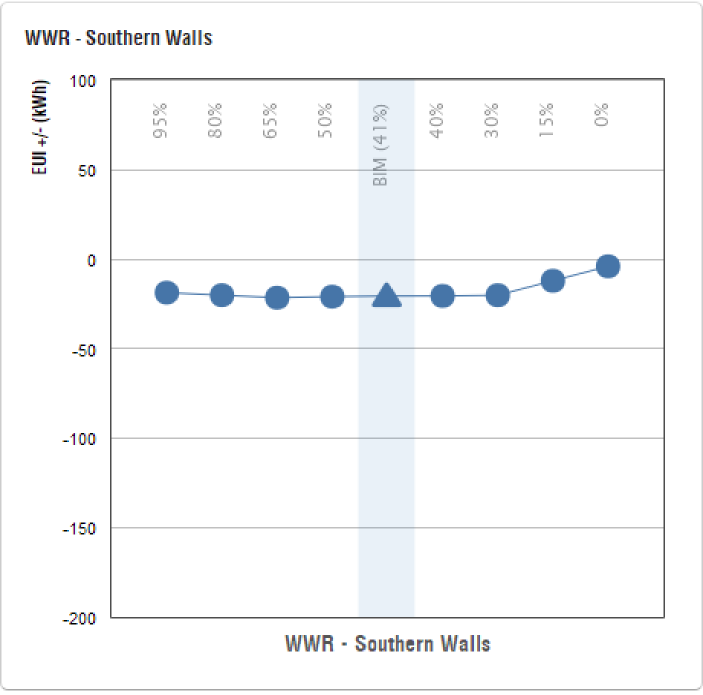


**Figure 9. 10** WWR - Southern Walls

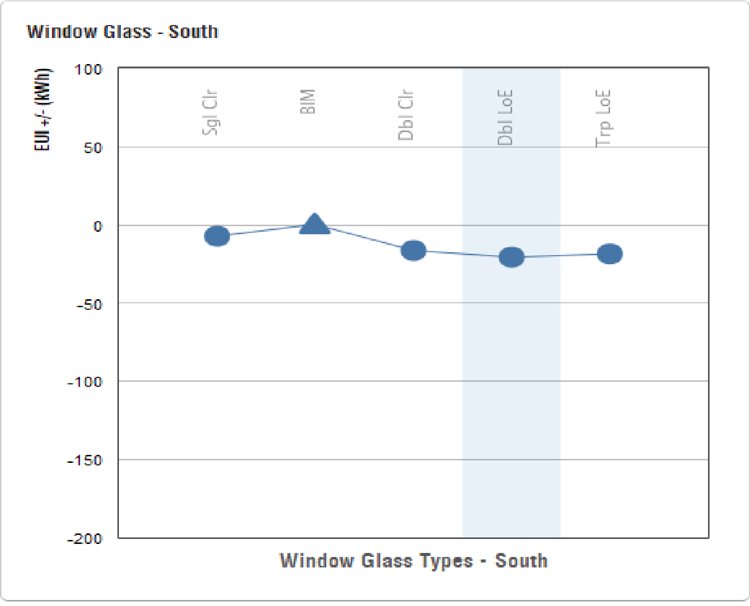


**Figure 9. 11** Window Glass Types - South

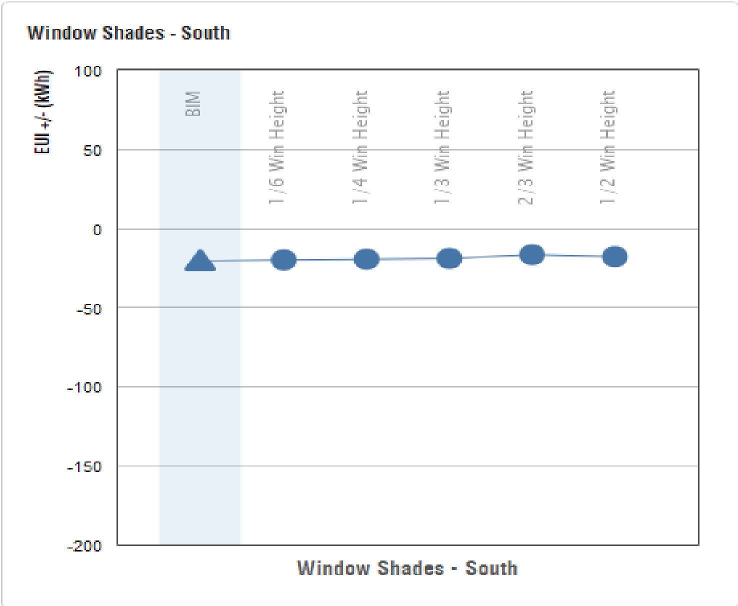


**Figure 9. 12** Window Shades - South

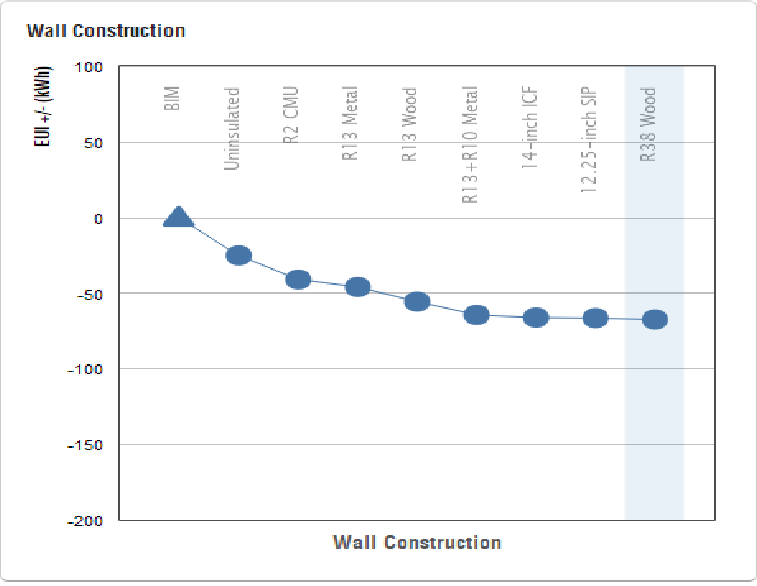


**Figure 9. 13** Wall Construction

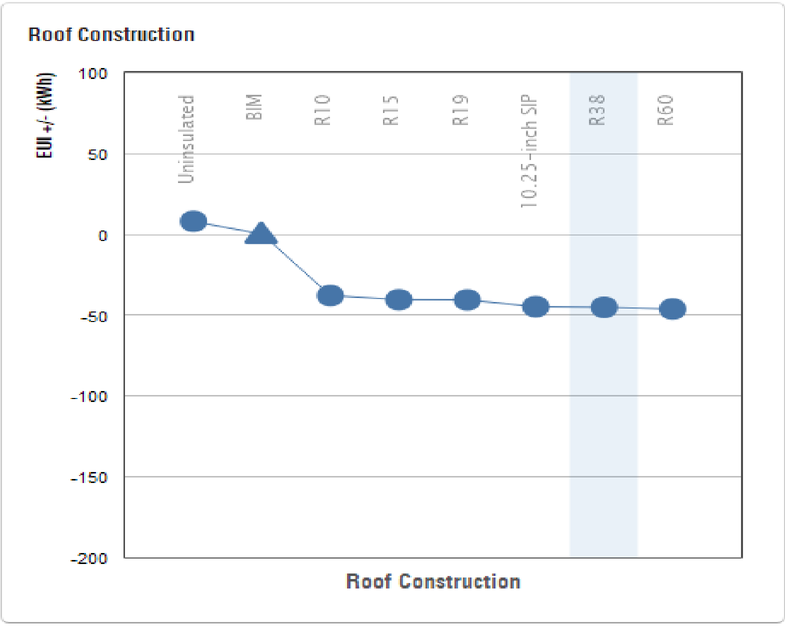


**Figure 9. 14** Roof Construction

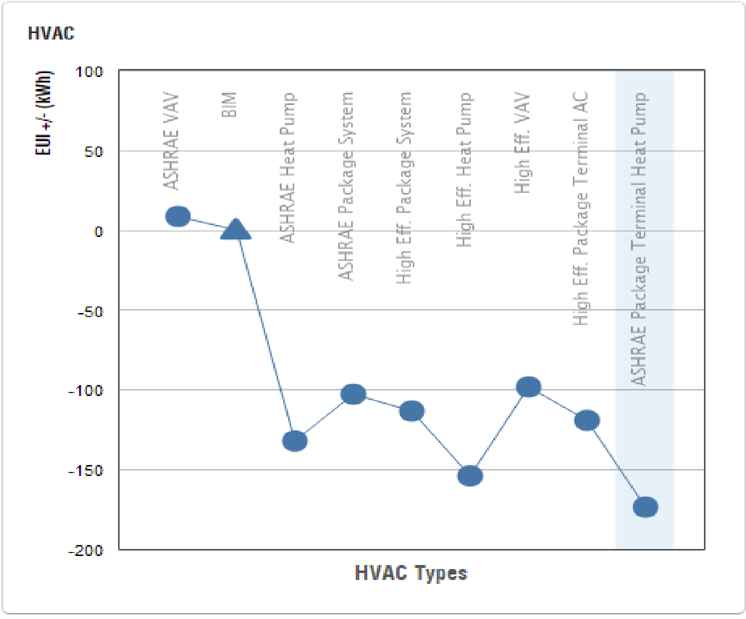


**Figure 9. 15** HAVC Types

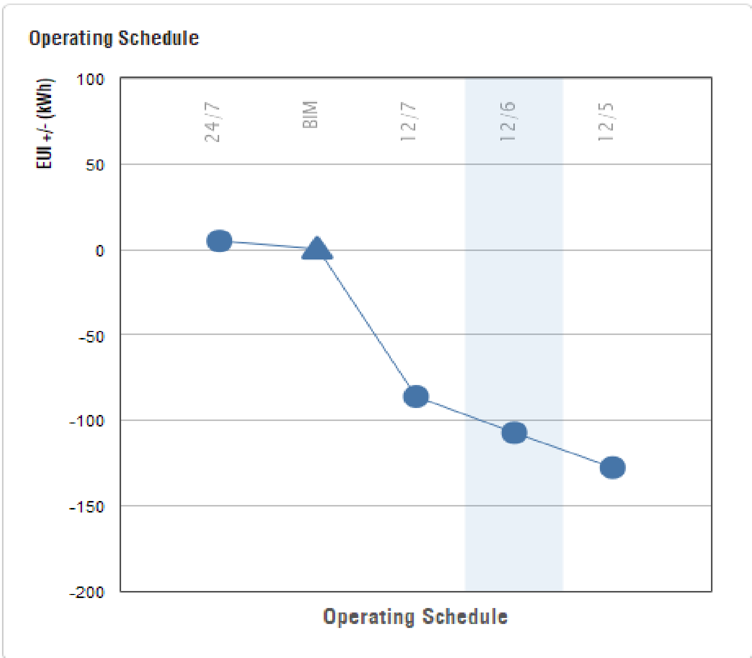


**Figure 9. 16** Operating Schedule

## b. Scenario comparison

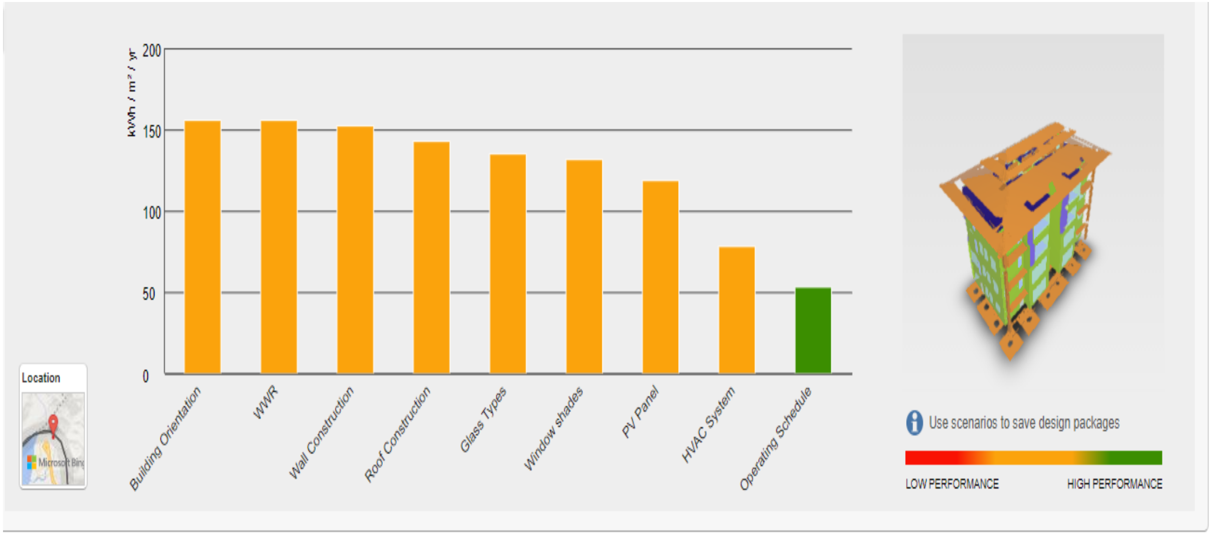


