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4D/5D Building Information Modelling; How to create an integrated model

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Muhammad Irfan Ghani

SOMMARIO

L'adozione della metodologia Building Information Modeling (BIM) nelle pratiche di ingegneria civile consente l'ottimizzazione della progettazione attraverso un maggiore controllo su tutte le componenti del progetto e un aumento dell'efficacia del lavoro di squadra tra tutti gli esperti coinvolti. Le variabili di tempo e di costo sono i due parametri più importanti nel processo di progettazione, in particolare nella progettazione delle infrastrutture, e le loro definizioni sono spesso oggetto di dibattito politico. Tenere conto delle variabili di tempo e di costo in un progetto significa risolvere problemi tecnici tipici cercando di trovare la soluzione migliore in termini di efficienza ed efficacia. L'ottimo si ottiene quando il risultato del progetto massimizza la qualità e l'efficacia della soluzione e riduce al minimo i tempi e i costi di esecuzione. Building Information Modeling offre il potenziale per raggiungere questi obiettivi soprattutto dopo lo sviluppo e l'uso di software che fornisce modelli n-dimensionali per simulare la pianificazione, la progettazione, la costruzione e il funzionamento di una struttura. In questa ricerca, l'obiettivo principale era trovare la corretta metodologia per realizzare il modello integrato 4D / 5D BIM. A tale scopo, in Autodesk Revit è stato creato un modello 3D composto da disciplina architettonica e strutturale. I modelli sono stati quindi importati in Autodesk Navisworks per l'analisi del rilevamento delle interferenze. Per ottenere il 4D/5D, i modelli 3D privi di scontri sono stati importati in STR Vision CPM utilizzando il formato IFC. I modelli federati sono stati utilizzati per il computo delle quantità e l'analisi dei costi. Le quantità analizzate sono state quindi collegate alla schedulazione per ottenere la piena integrazione dei modelli. Si è concluso che STR Vision si è rivelato uno strumento molto potente per la definizione di un modello dinamico in grado di consentire di reiterare qualsiasi modifica apportata al modello, risparmiando così tempo e costi.

Parole chiave: (BIM, IFC, Modello BIM integrato, Prelievi quantitativi, 4D/5D)

ABSTRACT

The adoption of the Building Information Modelling (BIM) methodology in civil engineering practices enables design optimization through greater control over all project components and a boost in the effectiveness of teamwork among all experts involved. Time and cost variables are the two most important parameters in the design process, especially in infrastructure design, and their definitions are often the subject of political debate. Taking time and cost variables into account in a project means solving typical technical problems by trying to find the best solution in terms of efficiency and effectiveness. Optimal is achieved when the outcome of the project maximizes the quality and effectiveness of the solution and minimizes the time and cost of execution. Building Information Modelling offers the potential to achieve this goals especially after the development and use of software that provides n-dimensional models to simulate the planning, design, construction and operation of a facilty. In this research, the key focus was to find the correct methodology for achieving the 4D/5D BIM integrated model. For this purpose, a 3D model was created in Autodesk Revit consisting of architectural and structural discipline. The models were then imported into Autodesk Navisworks for clash detection analysis. To achieve the 4D/5D, the 3D models free from clashes were imported into STR Vision CPM using IFC format. Federated models were used for quantity take-off and cost analysis. Analysed quantities were then linked with scheduling to achieve the full integration of models. It was concluded that STR Vision proved a very powerful tool for defining a dynamic model that can permit to reiterate any modification made to the model thus saving cost and time.

Keywords: (BIM, Integrated BIM model, IFC, Quantity take-offs, 4D/5D)

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1 INTRODUCTION

1.1 Problem Overview

The Architecture, Engineering and Construction (AEC) industry has been seeking techniques to reduce project costs, increase efficiency, productivity, and quality, and shorten project duration. Building Information Modelling (BIM) offers the potential to achieve these goals. BIM represents the development and use of computer-generated n-dimensional (n-D) models to simulate the planning, design, construction, and operation of a facility. It helps architects, engineers, and builders to visualize what is to be built in a simulated environment and identify potential problems in design, construction, or operation. BIM represents a new paradigm within AEC that promotes integration of the roles of all parties involved in a project. It has the potential to create both great efficiencies and harmony among stakeholders who, all too often in the past, saw each other as adversaries.

Time and cost variables are the two most important parameters in the design process, especially in infrastructure design, and their definitions are often the subject of political debate. Taking time and cost variables into account in a project means solving typical technical problems by trying to find the best solution in terms of efficiency and effectiveness. Optimal is achieved when the outcome of the project maximizes the quality and effectiveness of the solution and minimizes the time and cost of execution [1]. Simply, 4D is an extension of a 3D model. Clients can visualize the entire construction process, its milestones and virtually analyze the progress of construction activities before and during the project. Using existing BIM models and sequential designs, clients can simulate construction activities, identify collision and interference issues, track project logistics, and more. BIM models can be live linked to generate accurate quantity estimates, and costs of each building component using 5D cost estimation [2]. 5D BIM is a five-dimensional visualization of a project that consists of budget and cost considerations related to the project. 3D is a three-dimensional representation of geometry and design parameters, but 5D BIM allows stakeholders to understand, analyse, discover, and record the impact of changes on project costs [3]. Estimates for each component or service are attached to the BIM model, allowing estimators to extract detailed and accurate cost information from the BIM model [2]. The 5D helps contractors to visualize risk early and improve decision making process for the project success. The benefits of 5D BIM are enormous such as accurate cost estimation and forecasting, detailed quantity take offs, real time change to quantity take-offs as per design modification, faster decision-making process, improved collaboration among stake holders, assistant in swift material procurements. However, there are certain limitation in 4D-5D BIM modelling, such as, unstructured information in BIM model, unstructured information in scheduling program, difference in granularity of scheduling and BIM models, lack of 4D cycle concept, lack of single software solution for 5D implementation, high cost of implementation, change management, increased risk exposure and incompatibility with industry standards cost planning formats [2] [3].

Practically speaking, optimizing the infrastructure design process entails an iterative procedure that begins with the proper design process, enables the correct quantity of take-offs, and establishes an efficient schedule. Quantity surveys and time schedules are strongly connected to the initial design hypothesis in a one-way dialogue regarding the creation of the later phases in the conventional design approach. As a result, any change to the timetable may not necessarily reflect a change in the design specifications or quantity take-offs. A solution to these problems has been attempted in this work. To do this, a dynamic model that can incorporate time and cost variables into a bidirectional model and simultaneously update the parameters of the appropriate design model, quantity take-offs, and the timeline is provided. The proposed model is based on commercially accessible tools that are used to direct the design process toward the project's optimization.

1.2 Objectives of the project

The main objective of this project is to demonstratre the correct path for creating a valid 3D/4D/5D integrated model through BIM technical methods for a good plan of time and cost. Starting from a 3D model, it was demonstrate that in a correct BIM method, it is important to start from a parametric QTO and resource analysis to create a valid 4D/5D model. The process will be achieved in the following way;

a) Creating a 3D model uisng Revit
b) Federation of Architectural and Structural Model in Revit
c) Incorporating Schedules into 3D BIM model in Team System Software CPM
d) Creating 5D model by integrating the cost estimates into 4D BIM model.

1.3 Organization of thesis

Apart from the current chapter , this disserattion has furtehr three chapters that are breifly described as: Chapter 2, focuses on the literature review of model fedration and 4D-5D BIM integrated model. An overview of the previous researches has been presented. Chapter 3 is regarding the proposal of the framework for the correct path of 3D/4D/5D integrated model through BIM technical methods. This chapter includes a case study of four story building consistings of archetectural and structural deciplines. Chapter 4 shows the conclusions of the work, summarizing the main findings of the conducted work, as well as pinpointing some perspectives for future research. Finally, Appendices are presented at the end of the thesis.

2 Integrated BIM Model-Overview

2.1 Introduction

This chapter includes an overview of Building information Modelling in AEC industry, its benefits, limitations, dimensions, level of details required for BIM model, factors affecting project delivery, resource analysis, parametric quantity take offs, work break down structures (WBS), modelling tools and clashes that arises in the federated model. Also, at the end of this chapter different classifications used for 3D BIM model has been explained.

2.2 BIM in AEC Industry

Building Information Modelling is one of the most auspicious developments in the Architectural, Engineering, and Construction (AEC) Industry. It simulates the construction project in a virtual environment. The virtual model constructed with BIM technology contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities to realize the building [4]. The idea of "virtual building" suggests that the project can be tested, experimented with, and changed before it is completed. Virtual errors typically don't have major repercussions if they are discovered and dealt with early enough that they may be avoided throughout the project's actual construction [5]. There are several different kinds of information or data that may be produced from a building information model, including specifications, cost data, scope data, and schedules [6].

BIM is a collaborative concept that uses coordinated and streamlined software in various formats from 3D to 7D to increase efficiency and reduce time and cost in all phases of construction. Autodesk, the developer of various BIM software, defines BIM as “An intelligent 3D model-based process that helps architectures, engineers, contractors and other AEC industry professionals the insight and tools to effectively plan, design, collaborate, construct, and manage buildings and infrastructure [7]. It is a computer-aided technology for managing the information of a construction process focusing on communication, production, and analysis of building information models [7] [8]. In the past alot of discussion have been made on the nature of BIM whether to classify it as a process, set of tools or a model.

According to Kymmel [5] , a building information model is a computer-generated depiction of a building that may include all the data necessary to construct the building. In general, the phrase refers to both the model(s) that represent the project's physical properties and all the information that is both inside and related to each component of the model. However, Eastman et al. [8] asserted that BIM is merely a piece of software or a tool. Building information modeling is described in its context as a modeling technique and related set of procedures for creating, exchanging, and analyzing building models. Hardin [9], decsribes building information as a process and software that agrees with Eastman et.al. [8] and not merely a tool. The 2D, 3D, 4D (time elementscheduling), 5D (cost information), or nD (energy, sustainability, facilities management, etc.) representations of a project may be included in part or in full in a BIM. Building information modeling is then defined as a tool that could aid the team in accomplishing project goals; the BIM itself, however, shouldn't be the ultimate objective because it is only a tool. The act of producing and/or utilizing a BIM is referred to as building information modeling in this context [5]. A building's performance, its planning, its construction, and later on its operation are all described in digital, machine-readable documentation, which is referred to as "building information modeling" in tools, processes, and technologies. BIM thus describes a process rather than a thing. Building information models, on the other hand, are the output of modeling activities in this context and are further defined as digital, machine-readable records of a building's performance, planning, construction, and later operation [6].

A number of implementation challenges that hinder the process of building information modeling, including the following [6]:

a) BIM standards are not clearly specified.
b) There is no proper way for the various BIM products to communicate with one another.
c) New methods of team collaboration require new definitions for individual responsibility and liability.
d) Collaborative digital models must have clear legal ownership.
e) For design team, increased in dimensional reponsibilties results in additional legal liabilities.
f) Speeded-up procedures shorten the time required for the standard “checks and balances”.
g) How does the new BIM process affect the design team's financial compensation?

In short, building information model is a data-rich, object-oriented, intelligent, and digital representation of a facility from which different views and data required by different users can be extracted and analyzed to generate information for decision making and improving the delivery process of the facility [10]. The creation of an object-oriented database, “a database made up of intelligent elements like representations of doors, windows, and walls”, is crucial because it enables the storage of both quantitative and qualitative data about the project. So, although a door is merely a collection of lines in a 2D CAD drawing, it is an intelligent object in BIM that has data about its size, cost, manufacturer, timetable, and more. However, BIM goes above and beyond by building a relational database. This implies that every piece of data in the BIM is connected, and every region and object that is impacted by a change in one object in the database is updated right away. For instance, if a wall is removed, all statistics about the project's scope, cost, and timeline are immediately modified. The same thing happens if doors and windows are removed from a wall [6]. Figure 1 below summarised the concept of building information modelling where each project participants will share a single source of information.

Figure 1: Conceptual Diagram to Describe the Building Information Modelling Concept [6]

2.3 Benefits of Using BIM

The benefits of BIM are numerous whether it is implemented standalone or collaborative application. Some of the major benefits of BIM found in literature are listed below;

a) The most obvious advantage of BIM is the enhancement of visualization through the use of 3D models [5] [6]. It is predicted that 98 percent of the industry cannot understand sketching [6]. Many people find it difficult to interpret 2D drawings. While the 3D model produced by the BIM software, is designed directly as opposed to being created from a number of 2D perspectives. Any stage of the process can utilize it to visualize the design with the expectation that it will be dimensionally consistent in every perspective [8]. The main advantage of 3D visualization is that both technical and non-technical workers can evaluate it rapidly. Due to clear understanding provided by visualisation, the project's overall Request for Information during project implementation get reduced [11].
b) BIM technology permits simaltanous work of multiple diciplines. Colloboration with drawings is certainly possible, but it is more challeng and time consuming compared to 3D coordinated models. As a result, the design process not only takes less time, having fewer mistakes and omissions by giving earlier insight into the problems but also provides the oppurtunity for design to be continously enhanced. This is much more cost effective than tradional method in which value engineering is applied after the major design decision has been made [8].
c) One of the most important benefit of BIM is the dsicovery of design flaws and ommision prior to construction. It elimates design flaws, brought on by inconsisitant 2D drawings becasue the virtual 3D model serves as the source for all 2D and 3D drawings. Additionally, multi-systems systems interface are easily comapred and verified both systematically for hard/soft clashes and visually for any other kind of errors. Conflicts are found prior to being noticed in the field. The coordination between participating designers and contractors is improved, and errors omission are greately reduced, which in turn speed off the construction

process, reduces cost, lessen the possibilty of legal conflicts and provide a smoother process for entire project teams [6] [8].

d) Another benefit of BIM is the synconization of design and construction planning. By incorporating scheduling into 3D models, the users can visualize the construction sequence of the proposed construction approach [12]. 4D models help to eliminate the errors before going into the site. It helps even the less experineced professionals to visualize how the building will be constructed day by day and identify the casues of potential problems and oppurtunities for its imporvement [6] [8].
e) BIM reduces the constrcution cost by quickly or in some cases automatically updating sections, plan views and quantity take offs [11].

2.4 Parametric Objects in BIM

To understand the concept of Building Information Modelling, the concept of parametric object is necessary to differentiate it from traditional 2D models [6] [8]. Parametric BIM object is defined as;

a) Consists of geometric description, associated information, and rules.
b) There is no room for discrepancies because geometry is incorporated non-redundantly. An object's shape cannot be internally redundantly represented when it is displayed in three dimensions, such as by using several two-dimensional views. It is required that an object's elevation and plan match exactly. Dimensions cannot be manipulated.
c) Parametric rules for objects automatically adapt the associated geometries when inserted into a building model or when changes are made to associated objects. For instance, a wall will automatically accommodate a door, a light switch will automatically locate next to the correct side of the door, a wall will adjust itself automatically resize itself to automatically fit to a ceiling or roof, etc.
d) Objects can be defined at various levels of aggregation, allowing the user to define both a wall and all its associated parts. Objects can be defined and managed at any hierarchical level. For instance, if any change happens to a wall subcomponent, the total weight of the wall should change accordingly.
e) Object rules can indicate whether a particular modification violates the viability of an object related to size, manufacturability, etc.
f) Objects can link to, receive, transmit, or export set of attributes, such as structural materials, acoustic data, energy data, etc., to other applications and models.

2.5 Dimensions in BIM

It is important to keep in mind that BIM is more than just 3D modelling because it also gives the ability to handle a variety of data related to materials, costs, and time. In fact, a separate dimension is set each time a certain type of information is entered into the model, and as a result, different dimensions are formed [13] [14]. BIM basics state that there are seven recognizable "dimensions" but in some case it has been extended to 10D that are;

a) 2D Modelling: It was the earliest form of construction models, which consists of simple x-axis and y-axis. Such models were either created by hands or simple CAD drawings.

b) 3D Modelling: It consists of geometrical and graphical information.
c) 4D Modelling: It incorporates time scheduling into the 3D model, that is why along with 3D model, it also contains Gantt charts and timelines.
d) 5D Modelling: It contains cost management and construction estimation, etc along with 4D model.
e) 6D Modelling: It entails the addition of relevant data needed for sustainability and energy efficiency. With 6D, energy utilization may be analysed during the preliminary design stage.
f) 7D Modelling: It deals with facility management and maintenance operation throughout the building life cycle.
g) 8D Modelling: It deals with health safety during design and construction.
h) 9D Modelling: Also known as lean construction is considered another dimension of BIM which deals with optimization and streamlining all the phases required during project implementation by process digitization.
i) 10D Modelling: It deals with construction industrializations.

Figure 2: BIM Dimensions [13]

The 3D, 4D and 5D of BIM are further explained in the following sections.

2.5.1 3D BIM Dimension

3D BIM dimension is undoubtedly the BIM dimension with which most of the construction organization are familiar. It is also called coordinated or shared information model. The X, Y, and Z are the three geographic axis that makes up the building. It is usually confused that 3D BIM model just only contains geographical information which is not true. Building information, both graphical and non-graphical, must be created for 3D BIM to be shared in a common data environment (CDE). The model is enriched with data from different disciplines. Schematic designs, design development and documentation, construction documentation, and record drawings all use BIM 3D models [13] [14]. The benefits of 3D BIM model for architects, engineers and surveyors can be listed below;

a) It gives more accurate and detailed 3D visualization of the entire project.
b) It is useful to look for potential collisions.
c) It facilitates better collaboration among different stakeholders irrespective of their disciplines.
d) It provides real-time model updates which reduces errors, duplications, and interferences.
e) Due to better collaboration, it optimizes time and costs.

2.5.2 4D BIM Dimension

4D BIM provides additional dimensional information to a project by detailing task duration and scheduling to create a 3D picture of how the building grows as it progresses through the various construction phases. Time management is essential part of construction planning [1] [13] [14]. Some of the traditional methods involves are Gantt or Pert charts which has certain limitation such as;

a) Data loss from designer to construction firms.
b) Poor communication between supplier and work management.
c) Effective presence and management of materials on construction sites.

The ongoing requirement to decrease, manage, and re-organize project timing in response to increasingly dynamic and analytical evaluations can be accomplished by implementing new technologies and processes. As a data organization methodology, the "WBS - Work Breakdown Structure" allows the site manager to subdivide the entire construction process into elementary time periods that are linked to the elementary parts of the model that are viewed as a logical progression of simulated construction phases (Project time schedule) for improved control and management. With BIM project management software (4D BIM), data is linked to graphical representations of the components, making it easier for the project manager to consult and comprehend project information getting numerous advantages such as [13] [14];

a) Correct planning of construction site including schedule for each construction stage.
b) Effective collaboration between architects, contractors, and teams with clear deadlines.
c) Conflicts detections at earlier stages hence reduces conflicts and unnecessary delays.
d) Managing site status information and visualizing the impact of changes across the project's lifecycle.

2.5.3 5D BIM Dimension

This includes costs in addition to 4D BIM. The purpose of 5D is to integrate cost, scheduling, and design into a 3D model output [1]. The model is tasked with estimating the flow of funding for a project and showing the progress that has been accomplished with respect to it. In every construction project, visualization ensures viability and unparalleled accuracy. The key difference between the conventional approach and 5D modelling is the rate at which the project cost is updated and modified. The project cost varies due to changes or modifications in the design but can be updated anytime in 5D. Due to the fact that 5D BIM is all about evaluating, whether it be price, appearance, constructability, schedule, or anything else within the project's limits, it is also capable of filling the early design void by enabling all parties involved to sit down and calculate both the project design costs at the current time as well as how potential revisions can affect the project from different standpoints. With the help of 5D BIM, it is easy to conceptualize and assess each component of the project in advance, giving the information, one need to make decisions with remarkable accuracy [14]. The advantages of 5D BIM are numerous and extensive, and they include, but are not limited to, the following:

a) The ability to deliver data in real-time makes it simple to explore alternative ideas and provides the appropriate parties with regular updates on project expenses and other pertinent information, greatly increasing the project's efficiency.
b) Transparency is the key to success in projects, and major stakeholders may see the finished product exactly as it will appear and the exact budget estimate with a detailed breakdown.
c) It is much simpler to deliver an accurate project scope using 5D BIM’s combination of data modelling capabilities, which offers a huge improvement in predictability over traditional technologies. In 5D BIM, each building system makes use of a variety of variables in its calculations, including site conditions, building materials, phasing, and more.
d) Since the model can calculate the building cost again whenever there is a model update of any kind, it is much simpler to explore different project options.
e) It is possible for everyone to have a complete understanding of the project and all its many features, including design, cost drivers, and other elements, due to the availability of clear and accurate estimates of various project parameters. Having precise information regarding budgets, schedules, and the scope of a project helps to avoid misunderstandings and can be a crucial factor in funding decisions.

2.6 Level of Details/Developments (LOD)

Levels of development is a set of guidelines through which AEC professionals can effectively and precisely document, describe and specify building information model. Sometimes, Level of Detail (LOD) is used in place of Level of Development, however there is significant difference between both. The level of details represents that how much details is included in a model whereas the level of development indicates that how thoroughly the geometry of an element has been considered, and how much the project team can rely on the data when utilizing the model. In other words, the amount of information relevant to the development of a project and required to make actual decisions is referred as Level of Development whereas the total quantity of information that a BIM objects hold is referred to as level of details [15] [16]. In short, Level of Detail is the element’s input while Level of Development is the element’s reliable output. LOD describes the stages of development of various BIM systems and serves as an industry standard. Architects, engineers, and other professionals can interact with one other effectively and without confusion utilizing LOD specifications for quicker execution [17].

