POLITECNICO DI TORINO

MASTER DEGREE COURSE IN CIVIL ENGINEERING

MASTER'S DEGREE THESIS

BIM methodology, Case study of FCA Mirafiori

Supervisor

Prof. Anna Osello

Co. supervisor

Eng. Davide Aschieri

Candidate
Hussain Ikram
s277089

June 2022

Acknowledgment

First of all, I would like to sincerely appreciate Politecnico Di Torino to give me the opportunity to study here and my supervisor Prof. Anna Osello and Davide Aschieri, for trusting me with this challenging task. It would not have been possible to accomplish this thesis without their valuable suggestions, continuous guidance, and endless encouragement.

Especially I would like to thanks my parents for their unconditional support and love, to teaching me the principles and values that have contributed to my personal and professional life.

To my friends, everyone I shared with in and out of the university. Those who have become friends for life and those who will be my colleagues, thank you for all your support and encouragement.

Abstract

The objectives of this research were to define a BIM methodology for the construction and design of university campus for Politecnico Di Torino in an existing steel structure of FCA (Fiat Chrysler Automobile) warehouse which is part of Fiat Mirafiori industrial area in the south of Torino.

FCA was a warehouse of Fiat Mirafiori which is currently unfunctional so in this thesis we will propose an architectural design to convert the warehouse into university campus.

Moreover, the research carried out for this topic aims to study the applications of the BIM methodology in Construction Management discipline, for the construction of the building all design phases will be performed in a real case scenario, but the focus will be the architectural design.

The works were divided into the following steps and carried out in the planning stage of the building construction.

- 3D Modeling of existing building steel structure using Autodesk Revit 2020.
- New architectural design and space distribution using AutoCAD 2020.
- 3D Modeling of new design using Autodesk Revit 2020
- Rendering of architectural model.
- 4D Time analyses using MS Project.
- Simulation of time analyses in Autodesk Navisworks.

Table of Content

Acknowledgment 2

Abstract 3

Table of Content 4

List of Figures 7

1- Introduction 11

1.1 BIM: Building information Modeling 11

1.2 BIM and Infrastructure 13

1.3 CAD versus BIM 15

1.4 Interoperability in BIM 17

1.5 IFC: Industries Foundation Classes. 19

1.6 Dimensions of BIM 21

1.7 CDE: Common Data Environment 23

1.8 LOD: Level of Details 25

2- Methodology 27

2.1 Case Study: FCA Mirafiori 27

2.1.1 History of FCA Mirafiori 29

2.2 Workflow 31

2.3 Modelling software introduction. 33

2.4 Collection of Data about Project 34

2.5 BIM Model: 3D Modeling of an existing structure. 38

2.5.1 Column family creation.......... 38
2.5.2 Family for Roof Trusses.......... 42
2.5.3 BIM 3D Model.......... 44
2.6 Architecture planning in BIM.......... 46
2.6.1 BIM Context for Architectural practice.......... 46
2.7 Architectural Planning and Designing.......... 48
2.7.1 Required Spaces... 49
2.7.2 Conceptual Sketch.......... 50
2.8 2D Planning.......... 50
2.8.1 Grid Plan.......... 51
2.8.2 Zoning Plan.......... 51
2.8.3 Different stages of proposed Layout planning... 52
2.9 3D Modeling on Revit.......... 54
2.9.1 Components Uploading... 56
2.9.2 Merging Architectural Model in The Structure Model.......... 56
2.10 Architectural plan, sections, and views.......... 58
2.11 Views of Building after Rendering.......... 60
2.12 4D Time Analysis.......... 63
2.12.1 Scheduling of project using Microsoft project.......... 65
2.12.2 Defining Project parameters on Revit.......... 68
2.12.3 4D simulation on Autodesk Navisworks.......... 70

2.12.4 4D Simulation video.. 74

3- Conclusion and Results 76

4- References.. 77

List of Figures

Figure 1: BIM Concept [02] 11

Figure 2: Operations Involved in BIM process [04]... 12

Figure 3: Workflow of Building Information Modeling[05]................................ 13

Figure 4: BIM vs CAD [08]... 15

Figure 5: Component information on CAD and BIM [09].................................... 16

Figure 6: BIM Interoperability [11].. 18

Figure 7: Interoperability benefits associated with IFC [13] 20

Figure 8: BIM dimension [14]... 23

Figure 9: Concept of CDE [16] 23

Figure 10: CDE 1192 standard [18].. 24

Figure 11: Concept of LOD in BIM [20].. 25

Figure 12: Google Map Location [22]... 27

Figure 13: FCA product and assembly plant in Torino [23]................................ 28

Figure 14: Mirafiori in 1942 [24] 29

Figure 15: Mirafiori in 2011 [25] 30

Figure 16: Workflow Diagram [26].. 31

Figure 17: Autodesk Revit 2020 [27] 33

Figure 18: 2D plan of existing structure [28] 34

Figure 19: section ovest [29].. 35

Figure 20: section 1-1 [30] 35

Figure 21: Front view [31]... 35

Figure 22: Section A-A [32] 36

Figure 23: Image taken during site visit [33] 36

Figure 24: Internal view of building [34] 37

Figure 25: Image of building trusses [35] 37
Figure 26: Family Templates in Revit 2020 [36].. 38
Figure 27: 2D view of column Type-1 [37].. 39
Figure 28: 3D view of column type-1 [37] 39
Figure 29: 2D view of column Type-2 [38].. 39
Figure 30: 3D view of column Type-2 [38].. 39
Figure 31: 2D view of column Type-3 [39].. 40
Figure 32: 3D view of column type-3 [39] 40
Figure 33: 2D view of column Type-4 [40].. 40
Figure 34: 3D view of column Type-4 [40].. 40
Figure 35: 2D view of column Type-5 [41].. 41
Figure 36: 3D view of column Type-5 [41].. 41
Figure 37: 3D view of column Type-6 [42].. 41
Figure 38: Roof Truss template [43]... 42
Figure 39: 3D view of Roof Truss [44]... 42
Figure 40: 2D plan of roof truss [45] 43
Figure 41: 3D view of roof truss [46]... 43
Figure 42: 3D view of building structure with columns [47] 44
Figure 43: 3D view of building structure with floor [48]..................................... 44
Figure 44: BIM model of existing structure [49] 45
Figure 45: Architectural project phases [50] 47
Figure 46: Architecture In graphics [52] 48
Figure 47: Summary of the Required spaces for university campus [53]............. 49
Figure 48: Conceptual sketches image [54]... 50
Figure 49: Grid plan, in Autodesk AutoCAD 2020 [55].. 51

Figure 50: Zoning plan, in Autodesk AutoCAD 2020 [55] 51
Figure 51: Layout stage-1, in Autodesk AutoCAD 2020 [55] 52
Figure 52: Layout stage-2, in Autodesk AutoCAD 2020 [55] 52
Figure 53: Layout stage-3, in Autodesk AutoCAD 2020 [55] 53
Figure 54: Layout stage-4, in Autodesk AutoCAD 2020 [55] 53
Figure 55: Partition design , Autodesk Revit 2020 [56] 54
Figure 56: property types , Autodesk Revit 2020 [56] 54
Figure 57: Assembly edits, Autodesk Revit 2020 [56] 55
Figure 58: Material properties , Autodesk Revit 2020 [56] 55
Figure 59: Uploading Component, Autodesk Revit 2020 [56] 56
Figure 60: Linking architecture and structural model [56] 57
Figure 61: Ground Floor planning [57] 58
Figure 62: First Floor planning [57] 58
Figure 63: Section-AA building [57] 59
Figure 64: Section-BB of building [57] 59
Figure 65: Left Elevation [57] 59
Figure 66: Front Elevation of Building [57] 60
Figure 67: Internal view of study hall [58] 60
Figure 68l: Internal view of library [58] 60
Figure 69: Internal view of Auditorium [58] 61
Figure 70: Internal view of lecture room [58] 61
Figure 71: External 3D view of building [58] 62
Figure 72: QR code for Building views [59] 62
Figure 73: Setting of working hours & days in MS Project [63] 66
Figure 74: work breakdown structure (WBS) [63] 67

Figure 75: Creating Shared parameters [64] 68
Figure 76: Project parameters setting [64]... 69
Figure 77: Export .rwt file from Revit to .nwc Navisworks [64] 71
Figure 78: Export BIM model as .nwc file format [64] 71
Figure 79: Find Elements tool in Navisworks [66].. 72
Figure 80: Auto-Attach Rules in Navisworks [66] 73
Figure 81: 4D simulation during construction of ground floor [66] 74
Figure 82: 4D simulation during construction of first floor [66] 74
Figure 83: 4D simulation during construction of windows and door [66]............. 75
Figure 84: Video simulation on Navisworks [67] 75

1- Introduction

1.1 BIM: Building information Modeling

(BIM) Building information modeling is a 3D digital representation of physical characteristics of resources and creating facilities for information knowledge and decision making from the beginning stage to the demolishing period of any civil engineering project. Furthermore, the integration and transmission of project data and information is shared throughout the entire life cycle of project planning, operation, and maintenance, so that engineers and technical personnel can understand properly and respond to various building information. This provides a foundation for collaborative effort for the design team and all construction entities, including construction and operating units, to improve production efficiency, save money, and shorten project timelines.[01]

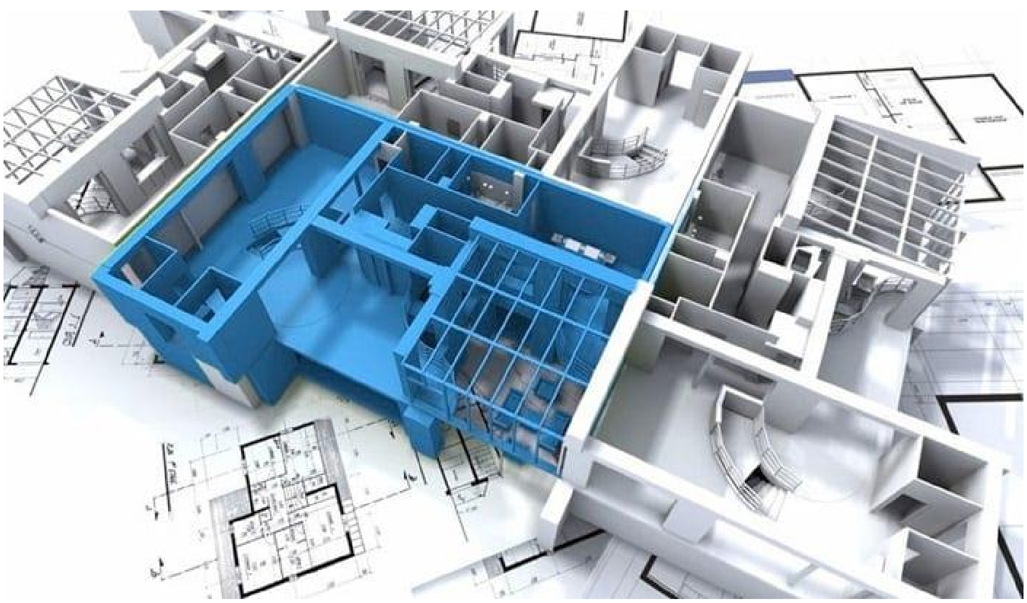


Figure 1: BIM Concept [02]

Building information modeling is concept that establishes a virtual three-dimensional model of building engineering and uses digital technology to give consistent and full information for each construction project.[03]. Professional qualities, geometric information, status information defining building components, and status information of non-component objects make up the information database (such as space and motion behavior). The degree of integration of construction engineering information is greatly improved by this three-dimensional model containing construction engineering information, and the method of producing information for simulation can make the process accessible and easy to understand the project information flow, reducing waste and risk, and saving effort and time. This is the process of removing all potential issues in a virtual environment before moving to a physical construction site, where all clash detection strategies and construction problems can be resolved, thereby providing a platform for engineering information exchange and sharing with project stakeholders.

Figure 2: Operations Involved in BIM process [04]

Visualization is one of the most common aspects of design model, using of camera's view with different angles around and inside the model which can be useful for explaining the aim and future goals of the project. It should be added that BIM is more than a 3D modeling it's about creating and maintaining of information at each element in the field of efficiently, environmental and lifecycle in a digital form. In the discussion of federation approach of BIM for the possibility of model making by different software in the use of packaging which will managing clash detection and visualization, like IFCs to use import a model into another format but it should know the report of how is successful can be this interoperability.

Figure 3: Workflow of Building Information Modeling[05]

1.2 BIM and Infrastructure

Apart from dimensions of BIM something that can be more precisely is the infrastructural side of BIM which is common syntax between horizontal and vertical assets in developing and classification for understanding the use of BIM growth. The term "building" is included in BIM, and early discussions of the technology were centered on the use and design of "buildings." It's important to understand that the full benefits of BIM may be viewed in a much broader context, and that the term "building" is employed as a verb rather than a noun. If we define 'infrastructure' as the physical framework required for any society's operation, or the services required for an economy to run, it is evident that "buildings" are a subset of infrastructure as a whole, and infrastructure provides context for the built environment.

The common misconception that infrastructure refers to the horizontal rather than the vertical part of the built environment is inaccurate and harmful in the adoption and usage of BIM. Furthermore, if infrastructure is solely linked to civil engineering parts of development, BIM's applications in the built environment are limited. As a result, infrastructure encompasses the entire built environment, rather than just roads and trains.[06].

With the conscious of interconnected the building with environmental context and condition, rather than it is not necessary to start a new project with new features, it can be started with existing features and improving its performance. This approach is supported for decision-making and data management which is not significantly better for those that must fit into existing infrastructure. To define or modify the existing landscape needed survey and topological surface environment, geographical or prediction model. Accurate information modelling is required for measure quantity and performing of assets and volumes. Almost all the components will be affected by a wider network located outside of the building which is connected to the site and underground assets with a clash potential for the risks of existing facilities. Although infrastructure consists of discrete components, they are frequently networked and continuous, necessitating segmentation. The network aspect is vital since it provides context to all components, and actions on one part might have an effect on others who are far away but connected.

1.3 CAD versus BIM

A CAD system's main purpose was to automate the drafting process. As a result, the original purpose of CAD software was to use graphical components like lines, arcs, and symbols to depict 2D geometry. For example, walls are simply represented as parallel lines in this context. The concept of layering was developed to bring together similar details, such as the lines used to represent walls on a specific 'wall layer,' in order to deduce some meaning from these graphical elements. This method could build and plot discrete 2D drawing files from CAD, but it couldn't capture more advanced information like element connections. 3D CAD's early concentration was almost entirely on generating geometry to facilitate visualization, with subsequent advances concentrating on realistic rendering and lighting effects.[07]

Figure 4: BIM vs CAD [08]

Building objects, which may represent the behavior of typical building parts, have lately supplanted 2D symbols in object-oriented CAD systems (OOCAD). Non-graphic properties can be added to these building pieces, and they can be displayed in different perspectives. This contains a parametric 3D geometry with a variable dimension that gives these objects "intelligence," allowing complicated geometric and relational relationships between architectural pieces to be represented. In this way, walls can be stretched, joined, have height, have a specific cross-section type, and "possess" related attributes. More importantly, abstract concepts like space can be defined by the relationships between physical building parts, identified (such as room number, room name, etc.), characterized (such as area, volume, usage, occupancy, etc.), and referenced (Listed in a room schedule, counted to calculate total floor area, etc.). Capturing these relationships and actions, as well as the intelligence's richness, was just not possible in the previous CAD paradigm.

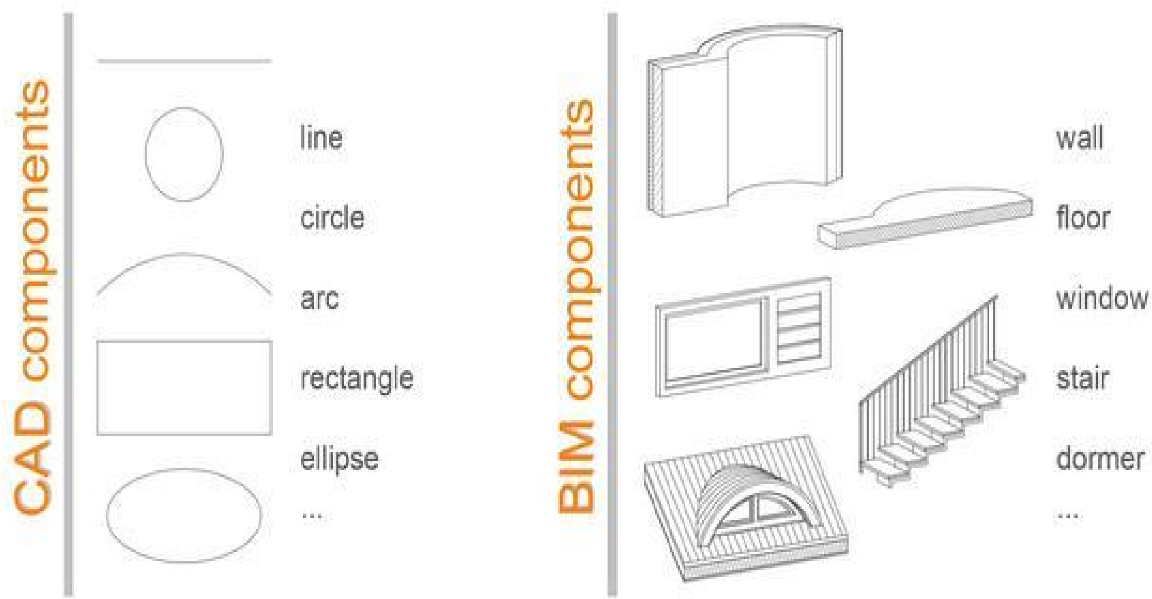


Figure 5: Component information on CAD and BIM [09]

Building information modeling (BIM) is the most recent generation of (OOCAD) systems, in which all of the intelligent building objects that make up a building design can be stored in a single 'project database' or 'virtual building' that contains all of the structure's information. For all building-related data, a building information model (BIM) provides a single, logical, and consistent source.[10]

1.4 Interoperability in BIM

Any building project's design is a complicated process involving many different professionals from various disciplines. The goal is to create a centralized model that each user may use and modify using different applications. As a result, optimizing the interchange of information between the various software is critical in order to reduce data loss. The concept of interoperability is an important component of the BIM approach.

According to AFUL group the interoperability between different software is "Interoperability is a characteristic of a product or system, whose interfaces are completely understood. With respect to software, the term interoperability is used to describe the capability of different programs to exchange data via a common set of exchange formats, to read and write the same file formats, and to use the same protocols".

Despite the fact that interoperability is one of the most important challenges in building information modeling (BIM), and software providers have made tremendous progress in the process, data loss occurs when a model is moved from one software to another. This issue can be found in software produced by the same company and fixing it will be a huge step toward making BIM more efficient.

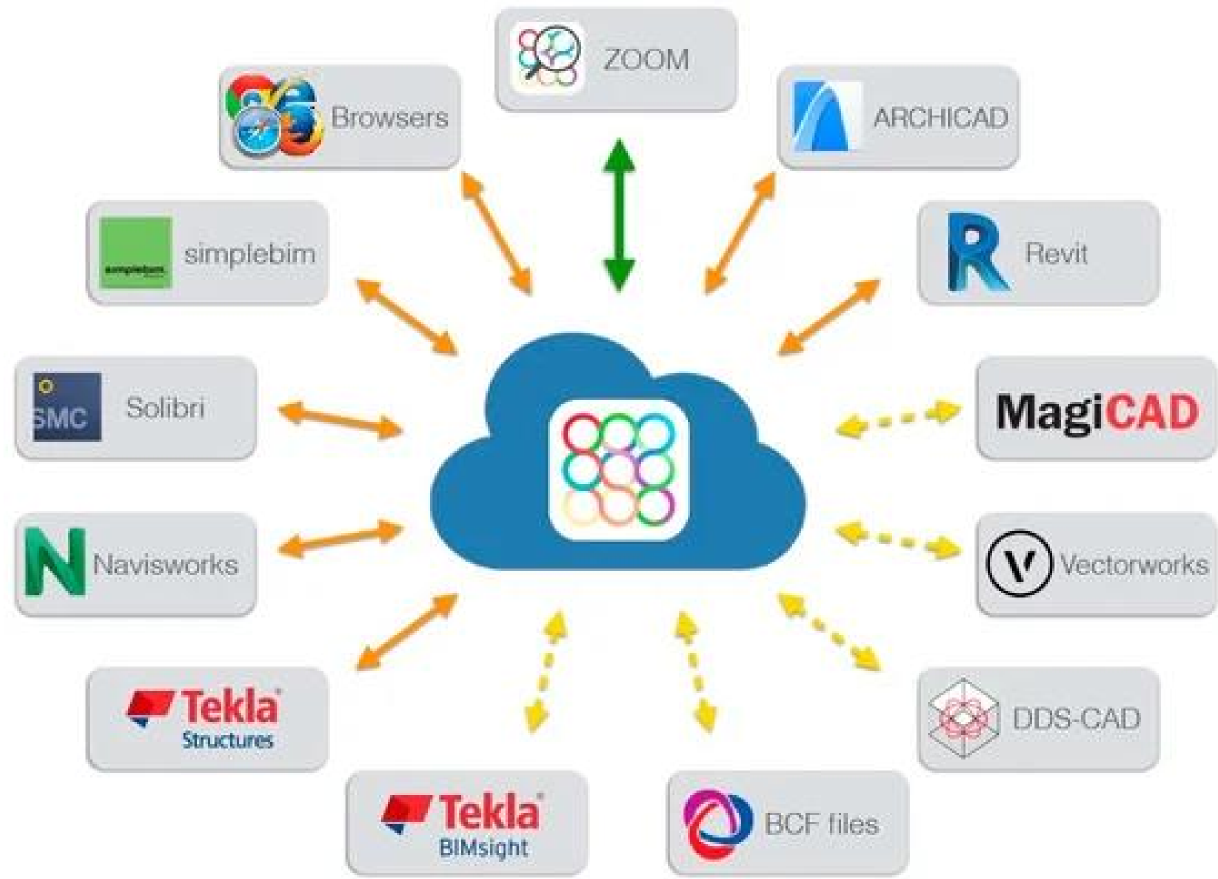


Figure 6: BIM Interoperability [11]

Building Smart, an organization dedicated to improving the design and construction of infrastructure and buildings, was founded to create certain basic guidelines for BIM. Many companies, including software houses, colleges, and construction design firms, are members of the group.

The establishment of a standard format for transmitting data: the Industry Foundation Classes is one of the major outcomes of this organization's efforts (IFC).

According to the Building Smart, an IFC “a standardized, digital description of the built environment, including buildings and civil infrastructure. It is an open, international standard (ISO 16739-1:2018), meant to be vendor-neutral, or agnostic, and usable across a wide range of hardware devices, software platforms, and interfaces for many different use cases.”

1.5 IFC: Industries Foundation Classes.

Companies in the Architecture, Engineering, and Construction (AEC) industry employ a variety of tools to design, commission, and run assets, and often have difficulty sharing data with one another. This is due to the fact that each software manufacturer has its own file format that is incompatible with other AEC design software.

The IFC model was created to help with the problem of data sharing between AEC stakeholders and asset management. The IFC has the advantage of allowing data to be shared in a format that is acceptable to all software, which promotes interoperability. Engineers, architects, construction companies, and asset managers may all exchange AEC data thanks to IFC. Figure 2 illustrates an example of certain data exchange features that are possible with IFC thanks to the IFC schema.[12]

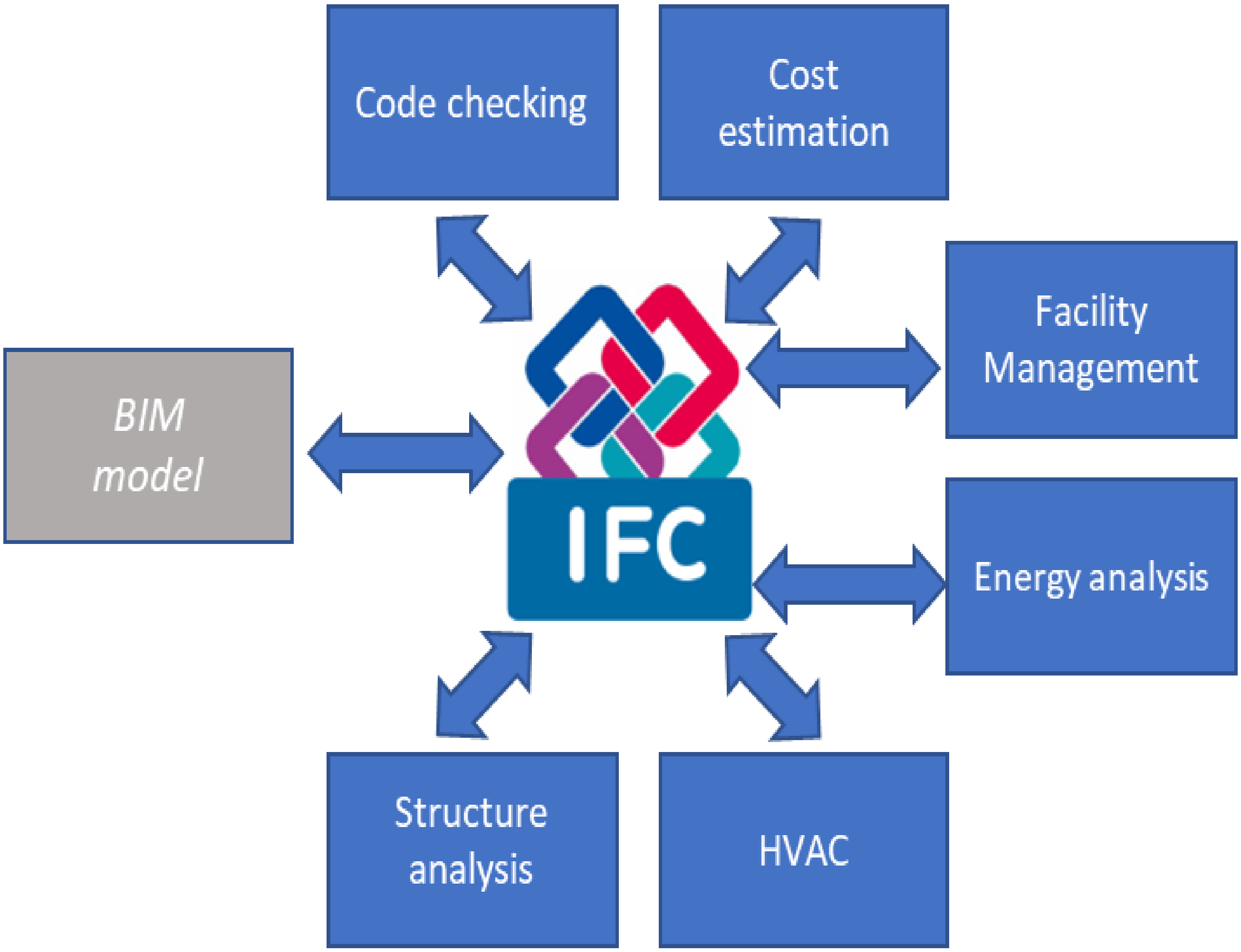


Figure 7: Interoperability benefits associated with IFC [13]

As a result, IFC is crucial as a standard file format through which information may be shared and exchanged at various stages during the design, construction, commissioning, and operation phases, allowing stakeholders to access data as needed. There is a unique International Standard (ISO 16739:2013) for the IFC schema, which recognizes the need of adhering to a consistent data interchange standard among AEC stakeholders and asset managers.

