Cost Based Integrated BIM Modelling For High Rise Building

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This to certify that the

BE Civil Final Year Project entitled

Cost Based Integrated BIM Modelling For High Rise Building

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has been accepted towards the partial fulfilment of the requirements

for BE Civil Degree.

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Dr. Rai Waqas Azfar

Project Advisor

WE DEDICATE OUR WORK TO OUR BELOVED PARENTS,
OUR RESPECTED TEACHERS, AND OUR ALMA MATER
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There are several individuals whose contributions have been vital for the completion of this project Dr. Rai Waqas our syndicate Advisor, was the driving force behind this work. He contributed valuable ideas and his reception of our ideas and suggestions has always been extremely encouraging. Through his exemplary guidance, we were able to achieve the objectives of this project. We proudly state that we are Dr. Rai Waqas's graduate students.

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Abstract

Due to lack of use of BIM (Building Information Modelling) in the construction industry in Pakistan a number of clashes and conflicts arise during the execution of the project hereby leading to the cost overruns and delays. Both cost overrun and delays can be controlled if BIM is deployed in the planning and design phase hereby paving the way for the smooth conduct of various activities involved in the project life cycle. The clash detection tool of the BIM provides us with an opportunity to visualize the clashes in the earlier stages of the project and hence pragmatic solution can be provided for countering the clashes in the execution phase of the project. Being a developing country both due to lack of awareness and availability of material such engineering materials are used in the construction of the structure which lead to increased energy consumption and it is one of the major issues of the high-rise buildings. The other part of the study focuses on energy efficiency. It sheds light on the importance of orientation and construction material of the building. The study reveals the importance of BIM with regards to the Project Integration Management. The effects of project integration management on the other two knowledge areas of time and cost have been analyzed in this case study. The case study was undertaken with the help of Autodesk Revit 2023 and Autodesk Navisworks Manage 2023. Modelling and Energy Analysis were done using Autodesk Revit 2023. The clash detection was performed using the same Autodesk Revit Model in a different format inthe Autodesk Navisworks Manage 2023.

CHAPTER 1

INTRODUCTION

1.1 Background

Due to traditional construction design practice, industry is suffering from poor coordination among multidisciplinary team during project design phase. Exchange of information between different teams is lagging due to past time practices but building information technology has potential to innovate and transform the information exchange and coordination process. As 70 percent of the cost of a building's construction is committed during the design phase, integrating diverse knowledge is critical throughout the construction process. Because it gives all parties involved in the project access to the most recent information about the building, which was previously unavailable, BIM is a crucial part of integrated project management. Building Information Modelling (BIM) is a futuristic technology that helps in the design and construction process. It enables participation from all parties in the design phase, building construction, and even building maintenance. BIM may be used in construction project integration management to enhance the essential cost-effective construction. When issuesdevelop and a project becomes more complicated, BIM may be used as a tool to aid with decision-making, including clash detection hence leads towards cost reduction and increases efficiency. In the beginning stages of a building project, clash detection is critical. Clash detection is the process of identifying conflicts among different building components.

The demand for high-energy efficiency buildings is growing as sustainability is more focused upon in the construction sector. Goals for sustainability are becomingincreasingly ambitious, requiring higher levels of energy and resource efficiency. Withthe growing demand for high-performance buildings and the associated challenges for designers, builders, and facility managers, including building energy analysis into the design, construction, operation, and maintenance of buildings has never been more important.

1.2 Project Management

Project Management is that the act of leading and coordinative human and material resources throughout the lifetime of a project to realize planned objectives of:

- Scope
- Quality
- Effort
- Cost
- Risk
- Time

Construction project integration typically involve the identification of project activities or tasks, their logical relationships, resource needs, durations, and their associated begin and end times. designing and programing will be thought to be 2 separate however dependent project management tasks. The inputs for these processes typically embody, as an example, the project specifications and drawings, data extracted from site visits, the availabilities of resources each in-house and outdoors organizations. Additionally, there are many forms of constraint that has got to be incorporated so as to maintain a sensible schedule:

- These constraints are also of technical in nature (e.g. technological constraints).
- They will be of social control kind (e.g. to accommodates the interim payments schedule per the contract).

The complexity of today's construction project has make the preparation of a practical schedule a difficult task for the project team. This can also be because many stakeholders (e.g., the owner, suppliers, subcontractors, etc.) are involved in the projetc , and every party might impose its constraints to the project, additionally, perhaps, to those mentionedearlier. Failure to include all the mandatory constraints might render the schedule generated impractical, necessitating frequent schedule change or re-planning. Imposing redundant constraints, on the opposite hand, might eliminate the possibility of getting a decent or sensible schedule.

In Pakistan, most of projects are delayed either thanks to lack of project management practices, or due to lack of execution of this management knowledge. This delay ends up in value over runs and ultimately a significant loss of valuable exchange of the country.

This can be not solely just in case of public sector but also in case of private sector. Projects delays result in rise of construction prices. Reason behind this can be thatcontractors, clients, and consultants typically don't invest time and effort in planning and integrating of their construction projects according to the established standards.

1.3 Definition of Project

A project could be a brief endeavor carried out to produce a novel good, service, or outcome. Projects' transient nature denotes a clear beginning and end. The tip is reached when the project's goals are met, when it is abandoned because its goals can't or won't be achieved, or when the project is no longer necessary.

- A project will consist of one individual, one organisational unit, or multiple structural units.
- A project will result in a product that may either be used as a service or as a component of another product.

Examples of project are:

- Developing a whole new good or service.
- Transportation a modification within the structure
- Creating a brand-new system
- Building or constructing infrastructure.
- Putting in place a fresh business method.

1.4 The Project Life Cycle

The project life cycle will be determined by the distinctive aspects of the organization. Each project includes a definite begin and an explicit finish, specific activities that crop up in between can vary with the project. The life cycle provides the fundamental framework for managing the project. Projects vary in size and quality, despite.

However giant or tiny, simple, or complex, all projects will be mapped to the subsequent life cycle structure, figure 1.1 explains the project life cycle:

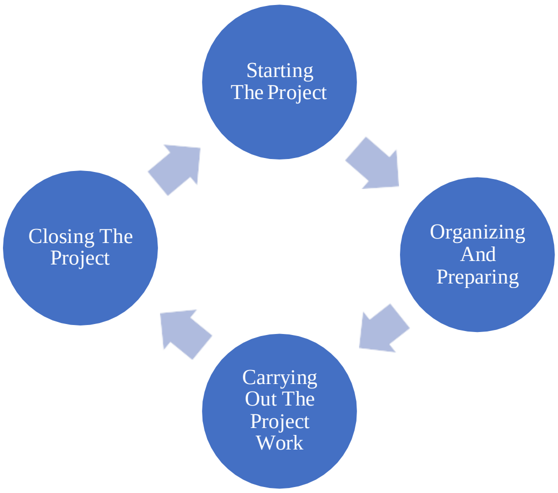

Figure 1.1 Various Stages of Project.

1.5 Project Management

Application of knowledge, abilities, techniques, and tools to project activities in order to meet project requirements is known as project management. Using the five process teams and the appropriate use and integration of logically categorized project management methodologies, projects are managed..

Smooth conduct of project usually includes:

- characteristic needs,
- Due to the project's distribution and planning, it must: • Address the needs of the stakeholders.
- Balance the limits of a competitive project..

The project relation is tied in the manner that if anyone factor changes, a minimum of one alternative issue is probably going to be changed completely, as an example, if the length of the schedule is lengthened, then eventually the budget has to be inflated to feature further quantiles of equipment and labor to complete an equivalent quantity of labor in less time. If a budget increase isn't doable, the scope of the project is also reduced to deliver a product in less time for an equivalent budget. The project stalkeholders should be ready to reach things and balance constrains so as to deliver a complete project.

1.6 Building Data Modeling

The use of latest technology and tools is one amongst the foremost necessary that structural engineers square measure victimization today to remain competitive. Engineers square measure perpetually trying to find new technique to boost and keep the pace on today's economy, meeting important points in work like productivity, coordination and downside finding. Making Building Information Modeling (BIM) will probably facilitate with these necessary aspects. The core feature that BIM offers is that the ability to integrate intelligent objects within the model. These intelligent objects contain all the inforelating to a selected element, from geometric characteristics to the means they act with alternative elements, creating the model rich with data.

The use of models isn't a brand-new technique. Huge corporations like Toyota are utilizing them for quite a while to support their plans and sophisticated engineering processes, particularly within the style and documentation section. Applying this same principle to infrastructures and building comes within the design, engineering and housing industry is what has developed in what we all know as BIM.

'However, it's been detected that housing industry has not fully fledged an equivalent increase in productivity that alternative disciplines fully fledged because of technological advance' (Teicholz 2004). 'The amount of uncertainty related to a construction method is typically high' (Hendrickson 1998). 'These limitations measure largely since collaboration and knowledge sharing between totally different team members has been poor. Stakeholders concerned sometimes don't seem to be on an equivalent page regarding the methodology to attain the result of the project' (Sequeira 2007). 'Also, the shortcoming to foresee the problems that would arise in field like operating area limitations, collision of building parts, clash of operating schedules of various project groups etc. was another major issue touching the productivity of a construction method' (Emmitt, whin et al. 2003). Thus, it absolutely was the necessity of our time to develop tools which give higher collaboration between stakeholders and a virtual setting ready to imitate the important building method providing increased mental image for the problems that may arise throughout construction method. Building data Modeling (BIM) guaranteesto solve the problems arises due to use drafting software which does not give clear understanding related to project.

1.7 Energy Analysis

The examination of a building's energy use is crucial for its energy efficiency design. The purpose of an energy consumption analysis of buildings is to optimize the building for energy efficiency by finding right building material, orientation , building envelope, window types and insulation for a specific geographical location and climatic conditions.

1.7.1 Simulation of Energy

Designing, constructing, and operating energy efficient structure may be a difficult and intimidating process. Engineers and architects may use building energy simulation to analyze building energy consumption early in the design process and improve the building model's performance. This information can assist designers in making better- informed decisions that increase building performance while lowering environmentalimpact. It may also be used to investigate the effects of building modifications on energy consumption. Alternative designs or materials may be quickly assessed to determine how they affect yearly energy usage, which can aid designers in making energy-efficient design decisions.

1.7.2 Analysis of Traditional Building Energy Usage

Traditional energy consumption analysis has a number of flaws, including difficulty obtaining information, energy consumption analysis of complex processes, and inaccurate analysis results.

Traditional building energy consumption analysis methodologies are clearly insufficient for data processing. One way is to compute the building thermal/cold load using a static algorithm, which ignores the building heat transfer delay and attenuation effects, resulting in a considerable difference between the calculated and real load. The alternative is to do an energy study by manually entering pertinent building data into dynamic simulation softwares. This approach frequently necessitates a large amount of human input, and the use of these softwares typically necessitates advanced professional understanding ofenergy analysis and computer-based modeling.

1.8 Problem Statement

- Due to lack of integration in planning and design phase clashes come up in execution phase which result in delays and cost overruns
- If Energy analysis be performed beforehand the actual construction of the building it will result in optimized energy consumption

1.9 Project Objectives

- To integrate as-built architectural, structural and MEP drawings in BIM environment and analyze the potential clashes among the models before the actual construction begins and hence reduce the wastage of cost and time.
- To check the energy efficiency of the building by varying the materials and orientation.

CHAPTER 2

LITERATURE REVIEW

2.1 Building Information Modelling (BIM)

BIM has drastically changed the way we design, document, and construct projects. In some ways, this development is even more significant than the transition from hand sketching to computer-aided design (CAD). From putting crooked lines on paper toputting intelligent things into a 3D space, BIM has had an huge impact in construction industry all over the world.

“BIM permits a building to be made just about, before putting a shovel within the ground. This method permits to find interference and construction connected issues before they arise saving project prices and delays. BIM permits easier coordination of various computer code and project personnel those results in improved productivity, communication, and internal control” (McGraw-Hill Construction, 2008). It transforms how buildings are designed; how they appear and the way they perform – adding intelligence to the buildings. The 3D model aids in the visualization, presentation, and creation of subject field materials. Because style changes are mechanically coordinated across the model, it saves time and reduces errors.

Building information Modeling (BIM) may be a platform for information sharing between project stakeholders whereas polishing off style and construction throughout project’s life cycle method and observe of virtual style and construction throughout its lifecycle.

From the initial planning stages, through conceptual design and alternative selection, supplier procurement, and the establishment of the most advanced phases, which include structural design and facilities, the BIM methodology encompasses the project's control, direction, monitoring, and control, as well as the management of all information generated throughout the project's development: from the initial planning stages, through conceptual design and alternative selection, supplier procurement, and the establishment of the most advanced phases, which include structural design and facilities. Without ignoring the monitoring, control, and management of facility development and future maintenance, the 4D, 5D, 6D, and 7D stages are key qualities such as energy efficiency, functional safety, and building and infrastructure sustainability. Table 2.1 depicts the various BIM dimensions in use.

Table 2.1 BIM Dimensions

Dimensions BIM	Properties	Aspects Developed in the Model
2D	2D Basic Documentation	Traditional two-dimensional (2D) plans Lines, planes images
3D	3D three-dimensional model	Graphic documentation in three dimensions (3D) Special geometric information Objects with properties 3D visualization of the project
4D	Programming the Execution Plan (Deadlines)	Simulation of Project phases Installations Simulation Design of the execution Plan
5D	Planning, Monitoring and Cost Control	Budget estimate of expenses Measurements of materials and labor Analysis of operating costs
6D	Sustainability and energy efficiency	Energy analysis Envelope variations and interactions Analysis of simulations and energy efficient and environmentally sustainable proposals
7D	Facility Management	BIM Life Cycle Analysis (LCA) Strategies BIM as built Building Operations and Maintenance Plan Model Logistical Control of the Project

2.2 BIM Types

2.2.1 Hollywood BIM

BIM is merely being utilized to create 3D models and other BIM characteristics, rather than leveraging the advanced features of BIM. Contractors may utilize it to obtain contracts without fully leveraging BIM's capabilities.

2.2.2 Lonely BIM

BIM adoption is isolated within a single organization, with data not being shared with other stakeholders.

2.2.3 BIM social

It's a more inclusive strategy that allows the engineer, architect, construction manager, and subcontractors to share data on project plans.

2.2.4 Intimate BIM

“When the designer, owner, and contractors share the risk and profit of utilizing BIM to achieve an integrated project BIM, both intimate and social, fosters the creation ofsuperior designs while also reducing time and expense” (Hergunsel 2011).

2.3 BIM Application Areas

A building information model can be used for the following purposes

2.3.1 Visualization

3D renderings, sections and elevations can be easily generated domestically with little extra effort.

2.3.2 Fabrication/Shop Drawings

It is easy to generate shop drawings for various building systems like MEP etc.

2.3.3 Code Reviews

Fire departments and other officials may use these models for building projects review.

2.3.3 Forensic Analysis

A building information model can be quickly modified to graphically depict probable failures, leaks, and evacuation plans, among other things

2.3.4 Facilities Management

BIM can be used by facilities management departments for restorations, space planning, and maintenance.

2.3.5 Cost Estimating

Cost estimating capabilities are included into BIM software. When the model is altered, material quantities are automatically extracted and modified.

2.3.6 Construction Sequencing

Cost estimating tools are included into BIM software. When the model is altered, the material quantities are automatically changed and extracted.

2.3.7 Conflict, Interference and Collision Detection

"Because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interference." (Salman Azhar, Michael Hein and Blake Sketoet al. 2008).

2.4 Benefits of BIM

2.4.1 Lower your building costs

BIM decreases construction costs, according to AIA (2007 Bottom Line Benefit)

- Provide a variation analysis
- More competitive material price
- RFIs are reduced
- Quicken the construction process

2.4.2 Construction Time is Cut

BIM decreases construction time by improving the processes and applications that follow.

- Enables better pre-construction planning
- Makes construction scheduling easier
- "Enhances the coordination of project design" (Hasan, Zaman et al.)
- "Enhances the quality of construction"

2.4.3 Improved Quality

By reducing project life cycle costs, BIM raises the quality of construction projects..