There are six level of developments (LODs) according to American Institute of Architects (AIA), which are explained in the following sections [15];

2.6.1 LOD 100

LOD 100 elements are used in the conceptual design/pre-design stage of a project. The model element may be graphically represented in the model using a symbol or other generic representation, but such representation does not meet the criteria for LOD 200. Other model elements can be used to derive information about the model element, such as cost per square foot and HVAC tonnage. As LOD 100 elements are non-geometric representation so any information derived from it must be considered approximate [17].

2.6.2 LOD 200

In LOD 200, the model element is represented graphically within the model as generic object, assembly or system with approximate size, shape, position, and orientation. The Model Element may also be associated with non-graphical information. Elements are generic placeholders in this LOD. They might be distinguished as the parts they symbolize, or they may be volumes for reserving space. Any data obtained from LOD 200 elements must be considered approximate [17].

2.6.3 LOD 300

The model element is a specific system, object, or assembly that is graphically represented within the model in terms of its, size, shape, location, and orientation. The model element may also be associated with non-graphic data. It is possible to measure the quantity, size, shape, location, and orientation of an element directly from the model without refereeing to non-modelled data like notes or dimension callouts. The element is precisely positioned in relation to the project origin, after the project origin is defined [17].

2.6.4 LOD 350

The model element is graphically represented within the model as a specific system, object, or assembly with regards to its amount, size, shape, placement, orientation, and interactions with other building systems. The model element may also be associated with non-graphical data. Parts required for the element's coordination with adjacent or attached elements are modelled. These components will consist of things like supports and connections. It is possible to measure an element's amount, size, shape, location, and orientation directly from the model without refereeing to non-modelled data like notes or dimension callouts [17].

2.6.5 LOD 400

The model element is graphically depicted as a particular system, object, or assembly within the model, complete with information on its dimensions, configuration, quantity, orientation, manufacturing, assembly, and installation. The model element can also have non-graphic data associated to it. The modelled LOD 400 element is accurate and detailed enough to fabricate the depicted component. The model can be used to take direct measurements of the element's quantity, size, shape, location, and orientation without making use of notes or dimension callouts, which are non-modelled data [17].

2.6.6 LOD 500

In LOD 500, model element is a representation that has been field verified in terms of its dimensions, compositions, quantity, shape, and orientation. The model element may also be associated with non-graphical information [17].

2.7 Nature of Information in BIM

There are several natures of information within the building information model. This applies to every piece of information that is connected to or a part of the components as well as the physical details of the model itself, such as its size and placement. It is crucial that the BIM has all the information needed to conduct an accurate analysis [5] [6]. The nature of information can be divided into following categories;

2.7.1 Component Information

The most fundamental information in a 3D model file is component information. The information is mostly visual and is inherent to the model portion itself. A 3D model’s components are also located precisely in reference to one another and an origin. A wall with material information or quantitative information, such as area, volume, and so on, is an example of component information [6].

2.7.2 Parametric Information

The parametric object’s editable information is referred to as parametric information. As it is a part of the object and consequently the model, this information does not come from an outside source. Some of this information is visual while a lot of it can be intellectual, such as part numbers or material-related characteristics like density (which provides weight dependent on the shape of the thing), R value, etc [6].

2.7.3 Linked Information

Information that is linked to a model but does not truly belong to it is referred to as linked information. These links might be visible or invisible. Invisible links could be, for example, connections to a database with cost information. Visible links could be "flags" that, when clicked, open a window or file to display that file. When two files are linked together, modifications made to one will also be made to the second linked file, and vice versa [6].

2.7.4 External Information

The term “external information” describes data that is produced independently of the BIM, such as a construction schedule, product manufacturer requirements, etc. External data might be integrated into the model or can exist independently. Without generating a connection to an electronic file, it is still feasible to reference a catalogue. It could be required to maintain the material available in printed form as an external reference because not all the information will be provided in a format that is compatible [6].

2.8 Integrated Project Delivery

Integrated Project Delivery is the most recently developed project delivery method. This method was developed and devised with full BIM implementation in mind. IPD and Design-Build (a project delivery method in which the owner usually transfers all design and construction risks to one contractual entity forcing designers and builders to work together towards a common interest and share the consequences togather in case of failed coordination) methods are quite similar because that they both require collaboration and integration among the different parties working on the project. Early involvement and risk sharing are the two components that differentiate Integrated Project Delivery from the other delivery techniques. While other project delivery methods, forbid any collaboration between designers and constructors as they are separate contracted parties and frequently compete for the owner's design preferences, IPD on the other hand, even more than in DB, requires all project participants to work as a team from the start [18].

Furthermore, in some project delivery methods, the risk is on the owner’s shoulder, or owned by designer and builder whereas in IDP, the risk is fully and equally shared among all the participants who are also covered by the same contract and fully share the scope and requirements of the entire project. However, along with the shared risk comes the shared benefit of a completed project, ensuring that every participant receives equal recognition for effective teamwork [18].

Comparing to other project delivery methods and process, it is simple to see why IPD and BIM work so well together. Still, it needs a shift in the team members’ thinking, including a more open outlook and a strong desire to step outside of their "comfort zone" of already proven process and tools. Regardless, of the fact that IPD is a relatively new type of contracting, it has gradually entered the AEC sector [18].

Benefits start to show up as soon as the team’s mentality changes. The owner can explain their point of view and aims to the entire team, allowing all the other project participants to improve the owner's anticipated results. On the other hand, builders can contribute early enough to the process with their building expertise to greatly lower the costs of changes and constructability-related difficulties [18].

Finally, designers benefit from the early involvement of builders in terms of accurate cost estimates and the resolution of pre-construction conflicts, pushing back the effort peak. This adds value to the project because it makes the construction phase faster and less expensive, so that waste of money and time is reduced to almost zero. According to the official IPD Guide issued by AIA in 2007, IPD is the project delivery approach that functions best when used with BIM tools and procedures: “Undoubtedly, BIM is employed in non-integrated processes and integrated projects can be completed without it. However, combining IPD and BIM is the only way to fully realize their potential benefits” [18] [19].

2.9 Resource Planning

Resource planning is the process of managing resources by determining their availability or necessity, monitoring their use, and gauging their efficacy across departments, projects, and roles. Anything used to complete and achieve project criteria is referred to as a resource. Resource planning can be compared to baking, where the project is a recipe and resource planning is the process of accurately preparing and following the recipe [20]. The essentials resources needed for construction projects are explained in following sub sections [21].

2.9.1 Human Resource

The workforce is the most important component of the construction resource pool. These are the people who bring the project into reality. Following are the different critical roles played by workforce in construction sector.

a) Estimator: The estimator oversees calculating the costs, supplies, and labour required to finish a project.
b) Architect: The role of the architect is to foresee the client's requirements and provide a unique solution in a blueprint.
c) Supervisor: The supervisor serves as a liaison between the management office and the field personnel. He/she makes sure that the two sides are effectively communicating.
d) Quantity Surveyor: Throughout the construction process, the quantity surveyor advises the customer on building costs and contractual issues while also serving as the architect's consultant.
e) Engineer: On a job site, engineers are essential and may have specialties in construction, electrical work, mechanical work, highway work, etc. For instance, civil engineers develop plans for their projects using computer software. Electrical engineers keep an eye on the project’s power needs and make sure that any risks are eliminated.
f) Construction Worker: Every construction project is propelled by its personnel. Once the project is planned, the workers get their hands dirty to make it a reality.

2.9.2 Equipment:

Heavy machinery is required for construction tasks. The equipment choice is influenced by the project’s duration and expense. Bulldozers, excavators, cranes, trenchers, and other heavy machinery are utilized in building projects.

2.9.3 Materials

The most typical kind of building material utilized in construction includes things like wood, cement, metals, bricks, concrete, clay, etc. Selection parameters like quality and cost-effectiveness are quite important.

2.9.4 Facilities:

Facilities not only boost efficiency but also the welfare of workers. All building sites must include the following amenities to comply with CDM regulations:

a) Living accommodations for the workers
b) Toilet and sanitary facilities.
c) Drinking water facilities.

d) Changing rooms and lockers
e) Canteen

2.10 Parametric Quantity Take off (QTOs)

Quantity take-off is one of the key task in the construction process since it serves as the starting point for many other operations. The building components are measured, and the results are utilized to calculate the costs and workload associated with each part. Quantity take-offs can be used to measure the work completed on site or the building's schematics. This data is compiled in a document that is commonly known as a bill of quantities. Traditionally, quantity take-offs are manual process which includes measuring design elements such as floor plans, elevations, cross sections etc but this approach is particularly prone to errors because it relies on human interpretation. Furthermore, 2D-based papers are error-prone whether they are created manually or with the use of CAD tools. Over the past 30 years, automation in the architecture, engineering, and construction (AEC) industry has been the major concern, particularly in academics community. Usually, automation in construction is linked to building technology or information management. Automation in the second category is primarily based on software. BIM is a highly automated tool in that inputs are automatically attached to the model and information is automatically updated, serving as a centralizing mechanism for a significant portion of the project's information [22].

It is possible to have a highly detailed Quantity Take-off (QTO) using BIM, giving to any item a cost in terms of parameter applied to the model elements. By integrating this information with the Work Breakdown Structure (WBS) and the timeline that defines the timing and resources required to complete any task, it is possible to manage those aspects, understanding the best option to improve costs and building site organization. Unlike the conventional approach, the BIM approach to defining quantity enables a direct connection between the items present in the model and the count reports automatically made inside the software. This characteristic strength of BIM enables the avoidance of data leakage, which is the most frequent failure in the conventional CAD process [23].

Most BIM solutions come with routines that do calculations based on an element's geometric attributes and provide spatial quantities like area and volume in text form. The usage of BIM-based QTO is said to reduce time and costs by providing simpler, yet more complete and accurate cost estimates for the project [24], but it is also a challenging feature that is typically only used by professionals [25]. Even though they can supply QTO tables, many BIM programs cannot manipulate that data [22].

Typically, various kinds of software are used for this. One of two methods is typically used to communicate data between the BIM and cost estimating software: a) Both systems define product data in the same proprietary format, and the exchange occurs without any data loss; b) both systems define product data in different proprietary formats, and the exchange occurs by converting the data to a third, common format, typically the Industry Foundation Classes (IFC). Despite having a wide range of applications, IFC is an ad-hoc standard data structure for the definition, classification, and organization of AEC data. However, it is unable to provide a lossless means of data sharing [22] [26].

2.11 Modelling Tools

Building information modelling is a challenging process that involves not just 3D modelling but also planning, designing, building, teamwork, and more. BIM is a great collaboration tool overall since it allows project participants to communicate relevant data. BIM itself works with so-called BIM objects, which are additions that can be made to the relevant 3D models and include things like doors, windows, plumbing, electrical components, and other building materials that can change how a project turns out in the end. The endeavour at standardization and unity is perhaps the most prominent trend in the BIM sector. Although the industry is not yet standardized because there are still too many diverse interpretations of publicly available specifications from various BIM companies, there is still progress being made. There are a lot of BIM software with different BIM systems, each having their own advantages and disadvantages. In the following section some of these software such as Autodesk Revit, Navisworks and STR vision CPM has been discussed. Among these, Autodesk Revit were used for 3D modelling in this thesis, Autodesk Navisworks for clash detection analysis and STR CPM were used for 4D/5D simulation.

2.11.1 Autodesk Revit

Autodesk Revit is a popular BIM construction program that tries to address many architectural and design issues. It was created by Autodesk and is one of the most widely used products in the sector. Architects, designers, MEP (mechanical, electrical, and plumbing) experts, contractors, and many other specialists can benefit from Revit’s feature set. By using models, the program itself provides an intelligent approach to various construction process phases.

By controlling several aspects of the process within the same system, this program, which is only compatible with Microsoft Windows, can greatly eliminate the miscommunication issues. The same approach also improves coordination efforts generally, and one can even simulate the aesthetics of various projects using it. Since Revit is a 4D BIM, it can track every stage of a construction project, from initial concepts to routine maintenance and/or demolition. Three versions of Revit were created by Autodesk for various building design disciplines:

a) Revit Architecture: Designed for architects and building designers, (formerly called Revit Building)
b) Revit Structure: For structural engineers,
c) Revit MEP: It was designed for mechanical, electrical and thermotechnical engineers (formerly Revit Systems)

The three versions have now been combined into a single software that includes all three modules as well as an analysis module.

2.11.2 STR Vision CPM

STR Vision CPM is a BIM construction-oriented software which integrates the 3D model of the project with the information of tools, equipment, human resources, and other activities necessary for the completion of job. Additionally, technical, and economic information is always managed and kept under check, both gradually (as per estimate) and to foresee the overall cost.

STR Vision intervenes in multiple stages of the BIM process, importing 3D models and allowing professionals to complete the 4D (Timing) and 5D processes (Cost Control). The most important roles include cost and budget analysis, work scheduling, technical and financial control of project or contract progress, and estimation. Through standard IFC, the STR Vision CPM software integrates with Autodesk Revit, BricsCAD, Graphisoft, ArchiCAD, Nemetschek, Allplan, and Tekla Structures, enabling the designer to continue using the tools they prefer to develop the 4D (timing) and 5D (costs) management platform that is most highly regarded by engineering firms and construction firms [27].

2.11.3 Autodesk Navisworks

Another BIM solution developed by Autodesk is Navisworks. The primary distinction between Navisworks and Revit is that Navisworks focuses more on providing AEC (architecture, engineering, and construction) professionals with a project review solution. Like Revit, it is compatible with MS Windows and can open, integrate, evaluate, and navigate through models created by other Autodesk 3D solutions without much problem.

Due to its nature, Navisworks is most crucial during the pre-construction phase of any project, where it may be used to regulate and foresee project outcomes. To aid in finding any issues before the real construction starts, both model coordination and collision detection are incorporated. Numerous other functions include model simulation, animation, data aggregation inside a single model, and many more.

2.12 Interoperability and IFC

Interoperability is the ability to exchange data between applications, which smooths workflows and sometimes facilitates their automation [8]. The AEC industry has experienced tremendous growth in applied technologies over the past few decades. Several designing platforms have emerged, some of which are specialized for one or more disciplines, such as Tekla for steel structures and Autodesk Revit for architectural, structural, and MEP modelling. Due to the existence of several BIM tools and designing disciplines, as well as the fact that each BIM tool has a unique file extension, the problem of transferring data between the various platforms arises when it is required to combine all the teams' work. To create the most accurate and comprehensive model possible, interoperability between the various tools is crucial. Therefore, it is a key component of building information modelling [28].

The problem of losing data is almost negligible when the different tools are from the same manufacturer, like the various BIM products from Autodesk, but it becomes more evident when transferring data between tools that are from different manufacturers. A lot of efforts were made to minimize and overcome this problem, and in the late 1990s the International Alliance for Interoperability (IAI) which is now known as buildingSMART, was founded by Autodesk and other BIM platform manufacturers. Its primary goal was to create standards, norms, and tools to assist the information flow between the various platforms [28].

The .IFC (Industry Foundation Classes) extension was created to serve as a shared neutral exchange format; rather than serving as the software's working format, it serves as a link between various platforms to transform data. As a result, every platform with this feature built in can export and import all of the model's data and geometry in.ifc format. IFC (Industry Foundation Class) is a universal standard for describing, transferring, and sharing information about building and facility management. It is an open-source and neutral data format which offers a set of definitions for every kind of object element used in the construction sector, as well as a text structure for storing these definitions in a data file [28] [29]. Since releasing the first edition of the.ifc exchange format, the International Alliance for Interoperability (IAI), currently buildingSMART, has made it go through multiple updates to improve its quality for data exchange in order to keep up with the rapid increase in AEC technology development and the appearance of new tools [28].

IFC separates all entities included in a project into rooted and non-rooted entities at the most fundamental level. A GUID (Global Unique Identifier), a 128-bit integer that is used to identify information in a computer system and that includes properties for name, description, and revision control, is used to identify rooted entities. Only when connected to a Rooted entity do, non-Rooted entities have a legitimate identity. The three abstract notions that make up IfcRoot are object definitions, relationships, and property sets [23]. An alternative to IFC format is .XML that is also used to transfer data from a BIM model to other programs that enable a facility's multidisciplinary analysis, including structural, thermic, lighting, etc [23].

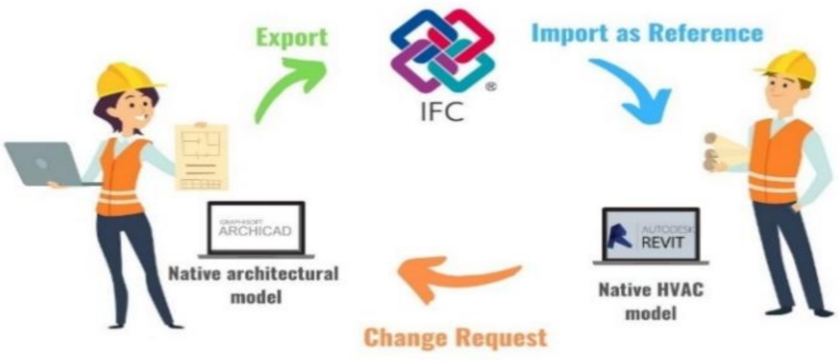

Figure 3: Workflow with IFC model between different disciplines[29]

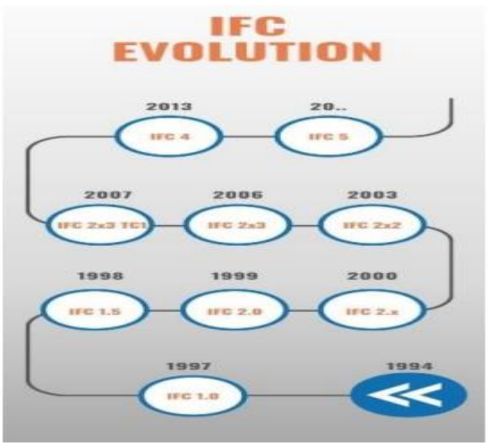

Figure 4: IFC Evolution

2.13 Clash Detection

One of the key goal of BIM is the achievement of cooperation and coordination between various parties involved in the project cycle, such as engineers, contractors, and owners. Before the development of BIM technology in the conventional methods of design, designers had to review their work manually by comparing between the different disciplines design to check compatibility level and discover conflicts between them. In addition to being time-consuming, that approach had a significant efficiency gap because not all conflicts were detected during design. When merging the design models from several disciplines into a single central or federated model, clash detection analysis is one of the essential components of the BIM technique that may be used to identify various types of clashes using pre-defined rules and filters [28].

There are three main types of clashes that can be found during clash detection analysis which are;

a) Hard Clashes: It occurs when two items or elements overlap in the model or cross paths with one another. If these conflicts are not resolved before construction begins, they will significantly increase the cost and duration of the project.
b) Soft Clashes: It occurs when elements or objects lack the necessary surrounding tolerance or space for operating or maintaining safely.
c) Workflow Clashes: It is also known as 4D clashes because it is concerned with clashes that arise in the time schedule of different activities of the construction process of the project.

Clashes detection analysis is very beneficial in assessing the structural integrity, energy efficiency, preventing late-stage redesign, scheduling clashes, ensuring efficient building operation, reducing human errors and many more.

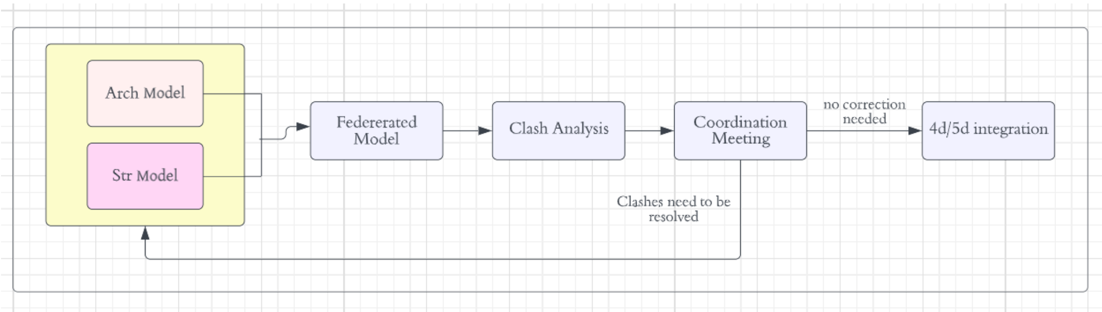

Figure 5:Decision making process

2.14 Naming Conventions

To ensure compatibility between BIM/CAD software and other data sources, the use of special characters must not be utilized in any naming conventions in order. All software that will be used must adhere to the same naming conventions. While CAD and other tools allow the use of a wide variety of characters, the effects of employing special characters might not be immediately apparent until data is transmitted to other software [30]. Therefore, the best practices listed below ought to be used;

a) CAD/BIM filenames, blocks, cells, objects, layers, styles, property sets, families, and parameters may only contain letters (A to Z), hyphens (-), underscores (_), and digits (0–9).
b) Characters like! " £ $ % ^ & * ( ) + = < > ? | \ / @' ~ #}] ¬ ` and spaces within the name shall not be used.

