DEVELOPMENT OF 5D MODEL, ENERGY EFFICIENCY AND SUSTAINABILITY ANALYSIS USING BIM.

M. Sami Ur Rehman (G.L)	**2011-NUST-SCEE-BE-CE-73**
Husnain Arshad	**2011-NUST-SCEE-BE-CE-35**
Shumail Farooq	**2011-NUST-SCEE-BE-CE-75**
Talha Maqbool	**2011-NUST-SCEE-BE-CE-116**

A report submitted in partial fulfillment

Of

The requirements for the degree of

Bachelors of Engineering

In

Civil Engineering

NUST Institute of Civil Engineering (NICE)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences & Technology

Islamabad, Pakistan.

This is to certify that the report

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Has been accepted towards partial fulfillment

Of

The requirements for the degree of

Bachelors in Civil Engineering

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ABSTRACT

Building Information Modeling (BIM) has been a great innovation in construction industry. It has revolutionized the architecture and construction fields. Most of the world is moving towards advancement in technologies and modernization in computer techniques. This includes all the data integration that leads to reduction in work greatly. It is the method of documenting all the data of the construction project in such a manner that it integrates all the departments. As a result the handling of data has become very effective. In the construction industry the two main stakeholders the contractor and the client are in search of these things. The contractor wants the project time to be reduced and the owner wants to spend as less as possible. Along with it certain models are prepared prior to the execution of the project during the planning phase, which give detailed visualizations of the project that given that at the very start of the project all the stakeholders are having a very good idea of what the end product would be.

The report opens with a detailed introduction about BIM; its different dimensions, advantages, limitations along with the detailed description of subject matter. It proceeds with a literature review of BIM by different surveys. The literature review explains the benefits and barriers which are hindering BIM's implementation. The results of surveys are being discussed. The research will lead towards the use of BIM in the local industries. The importance, barriers and problems regarding implementation of BIM.

A case study is done of whose methodology is described in detail, which comprises of designing of a 5D project and completing all its details i.e., from plans up to its 3D modeling, which is visualization of project, cost estimation, time taken to make complete end product. Energy efficiency and sustainability analysis are the major areas of application in regard to our project.

DEDICATION

We would like to dedicate our work to our parents. It is because of only them, we have come this far. They have always been there for us. Whenever we needed their help of any time, they never denied us. They are the ones due to which we have fulfilled our dreams of becoming an engineer.

ACKNOWLEDGEMENT

Carrying out a project requires hard work and sheer determination. But it is never possible without the help and guidance. First and foremost, all thanks to ALLAH ALMIGHTY without even the slightest change in this world cannot happen.

A special thanks to our university NUST, and our department NICE. Without their assistance and dedicated involvement in every step throughout the process, this project would have never been accomplished.

Apart from the efforts, the success of any project depends largely on the encouragement and guidelines of many others. We would like to take this opportunity to express our gratitude to the people who have been instrumental in the successful completion of this project. We would like to show our greatest appreciation to Prof. M. Jamaluddin Thaheem. We can't say thank you enough for his tremendous support and help. We feel motivated and encouraged every time we attend his meeting. Without his encouragement and guidance this project would not have materialized.

The guidance and support received from all the members who contributed and who are contributing to this project, was vital for the project. We are grateful for their constant support and help.

And last but most importantly, we all like to pay gratitude to our PARENTS who have been supporting us throughout our life and are still supporting us in performing the project.

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LIST OF ACRONYMS

AEC	**Architecture, Engineering and Construction**
BIM	**Building Information Modeling**
UK	**United Kingdom**
CAD	**Computer aided design**
CIFE	**Centre for Integrated Facility Management**
GBXML	**Green Building eXtensible Markup Language**
HVAC	**Heating, ventilation and air conditioning**
LAN	**Local Area Network**
LOD	**Level of Detail**
NUST	**National University of Sciences and Technology**
PMO	**Project Management Office**
MEP	**Mechanical, Electrical and Plumbing**
RFI	**Request for information**
ROI	**Return on Investment**
UTF	**Unicode Transformation Format**