1.6 Dimensions of BIM

The BIM approach is in charge of handling all phases of a project's life cycle, from design to construction and maintenance, and allowing stakeholders to oversee and organize the entire process. Due of the numerous talents involved in this process, it is common to divide it into different dimensions, which are shown below.

- **1D:** This is the initial dimension, and it refers to the notion that the project is based on. This step is usually associated with the investigation of the location, geometry, and preliminary cost estimates.

- **2D:** The general characteristics of a construction project, such as material properties, structural scheme, loads applied, and 2D drawings, are defined in the second dimension. In comparison to the 1D, the information obtained is more.

- **3D Simulation of the work:** A 3D digital model is generated using the information available in 1D and 2D. A wide range of professionals are involved in the creation of the model, which is always evolving as a result of dynamic process. Important goal of this step is to get the model as-built.

- **4D Time Management:** This dimension contains the time schedule evaluation for the design and construction phase of a project. In 4D we also perform time-space conflict analysis. It is feasible to see the various construction phases in relation to time using BIM software such as Revit and Naviswork.

- **5D Cost Management:** This dimension has to do with estimating and analyzing costs. The ultimate goal is to keep spending within the set budget. The number of materials and fee comparisons are done in this step.

- **6D Facility Management:** This dimension has to do with estimating and analyzing costs. The ultimate goal is to keep spending within the set budget. The number of materials and fee comparisons are done in this step.

- **7D Sustainability:** For construction projects with a service life of 100 years, this dimension is critical. The cost of project construction and maintenance is determined by the structural scheme selected during the planning stage of the project, thus decisions proposed during design and planning stages are important.

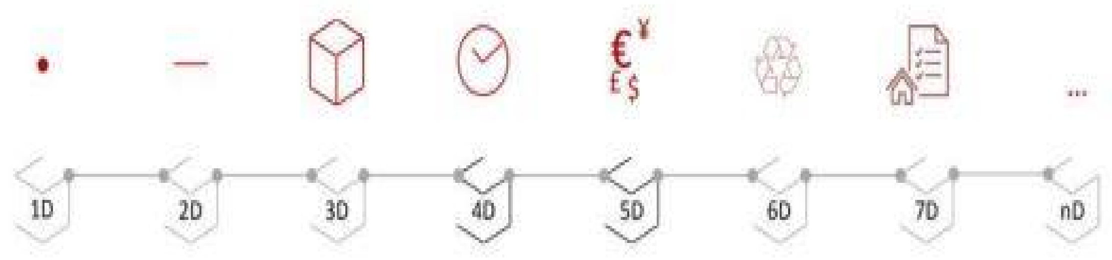


Figure 8: BIM dimension [14]

1.7 CDE: Common Data Environment

In an information management system, project models, plans, data, records, and contract documents in general must be collected according to a structured arrangement. The concept of Common Data Environment (CDE), introduced in the UK design regulation BSI (2007) 1192-1:2007 [15], is recalled digitally in PAS 1192-2:2013.

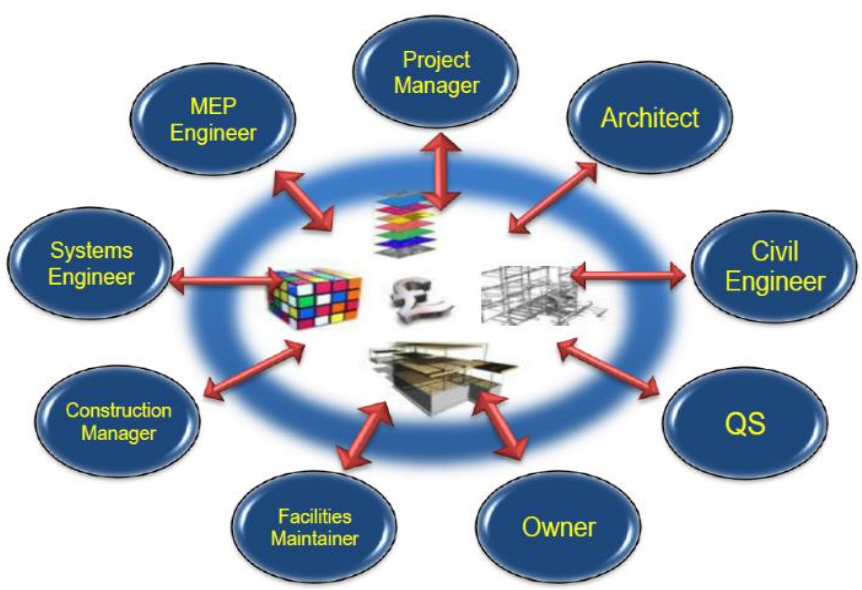


Figure 9: Concept of CDE [16]

CDE is defined as a location where all parties participating in a job order can store, share, manage, and process data in order to complete their tasks.[17] The structure envisioned in the UK standard system is built on four scopes of action: work in progress, share, publish, and archive, in which information passes via several approval gates.

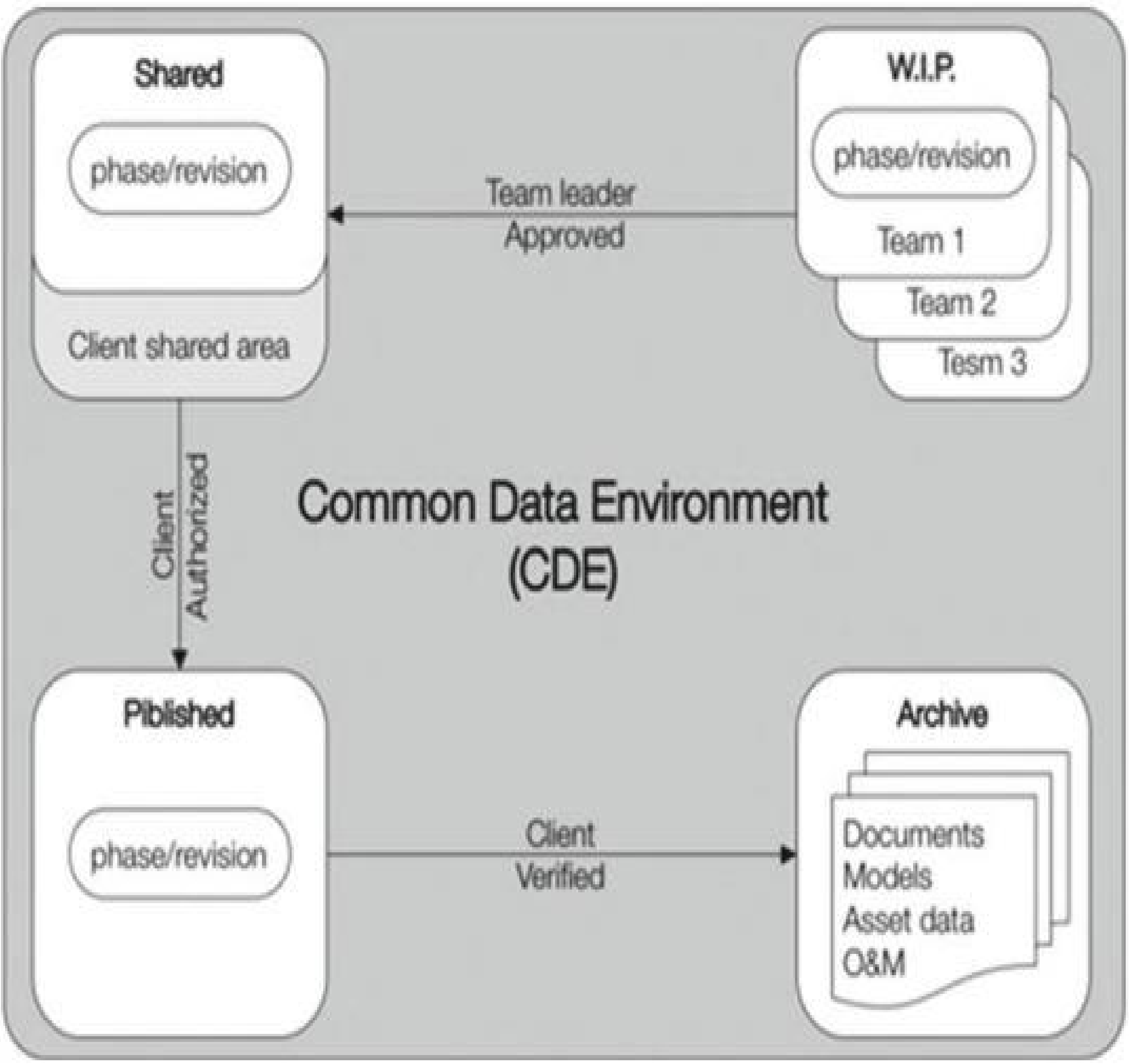


Figure 10: CDE 1192 standard [18]

1.8 LOD: Level of Details

LOD level of details is the degree to which the object's geometry and attached information are defined, the degree at which team members of project may rely on the information while using the model. Level of details is an essentially part of the project that how much details are included in the model [19].

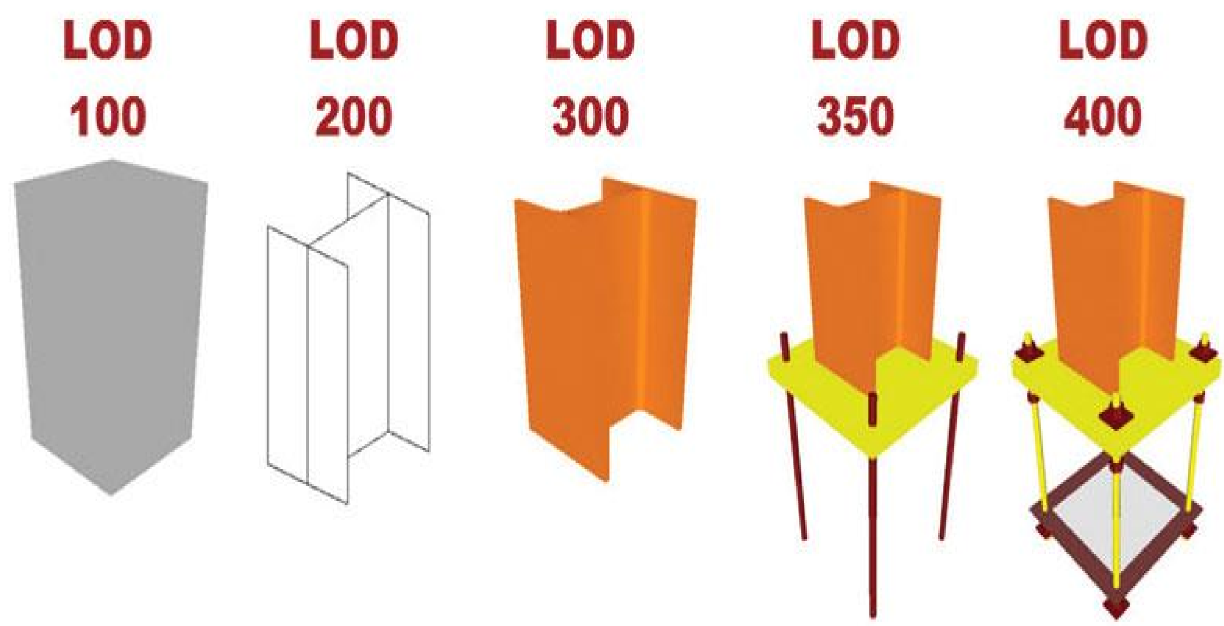


Figure 11: Concept of LOD in BIM [20]

The LOD framework defines the following content requirements for model elements

LOD 100: The Elementary model can be graphically represented in the model using a symbol or other generic representation, but it does not meet the LOD 200 requirements. Other parts of this model can be used to obtain information about the model element (for example, cost per square meter, weight, and so on).

LOD 200: Within the model, the model element is represented graphically as a generic system, object, or assembly with estimated quantities, size, shape, position, and orientation. The element can also be linked to non-graphic data.

LOD 300: In terms of number, size, shape, position, and orientation, the model element is graphically represented as a specific system, item, or assembly within the model. The model element can also be linked to non-graphical data.

LOD 400: The model element is graphically represented within the model as a specific system, assembled or item with specifics for production, assembly, installation, and information in terms of size, shape, location, quantity, and orientation. Non-graphical data can also be linked to the model's elements.

LOD 500: The model element is a size, shape, position, quantity, and orientation representation that has been confirmed on-site. Non-graphical data can be related to model elements as well. [21].

2- Methodology

2.1 Case Study: FCA Mirafiori

Few places are more representative of the modern Italian identity that is Fiat Chrysler Automobiles (FCA) Mirafiori which can be considered as the highest model of industrialization founded on the great factory that pursued more than a century. FCA (Fiat Chrysler Automobile) warehouse which is part of Fiat Mirafiori industrial area in the south of Torino.

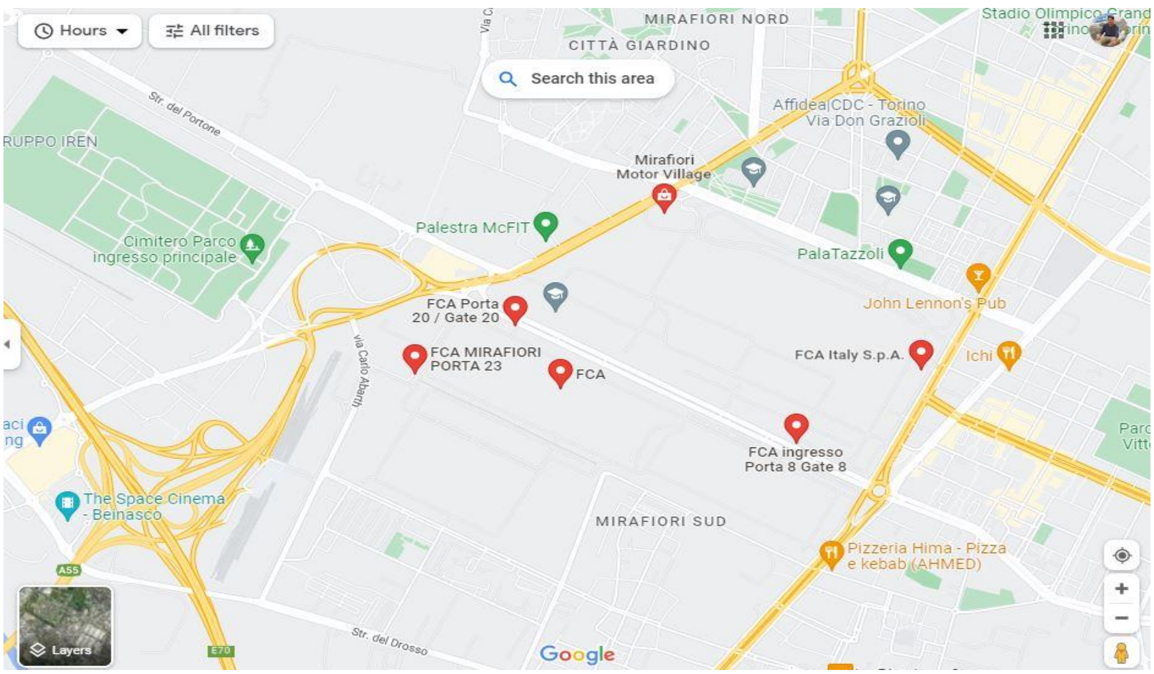


Figure 12: Google Map Location [22]

FCA Mirafiori is an international automotive company engaged in the development, design, engineering, marketing and manufacture of vehicles, body components, control units and spare parts worldwide. The company has many car brands such as Abarth, Dodge, Fiat, Fiat Professional, Jeep, Lancia, Alfa Romeo, Chrysler, Ram, SRT and Maserati, as well as Mopar, the spare parts and services brand.

In addition, the Group has more than 40 research and development centers (more than 20 in Europe) and more than 100 factories and sells through dealers and distributors in more than 130 countries. The tax headquarters located in Netherlands, it was born from the reorganization of the Italian group Fiat SPA and the US group Chrysler Corporation.

In Italy, there are almost 14 production plants and 6 from them are in the city of Torino (Fig. 10). Moreover, the case study focused on the Fiat Mirafiori industrial complex, the biggest plant in Torino city. In fact, the Fiat Mirafiori plant is representation of Torino as an industrial city, an impressive and social history of the Piedmonte capital. The complex consists of an area of 2,000,000 sq.mt, making it the one of the largest industrial complexes in Italy. The factory’s production capacity is 1,115 vehicles per day.

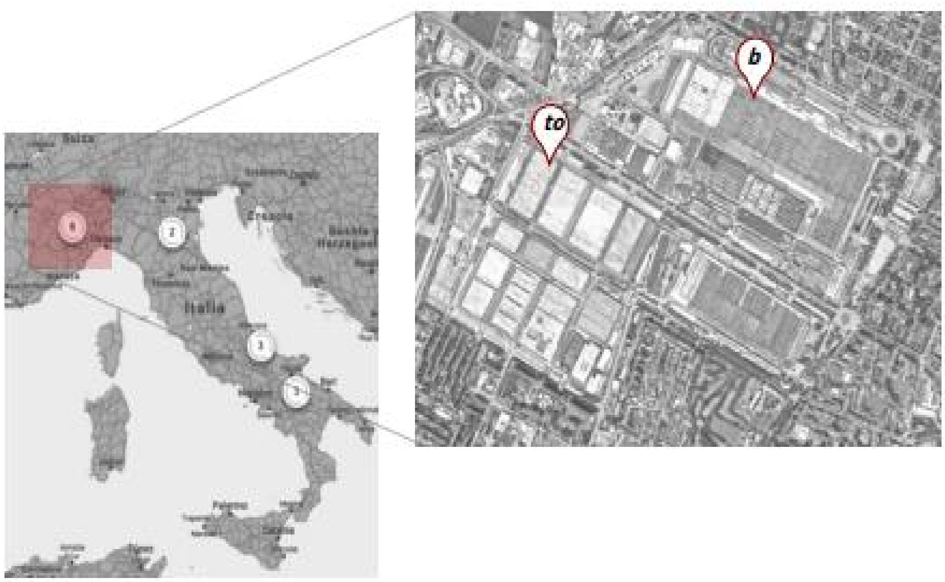


Figure 13: FCA product and assembly plant in Torino [23]

2.1.1 History of FCA Mirafiori

Inaugurated on 15th May 1939 by *Mussolini Benito*. Fiat 700 was the first model produced and the project was left due to stat of world war-II. Car production again started 1947 with the release of its second series the Fiate-500-B with the relocation of Fiat-1100 which was built in Lingotto factory.

Figure 14: Mirafiori in 1942 [24]

In 1956 "Mirafiori-Sud" was established, for metal sheet stamping and mechanical machining (gearboxes & engines) were located and expanded, while the previous place Mirafiori-Nord remained for paving, painting, assembly, finishing and for the test track.

In 1970 it was upgrades for the production line of its most famous model that was Fiat 131 during which the plant reached to its peak production the technology used was named as 131 Mirafiori in which a numerical alpha denomination was reintroduced. The total sold units of 131 was 1,513,800 during the period from 1974 to 1983.

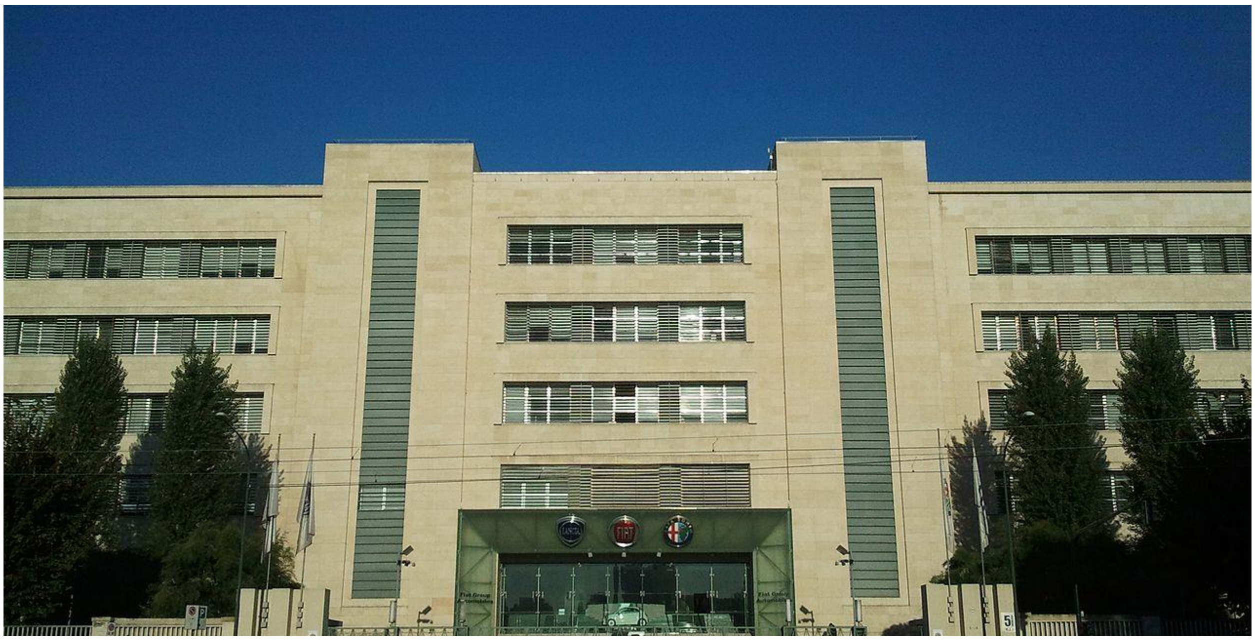


Figure 15: Mirafiori in 2011 [25]

In 2008 new headquarter Abarth was established, and a new model Fiat 500 was also released at the day of inauguration and in 2012 July production of Fiat Idea & Lancia Musa was also started after that in 2016 production of luxury sport Maserati was started in November 2018 FCA Mirafiori announced the production of Electric Fiat 500 which was planned to release in 2020 and in July 2019 FCA decide to start investing 788m euro to produce Electric Fiat 500e.

2.2 Workflow

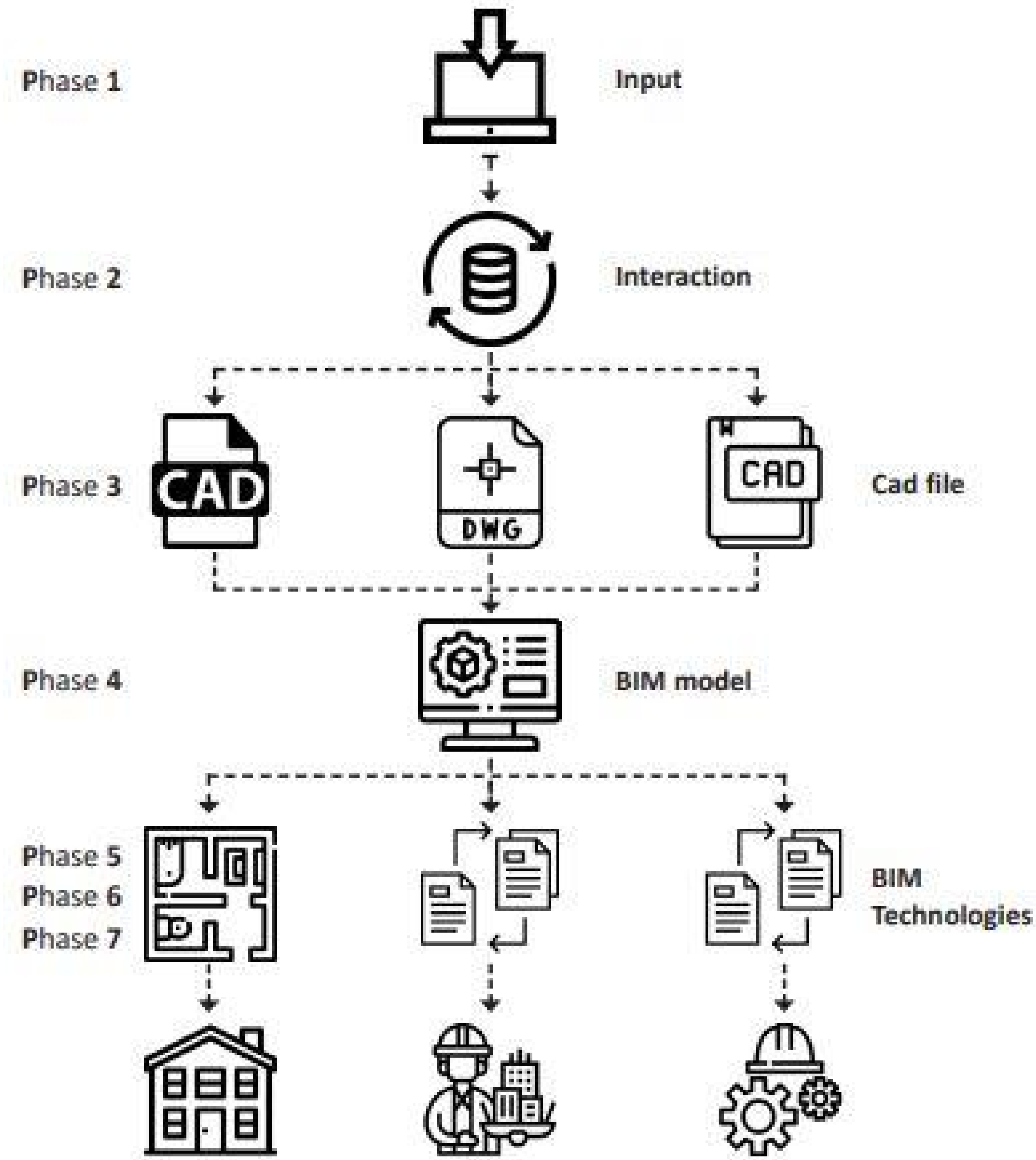


Figure 16: Workflow Diagram [26]

According to the workflow diagram fig. 16 which shows the methodology followed and all the work done during different phases to complete the project. The project work is divided in three parts that are 3D modeling of existing structure (Autodesk Revit 2020), propose an Archi ureal design to utilize the structure as a Polito campus and the construction management part.