- Design to maximize available space, equipment size, and energy usage..
- Construction: Reduce costs and schedule projects more quickly and efficiently.

2.4.4 Reduce Uncertainties

BIM improves construction project quality by lowering project life cycle costs.

- Design: Space, equipment size, and energy consumption should all be optimized.
- Construction: Reduce costs and schedule projects more quickly and efficiently.

2.4.5 Quicker and Faster Method

"Change orders, rework during construction, and design coordination concerns will all be reduced using BIM, as will the initial project cost. As a result, contractors will sharpen their pencils and provide price based on known elements, the number of unknowns, contingency pricing, and decreased site coordination tasks" (Patrick C. Suermann and Raja R.A. Issa, 2009). "BIM modeling tools generate constant quantity 3D models that possess all the knowledge associated with a project" (Carmona, Jorge et al. 2007). "These BIM models square measure foreign to alternative tools for various purpose like QTO, simulation (scheduling), structural analysis, energy analysis, clash detection etc. Studies have shown BIM to be a quickly growing trend in housing industry with additional construction corporations preferring BIM" (Sattineni and II 2011) and states just like the United Kingdom encouraging the adoption of BIM given its Brobdingnagian applications and edges its promise. Table 2.2 explains the different phases of project lifecycle briefly

Table 2.2 Project Lifecycle

Life cycle phase	Benefits
Planning	• Provide easy and quick alternative analysis. • Facilitates energy analysis and modeling. • Provide easy quantity and cost estimates. • Facilitates specifications development.
Design	• Improves coordination. • Provide easy information exchange. • Provide auto code checking. • Facilitates easy tracking of design changes.
Construction	• Reduce interpretation problems. • Improves coordination among various trades. • Reduces Request for Information (RFI). • Reduces material value. • Reduces Constructability problems. • Facilitates proper equipment selection.
Operations and maintenance	• Reduces down time. • Reduces rework and wastage. • Resolves space management issues. • Facilitates emergency evacuation planning.

2.5 BIM Applications Tools

Building Information Modelling tools are utilized across the construction sector, and they are summarized below in Table 2.3.

Table 2.3 Project Lifecycle

Company	Software	Primary Usage
Autodesk	Revit	BIM Model generation
	Navisworks	Clash Detection,4D Scheduling, Quantity Takeoff
	Robot Structural Analysis	Structural Analysis
	Green Building Studio	Energy Analysis
Graphisoft	ArchiCAD	BIM Model generation
	Estimator	Estimation
	EcoDesigner	Energy Analysis
Bentley	AECOsim	BIM Model Generation
	Project Wise Navigator	Review and Analysis
Tekla	Tekla Structures	Structural Model generation and Detailing
	Tekla BIMsight	Review and Analysis
Vico	Vico Control	4D Scheduling
	Takeoff Manager	Quantity Takeoff
Synchro	Synchro Professional	4D Scheduling
Innovaya	Visual 4D Simulation	4D Scheduling
	Visual Estimating	Estimation
	Visual Quantity Takeoff	Quantity Takeoff
U.S. Cost	Success Estimator	Estimation
On Center	On Center	Quantity Takeoff
Exactal	Exactal	Quantity Takeoff

2.6 Construction Management BIM

“The contractor's actions have a direct impact on the project's progress and expense. Due to coordination mistakes, lost material, labor inefficiencies, and other issues in present building practice, up to 30% of the cost of construction is squandered in the field” (CURT 2002). BIM eliminates the inefficiencies noted above, increasing project productivity, and lowering project costs. The projected "cost of poor interoperability in the U.S. capital facilities business is $15.8 billion per year," according to (Gallaher, O'Connor et al.

2004), and by providing a more integrated project life cycle, the AEC sector hopes to reduce this $15.8 billion loss. To increase the effectiveness of a plan, project stakeholders might use BIM in scheduling, estimating, and project controls.

2.7 BIM and the Role of Project Stakeholders

What can be derived from a BIM model is that it is essentially a well-organized means of keeping all processes, such as engineering, planning, developing, and fundamentally managing a building, coordinated. It is acceptable to say that the Building Information Model must be built before the model can be used as a technique. After the procedure has been designed, the model can be used as a component of the traditional workplace culture for the various workers involved in the construction process. Coenders refers to this understanding of the Building Information Model as "BIM as a vision" (2009).

Using the Building Information Model in the workplace has many benefits, including increased collaboration and coordination between individuals working on a project, which results in a more effective flow of work. Another significant advantage is that there is less repetition, as the same information is not entered many times. This is due to the fact that raw data is given into a typical model rather than cluttered data provided by all participants. The use of the Building Information Model also reduces errors that manifest themselves in other construction and design problems. Different branches of engineering have different models, such as those that focus on structural components or others that are primarily concerned with software.

Examples of models used in fields connected to mechanical or electrical engineering are models used to investigate ventilation systems or models for environmental design. The amount of errors (related to construction and design) is slightly reduced since all the components that "clash" are obvious and mistakes are simple to correct right away because all the pieces of the various orders are brought together in the Building Information Model application. Coenders (2009) also makes the case for BIM as a software technology, and there it is implied that the programming standards currently in use are a far cry from the goal and the current requisitions are very simplistic.

2.8 Construction Project Integration

In construction projects, integration management is defined as coordination of the different project element, effective communication of stake holders, management of resources and delegation of task. Many stakeholders are involved in this task, including the project manager, design manager, architect, political parties, and so on. They all have significant duties and roles in the project.

The most essential knowledge area is integration management, which provides a platform for procedures and activities that integrate and coordinate the diverse aspects of project management into a single chain. Similarly, for a project to succeed, strong and successful construction project coordination and integration of the many disciplines are required. Miscommunication, as well as isolated working of different stakeholders, is a major issue that we have seen in many constructions project models. Rather than working on any kind of project as a team, rather operating as a separate and different piece is quite rubbish, many researchers say.

Even though our new advanced management techniques shown that the interface coordination process of managing is critical to achieving the aim. Highly effected and new technology automatic software like BIM (Revit 360, civil 3D, Navisworks etc.) are major resources that will assist to increase the quality of the project in a very short time, and people who work with that software must be able to operate them technically and manage them. When extra time is required to bring a construction project to a close outside of its initial (planned) timeline, it frequently results in a significant loss in project cost, time, conflicts, arbitration, litigation, and abandonment. As a result, recognizing the source of delays and avoiding them, leads to improvement.

2.9 Change management

The Latham Report generated a 'push' within the construction industry to openly embrace building information technology in order to achieve a 30 percent actual cost reduction over the life cycle of a project. Change management was approved, albeit its effectivenesswas questioned, as only slight advances in construction productivity were realized between 1995 and 2005.Adapting to controlling, and implementing change is the goal of change management.

Construction firms have proven their ability to adapt to change, as evidenced by their willingness to embrace technological innovations such as BIM. Controlling and accomplishing change in Pakistan has been difficult due to a lack of experience, training, and education in adopting BIM for asset management. Fundamentally, in order to ensure that productivity gains are realized as a result of the accumulated data, change management in the construction industry should focus on defining and implementing procedures and/or technologies to deal with the changes that will be brought about by the adoption of BIM. As a result, change management in BIM should be considered as a systematic strategy to evaluate its efficacy throughout a project's life cycle; hence, changemanagement should be treated as a continual renewal process.

2.10 Impact of Change Order Evaluation System Based On BIM

The BIM-based Impact of Change Order Evaluation System (BICOES) is a tool that helps all project participants evaluates the effects of change orders on scope, cost, and schedule. The BICOES will concentrate on the following aspects of assessing construction alteration effects:

- Identify elements that have changed. The system detects both changed and impacted items based on the updated criteria assigned, such as location, number, and substance. The change identification report is a good place to start if you want to dig deeper.
- Calculate the time and financial costs of change.
- The system evaluates the effects of a modification order on project objectives (time and cost). The BICOES can do cost and delay analysis.

Display the findings: The system uses BIM to illustrate the above outcomes. The results are turned into color-coded 3D models that show the effects of a changing order graphically. The method between Revit and Navisworks is shown in Figure 2.1.

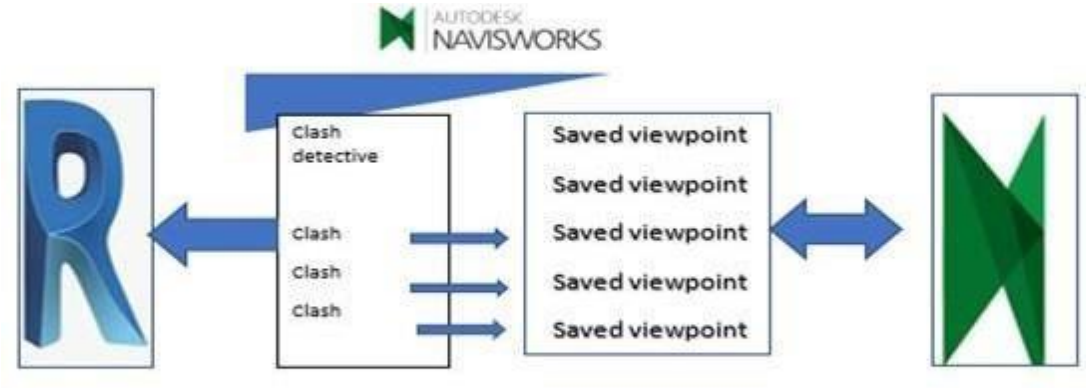

Figure 2.1 Autodesk Revit and Navisworks Coordination

2.11 Categories of Clashes

In BIM-based clash detection, there are two categories of collisions.

2.11.1 Hard Clashes

A 'hard clash' occurs when members of two groups collide. Hard clashes are geometrical issues. When at a particular time, two different elements share the same coordinates. For example, if a duct and column are sharing the same coordinates.

2.11.2 Soft Clashes

A 'soft clash' is a design fault. This is a failure to secure enough room for other things. Access, insulation, and safety are all components. Soft clashes occur when clearance space is insufficient for maintenance activities. For example, the space above a window isnot enough for providing a lintel beam.

2.11.3 4D Workflow

Workflow conflicts, as the name implies, are timetable conflicts. They genuinely indicate a misalignment of schedules between contractors or a conflict over equipment or material delivery. It's known as a 4D clash since it's caused by scheduling problems that affect the efficiency of the entire construction enterprise.

It has the ability to interrupt construction activity because when one timetable is disturbed, it has repercussions across multiple disciplines.

2.12 Clash Detection

BIM can be deployed to improve the project performance during the following phases:

- Construction feasibility review
- Quantity take-off
- Process management simulation

With the passage of time, construction companies in Pakistan have realized that instead of using conventional techniques and software for construction project management, it's better to have a paradigm shift and BIM shall be employed to improve the projectefficiency. During the construction phase,

BIM can play an important role in constructability review especially with regards to pre-construction phase and decision-making method. With the advancement of building information modeling in the construction industry clash detection processes are the needs of time, as clash detection is a function that can be utilized on construction sites that can help to ensure close coordination among the various stakeholders.

In spite of the growing need of the clash detection in Pakistan construction industry there is still a lack of individuals who are well acquainted with the modern tools of clash detection as an abettor for efficient project management. Furthermore, according to an analysis of BIM-related guidelines, the content for the BIM process during the construction phase primarily relates to the concept and outlined fields to which the BIM can be applied, and it is insufficient to establish or improve the concrete process of the BIM-based clash detection process.

As a result, the goal of this research is to develop a clash detection mechanism that can be used in BIM-based building projects, as well as a collaborative system for efficient constructability evaluation. When it comes to the coordination process, the BIM coordinator bears a lot of the responsibility for resolving constructability issues. If a high-quality, clash-detected, and clash-resolved model data is provided to the field crew fast there is more time to anticipate constructability issues and, as a result, it will decrease onsite rework. Fig 2.2 explains the process of identifying clashes in BIM.

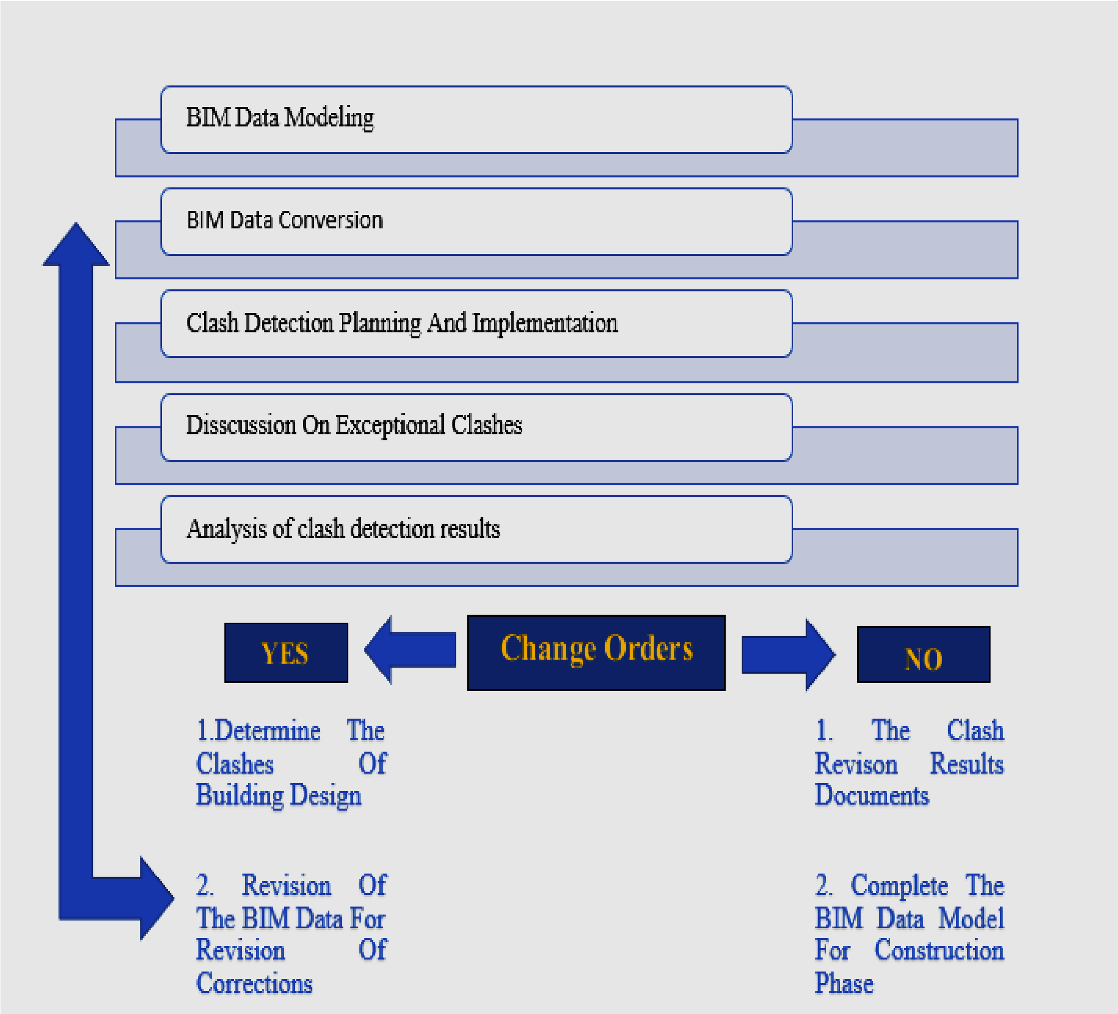

Figure 2.2 BIM Strategy

2.13 Software Used for Clash Detection

A BIM model for construction, structure MEP (machine/fire resistance/electricity), and then, in the construction document phase, conflict detection software is used to evaluate whether there is a 'hard conflict' between construction-structure/construction-MEP/structure and MEP (which includes Autodesk Navisworks, Solibi Model Checker Solibri). During the construction phase, the purpose of conflict detection is to find's soft clash' for constructability evaluation, which requires the detection of 'hard clash' beforehand.

The 'hard clash' can only be avoided if the clash detection performed during the building document phase is totally reliable. It was revealed that it is difficult to build an integrated model and conduct clash detection when the project basis point (the coordination set to integrate BIM for each field into one) does not coincide across models; or the 2D drawings do not match the BIM models. In these cases, it's critical to double-check for 'hard collisions.