2.14.1 Revit Files Naming Convention

For the naming convention, the British standard [31] are thoroughly used, "Collaborative production of architectural, engineering and construction information - Code of practice". This code of practice is used in the files naming convention, as well as the elements inside these files, like families and family types. A container must have the following fields: Project, Originator, Volume, Location, Type, Role, Presentation Number, then we added the Revit version so it can be distinguished for the future users.

For example, for the structural file name convention it will be "*BIMA-I-00-M3-S-0001_R22.rvt*", as for the architectural file, it will be "*BIMA-I-00-M3-A-0001_R22.rvt*".

Table 1: Naming of files [31]

Field	Obligation	Clause
Project	Required	**6**
Originator	Required	**7**
A1 Volume or system A1	Required	**8.1.2**
Levels and locations	Required	**8.1.3**
Type	Required	**9**
Role	Required	**10**
Classification	Optional	**11**
Number	Required	**13**
Suitability A)	A1 metadata A1	**15.2.2**
Revision A)	A1 metadata A1	**15.2.3**

A) If files pass through an environment where there is no directory context, this field can be included to document the suitability and revision.

The A1 metadata A1 fields "suitability" and "revision" should be used or omitted together.

2.14.2 Families Naming Convention

For the families used inside Autodesk Revit, the name shall contain the project name, type, role, and a number that indicates numerical value related to the family "ex. thickness". In some cases, some of the main fields shall be omitted such as location, and Volume as it is not useful for the elements to be identified by these specific fields. This shall contain the main metadata to describe them inside the project, for example (BIMA_INT_BW_A_100), this indicates an Architectural internal brick wall with 100mm thickness, inside the "BIMA" project.

2.15 Work Break Down Structure (WBS)

The WBS is a list of every task that needs to be completed as part of a project. It is a useful tool for the project manager to identify all the activities taking place on the job site. It makes all the sub-tasks easier to comprehend and to express in a hierarchical and comprehensible fashion. The WBS establishes a connection between the tasks that must be completed to complete the end artifact. The 100 percent rule is one of the main rules that governs the WBS. It states that all tasks and activities, whether internal or external must be included in the WBS to deliver the final project. It is necessary to list every activity in WBS and is applicable to any level of the hierarchical representation. Secondary tasks should represent 100% of the main tasks that include them. Since tracking items that are too small and/or numerous will be challenging, especially if they are planned for a distant future, it is crucial to concentrate on the degree of detail of the WBS and identify the highest point of detail of the tasks sub-division. An effective way may be using the progressive elaboration, which involves the creation of most detailed parts of the WBS, just before the work begin. The WBS for the construction sector is regulated in many countries, each of them proposes a unique hierarchical classification of numerous categories, including not only constructive elements but also activities, management processes, places, etc. All of them can be helpful in identifying and categorizing an entity in a construction process, from the preliminary stage to the final dismissal [23].

The Work Breakdown Structure is a “deliverable-oriented hierarchical decomposition of the work to be completed by the project team” according to the PMI Project Management Book of Knowledge (PMBOK). WBS can be divided into two categories: deliverable-based and phase-based. The deliverable-based strategy is the most popular and preferred method. The Elements listed in the first Level of the WBS are the primary distinction between the two methodologies. Figure 03 and Figure 04 present the overview of both these methodologies. A distinct identification code for each item must be defined for the BIM model to be effective. Furthermore, to compute the different elements independently, it can be helpful to give the code a recognized structure. Therefore, it appears that using the standard project WBS is the best option for this problem [1]. The project WBS must meet the following criteria:

a) Each element’s code must be unique;
b) The structure must be built on many layers, such as macro-activities;
c) It must be able to filter out items that were completed at the same time as other elements in the schedule.

Generally, the BIM Coordinator will identify the shared parameters that every element of the model must possess (i.e., a parameter for each level of the WBS structure) after the WBS code creation guidelines have been established. The BIM Specialist will then provide values to each field of the various parameters with the code [1].

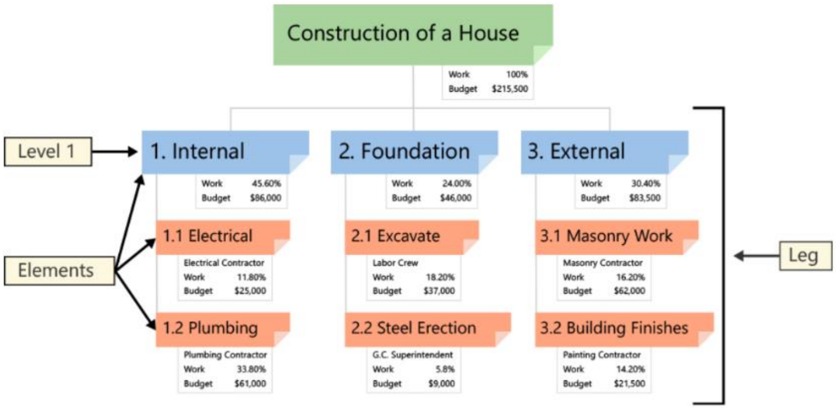

Figure 6: Deliverable based WBS [32]

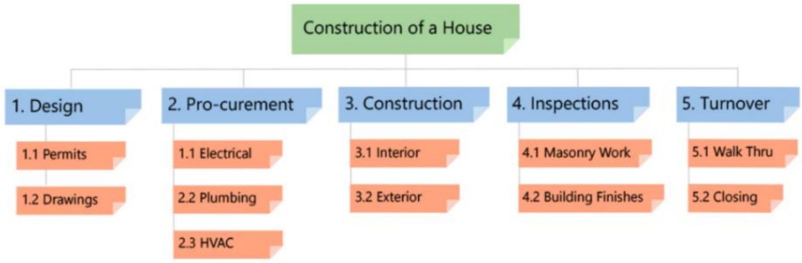

Figure 7: Phase based WBS [32]

The standards that govern the building construction industry are examined in the following section that follow to comprehend the differences among the most widely used classification schemes around the world, including Uniformat, Master format, Uniclass, Masterclass, and UNI 8290 [23].

2.16 Classification Systems

Classification systems have been used in the AEC industry since even before BIM was introduced to that industry, and they are essential because their primary goal is to identify any building component in the most clear way possible, allowing all the actors involved in a project to exchange information about every component of the building by simply communicating a series of digits. This is crucial when it comes to time schedules or quantity take-offs, in which every cent must be calculated precisely, that is the main reason why classification systems are used in the AEC industry. One method of codifying building components for identification during work planning, clash detection, site simulation, quantity take-off, in situ lists, and schedules has involved assigning them a code made up of a combination of acronyms that represent various types of information about them. These codes are arbitrarily produced having the following format like AA BB CC XX YY ZZ, [23] [18] where each segment of the previous code stands for a group of numbers or letters that can be used to deduce information about a component, such as its discipline, type of building, structure, elevation, area, category of element, product, and so forth, up to a potential progressive installation number. The problem with using a similar system is that one can find themselves adopting fresh code for each project that has been written from scratch because the prior one might not be appropriate. Since the code itself was developed based on arbitrary criteria, it also becomes more challenging (and occasionally more prone to error, misinterpretation, or misunderstanding) to be able to explain this code to all the actors participating in the project. This means that in order to prevent communication and understanding issues between the professionals involved, it is necessary to have a common foundation that is stable, that anyone can understand and apply in a clear and unambiguous manner, and that may continue to serve as a benchmark for each project, always adoptable and equal to itself. For this purpose classification systems were introduced which are all based on ISO 12006-2:2015 ‘Building construction – Organization of information about construction works – Part 2: Framework for classification international standards. As the name implies, this norm governs the classification of building elements and establishes a framework for titles and information needed given a variety of options and information object classes, according to specific subdivisions like function, form, activity, element, product, etc. This makes it essential for an ideal building information management system. This set of recommendations for building break-up systems covers every stage of a facility’s life cycle, from initial planning to final deconstruction. They can be used in both building and civil engineering [18]. These classifications systems are explained as below;

2.16.1 Uniformat II Classification System

Uniformat II is a standard method for classifying and organizing information related to building processes [23]. This classification systems were created by American Institute of Architects (AIA) between 1973 and 1989 and it underwent several revision before arriving at Uniformat II edition [18]. It is most widely used in United States and Canada for classifying building specification, cost estimation and cost analysis [33]. The Uniformat requirements are; -

a) Classifications with a hierarchical structure.
b) Content selected by sectors operators based on a high cost incidence.

Uniformat is a three-level classification system. The first level unites the major object category families, such as foundations, partitions, and enclosures. The first level is broken down into subgroups in the second level, whereas the third level specifies the items present in the second level. A fourth level was included in the most recent edition to have the deepest amount of information.

Table 2:ASTM Uniformat II Classification for Building Elements (E1557-97) [34]

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls
B SHELL	B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
	B20 Exterior Enclosure	B2010 Exterior Walls B2020 Exterior Windows B2030 Exterior Doors
	B30 Roofing	B3010 Roof Coverings B3020 Roof Openings
C INTERIORS	C10 Interior Construction	C1010 Partitions C1020 Interior Doors C1030 Fittings
	C20 Stairs	C2010 Stair Construction C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes
D SERVICES	D10 Conveying	D1010 Elevators & Lifts D1020 Escalators & Moving Walks D1090 Other Conveying Systems
	D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2090 Other Plumbing Systems
	D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems D3030 Cooling Generating Systems D3040 Distribution Systems D3050 Terminal & Package Units D3060 Controls & Instrumentation D3070 Systems Testing & Balancing D3090 Other HVAC Systems & Equipment

2.16.2 Masterformat Classification System

Construction Specification Institute (CSI) and Construction Specification Canada (CSC), respectively, developed the Masterformat standard for information classification connected to the building sector with the objective of classifying information relevant to facility constructions and maintenance. When it was first made available in 1995, it had 16 tables. By 2004, the standard had grown to 50 divisions, with multiple parts within each division [23].

Table 3: MasterFormat table [35]

02 00 00	**EXISTING CONDITIONS**
02 01 00	**Maintenance of Existing Conditions**
02 01 50	Maintenance of Site Remediation
02 01 65	Maintenance of Underground Storage Tank Removal
02 01 80	Maintenance of Facility Remediation
02 01 86	Maintenance of Hazardous Waste Drum Handling
02 05 00	**Common Work Results for Existing Conditions**
02 05 19	Geosynthetics for Existing Conditions
02 05 19.13	Geotextiles for Existing Conditions
02 05 19.16	Geomembranes for Existing Conditions
02 05 19.19	Geogrids for Existing Conditions
02 06 00	**Schedules for Existing Conditions**
02 06 30	Schedules for Subsurface Investigations
02 06 30.13	Boring or Test Pit Log Schedule
02 06 50	Schedules for Site Remediation
02 06 65	Schedules for Underground Storage Tank Removal
02 06 80	Schedules for Facility Remediation
02 06 86	Schedules for Hazardous Waste Drum Handling
02 08 00	**Commissioning of Existing Conditions**

2.16.3 Uniclass Classification System

Uniclass is a unified classification system for all sectors of UK construction industry, first published in 1997 and strongly modified with time. The newest version is called Uniclass II or Uniclass 2015. It complies with ISO 12006-2 standard that is why it can be used internationally. It consists of 11 tables classifying items of all scales ranging from facilities such as railway, to product like anchor plates, flue liners, LED lamps etc [23] [33] [36]. The tables of Uniclass classification are;

a) Activities
b) Complexes
c) Elements
d) Entities (by shapes)
e) Entities (by function)
f) Project phases
g) Construction Product
h) Spaces
i) System
j) Work results
k) CAD

These tables are designed to be flexible and able to accommodate enough codings to assure coverage for a variety of items and circumstances, and to highlight forthcoming developments and technological advancements. Each code is made up of four or five character pairs. The first pair uses letters to specify which table is being used. The next four pairs are used to represent groups, subgroup, sections and items. An example for structural element classification is presented below;

EF_20 Structural elements

EF_20_05 Substructure

EF_20_05_30 Foundations

In the above example, EF represent entities by function, 20 represent the group which is structural element, 05 represents the subgroup of substructures, and 30 represents the section which is foundation in this case [37].

2.16.4 Omniclass Classification System

Omniclass, which was developed in North America where it is extensively used, is a very helpful tool for storing information about buildings and projects. It can be utilized during the entire building life-cycle, from the designing stage to the dismissal. Omincalss was believed to includeevery level of construction details for any location, whether it be industrial, residential, or commercial. It is made up of 15 tables, each of which deals with a distinct type of information and which can be used independently of the others depending on the kind of information needed [23]. The 15 tables are as follows:

a) Table 11: Construction Entities by Function
b) Table 12: Construction Entities by Form
c) Table 13: Spaces by Function
d) Table 14: Spaces by Form
e) Table 21: Elements
f) Table 22: Work results
g) Table 23: Products
h) Table 31: Phases
i) Table 32: Services
j) Table 33: Deciplines
k) Table 34: Organizational Roles
l) Table 35: Tools
m) Table 36: Information
n) Table 41: Materials
o) Table 49: Properties

OmniClass is intended to cover all built-environment items at every size, including finished buildings, massive projects, multi-structure complexes, individual products, and component materials. All types of construction, including vertical and horizontal, commercial, residential, and industrial, are intended to be addressed. In contrast to many of the systems that came before it, Omniclass also handles the activities, people, tools, and data that are used or involved in the creation, building, upkeep, and use of these facilities [23].

2.16.5 UNI8290 Classification System

The UNI 8290 is an Italian standard created by the Italian Standard Organization (UNI). It was first published in 1983 with the intention of classifying all construction elements into three levels; a) class of technology units, b) class of technical elements, and c) class of technology units. The standard was intended to be expandable by adding new levels up to the fifth, but only the first three are present in the initial edition. The building complex is broken down into its smallest components in a hierarchical fashion, starting with the largest grouping, known as the Class of Technology Units, which is then broken down into its smallest components [23].

Through this classification, it is possible to identify the technical elements and understand from which field it is coming from. This appears useful to create a table of codes intended to make analytical estimates, and to create a hierarchical decomposition of the entire complex, also known as WBS, where it is possible to list all the tasks required to complete a building project. These kinds of information become very useful with BIM use, by applying these codes to items contained in the BIM environment that could store many information in any element in the form of parameters and use them to make project management and cost analysis, an easiest way to obtain 4D and 5D project [23].

Table 4: UNI-8290 [38]

Classi di unità tecnologiche	Unità tecnologiche	Classi di elementi tecnici
1 Struttura portante	1.1 …di fondazione	1.1.1. … dirette 1.1.2. … indirette
	1.2 …di elevazione	1.2.1. ... verticali 1.2.2. … orizzontali ed inclinate 1.2.3. … spaziali
	1.3 … contenimento	1.3.1. … verticali 1.3.2. … orizzontali
2 Chiusura	2.1 … verticale	2.1.1. Pareti perimetrali verticali 2.1.2. Infissi esterni verticali
	2.2 … orizz. inferiore	2.2.1. Solai a terra 2.2.2. Infissi orizzontali
	2.3 … orizz. su spazi esterni	2.3.1. Solai su spazi aperti
	2.4 … superiore	2.4.1. Coperture 2.4.2. Infissi esterni orizzontali
3 Partizione interna	3.1 … verticale	3.1.1. Pareti interne verticali 3.1.2. Infissi interni verticali 3.1.3. Elementi di protezione
	3.2 … orizzontale	3.2.1. Solai 3.2.2. Soppalchi 3.2.3. Infissi interni orizzontali
	3.3 … inclinata	3.3.1. Scale interne 3.3.2. Rampe interne
4 Partizione esterna	4.1 … verticale	4.1.1. Elementi di protezione 4.1.2. Elementi di separazione
	4.2 … orizzontale	4.2.1. Balconi e logge 4.2.2. Passerelle

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3 Integrated BIM Model Development (3D/4D/5D BIM model)

3.1 Introduction

This chapter consists of the through steps and procedure followed for the development of an integrated 4D/5D BIM model. Autodesk Revit were used for the 3D development of building model consisting of Architectural and Structural disciplines. Clash detection analyses were carried out in Autodesk Navisworks and were resolved through switchback between Navisworks and Revit. Furthermore, clash free models from both disciplines were then exported through .IFC format to STR vision CPM for 4D/5D analysis.

3.2 3D Model Development

The BIM methodology differs from traditional design methods like paper-based design and CAD design methods in that it enables greater collaboration and organization between different design teams. The BIM methodology is also more effective and quicker in the process of checking and updating. The old traditional methods, while quicker in drawing and in finalizing the project, typically result in many errors and omissions because each discipline is working independently. Contrarily, the revolutionary BIM method made it possible to combine the efforts of all the teams into a single model, which prevented faults and clashes from being discovered during the construction phase, saved money, and speed up project completion.

The construction industry is fundamentally reliant on 3D BIM technology. Undoubtedly, every construction sector is familiar with 3D BIM modelling. A 3D model shall contain both graphical and non-graphical data necessary for the successful execution of the project. It plays as a foundation for other dimensions of BIM and their accuracy is directly connected to the accuracy of 3D model.

The first step in creating a BIM model is selecting the best platform to work on. In this case, Autodesk Revit 2022 was selected because it offers several options for data sharing and work collaboration, including integrated models and federated models. The model in this case is a four-story residential building consisting of Structural and Architectural disciplines. Before model development, a Revit template has been prepared with proper unit and proper levels.

3.2.1 Structural Model

3.2.1.1 Structural Element

The term “structural components” refers to those sections of building that transfer loads from the upper, or “super structure”, to the lower, or “substructures”. The load-bearing walls, beams, columns, slab, and stairs, if any, make up the superstructure’s structural components. The foundation, which can be a slab, step foundation, or piles, makes up the substructure portion. These options rely on the exposed loads that the structure will sustain throughout its service life. In this project, the structural model consists of;

a) Foundation Slab

b) Columns
c) Floor Slab
d) Roof
e) Stairs

Autodesk Structural template has been used for the creation of structural model, which contains different built-in families for structural elements. After creating grids and levels for the model, structural elements were created starting from foundation slabs, columns, floor slab and the repeating the same till last story, where roof slab were created. In the following figure, the structural model has been shown;

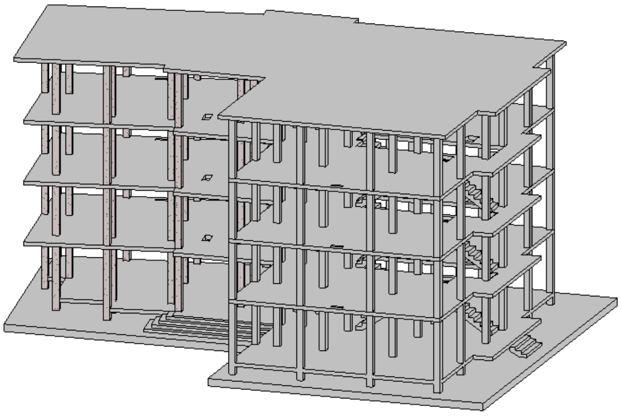


Figure 8: 3D Structural model

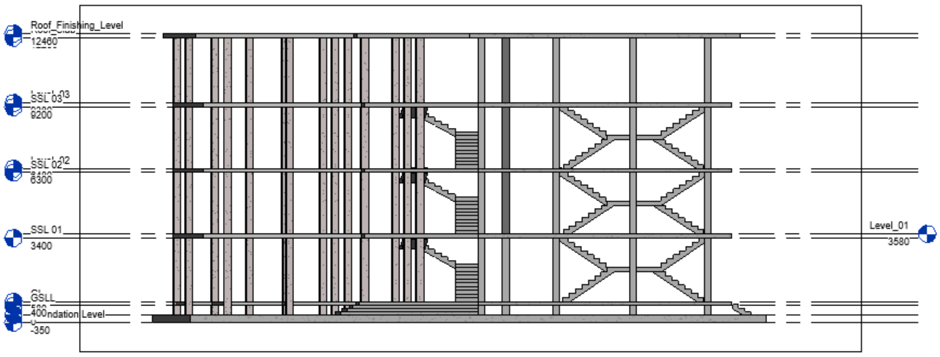


Figure 9: Cross sectional view of structural model

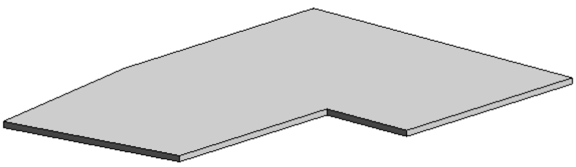


Figure 10: Foundation Slab

Figure 11: Floor Slab

Figure 12: Columns

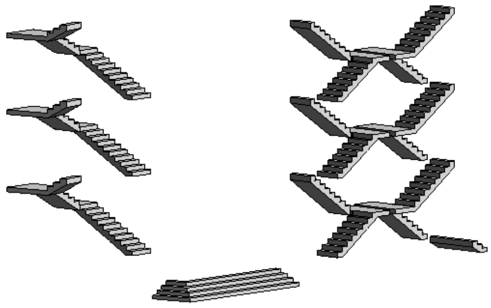


Figure 13: Stairs

3.2.1.2 Meta Data for Structural Components

After modelling the structural components, all the elements were populated with meta data such as classification code and WBS parameters. For WBS codes to be inserted a shared instance parameter was used to assign it to all the elements according to its construction phases. IFC parameters were also created for the correct mapping during exportation of the Revit file through IFC to be used for 4D /5D modelling. In the following Figure 14, the meta data for a column has been shown.