Chapter 1

INTRODUCTION

The world is continuously changing. Everything in the world requires change and innovation for better performance. Construction industry has been also gone through different phases of modifications which added to the better working of professionals. This field is quite vast and taking a step to modify which can show the final results of construction will be a great help. In past, it was very difficult to predict accurately about the success and other scenarios of the project. The time when advancement of computer started, 2 Dimensional Computer Aided Design (2D CAD) was adopted as an innovative drawing tool in the AEC industry. After 1945, American martial technology was being used in the civil department. Ivan Sutherland introduced SKETCHPAD that became the foundation of CAD. In its early periods the concept of CAD was not being used on a large scale. However, with the passage of time, personal computers were made available to every person in their home. This changed things drastically. A company named AUTODESK developed AUTOCAD which was then being used by most of the architects of the world. [3]

First AUTOCAD was only used for 2D modeling. Then with some research in the particular field, it developed into 3D. This wholly changed the relationship between the architect and the civil engineer. People started moving towards more innovations and started thinking about adding more things that can add to the visualization of projects. People can now see more details and can see the outcome of their project with greater predictability.

But still the construction industry has not developed as much as other technological fields. There are limitations, which hinders the collaboration between people working on the field and people in office. This problem is taken into account in past decade. New innovative measures are introduced in the construction line .BIM is

one of its kind.
The National Building Information Model Standard Project Committee has the following definition:

"Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition."(Wikipedia)

Collecting the information from different sources used to visualize the virtual BIM model, all the participants involved in the project can visualize the processes of designing and analyzing the projects. With the addition of 3rd dimension to the traditional two dimensions helped stake holders in avoiding the clashes between different works way before the project was made. Beyond 3D BIM adds intelligence to the model by making information about each element available to the users.

1.1 Objectives:

- Integration of construction processes of client requirements, designs, construction and operation using tools of BIM.
- Develop a 5D model of the construction, which includes the 3D visualization of the project, the cost estimation, scheduling and simulation.
- Applying BIM, focusing on aspects of Energy efficiency and Sustainability.
- Suggesting alternatives based on analysis of sustainability factors and energy consumption.

1.2 Reason for BIM as selection for Research Area:

BIM is the latest technique introduced in construction industry. As a professional involved in construction industry, one must know about the latest techniques and modern innovations beings used in his field. BIM is being adopted in construction industry in developed industries; even UK is going to make it compulsory to use BIM in every project by 2016. So, one going to construction industry must have adequate information about the newest practices and learn to

use them. Using BIM in local industry can cause revolution in construction industry as people are worried about their money and design of project. BIM offers them the best solution with its vast area of application that leads to even 7D. By different studies in different projects by professionals it has been seen that BIM has a great hand in reducing costs of the project. One should be familiar with it as it can benefit the people whose stakes are involved. Hence, by looking at its exponential growth, we decided to select BIM as research area.

1.3 Application Area:

The inculcation of data which is being used in making BIM model, this can be utilized for other different other important processes like costing, procurement, sustainability, safety, off-site or modular construction, owner space management and tracking, mission critical, operations and maintenance and disaster planning to name but a few.

Ultimately, however, BIM is basically about integrating data all together from different sources, it is about how the knowledge and wisdom of people can be brought together into a collaborative process and about different stake holders and professionals involved to deliver a fully integrated project that meets all goals and objectives aspired to in from the beginning. [6]

IF BIM is being implied as planned, it can create revolution in construction industry in its operation, function, look and its workability.

Chapter 2

LITERATURE REVIEW

Currently, the AEC industry is going through the iterative phase. Changes are taking place. But still the AEC industry is fragmented in case of delivery of project. The timely exchange of information plays a vital role in success of construction projects. Methods have evolved to reduce the delays in time like 3D CAD tools, project Web sites etc. But these methods are not enough. Due to a lot of people and operations involved, it's very difficult to predict the real time in which it is said that construction activities will be completed.