Phase-1	Site visit and the collection of all available data in the form of 2D drawings, point cloud and pictures.
Phase-2	After collecting all the available and useful information are classified in the traditional way of 2D drawings.
Phase-3	Integration of all the available information in the form of 2D drawings and pictures into a BIM model for data management.
Phase-4	3D modeling of an existing steel structure using Autodesk Revit 2020 based on the available data in the form of drawings and pictures this was the basic work of architectural part.
Phase-5	Based on the 3D model of existing structure an architectural design is proposed to utilize the space for the use of university campus.
Phase-6	For the management part based on the BIM model 4D time analysis is performed to complete the project on time.

2.3 Modelling software introduction.

Autodesk Revit is a platform that supports the design, construction, and scheduling of any construction project. Building Information Modeling (BIM) provide information needed about project design, quantity, and stage.

Figure 17: Autodesk Revit 2020 [27]

- With parametric accuracy, precision, and convenience, model shapes, structures, and systems in 3D.
- As projects evolve, streamline documentation work with quick modifications to plans, elevations, schedules, and sections.
- Provide specialized toolsets and a uniform project environment to interdisciplinary teams.

2.4 Collection of Data about Project

The first step to of the project was to collect all the available data in the form of 2D drawings, point cloud, and pictures, we were able to get some previous 2D AutoCAD drawing with plan, views, and section but some information was messing in those drawings, so we decided to take help from pictures and videos which was taken during site visit. Some plans of AutoCAD 2D drawings are shown below.

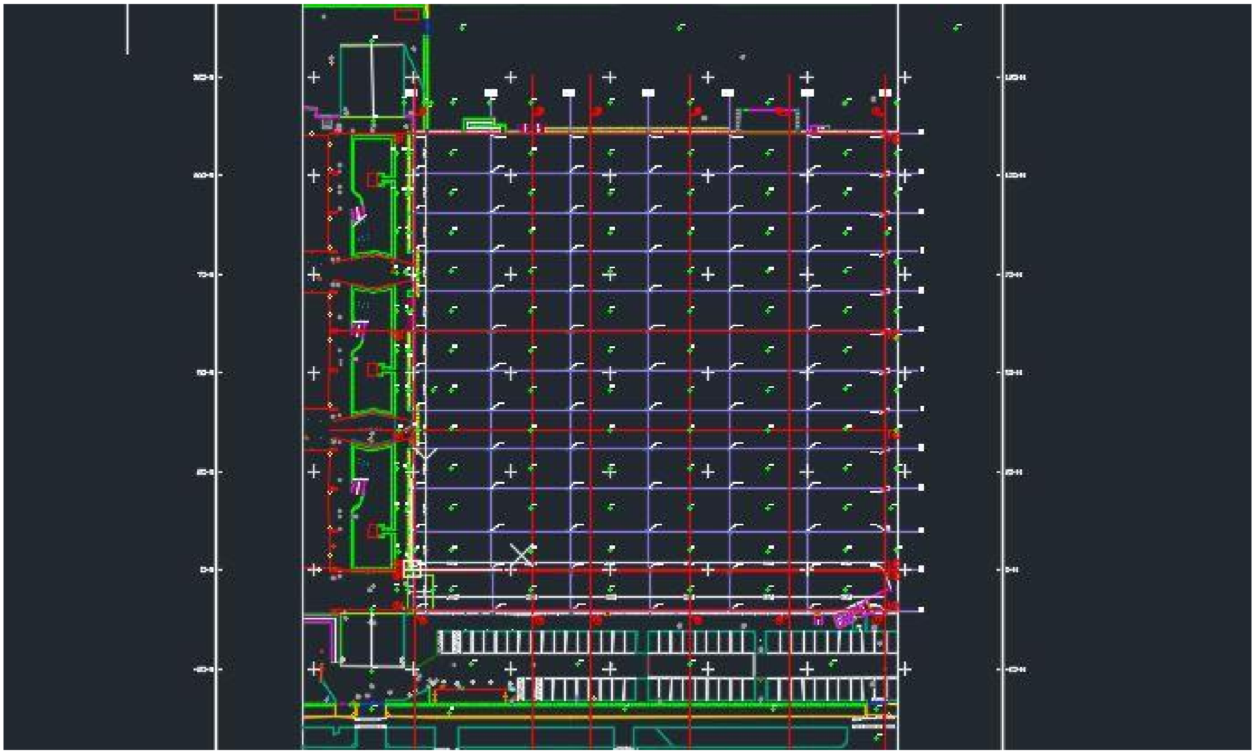


Figure 18: 2D plan of existing structure [28]

The elevation and some section of the building which are taken from the existing AutoCAD 2D drawing are shown below.

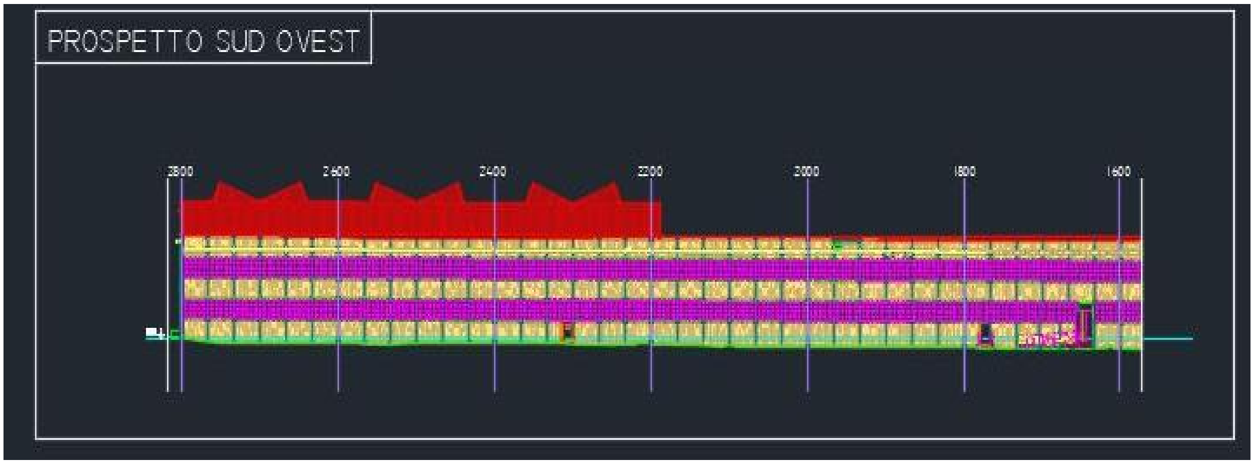


Figure 19: section ovest [29]

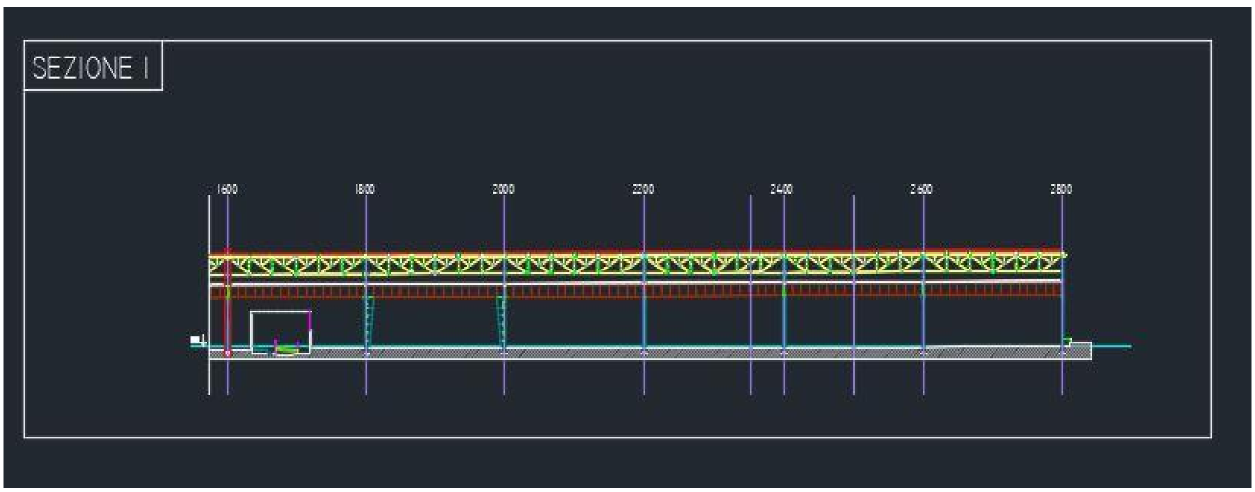


Figure 20: section 1-1 [30]

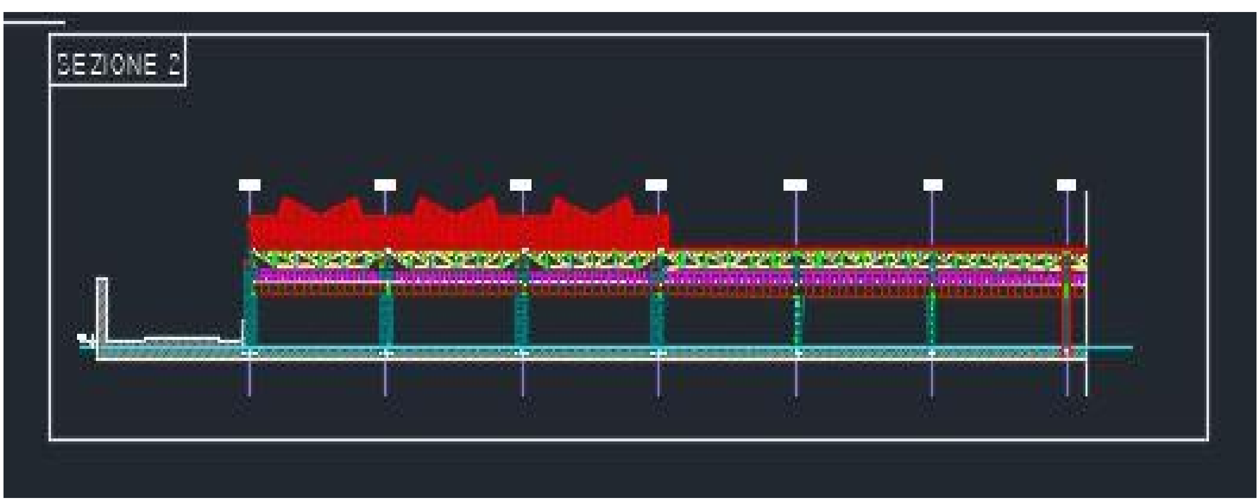


Figure 21: Front view [31]

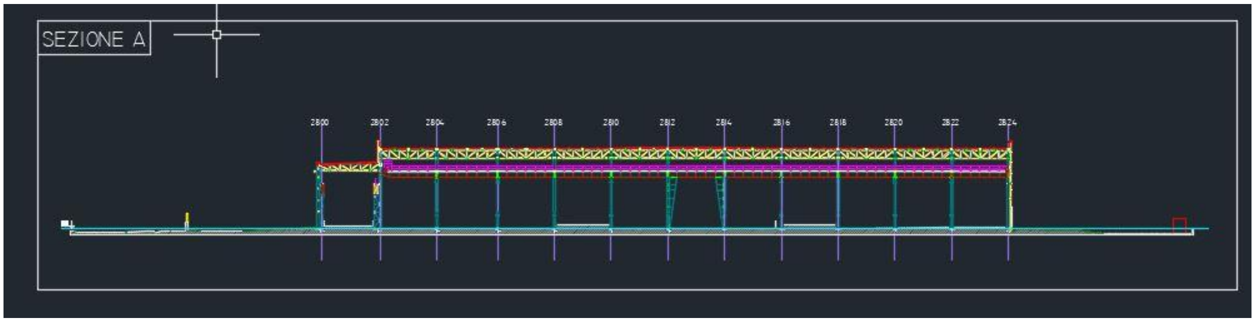


Figure 22: Section A-A [32]

As the information which was available on AutoCAD 2D drawing was not complete a lot of information like the section of columns and beams the dealings of trusses and connections between them, to know all these details we decided to take help from pictures and videos of the existing building which was taken during site visit which was useful to get enough information for 3D modeling.

The main entrance of the building.

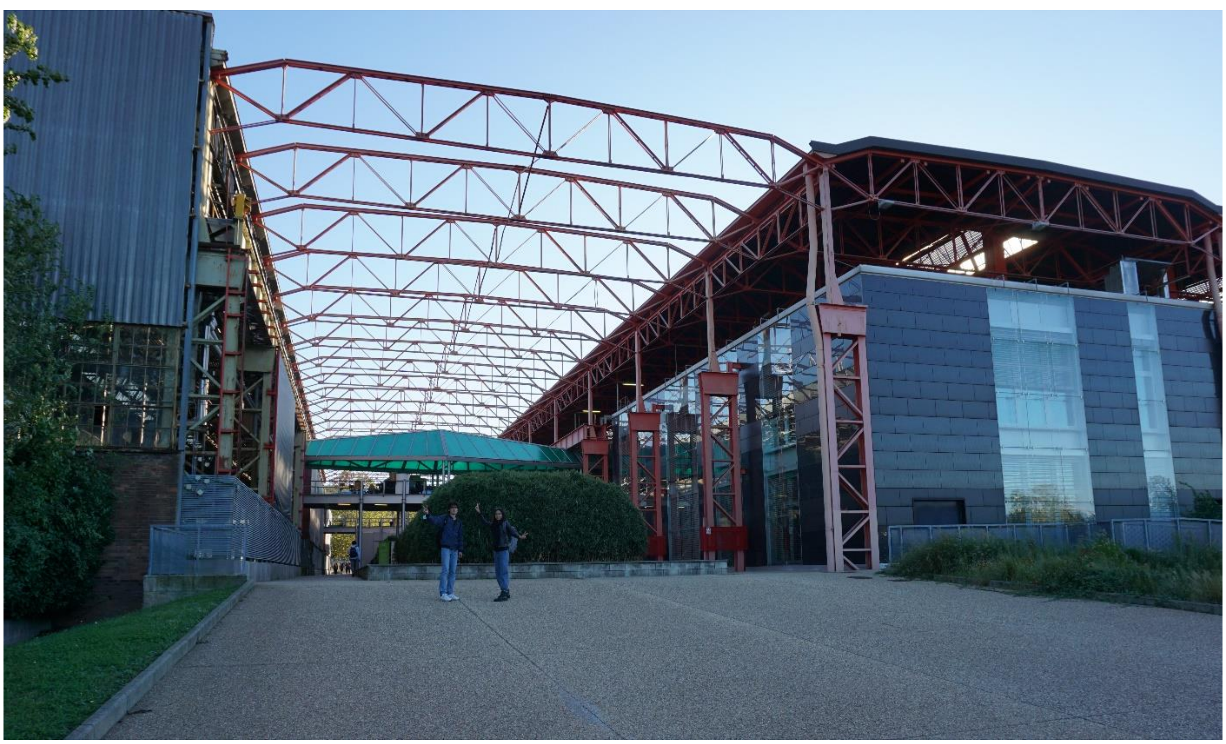


Figure 23: Image taken during site visit [33]

Picture of different columens inside the building.

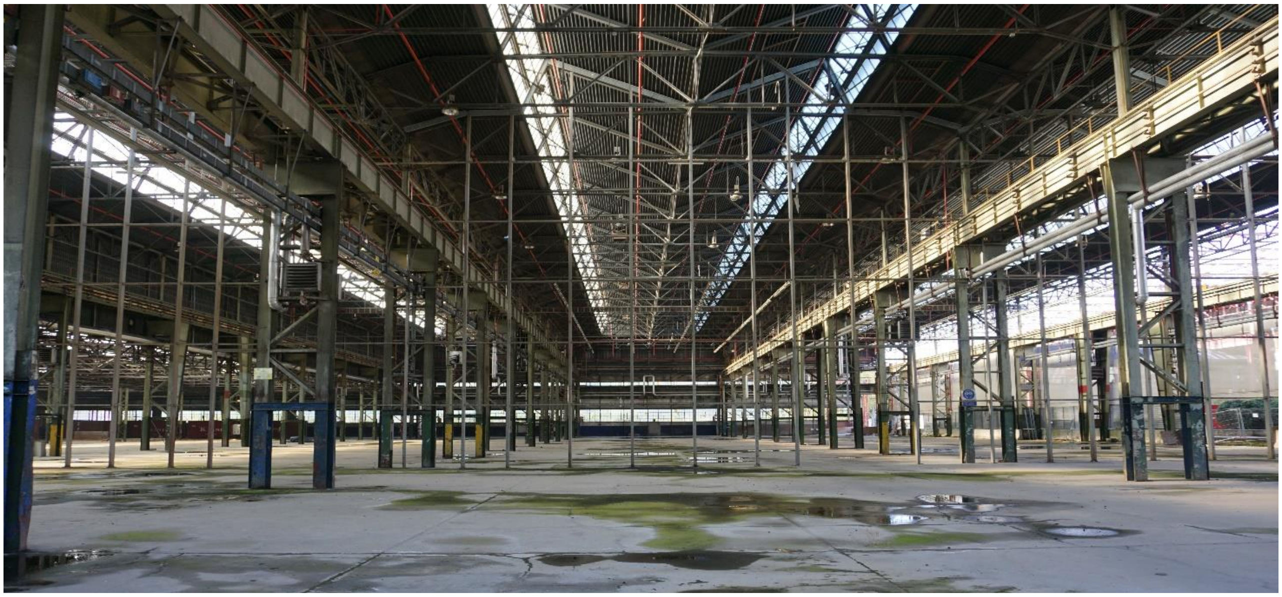


Figure 24: Internal view of building [34]

The main trusses of the building.

Figure 25: Image of building trusses [35]

2.5 BIM Model: 3D Modeling of an existing structure.

To create BIM model, we first analyze all the technical drawings of the construction project graphically in the form of horizontal and vertical sections, and views. Which needed to complete the 3D modeling of building. Autodesk Revit 2020 was used to create 3D modeling of an existing steel structure.

One of the good options in Revit 2020 is that it offers different templates to create different family for columns, trusses, beams, footing, walls windows etc. One can create family according to own need of different shape and size. In this project it was difficult to find the already available family of columns, beam, and trusses so we decided to create our own family for column, beam, and trusses.

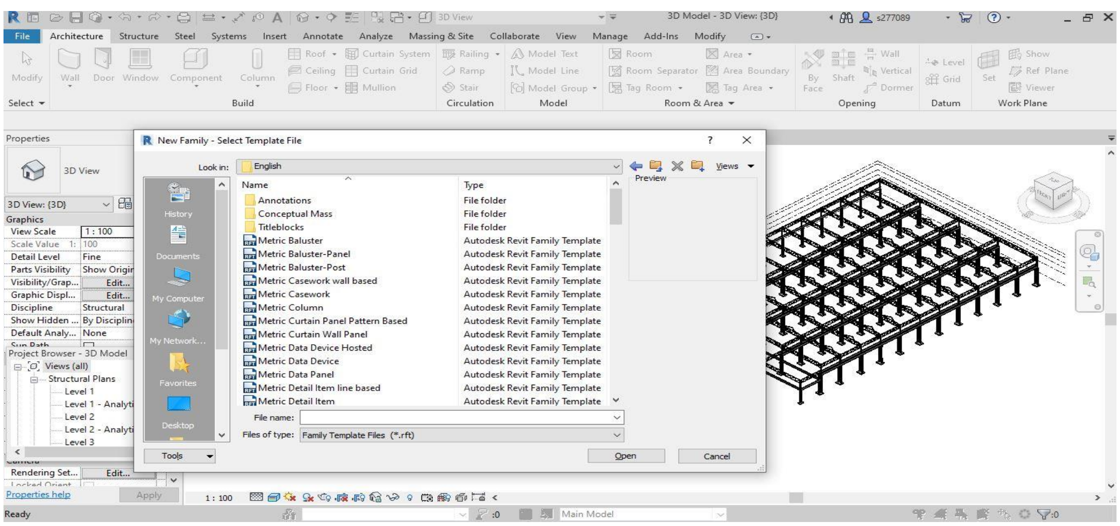


Figure 26: Family Templates in Revit 2020 [36]

2.5.1 Column family creation.

A generic template was used to create column family in this tool Revit offer a generic 2D templates which we can change and edit according to our own need with the help of Extrusion command we can covert these 2D templates into 3D shapes and use the in-3D BIM model.

In the project building there were 6 different types of columns have different shape and size so one by one 6 different family of columns was created the 2D plan and 3D views of columns are shown below.

2D plan and 3D view of column type 1

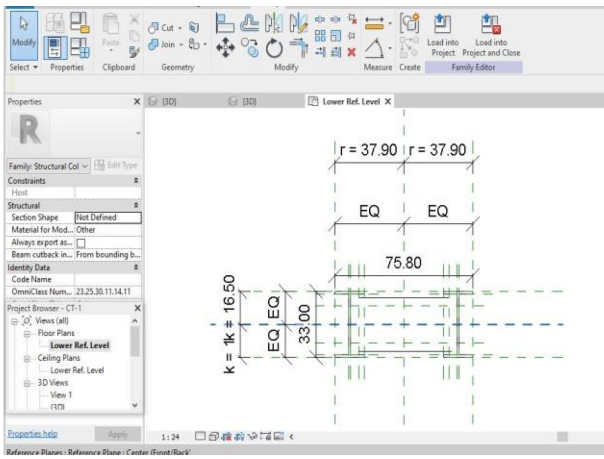


Figure 27: 2D view of column Type-1 [37]

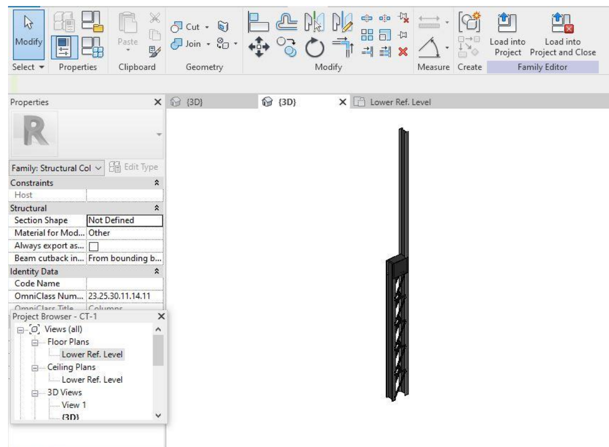


Figure 28: 3D view of column type-1 [37]

2D Plan and 3D view of column type 2

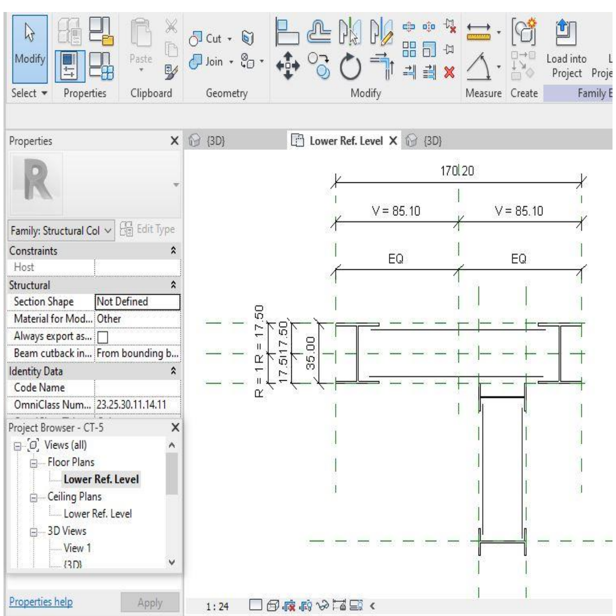


Figure 29: 2D view of column Type-2 [38]

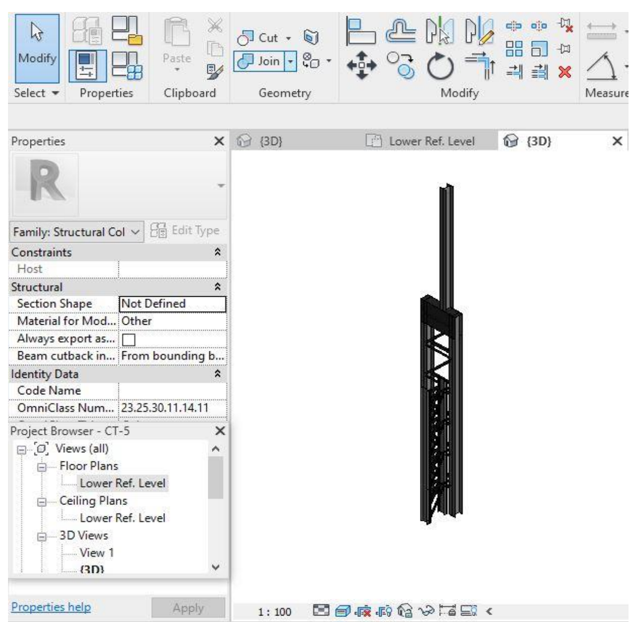


Figure 30: 3D view of column Type-2 [38]