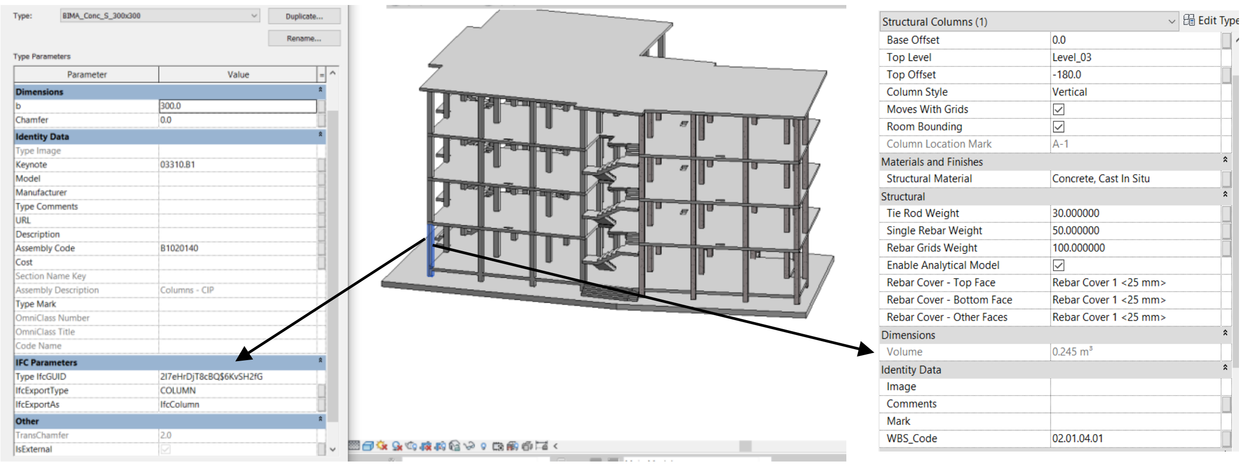


Figure 14:Metadata of structural column

3.2.2 Architectural Model

3.2.2.1 Architectural Elements

After creating structural model, the structural model was linked to copy the grids and levels for architectural model. Floor levels has been set with correct dimensions and each slab were placed in the correct level. As the objective of the model is to extract quantity take-off and cost estimation, the wall and floor elements were created in different layers separately that represent different construction materials. The architectural element of the model consists of;

a) Walls (interior & exteriors)
b) Insulations
c) Railing
d) Windows
e) Doors
f) Floors

Figure 15: Architectural model

3.2.2.2 Metadata for Architectural Elements

The same procedure was applied for the population of architectural elements with metadata and WBS codes as employed in structural elements. Shared parameters were created to inserts WBS codes to architectural elements according to construction phase. A metadata for a wall has been shown in the following figure.

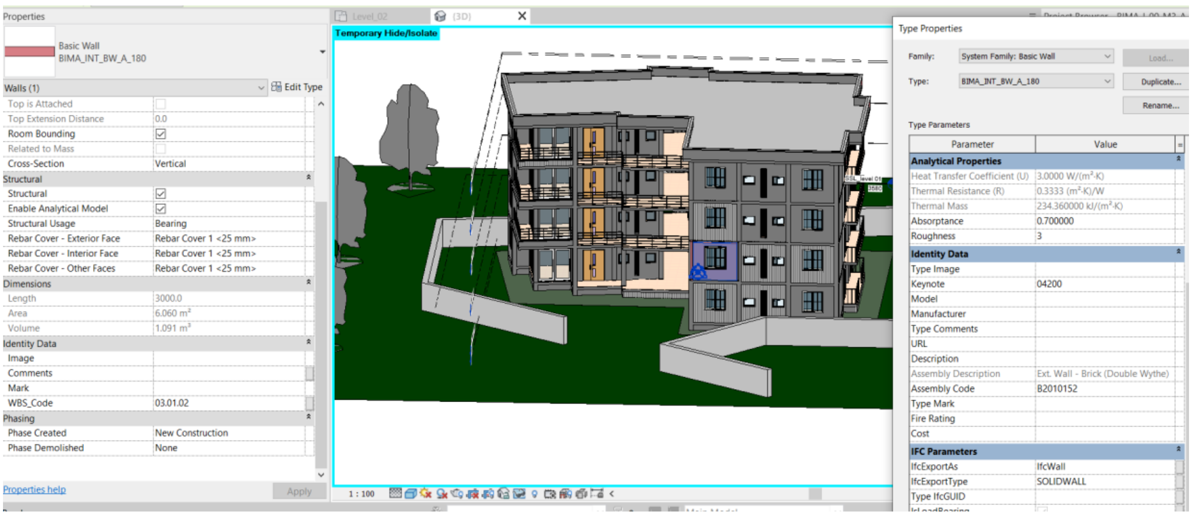


Figure 16: Metadata of architectural wall

3.2.3 Shared Parameters

Parameters that can be added to families or projects and subsequently shared with other families or projects are known as shared parameters. It is possible to add specific information that is not already present in the family file or the project. A schedule can be made using the family categories if a common parameter is generated and added to them. It is referred to as a multi-category schedule in Revit. The families that are modelled in Revit include several parameters in their properties that are designed to give them information and to help arrange their hierarchical structure if many families are related to one another. The ability to return to a family hierarchy makes analysis activities during the phase of project management and maintenance easier.

Shared parameters can be considered as information containers that are applicable to numerous families or projects. The list of shared parameters can be imported for every project because it is kept in a separate text file (.txt) that can be saved in the common area. In this project shared parameter file for Autodesk Revit were used using the procedure listed below;

(Manage tab → Settings panel → Shared Parameters →Browse → Select shared parameters file)

In this project, WBS codes were created as shared parameters which are helpful in making selection sets of elements in Navisworks for clash detection analysis and can also be used for 4D/5D simulations.

3.2.4 Revit files and families naming convention for Structural and Architectural Model

As already explained in the section 2.13.1 of chapter 02, British Standard (BS-1192; 2007+A2 2015) were used for naming the files and families for architectural and structural model.

The structural file was named as "*BIMA-I-00-M3-S-0001_R22.rvt*", and the architectural file, as "*BIMA-I-00-M3-A-0001_R22.rvt*".

Table 5: Naming Convention of Revit files

Field	Information	Description
Project	BIMA	BIMA+ final thesis
Originator	I	Irfan
Volume	00	As I have single building so don't need multiple volume
Type	M3	3D model type
Role	S/A	Structural/ Architectural
Presentation	0001	project number of the file
Revit Version	R22	Autodesk Revit 2022
Extension	. rvt	Revit project native file extension

Similarly, for the families used inside the project, the naming convention follow the same scheme as explained in the Table 5. For example (BIMA_INT_BW_A_100), this indicates an architectural internal brick wall with 100mm thickness, inside the "BIMA" project.

3.2.5 Federated BIM Model

Federated BIM models can be considered as the combination of models of various disciplines (structural, architectural, MEP, etc) together into one. Additionally, they serve the function of giving a comprehensive model of the entire project to ease information exchange, collaboration between design disciplines, and most importantly, interference checks and validations of any design-related issues.

For clash analysis to be carried out, it is necessary to combine all the different disciplines i.e., in this case architectural and structural models into one federated one. After populating the structural and architectural model with all the relevant information, the next step was to create federated model for further usage for 4D/5D modelling. The federated model was created using the following steps;

First a single empty Revit project template was opened, and both the structural and architectural models were linked into it using insert tab by means of shared coordinates. The coordinates for all the files need to be the same otherwise, the linked models will not coordinate correctly. Secondly, after the files were linked, the discipline was changed from architectural to coordinated one to see all the disciplines together. In the following Figure 17, the federated model has been shown. Navisworks provides three ways to create a federated models. a) Using .IFC files of different disciplines b) Directly opening .RVT files into Navisworks and selecting both to show the federated model which is helpful for clash detection analysis c) exporting as .NWC files.

Figure 17: Federated model

3.3 Clash Detection Analysis

Autodesk Navisworks is a very powerful tool used for photorealistic rendering, quantity take-offs, 4D simulation and clash detection of building elements. In this project, it was used for carrying out clash detections of building exercise for all elements. The models (architectural and structural) were exported from Revit to Navisworks using .NWC file format which allows the file generated from authoring software to be native Navisworks file but function as a cache file without any actual geometries in the Navisworks file. In case of any changes, the .NWC file is updated and Navisworks re-caches if the data in the original file is newer than the older .NWC file.

Before starting clash detection, it is necessary to establish some rules and guidelines to specify among which elements the clash detection shall be carried. It is usually done by creating clash detection matrix in two level of coordination (LC1 and LC2), which shows the sequence for which the clash detection would be carried out and to make quick decisions on which elements of a particular system should adapt to another system in clash cases. The clash detection matrix adopted for the given project are presented below;

Table 6: Clash detection matrix for architectural model

LC1						
Model	Arch Model					
Arch Model	Object Class	Windows	Doors	Walls	Floors	Railings
	Windows					
	Doors					
	Walls					
	Floors					
	Railing					

Table 7: Clash detection matrix for structural model

LC1				
Model	STR Model			
STR Model	Object Class	Slabs	Stairs	Columns
	Slabs			
	Stairs			
	Columns			

Table 8: Clash detection matrix for architectural vs structural model

LC2						
Model	Arch Model					
STR Model	Object Class	Doors	Floors	Railings	Walls	Windows
	Slabs					
	Stairs					
	Columns					

In the above tables, the greenish cells mean that the clash between these components are critical, whereas the red one represents that the clashes were not required in the project based on the relation among the elements.

Also, for the ease of correction of all the detected clashes, a tool called “Navisworks Switchback” was used to switchback any selected element in Navisworks environment to Revit environment in real time. This can make the correction and validation process much faster.

3.3.1 Coordination Level 1- Among Architectural Elements

The architectural model was exported to Navisworks as an .NWC file from Revit. Using the established matrix above, selection sets were created in Navisworks in the same order. Using the "Same Name" rule to select and group elements in the same category. As there are three types of clashes (hard, soft and workflow), as already explained in Section 2.12 of Chapter 2 so only hard clashes were checked in this project. Mostly soft clashes are used to check the clearance between two elements especially if MEP discipline is involved but in the given case as there is no MEP discipline, that is why tests were restricted to check only hard clashes. By running the clash test, after selecting the set A and set B element, the software performs the analysis and shows if there are any coinciding elements. For architectural model, there were no clashes detected among the elements. Following figures shows the clash analysis carried out for architectural model.

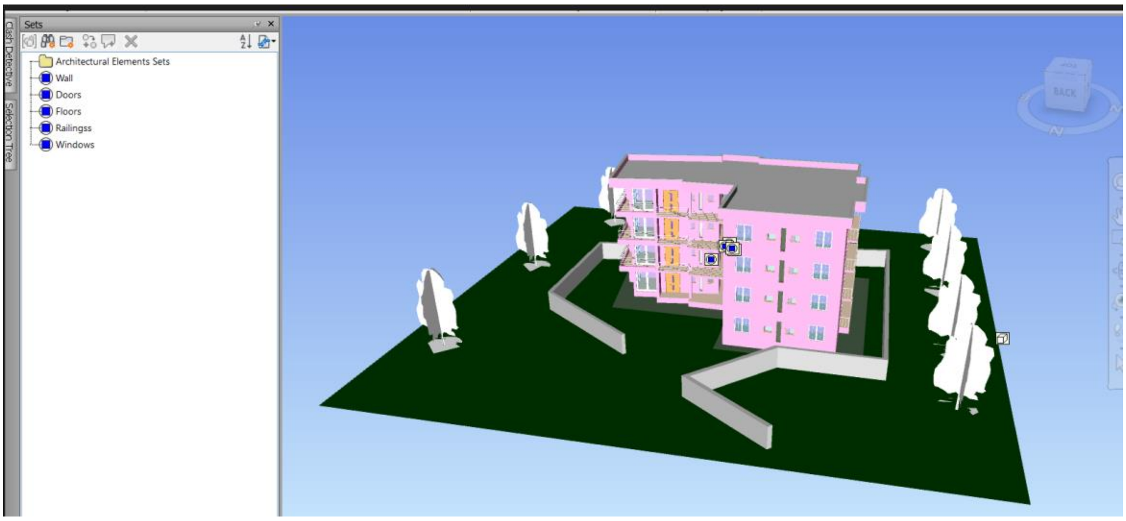


Figure 18: Selection set for architectural elements

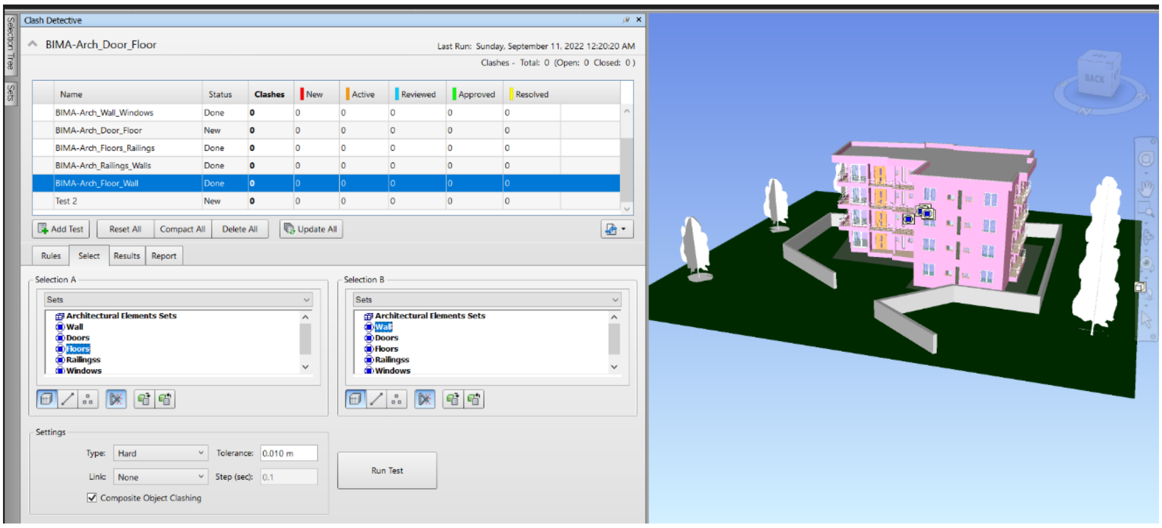


Figure 19: Clash test between floors and wall in architectural model

3.3.2 Coordination Level 1- Among Structural Elements

The structural model was exported as an .NWC file from Revit into Navisworks the same way as carried out for the architectural model. Using established matrix as shown in Table 1Table 7, selection sets were created for structural columns, slabs, and stairs. After setting up the tolerance and selecting sets like slab in Set A and stairs in Set B, the test was run. No clashes were detected among the structural elements. Following figure shows the 3D model of structural discipline in Navisworks environment along with selection sets and the result of clash detection test.

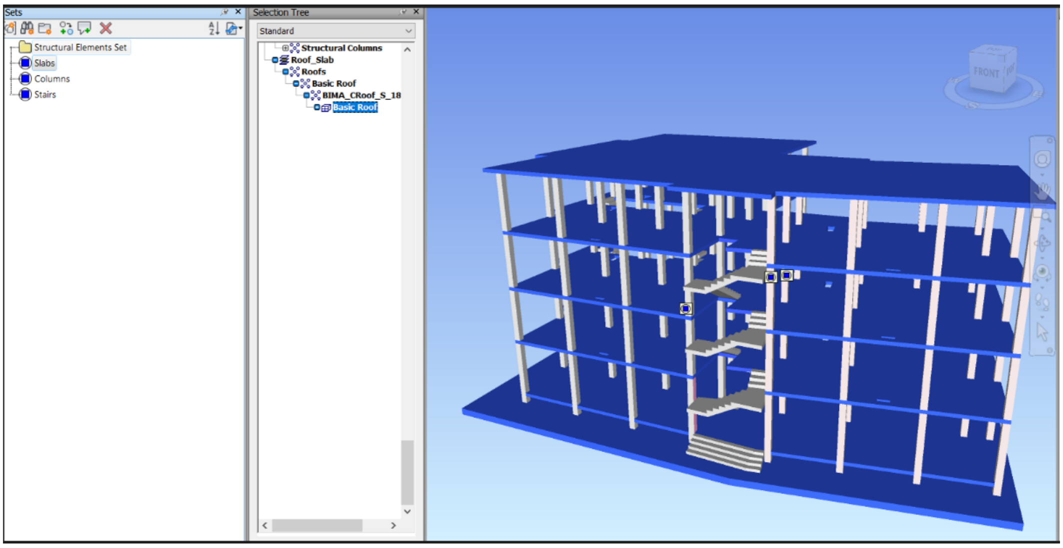


Figure 20:3D structural model and selection sets for elements

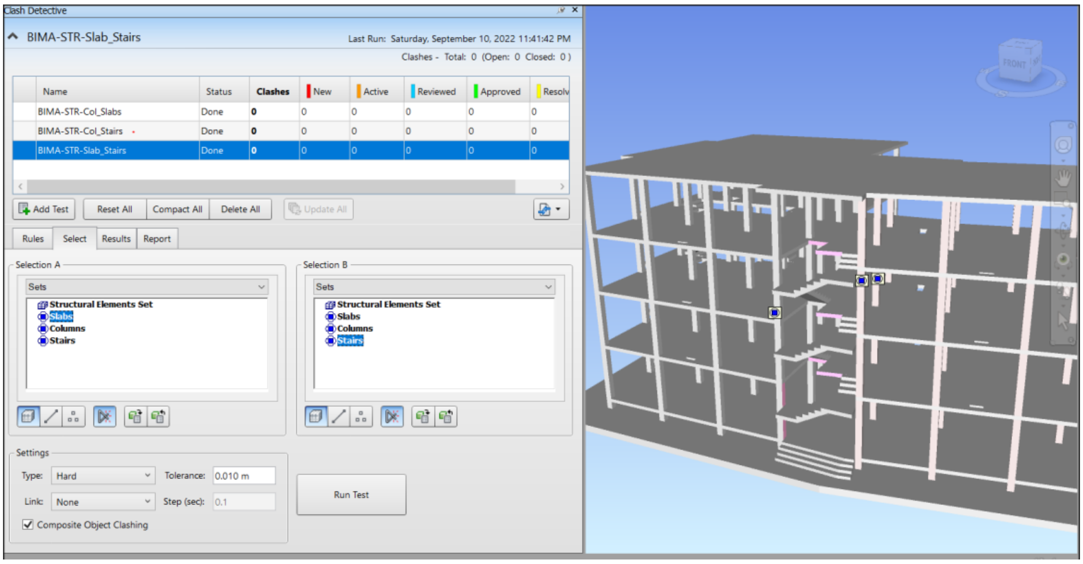


Figure 21: Clash test between slabs and stairs in structural model

3.3.3 Coordination level 2 - Architectural vs Structural Element

Clash detection between structural and architectural elements at an early state of a project is very necessary to resolve any conflicts between these disciplines prior to the commencement of construction work on the site. Both structural and architectural models (LC1 clash free) were exported to Navisworks as .NWC file from Revit. Using the established matrix as shown in Table 8 selection sets for elements were created under their corresponding discipline. After running the test, clashes were found between the two disciplines. The model containing clashes has been shown in Figure 22.

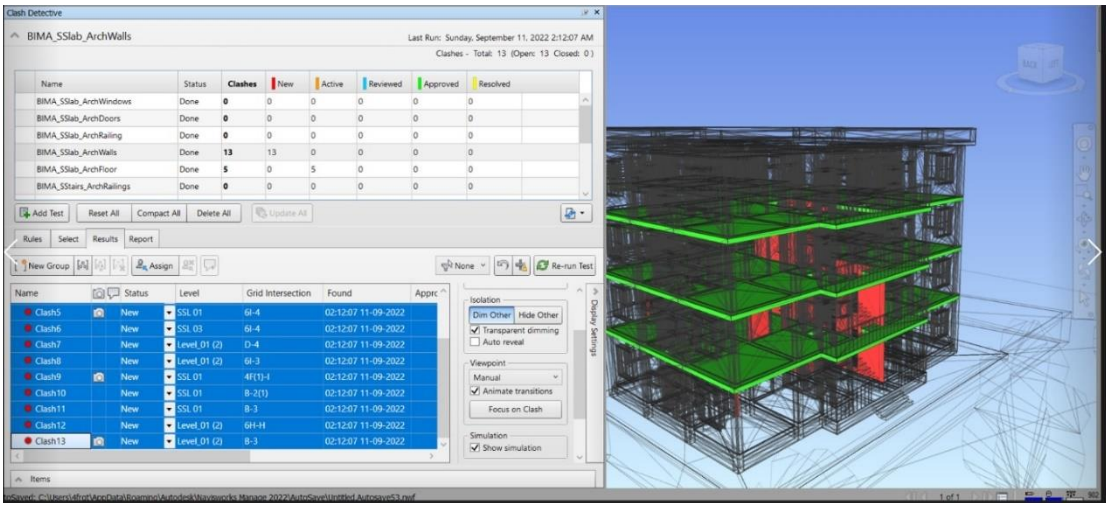


Figure 22: Federated model containing clashes

Using the switchback tool, the elements containing clashes were selected in Navisworks and switchback to Revit window which shows the exact location of the elements in real time to amend the changes. The updated model was then saved, replaced with the older one and exported again as .NWC file to Navisworks. By refreshing the models in the project, the clash tests are updated to see the results of amended model. After the whole clashes were resolved, the file was saved as an .NWF file to maintain the .NWC files in the Navisworks. A final summary of the clash report was exported as HTML (tabular), the result of which has been given in the appendix of this thesis.