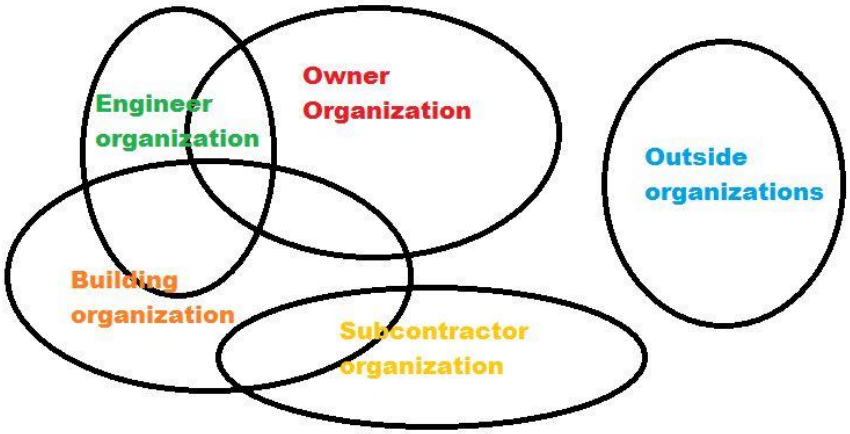


Figure 2-1 Boundaries of Work of Stake Holders

Projects ranging up to 10 million $ or more, have mostly same type of statistics. The following data is a study compiled by Maged Abdlesayed of Tardif, Murray & Associates, a construction company located in Qubec, Canada. This shows, how

large number of people and documents are difficult to manage:

Table 2-1 Comparison of Construction documents bulk

Items	**Quantity**
Companies	420
Individuals	850
Documents generated	50
Bank boxes to hold documents	25
4-Drawer filling cabinets	6
Number of pages	56000

Now, the technology required to hold the equivalent data:

Table 2-2 Comparison of Construction documents bulk

Items	**Quantity**
Gigabytes of electronic data to hold this volume of paper	3 GB
Number of compact disc	6

In the 21st century, most of the evolution in industry has been achieved through advancement in computer science. The basic objective of evolution is to make people attain their goals easily. This technical evolution has also shown its colors in the Engineering, Architecture and Construction (AEC) Industry. In the past decade of the AEC industry, design tools have been improved from two dimension modeling to 3D modeling. Now a days, some software companies such as that they produce new design software based on the concept of Building Information Modeling (BIM) like AUTODESK which has introduced REVIT.

Companies which includes design firms, contractors, project planners, operators and maintenance agencies used current BIM software to handle diverse mega projects from wastewater plants, electricity, water, gas and communication utilities to bridges and ports, roads from houses, apartments, schools and shops to factories, offices, warehouses and prisons, etc.

2.1 CAD Systems:

Although building information modeling is a complete methodology of project delivery and not a technology, it does require suitable technology to be implemented effectively. Some examples are given in increasing order of effectiveness below:

- **CAD**
- **Object CAD**
- **Parametric building modeling**

2.1.1 CAD Technology:

Drafting can be done using this technology very effectively in fact better than any other technology because of the low effort required for it. However greater effort is required if higher efficiencies are to be achieved resulting in higher administrative and management costs. Skill of the professionals handling data input defines the standard being maintained in drafting, layers naming etc. Effectiveness in the building information modeling range can be achieved using CAD but the level of effort required is so high that it is rarely practiced at this level. Autodesk® AutoCAD can be referred as an example of CAD technology software.

2.1.2 Object CAD Technology:

Object CAD simulates building components in a CAD-based environment, envisaging both 3D and 2D geometry and extraction of data from them to evaluate quantities and costs. Coordination of various representations of the project data can be done effectively using this technology and can be extended into building information modeling. However its effectiveness is dependent on user skill level. Object CAD cannot ensure the achievement of high quality data coordination for the highest levels of building information modeling efficiency. Example includes Autodesk® Architectural Desktop and Autodesk® Building Systems software. [7]

2.1.3 Parametric Building Modeling Technology:

Parametric building modeling technology is equivalent to the assessment support systems adopted in the commercial industry. These systems combine a data model which includes geometry and data with a behavioral model like change

management that gives meaning to the data through relationships. The outcome of this activity can simulate the behavior of a real life project or system, a building in our case. Some important features of software based on parametric building modeling technology include:

• An integrated database is generated including all the Information about the building project

Which is parametric and therefore completely interrelated.

• Any change to the relationships among objects is seen to show its effect on the other representations of the project data.

• User can define all relationships in a plan which not only includes the relationships that have been preprogrammed by the developers but also the parametric objects.