Because the construction plan, including the Zoning plan and the member categorization system, is not reflected in a construction document BIM model, it is critical to check for 'hard clashes' during the construction phase. Certain model revisions are undoubtedly required to use a BIM model throughout the construction phase, and the 'hard clashes' must be reviewed again, delaying the use of the BIM for a period while the consequences of soft clashes' and constructability review are dealt.

2.13.1 Navisworks Working Model

In order to facilitate design review, coordination analysis, model simulation, and presentation, Autodesk Navisworks serves as a model aggregator, collecting 3D models and pertinent design data in one location. Tools like Clash Detective, TimeLiner, Animator, and others are available in Navisworks. In order to evaluate the design and offer accurate construction and operating estimates, it enables a hands-on evaluation of the virtual project model.

2.13.2 Additional Features of Navisworks

Navisworks Manage is a model aggregator that brings together 3D models and their design data in one place.It allows for the evaluation of design and constructability, as well as coordination analysis, simulation, presentation, and communication. It has a share view capability, and users may compare models across platforms (Revit, Inventor, Rhinoceros,

Solidworks, Sketchup, Allplan, Robot, and CYPE, etc.) It includes features like Clash Detective, Animator, Time Liner, Quantification Workbook, and more.

2.13.3 Breakdown of Old Coordination Process

Let's break out how to work through the coordination process purely in software like Navisworks to get a clearer understanding of what this looks like now.

Each subcontractor, consultant, and fabrication crew create their own model, which they then share with the general contractor, who aggregates it in Navisworks. The GC's BIM coordinator then analyses the models for conflicts, prepares an Excel clash report, and distributes it to the design teams. After some discussion (typically during the weekly coordination meeting), each team returns to work to settle the conflicts that were allocated to them. This approach is continued until the challenges with coordination are overcome. Figure 2.3 explains the basic procedure of old coordination between different project stakeholders.

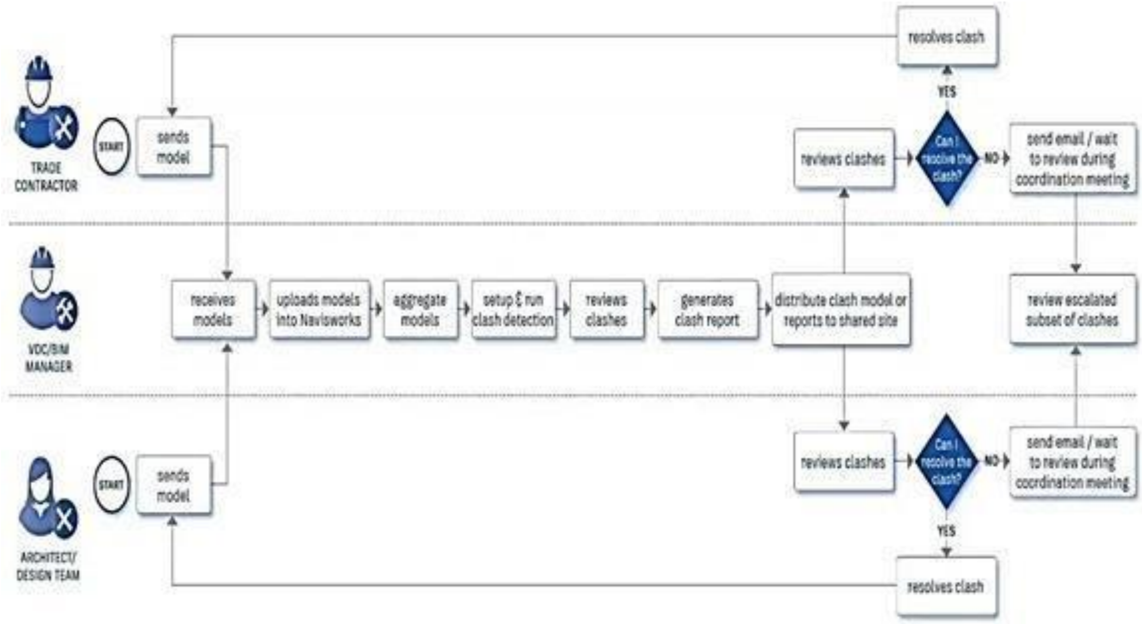

Figure 2.3 Old Coordination Procedures Adapted from Researchgate.net

The BIM coordinator is the sole individual with complete knowledge of what has to be changed or redesigned in a normal coordination process. As a result, people wind up wasting a lot of time on activities such as:

Constructing a rule-based collision detection system

- Thousands of "false conflicts" that don't require a professional to resolve
- capturing models
- Obtaining files
- Spreadsheet creation

If design teams wish to investigate collisions independently, they'll require Navisworks as well as access to all the multi-discipline models. This method is effective, but it might create bottlenecks if project participants rely primarily on the BIM coordinator to manage everything.

2.13.4 Optimal Workflow of Navisworks

Manual work consumes a large portion of the BIM coordinator's time, reducing their capacity to turn things around fast. In the end, this procedure costs both time and money during project life cycle.

With the inbuilt Clash Detective tool in Navisworks, you can detect faults quickly. It becomes part of an equally strong Issue management ecosystem when connected to BIM collab Cloud. Allow us to walk you through the process and illustrate the procedure.

Creating Saved Viewpoints to convey difficulties is the standard approach forNavisworks users. These Saved Viewpoints can be manually constructed or produced using the Clash Detective. They may be shared within the Autodesk BIM ecosystem once they've been developed.

2.13.5 Applications of Navisworks Clash Detection

It assists us in identifying, avoiding, and resolving issues in the virtual model before to the commencement of construction, minimizing costs and schedule risks while also modification orders and RFIs.

By merging spatial coordination with construction planning, Autodesk Navisworks Manage offers simulation, coordination analysis, and change management during active construction.

2.13.6 Drawbacks of Navisworks Clash Detection

There are a few drawbacks to this workflow:

- Viewpoints saved in Autodesk can only be shared inside the Autodesk environment, not with other (open BIM) tools.
- Clashes can only be controlled with Navisworks' Clash Detective.
- A Saved Viewpoint is not synced with any status update to a clash in the Clash Detective.
- It is necessary to establish a new Saved Viewpoint. The history of the clash is split between the numerous Saved Viewpoints.

- Saved Viewpoints established by hand cannot be controlled using the Clash Detective.

2.14 Energy Analysis Using BIM

The global focus is on effectively controlling and reducing building energy consumption. In the past, a wide range of study on building energy savings (BES) had been proposed. BIM is employed because of its ability to create and manage information throughout a building's life cycle. While BPM enables for the optimization of the retrofit workflow by giving all essential stakeholders with

- The tools to better understand their roles and responsibilities in the retrofit process,
- The technological framework and data required to execute BIM successfully within the project.

BIM can aid in the attainment of sustainability ratings for energy-efficient renovations. The majority of the current building stock was built before 1990 and does not have pre- existing or updated construction data. These buildings could only benefit from BIM if the data collection technique could produce as-built BIM in a reasonable amount of time and at a reasonable cost. As a result, data collection solutions should be more user-friendly, cost-effective, and feature automated data processing to solve the technical challenges of integrating BIM in existing buildings, decreasing effort and model preparation time. In addition, to overcome the lack of acceptable interoperability between different software programs, new BIM platforms (such as BIM collab) and universal data standards (such as IFC, gbXML, and others) must be regularly improved. The final technical barrier is the difficulty of keeping information in BIM format up to current during the building's existence. Finally, the current study suggests future research directions, such as intelligent energy management and control system integration, quantitative and qualitative studies of Building Energy Modeling interaction, and a thorough summary and quantitative analysis of Building Energy Modeling driving and hindering factors. This study contributes by providing researchers and practitioners with a complete understanding of the research state and developments in the field of Building Energy Modeling.

2.14.1 BIM-Based Energy Simulation Analysis

The construction industry is rapidly accepting Structure Information Modeling (BIM) as an innovative way for combining a wide range of data connected to a building. Different building energy modelling software may import these BIM files and execute energy simulations. Building information modelling (BIM) has substantially increased the efficiency and accuracy of building energy efficiency design, as well as reducing duplication of work and facilitating project information flow. It has been discovered that using simulation to estimate building energy efficiency reduces energy consumption and greenhouse gas emissions dramatically.

2.14.2 BIM's Advantages in Building Energy Analysis

BIM provides properties that can be used to mimic energy analysis and accurately predict building energy use. BIM software may create a virtual 3D building model, which is a database containing all of the building's data. By importing a large amount of data from the model into the energy analysis tool, a large amount of data can be automatically recognized and analyzed, and the energy efficiency study findings can be obtained quickly and conveniently. With a BIM model, an energy analysis tool may assist speed upthe process, give more thorough and precise data, and design energy-efficient structures.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The project is divided into two halves. The first section is about clash detection, while the second section is about energy analysis. The first part focuses on the issues that arise due to lack of coordination among the various stakeholders. The second part of the project focuses on excessive energy consumption due to inappropriate selection of material, improper orientation of the building and the wrong placement of openings . After the collection of the project data from the various stakeholders, an endeavor was made to model the structure in BIM environment and to identify the various clashes beforehand the actual execution of the project. The analysis revealed the importance of modern BIM software for the efficient management of the project. Had the delays been identified early in the project life cycle the project would have been completed earlier and with fewer variation orders. The BIM methodology is at the heart of the construction industries and built environment's digital revolution. Governments and public advocates all over Pakistan and the globe acknowledge BIM is recognized as a strategic component for cost, social, and environmental quality, as well as for setting development and competitiveness strategies in the sector, by governments and public advocates all over Pakistan and the world. Many companies are proactively implementing BIM in the building execution and operation of public goods to ensure these economic, environmental, and social benefits. The next endeavor was made to conduct an energy analysis of the as built structure using Autodesk Revit and Autodesk INSIGHT. By varying these different parameters simultaneously (including orientation, material properties, types of windows etc.), the heating and cooling annual end usage requirements varied. The whole methodology ofthis project is explained below.

3.2 3D Modelling in BIM from 2D Drawings

3.2.1 Architectural Model

Architectural 2D Drawings provided in CAD format were converted to an Architectural 3D Model using Autodesk Revit 2023. Fig. 3.1 shows the 2D working drawing of the ground floor of the building which was acquired from project stakeholders. All thedrawings were then transformed to a 3D model using tools of Autodesk Revit 2023. Frontelevation of the Architectural 3D Model is shown in the Fig. 3.2 also final 3D view of Architectural Model is shown in Fig 3.3.

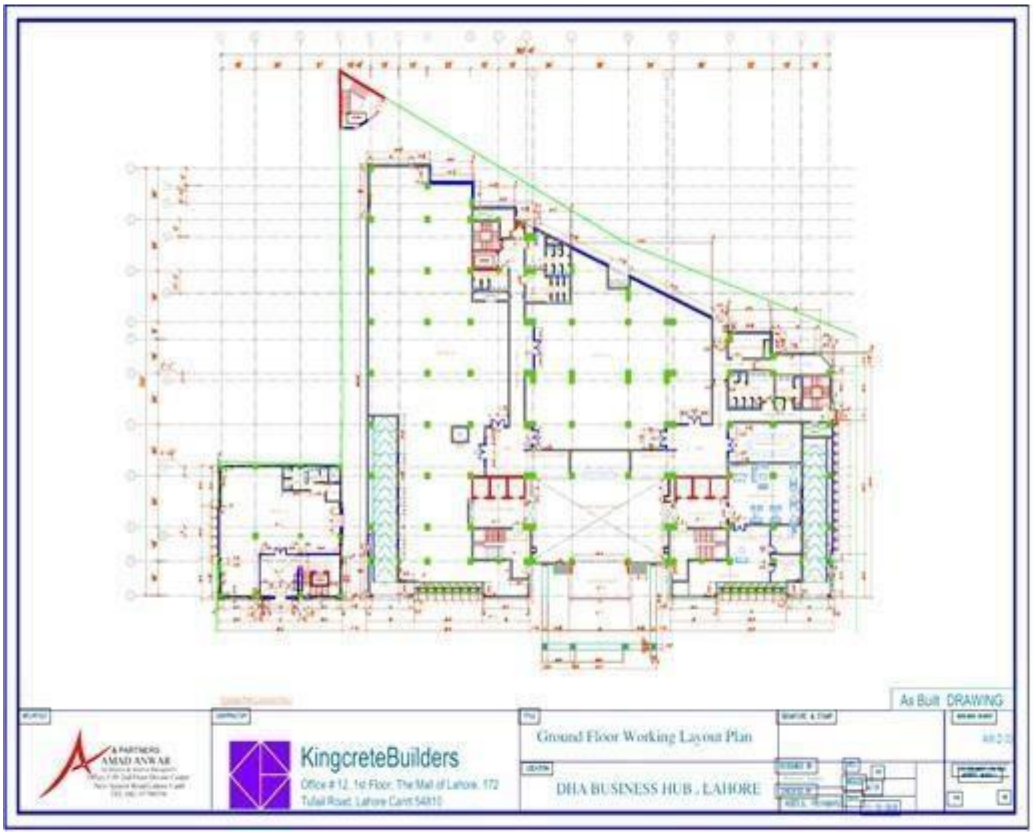

Figure 3.1 2D Drawing of Ground Floor Acquired from Stakeholder

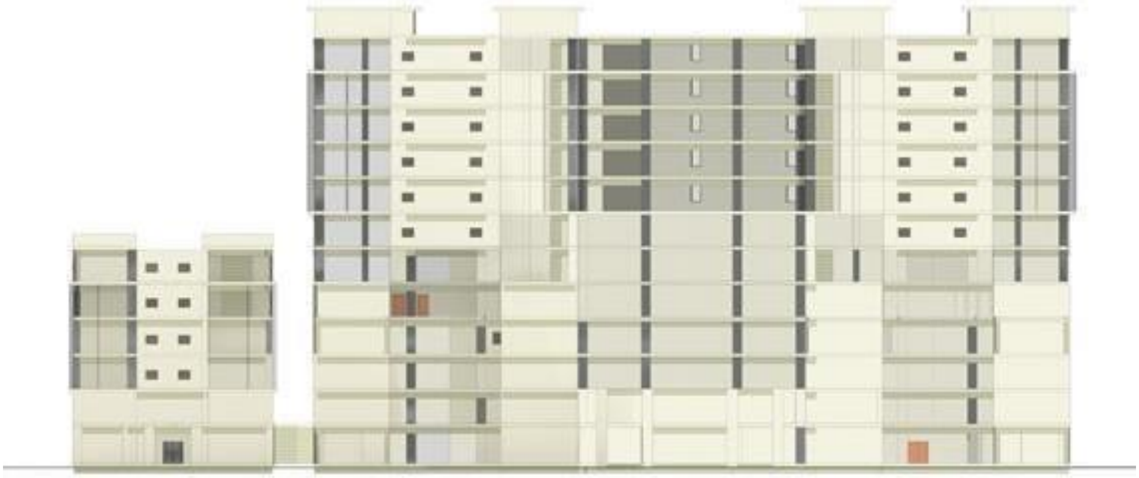

Figure3.2 2D Drawing of Ground Floor Acquired from Stakeholder

Figure 3.3 3D view of Architecture Model

3.2.2 Structural Model

Similar to the architectural model, the 2D drawings from CAD format were also transformed to 3D model in Autodesk Revit 2023. Figure 3.4 shows the provided 2D Structure drawing of the typical floor of the building which was acquired from project stakeholders. All the drawings were then transformed into a 3D Structure model. 3D view of the created Structure model is shown in figure 3.5 and figure 3.6. The 3D view in figure 3.5 is without slab while figure 3.6 shows 3D view of model with all floor slabs.