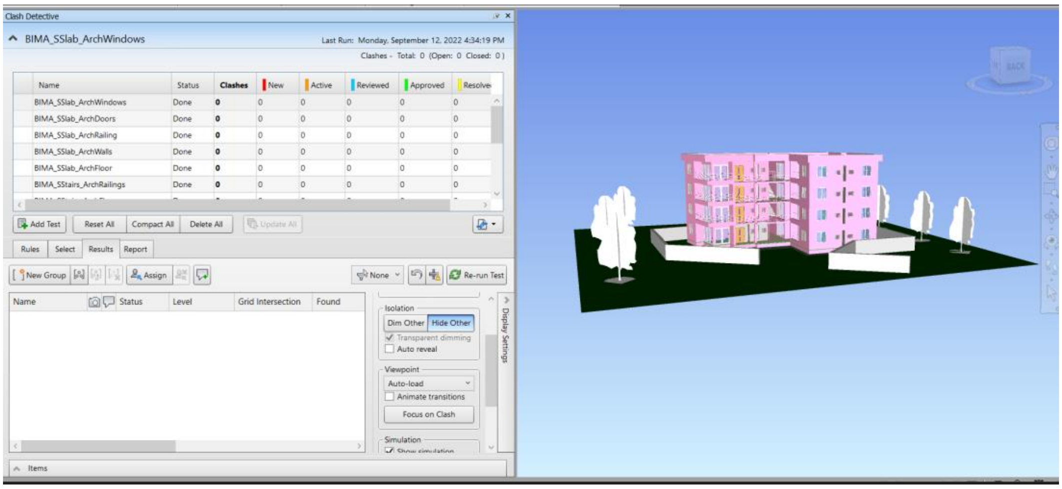


Figure 23: Federated model free from clashes

3.4 Work Breakdown Structure (WBS)

Work Breakdown Structure (WBS) is the initial step to fully understand every step necessary to finish the project. As briefly explained in the Introductory chapter, it aims to break down all the project related tasks into hierarchical categories. In this case, the activities are tightly related to the materials needed, determined by the pricing list. The tasks were divided into six larger categories in the first degree, in the following order: a) building site preparation b) structural works c) completion works d) finishing works e) door and windows installation f) roofing work. These categories were chosen to have a generalized first classification, after which the tasks were further subdivided into more specific ones. The WBS is represented by a division of numbers with each number denoting a degree of the scale. The work breaks down structure for the project has been presented in Figure 24.

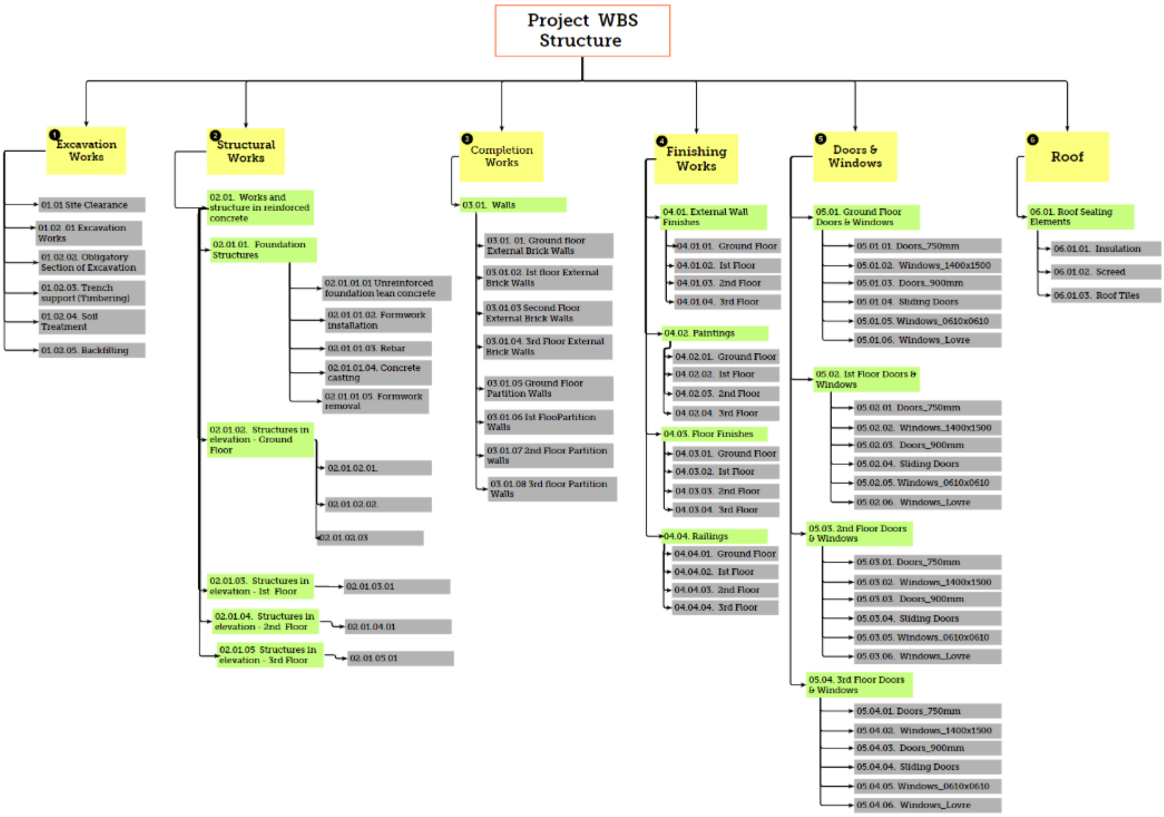


Figure 24: WBS for the Project

3.5 4D/5D Model Integration in STR Vision CPM

STR Vision CPM is a very comprehensive software for construction project management. Along with estimation and jobs accounting, STR Vision CPM is also used to manage pricelists, create price and supporting analyses, plan jobs using Gantt charts, create work maintenance schedules, safety plans, special tender specifications, maintain a daily jobs journal, and extract data in the form of reports using the integrated business intelligence. Currently, STR Vision CPM is a crucial tool for BIM design and execution. A 3D design model containing time (4D) and cost (5D) information may be produced using the quantity take off module in conjunction with both design and engineering applications thanks to the .IFC standard.

In this project, I used the student version of this software which were provided by the company for the completion of the project which has some limitations as some data such as online pricelist etc were not accessible. In the following sections, the methodology adopted for the thorough integration of BIM model in this software environment has been explained in detail such as pricelist creation (resource allocation), quantity take offs, scheduling and 4D simulation at the end of this chapter.

3.5.1 Price Lists and Resources Definition

The first step in STR Vision CPM is to create a price lists of all the resources to be used in the project. It can be materials, labours, or machinery. All the resources were defined according to the breakdown structure as it was easier to be used in quantity take offs. As a reference the pricelist provided in the BIMA+ module 5 were used in this project as the online pricelist of the company were not accessible due to the software license. In conventional methods, first time-schedule is created along with the resources reaching the 4D integration and then cost estimation is linked with the 4D schedules reaching to the 5D which is the mere goal of this thesis but in STR Vision CPM the methods of 4D and 5D is a bit different. In this software, first the cost estimation is done after defining resources and taking off the quantities from the 3D federated model and then scheduling is done to get a complete 4D/5D model. The pricelist of materials is given Table 9.

Table 9: Pricelist of materials

CATEGORY				DIRECT UNIT COST		% IND. COST (€/u.i)	% GENERAL COST (€/u.i)	% PROFIT (€/u.i)	PRICE	
N.	Code	Activity	Description	Value	€/u.i	15%	7%	5%	Value	€/u.i
01.			**Excavation, demolition and backfilling**							
	E_0010	Demolition of the whole building	Complete demolition of the existing building including roof and doors and windows, cleared exclusively of furniture and materials deposited inside it. Included: - The handling, selection and deposit of the resulting materials within the site; - Loading and transport of waste deriving from the demolition of buildings, at authorized dumps, including management, possible fees for landfill rights and bureaucratic procedures concerning transport and delivery.	180	€/m3	27,00	14,49	11,07	**232,56**	€/m3
	E_0020	General excavation 1: removal of the superficial protion of cultivated land	Removal of the portion of cultivated land in order to allocate it to excavations. The excavation is carried out by machine (with a excavator) and with an approximate perimeter. The excavated earth is moved away from the excavation area by means of a bulldozer and then it is piled up in a special area of the construction site.	2,96	€/m3	0,44	0,24	0,18	**3,83**	€/m3
	E_0030	Obligatory section excavation	Obligatory section excavations of materials of any nature and consistency, excluding solid rocks, both dry and wet. The excavation is carried out by mechanical means and the waste materials (excavated earth) are deposited in a specific area of the site, awaiting disposal. Part of the waste materials is disposed in authorized landfills and the other part is used for backfilling.	11,50	€/m3	1,73	0,93	0,71	**14,86**	€/m3
	E_0040	Backfilling	Backfilling or filling of voids performed with mechanical means and selected materials of suitable granulometry, free from organic substances. The material used to carry out the backfill is coming from the excavations	6,45	€/m3	0,97	0,52	0,40	**8,34**	€/m3
02.			**Structural works**							
	S_0010	Unreinforced foundation lean concrete	Premixed cement conglomerate for sub-foundation, unarmed or weakly reinforced structures. Rck ≥ 25 N / Mpa. The material is supplied by means of a truck mixer and cast in situ by means of a pump.	73,50	€/m3	11,03	5,92	4,52	**94,96**	€/m3
	S_0011	Aerated crawl space	Under-floor cavity formed by disposable plastic elements in various heights, filling casting with C20 / 25 concrete, to form an upper slab with a minimum thickness of 5 cm. Excluding any iron armor and containment edges if necessary.	68,71	€/m2	10,31	5,53	4,23	**88,78**	€/m2
	S_0020	Formwork installation	Wood formwork for concrete conglomerate castings for foundation structures (plinths, back beams, curbs, etc.). The wood formwork is shaped in construction site. The processing waste is disposed in authorized dumps, without being stored in a specific part of the site.	29,46	€/m2	4,42	2,37	1,81	**38,06**	€/m2
	S_0030	Rebar	Supply and installation of rods for rebar of reinforced concrete structures, supplied already shaped according to project executives,in smooth bars or with improved adhesion of type B450C.The bars are pre-shaped: consequently, there is no need to allocate a yard space to the processing of the rods, no tools or equipment are needed for cutting the irons, there are no scraps and there is no need to dispose of the waste material.	2,62	€/kg	0,39	0,21	0,16	**3,38**	€/kg
	S_0040	Concrete casting	Cement conglomerate for foundation structures BASEMENT STRUCTURE packaged according to the law (and to the mix design) with cement and calculated aggregates or of inert river of suitable granulometry, given in work including compaction by hand or with mechanical vibrators, to give the finished work in a workmanlike manner. Excluding only reinforcing steel bars and the wood formwork. Cementitious conglomerate with Rck ≥ 30 N / Mpa.	92,19	€/m3	13,83	7,42	5,67	**119,11**	€/m3
	S_0041	Formwork removal	Removal of formwork by meand of 2 operators. This operation can be performed on: pillar's formwork, foundation's formwork, basaments and slabs formwork and on load bearing wall's formwork.	8,32	€/m2	1,25	0,67	0,51	**10,74**	€/m2

03.	Completion works									
	C_0010	Hollow bricks external masonry 20x25x13 cm	Hollow bricks external mansory 20 x 25 x 13 cm, thickness 20 cm, with cement mortar , including the burden of shoulder formation, turn, edges, pilasters, internal work surfaces.	67,60	€/m2	10,14	5,44	4,16	87,34	€/m2
	M_0010	Light concrete screed	Cement-based screed of expanded clay, laid in place on a perfect plan configured according to pre-established slopes, for an average thickness of 10 cm, including every other burden and teaching to give the finished work as a rule of art	16,63	€/m3	2,49	1,34	1,02	21,49	€/m3
04.	Finishing works									
	F_0010	Insulating wall cladding (ETICS system)	Thermal insulation in sintered expanded polystyrene slabs with delayed flame propagation (class I), applied with special mortar or with special stainless metal fasteners, including scraps, scaffolding up to a height of 4 m from the supporting surface , the throw and the decrease of materials, every other burden and teaching to give the finished work in a workmanlike manner. Density: 15 kg/m2	4,75	€/m2	0,71	0,38	0,29	6,14	€/m2
	F_0011	XPS floor panels	Thermal insulation in rolls consisting of a self-extinguishing single-layer expanded polystyrene extruded panel with a density of 35-40 kg / mc and a unitary thermal conductivity of no more than 0.021 Kcal / mh ° C, cut into 50 mm wide strips.	20,80	€/m2	3,12	1,67	1,28	26,87	€/m2
	F_0050	Plaster on outer walls - external side	Civil plaster of premixed sand-cement for external use, contained in silos of 3000 liters, laid by means of a spray pump, leveled by means of screed and trowel. Every other burden and teaching to give the work done to perfection. Thickness: 20 mm; Density: 1,530 kg/m³.	20,77	€/m2	3,12	1,67	1,28	26,84	€/m2
	F_0060	Plaster on internal walls	Civil plaster of premixed sand-cement for internal use of vertical, horizontal and curve surfaces, contained in silos of 3000 liters, laid by means of a spray pump, leveled by means of screed and trowel. Every other burden and teaching to give the work done to perfection. Thickness: 15 mm; Density: 1,370 kg/m³.	19,43	€/m2	2,91	1,56	1,20	25,11	€/m2
	F_0170	Baseboard	Placing of plinth in wooden materials, with fixing by means of adhesive glue or nails,every other burden and teaching to give the finished work a rule of art.	6,37	€/m	0,96	0,51	0,39	8,23	€/m
	F_0210	Painting on outer walls - external side	Application of white paint by means of a spray pump (performed with a machine with perfect coverage), including pulling and falling materials, service bridges up to 4 m from the support surface and every other burden and teaching to give the finished work in a workmanlike manner. Application on vertical, horizontal and inclined surfaces of civil plaster.	19,43	€/m2	2,91	1,56	1,20	25,11	€/m2
	F_0220	Painting on internal walls		19,43	€/m2	2,91	1,56	1,20	25,11	€/m2
	F_0430	Painting on floor's ceiling		19,43	€/m2	2,91	1,56	1,20	25,11	€/m2
	F_0530	Gres	Stoneware tile floor, installed on a cement mortar base of type 325 with a thickness of not less than 2 cm, including the sealing of the wall joints, cuts, scraps, special pieces, the possible formation of joints of expansion, shooting at the top and the drop in materials, washing with acid, final cleaning and every other burden to give the finished work in a workmanlike manner..	22,70	€/m2	3,41	1,83	1,40	29,33	€/m2
05.	Doors and windows									
	D_0030	Door	Double-leaf sliding internal doors, in hollow-core fir wood, with honeycomb cellular internal structure, 48 mm finished thickness, perimeter frame in fir wood and fiber-reinforced panels, casement with shoulder, complete with exhibitions and counter-shows, frame ad inlets from 80 to 120 mm. Including aluminum handle type heavy, the anuba type hinges in 13 mm steel, the lock with two keys; finishing with primer and varnishing with polyurethane lacquers, the false frame.	205,5	€/cad	30,83	16,54	12,64	265,49	€/cad
	D_0040	Subframe	Fir wood counter frames for doors and windows, of variable width and minimum thickness of 2.5 cm, planed and flattened, complete with suitable grappas for anchoring to the masonry, cuts to size, scraps, including the necessary masonry work , the throw and the drop of materials, the service bridges up to 4 m from the support surface, every other burden and teaching to give the finished work in a workmanlike manner.	7,46	€/m	1,12	0,60	0,46	9,64	€/m
	D_0050	Window	Windows or French windows, in one or more lots, with flag or vasistas opening, consisting of a fixed frame with a minimum section of 8x4.5 cm, connected with suitable anchoring to the sub-frame; the openable or fixed parts consist of frames (minimum section of 4.5x4.5 cm) molded on both sides and with base or base crosspiece of 15-20 cm height; possible intermediate crossbars with double batten also with a curved profile or with a lupine profile, a draped wedge-shaped drainer in the external part, a channel guide in the internal panels for fixing the glass, suitably molded laths; including exhibitions, frames and contours for securing the glass (fixing to be paid separately), complete with suitable brass fittings, also chromed, such as: heavy-duty hinges with a minimum height of 14 cm, two for each mobile part of the window or three for the door-window, cremone bolts encased with a decoy nose and heavy brass handle, also chrome-plated, possible hooks and chains of stop in brass or chromed steel with relative wall plugs; every other burden and teaching to give the finished work a rule of art: fir or chestnut frame, finished thickness of 7.5 cm, double swing with	270,52	€/cad	40,58	21,78	16,64	349,52	€/cad
	D_0060	Window sill	Artifacts in decorative marble, cut and finished in the factory with specific marble, smooth surface view, for contours, shoulders, hats, window sills, thresholds and the like.. Thickness: 2 cm	119,39	€/m2	16,83	122,52	12,25 €	1,13	€/m2
06.	Roof									
	R_0010	Steam barrier	Steam barrier consisting of a polyethylene sheet, laid dry with 5 cm overlap, flaps on the vertical walls not less than 10 cm. Lay on support suitably prepared at any height, on flat, curved and inclined surfaces, including any scaffolding up to a height of 4 m from the supporting surface, the pull and the decrease of materials, each other burden and teaching to give the finished work in a workmanlike manner.	2,25	€/m2	127,22	926,16	92,62	0,01	€/m2
	R_0020	Waterproofing	Prefabricated waterproof covering consisting of an elastomeric polymer-bitumen membrane reinforced with continuous non-woven polyester fabric. Laying on a laying surface properly prepared at any height, on flat, curved and inclined surfaces, including any scaffolding up to a height of 4 m from the support surface, the throw and the drop in materials, every other burden and teaching to give the work done to perfection. Thickness: 3 mm	13,93	€/m2	744,71	5421,62	542,16	428,01	€/m2

The pricelist in STR CPM has been created using the following steps;

Using the above procedure, a complete pricelists were defined inside the software for the project defining the per unit costs of the items as shown in Figure 25. It is also possible to import or export pricelist from excel.

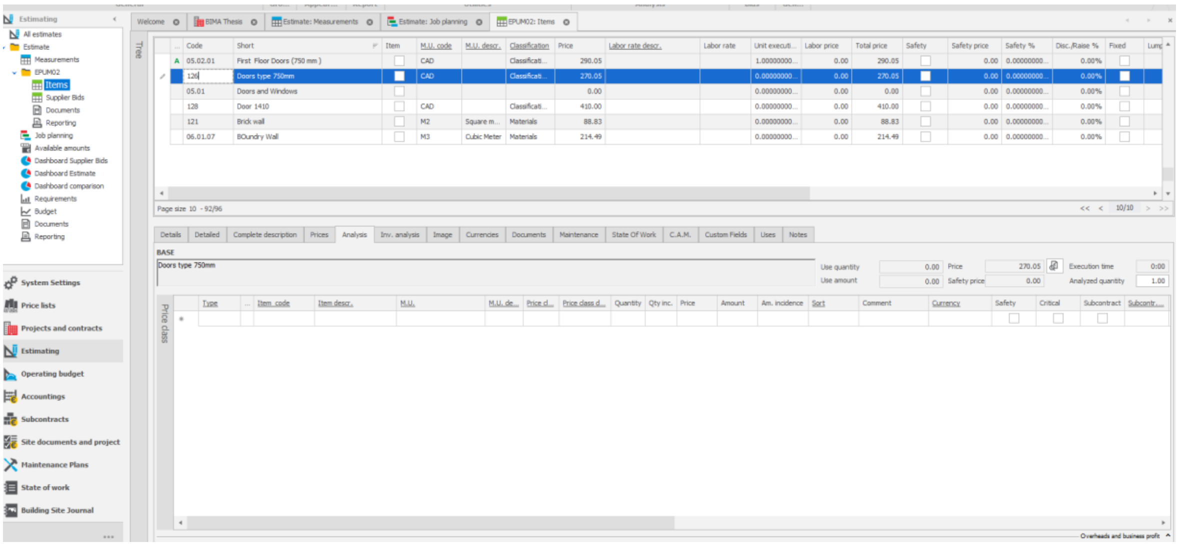


Figure 25: Pricelist of items in STR vision CPM

3.5.2 Quantity Take-offs and Cost Analysis

After defining pricelist, the project under the name of “BIMA Thesis” were established using Project and Contract option available on the left corner of the software interface. By setting the project as current, allows all the modules and activities to refer to the current project. Similarly, the pricelist defined as explained in the Section 3.5.1 will be used for this project. Inside the project, there are different option available such as measurements, pricelist, WBS, rates, .IFC etc. Using .IFC, the 3D models of architecture and structure were imported to create a federated model as shown in Figure 26.