Parametric building modeling can offer remarkable benefits but in order to reap these benefits a shift from traditional ways of project delivery to the new way of working of parametric modeling achieving the building information modeling efficiency is required. Autodesk® Revit can be cited as an example of software which use this technology. (Autodesk 2003)

2.2 Dimensions of BIM:

2.2.1 3D Modeling:

The central contrast in between BIM and customary 3D CAD software is that the CAD software depicts a building by 3D perspectives, for example, elevations, areas and several other features by dimensions only. If we make changes to any one of the specifications or views then we have to check each and every other perspective and we must redesign accordingly. This process is the main reason behind the poor and faulty documentation of such mega projects. What's more, information in these 3D drawings are graphical substances just, for example, lines, curves and circles, rather than the canny context oriented semantic of BIM models, where articles are characterized as far as building components and frameworks, for example, spaces, dividers, shafts and segments. A building data model conveys all data identified with the building, including its physical and

utilitarian qualities and task life cycle data, in a progression of "brilliant items". Case in point, a cooling unit inside of a BIM would likewise contain information about its supplier, operation and upkeep systems, stream rates and leeway necessities.

BIM models are created, to scale, in 3D space; every single real framework can be outwardly checked for obstructions. This procedure can affirm that funneling does not cover with steel shafts, conduits or dividers. After every single building framework are made in 3D and joined into BIM, these frameworks are then combined. All utensils, apparatuses, furniture's, channels, conductors, basic individuals, link plate and other building hardware are checked through "conflict recognition" devices to figure out and resolve conflicts before frameworks are built in the building. Some early cases have demonstrated an 80% diminishing in field-related inquiries and conflicts because of this precise utilization of BIM. All mechanical, electrical, pipes, fire insurance, basic, and compositional frameworks are incorporated before they are made-up and fitted in field. Frameworks Coordination Teamwork of the development group with the modeler, engineer and the proprietor is favored to be begun on right on time phases of configuration stage. Around then, the Building Information Modeling should specifically be actualized. On the off chance that the draftsman is just giving 2D drawings, then the development administrator ought to make an interpretation of the 2D drawings to 3D canny models. At the point when the claim to fame builders, especially the MEP foremen and the steel fabricators are concerned, they have to spatially coordinate their work. The 3D coordination can be begun directly after the model is made to verify that any same space impedance (hard conflict) or freedom conflict (delicate conflict) clashes are determined. All in all, the coordination endeavors of development supervisor and claim to fame builders ahead of time of development help to diminishing configuration blunders immensely and to better see early the work to be finished.

2.2.2 4D Scheduling and Sequencing:

In this technique a parameter is relegated to a BIM article called phase. A BIM item may be appointed existing and new development phase for remodel undertakings, pulverized phase for provisional development as a parameter accordingly grouping diverse BIM articles as indicated by the phase allocated to them. The fundamental course of events of a venture can likewise be characterized amid outlining which obliges an inherent booking device in outline programming. In Autodesk Revit Architecture™, under the venture phase's tab the aforementioned phases or essential course of events can be characterized and relegated to the BIM objects which creates a breakdown of task phases once the model is finished. Channels can likewise be connected, under the phase channel tab which will just demonstrate the items connected with the sifted phase(s). This technique is however utilized for essential task staging since date and time are not relegated to the said phases. For more exact planning, schedules produced by devices, for example, primavera are consolidated into the model.

In a major venture there are a large number of diverse exercises that are joined with one another in distinctive ways. As the quantity of exercises build the comprehension of the development phase time arrangement will diminish. This thus can lead complexities to see which crash a certain work assignment has on the undertaking. At the point when utilizing BIM it is very helpful in developing the BIM model. Using BIM based software you have proper directions while modelling a building. You cannot perform a certain task before e.g. you can't cast concrete before building formwork and introduced the fortification. The data in the 4-D model can be envisioned in a basic and instinctive way. This thus will build the comprehension of the development phase time arrangement and which affects a deviation from the time arrangement will bring about on the task. The 4-D show likewise has advantages with regards to:

- Communication, the planer can with the guide of the model picture distinctive phases in the execution. This can be passed on to the

development site work 23 groups additionally to different partners in the undertaking. It will likewise be prone to utilize the model to picture how a troublesome action should be built.

- Multiple partners, the model can be utilized to help the correspondence between the venture group and laypersons e.g. what sway the execution will have on the entrance to distinctive key establishments.

- Site logistics, the 4-D model can be utilized to consolidate provisional development segments. E.g. set down regions, lodging streets or spots were to store vast types of gear as a screen.