Figure 3.4 2D Structure Drawing Ground Floor

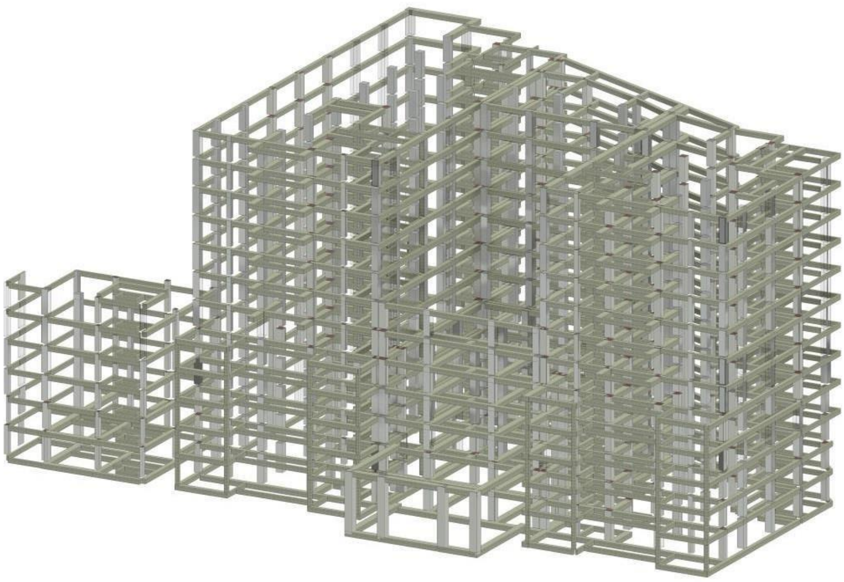

Figure 3.5 3D View of Structural Model with no Slab

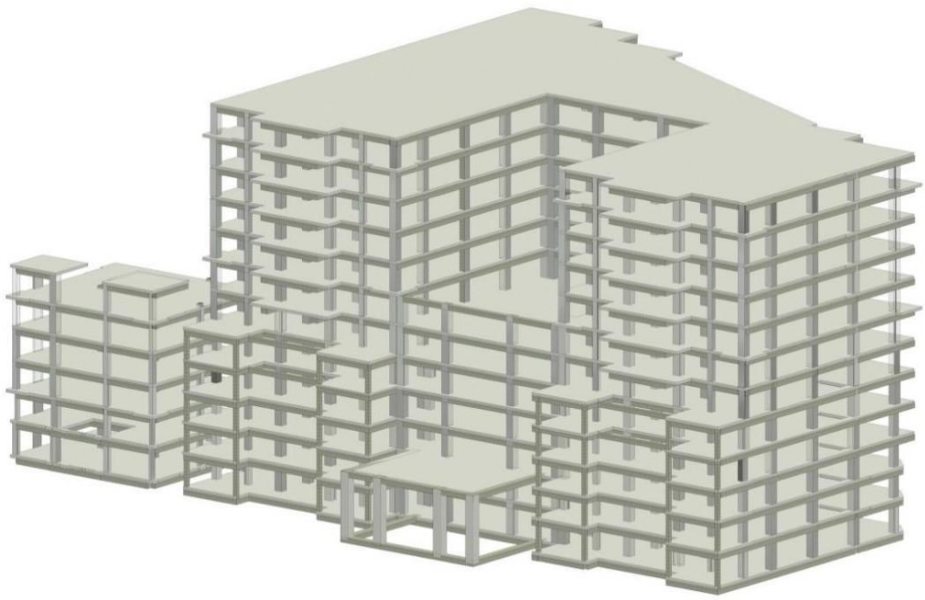

Figure 3.6 3D View of Structure Model with all Floor Slabs

3.2.3 Mechanical, Electrical, and Plumbing Model

Finally, MEP model of building was created from 2D CAD provided using Autodesk Revit 2023. Figure 3.7 shows the 2D drawings of Ground Floor MEP systems.

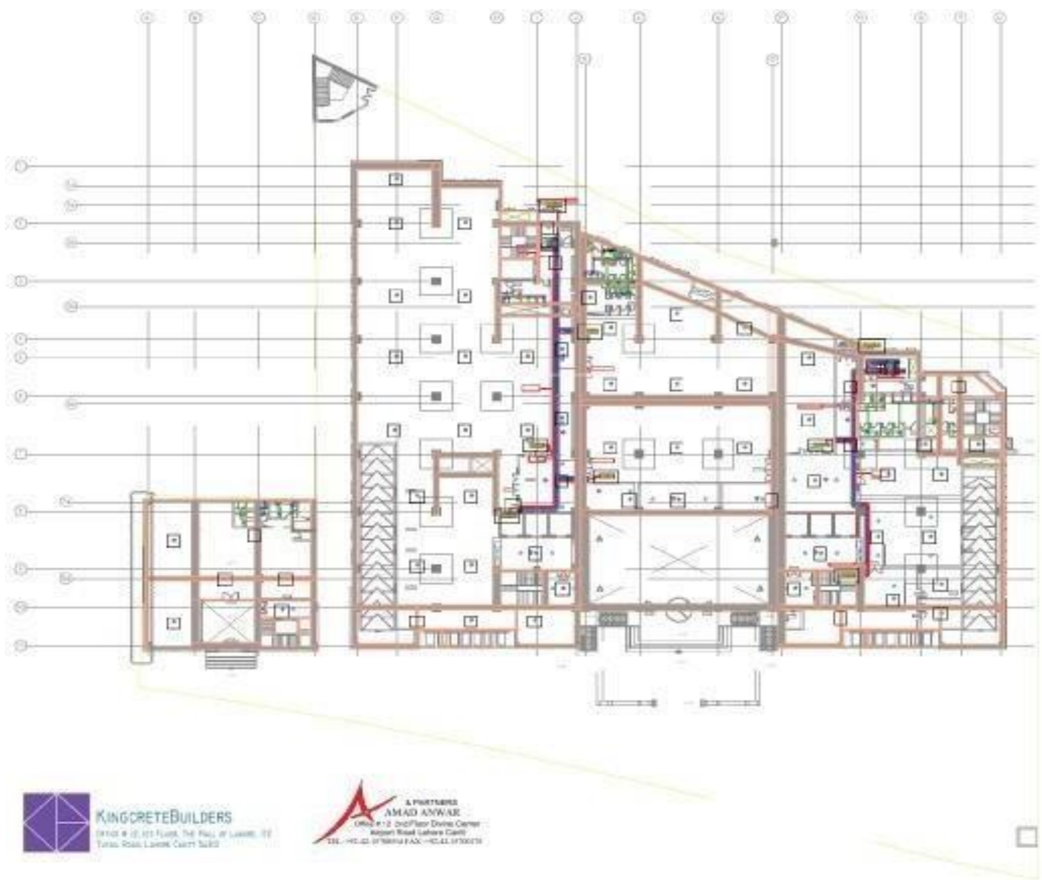

Figure 3.7 2D MEP Drawing Ground Floor

The final 3D model of MEP systems corresponding to Architectural Model is shown in Figure 3.8. After which at last a final rendered image was created in Autodesk Revit 2023 which is shown in figure 3.9.

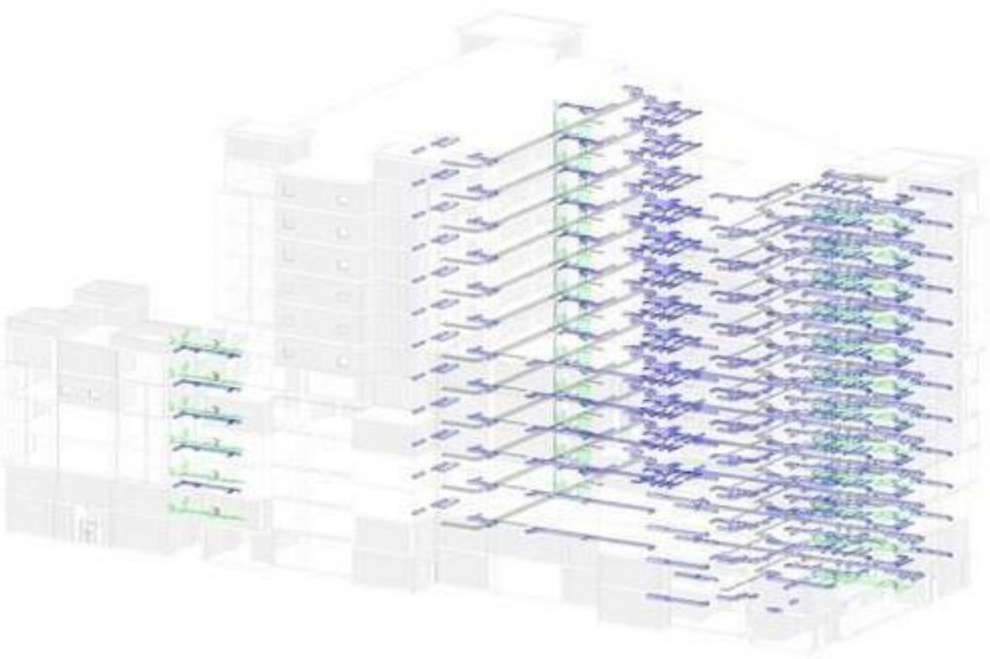

Figure 3.8 MEP Model 3D View

Figure 3.9 Final Rendered Image of BIM Model

3.3 Export 3D Model to Autodesk Navisworks Manage 2023

After 3D Modelling of the building the model was then exported to Autodesk Navisworks 2023 in form of .nwc file. Following steps demonstrate the process of exporting the model in Autodesk Revit 2023:

3.3.1 Step-1

After opening the document in Autodesk Revit 2023 go to Add-Ins Panel as shown in Figure 3.10.

Figure 3.10 Step-1 Add-Ins Panel

3.3.2 Step-2

Click External Tools drop-down button and then select Navisworks 2023 as shown in the Figure 3.11

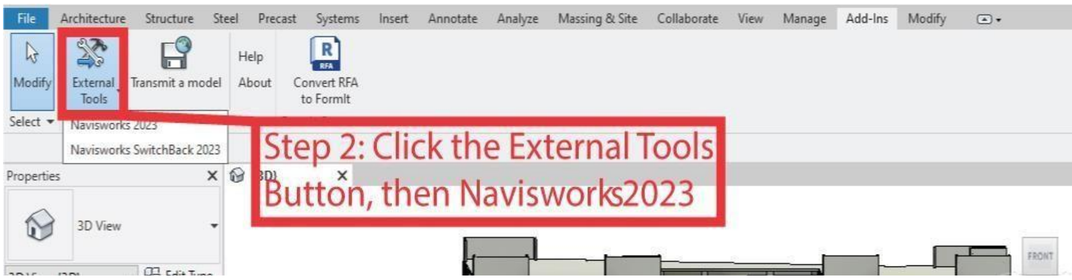

Figure 3.11 Step-2 External Tools Drop-down Button.

3.3.3 Step-3

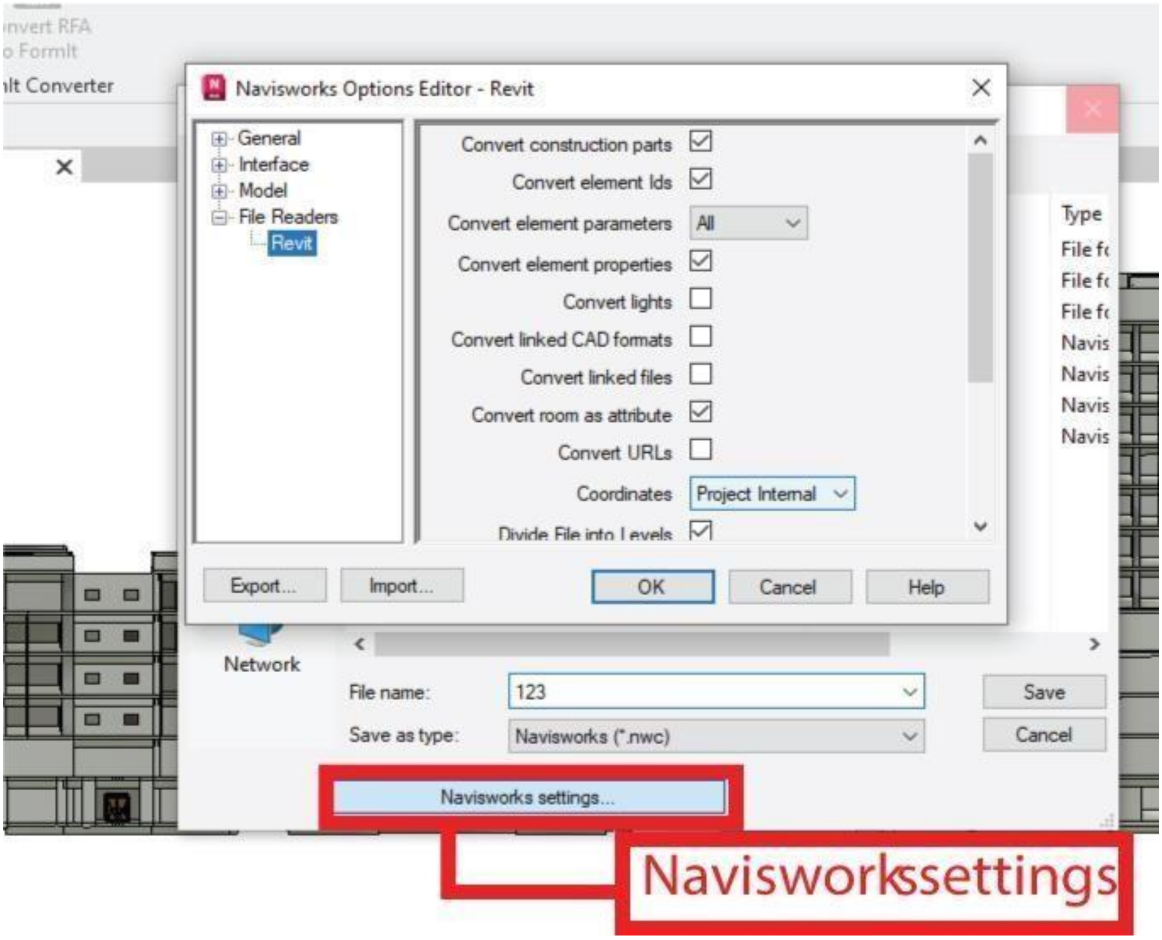

Figure 3.12 Step-3 Navisworks Settings

As shown in the Figure 3.12, in the new window click Navisworks settings button and select appropriate settings and then save the file in .nwc format at desired location.

Figure 3.13 and Figure 3.14 show the Autodesk Navisworks Manage 2023 interface and imported Architectural, Structural and MEP systems 3D BIM models which were exported from Autodesk Revit 2023.