2D Plan and 3D view of column type 3

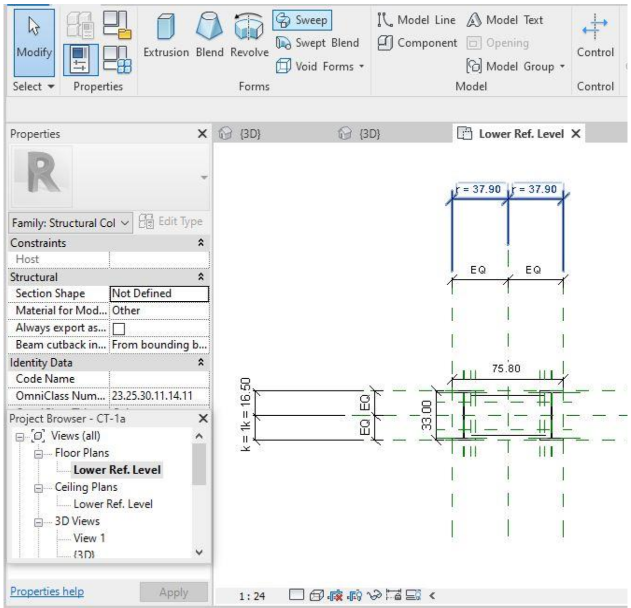


Figure 31: 2D view of column Type-3 [39]

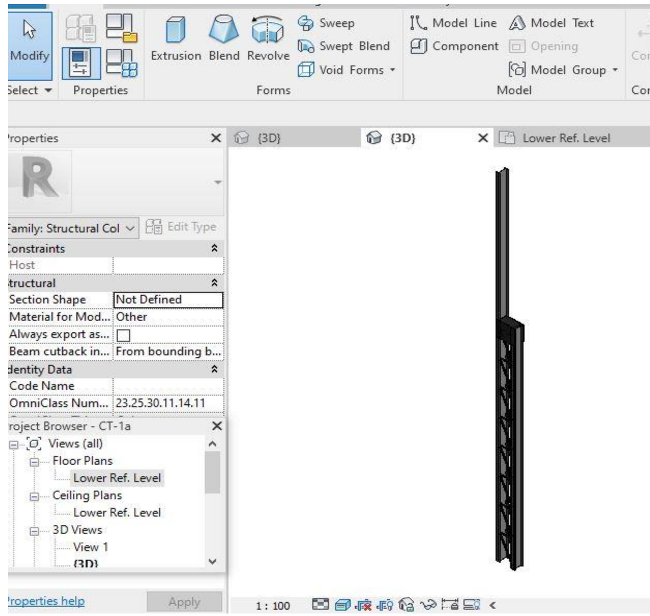


Figure 32: 3D view of column type-3 [39]

2D Plan and 3D view of column type 4

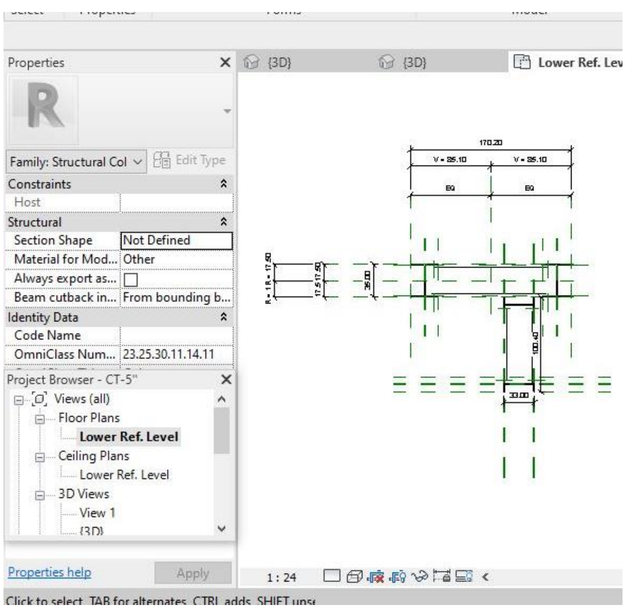


Figure 33: 2D view of column Type-4 [40]

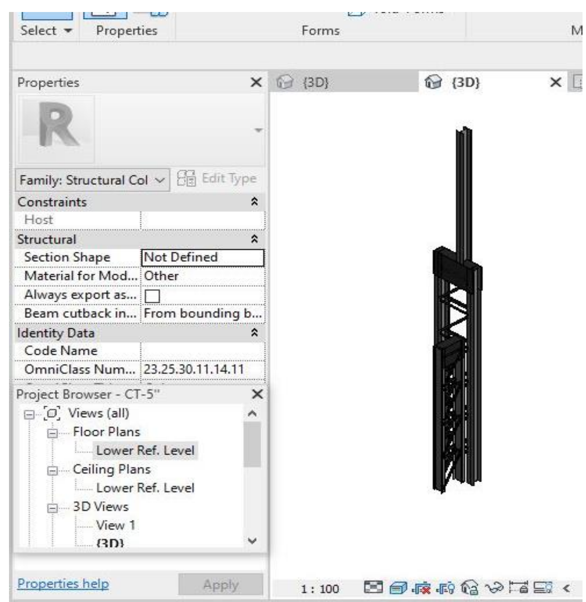


Figure 34: 3D view of column Type-4 [40]

2D Plan and 3D view of column type 5

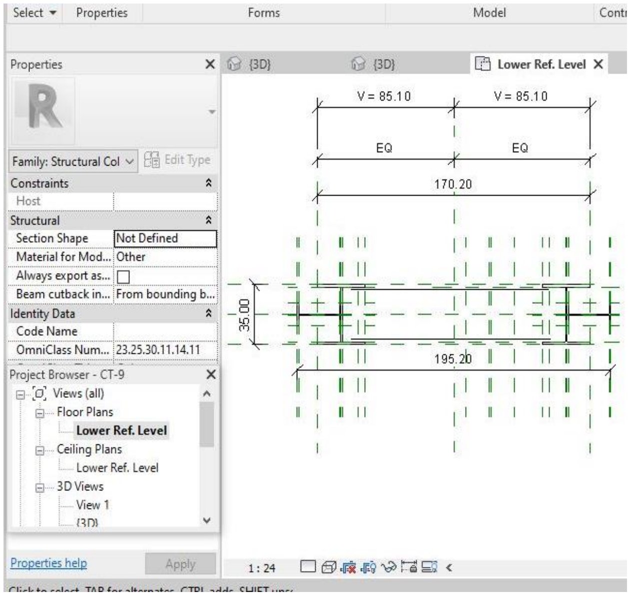


Figure 35: 2D view of column Type-5 [41]

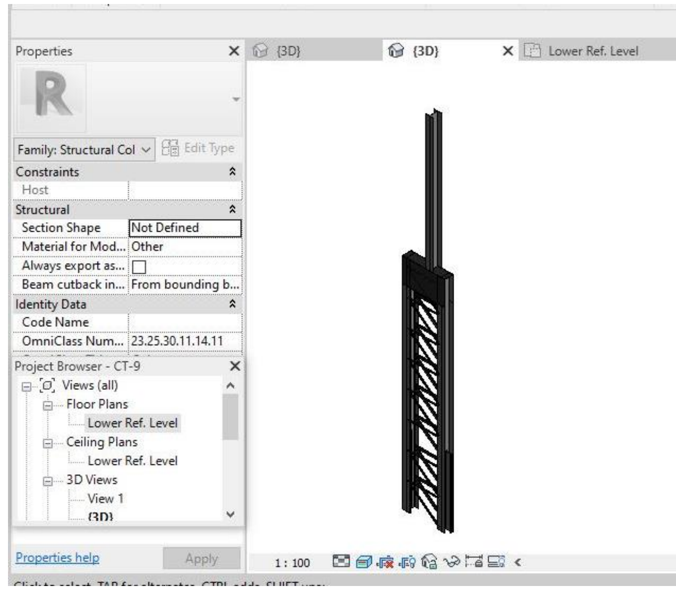


Figure 36: 3D view of column Type-5 [41]

2D Plan and 3D view of column type 6

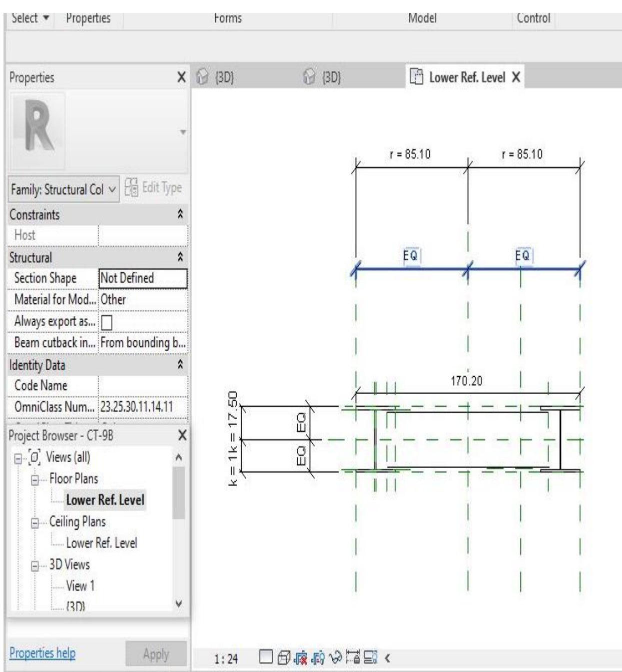


Figure 36: 2D view of column Type-6 [42]

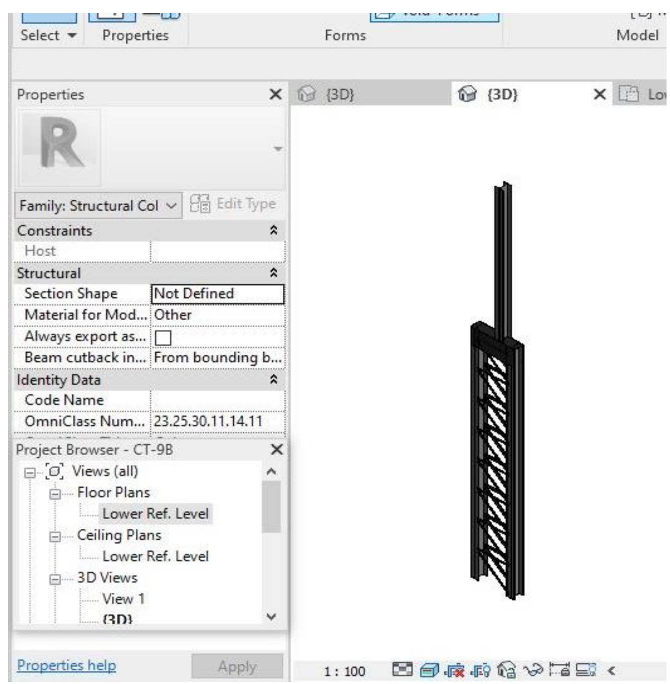


Figure 37: 3D view of column Type-6 [42]

2.5.2 Family for Roof Trusses

A generic template was used to create family for roof trusses in this template Revit offer a generic 2D templates which we can change and edit according to our own need, we can covert these 2D templates into 3D shapes and select size and element type according to our own requirement and use it in-3D BIM model.

In the project building there were 3 different types of trusses have different shape and size, so we create 3 different family for roof trusses was created the 2D plan and 3D views of trusses are shown below.

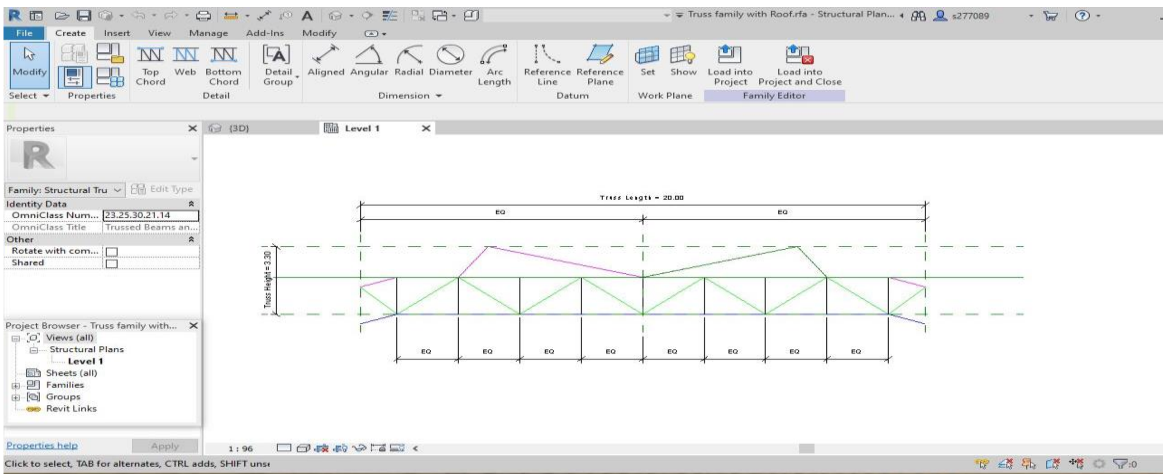


Figure 38: Roof Truss template [43]

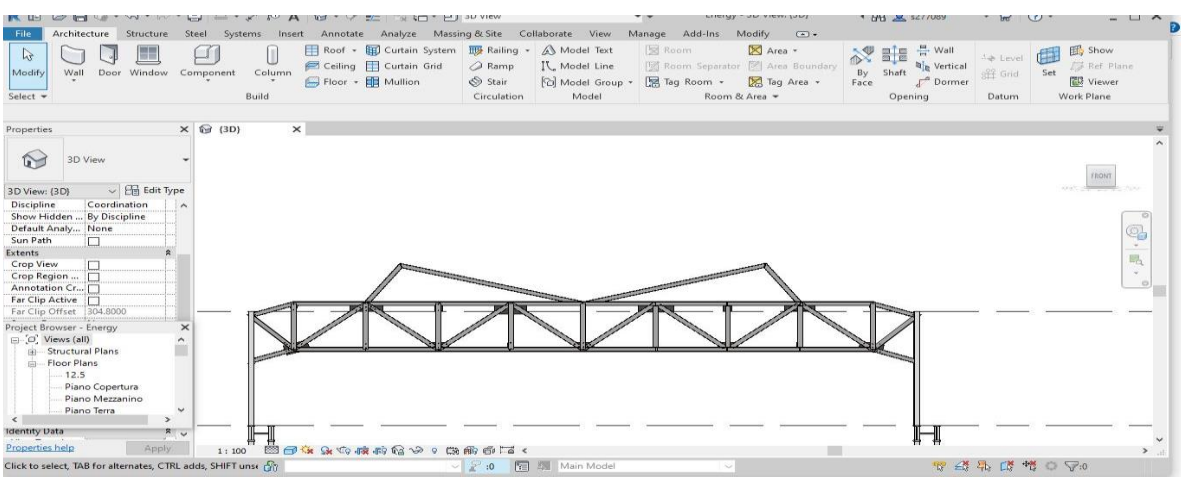


Figure 39: 3D view of Roof Truss [44]

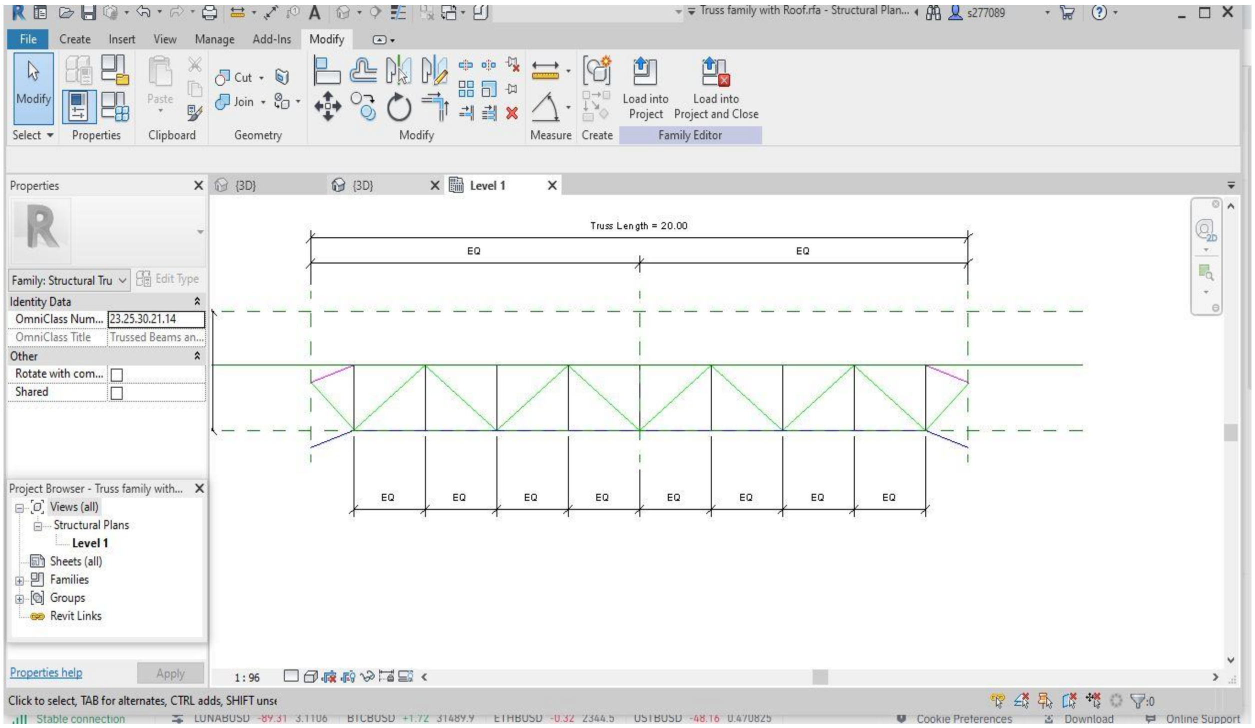


Figure 40: 2D plan of roof truss [45]

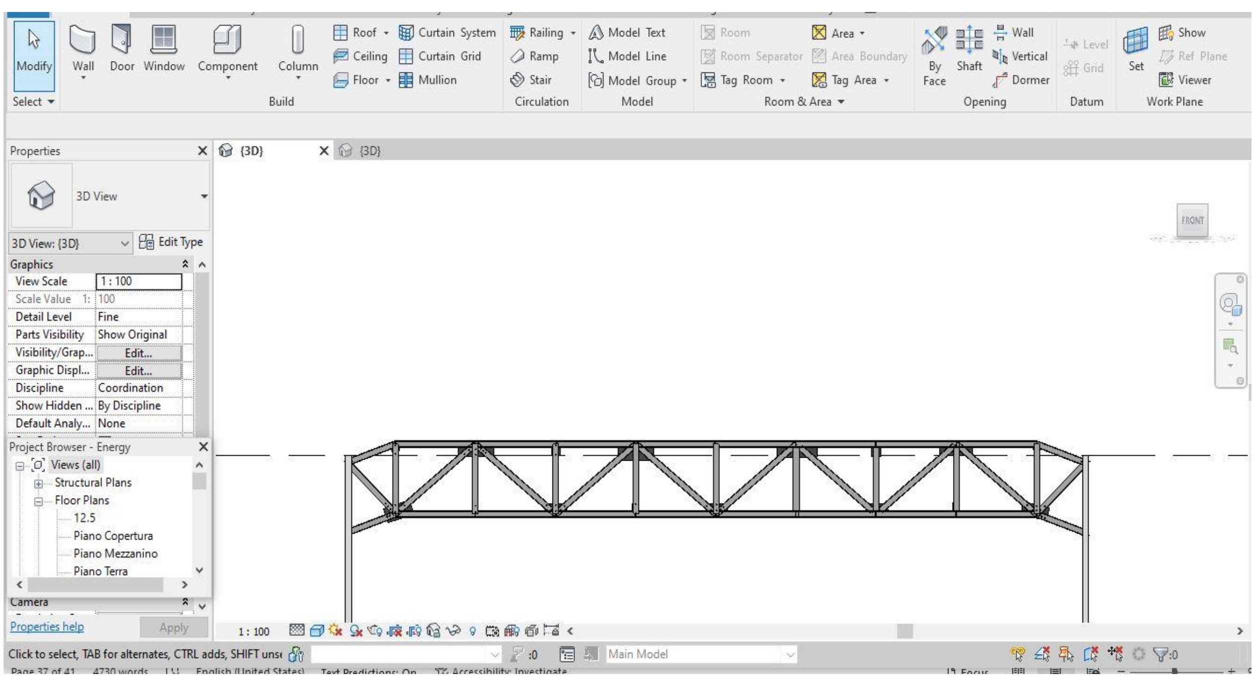


Figure 41: 3D view of roof truss [46]

2.5.3 BIM 3D Model

After creating all the required families of columns, beams, and trusses of different shape and size we will be able to create a BIM model with complete information needed for any project. In this project there was no need of creating family for other building elements like walls, footing, floor etc. because for that we can use already available standard elements. Some 3D views of building structure are shown below.

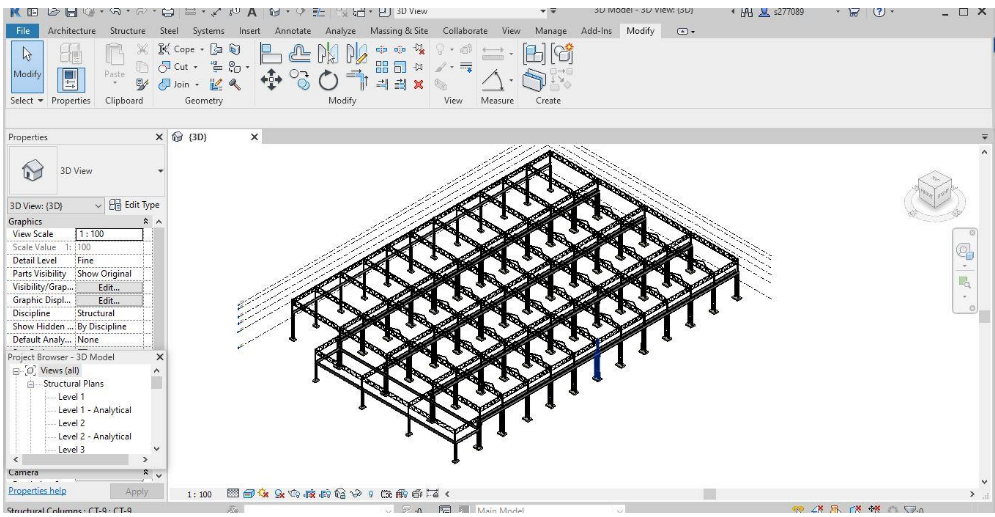


Figure 42: 3D view of building structure with columns [47]

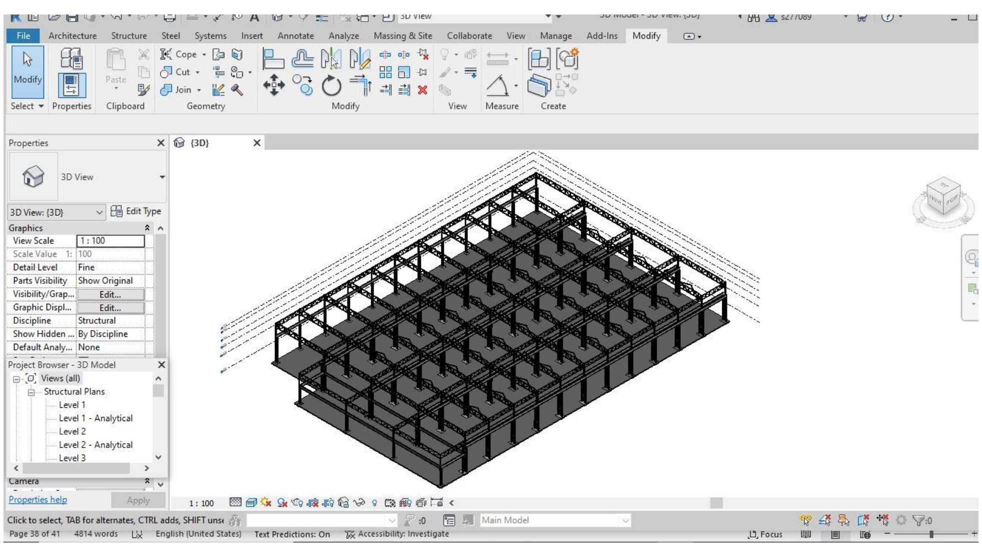


Figure 43: 3D view of building structure with floor [48]

One of the important concepts in 3D BIM modeling is the workset. Worksets are stages or portions on which projects can be split within Autodesk Revit models 3D model. workset are the collection of building elements (such as walls, columns, doors, footing, floors, beams, stairs, etc.) or other graphic elements such ass (views or sheets are worksets). When collaborative work is enabled in the file, each element in the project is contained in one and only one workset so during the modeling, each element should be placed in the corresponding workset. The entire 3D BIM model with all the building elements is shown below.