- Trade coordination, a 4-D model may comprehend data about expected time and space stream of exchanges on the development site.
- Analyze the working progress, by using an up-dated 4-D model the planer can simply check whether the execution of the project is running on schedule or behind (Andreas Winberg and Erik 2010)

2.2.3 5D Cost Estimation:

Choice making in any venture is exclusively reliant upon expense and natural effects. Both of these components oblige amounts of the material being utilized as a part of the undertaking. Considering the dynamic nature of such development ventures, precise amounts will be obliged in an opportune way. Customarily, estimators utilized the 2D attracting sheets to perform the amount portrayed the difficulties of this technique as takes after. For expansive ventures, manual departure can be an exceptionally lengthy and dreary undertaking. An estimator must utilize an all-around composed efficient system for departure to abstain from missing or twofold including things. An estimator must additionally take exceptional care when exchanging estimations to their record by checking

that each estimation will be recorded effectively. Furthermore, the record must be sorted out in a manner that when changes happen or estimations must be checked the estimator can undoubtedly audit the estimations performed.

Utilizing BIM innovation amount departures can be produced straightforwardly from the model. The most compelling thing about this procedure is that the data stays steady all through the venture and the changes can be suited effectively.

BIM software(s) have assembled in expense evaluating elements. Material amounts are separated consequently and changed when any progressions are entered in the model. A BIM model can likewise be specifically connected to an estimation program, i.e. a guide programming/ program for the BIM demonstrating program that is portrayed on estimation undertakings. By utilizing this sort of project the planers will have the capacity to relate the developments parts and its gathering with the assets that is needed for execution, e.g. a cast of a particular solid section obliges three gifted laborers, a solid truck with its convenience street, eight square meters of formwork, quality keep an eye on solid etcetera. By utilizing this instrument the planer will have the capacity to assess diverse development set-ups. This thus opens up the likelihood to upgrade the creation stage, e.g. through collect sufficient size of a work group, co-working material stream or arranging the work so the substantial hardware, for example, wheel loaders, will be used however much as could reasonably be expected.) Use of expense evaluating in BIM, The two principle basics of an expense estimate are amount take-off and estimating. Amounts from a Building Information Model can be sent out to an expense database or an exceed expectations document. On the other hand, estimating can't be removed from the model. Expense assessing needs the expertise of the expense estimator to look at the segments of a material and how they get introduced. In the event that the evaluating for a certain movement is not possible in the database, cost estimator may require an extra breakdown of the component for more precise estimating. For example, if a cement pour movement is occurring, the model may report for the level of point of interest for the rebar, wire lattice, pour stop,

formwork, concrete and so forth., however exclude it as a feature of the amount take-off extraction. Cost estimator may require this level of subtle element from the model to make sense of the unit value which embody the unit material expense, unit work cost, overhead and benefit. The unit work expense is driven by the assembly and execution spans, and the work pay while the unit material expense is the measure of the material expenses utilized for the action per unit. Once the unit cost is come to, the expense of the entire action can be accomplished by duplication of the aggregate amount separated from BIM and unit cost. In Building Information Model, the information yield is as exact as the information info. It is significantly vital to have the foreman and the planner to concede to part definitions. For example, if a draftsman is demonstrating solid piece to demonstrate the rooftop for displaying goals, the rooftop amount data won't be precisely represented amount extraction purposes in the model. As a rule, the BIM skill is an extraordinary instrument to enhance the proficiency of the estimators through amount extraction from the model especially if the development and outline collaboration collectively.

2.2.4 6D Energy Analysis:

The world is trying to fight with a situation of climate change effects, trying to reduce the carbon contents and using energy efficient technology to improve our atmosphere. Recent studies show that buildings are biggest source of harmful emissions and inefficient energy systems. At the same time, these buildings possess the potential of minimizing the greenhouse effect to a great extent. Such as a process named as retrofitting can help a lot in reducing the unwanted emissions in an effective way. With this change in progress, every nation is trying to work on its problems. Meanwhile engineering personals can be leading the way to improve the inefficiency in these buildings. Energy consumption can be reduced to a level where it will not harm the environment.

A lot of building stock is present in the current world. United States only contributes 76.9 billion square feet of building material. Whereas, China have a building area covered up to 44 billion square feet. Planning and working on

controlling the energy emissions from these buildings can contribute to energy efficiency greatly.