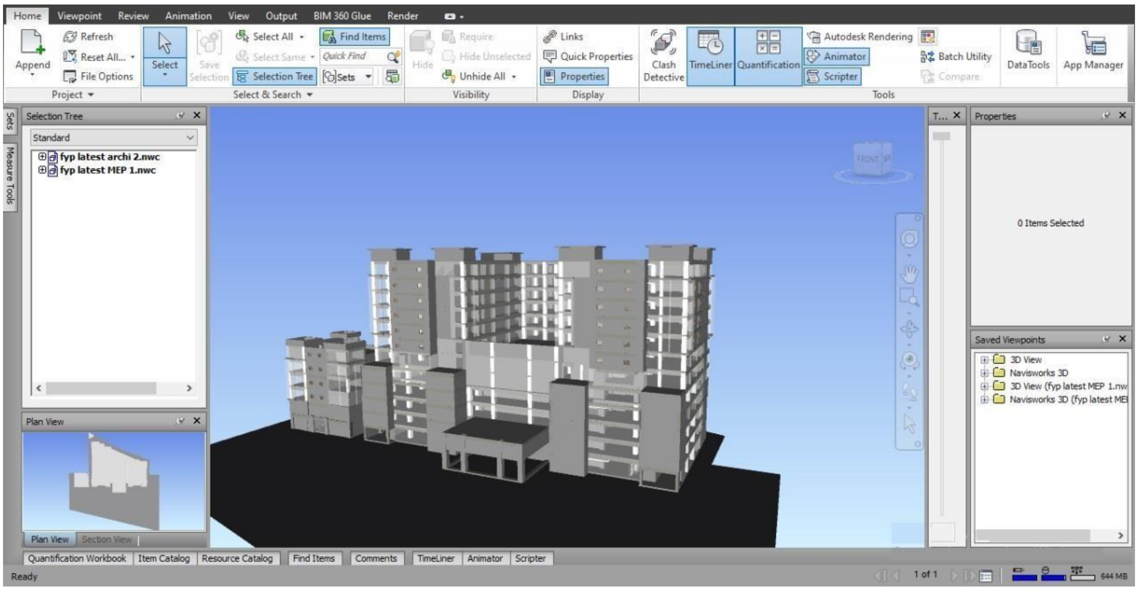

Figure 3.13 Architectural and Structural Model in Autodesk Navisworks Manage 2023

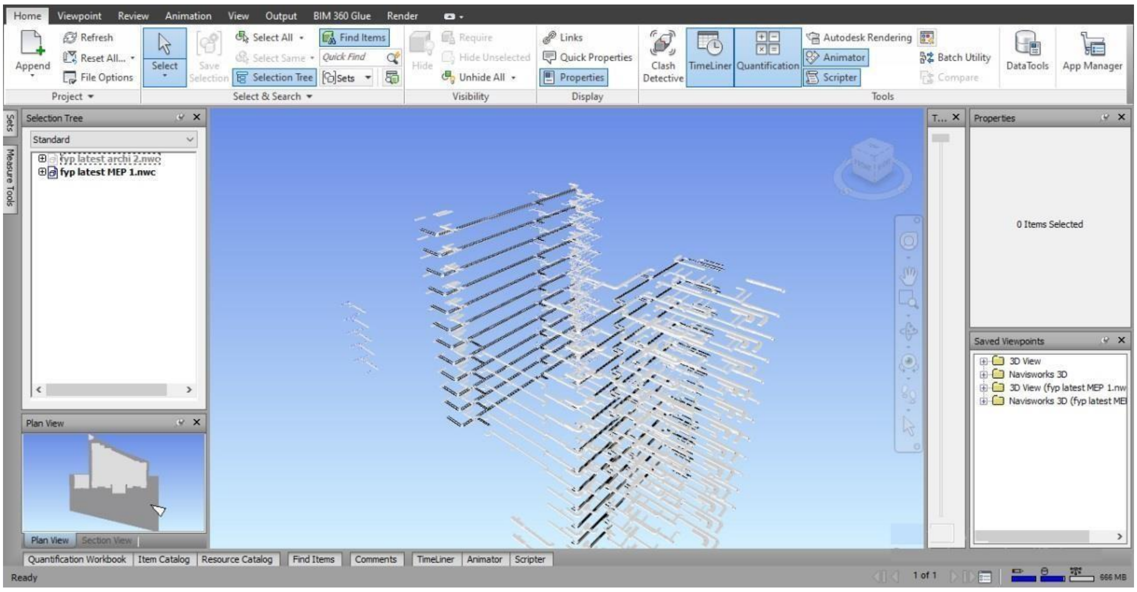

Figure 3.14 MEP systems Model in Autodesk Navisworks Manage 2023

3.4 Clash Detection

Clash detection among different components of building was done in Autodesk Navisworks Manage 2023 which are:

- Clashes of Beams and MEP systems (H-VAC ducts, Electric Cable Trays, and Plumbing Pipes)

- Clashes of Columns and MEP systems (H-VAC ducts, Electric Cable Trays, and Plumbing Pipes)
- Clashes of Slabs and MEP systems (H-VAC ducts, Electric Cable Trays, and Plumbing Pipes)

For that purpose, search sets were created which included Beams, Columns, Slabs, and MEP systems separately in each of them as shown in the figure 3.15. After creation of search sets Clash Detective was opened from panel as shown in figure 3.16.

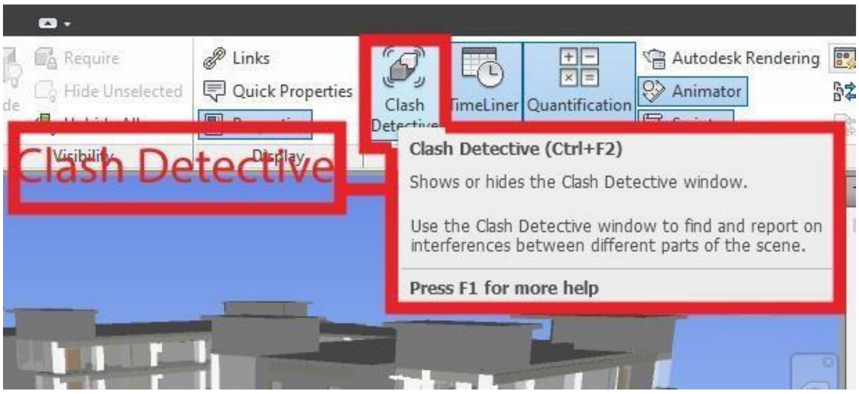

Figure 3.15 Clash Detective Button

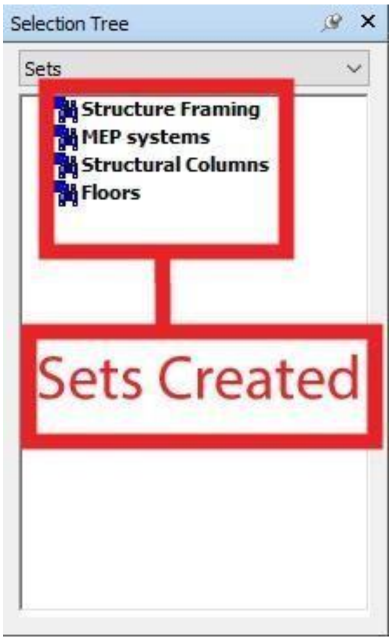

Figure 3.16 Search Sets in Autodesk Navisworks Manage 2023

When window of Clash Detective has opened, new test was run using created search sets in a way that the components against which clash detection was to be performed were checked on opposite sides as shown in the Figure 3.17. When the Test was run, report was generated in the desired format.

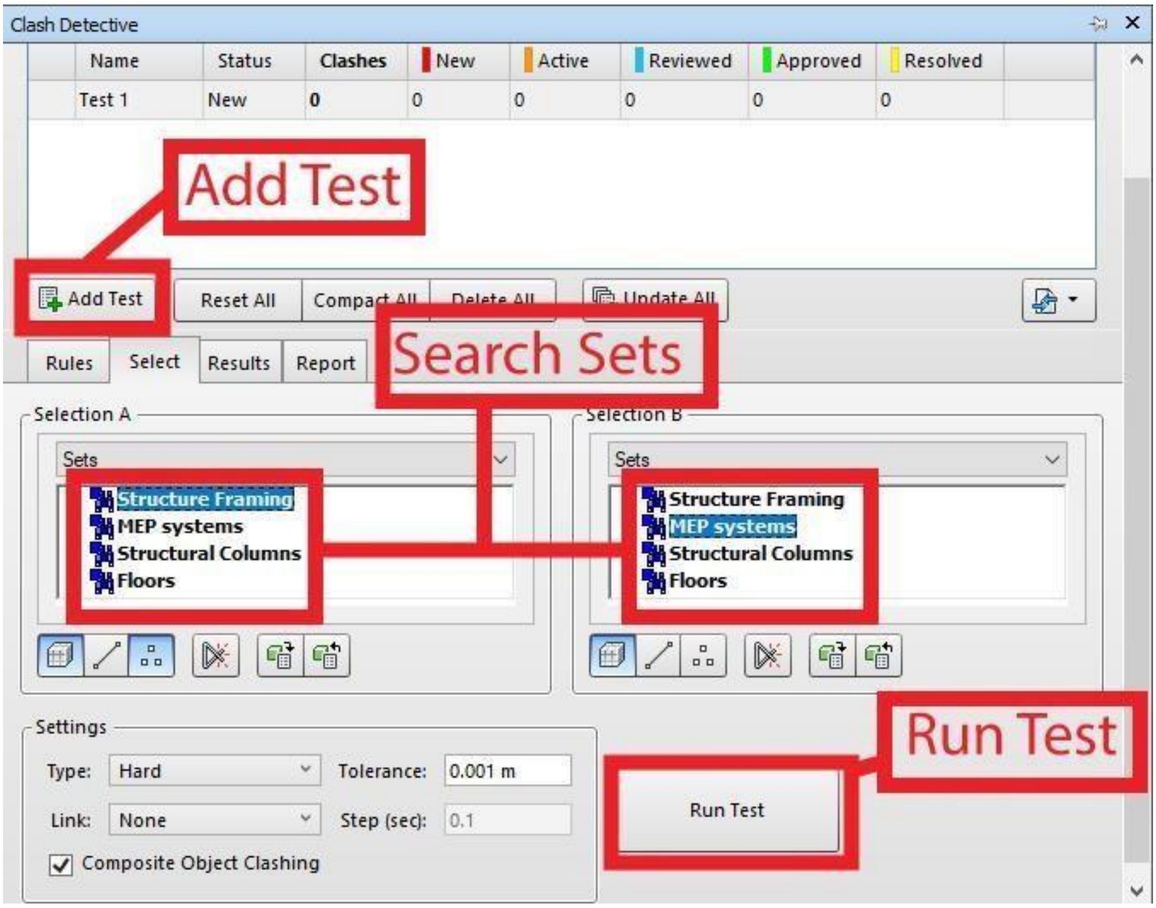

Figure 3.17 Run Test of Clash Detection

3.5 Identify Clashes in Autodesk Revit

Most convenient method of identifying clashes in Autodesk Revit 2023 is by searching elements by their IDs. Because the Element IDs were also provided in the clash reports elements can easily be found in using them. Figure 3.18 shows a single clash identification process in Autodesk Revit 2023 that can be followed to identify location of clash which makes the designing process more time efficient.

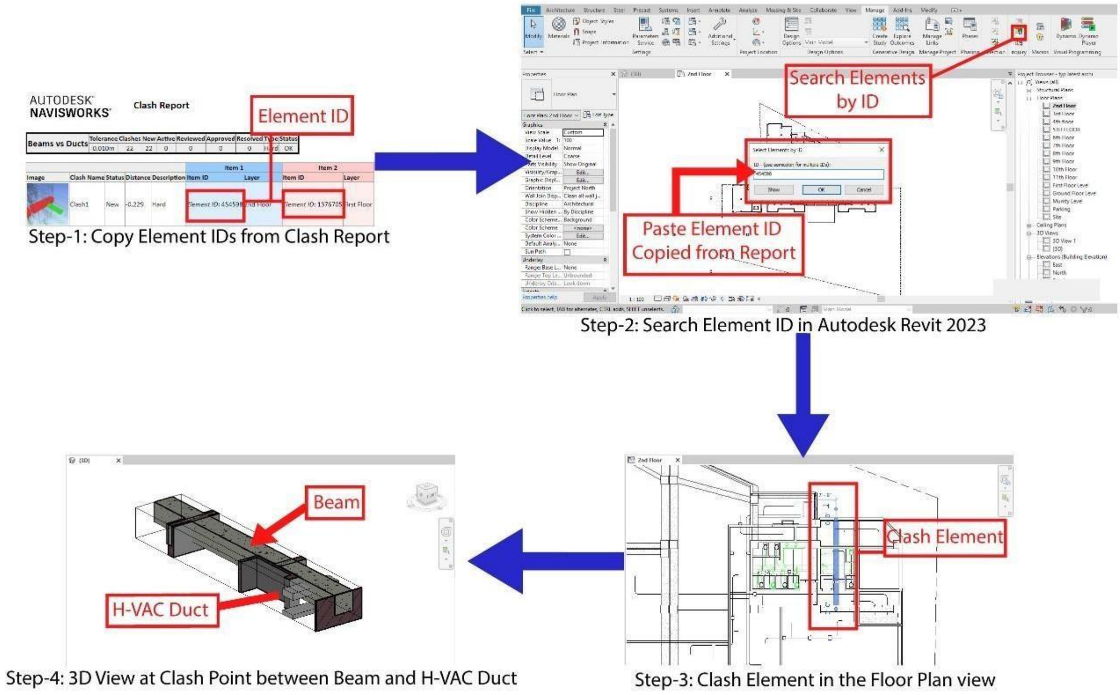

Figure 3.18 Steps to Identify Clash Elements in Autodesk Revit 2023

3.6 Energy Analysis

With the end goal of the Energy Analysis of working with the help of Autodesk INSIGHT and Revit software, a contextual investigation of DHA Business Hub building was done. This building (G+11) is situated at DHA, Phase 8, Lahore, Pakistan. The three- dimensional model of the structure is made using Revit software and the model is additionally investigated utilizing Autodesk INSIGHT. A 3D model, shown in Figure 3.18, was made using Autodesk Revit with the assistance of provided data in the form of floor plans of the DHA Business Hub.

Figure 3.18 3D Model DHA Business Hub

The energy analysis of this building involves following steps:

- The drawings and data were gathered about the structure to be examined.
- A 3D model utilizing the Autodesk Revit 2023 with the assistance of the drawings gathered was made as described in section 3.1.
- The energy setting like **structure type, building working timetable, sort of HVAC framework**, and so on were changed during the different phases of analysis.
- The structure utilizing Internet Mapping Service was found in Autodesk Revit.
- The structure energy model was naturally made utilizing the analyze panel inRevit software.
- Run and then analyze model over cloud in Autodesk INSIGHT.

Figure 3.19 explains steps involved in energy analysis

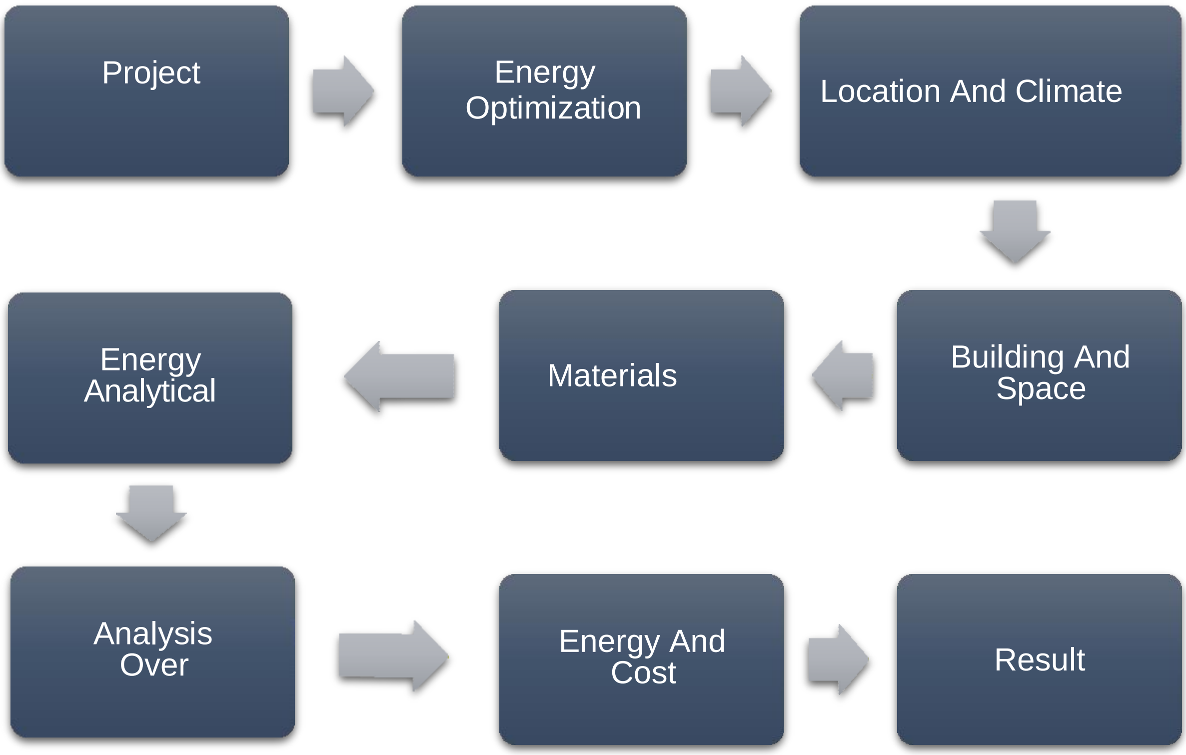

Figure 3.19 Steps involved in Energy Analysis

The Insight tool is used for energy simulation, which is a cloud-based tool, we must sign in to our Autodesk account. If we want to consider the thermal characteristics of the building materials, we have used the material thermal properties option in Revit.