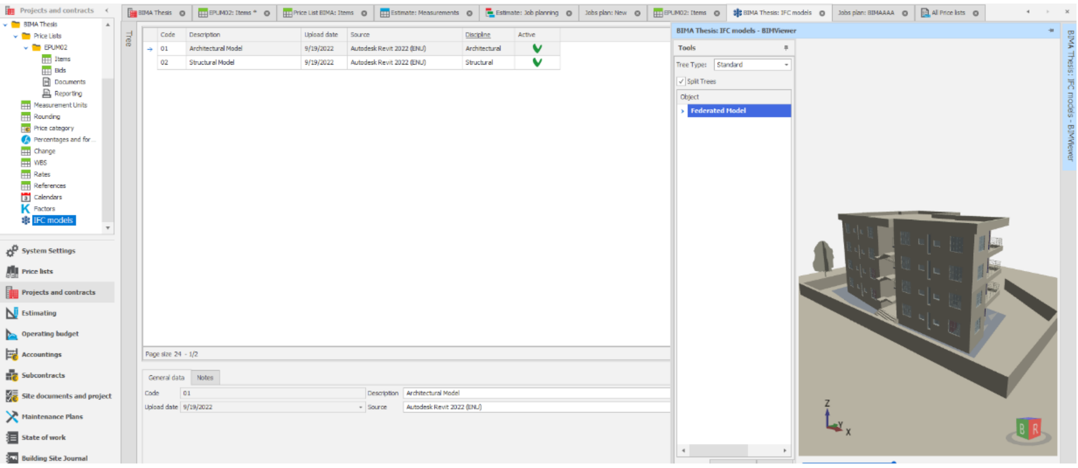
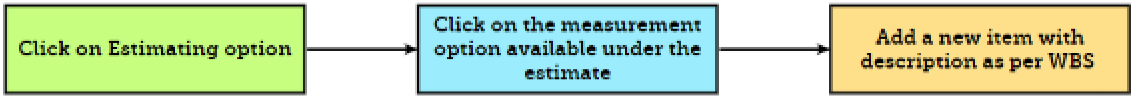


Figure 26: Federated BIM model in STR Vision CPM

This federated model was used for the estimation of element quantities. Quantity take-offs (QTO) are a detailed measurement of materials and labour needed to complete a construction project. They are developed by an estimator during the pre-construction phase. This process includes breaking the project down into smaller and more manageable units that are easier to measure or estimate. The level of detail required for measurement may vary. These measurements are used to format a bid on the scope of construction. For quantity take off, all the items as per WBS were created using the following steps.



Once the items were created according to the WBS hierarchical class, the next step was to take off the quantities from the federated model. There are different options available for this purpose, such as selecting elements manually and then dragging down to the specific class already defined but this process is cumbersome, having greater chances of mistakes and does not add much to the BIM process which is the reduction of time and improving efficiency. The next option is to filter all the elements according to WBS hierarchical class and measure their quantity using the IFC parameters. This method was employed in this project which is more convenient and effective then the first one. In this way, the quantity of all elements was calculated according to their specification such volume for concrete, area for walls and number of items for windows/doors. In case there is modification in the models, the estimates can be updated and compared using update estimates option available in the software.

Under the analysis option inside the selected elements, the resources such as material and labours/worker needed for the unit completion of the selected items were defined. In this way, cost analysis was done for every component and the resulting cost is the combination of direct/indirect cost of the component and labour cost.

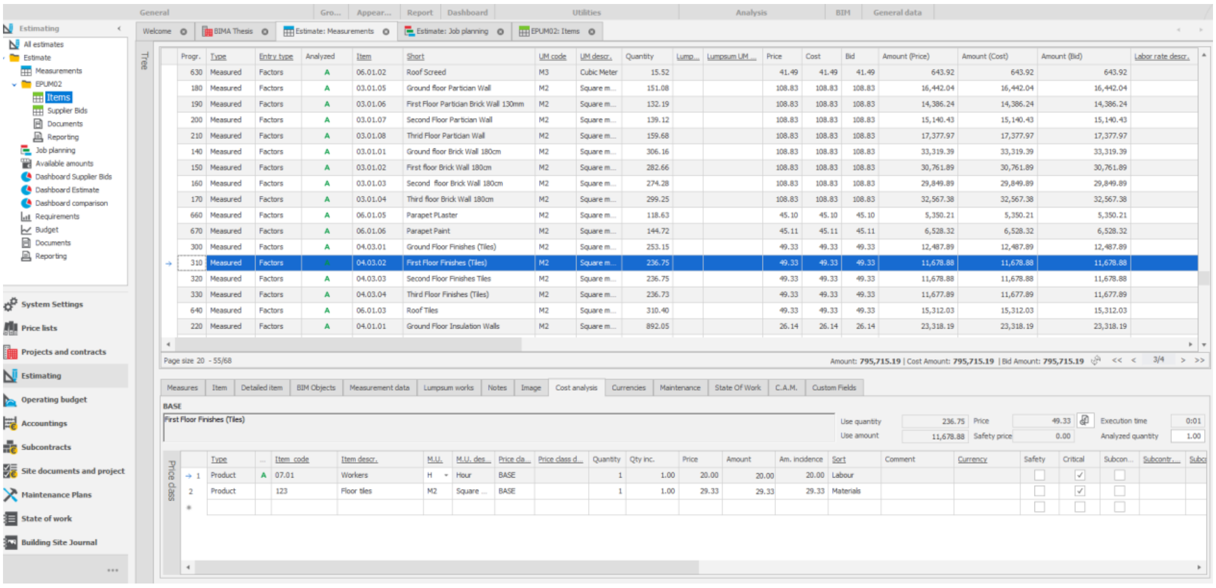


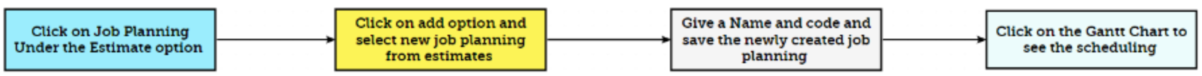
Figure 27: Cost analysis of floor finishes

3.5.3 Time Schedule and Gantt Chart (4D)

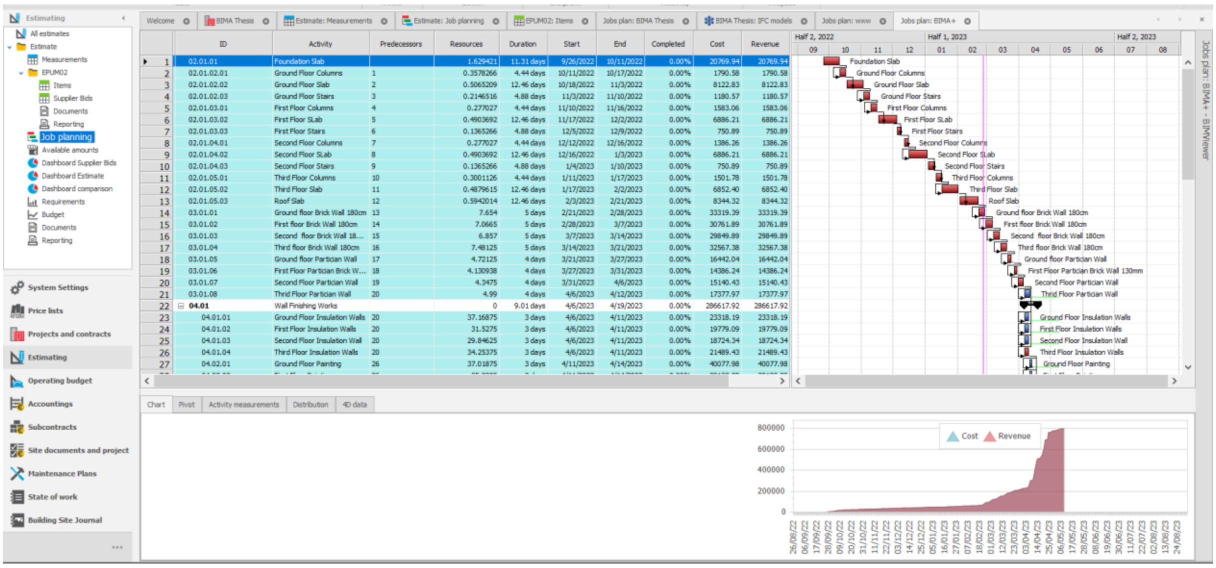
The creation of a time schedule, a potent instrument utilized in many industrial situations and not just in the construction sector, is the most crucial step in a 4D project. Time schedules can be used for any productive tasks. In this scenario, the purpose was to implement the project with a costs analysis and then attain the fifth dimension by applying the resources in terms of costs to any activities. This consisted of associating a timeframe to each activity already identified in the WBS. The Gantt chart, created for the first time in 1917 by American engineer Henry Laurence Gantt [39], is an easily readable time schedule where any task is applied a timing, so an initial and final date, a resource in terms of material, work, or cost resource. In this way, it is possible to manage in one integrated tool all that concern costs, time, human resource, and monitoring in real time the accomplishing degree of the project, which permit to have a complete overview. The relation between the activities can be divided into the following four categories.

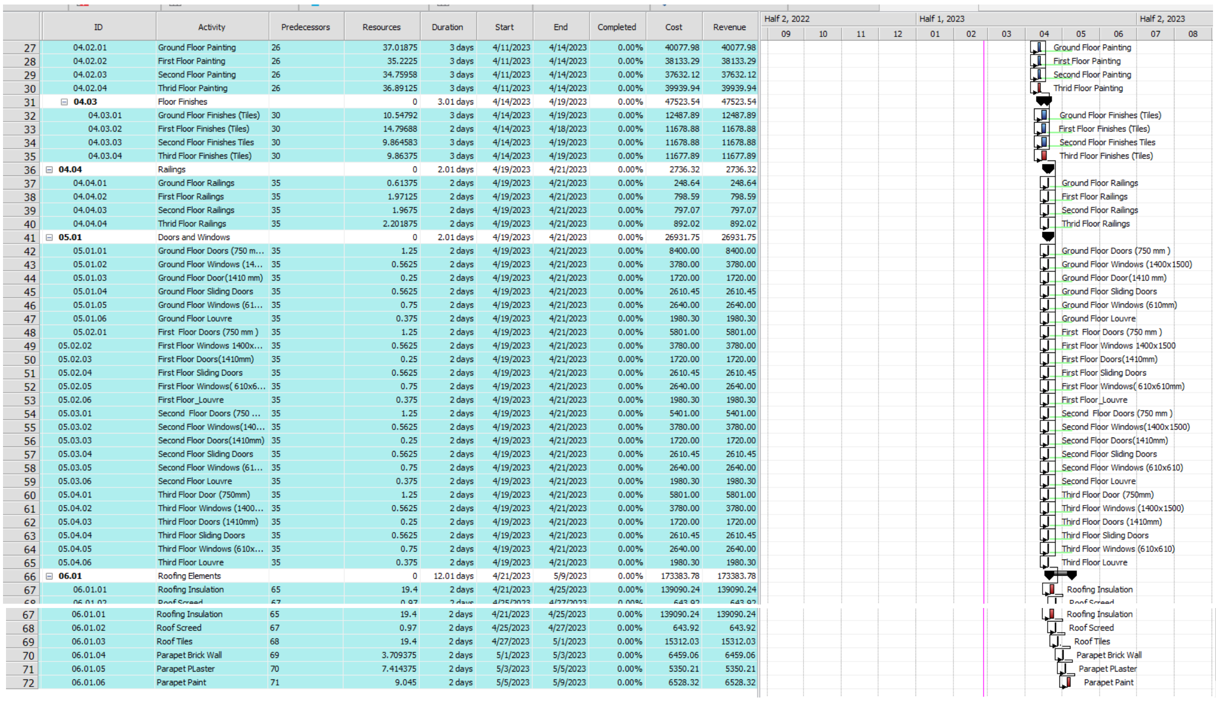
a) End - Start: This relationship, which is more frequently employed, states that the next activity starts when the preceding one stops.
b) Start - Start: When two or more operations get underway simultaneously.
c) End - End: Because the final date links two activities, they can begin at separate times but must conclude on the same day.
d) Start - End: The chosen activity must come to an end before the other does.

Usually, MS Project or Primavera is used for scheduling the construction activities, but STR Vision CPM has the advantage of having built in option of job scheduling from the estimated quantities. The per unit cost of analysed quantity for each activity were already carried out in the cost analysis but the total time required for the completion of each activity were done in the job planning. Once the time for each activity is defined, the software automatically calculates the total cost of the activity by multiplying the resources with unit execution time. Gantt Chart/Job Planning for this project were created using the following steps.



A complete schedule of activities with cost and duration has been presented in the figure …





	ID	Activity	Predecessors	Resources	Duration	Start	End	Completed	Cost	Revenue
27	04.02.01	Ground Floor Painting	26	37.01875	3 days	4/11/2023	4/14/2023	0.00%	40077.98	40077.98
28	04.02.02	First Floor Painting	26	35.2225	3 days	4/11/2023	4/14/2023	0.00%	38133.29	38133.29
29	04.02.03	Second Floor Painting	26	34.75958	3 days	4/11/2023	4/14/2023	0.00%	37632.12	37632.12
30	04.02.04	Thrid Floor Painting	26	36.89125	3 days	4/11/2023	4/14/2023	0.00%	39939.94	39939.94
31	**04.03**	Floor Finishes		0	3.01 days	4/14/2023	4/19/2023	0.00%	47523.54	47523.54
32	04.03.01	Ground Floor Finishes (Tiles)	30	10.54792	3 days	4/14/2023	4/19/2023	0.00%	12487.89	12487.89
33	04.03.02	First Floor Finishes (Tiles)	30	14.79688	2 days	4/14/2023	4/18/2023	0.00%	11678.88	11678.88
34	04.03.03	Second Floor Finishes Tiles	30	9.864583	3 days	4/14/2023	4/19/2023	0.00%	11678.88	11678.88
35	04.03.04	Third Floor Finishes (Tiles)	30	9.86375	3 days	4/14/2023	4/19/2023	0.00%	11677.89	11677.89
36	**04.04**	Railings		0	2.01 days	4/19/2023	4/21/2023	0.00%	2736.32	2736.32
37	04.04.01	Ground Floor Railings	35	0.61375	2 days	4/19/2023	4/21/2023	0.00%	248.64	248.64
38	04.04.02	First Floor Railings	35	1.97125	2 days	4/19/2023	4/21/2023	0.00%	798.59	798.59
39	04.04.03	Second Floor Railings	35	1.9675	2 days	4/19/2023	4/21/2023	0.00%	797.07	797.07
40	04.04.04	Thrid Floor Railings	35	2.201875	2 days	4/19/2023	4/21/2023	0.00%	892.02	892.02
41	**05.01**	Doors and Windows		0	2.01 days	4/19/2023	4/21/2023	0.00%	26931.75	26931.75
42	05.01.01	Ground Floor Doors (750 m...	35	1.25	2 days	4/19/2023	4/21/2023	0.00%	8400.00	8400.00
43	05.01.02	Ground Floor Windows (14...	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	3780.00	3780.00
44	05.01.03	Ground Floor Door(1410 mm)	35	0.25	2 days	4/19/2023	4/21/2023	0.00%	1720.00	1720.00
45	05.01.04	Ground Floor Sliding Doors	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	2610.45	2610.45
46	05.01.05	Ground Floor Windows (61...	35	0.75	2 days	4/19/2023	4/21/2023	0.00%	2640.00	2640.00
47	05.01.06	Ground Floor Louvre	35	0.375	2 days	4/19/2023	4/21/2023	0.00%	1980.30	1980.30
48	05.02.01	First Floor Doors (750 mm)	35	1.25	2 days	4/19/2023	4/21/2023	0.00%	5801.00	5801.00
49	05.02.02	First Floor Windows 1400x...	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	3780.00	3780.00
50	05.02.03	First Floor Doors(1410mm)	35	0.25	2 days	4/19/2023	4/21/2023	0.00%	1720.00	1720.00
51	05.02.04	First Floor Sliding Doors	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	2610.45	2610.45
52	05.02.05	First Floor Windows(610x6...	35	0.75	2 days	4/19/2023	4/21/2023	0.00%	2640.00	2640.00
53	05.02.06	First Floor_Louvre	35	0.375	2 days	4/19/2023	4/21/2023	0.00%	1980.30	1980.30
54	05.03.01	Second Floor Doors (750 ...	35	1.25	2 days	4/19/2023	4/21/2023	0.00%	5401.00	5401.00
55	05.03.02	Second Floor Windows(140...	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	3780.00	3780.00
56	05.03.03	Second Floor Doors(1410mm)	35	0.25	2 days	4/19/2023	4/21/2023	0.00%	1720.00	1720.00
57	05.03.04	Second Floor Sliding Doors	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	2610.45	2610.45
58	05.03.05	Second Floor Windows (61...	35	0.75	2 days	4/19/2023	4/21/2023	0.00%	2640.00	2640.00
59	05.03.06	Second Floor Louvre	35	0.375	2 days	4/19/2023	4/21/2023	0.00%	1980.30	1980.30
60	05.04.01	Third Floor Door (750mm)	35	1.25	2 days	4/19/2023	4/21/2023	0.00%	5801.00	5801.00
61	05.04.02	Third Floor Windows (1400...	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	3780.00	3780.00
62	05.04.03	Third Floor Doors (1410mm)	35	0.25	2 days	4/19/2023	4/21/2023	0.00%	1720.00	1720.00
63	05.04.04	Third Floor Sliding Doors	35	0.5625	2 days	4/19/2023	4/21/2023	0.00%	2610.45	2610.45
64	05.04.05	Third Floor Windows (610x...	35	0.75	2 days	4/19/2023	4/21/2023	0.00%	2640.00	2640.00
65	05.04.06	Third Floor Louvre	35	0.375	2 days	4/19/2023	4/21/2023	0.00%	1980.30	1980.30
66	**06.01**	Roofing Elements		0	12.01 days	4/21/2023	5/9/2023	0.00%	173383.78	173383.78
67	06.01.01	Roofing Insulation	65	19.4	2 days	4/21/2023	4/25/2023	0.00%	139090.24	139090.24
67	06.01.01	Roofing Insulation	65	19.4	2 days	4/21/2023	4/25/2023	0.00%	139090.24	139090.24
68	06.01.02	Roof Screed	67	0.97	2 days	4/25/2023	4/27/2023	0.00%	643.92	643.92
69	06.01.03	Roof Tiles	68	19.4	2 days	4/27/2023	5/1/2023	0.00%	15312.03	15312.03
70	06.01.04	Parapet Brick Wall	69	3.709375	2 days	5/1/2023	5/3/2023	0.00%	6459.06	6459.06
71	06.01.05	Parapet PLaster	70	7.414375	2 days	5/3/2023	5/5/2023	0.00%	5350.21	5350.21
72	06.01.06	Parapet Paint	71	9.045	2 days	5/5/2023	5/9/2023	0.00%	6528.32	6528.32

Figure 28: Schedule of activities (Gantt Chart)

From the Gantt chart it can be observed that construction management process is very complex consisting of many activities even for a small four story building. Therefore, a thorough knowledge of construction activiteis and resource levelling is utmost necessary. In the Gantt chart, the first column respresents the task numbering automatically assigned by the software itself, the secon column respresents the "ID" which is the work break down structure, followed by a column representing the description of activities. Every activity has a start and end date linked together by the predecessor which shows how the succeeding activity will be carried on construction site based on its relationship with the previous one.

At the bottom, a chart has been shown which represent the cost and revenue generated from the project. As in this project, there were no predefined cost of the project so both the cost and revenue for the project is the same. This is usually helpful for accounting and bidding purposes where every project has a bid and construction price and can be compared to see the profitability of project.

3.6 4D/5D Simulation

The Gantt chart consists of both the time duration (4D) and costs (5D) of each activity thus reaching the goal of 4D/5D integration of BIM model, however, it was not possible to get the simulation in real time. As this software provide an extensive platform for accounting, budgeting, estimation, and state of work, however, due to limited resources available on this software, there is huge room for the extensive research to be carried out. In my case, the 4D simulation tab was grey not allowing the activities to be seen in real time, thus it is suggested as future work for the researchers who will work on this platform.

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4 Conclusion

The main objective of this dissertation was to identify the correct pathway for the 4D/5D integration of BIM model. The need of this work regards the fact that construction industry has been seeking solution to reduce project costs, increase efficiency, productivity, quality and shorten project duration. Building Information Modelling offers the potential to achieve this goals especially after the development and use of software that provides n-dimensional models to simulate the planning, design, construction and operation of a facilty. 4D/5D BIM for costing and scheduling provides useful provisions to save time and cost of a project. In more detail, 4D and 5D BIM are assigned to explore new paths for a better control of a project. 4D BIM allows linking tasks in a project plan with 3D model components and allows to compare different options by visualizing work sequences and duration of every task. This enables identifying problems that may not be visible within the traditional schedules, creating scenarios to assess feasibility of executions, finding the best solution and see the impact in 3D after updating the Gantt chart. It also helps to analyse how the building process will appear at different project stages. Furthermore, the use of 5D BIM allow to generate models which can identify how modifications on materials, layouts, constructive methodology and other design elements can affect the layout of an infrastructure as well as related costs.