**Figure 9. 17** Scenario Comparison

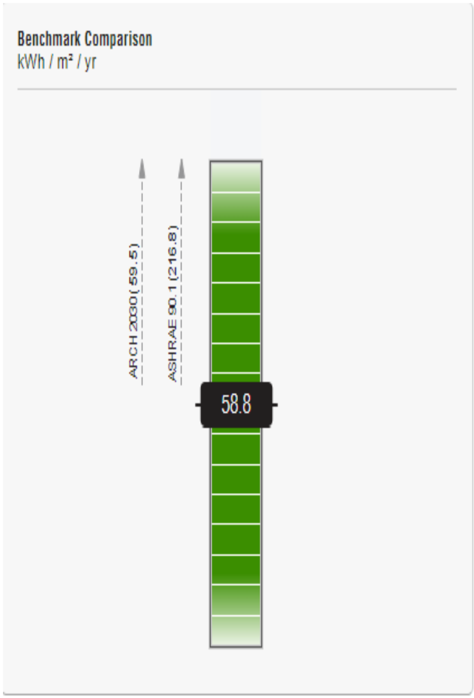


**Figure 9. 18** EUI after Changing Design Criteria

### c. Result of Energy Optimization

The energy intensity use was lowered from 158 kWh/$m^2$/year to 58.8 kWh/$m^2$/year after changing the various design parameters of our building. We could easily bring the energy use intensity and its cost to a desirable amount by altering the design criteria in Insight.

**Table 9.1** Energy Optimization results

| **Scenario** | **Initial status of building** | **After the optimization** | **Reduction in energy use intensity (KW/hr/m2) from current state** |
|---|---|---|---|
| Building orientation | 0 degree from project North of building. | 45 degrees | 2 |
| Window wall ratio | 41% | 41% | 3 |
| Wall construction | Common brick | R38 wall | 10 |
| Window Glass type | Single glazed type | Double glazing LoE | 2 |
| Roof construction | No insulation | R38 roof | 7 |
| Window Shades | No shade | No shade | 1 |
| HVAC types | | ASHRAE package terminal heat pump | 70.2 |
| Operating schedule | 24/7 | 12/6 | 29.9 |

### d. Observation

The findings from Autodesk Insights suggest that the building orientation should be 45 degrees north facing. The wall construction and roof construction to be R38. For the minimum solar heat gain, the window glass should be constructed with double glazing Low-E materials and 41% of window-to-wall in the south for natural ventilation. The most contribution in reduced energy consumption was from operating schedule and HVAC system types. By following the study's suggested passive design solutions, the analyzed building saves 62.7 percent in annual energy use. This entire procedure would aid in energy optimization throughout the building's life cycle, resulting in a high-performance structure.