In the location, we updated the Project location details. We used an Internet mapping service for the selected building type, as well as the use of the building type from the list. The project's location will aid in identifying the most convenient location, weather station and weather information for the project area. Steps for this procedure are given below:

- Click on the analyze panel in Revit
- Navigate to the Energy optimization and enter locational data

This is beneficial to the analytical process as shown in Figure 3.20.

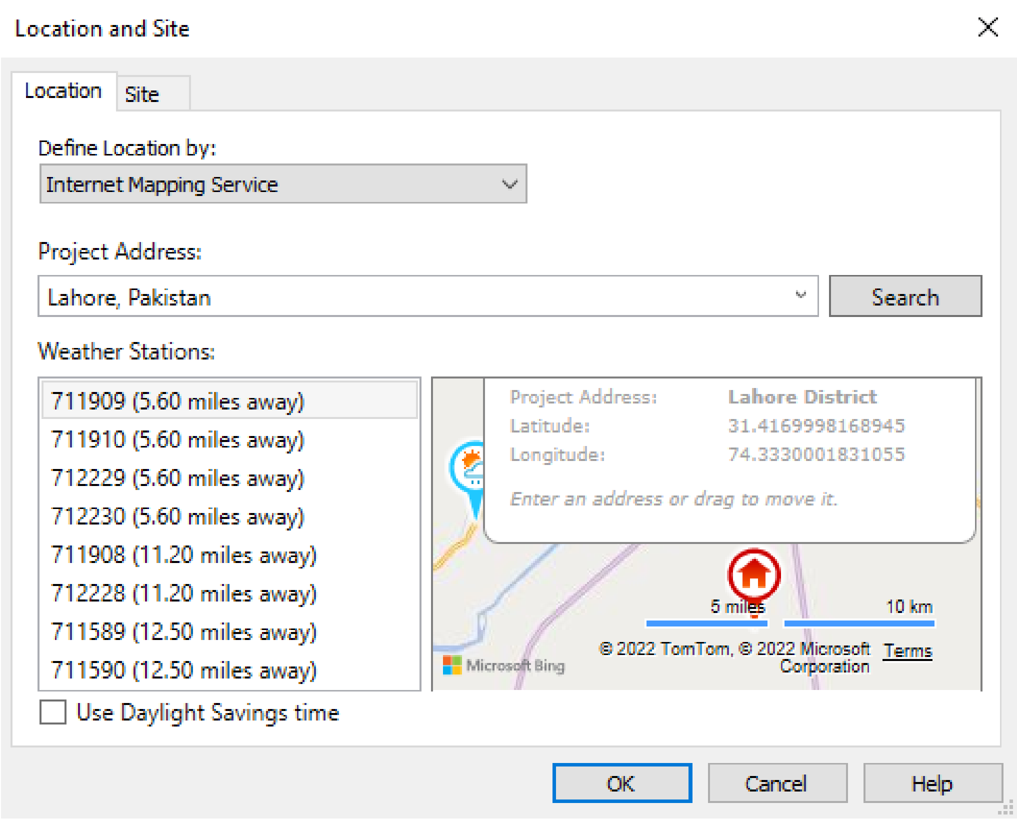

Figure 3.20 Locational Data

The additional information option for Advanced Energy Setting and Energy Setting can also be found in Autodesk Revit' Analyze panel, in which the data of building (building type, building specifications, operating schedule, air information) were inserted. As we know that building operating schedule affects the energy consumption of the building hence it will lead to the increase in the energy cost per year. It means that higher the operating schedule of the building, higher will be the energy consumption hence leading towards gradual increase in cost and vice versa. Steps for this procedure are:

- Open Analyze panel in Revit
- In Energy Optimization navigate to the energy settings and modify advanced energy settings
- Enter building type, building service, and building operating schedule. The figure 3.21 shows the Advanced Energy Settings (building type and operating schedule).

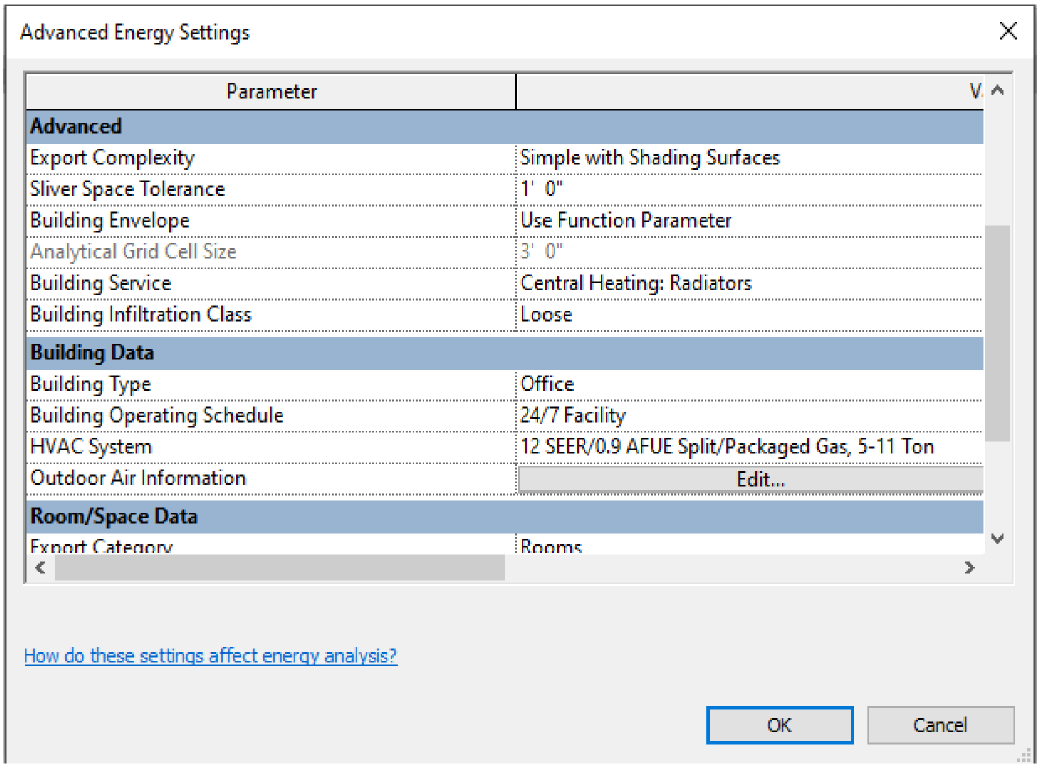

Figure 3.21 Advance Energy Settings

After we've finished with all the energy and advanced energy settings, steps for the next procedure are:

- Click on create energy analytical model (EAM)
- To get an energy analysis report, we click on generate option
- This option uploads EAM to the Autodesk cloud
- Then it generates energy report by analyzing EAM in Revit INSIGHT

Figure 3.22 shows the Energy Analytical Model.

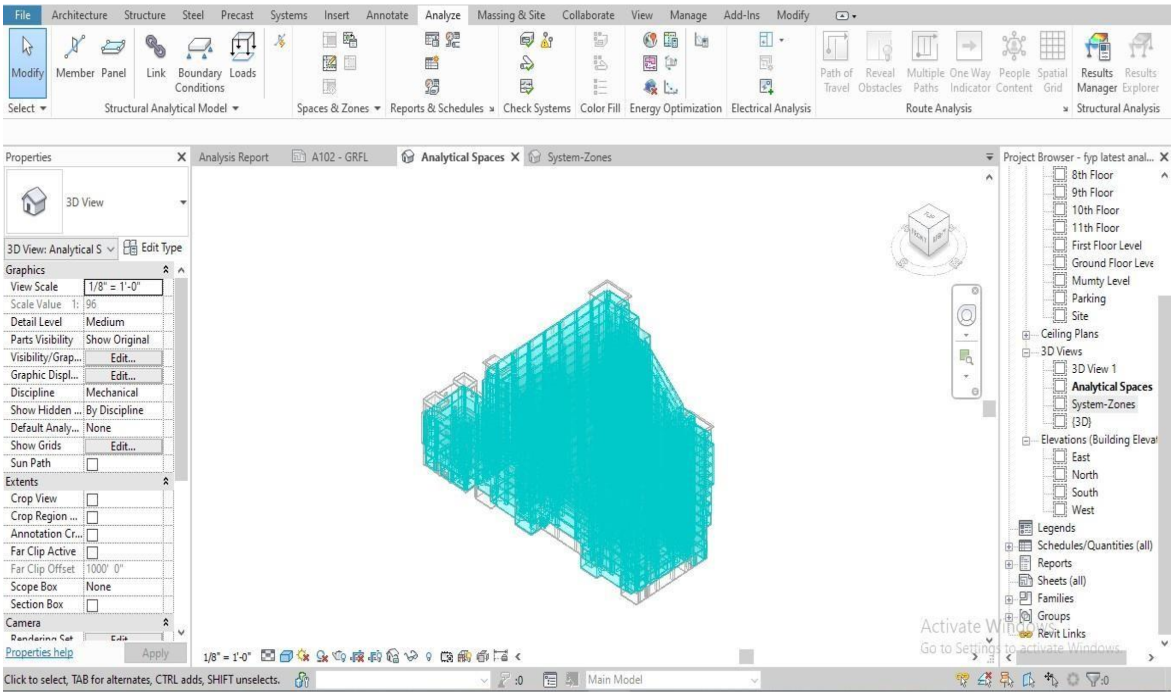

Figure 3.22 Energy Analytical Model, Created in Autodesk Revit 2023

For determining the annual energy usage and heat and cooling requirements of DHA Business Hub, the four system analyses were run. In first two system analyses we use concrete building blocks as a building material same for both analyses but orientation changed, once it was north facing then changed to south facing. While in second system analysis, orientation was kept same as north facing but wall construction material was changed, once it was clay bricks and second time it was changed fly-ash bricks.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Clash Detection

After completing the 3D modeling, the model was imported to Navisworks Manage 2023.The clash detective tool of Navisworks Manage 2023 helped us to find **eighty-six** clashes,after setting the tolerance at **0.01m**, which is the minimum overlapping distance of two clashing elements after which the clash will appear in the clash report. The hard clashes detected were of following types:

- Beams vs Ducts
- Beams vs Cable tray
- Beams vs Plumbing
- Columns vs Cable tray
- Slab vs Plumbing

Resolution of each clash according to variation order took a lengthy timespan. For each hard clash, a Request for Information was generated to refer the issue to the concerned consultant. The consultant then transferred the RFI to respective designer. Then the designer counterchecked the clash on site and provided a pragmatic solution which took some specific time. The contractor resolved the clash as per variation order.

It was found out that a total of twenty-two hard clashes were detected between beams and ducts that caused major delay and wastage of costs. Figure 4.1 shows a particular clash that appeared between beam and duct. According to the variation orders the time taken to resolve a particular clash was about 19 days which varied with time because of the variation in characteristics of each clash.

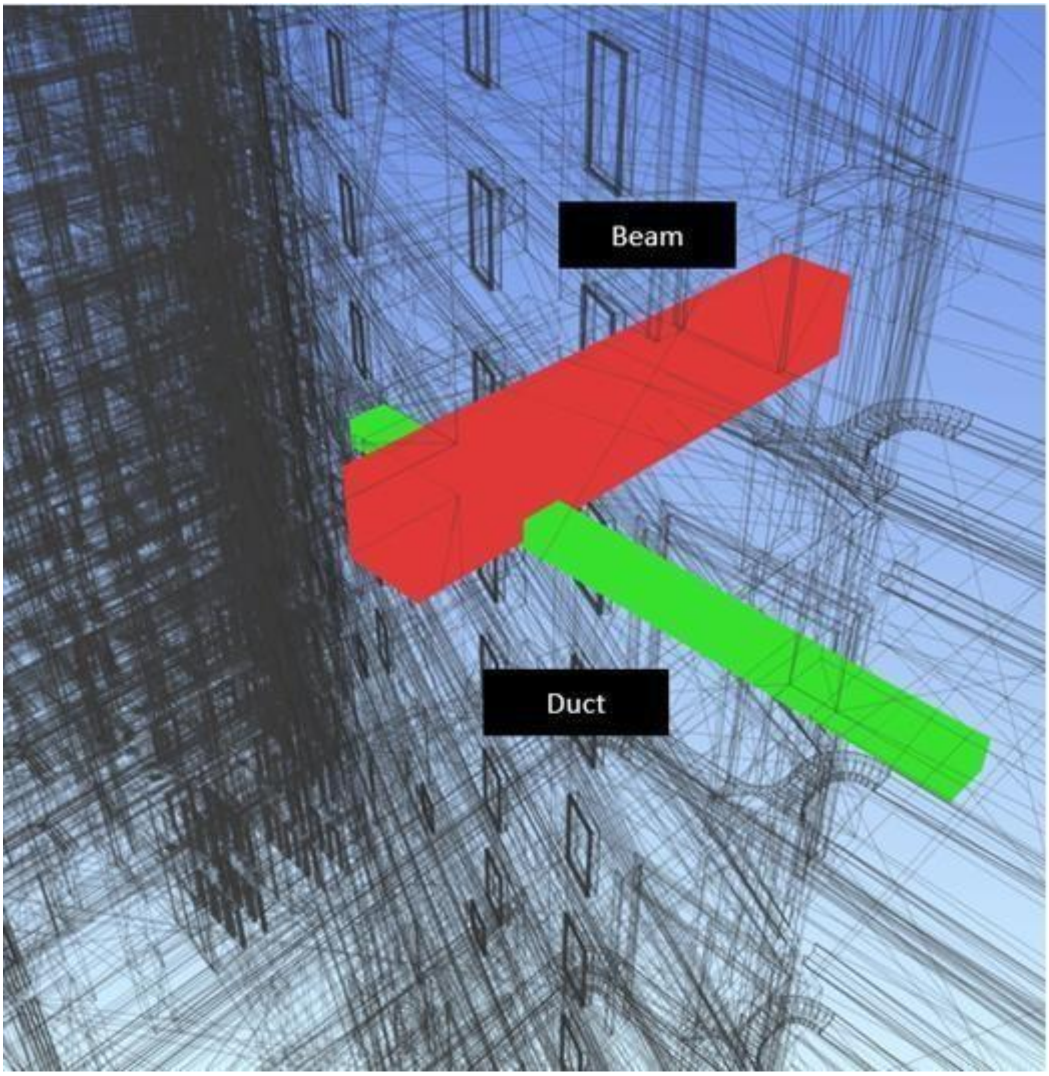

Figure 4.1 Clash Between Beam and Duct

Seven hard clashes were found between beams and cable tray. A particular clash found between beam and cable tray resulted in a delay of 18 days. Figure 4.2 shows an image of a particular clash between column and cable tray on the sixth floor generated by the Autodesk Navisworks 2023.