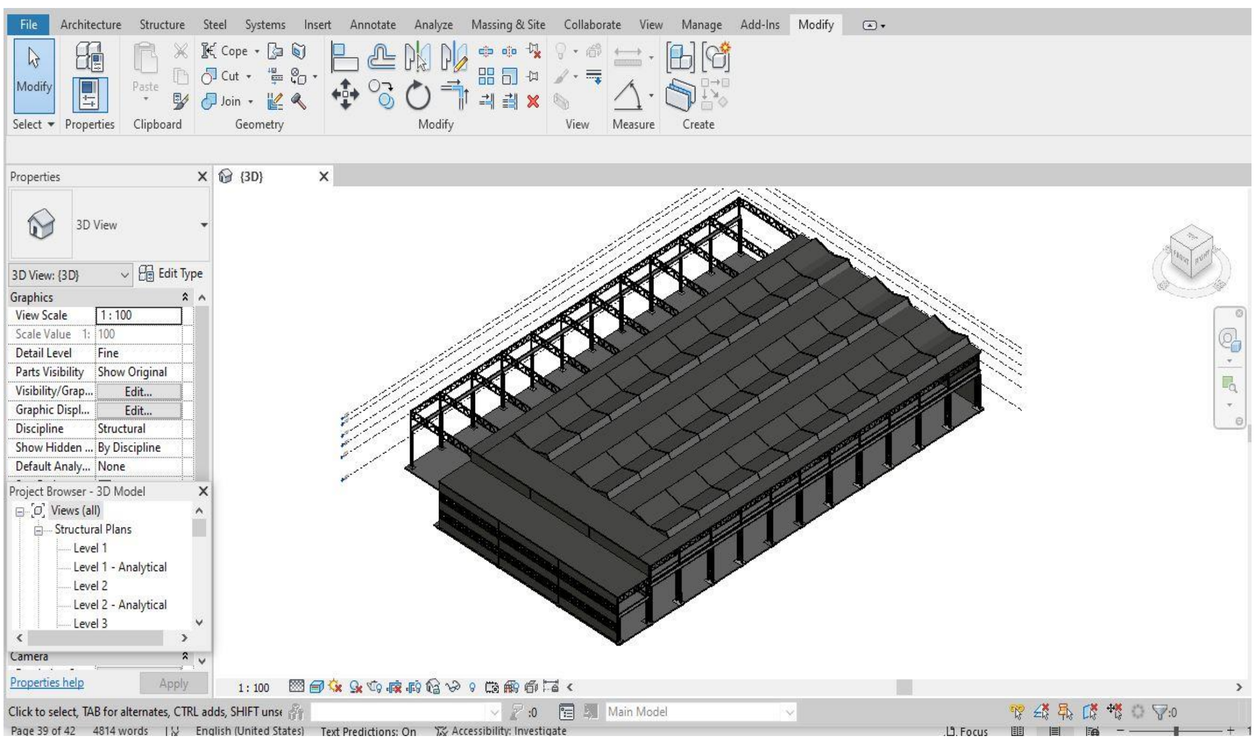


Figure 44: BIM model of existing structure [49]

2.6 Architecture planning in BIM

2.6.1 BIM Context for Architectural practice

The capabilities that BIM promises will be addressed in order to comprehend the consequences of BIM deployment on architectural practices. Each of these potential capacities may necessitate a similar level of BIM ready in the three dimensions described. For example, when it comes to documentation, we'll look at what processes and technologies are needed, as well as what professional skills or behaviors are required for a proper documentation workflow in BIM ecosystems. Obviously, such a conversation will be expanded upon in light of their contributions and implications for architectural practices. It's worth noting that by Architectural Practices, we mean anybody that engages in architectural practice, whether it's a major corporation or a single architect.

Phase-1: Programming what to build: The owner and architect examine the project's requirements (number of rooms, function of spaces, etc.), ensuring that the owner's needs, wants, and budget are all met.

Phase-2: Schematic Design/Rough Sketches: The architect prepares a schematic design, which is a series of rough sketches that illustrate the room and site plan.

Phase-3: Design Development/Refining the Design: More detailed drawings are created by the architect to show other features of the proposed design. All of the rooms are shown in the exact size and shape on the floor plans.

Phase-4: Preparation of Construction Documents: The architect creates comprehensive drawings and specifications after the owner approves the design, which the contractor will use to determine the real construction cost and build the project.

Phase-5: Hiring the Contractor: The contractor is chosen by the owner. The architect could be prepared to offer some advice. In many circumstances, owners select from a list of contractors who have been requested to submit bids for the job.

Phase-6: Project Close Out: The architect can assist in the completion of the project by verifying that it is complete and suitable for use, as well as ensuring that the contractor is entitled to final payment.

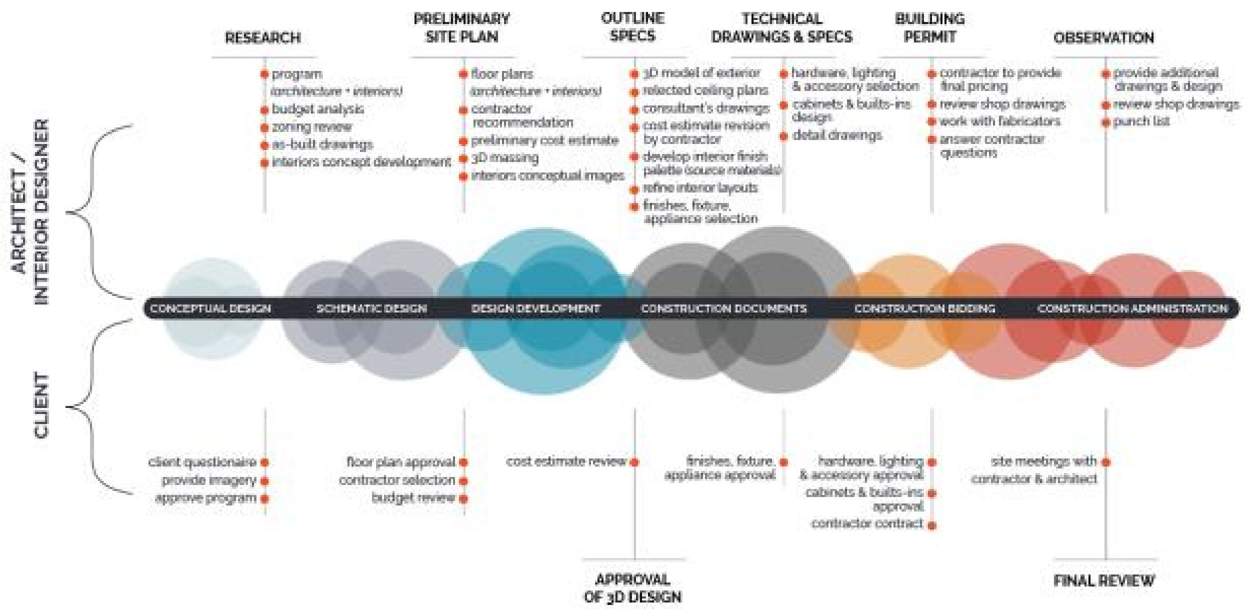


Figure 45: Architectural project phases [50]

The architectural project and services phases of conceptual design, schematic design, design development, construction documentation, construction bidding, and construction administration are depicted in the diagram above.

2.7 Architectural Planning and Designing

The process of planning, designing, and constructing buildings or other structures is referred to as architecture. Architectural works, in the form of structures, are frequently regarded as cultural emblems and works of art.[51]

Architecture work in this projected started from sketch of the concept, planning in AutoCAD 2020, space distribution, windows ,door placement, furniture design and then imported this planning in Revit 2020 for 3d architecture modeling, placement of components and furthermore it merged to 3d structure model for final rendering and simulation process.

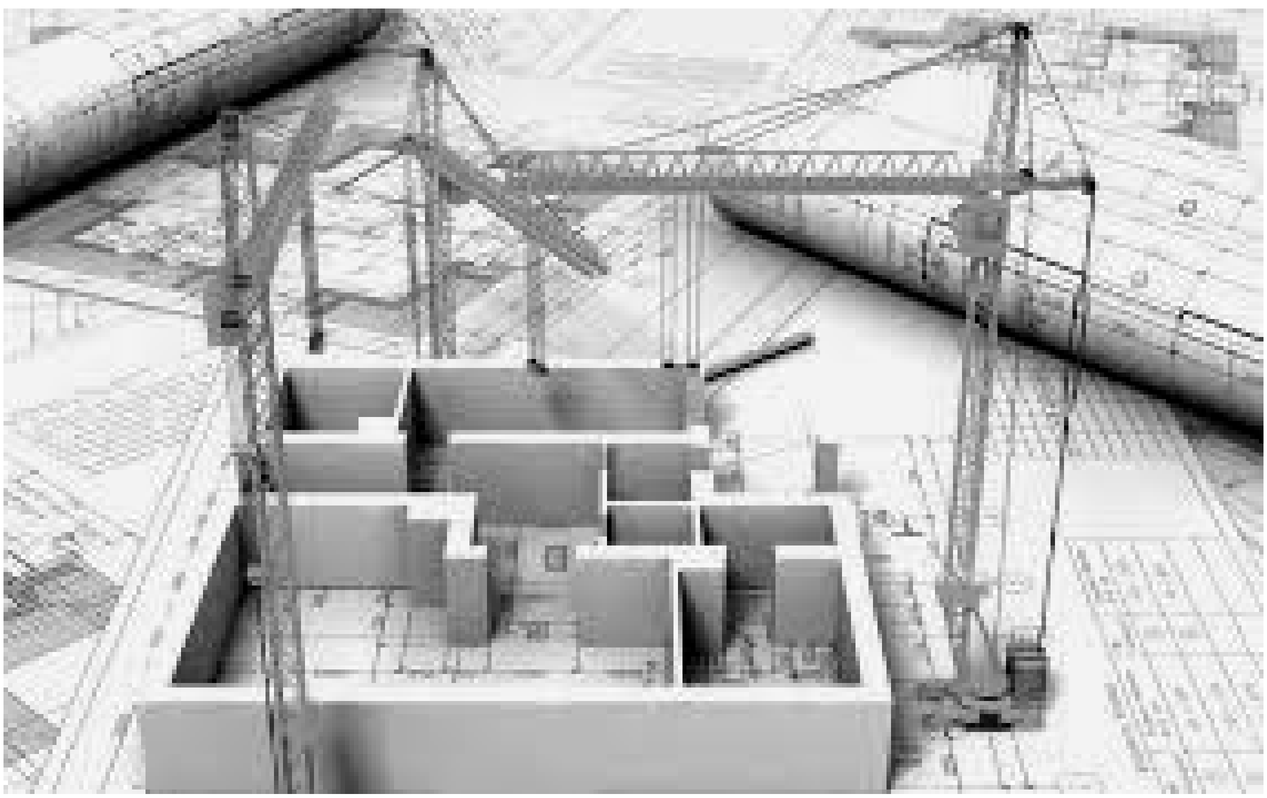


Figure 46: Architecture In graphics [52]

2.7.1 Required Spaces.

Before starting any kind of project Architects need to make design brief for whole project according to needs and requirements of the project, in this project spaces that to be designs are briefly as.

- Entrance area
- Lobby
- Administration area
- Academic areas
- Mensa service
- General Sitting and games area
- Services Area

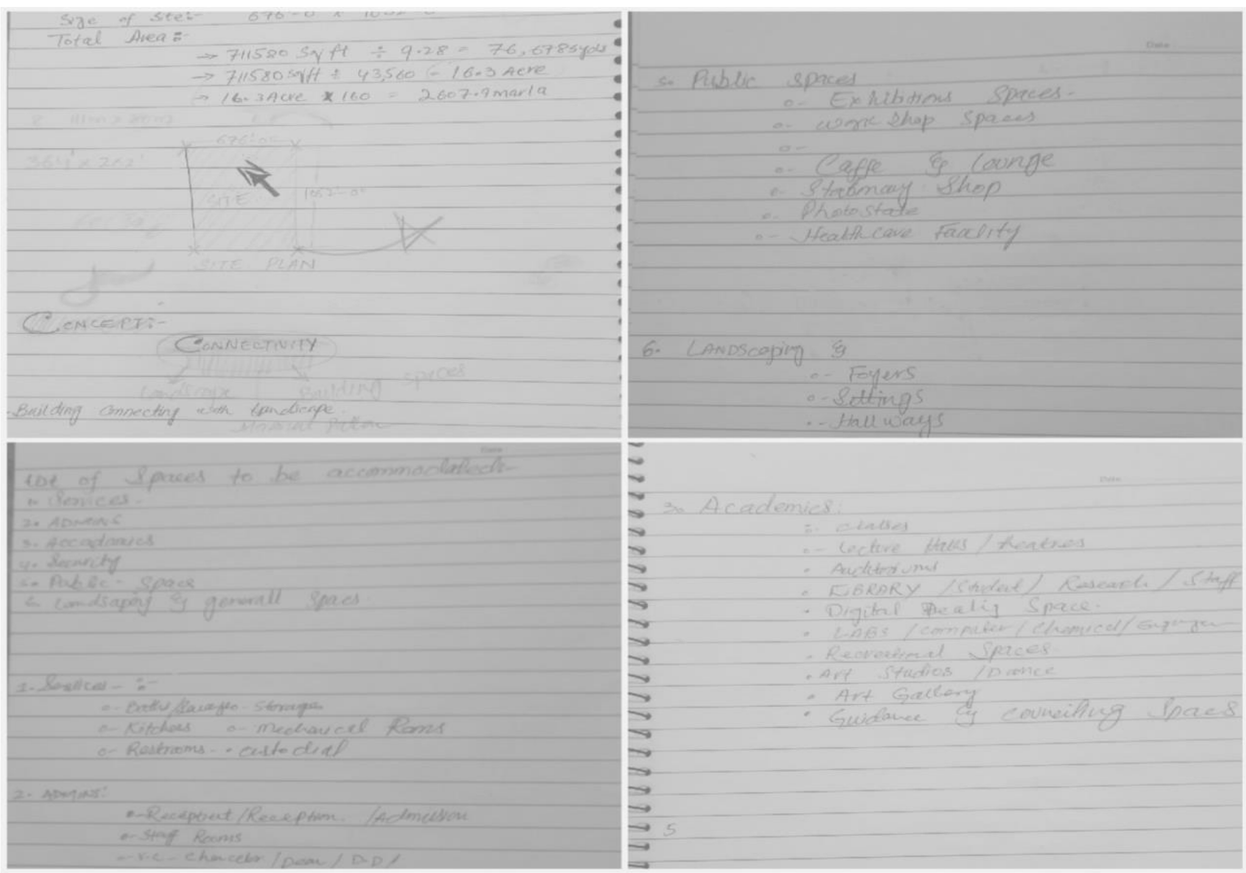


Figure 47: Summary of the Required spaces for university campus [53]

2.7.2 Conceptual Sketch

Conceptual sketches are prepared for the startup of the planning phase to give a pathway and brainstorming for the space distribution.

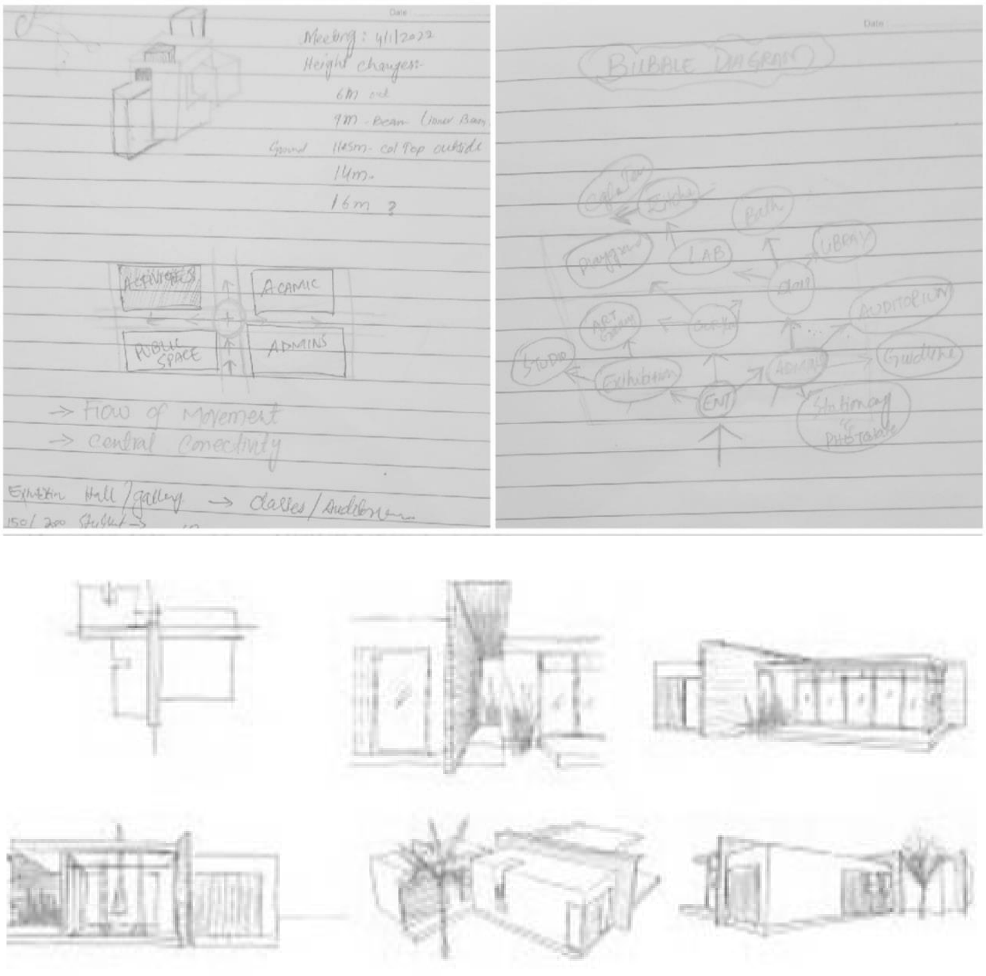


Figure 48: Conceptual sketches image [54]

2.8 2D Planning

We first started Architectural planning in AutoCAD 2020, from development to Final stage as described in series of figures below.

2.8.1 Grid Plan

The structural grid is drawn in AutoCAD 2020, for the architectural Planning reference with the structure.

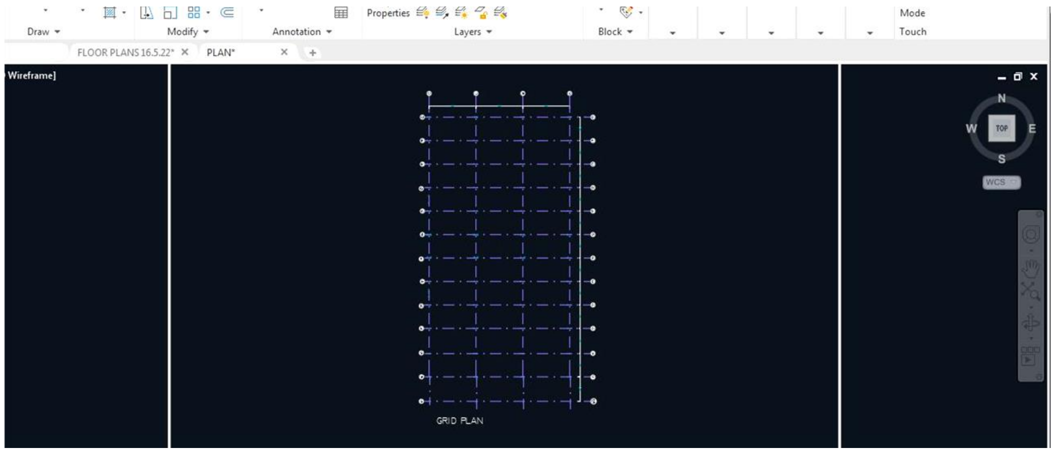


Figure 49: Grid plan, in Autodesk AutoCAD 2020 [55]

2.8.2 Zoning Plan

Zoning performed in the given area according to the academic space connections using Autodesk AutoCAD 2020, With Different colors of lines and layers for the visual identifications and central point of emergence is created which connect other spaces in the center.

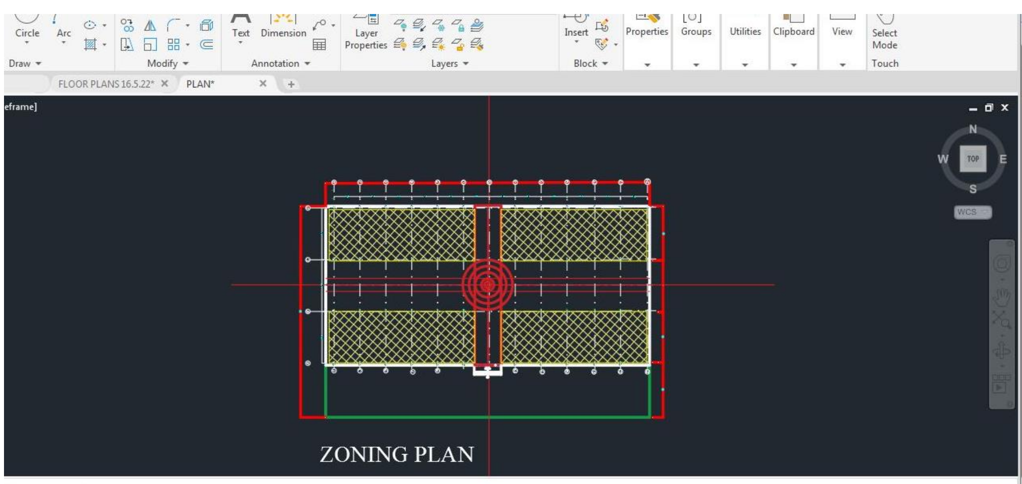


Figure 50: Zoning plan, in Autodesk AutoCAD 2020 [55]

2.8.3 Different stages of proposed Layout planning.

Proposed Layout planning Stage-1

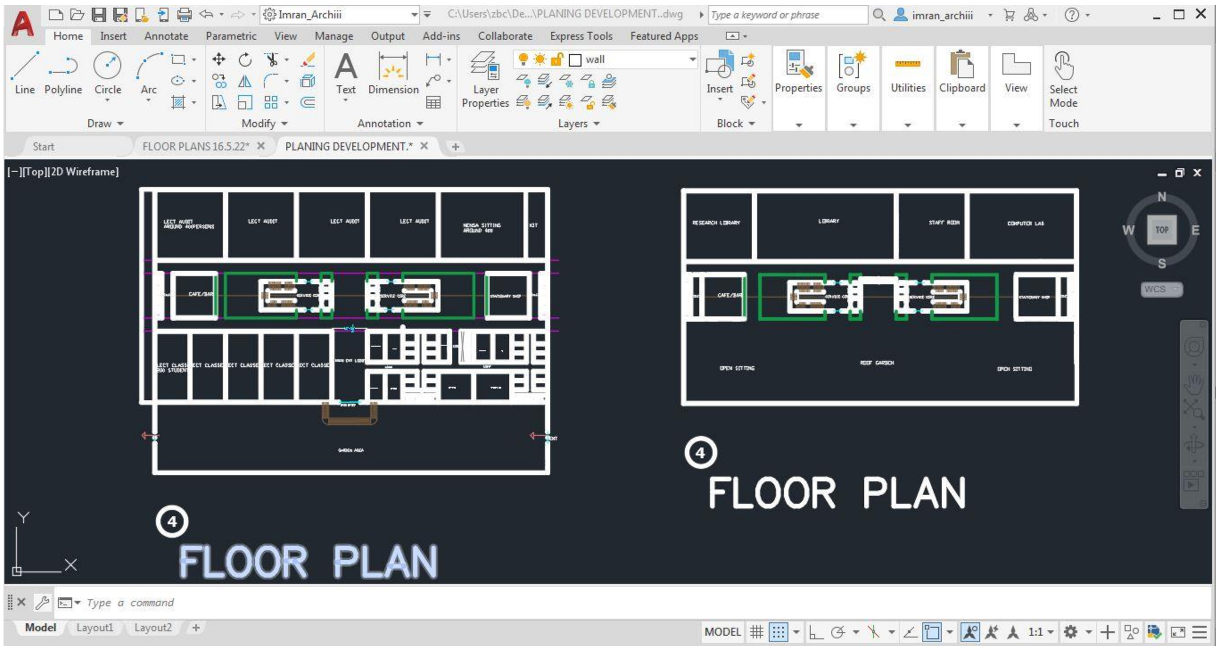


Figure 51: Layout stage-1, in Autodesk AutoCAD 2020 [55]

Proposed Layout planning Stage-2

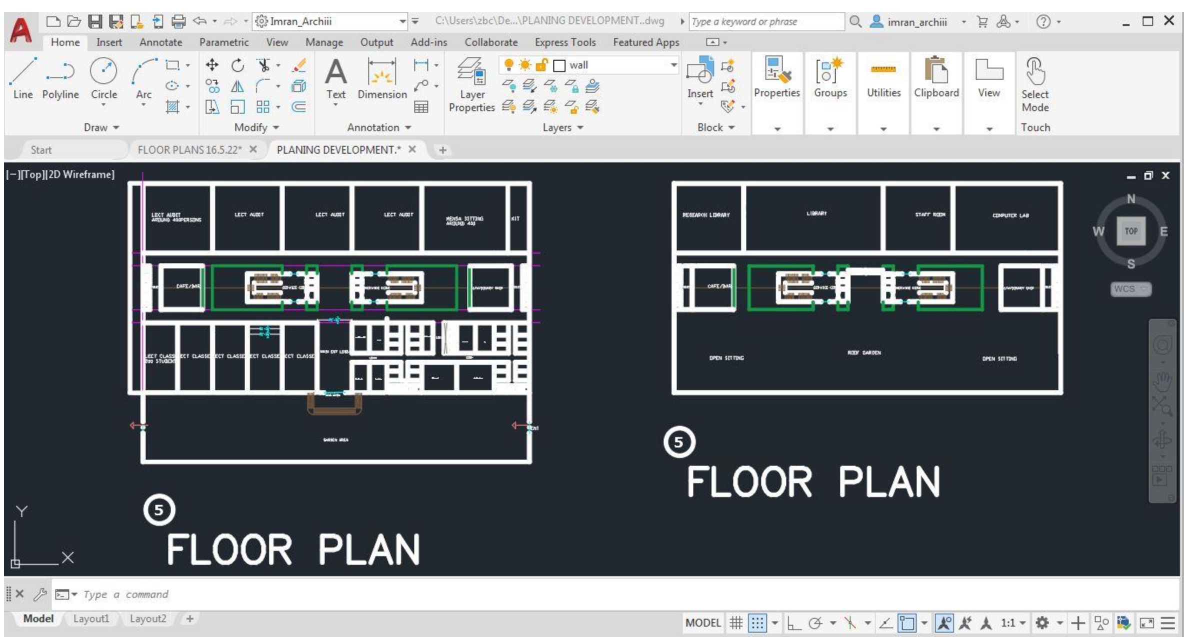


Figure 52: Layout stage-2, in Autodesk AutoCAD 2020 [55]