In this work, STR Vision has been used for the 4D/5D modelling of the BIM model. The following points were concluded during the course of this project.

a) It was concluded during this study that to achieve a correct 4D/5D integrated model, it is essntial that the 3D model should have the correct parameters and data as it provide a base for other dimensions of BIM. Some Revit families does not have the properties required for the quantity take-offs therefore, some new parameters were generated.
b) STR Vision has been proved to be a very powerful tool for the modelling of integrated BIM model as it provided the 4D scheduling and 5D cost estimation with built in options rather than estimating cost in software like MS Excel and scheduling in MS Project and later on linking all the data in 4D/5D software. However, it does not provided clash detection analysis for which Autdodesk Naviswork is widely recommended.
c) STR Vision provides a dynamic appraoch to any modifcation made to the model. Any changes to the estimates or schedules is directly refelected in the model.
d) To achieve the goals of integated BIM model efficiently, it is important to “start with the end gaols in mind” and having a suitable workbreak down structrue for the project. In this project, WBS were created at the start of the project which proved very helpful in cost estimation and scheduling. Otherwise, a lot of time would have been spent for taking the correct quantity take off from model and deciding the orders of activity to take place.

4.1 Future Recommendations

It is important to fully understand the tools that are applied during the process. STR Vision CPM being powerful, yet unexplored tool requires a lot of research to fully utilize its capacity in BIM. In this project, 4D simulation was not achieved due to the limited research available on this tool that is why it is recommended for future work to find a method to link the model data with 4D simulation. It will be helpful for visualisation of the model in real time which in turn will provide better understanding of construction activities and reducing errors.

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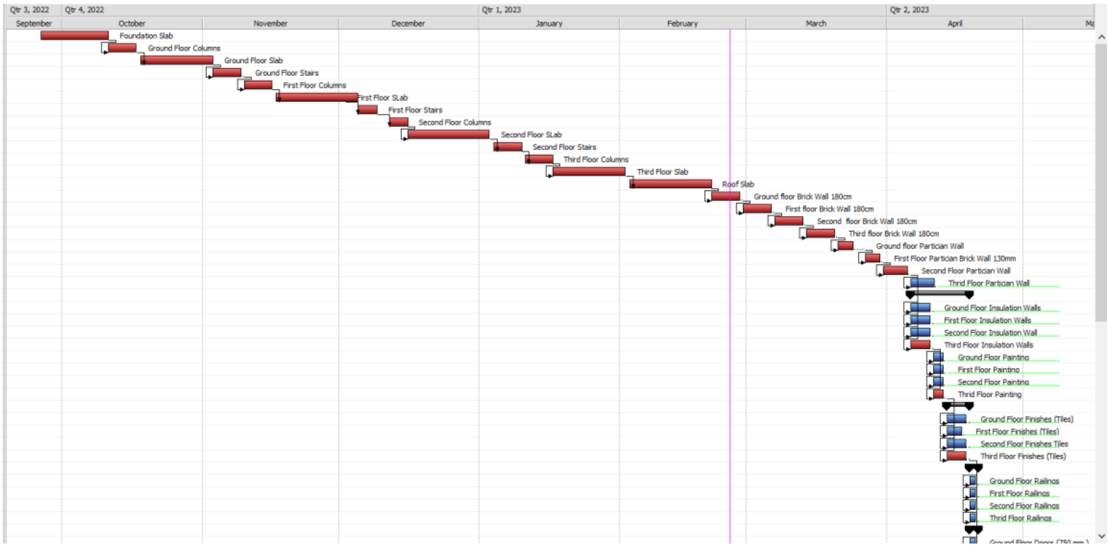
LIST OF ACRONYMS AND ABBREVIATIONS

BIM	Building Information Modelling
3D Model	Three-dimensional model
QTOs	Quantity take-offs
IFC	Industrial Foundation Class
WBS	Work Break-down Structure
LOD	Level of Detail/Development
IAI	International Alliance for Interoperability
CDE	Common Data Environment
AEC	Architectural/Engineering/Construction
CAD	Computer Aided Design
IPD	Integrated Project Delivery
MEP	Mechanical/Electrical/Plumbing
DBM	Design Build Method
AIA	American Institute of Architects
CSI	Construction Specification Institute
ISO	International Organization for Standardization

APPENDIX



Gantt Chart

Clash Report

AUTODESK® NAVISWORKS® **Clash Report**

BIMA_SSlab_ArchWindows	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SSlab_ArchDoors	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

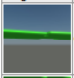
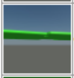
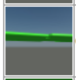
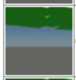
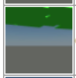
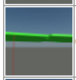
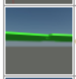
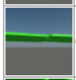
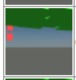
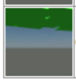
								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SSlab_ArchRailing	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SSlab_ArchWalls	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	13	13	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash1	New	-0.200	A-4 : SSL 01	Hard	2022/9/11 0:12	x:-10.588, y:3.526, z:3.400	*Element ID*: 775238	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash2	New	-0.200	A-4 : Level_01	Hard	2022/9/11 0:12	x:-10.586, y:3.524, z:6.300	*Element ID*: 849396	FFL_level 01	Wall Texture, Orange Peel	Solid	*Element ID*: 952445	Level_02	Wall Texture, Orange Peel	Solid
	Clash3	New	-0.200	6I-3 : SSL 01	Hard	2022/9/11 0:12	x:-1.863, y:5.622, z:3.400	*Element ID*: 775452	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash4	New	-0.180	6I-3 : SSL 03	Hard	2022/9/11 0:12	x:-2.143, y:5.622, z:9.200	*Element ID*: 972789	FFL_Level_02	Wall Texture, Orange Peel	Solid	*Element ID*: 1012115	Level_03	Wall Texture, Orange Peel	Solid
	Clash5	New	-0.180	6I-4 : SSL 01	Hard	2022/9/11 0:12	x:-2.076, y:3.526, z:3.400	*Element ID*: 775736	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash6	New	-0.180	6I-4 : SSL 03	Hard	2022/9/11 0:12	x:-2.143, y:3.526, z:9.200	*Element ID*: 972791	FFL_Level_02	Wall Texture, Orange Peel	Solid	*Element ID*: 1012115	Level_03	Wall Texture, Orange Peel	Solid
	Clash7	New	-0.180	D-4 : Level_01	Hard	2022/9/11 0:12	x:-3.524, y:3.524, z:6.300	*Element ID*: 849399	FFL_level 01	Wall Texture, Orange Peel	Solid	*Element ID*: 952445	Level_02	Wall Texture, Orange Peel	Solid
	Clash8	New	-0.180	6I-3 : Level_01	Hard	2022/9/11 0:12	x:-1.712, y:5.622, z:6.300	*Element ID*: 849397	FFL_level 01	Wall Texture, Orange Peel	Solid	*Element ID*: 952445	Level_02	Wall Texture, Orange Peel	Solid
	Clash9	New	-0.153	4F-I : SSL 01	Hard	2022/9/11 0:12	x:8.196, y:5.775, z:3.400	*Element ID*: 523632	NSL	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash10	New	-0.091	B-2 : SSL 01	Hard	2022/9/11 0:12	x:-7.761, y:10.731, z:3.400	*Element ID*: 752056	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash11	New	-0.030	B-3 : SSL 01	Hard	2022/9/11 0:12	x:-6.984, y:5.654, z:3.400	*Element ID*: 775887	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash12	New	-0.020	6H-H : Level_01	Hard	2022/9/11 0:12	x:8.741, y:-2.553, z:6.300	*Element ID*: 865878	FFL_level 01	Wall Texture, Orange Peel	Solid	*Element ID*: 952445	Level_02	Wall Texture, Orange Peel	Solid
	Clash13	New	-0.020	B-3 : Level_01	Hard	2022/9/11 0:12	x:-7.018, y:5.958, z:6.300	*Element ID*: 865771	FFL_level 01	Wall Texture, Orange Peel	Solid	*Element ID*: 952445	Level_02	Wall Texture, Orange Peel	Solid

BIMA_SSlab_ArchFloor	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	5	0	5	0	0	0	Hard	OK

								Item 1				Item 2			
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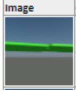
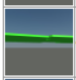
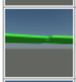
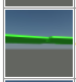
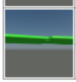
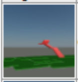
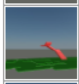
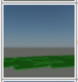
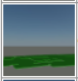
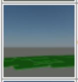
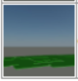
	Clash1	Active	-0.200	A-4 : SSL 01	Hard	2022/9/11 0:13	x:-10.588, y:3.526, z:3.400	*Element ID*: 775238	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash2	Active	-0.200	6I-3 : SSL 01	Hard	2022/9/11 0:13	x:-1.863, y:5.622, z:3.400	*Element ID*: 775452	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash3	Active	-0.180	6I-4 : SSL 01	Hard	2022/9/11 0:13	x:-2.076, y:3.526, z:3.400	*Element ID*: 775736	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash4	Active	-0.091	B-2 : SSL 01	Hard	2022/9/11 0:13	x:-7.761, y:10.731, z:3.400	*Element ID*: 752056	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid
	Clash5	Active	-0.030	B-3 : SSL 01	Hard	2022/9/11 0:13	x:-6.984, y:5.654, z:3.400	*Element ID*: 775887	FFL_Ground_Floor	Wall Texture, Orange Peel	Solid	*Element ID*: 750402	Level_01	Wall Texture, Orange Peel	Solid

BIMA_SStairs_ArchRailings	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

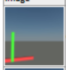
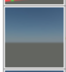
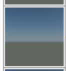
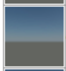
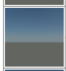
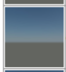
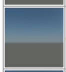
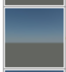
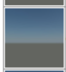
BIMA_SStairs_ArchFloors	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	6	6	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash1	New	-0.020	E-5 : GL	Hard	2022/9/11 0:18	x:0.716, y:-0.752, z:0.600	*Element ID*: 743101	<No level>	Concrete, Cast In Situ	Solid	*Element ID*: 549330	FFL_Ground_Floor	Ceramic Tile	Solid
	Clash2	New	-0.020	E-5 : GL	Hard	2022/9/11 0:18	x:0.716, y:-0.752, z:0.600	*Element ID*: 743101	GL	Concrete, Cast In Situ	Solid	*Element ID*: 549330	FFL_Ground_Floor	Ceramic Tile	Solid
	Clash3	New	-0.020	D-3 : GL	Hard	2022/9/11 0:18	x:-4.073, y:4.622, z:0.600	*Element ID*: 652386	GL	Concrete, Cast In Situ	Solid	*Element ID*: 549330	FFL_Ground_Floor	Ceramic Tile	Solid
	Clash4	New	-0.020	D-3 : GL	Hard	2022/9/11 0:18	x:-4.073, y:4.622, z:0.600	*Element ID*: 652386	<No level>	Concrete, Cast In Situ	Solid	*Element ID*: 549330	FFL_Ground_Floor	Ceramic Tile	Solid
	Clash5	New	-0.020	A-4 : GL	Hard	2022/9/11 0:18	x:-9.999, y:4.526, z:0.600	*Element ID*: 1138137	<No level>	Concrete, Cast In Situ	Solid	*Element ID*: 549330	FFL_Ground_Floor	Ceramic Tile	Solid
	Clash6	New	-0.020	A-4 : GL	Hard	2022/9/11 0:18	x:-9.999, y:4.526, z:0.600	*Element ID*: 1138137	GL	Concrete, Cast In Situ	Solid	*Element ID*: 549330	FFL_Ground_Floor	Ceramic Tile	Solid

BIMA_SStairs_ArchWalls	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SColumns_Walls	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	84	84	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash1	New	-0.204	4F-I : GSLL	Hard	2022/9/11 0:20	x:8.378, y:4.244, z:0.400	*Element ID*: 385139	NSL	Brick, Common	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
	Clash2	New	-0.150	6I-3 : Level_01	Hard	2022/9/11 0:20	x:-1.418, y:5.924, z:5.900	*Element ID*: 851533	Level_01	Wall Texture, Orange Peel	Solid	*Element ID*: 900617	SSL_Level_02	Brick, Common	Solid
	Clash3	New	-0.150	6I-2 : Level_01	Hard	2022/9/11 0:20	x:-1.411, y:9.224, z:5.900	*Element ID*: 851531	Level_01	Concrete, Cast In Situ	Solid	*Element ID*: 900617	SSL_Level_02	Brick, Common	Solid
	Clash4	New	-0.150	6I-3 : GL	Hard	2022/9/11 0:20	x:-1.418, y:5.924, z:2.980	*Element ID*: 454508	SSL_level 01	Brick, Common	Solid	*Element ID*: 411235	NSL	Concrete, Cast In Situ	Solid
	Clash5	New	-0.150	6I-2 : GL	Hard	2022/9/11 0:20	x:-1.411, y:9.224, z:2.980	*Element ID*: 454508	SSL_level 01	Brick, Common	Solid	*Element ID*: 411189	NSL	Concrete, Cast In Situ	Solid
	Clash6	New	-0.150	5G-J : GL	Hard	2022/9/11 0:20	x:11.293, y:1.304, z:2.980	*Element ID*: 454445	SSL_level 01	Brick, Common	Solid	*Element ID*: 376722	NSL	Concrete - Precast Concrete - 35 MPa	Solid
	Clash7	New	-0.150	6N-6Q : Level_02	Hard	2022/9/11 0:20	x:11.293, y:1.304, z:8.900	*Element ID*: 963345	FFL_Level_03	Brick, Common	Solid	*Element ID*: 945039	Level_02	Concrete - Precast Concrete - 35 MPa	Solid
	Clash8	New	-0.150	5G-J : Level_01	Hard	2022/9/11 0:20	x:11.293, y:1.304, z:6.000	*Element ID*: 895395	SSL_Level_02	Brick, Common	Solid	*Element ID*: 851517	Level_01	Concrete - Precast Concrete - 35 MPa	Solid
	Clash9	New	-0.150	6N-6Q : Level_03	Hard	2022/9/11 0:20	x:11.293, y:1.304, z:11.820	*Element ID*: 1013061	Level_03	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 1020937	Roof_Slab	Brick, Common	Solid
	Clash10	New	-0.150	6N-6P : Level_02	Hard	2022/9/11 0:20	x:10.784, y:4.565, z:8.900	*Element ID*: 945037	Level_02	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 963345	FFL_Level_03	Brick, Common	Solid

Clash10	New	-0.150	6N-6P : Level_02	Hard	2022/9/11 0:20	x:10.784, y:4.565, z:8.900	*Element ID*: 945037	Level_02	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 963345	FFL_Level_03	Brick, Common	Solid
Clash11	New	-0.150	6N-6P : Level_03	Hard	2022/9/11 0:20	x:10.784, y:4.565, z:11.820	*Element ID*: 1019293	Level_03	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 1020937	Roof_Slab	Brick, Common	Solid
Clash12	New	-0.150	4F-J : Level_01	Hard	2022/9/11 0:20	x:10.784, y:4.565, z:6.000	*Element ID*: 851515	Level_01	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 895395	SSL_Level_02	Brick, Common	Solid
Clash13	New	-0.150	4F-J : GL	Hard	2022/9/11 0:20	x:10.784, y:4.565, z:2.980	*Element ID*: 376233	NSL	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 454445	SSL_level 01	Brick, Common	Solid
Clash14	New	-0.060	6I-2 : GSLL	Hard	2022/9/11 0:20	x:-1.411, y:9.224, z:0.400	*Element ID*: 411189	NSL	Concrete, Cast In Situ	Solid	*Element ID*: 411071	NSL	Brick, Common	Solid
Clash15	New	-0.060	6I-2 : NSL	Hard	2022/9/11 0:20	x:-1.351, y:9.464, z:0.048	*Element ID*: 410609	NSL	Brick, Common	Solid	*Element ID*: 411189	NSL	Concrete, Cast In Situ	Solid
Clash16	New	-0.060	6I-2 : NSL	Hard	2022/9/11 0:20	x:-1.351, y:9.464, z:0.000	*Element ID*: 477471	NSL	Rigid insulation	Solid	*Element ID*: 411189	NSL	Concrete, Cast In Situ	Solid
Clash17	New	-0.060	D-2 : NSL	Hard	2022/9/11 0:20	x:-3.586, y:9.464, z:0.320	*Element ID*: 411172	NSL	Concrete, Cast In Situ	Solid	*Element ID*: 410609	NSL	Brick, Common	Solid
Clash18	New	-0.060	4F-I : GL	Hard	2022/9/11 0:20	x:8.078, y:4.219, z:0.580	*Element ID*: 602803	SSL_GF	Brick, Common	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
Clash19	New	-0.060	4F-I : GSLL	Hard	2022/9/11 0:20	x:8.162, y:4.453, z:0.400	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 476432	NSL	Cladding, Vertical Ribbed	Solid
Clash20	New	-0.060	4F-I : NSL	Hard	2022/9/11 0:20	x:8.162, y:4.453, z:0.023	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 391999	NSL	Brick, Common	Solid

Clash20	New	-0.060	4F-I : NSL	Hard	2022/9/11 0:20	x:8.162, y:4.453, z:0.023	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 391999	NSL	Brick, Common	Solid
Clash21	New	-0.060	6I-2 : NSL	Hard	2022/9/11 0:20	x:-1.651, y:9.284, z:0.012	*Element ID*: 477491	NSL	Rigid insulation	Solid	*Element ID*: 411189	NSL	Concrete, Cast In Situ	Solid
Clash22	New	-0.060	4F-I : GSLL	Hard	2022/9/11 0:20	x:8.044, y:4.433, z:0.400	*Element ID*: 475037	NSL	Cladding, Vertical Ribbed	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
Clash23	New	-0.060	4F-I : GL	Hard	2022/9/11 0:20	x:8.053, y:4.375, z:0.870	*Element ID*: 514508	FFL_Ground_Floor	Rigid insulation	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
Clash24	New	-0.060	4F-I : GL	Hard	2022/9/11 0:20	x:8.081, y:4.197, z:3.331	*Element ID*: 611997	FFL_Ground_Floor	Rigid insulation	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
Clash25	New	-0.060	6N-6P : Level_03	Hard	2022/9/11 0:20	x:10.717, y:4.556, z:11.820	*Element ID*: 1019293	Level_03	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 1024622	Roof_Slab	Default Wall	Solid
Clash26	New	-0.060	4F-J : Level_01	Hard	2022/9/11 0:20	x:10.708, y:4.612, z:5.980	*Element ID*: 851515	Level_01	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 881349	SSL_Level_02	Default Wall	Solid
Clash27	New	-0.060	4F-I : NSL	Hard	2022/9/11 0:20	x:8.081, y:4.197, z:0.000	*Element ID*: 603228	NSL	Rigid insulation	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
Clash28	New	-0.058	6N-6Q : Level_03	Hard	2022/9/11 0:20	x:11.471, y:1.333, z:11.820	*Element ID*: 1020769	Roof_Slab	Cladding, Vertical Ribbed	Solid	*Element ID*: 1013061	Level_03	Concrete - Precast Concrete - 35 MPa	Solid
Clash29	New	-0.058	E-4 : Level_03	Hard	2022/9/11 0:20	x:-0.526, y:3.224, z:11.860	*Element ID*: 1024336	Roof_Slab	Rigid insulation	Solid	*Element ID*: 1013027	Level_03	Concrete, Cast In Situ	Solid
Clash30	New	-0.058	6I-2 : Level_02	Hard	2022/9/11 0:20	x:-1.591, y:9.224, z:9.193	*Element ID*: 945053	Level_02	Concrete, Cast In Situ	Solid	*Element ID*: 977181	SSL_Level_03	Rigid insulation	Solid
Clash31	New	-0.058	6I-2 : Level_03	Hard	2022/9/11 0:20	x:-1.592, y:9.224, z:11.880	*Element ID*: 1013075	Level_03	Concrete, Cast In Situ	Solid	*Element ID*: 1051570	Roof_Slab	Default Wall	Solid
Clash32	New	-0.058	5G-J : GL	Hard	2022/9/11 0:20	x:11.293, y:1.304, z:2.987	*Element ID*: 497665	SSL_level 01	Rigid insulation	Solid	*Element ID*: 376722	NSL	Concrete - Precast Concrete - 35 MPa	Solid
Clash33	New	-0.058	6N-6Q : Level_03	Hard	2022/9/11 0:20	x:11.293, y:1.304, z:11.828	*Element ID*: 1024744	Roof_Slab	Rigid insulation	Solid	*Element ID*: 1013061	Level_03	Concrete - Precast Concrete - 35 MPa	Solid
Clash34	New	-0.058	6N-6P : Level_02	Hard	2022/9/11 0:20	x:10.776, y:4.564, z:8.905	*Element ID*: 963390	FFL_Level_03	Rigid insulation	Solid	*Element ID*: 945037	Level_02	Concrete - Precast Concrete - 35 MPa	Solid