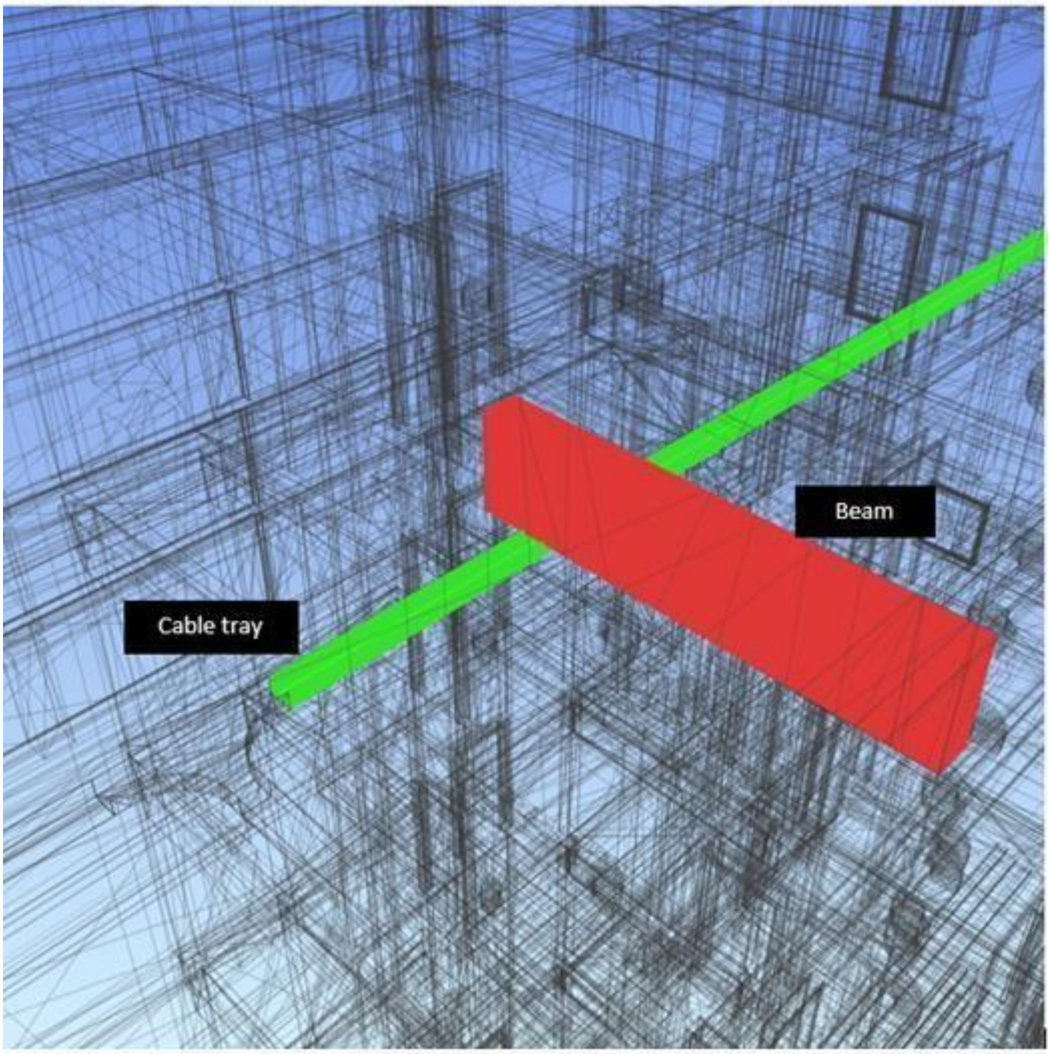

Figure 4.2 Clash Between Beam and Cable Tray

There were twenty-one hard clashes detected by the Autodesk Navisworks 2023 between beams and plumbing systems. The beams clashed with vent pipes, sanitary and sewer pipes. Total days to resolve a particular clash of beam and plumbing system by the contractor took almost 20 days. Figure 4.3 shows a particular clash between beam and plumbing pipe on the second floor.

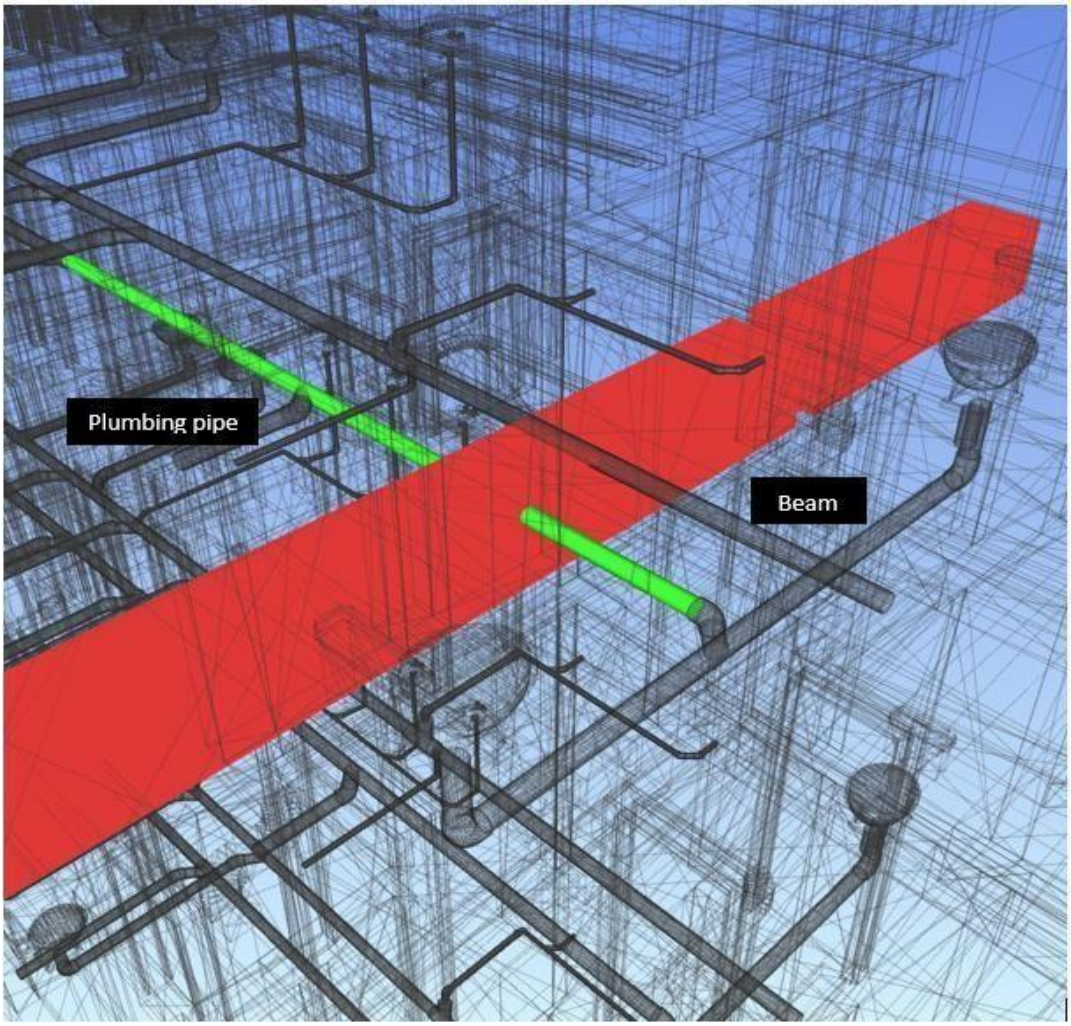

Figure 4.3 Clash between Beam and Plumbing Pipe on Second Floor.

Ten hard clashes were found between slabs and plumbing systems. These clashes were also of varying characteristics like any other clash type and it took different time toresolve each clash. The time taken by a particular clash of slabs and plumbing pipes to be resolved by the contractor was almost 14 days according to variation order. A particular clash between slab and plumbing pipe on the Sixth floor is shown in the figure 4.4 that was generated in Autodesk Navisworks 2023.

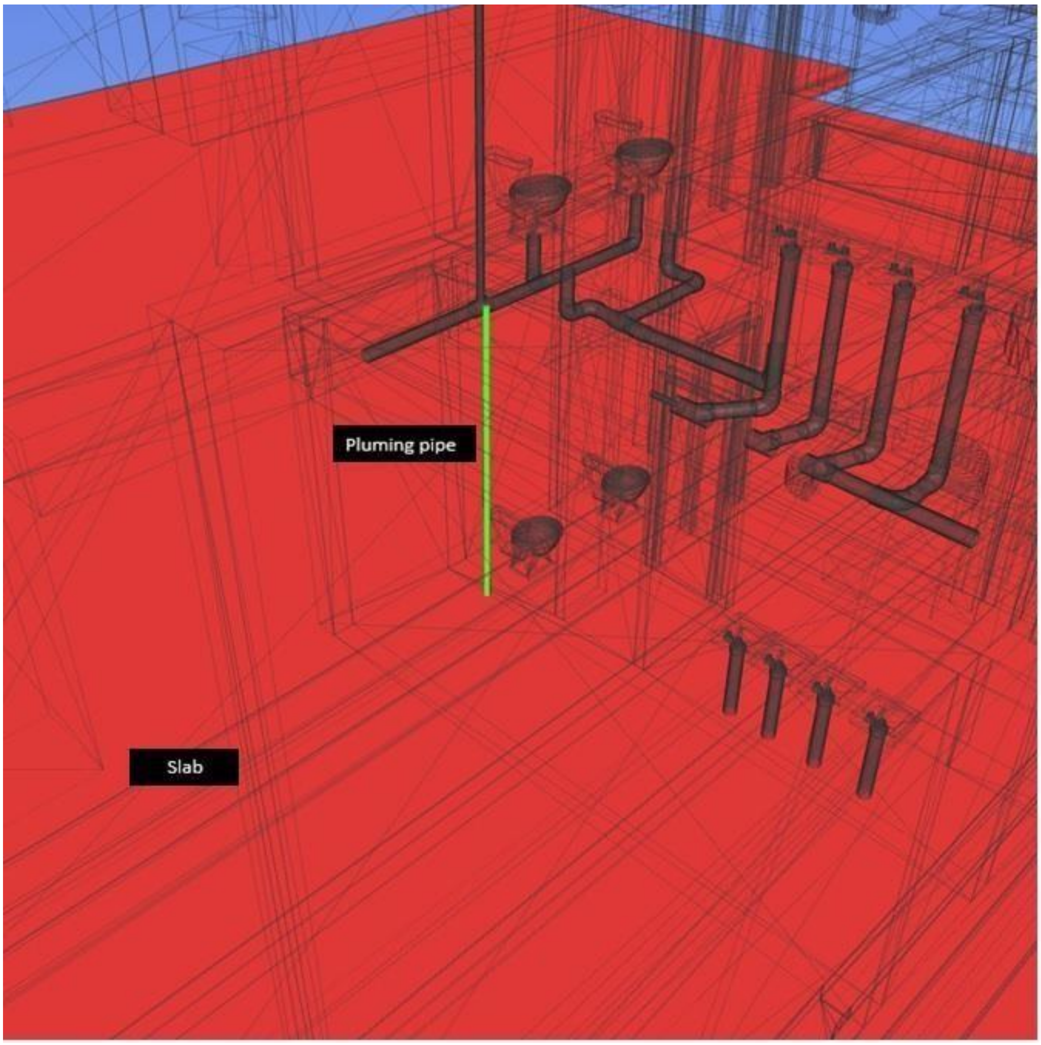

Figure 4.4 Clash between Slab and Plumbing pipe on 6th floor.

Most number of hard clashes was found between columns and cable trays which were Twenty-six hard clashes. Time taken to resolve a particular clash of column and cable tray by the contractor was 15 days according to the variation order. This type of clashes was rectified by deviating cable trays from its path. Figure 4.5 shows a particular clash of between column and cable tray.

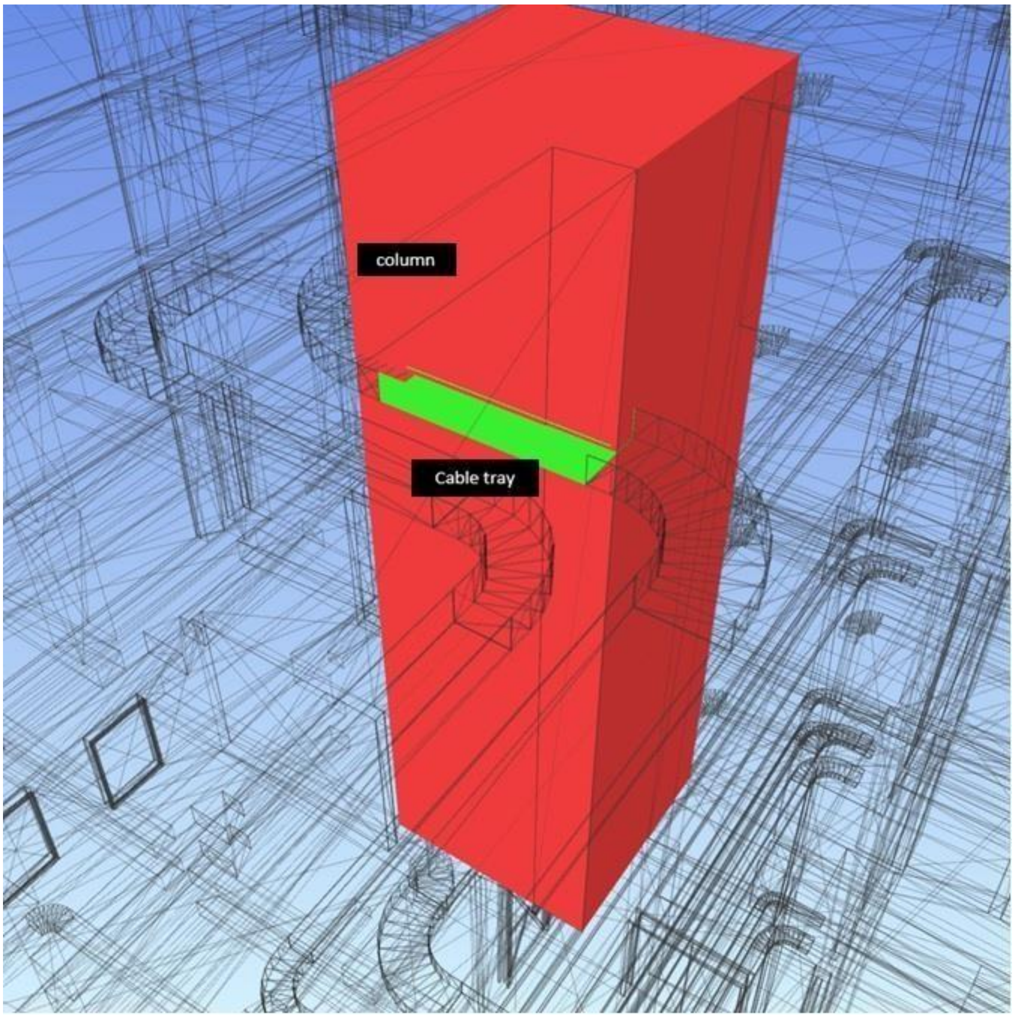

Figure 4.5 Clash between Column vs Cable tray on 3rd floor

4.1.2 Time and Cost Analysis of Clash Detection

As described earlier, the resolution of the clashes was done by change order procedure which is obviously a tedious process and might take up to a month to resolve a single clash. Following results are verified from two professional site engineers who were also involved during the construction of the whole project.

In order to find out the time taken to resolve all clashes we extracted data from Requests For Information. Requests For Information helped us in finding the total time to resolve the a particular clash of each type. This time was further divided into the phases through which a clash was resolved, which included all the stages from generation of Request For Information by the contractor to the final implementation of the change order by contractor on the site. Table 4.1 shows the estimated time to resolve all the clashes.

Table 4.1 Estimated Time to Resolve the Clashes

Nature of clash		Time taken to generate RFI by Contractor	Transfer of RFI to respective designer by consultant	Time taken by the designer to reply	Verification of clash resolution by the consultant	Issuance of change order by the consultant to the cotractor	Issue resolved by the general constactor on site	Total	Total clashes	Time to Resolve All Clashes
		(days)								
Clash between beams &	Cable trays	1	3	7	3	2	2	18	7	52
	Ducts	2	2	6	5	2	2	19	22	55
	Plumbing Pipes	1	4	7	3	4	1	20	21	39
Clash between columns &	Cable tray	2	3	4	2	2	2	15	26	43
Clash between slab &	Plumbing Pipes	3	4	2	1	2	2	14	10	40
							Total		86	229

Total time to resolve all the clashes was then estimated by taking into account the fact that the time which a clash took to resolve always varied for each clash because ofreasons like change of quantum of work, channel already formed between designer and consultant on similar clashes, designer familiarity with the type of clashes appearing, etc. From all those calculation we estimated that about **229** days were used while resolving allthe clashes.

Now coming towards the cost estimation we needed first the average time to resolve each clash which was easily calculated by dividing the number of clashes of each nature by the total time taken to resolve all these clashes. Table 4.2 shows the average time to resolve each clash.