# CHAPTER 10: CONCLUSION

- The construction industry plays a vital role in the socio-economic development of any country.
- BIM has been widely used in the construction sector for the past 20 years, with proven benefits including decreased inefficiencies, increased productivity, and improved collaboration among project stakeholders.
- The study found several benefits of BIM over traditional methods, including using a single 3D model for visualization, documentation, structure analysis, cost estimation, time scheduling, and energy analysis model with related information.
- BIM can save time and produce accurate quantity and material takeoff for producing the bill of quantities, as compared to using AutoCAD for different plan and view drawing.
- However, there are some barriers to implementing BIM in the country, including a lack of proper initiation and direction from the government, construction firms, and officials.
- Additionally, many people across the country are not familiar with the concept of BIM.
- The construction industry has been trying to improve the way we build and manage structures, but has not found a clear path to do so.
- BIM (Building Information Modelling) aims to digitalize the construction industry, and this study explores its implementation.
- BIM tools are integrated and can be used effectively to design, analyze, and manage building construction.
- Autodesk Revit, an object-oriented tool, allows for the generation of architectural, structural, and MEP models without drawing lines.
- Material details can be seen with a click, including thermal and physical properties, and building cost estimation is auto-generated in the model.
- Changes to the model are reflected in the cost schedule.
- Visualization and simulation of the construction phase, including time and cost, are possible.

- Clash detection is avoided during the design process by detecting and warning about overlapping systems.
- BIM energy analysis tool helps achieve sustainable building construction by optimizing energy at the conceptual phase of design.
- Collaboration between different stakeholders is made possible through the interactive management of construction.

## 10.1 Future Scope

- The study suggests that collaboration can be improved by using cloud-based software like BIM360 and Autodesk Construction Cloud.
- Proper standards are essential for the successful implementation of BIM in the construction industry.
- Imported standards may not be suitable for a country like Bhutan, so it is necessary to develop comprehensive standards that all construction parties can understand and follow.
- Framing comprehensible standards would ensure that all parties involved in the construction process are on the same page and can work together effectively.
- BIM implementation should be explored in more detail to gain an in-depth understanding of its benefits and limitations in the context of Bhutan.
- Further exploitation of BIM could help to identify areas where it can be leveraged to improve construction practices in the country.
- Overall, the study highlights the need for collaboration, proper standards, and further exploration of BIM in Bhutan's construction industry to drive its successful implementation and reap its benefits.