Clash48	New	-0.030	4F-I : Level_01	Hard	2022/9/11 0:20	x:8.409, y:4.429, z:5.980	*Element ID*: 851539	Level_01	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 881304	SSL_Level_02	Brick, Common	Solid
Clash49	New	-0.030	6M-6P : Level_03	Hard	2022/9/11 0:20	x:8.437, y:4.254, z:12.274	*Element ID*: 1013083	Level_03	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 1024622	Roof_Slab	Rigid insulation	Solid
Clash50	New	-0.030	E-4 : Roof_Slab	Hard	2022/9/11 0:20	x:8.437, y:4.254, z:12.280	*Element ID*: 1013083	Level_03	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 1020939	Roof_Slab	Brick, Common	Solid
Clash51	New	-0.030	6M-6P : SSL 03	Hard	2022/9/11 0:20	x:8.437, y:4.254, z:9.200	*Element ID*: 945061	Level_02	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 964450	FFL_Level_03	Rigid insulation	Solid
Clash52	New	-0.030	4F-I : Level_01	Hard	2022/9/11 0:20	x:8.437, y:4.254, z:6.296	*Element ID*: 851539	Level_01	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 881349	SSL_Level_02	Rigid insulation	Solid
Clash53	New	-0.030	6M-6P : Level_03	Hard	2022/9/11 0:20	x:8.399, y:4.491, z:11.820	*Element ID*: 1013083	Level_03	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 1020770	Roof_Slab	Cladding, Vertical Ribbed	Solid
Clash54	New	-0.030	6M-6P : Level_02	Hard	2022/9/11 0:20	x:8.399, y:4.491, z:8.900	*Element ID*: 945061	Level_02	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 964358	FFL_Level_03	Cladding, Vertical Ribbed	Solid
Clash55	New	-0.030	4F-I : Level_01	Hard	2022/9/11 0:20	x:8.399, y:4.491, z:5.980	*Element ID*: 851539	Level_01	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 881210	SSL_Level_02	Cladding, Vertical Ribbed	Solid
Clash56	New	-0.030	E-5 : Level_03	Hard	2022/9/11 0:20	x:-0.526, y:-0.076, z:11.860	*Element ID*: 1024336	Roof_Slab	Rigid insulation	Solid	*Element ID*: 1013041	Level_03	Wall Texture, Orange Peel	Solid
Clash57	New	-0.030	E-5 : Level_01	Hard	2022/9/11 0:20	x:-0.526, y:-0.076, z:5.900	*Element ID*: 904869	SSL_Level_02	Rigid insulation	Solid	*Element ID*: 851495	Level_01	Wall Texture, Orange Peel	Solid
Clash58	New	-0.030	E-5 : Level_01	Hard	2022/9/11 0:20	x:-0.346, y:-0.076, z:5.900	*Element ID*: 904702	SSL_Level_02	Rigid insulation	Solid	*Element ID*: 851495	Level_01	Wall Texture, Orange Peel	Solid
Clash59	New	-0.030	E-5 : GL	Hard	2022/9/11 0:20	x:-0.346, y:-0.076, z:2.980	*Element ID*: 370879	NSL	Concrete, Cast In Situ	Solid	*Element ID*: 589875	SSL_level 01	Rigid insulation	Solid
Clash60	New	-0.030	5G-J : Level_01	Hard	2022/9/11 0:20	x:11.268, y:1.300, z:6.000	*Element ID*: 895465	SSL_Level_02	Default Wall	Solid	*Element ID*: 851517	Level_01	Concrete - Precast Concrete - 35 MPa	Solid
Clash61	New	-0.030	6N-6P : Level_03	Hard	2022/9/11 0:20	x:10.954, y:4.592, z:11.820	*Element ID*: 1020769	Roof_Slab	Cladding, Vertical Ribbed	Solid	*Element ID*: 1019293	Level_03	Concrete - Precast Concrete - 35 MPa	Solid
Clash62	New	-0.030	6N-6P : Level_02	Hard	2022/9/11 0:20	x:10.954, y:4.592, z:8.900	*Element ID*: 963660	FFL_Level_03	Cladding, Vertical Ribbed	Solid	*Element ID*: 945037	Level_02	Concrete - Precast Concrete - 35 MPa	Solid
Clash63	New	-0.030	4F-J : Level_01	Hard	2022/9/11 0:20	x:11.011, y:4.601, z:6.000	*Element ID*: 851515	Level_01	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 895333	SSL_Level_02	Cladding, Vertical Ribbed	Solid
Clash64	New	-0.030	4F-J : GL	Hard	2022/9/11 0:20	x:11.011, y:4.601, z:2.980	*Element ID*: 376233	NSL	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 510611	SSL_level 01	Cladding, Vertical Ribbed	Solid
Clash65	New	-0.030	E-4 : Level_01	Hard	2022/9/11 0:20	x:-0.526, y:3.224, z:5.900	*Element ID*: 851481	Level_01	Concrete, Cast In Situ	Solid	*Element ID*: 904869	SSL_Level_02	Rigid insulation	Solid
Clash66	New	-0.030	E-4 : Level_01	Hard	2022/9/11 0:20	x:-0.346, y:3.224, z:5.900	*Element ID*: 851481	Level_01	Concrete, Cast In Situ	Solid	*Element ID*: 904702	SSL_Level_02	Rigid insulation	Solid
Clash67	New	-0.030	E-4 : GL	Hard	2022/9/11 0:20	x:-0.346, y:3.224, z:2.980	*Element ID*: 589875	SSL_level 01	Rigid insulation	Solid	*Element ID*: 370751	NSL	Concrete, Cast In Situ	Solid
Clash68	New	-0.030	E-4 : Level_02	Hard	2022/9/11 0:20	x:-0.526, y:3.224, z:8.800	*Element ID*: 977620	SSL_Level_03	Default Wall	Solid	*Element ID*: 945003	Level_02	Concrete, Cast In Situ	Solid
Clash69	New	-0.030	E-4 : GL	Hard	2022/9/11 0:20	x:-0.526, y:3.224, z:2.980	*Element ID*: 589830	SSL_level 01	Default Wall	Solid	*Element ID*: 370751	NSL	Concrete, Cast In Situ	Solid
Clash70	New	-0.030	6I-3 : Level_03	Hard	2022/9/11 0:20	x:-1.608, y:5.924, z:11.880	*Element ID*: 1013077	Level_03	Wall Texture, Orange Peel	Solid	*Element ID*: 1051570	Roof_Slab	Default Wall	Solid
Clash71	New	-0.030	6I-3 : SSL 03	Hard	2022/9/11 0:20	x:-1.591, y:5.924, z:9.200	*Element ID*: 945055	Level_02	Wall Texture, Orange Peel	Solid	*Element ID*: 977181	SSL_Level_03	Rigid insulation	Solid
Clash72	New	-0.030	6I-3 : Level_01	Hard	2022/9/11 0:20	x:-1.410, y:5.924, z:5.900	*Element ID*: 900579	SSL_Level_02	Default Wall	Solid	*Element ID*: 851533	Level_01	Wall Texture, Orange Peel	Solid
Clash73	New	-0.030	6I-3 : Level_01	Hard	2022/9/11 0:20	x:-1.605, y:5.924, z:5.900	*Element ID*: 900664	SSL_Level_02	Default Wall	Solid	*Element ID*: 851533	Level_01	Wall Texture, Orange Peel	Solid
Clash74	New	-0.030	6I-3 : Level_03	Hard	2022/9/11 0:20	x:-1.411, y:5.924, z:11.880	*Element ID*: 1013077	Level_03	Wall Texture, Orange Peel	Solid	*Element ID*: 1051453	Roof_Slab	Rigid insulation	Solid
Clash75	New	-0.030	6I-3 : GL	Hard	2022/9/11 0:20	x:-1.612, y:5.924, z:2.980	*Element ID*: 491615	SSL_level 01	Default Wall	Solid	*Element ID*: 411235	NSL	Concrete, Cast In Situ	Solid
Clash76	New	-0.030	6I-3 : GL	Hard	2022/9/11 0:20	x:-1.410, y:5.924, z:2.980	*Element ID*: 491823	SSL_level 01	Default Wall	Solid	*Element ID*: 411235	NSL	Concrete, Cast In Situ	Solid

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash74	New	-0.030	6I-3 : Level_03	Hard	2022/9/11 0:20	x:-1.411, y:5.924, z:11.880	*Element ID*: 1013077	Level_03	Wall Texture, Orange Peel	Solid	*Element ID*: 1051453	Roof_Slab	Rigid insulation	Solid
	Clash75	New	-0.030	6I-3 : GL	Hard	2022/9/11 0:20	x:-1.612, y:5.924, z:2.980	*Element ID*: 491615	SSL_level 01	Default Wall	Solid	*Element ID*: 411235	NSL	Concrete, Cast In Situ	Solid
	Clash76	New	-0.030	6I-3 : GL	Hard	2022/9/11 0:20	x:-1.410, y:5.924, z:2.980	*Element ID*: 491823	SSL_level 01	Default Wall	Solid	*Element ID*: 411235	NSL	Concrete, Cast In Situ	Solid
	Clash77	New	-0.030	6I-3 : Level_02	Hard	2022/9/11 0:20	x:-1.353, y:5.924, z:8.820	*Element ID*: 945055	Level_02	Wall Texture, Orange Peel	Solid	*Element ID*: 977088	SSL_Level_03	Default Wall	Solid
	Clash78	New	-0.030	6I-2 : Level_03	Hard	2022/9/11 0:20	x:-1.411, y:9.224, z:12.255	*Element ID*: 1013075	Level_03	Concrete, Cast In Situ	Solid	*Element ID*: 1051453	Roof_Slab	Rigid insulation	Solid
	Clash79	New	-0.030	6I-2 : Level_01	Hard	2022/9/11 0:20	x:-1.396, y:9.224, z:5.900	*Element ID*: 851531	Level_01	Concrete, Cast In Situ	Solid	*Element ID*: 900579	SSL_Level_02	Default Wall	Solid
	Clash80	New	-0.030	6I-2 : Level_01	Hard	2022/9/11 0:20	x:-1.649, y:9.224, z:5.900	*Element ID*: 851531	Level_01	Concrete, Cast In Situ	Solid	*Element ID*: 900664	SSL_Level_02	Default Wall	Solid
	Clash81	New	-0.030	6I-2 : GL	Hard	2022/9/11 0:20	x:-1.591, y:9.224, z:2.980	*Element ID*: 491615	SSL_level 01	Default Wall	Solid	*Element ID*: 411189	NSL	Concrete, Cast In Situ	Solid
	Clash82	New	-0.030	5G-J : Level_01	Hard	2022/9/11 0:20	x:11.471, y:1.332, z:6.000	*Element ID*: 895333	SSL_Level_02	Cladding, Vertical Ribbed	Solid	*Element ID*: 851517	Level_01	Concrete - Precast Concrete - 35 MPa	Solid
	Clash83	New	-0.030	5G-J : GL	Hard	2022/9/11 0:20	x:11.471, y:1.332, z:2.980	*Element ID*: 510611	SSL_level 01	Cladding, Vertical Ribbed	Solid	*Element ID*: 376722	NSL	Concrete - Precast Concrete - 35 MPa	Solid
	Clash84	New	-0.030	6N-6Q : Level_02	Hard	2022/9/11 0:20	x:11.471, y:1.332, z:8.900	*Element ID*: 963660	FFL_Level_03	Cladding, Vertical Ribbed	Solid	*Element ID*: 945039	Level_02	Concrete - Precast Concrete - 35 MPa	Solid

BIMA_SColumns_ArchWindows	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SColumns_ArchRailings	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SColumns_ArchWindows	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SColumns_ArchRailings	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SColumns_ArchDoors	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	0	0	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type

BIMA_SColumns_Walls	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.010m	3	3	0	0	0	0	Hard	OK

								Item 1				Item 2			
Image	Clash Name	Status	Distance	Grid Location	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash1	New	-0.060	4F-I : GL	Hard	2022/9/11 0:24	x:8.053, y:4.375, z:0.870	*Element ID*: 514508	FFL_Ground_Floor	Rigid insulation	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid
	Clash2	New	-0.060	4F-I : GSLL	Hard	2022/9/11 0:24	x:8.053, y:4.375, z:0.580	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid	*Element ID*: 549330	FFL_Ground_Floor	Plaster	Solid
	Clash3	New	-0.060	4F-I : GL	Hard	2022/9/11 0:24	x:8.081, y:4.197, z:3.331	*Element ID*: 611997	FFL_Ground_Floor	Rigid insulation	Solid	*Element ID*: 611642	NSL	Concrete - Precast Concrete - 35 MPa	Solid

WBS and Time Management in Microsoft Excel

N.	Categories				Code	Activity	Days (8h) _0.33day	Cumulative Time (Days)
01.	Excavation,Site Clearance,Demolition and Backfilling							
	01.01 Demolition Works							
					E_0000	Site Clearnce	2	2
	01.02 Excavation Works							
					E_0010	Excavation Works	0.09	2.09
					E_0011	Obligatory Section of Excavation	12.3	14.39
					E_0012	Trench support	0.1	14.49
					E_0013	Soil Treatment	0.5	14.99
					E_0014	Backfilling	0.5	29.98
02.	Structural works							
	02.01 Works and structures in reiforced concrete							
		02.01.01	Foundation structures					
					S_0010	Unreinforced foundation le	0.45	30.43
					S_0011	Aerated crawl space	5.6	36.03
					S_0012	Formwork installation	0.34	36.37
					S_0013	Rebar	2.75	39.12
					S_0014	Concrete casting	1.95	41.87
					S_0015	Formwork removal	0.22	42.09
		02.01.02	in elevation - Ground Floor				11.31	
			02.01.02.01	Pillars cast in situ				
					S_0016	Formwork installation	1.68	43.77
					S_0017	Rebar	0.46	44.23
					S_0018	Concrete casting	0.08	44.31
							2.22	
			02.01.02.02	Slabs				
					S_0019	Formwork installation	4.54	48.85
					S_0020	Concrete casting	0.84	49.69
					S_0021	Rebar	4.71	54.4
					S_0022	Electrowelded mesh	0.08	54.48
					S_0023	Formwork removal	2.29	56.77
			02.01.02.04	Stairs			12.46	
					S_0024	Formwork installation	1.68	58.45
					S_0025	Rebar	1.5	59.95
					S_0026	Concrete casting	1.2	61.15
					S_0027	Formwork removal	0.5	61.65
		02.01.03	Structures in elevation - First Floor					
			02.01.03.01	Pillars cast in situ				
					S_0028	Formwork installation	1.68	63.33
					S_0029	Rebar	0.46	63.79
					S_0030	Concrete casting	0.08	63.87
					S_0031	Formwork removal	0.85	64.72
					S_0032	Formwork removal	2.29	67.01
			02.01.03.04	Stairs				
					S_0033	Formwork installation	1.68	68.69
					S_0034	Rebar	1.5	70.19
					S_0035	Concrete casting	1.2	71.39
					S_0036	Formwork removal	0.5	71.89
		02.01.04	Structures in elevation - Second Floor					
			02.01.04.01	Pillars cast in situ				
					S_0037	formwork installation	1.68	73.57
					S_0038	rebar	0.46	74.03
					S_0039	concrete casting	0.08	74.11
					S_0040	formwork removal	0.85	74.96
			02.01.04.02	Slabs				
					S_0041	formwork installation	4.54	79.5
					S_0042	concrete casting	0.84	80.34
					S_0043	rebar	4.71	85.05
					S_0044	electrowelded mesh	0.08	85.13
					S_0045	formwork removal	2.29	87.42
			02.01.04.03	Stairs				
					S_0046	Formwork installation	1.68	89.1
					S_0047	Rebar	1.5	90.6
					S_0048	Concrete casting	1.2	91.8
					S_0049	Formwork removal	0.5	92.3
		02.01.05	Structures in elevation - Third Floor					
			02.01.05.01	Pillars cast in situ				
					S_0050	Formwork installation	1.68	93.98
					S_0051	Rebar	0.46	94.44
					S_0052	Concrete casting	0.08	94.52
					S_0053	Formwork removal	0.85	95.37
			02.01.05.02	Third Floor Slab				
					S_0054	Formwork installation	6.1	101.47
					S_0055	Concrete casting	1.1	102.57
					S_0056	Rebar	5.63	108.2
					S_0057	Electrowelded mesh	0.11	108.31
					S_0058	Formwork removal	3.08	111.39
			02.01.05.03	Roof Slab				
					S_0059	Formwork installation	6.1	117.49
					S_0060	Concrete casting	1.1	118.59
					S_0061	Rebar	5.63	124.22
					S_0062	Electrowelded mesh	0.11	124.33
					S_0063	Formwork removal	3.08	127.41

03.	Completion works					
	03.01 Walls					
		03.01.01 Ground floor external walls	C_0010	Brick Masonry Wall 180mm	5	132.41
		03.01.02 First floor external walls	C_0011	Brick Masonry Wall 180mm	5	137.41
		03.01.03 Second floor external walls	C_0012	Brick Masonry Wall 180mm	5	142.41
		03.01.04 Third floor external walls	C_0013	Brick Masonry Wall 180mm	5	147.41
		03.01.05 *Ground Floor Partition walls*	C_0014	Brick Masonry Wall 130mm	4	151.41
		03.01.06 First Floor Partition walls	C_0017	Brick Masonry Wall 130mm	4	155.41
		03.01.07 Second Floor Partition walls	C_0019	Brick Masonry Wall 130mm	4	159.41
		03.01.08 Third Floor Partition walls	C_0021	Brick Masonry Wall 130mm	4	163.41
					0	163.41
04.	Finishing works					
	04.01 External Wall Finishes					
		04.01.01 Ground floor	F_0010	Insulating Wall cladding (ETIC	2	165.41
		04.01.02 First floor	F_0011	Insulating Wall cladding (ETIC	2	167.41
		04.01.03 Second floor	F_0012	Insulating Wall cladding (ETIC	2	169.41
		04.01.04 Third floor	F_0013	Insulating Wall cladding (ETIC	2	171.41
	04.02 Painting					
		04.02.01 Ground Floor Painting	F_0014	Wall Paint	2	173.41
		04.02.02 First Floor Painting	F_0015	Wall Paint	2	175.41
		04.02.03 Second Floor Painting	F_0016	Wall Paint	2	177.41
		04.02.04 Third Floor Painting	F_0017	Wall Paint	2	179.41
	04.03 Floor Finishes					
		04.03.01 floor finish ground floor	F_0018	Ceremic Tiles	3	182.41
		04.03.02 floor finish first floor	F_0019	Ceremic Tiles	3	185.41
		04.03.03 floor finish second floor	F_0020	Ceremic Tiles	3	188.41
		04.03.04 floor finish third floor	F_0021	Ceremic Tiles	3	191.41
	04.04 Railing					
		04.04.01 Ground floor - Railing	**F_0022**	Wrought iron railings fabricat	**2**	**193.41**
		04.04.02 First floor - Railing	F_0023	Wrought iron railings fabricat	2	195.41
		04.04.03 Second Floor - Railing	F_0024	Wrought iron railings fabricat	2	197.41
		04.04.04 Third Floor - Railing	F_0025	Wrought iron railings fabricat	2	199.41
05.	Doors and windows					
	05.01 Ground floor - doors and windows					
		05.01.01 Door 750mm	D_0010		2	201.41
		05.01.02 Windows 1400x1500	D_0011		2	203.41
		05.01.03 Doors (1410mm)	D_0012		2	205.41
		05.01.04 Sliding Doors	D_0013		2	207.41
		05.01.05 Windows 610x610	D_0014		2	209.41
		05.01.06 Windows_Louvre	D_0015		2	211.41
	05.02 First floor - doors and windows					
		05.02.01 Door 750mm	D_0016		2	213.41
		05.02.02 Windows 1400x1500	D_0017		2	215.41
		05.02.03 Doors (1410mm)	D_0018		2	217.41
		05.02.04 Sliding Doors	D_0019		2	219.41
		05.02.05 Windows 610x610	D_0020		2	221.41
		05.02.06 Windows_Louvre	D_0021		2	223.41
	05.03 Second floor - doors and windows					
		05.03.01 Door 750mm	D_0022		2	225.41
		05.03.02 Windows 1400x1500	D_0023		2	227.41
		05.03.03 Doors (1410mm)	D_0024		2	229.41
		05.03.04 Sliding Doors	D_0025		2	231.41
		05.03.05 Windows 610x610	D_0026		2	233.41
		05.03.06 Windows_Louvre	D_0027		2	235.41
	05.04 Third floor - doors and windows					
		05.04.01 Door 750mm	D_0028		2	237.41
		05.04.02 Windows 1400x1500	D_0029		2	239.41
		05.04.03 Doors (1410mm)	D_0030		2	241.41
		05.04.04 Sliding Doors	D_0031		2	243.41
		05.04.05 Windows 610x610	D_0032		2	245.41
		05.04.06 Windows_Louvre	D_0033		2	247.41
06.	Roof					
	06.01 Sealing Elements					
		06.01.01 Insulation	R_0010	Waterproofing/	2	249.41
		06.01.02 Screed	R_0011	Cement/Sand Mortar	2	251.41
		06.01.03 Roof Tiles	R_0012	Ceremic Tiles	2	253.41
		06.01.03 Parapet Brick Wall	R_0013	Bricks	2	255.41
		06.01.03 Parapet Plaster	R_0014	Cement Mortar	2	257.41
		06.01.03 Parapet Paint	R_0015	Paint	2	259.41