1Table 4.2 Average Time to Resolve Each Clash

Nature of clash		Total clashes (a)	Time to Resolve All Clashes (b)	Average time taken by one clash to resolve (b/a)
		(days)		
Clash between beams &	Cable trays	7	52	7.43
	Ducts	22	55	2.50
	Plumbing Pipes	21	39	1.86
Clash between columns &	Cable tray	26	43	1.65
Clash between slab &	Plumbing Pipes	10	40	4.00
	Total	86	229	

Then we estimated material cost per clash which was as per the Bill of Quantities we acquired from contractor. After which miscellaneous cost was calculated for each clash which was 0.01% of the total project cost according to FIDIC red book clause 12.3 b (ii). This miscellaneous cost included the liquidity damages, Escalation charges, Manufacturing and supplies charges, and Labor costs etc. Total of **PKR 64489382/-** was the ultimate cost to resolve all the clashes details of which are shown in the table 4.3.

Table 4.3 Cost Estimation to Resolve All Clashes

Nature of Clash		Material Cost per Clash (PKR)	Total Clashes	Average Time to Resolve single Clash (days)	Misc. Costs (PKR)	Total Cost per Clash (PKR)	Total Cost for all Clashes (PKR)
Clash between Beams &	Cable Tray	5000	7	7.43	2080000	2085000	14595000
	Ducts	7500	22	2.50	700000	707500	15565000
	Plumbing	4000	21	1.86	520000	524000	11004000
Clash between Columns &	Cable Tray	3000	26	1.65	463077	466077	12118000
Clash between Slab &	Plumbing	738	10	4.00	1120000	1120738	11207382
						Total	64489382

4.1 Energy Analysis:

First the results obtained from the energy analysis of the DHA Business Hub, Phase 8, DHA Lahore with the BIM Software tool were presented. Following that, the building's behavior was analyzed from an energy and environmental standpoint, using the BIM software platform to investigate the many feasible improvement options for the building were also analyzed in the discussion and results section.

4.1.1 Energy Analysis Results for Change in Material and Orientation

The energy analysis of the building consisted of two scenarios, by changing material and by changing orientation of the building. These scenarios are further discussed below.

4.1.1.1 Energy End Usage with Change in Wall Construction Material

Firstly energy usage report was generated in Autodesk Revit while selecting clay brick as wall construction material which is the actual material used in the building construction and then material was changed to fly ash brick. Analytical properties of materials are discussed below in table 4.4.

Table 4.4 Analytical Properties of Wall Construction Materials

Properties	Fly Ash Brick	Clay Brick
Heat Transfer Coefficient (U)	**1.4899 W/(m^2.K)**	**2.36 W/(m^2.K)**
Thermal Resistance (R)	0.6712 m^2.K / W	0.42 m^2.K / W
Thermal Mass	18.41 BTU / (ft^2 ° F)	14.56 BTU / (ft^2 ° F)
Absorptance	0.10000	0.10000
Roughness	1	1

The results generated by Autodesk Revit for annual energy end usage for clay brick and fly ash brick as wall construction material are shown in the pie chart shown in the figure 4.6.

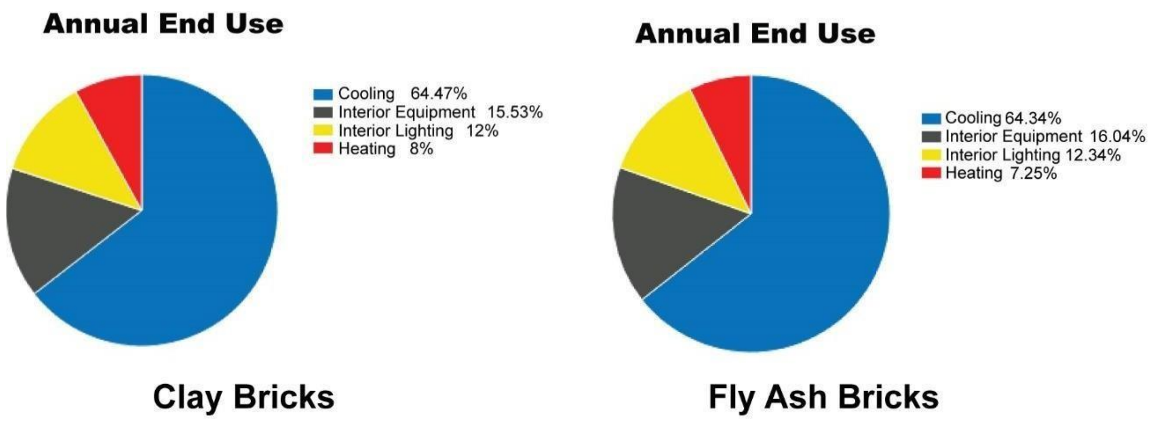

Figure 4.6 Differences between Annual Energy End Usage for clay brick and fly ash brick.

Table 4.5 Annual Energy End Usages for Clay brick and Fly ash brick

Construction Material	**Heating** (kBTU)	**Cooling** (kBTU)	**Interior Lighting** (kBTU)	**Interior Equipment** (kBTU)	**Total End Usage** (kBTU)
Clay Brick	2,019,194	16,193,444	3,000,652	3,900,847	25,114,137
Fly ash Brick	1762687	15650804	3000652	3,900,847	24314990

From table 4.5 we compared the energy end usage values for heating load, cooling load, interior lighting and interior equipment for both wall construction materials which are clay brick and fly ash brick. Table 4.6 shows the difference in all the above discussed annual energy usages by subtracting energy usages for clay brick from energy usages for fly ash brick.

Table 4.6 Comparison between Annual Energy Usages for Clay brick and Fly ash brick as Wall Construction Material

	Heating (kBTU)	**Cooling** (kBTU)	**Interior Lighting** (kBTU)	**Interior Equipment** (kBTU)	**Total End Usage** (kBTU)
Difference in Energy Usages due to Material Change	256507	542640	0	0	799147

It is clear in table 4.6 that Annual energy end usage is lesser when wall construction material is fly ash brick while it is higher when clay bricks are used as wall construction material which means it is better to use fly ash brick as wall construction material. This way we shall be able to save energy up to 799,147 kBTU, which is equal to about **234150 kWh** (799,147 x 0.293).

4.1.1.2 Energy End Usage with Change in Orientation

To analyze the energy end usage for change in orientation of building results from report created in Autodesk Revit were similarly used. The original orientation of the building is North facing which is also shown in Google Earth Image in figure 5.6. For the purpose of Energy analysis we changed the orientation of building in Autodesk Revit from North facing to South facing while keeping the construction material as clay brick for both orientations and then again run the analysis. The South facing orientation of the building in Revit is shown in figure 4.7.

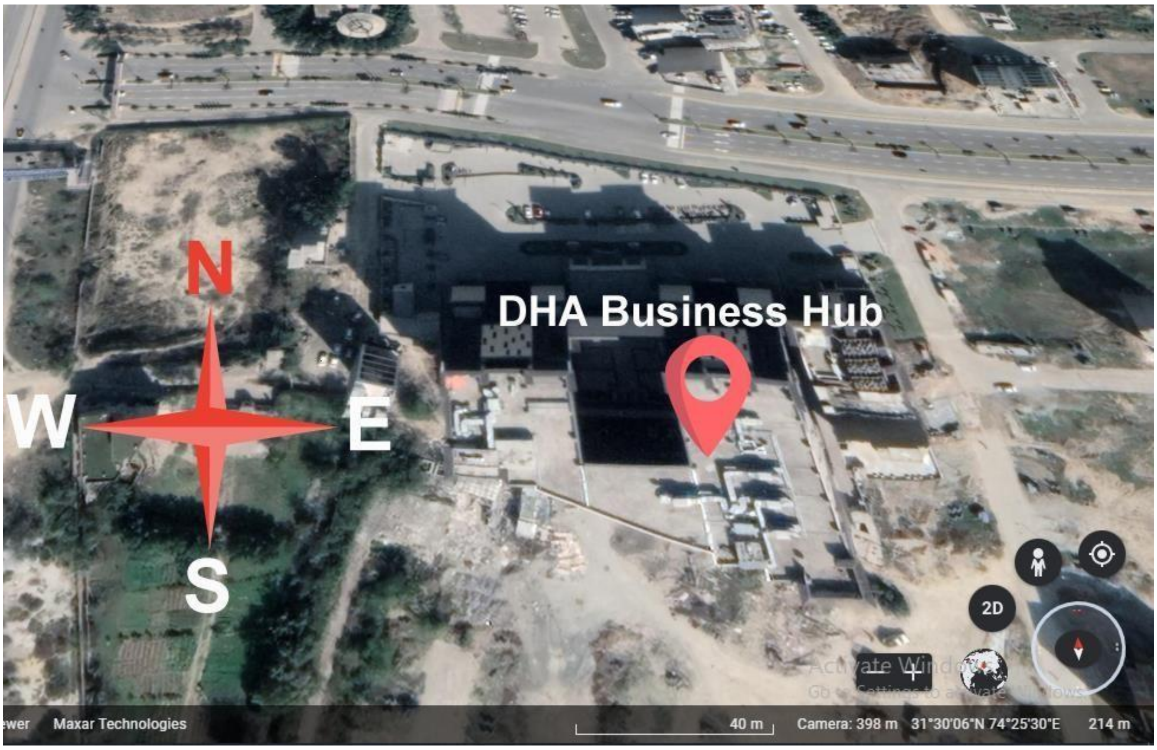

Figure 4.7 Google Earth Image of DHA Business Hub Facing North

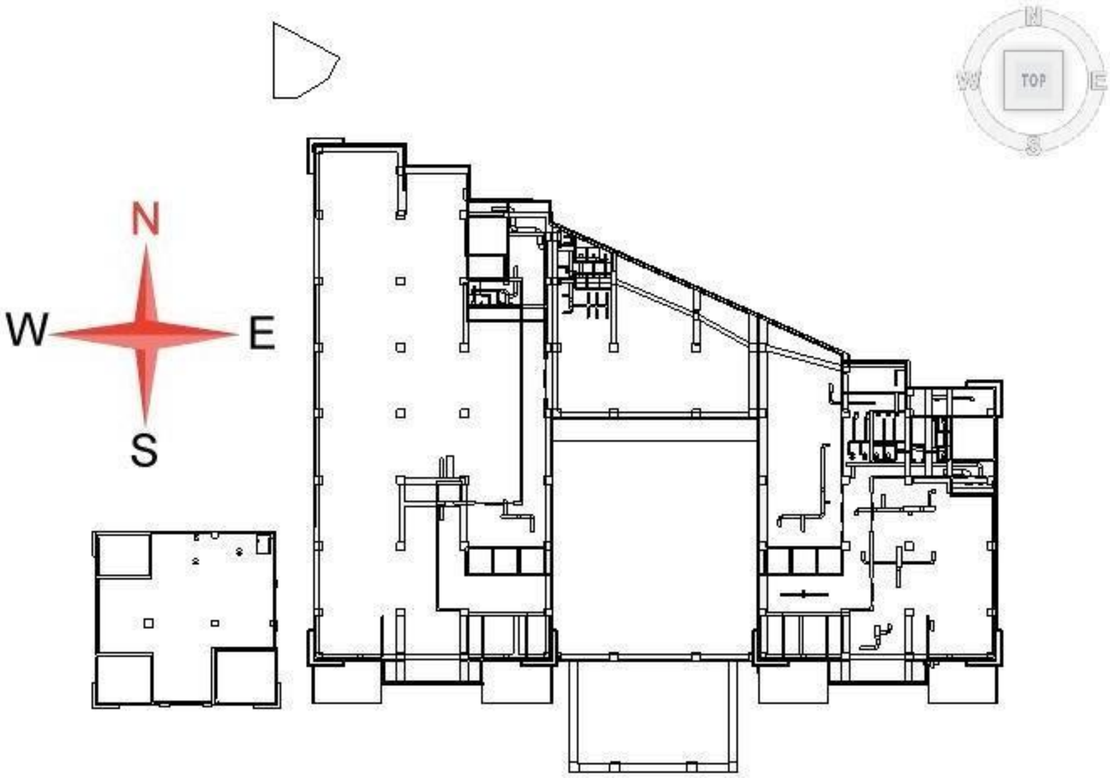

Figure 4.8 South Facing DHA Business Hub 2D View of Model in Autodesk Revit

The results obtained by changing building orientation while keeping the construction material same are shown in the table 4.7.

Table 4.7 Annual Energy End Usages for North Facing and South Facing Orientations

Orientations	**Heating** (kBTU)	**Cooling** (kBTU)	**Interior Lighting** (kBTU)	**Interior Equipment** (kBTU)	**Total End Usage** (kBTU)
North Facing	2,019,194	16,193,444	3,000,652	3,900,847	25,114,137
South Facing	2,041,509	16,255,874	3,003,075	3,900,847	25,201,305

We compared the values of heating load, cooling load, Interior lighting load and interior equipment loads obtained from table 4.7 to see the difference in above discussed energy usages because of the change in orientation of the building. The difference of energy usages is shown in table 4.8 which is obtained by subtracting energy usage values ofNorth facing orientation from South facing orientation.

Table 4.8 Comparison between Annual Energy Usages for North Facing and South Facing Orientation

	Heating (kBTU)	**Cooling** (kBTU)	**Interior Lighting** (kBTU)	**Interior Equipment** (kBTU)	**Total End Usage** (kBTU)
Difference in Energy Usages due to Orientation	-22,315	-62,430	-2423	0	-87168

From table 5.4 it can be clearly seen that north facing orientation gives relatively lesser energy usage values for all four criteria than south faced orientation. The total energy used per year would have been higher by **87,168 kBTU** which is about **25,540.224 kWh** (87,168 x 0.293), if the building was designed and constructed facing towards south.

4.2.3 Result of Energy Analysis

The amount of energy that could be saved from above scenarios is total of **234150 kWh**. According to globalpetrolprices.com in 2022 electricity price for **1 kWh** in Pakistan for business sector is PKR **27.02** as shown in the table 4.9.

Table 4.9 Electricity prices in Pakistan (globalpetrolprices.com 2022)

Pakistan electricity prices

Pakistan electricity prices	Household, kWh	Business, kWh
Pakistan Rupee	9.230	27.020
Pakistan Rupee	9.230	27.020

source: globalpetrolprices.com

Thus, total electricity cost that could have been saved using fly ash as wall construction material with same orientation is equal to **PKR 6,326,733/-** per year.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

It can be concluded that

- If the BIM was implemented in design process it would have saved considerable cost and time.
- About 229 days and PKR 64.5 Million could have been if BIM was used in the design phase of the project.
- If energy analysis is performed during the design phase then **PKR 6.3 Million** could be reduced annually.
- It help us choosing better options of building material, orientation, window glazing and building operating schedule

5.2 Recommendations

5.2.1 Clash detection recommendations

- To make the process of clash detection easy, BIM central cloud system shall be established to ensure that all the drawings are updated consistently. All the stakeholders should have access to that cloud system so that they have situation awareness.
- All the stakeholders shall be abreast of the clashes that are found, and a solution shall be generated as early as possible so as to reduce the cost and time.
- It's challenging to concentrate on taking on new tasks while dealing with inefficiencies, poor communication, missed deadlines, or other project problems. Therefore a mobile based computing should be used in applications Where you can carry out such tasks from any place, your capacity to keep up with opportunities, discuss projects with others, submit bids, keep track of deadlines, and respond to inquiries is increased.by using this system the likelihood of receiving further work increases when project information is easily available, and specifics are swiftly communicated to clients.

5.2.2 Energy Analysis Recommendations

- Actual material properties should be measured that have been used in the building and measured properties should be feed in Revit Database to get accurate results.
- H-VAC system that has been used in Revit Model should match with Actual H-VAC system. Properties such as energy efficiency, energy consumption and output should be similar of both virtual and real model. It will lead to more accurate results.
- Use sensors devices to measure real time data of the actual environment and feed into the Revit model so that virtual energy analysis is as close as real time.
- Use of the cloud system that supports informed decision-making throughout the project lifecycle for project, design, and construction teams, such as BIM 360 that connects your teams and data in real-time, empowering project members to anticipate, optimize, and manage all aspects of project performance.
- To develop a digital model where we can minimize costs and remain on time by anticipating safety risks, monitor quality proactively, automate processes, and cut back on rework.
- The project geometry of an architectural model need not to be recreated for full energy analysis. Your company can produce better-performing structures more quickly.

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