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# APPENDIX

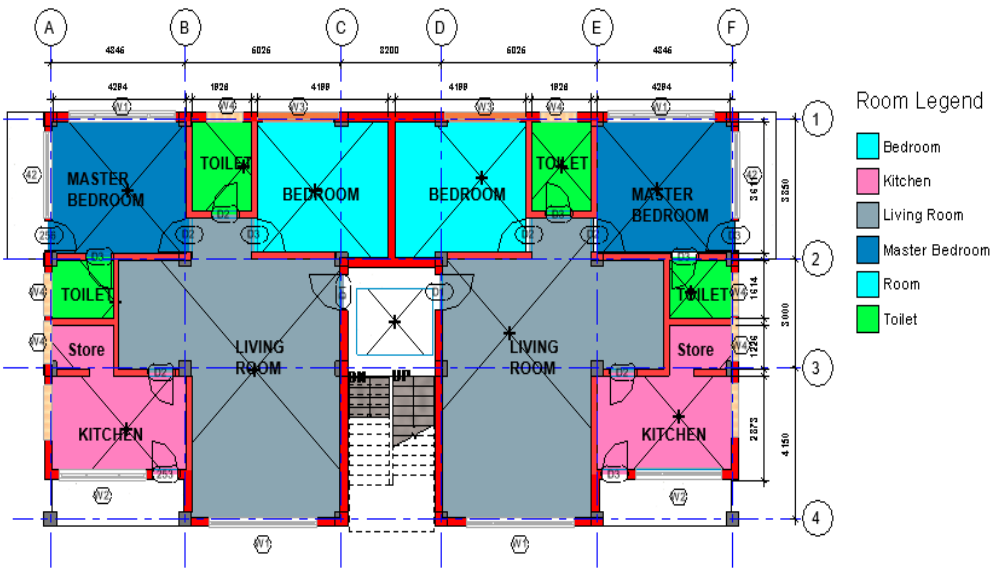


**Figure 11.1** Plan


**Figure 11.2** Front view


**Figure 11.3** Back view

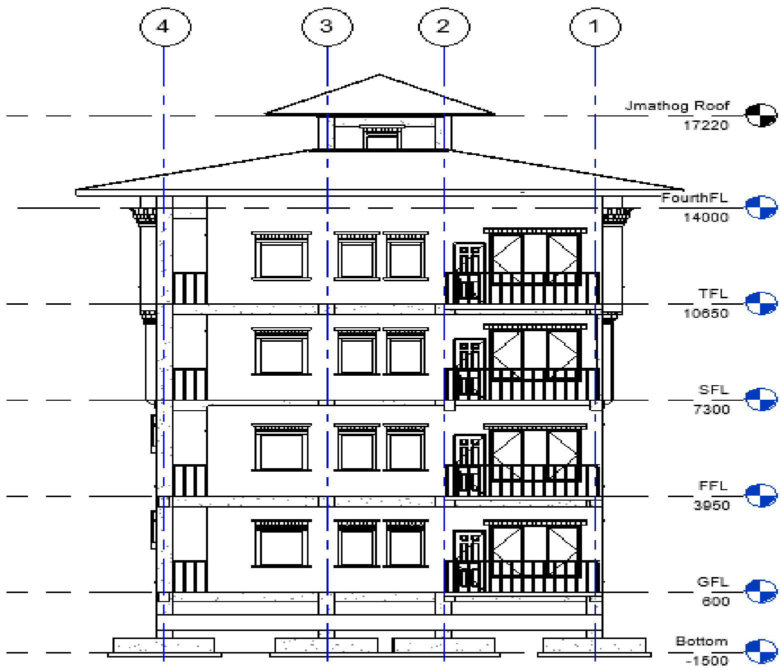


**Figure 11.4** Side Elevation

**Bhutan Schedule Rate (BSR)**

*Bhutan Schedule of Rates - 2020*

| Code | Description | Units | PL | GP | S/J | TH |
|---|---|---|---|---|---|---|
| **BASIC RATES - BRICK** | | | | | | |
| **Brick materials** | | | | | | |
| MT0125 | Bricks 2nd class | **1000#** | 9666.67 | 9000.00 | 9500.00 | 14750.00 |
| MT0126 | Brick aggregate | **cu.m** | 2051.60 | 1989.00 | 2080.80 | 2305.20 |
| MT0127 | Graded brick aggregate | **cu.m** | 2071.64 | 2029.80 | 1951.63 | 2417.40 |
| MT0128 | Interlocking cement earth block | **1000#** | 23500.00 | 23500.00 | 23500.00 | 23225.00 |
| MT0129 | Interlocking cement earth block | **1000#** | 14600.00 | 14500.00 | 14500.00 | 14390.00 |
| MT0130 | Concrete block bricks - Hollow Block | **1000#** | 40666.67 | 40666.67 | 40666.67 | 47000.00 |
| MT0131 | Concrete block bricks - Solid Brick | **1000#** | 10075.00 | 9550.00 | 10037.50 | 12150.00 |
| MT0132 | Concrete block bricks - Porous brick | **1000#** | 9912.50 | 9383.33 | 9662.50 | 11650.00 |
| MT0133 | Concrete block bricks - Partition Hollow Brick | **1000#** | 35000.00 | 33333.33 | 35000.00 | 36000.00 |

**Figure 11.15** Brick material rate according to BSR

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