Proposed Layout planning Stage-3

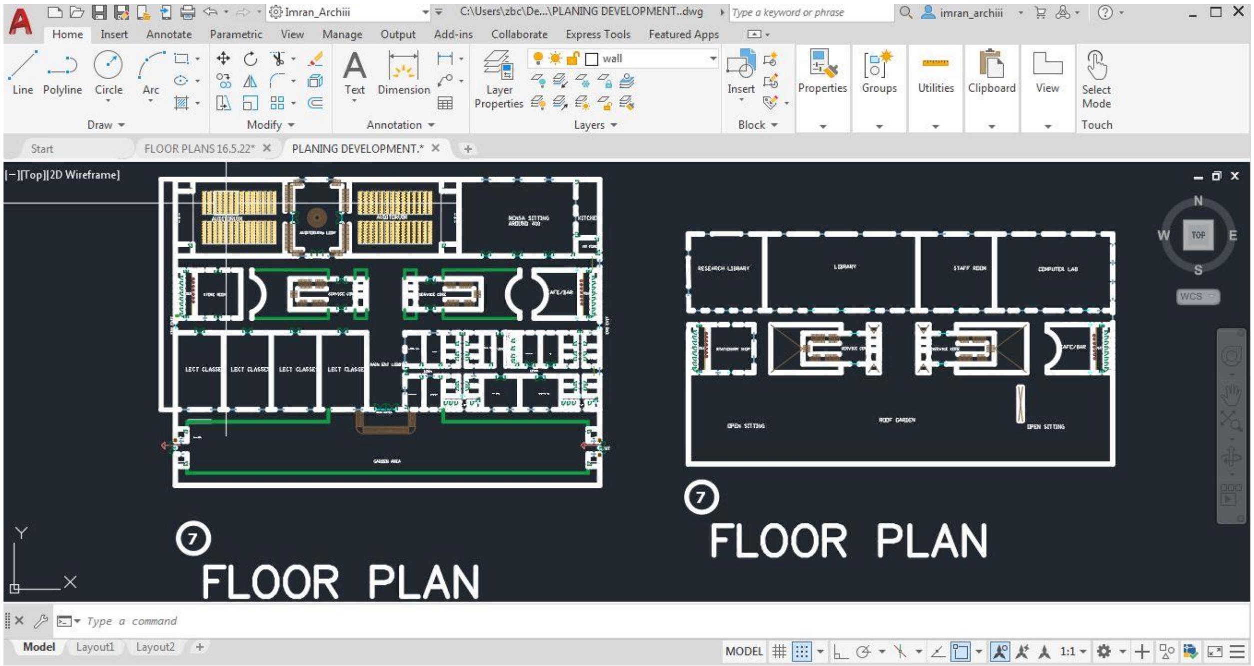


Figure 53: Layout stage-3, in Autodesk AutoCAD 2020 [55]

Proposed Layout planning Final Stage 4

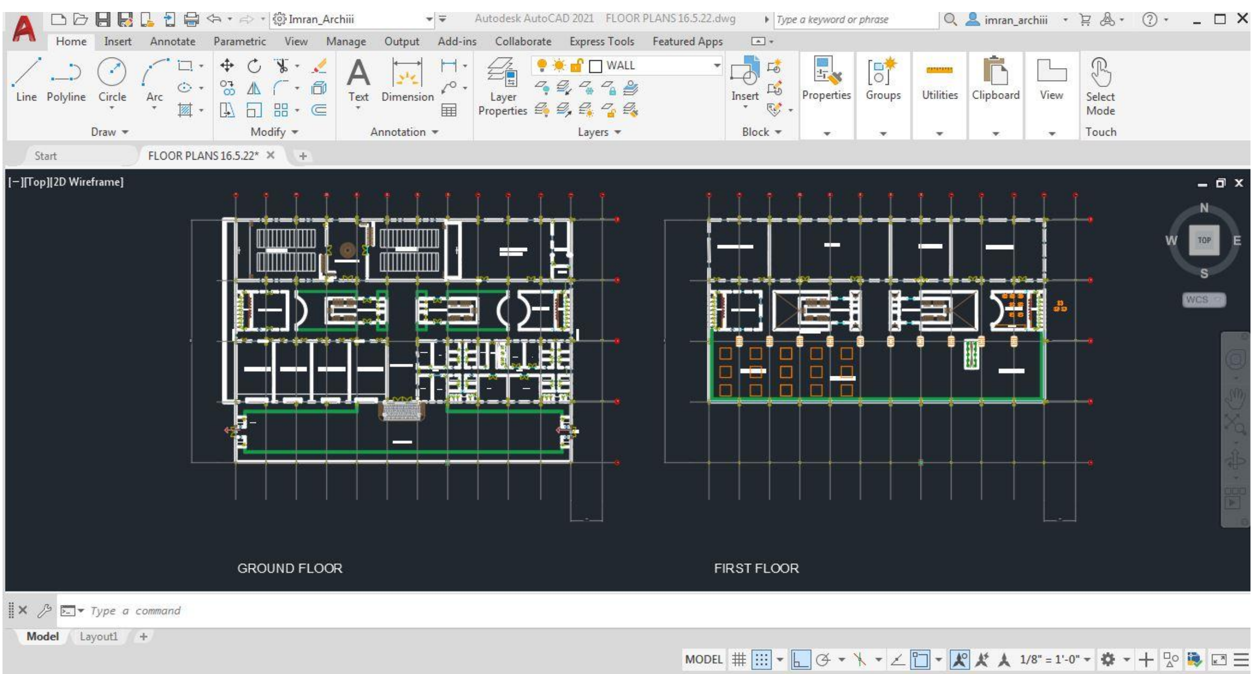


Figure 54: Layout stage-4, in Autodesk AutoCAD 2020 [55]

2.9 3D Modeling on Revit

The most important phase of Revit 3D modeling is creating walls, doors, stairs, windows, floors, ceilings, roofs, and other necessary design elements that proposed in CAD Planning. This is time taking phase where we have to decide all the specifications of construction material like thickness and material of the walls, Door windows heights and framing materials, flooring patterns, ceiling design, and so on, all these details need to be shown in the project.

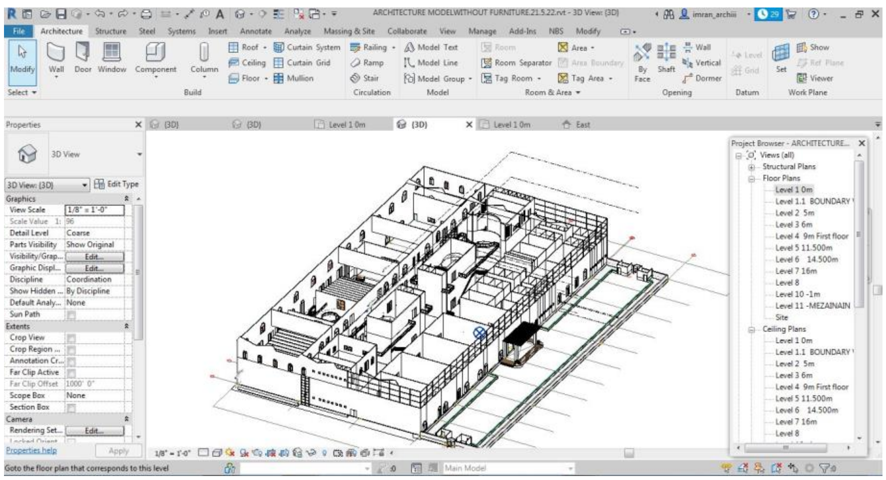


Figure 55: Partition design , Autodesk Revit 2020 [56]

Changing types of material ,thickness and appearance graphics of the material.

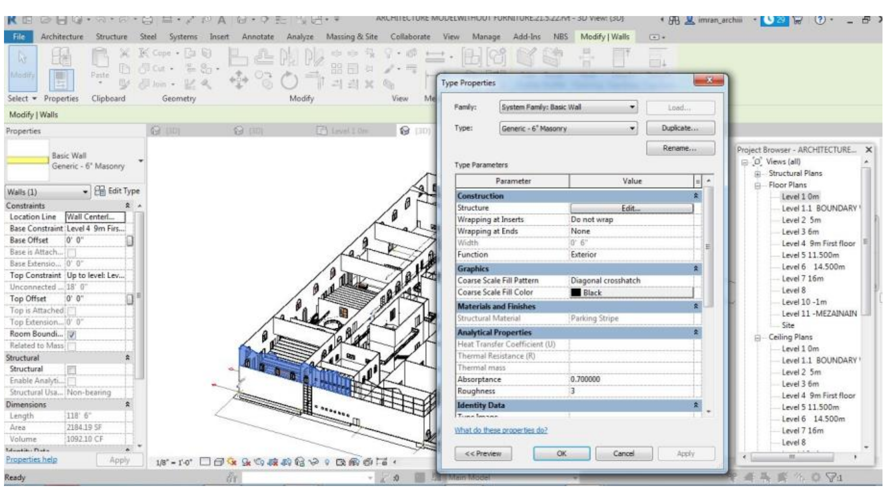


Figure 56: property types , Autodesk Revit 2020 [56]

Edit assembly, where we can change the thickness and addition of layers in your object either inside or outside of the object.

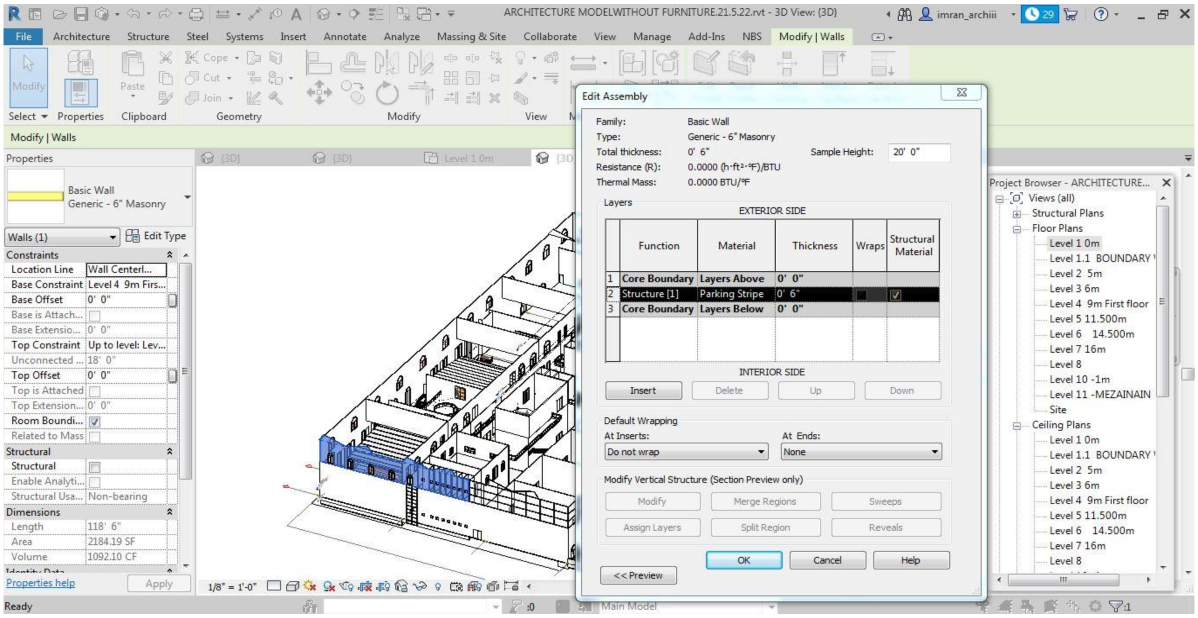


Figure 57: Assembly edits, Autodesk Revit 2020 [56]

Material browser, where materials specifically selected the appearances and graphics of the materials to be set which will be affected in the renderings.

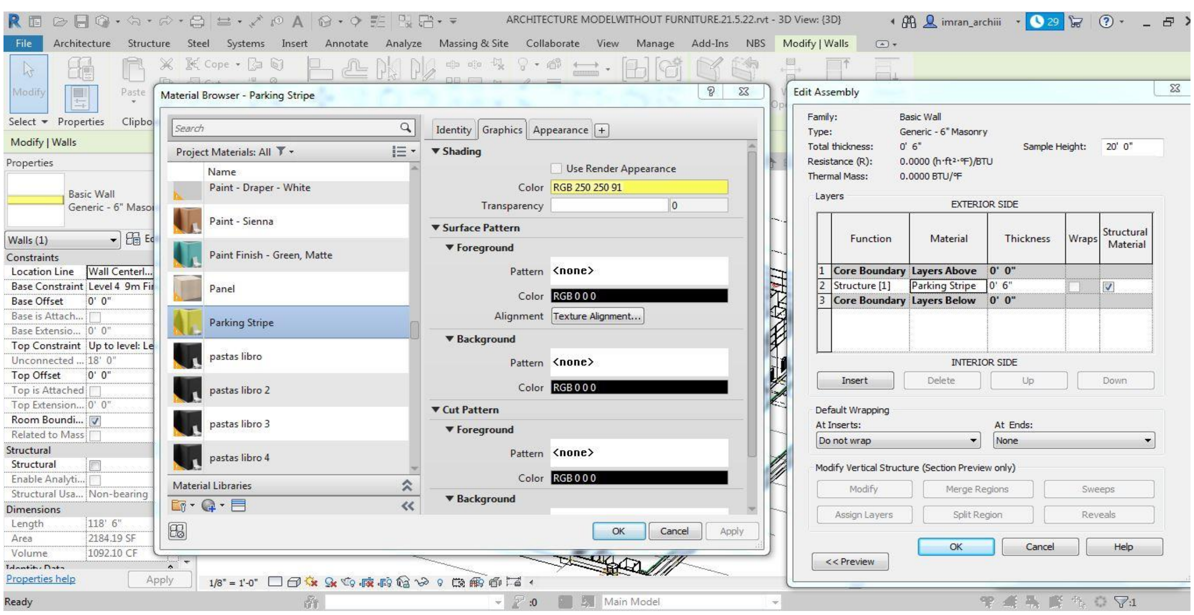


Figure 58: Material properties , Autodesk Revit 2020 [56]

2.9.1 Components Uploading.

In this phase we add furniture, fixtures, landscaping, fencing, and other suggested elements from the components option, it could be from within the project from the property browser or from the load family.

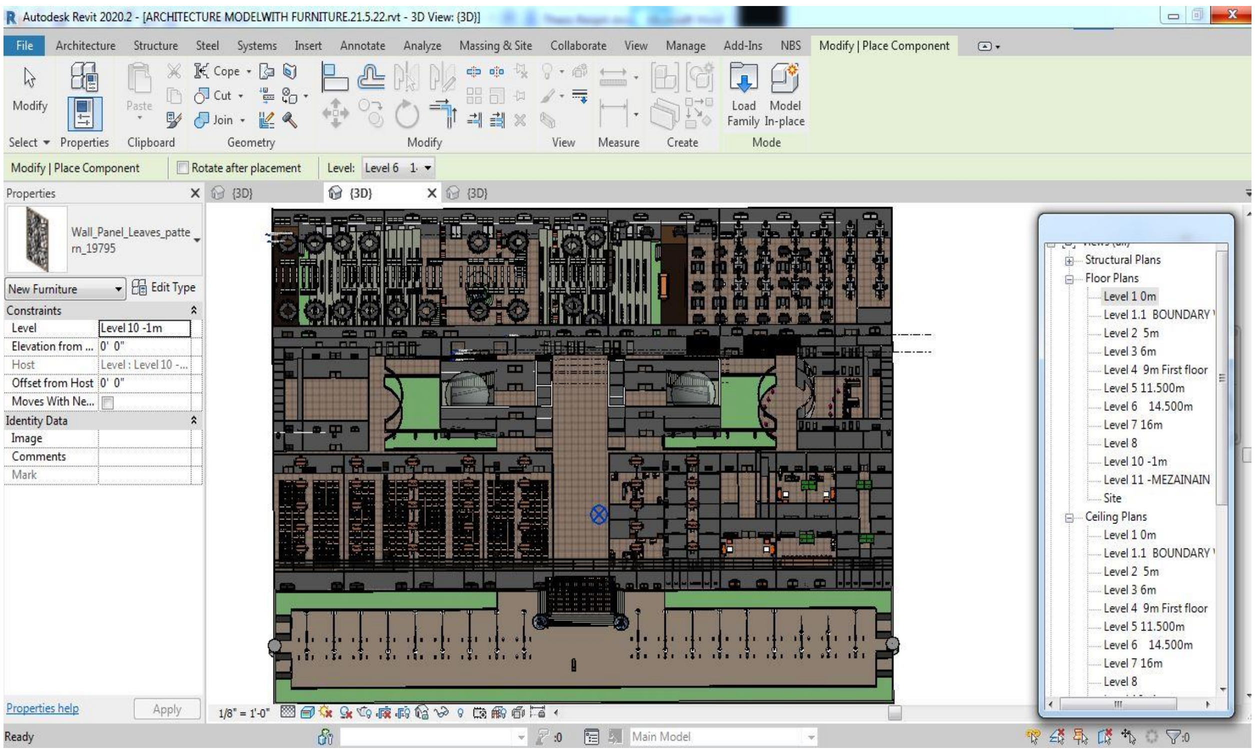


Figure 59: Uploading Component, Autodesk Revit 2020 [56]

2.9.2 Merging Architectural Model in The Structure Model

After completion of 3D modeling work in Rivet, architectural model will be linked into Structure model with the existing structure design in Revit structure project earlier. It will be merged from insert, manage links, then add and upload it in to project in the specified level which will be as same the structure level in the base.

Architecture model placed in the structure model to confirm the Structural elements are fitted in their right positions or not so if any conflicts and disturbances seen after linking models with each other then again relocating and movement of architecture elements proceeded and again liked as it is.

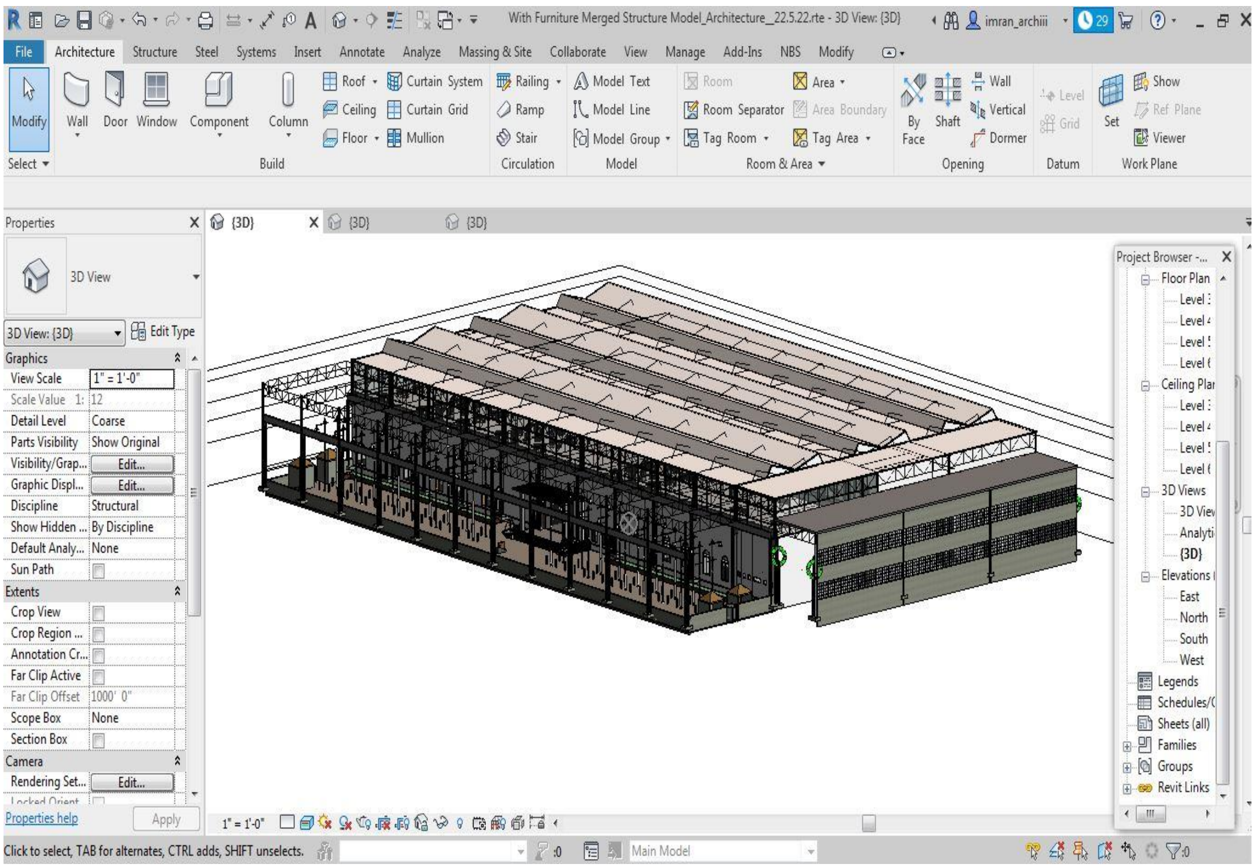


Figure 60: Linking architecture and structural model [56]

The above figure shows the structural model when it is merged with final version of architectural 3D model which we created on Autodesk Revit 2020 this help us to detect clashes between structural and architectural model if there is any.

2.10 Architectural plan, sections, and views

GROUND FLOOR PLAN

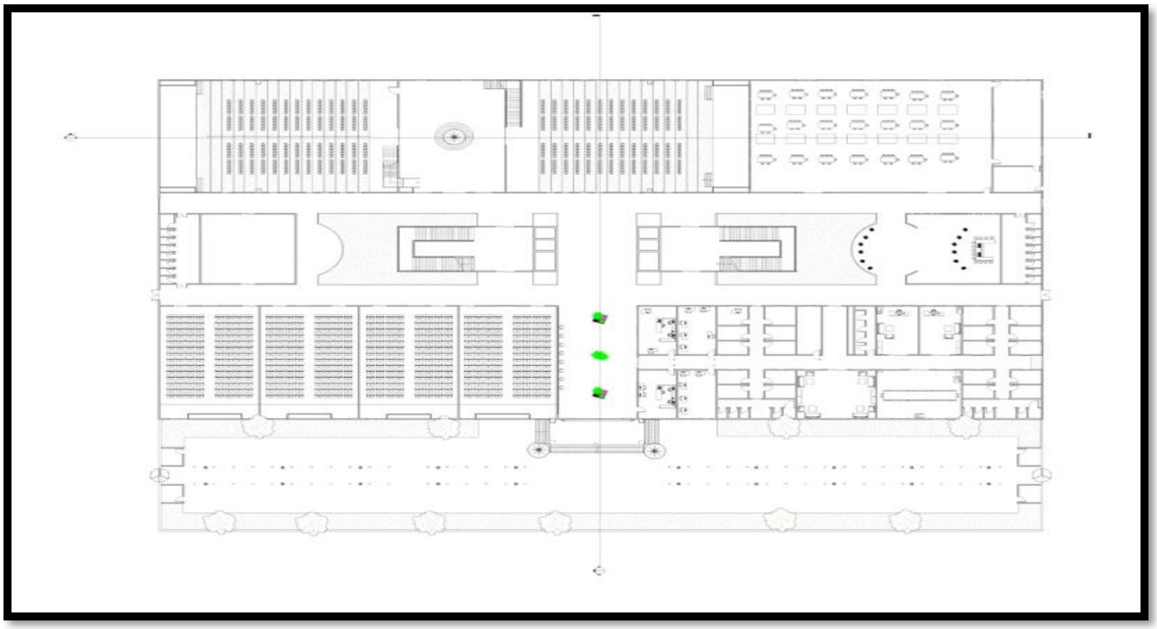


Figure 61: Ground Floor planning [57]

FIRST FLOOR PLAN

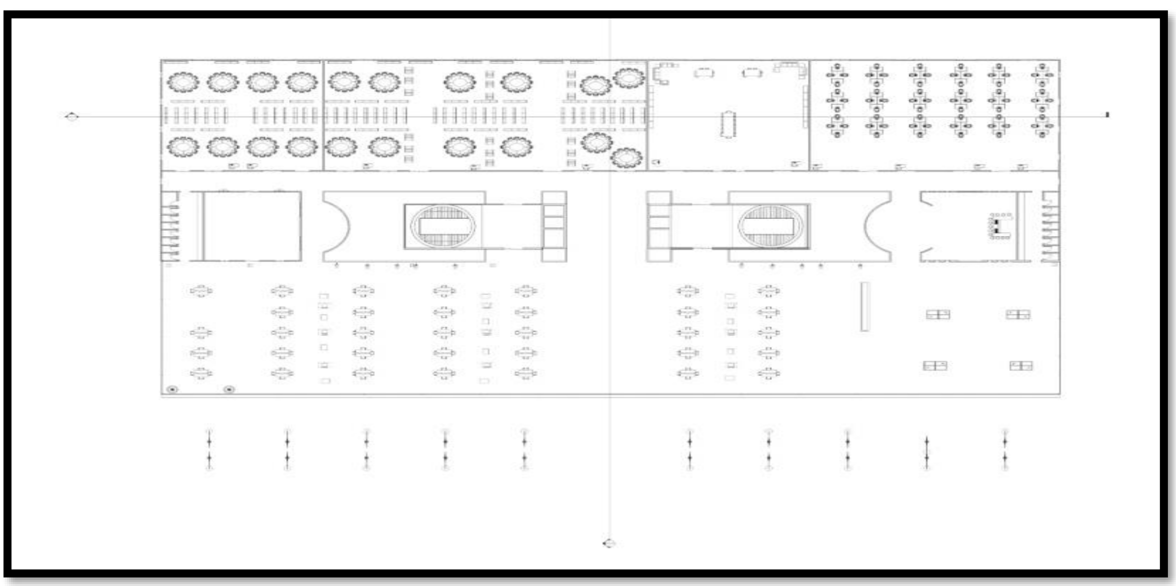


Figure 62: First Floor planning [57]

SECTION AA

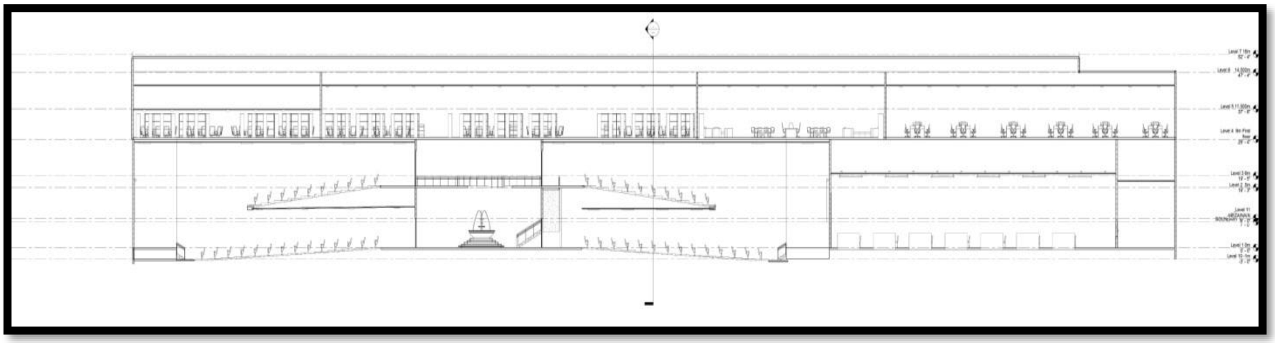


Figure 63: Section-AA building [57]

SECTION BB

Figure 64: Section-BB of building [57]

LEFT ELEVATION

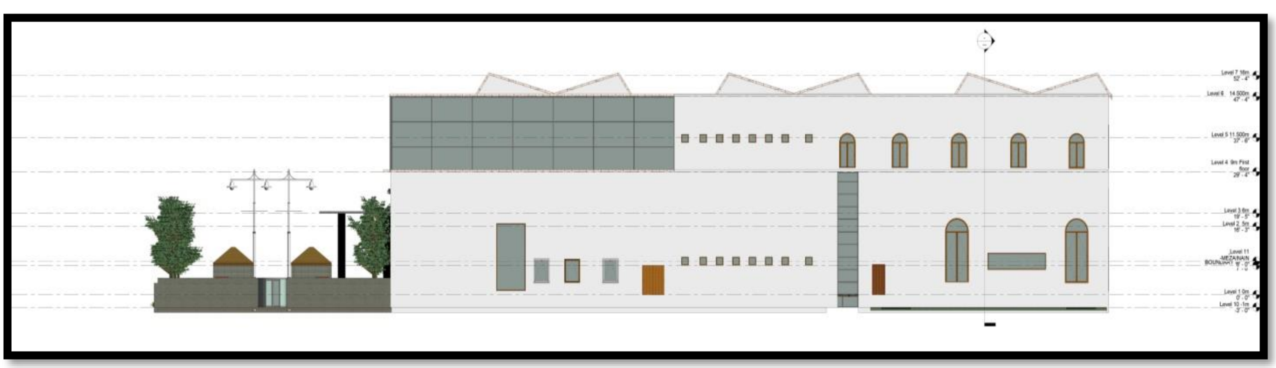


Figure 65: Left Elevation [57]

FRONT ELEVATION

Figure 66: Front Elevation of Building [57]

2.11 Views of Building after Rendering

The final phase in any architectural design of a project is to perform rendering which gives a clear look close to the reality, we use Autodesk cloud Rendering of project some external and internal views of building including lecture halls and auditorium are shown below.

Figure 67: Internal view of study hall [58]

Figure 68l: Internal view of library [58]

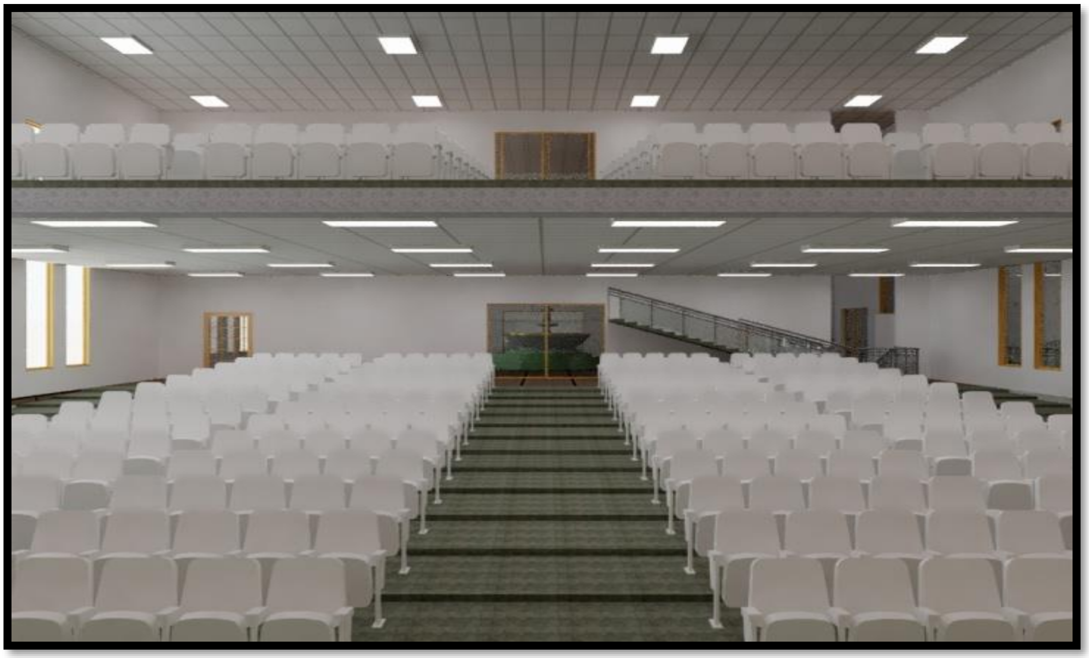


Figure 69: Internal view of Auditorium [58]

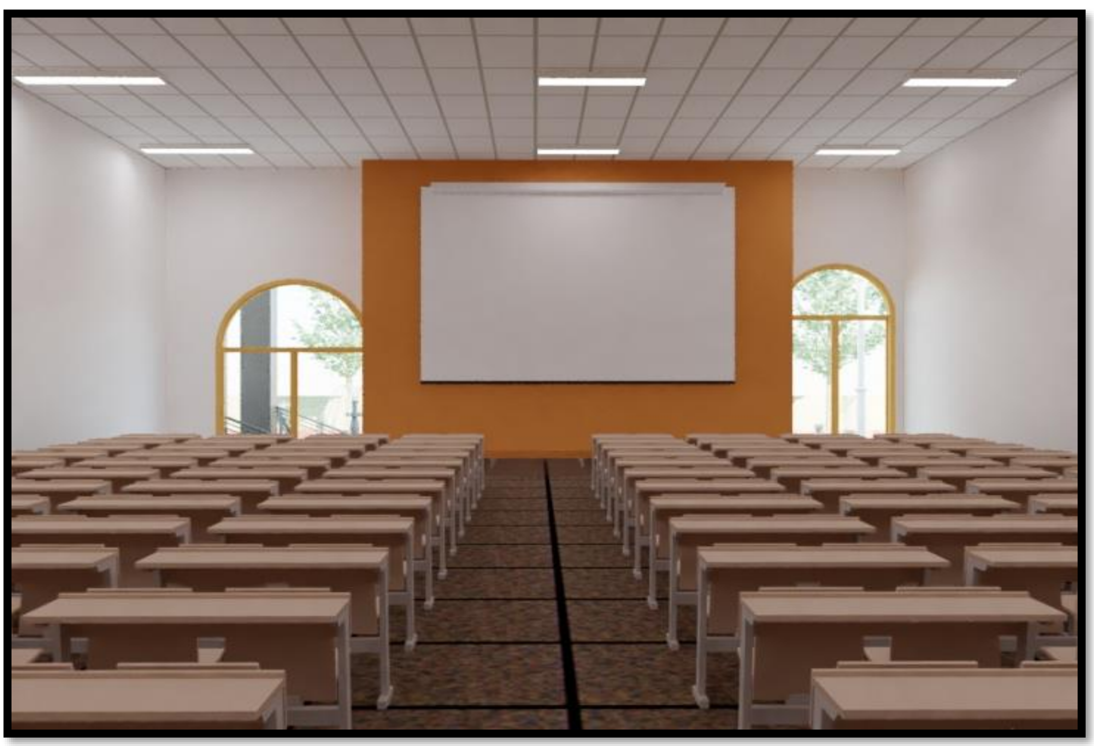


Figure 70: Internal view of lecture room [58]

The external 3D view of building after Rendering is show as below

Figure 71: External 3D view of building [58]

The detailed views of building after rendering and combined together in one file which can be assessed with the help of the below QR code.

Scan me!

Figure 72: QR code for Building views [59]

2.12 4D Time Analysis

We build a schedule for the entire construction project using 4D time analysis and management, which allows us to control the project timeline connected to the workload both in the preliminary and construction phases. This includes the execution of each and every individual task, which necessitates the allocation of sufficient time and careful preparation in terms of when the activity should begin and when it should end. The following are the fundamental concepts involved in the creation of 4D time analysis.

- I dentification of different activities involved in any construction project.
- Estimation of time duration for each and every individual activity that are involved in the project.
- Estimation and allocation of resources for the execution of the project's various operations.
- The most important is to identify the dependencies and the relation of different activities on one another.

By using the mechanical resources, the efficiency for the development of any activity will be estimated and the proper time duration will be calculated to perform the activity. The performance rate is usually taken on the bases of previous experience, literature, and back analysis of any similar projects.

"Construction means all human actions, including those undertaken with the help of or solely by plant and equipment, intended to produce or alter facilities" [60]

In any construction project we usually defined a set of different possible activates which has a specific start and finish date and time, the completion timeline of any construction project depends on these activities. In every construction project, project manager must organize these activities to control the timeline of project to successfully complete and handover it on agreed time.

Usually in any construction project the allocation of resources is arranged based on the activates of construction project that have to be performed on the required date and time, hence the basic purpose of construct management is to identify and improve the efficiency of work and allocation of resources for any activity.

Every construction project has different teams working for the same project but on different activates and for these activities there is necessity of individual for monitoring all these teams with proper supervision.

There is much software to simulate and monitor these activates the most common are Oracle Primavera P6, MS project, Autodesk Navisworks and many other.

"4D is a planning process to link the construction activities represented in time schedules with 3D models to develop a real-time graphical simulation of construction progress against time. Adding the 4th dimension 'Time' offers an opportunity to evaluate the buildability and workflow planning of a project. Project participants can effectively visualize, analyze, and communicate problems regarding sequential, spatial, and temporal aspects of construction progress. Consequently, much more robust schedules, and site layout and logistic plans can be generated to improve productivity."[61]

2.12.1 Scheduling of project using Microsoft project

MS Project is offered by Microsoft which is one of the common and very easy to use software, which allow users to organize every project and the sub activities in the project that must be completed in a specific time frame to finish the project within the deadline.

For the successful completion of any construction project the tool Microsoft Project play an important role because it permits its user to define work breakdown structure (WBS), in WBS we breakdown the whole construction project into small group of activities/tasks which must be completed on the defined timeline to control the deadlines, In order to have a better management of the project work as well as a better assessment of the real construction times, the progress of the project should be determined as the completion of a set of activities, and the real time for the project completion may be projected based on this estimate.

Microsoft Project allow users to identify the critical routs and the activities that can cause the possible delays for any construction, so construction manager should pay a special attention for those group of activities because if these activities are not performed on time, with delay of project these activities can also affect the project budget. Using this tool, it will be easy for the construction project manager to determine the time span for any cash inflow for starting the construction project.

The construction project has a start date; after that, a completion time will be anticipated for each activity/task based on usual performance and the sort of resources available. MS Project allows you to insert details about human and machine resources.

"BIM is largely associated with product design model, while construction specific work breakdown structure (WBS), or work package information, is not sufficiently represented or readily available in the BIM system for BIM – based activity – level construction scheduling".[62]

So, to create work breakdown structure (WBS) we will use Microsoft Project to divide the whole project into a series of activities to from start to end. To estimate the duration of each activity we considered 8 working hours in a day and 5 working days in a week so we have 40 working days in a week.

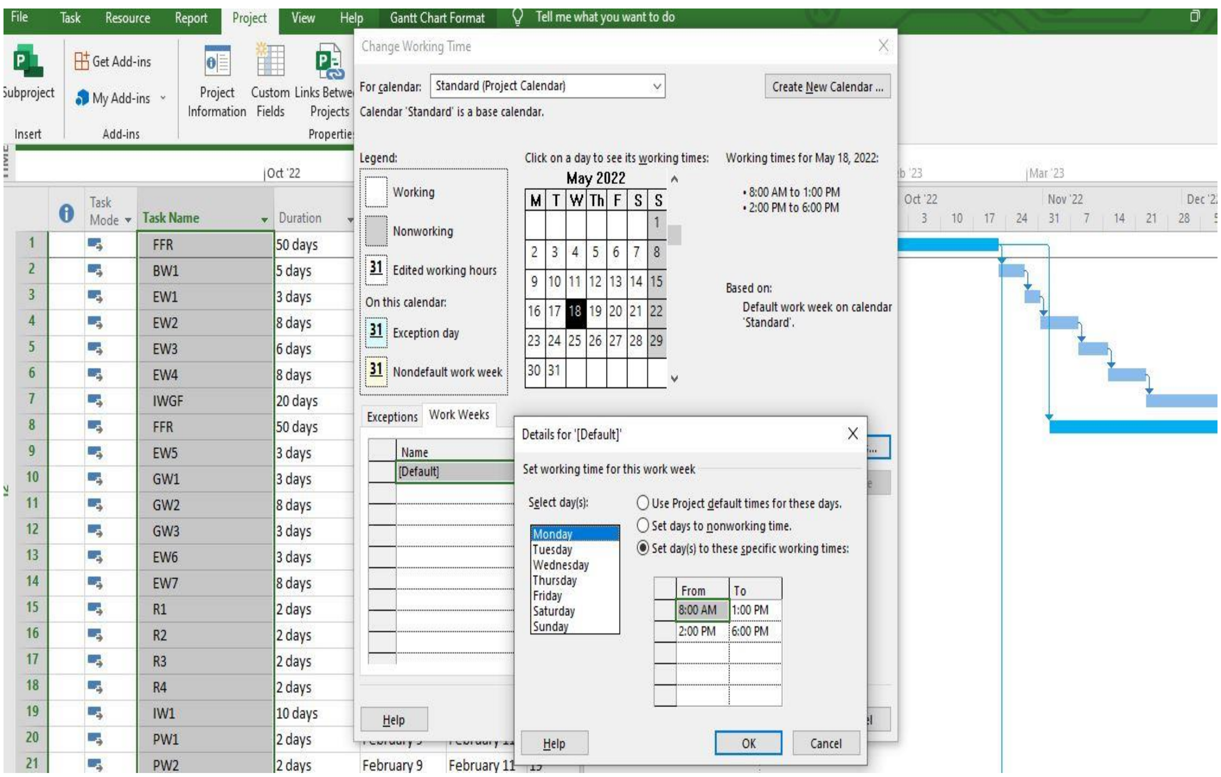
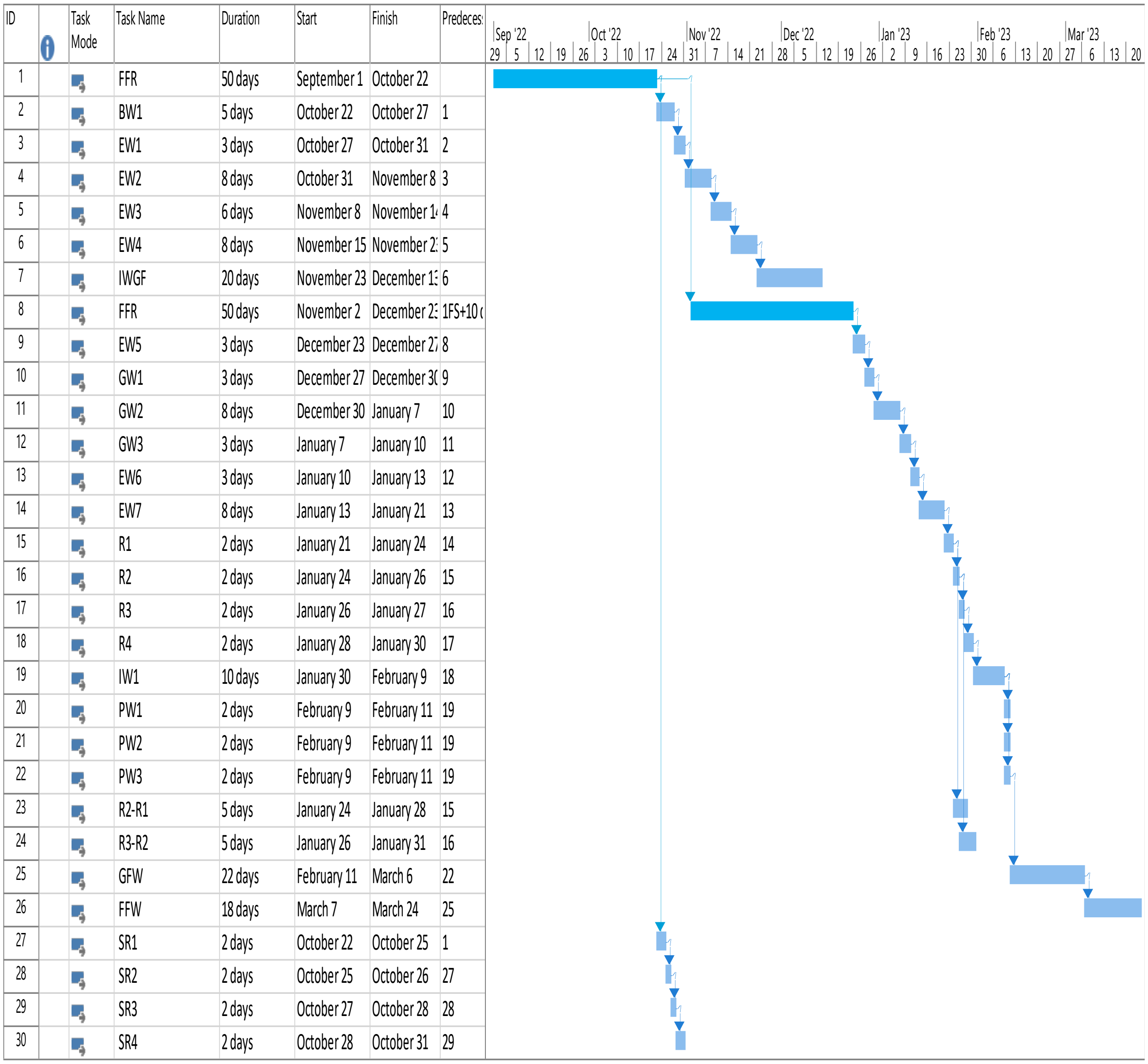


Figure 73: Setting of working hours & days in MS Project [63]

We can proceed to doing some planning analysis and then construct the Gantt chart after evaluating the durations of each single individual task, identifying the dependencies between the numerous activities, and allocating resources for the execution of each individual activity/task.



ID		Task Mode	Task Name	Duration	Start	Finish	Predeces
1			FFR	50 days	September 1	October 22	
2			BW1	5 days	October 22	October 27	1
3			EW1	3 days	October 27	October 31	2
4			EW2	8 days	October 31	November 8	3
5			EW3	6 days	November 8	November 1	4
6			EW4	8 days	November 15	November 2	5
7			IWGF	20 days	November 23	December 1	6
8			FFR	50 days	November 2	December 2	1FS+10
9			EW5	3 days	December 23	December 2	8
10			GW1	3 days	December 27	December 3	9
11			GW2	8 days	December 30	January 7	10
12			GW3	3 days	January 7	January 10	11
13			EW6	3 days	January 10	January 13	12
14			EW7	8 days	January 13	January 21	13
15			R1	2 days	January 21	January 24	14
16			R2	2 days	January 24	January 26	15
17			R3	2 days	January 26	January 27	16
18			R4	2 days	January 28	January 30	17
19			IW1	10 days	January 30	February 9	18
20			PW1	2 days	February 9	February 11	19
21			PW2	2 days	February 9	February 11	19
22			PW3	2 days	February 9	February 11	19
23			R2-R1	5 days	January 24	January 28	15
24			R3-R2	5 days	January 26	January 31	16
25			GFW	22 days	February 11	March 6	22
26			FFW	18 days	March 7	March 24	25
27			SR1	2 days	October 22	October 25	1
28			SR2	2 days	October 25	October 26	27
29			SR3	2 days	October 27	October 28	28
30			SR4	2 days	October 28	October 31	29

Figure 74: work breakdown structure (WBS) [63]

On the bases of the activities planned on Microsoft Project the duration of project is almost 204 days considering 8 working hours per day from 8 am to 6 pm in evening.

2.12.2 Defining Project parameters on Revit

One of the most important tasks in 4D Time analyses and simulation is to create project parameters which will help us to link the Autodesk Revit model with the work breakdown structure (WBS) created in Microsoft Project when we import both Revit model and WBS in Autodesk Naviswork for simulation, because in Autodesk Navisworks we will apply filter to identify different building elements for simulation.

So, there should be a unique ID or name for each element, and it should be the with the same name as a task or activity in Microsoft Project in this way if we apply filter in Autodesk Navisworks, it will automatically pick the same element from Revit model and the same activity from work breakdown structure (WBS).

To perform this activity, we have to first define a unique name for each building element in Revit, to do this job in Revit we create shared parameters with new group and ID as shown in the below picture from Revit.

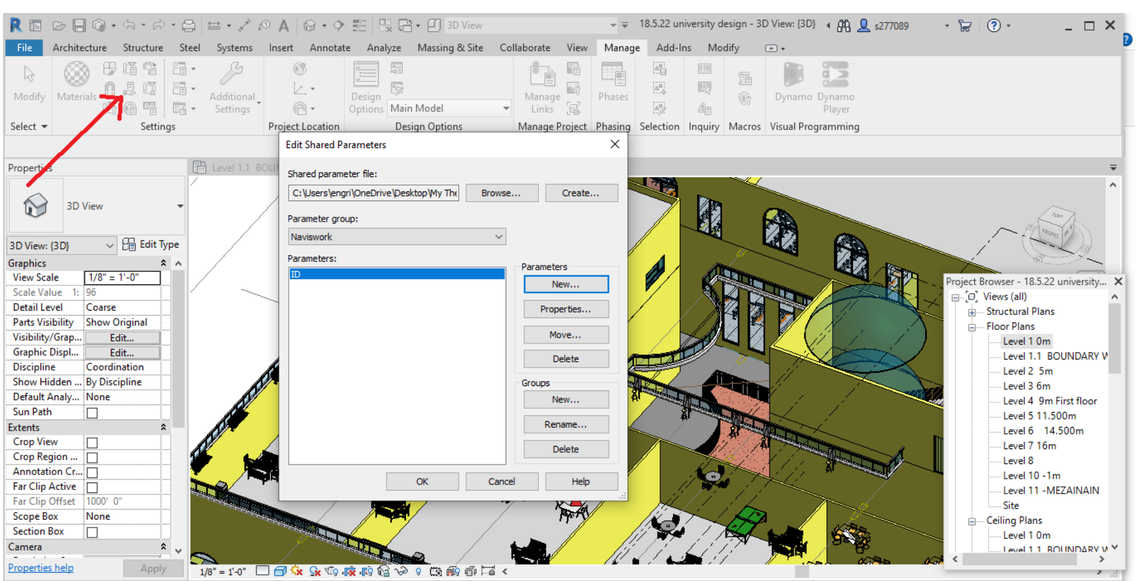


Figure 75: Creating Shared parameters [64]

After creating groups for shared parameters, we than go to project parameters to define the properties of parameters like categories and type.

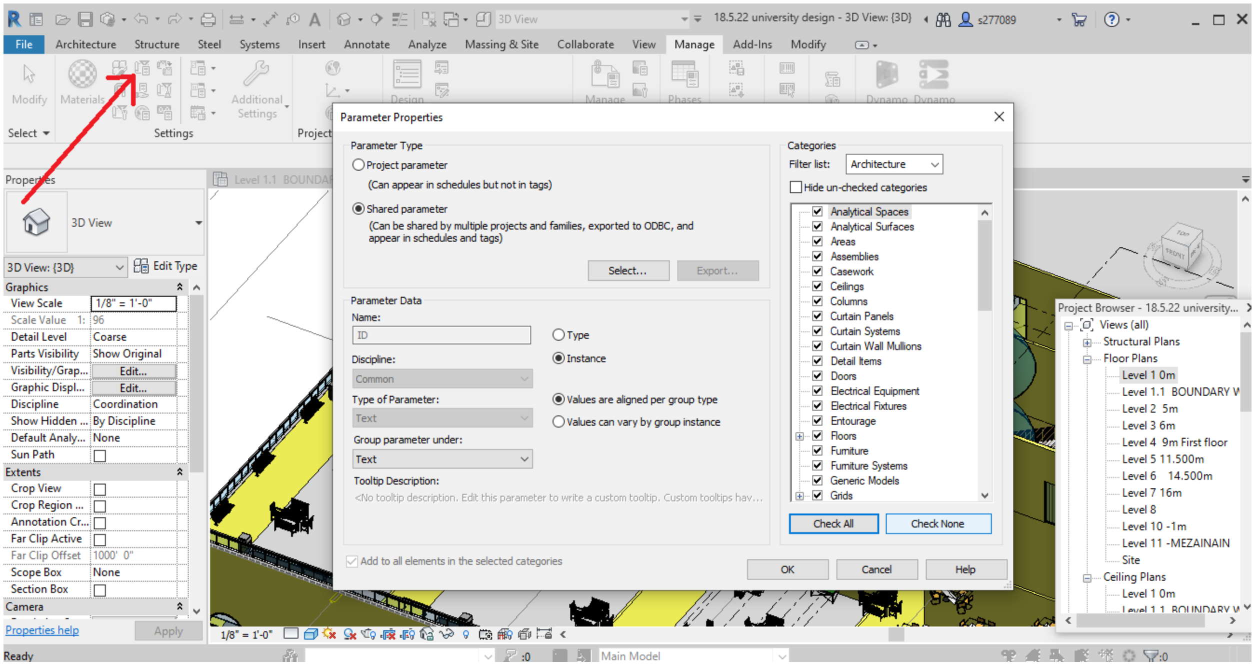


Figure 76: Project parameters setting [64]

Once we finished creating shared project parameters and give a specific name and ID for each and every element in the building project, we can now import this Autodesk Revit 2020 model in Autodesk Navisworks to create a simulation and see how the project will be completed in real time. As both Autodesk Revit and Autodesk Navisworks belong to same company or family of software so there is a good Interoperability between these two different software and we will not lose any data while importing the project model from Autodesk Revit to Autodesk Navisworks.

2.12.3 4D simulation on Autodesk Navisworks

Navisworks comes into play in view of the opening of the construction site, in fact, it deals with the coordination, analysis and planning of construction times and costs, in a BIM environment. Navisworks allows you to collect in a single project data and BIM models from all the most popular applications, both from Autodesk and from its competitors, from Civil 3D to Microstation, ArchiCAD to Revit, 3ds Max to Inventor, Rhino to SolidWorks, etc. In this way it allows you to check numerous aspects of a complex project in one fell swoop , which many designers may have worked on, using different software.

Secondly, we have the possibility to carry out an accurate control of the interferences of any building elements (clash detection), very important to identify the problems in the design phase. Thus, avoiding waste of time and additional costs due to the need to remedy an interference when one is on the construction site.

Navisworks is available as a single product, in two versions: Simulate and Manage, which adds interference checking and other advanced features. It is also contained in some Autodesk Suites, such as the Infrastructure Design Suite and the Building Design Suite. Premium versions contain Navisworks Simulate; Ultimate versions contain Navisworks Manage.[65]

To carry out the 4D simulation in Autodesk Navisworks we need to import BIM model from Autodesk Revit and work breakdown structure (WBS) from MS Project to import BIM model from Revit for this we have “External Tools” option on Revit from this tool will convert BIM model into Navisworks Switchback 2020 and then with the help of export option we can export the file as .nwc (NWC) which we can easily import into Autodesk Navisworks.

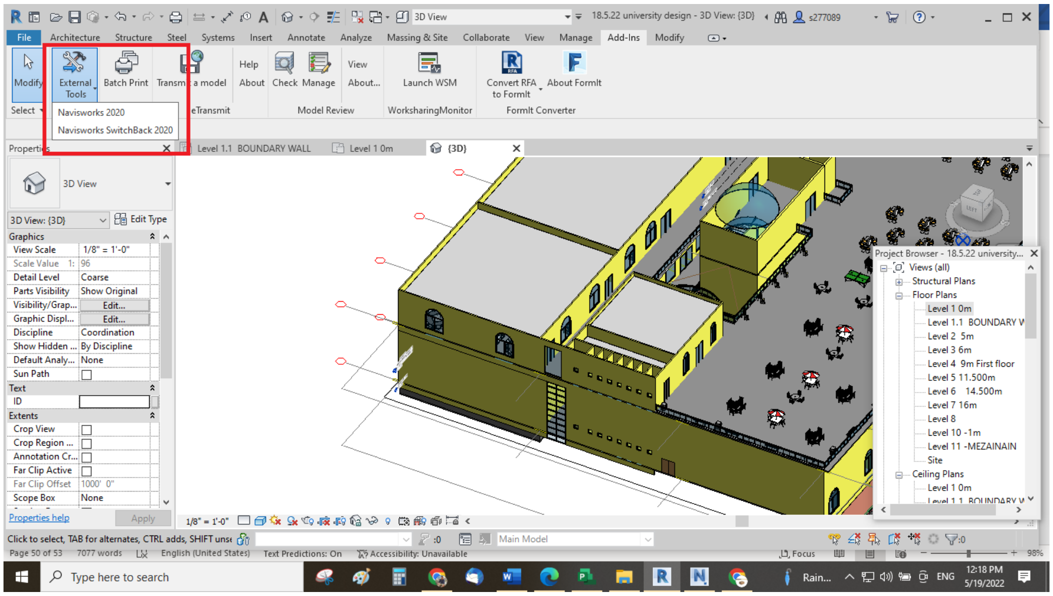


Figure 77: Export .rwt file from Revit to .nwc Navisworks [64]

To import the shared parameters from Autodesk Revit to Autodesk Naviswork we have to be careful about interpretability while exporting model, we should export the BIM model as .nwc format and change the setting as shown in the below figure.

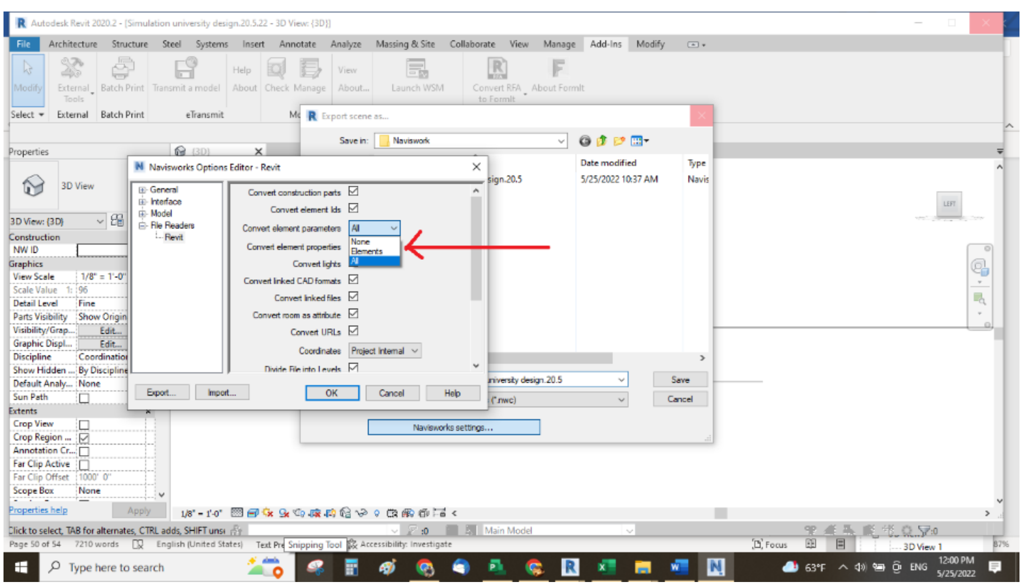


Figure 78: Export BIM model as .nwc file format [64]

Once we import BIM model from Autodesk Revit to Autodesk Naviswork the next task is to find all those elements which we defined on Autodesk Naviswork, to perform this task on Naviswork there is an option of "find items" by using this tool we will find all the items and save them with their unique IDs.

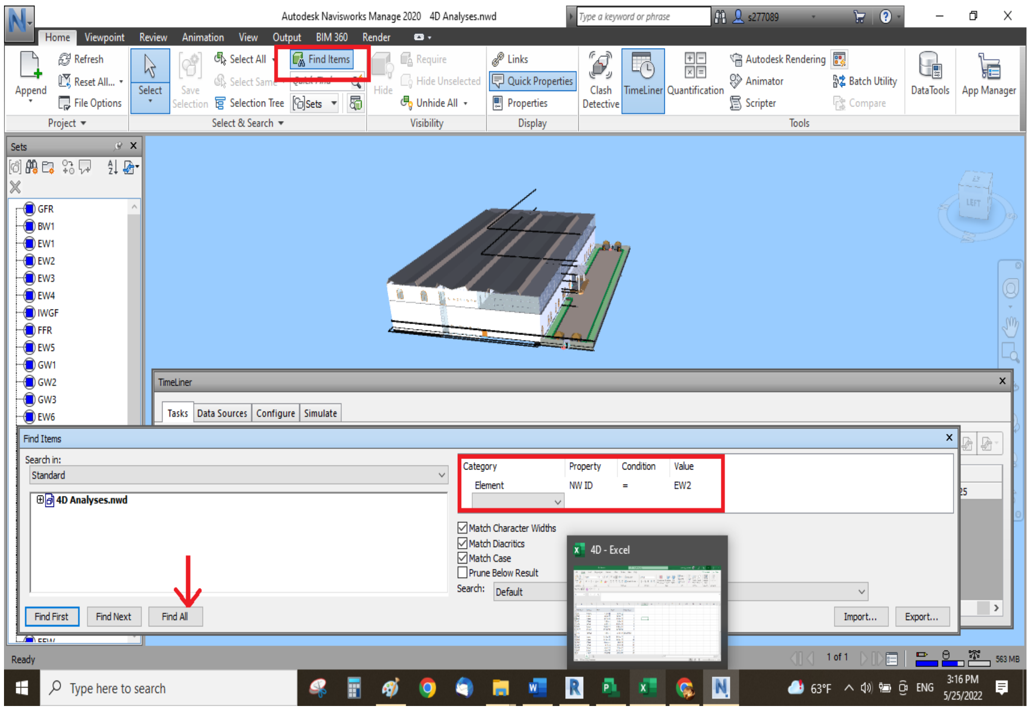


Figure 79: Find Elements tool in Navisworks [66]

To import thee work breakdown structure (WBS) which we generated on MS Project we first save the WBS in .csv file format because it is more easy to import .csv file format in Autodesk Navisworks, so from Data sources option in TimeLiner we import .csv file and "Rebuild Task Hierarchy", now both BIM model and work breakdown structure are ready in Navisworks but the problem is that the WBS is not connected with the BIM model so first we have to connect them, for this purpose there is a tool called "Auto-Attach Using Rules" in which we apply rules to automatically attach BIM model with work breakdown structure WBS with in which we *Map TimeLiner Tasks from Column Name to Selection Sets with the same name, Matching case.*

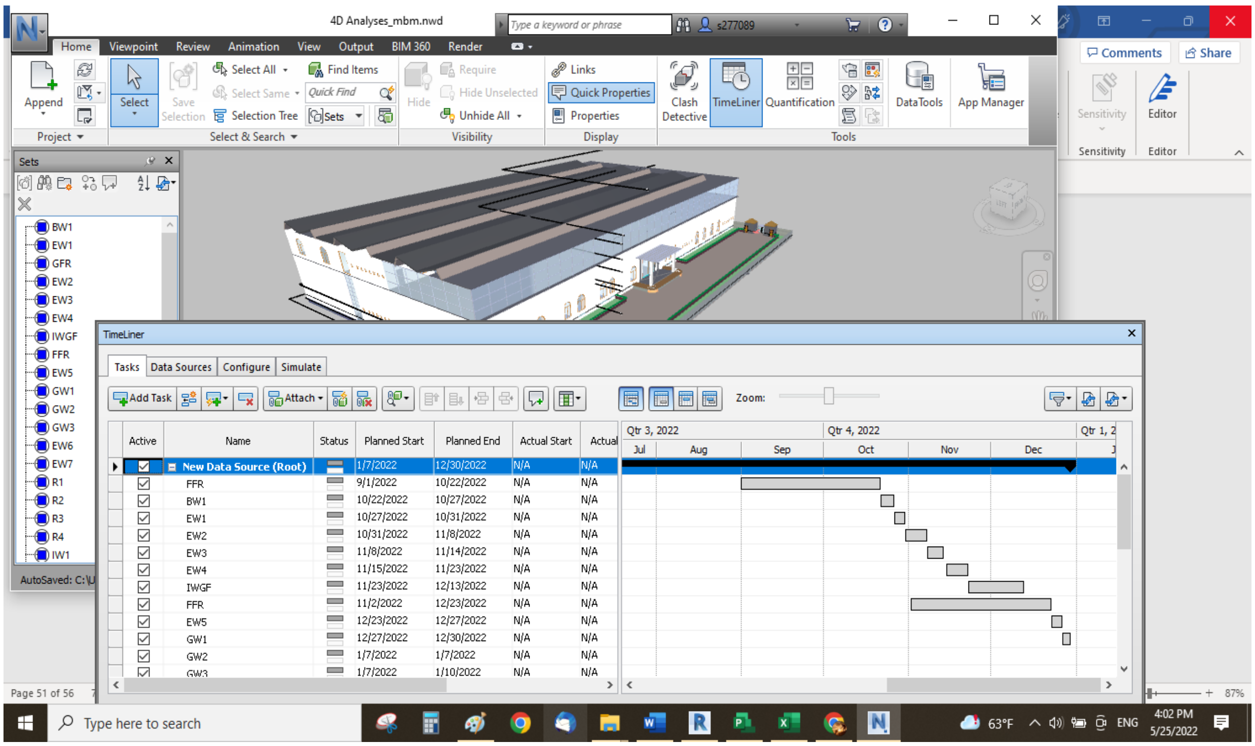


Figure 80: Auto-Attach Rules in Navisworks [66]

After attaching BIM model with work breakdown structure (WBS) now we are able to run the simulation video which will show us the step by step activates performed during the construction phase of the project it will also give us the total time of construction according to the WBS which we created on MS project the total time of construction of the project was estimated as 198 hours considering that there is no delays during the construction period, we assume the standard working time of 8 hours per day from 8:00 am in morning 5:00 pm in evening including 1 hour of break in afternoon.

2.12.4 4D Simulation video

Some pictures of simulation are mentioned below which shows the construction of project at different stages.

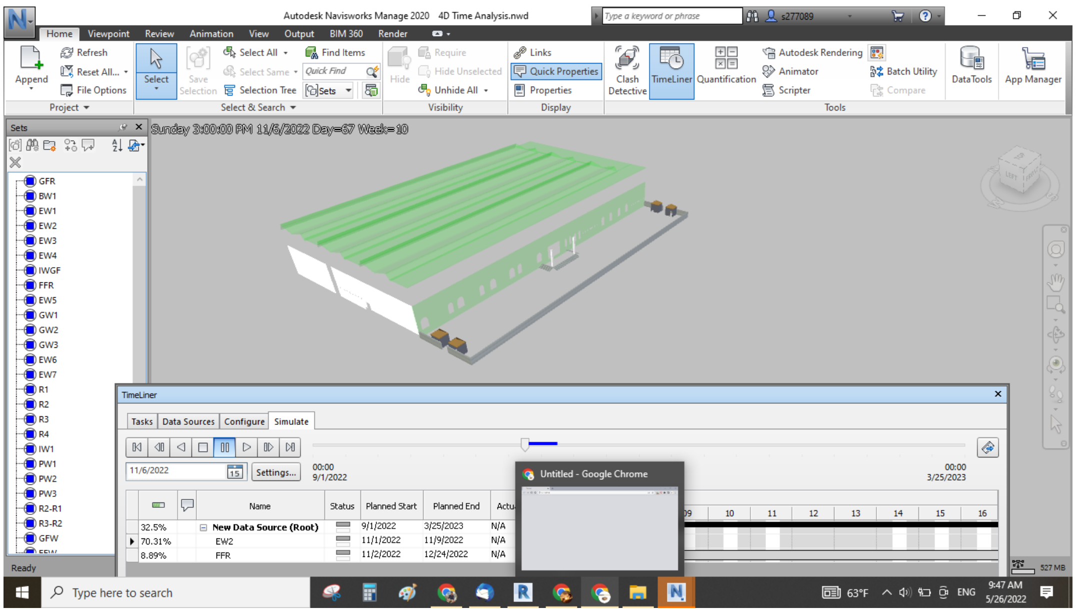


Figure 81: 4D simulation during construction of ground floor [66]

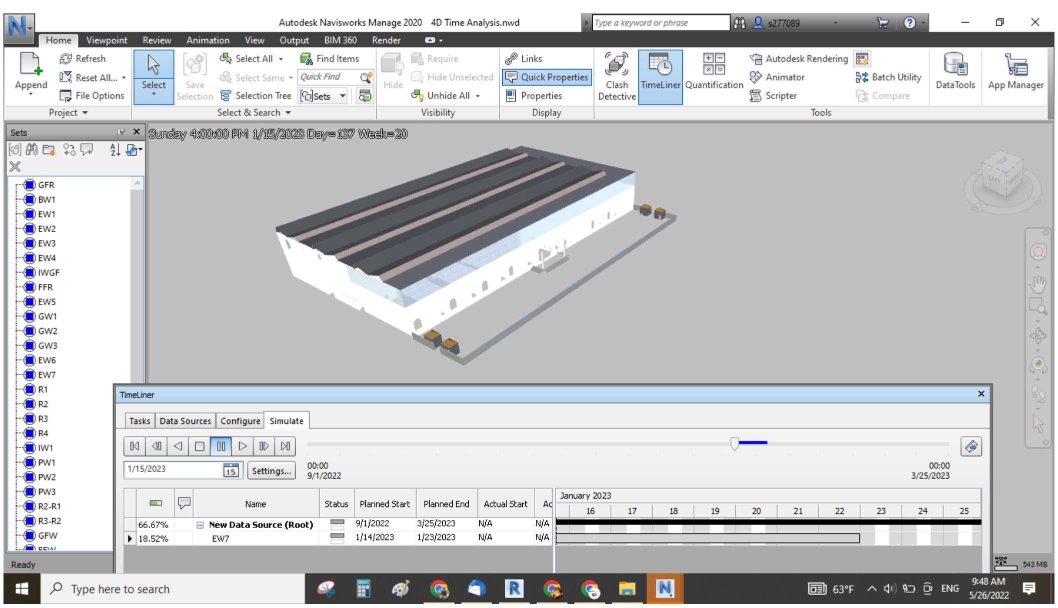


Figure 82: 4D simulation during construction of first floor [66]

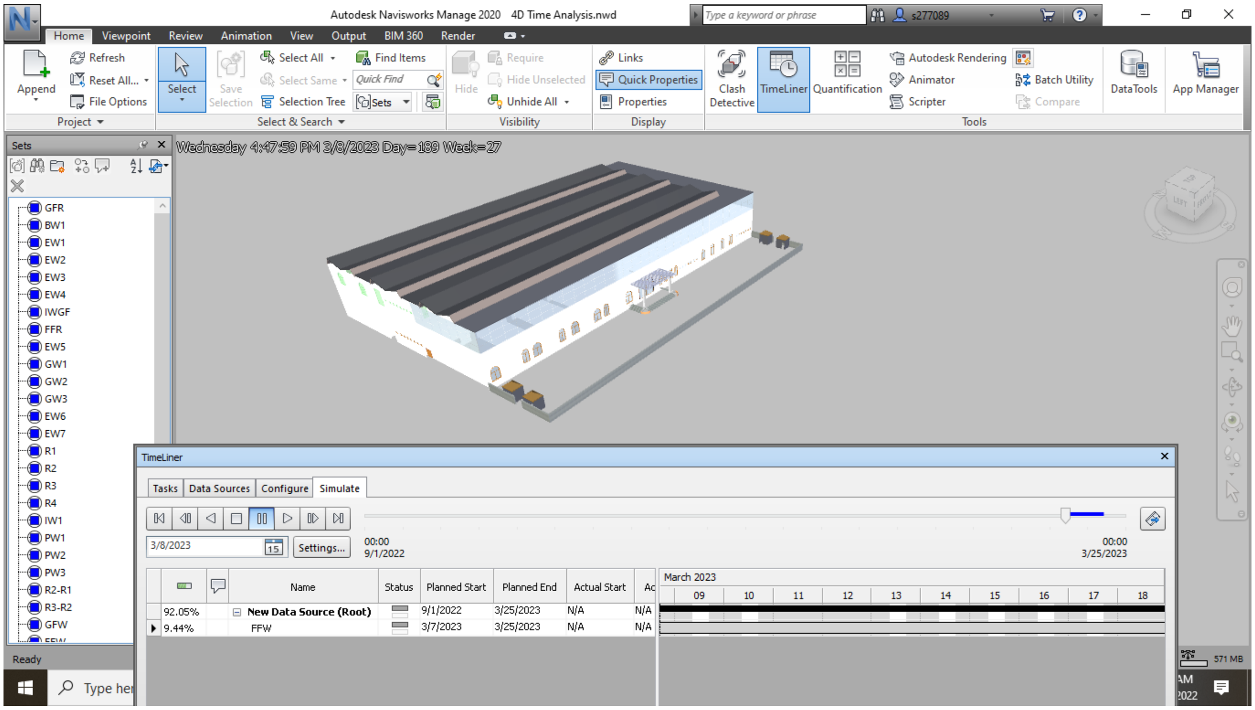


Figure 83: 4D simulation during construction of windows and door [66]

The complete video of 4D time analysis and the video simulation on Autodesk Navisworks 2020 can be watched by scanning the below QR code

Figure 84: Video simulation on Navisworks [67]

3- Conclusion and Results

- The 3D BIM model of existing steel structure of FCA Mirafiori is created on Autodesk Revit 2020, the level of details in this stage was LOD 400.
- After creating BIM model, it was decided to convert the old existing building structure into university campus for the use of Politecnico Di Torino, so we had to propose a feasible architectural plan to fully utilize the space.
- We decided to provide a RCC slab of 20 cm at level of 9m to divide the existing building structure into 2 floors, ground floor for lecture halls auditoriums and Mensa service and first floor for library, labs and study area.
- In ground floor we designed 5 lecture halls having capacity of around 100 students in each lecture hall and 2 auditoriums having capacity of around 200students in each auditorium.
- An intermediate reinforced concrete slab of 30cm is provided to fully utilize the height of auditoriums which helps us to increase the capacity of students to almost 200 in each.
- On the first floor we provided a computer lab, library and an open area for general setting which can be utilize as study area.
- After architectural modeling we use Autodesk cloud Rendering for the final Rendering of model.
- For the management purpose, Microsoft project was used to create work breakdown structure (WBS) according to which we will be able to finish the project in 198 days considering the normal conditions.
- Navisworks was used to for simulation of 4D time analysis to simulate the activates performed during the construction stages.

4- References

[01] BIM in current and Future Practice (Karen kensek, Douglas Noble 2014)

[02] https://www.ceramica.info/en/articoli/bim-disciplinary-model-ceramic-tiles/

[03] BIM and Construction Management (Brand Hardin, Dave McCool 2015)

[04] https://blogs.opentext.com/why-level-3-building-information-modeling-is-about-to-change-everything/

[05] https://new.siemens.com/it/it/prodotti/buildingtechnologies/digitalizzazione/bim.html

[06] Construction Manager's BIM Handbook (John Eynon, 2016)

[07] Building Information Modeling Two Years Later 2007 https://bimingargentina.wordpress.com/2007/01/06/building-information-modeling-two-years-later/#more-545

[08] https://www.cadtobim.com/what-is-bim.html

[09] https://www.cadtobim.com/what-is-bim.html

[10] Building Information Modeling Two Years Later Huge Potential, Some Success, and Several Limitations (Ian Howell and Bob Batcheler 2007) https://bimingargentina.wordpress.com/2007/01/06/building-information-modeling-two-years-later/#more-545

[11] BIM Interoperability

[12] https://blog.buildingsmart.org/blog/importantifc (The importance of IFC in BIM, Oliver Wheeler, 2020)

[13] https://blog.buildingsmart.org/blog/importantifc (The importance of IFC in BIM, Oliver Wheeler, 2020)

[14] New opportunities for AEC industry (Prof. Anna Osello)

[15] The British Standards Institution (2007) BS 1192:2007, collaborative production of architectural, engineering, and construction information code of practice UK

[16] BIM and CDE in Design and Construction of London Crossrail https://www.e-zigurat.com/blog/en/bim-cde-design-construction-london-crossrail/

[17] BIM-Based Collaborative Building Process Management (Bruno Daniotti 2019)

[18] BIM-Based Collaborative Building Process Management (Bruno Daniotti 2019)

[19] I LOD in UNI 11337: 2017 (https://www.ingenio-web.it/6590-i-lod-nella-uni-113372017)

[20] LOD Lorenzo Nissim 2015 (https://www.ibimi.it/lod-livello-di-dettaglio-per-il-bim/)

[21] LOD Lorenzo Nissim 2015 (https://www.ibimi.it/lod-livello-di-dettaglio-per-il-bim/)

[22] https://www.google.com/maps/search/fca+mirafiori/@45.0300552,7.6185345,13z (Google Map)

[23] https://www.fcagroup.com/en-US/group/regions/emea/Pages/centro_storico.aspx

[24] https://en.wikipedia.org/wiki/Fiat_Mirafiori

[25] https://en.wikipedia.org/wiki/Fiat_Mirafiori

[26] Workflow Diagram on methodology (own design)

[27] https://blogs.autodesk.com/revit/2019/04/10/youve-got-to-see-whats-new-in-revit-2020/

[28] AutoCAD drawing of an existing building. (Available data)

[29] AutoCAD drawing of an existing building.

[30] AutoCAD drawing of an existing building. (Provided CAD drawings)

[31] AutoCAD drawing of an existing building.

[32] AutoCAD drawing of an existing building.

[33] Main entrance of building (Image taken during site visit)

[34] Internal view of building (image taken during site visit)

[35] Image of building roof trusses (image take during site visit)

[36] Different family templates available on Revit 2020 (BIM 3D model from Autodesk Revit 2020)

[37] 2D plan and 3D view of column family 1 (source: BIM model in Autodesk Revit 2020)

[38] 2D plan and 3D view of column family 2 (3D BIM model Revit 20020)

[39] 2D plan with 3D view of column family 3 (source: BIM model in Autodesk Revit 2020)

[40] 2D template and 3D view of column family 4 (source: BIM model on Autodesk Revit 2020)

[41] 2D plan and 3D view of column family 5 (source: BIM model Revit 2020)

[42] 2D template and 3D view of column family 6 (source: BIM model from Autodesk Revit 2020)

[43] Template created for roof truss (source: 3D BIM model on Autodesk Revit 2020)

[44] 3D view of roof truss placed on the building structure (source: BIM model on Autodesk Revit 2020)

[45] Family template created for roof truss (source: BIM 3D model on Revit)

[46] 3D view of truss placed on building structure (source: 3D model on Revit 2020)

[47] BIM model with columns (source: 3D BIM model on Autodesk Revit 2020)

[48] 3D view of building structure with floor (source: 3D BIM model on Autodesk Revit 2020)

[49] BIM model of existing structure (source: 3D BIM model on Autodesk Revit 2020)

[50] Architectural project phases – courtesy of HMH Architecture + Interiors. (2014)

[51] https://en.wikipedia.org/wiki/Architecture

[52] https://www.google.com/url?sa=i& (Architecture In graphics)

[53] Summary of the Required spaces for university campus (own sketches)

[54] Conceptual sketches image (own sketches)

[55] Own model Autodesk AutoCAD

[56] BIM 3D Model on Autodesk Revit (own model)

[57] 3D planning of building on Autodesk Revit.

[58] Different views of Building created on Autodesk Cloud Rendering

[59] QR code to see the PDF file of building views after Rendering.

[60] Radosavljevic & Bennett, 2012

[61] Kameedan, 2010, p.285 (Smith,2007)

[62] Liu, Al-Hussein, & Lu, 2015

[63] Work breakdown structure on Microsoft project

[64] 3D BIM model on Autodesk Naviswork (Own work)

[65] https://www.gisinfrastrutture.it/2015/09/conosci-autodesk-navisworks/ (GimmiGIS in BIM for Infrastructures , Civil 3D , ENI , Linea 2016 , Prog. Road)

[66] 4D analysis on Autodesk Navisworks (own model time dependent model)

[67] QR code generated on GRFI https://www.qrfy.mobi/my-qr-codes/qr/90710