BIM is accepted to be a basic component in decreasing wasted energy and natural harm. BIM makes the energy analysis simpler and more straightforward and obliges minimal manual work. Utilizing BIM as a part of the outline process, energy analysis is done is different phases of the configuration process with expanding level of subtle element accessible for the most recent energy analysis. Reenactment is less expensive than building a non-energy proficient building. The BIM instruments foresee building energy use and propose plan choices which will make the building more energy effective.

With BIM, a significant part of the information alluring for supporting execution analysis is caught actually as configuration on the undertaking continues. By utilizing a building data model, planners can investigate how a building will perform, even in the early phases of configuration and outfitted with this data, they can rapidly survey outline options and settle on enhanced choices to emphasize on a green configuration. By improving the outline and analysis capacities, BIM helps the important counts needed to improve building execution. BIM and its reliance on a computerized building model excuses the outline and analysis capacities, letting planners to rapidly assess plan choices and settle on better choices to emphasize on a greener configuration. It is found that the greater part of experts who are actualizing BIM-based sustainability investigations are basically designers and foremen. The investigations sorts with the most well-known utilization are energy analysis, charming, introduction analysis, sun powered analysis, building, massing analysis and site analysis. The majority of these experts acknowledged some to-huge time and expenses reserve funds when contrasted with the customary routines. The product sorts which appear to have the most widely recognized utilization are Autodesk Ecotect, Virtual Environment (VE)^{TM} Autodesk Green Building Studio (GBS)^{TM}, and Integrated Environmental Solutions (IES).

2.2.5 7D Operations and Maintenance:

Facilities management divisions can likewise utilize BIM for remodels, repairs, rebuilding efforts, space arranging, and operations upkeep. Managers can give a record Building Information Model to the proprietor after the finish of a task. The model contains the consolidation of the as-assembled drawings from the subcontractors. Furthermore, every item property in the model can likewise make note of connections to submittals, operations and support, and guarantee data. Brought together programming database can help the facilities management division to discover data less demanding. Record model can be utilized for security management and wellbeing data, for example, crisis lighting, crisis force, departure, fire quenchers, flame alert, smoke identifier and sprinkler frameworks. The interoperability of the record model with different programming could possibly be a test. Furthermore, the proprietor needs to be willing to apportion spending plan to prepare representatives, redesign and keep up the record Building Information Model. Besides, the office management group can dissect vitality effectiveness of a for all intents and purposes/ digitally fabricated model. Notwithstanding that, facilities management group can arrange with record model to keep up, track and redesign structures by utilizing spatial (3D) data, for example, furniture, hardware, and MEP (mechanical, electrical, and plumbing) associations. At last, the facilities management office can utilize the model to create cost and timetable effects for support and remodel ventures. Generally speaking, a record model can be utilized for improvement of time, expense and quality for office management and upkeep. As the advantages of the record model are perceived, the proprietors will be all the more requesting of the record BIM Model. An exact record show that contains the extent of the task and the needs of the facilities management division can help the proprietor oversee and keep up the building hugely. This can leave a dependable positive impression of the undertaking director to the proprietor of the task.

2.3 Uses of BIM:

2.3.1 Visualization

In-house 3D renderings can be easily generated with little additional effort.

2.3.2 Fabrication/Shop Drawings

Shop drawings can be easily generated for various building systems, e.g. once the model is complete the sheet metal ductwork shop drawing can be produced quickly.

2.3.3 Code Reviews

For building projects review fire extinguishers and other officials may use these models.

2.3.4 Forensic Analysis

To show graphically the potential failures, leaks, evacuation plans, etc. a building information model can be used.

2.3.5 Facilities Management

BIM can be used by facilities management departments for remodeling, planning of space, and operations of maintenance.

2.3.6 Cost Estimating

BIM software(s) have built-in cost estimating features. Material quantities can be easily extracted and changes when any alterations are made in the model.

2.3.7 Construction Sequencing

To create material ordering, fabrication, and delivery schedules for all building components a building information model can be used effectively.

2.3.8 Conflict and Collision Detection

BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences.

Summarized form of uses of BIM is shown in following table:

Table 2-3 Uses of BIM [9]

PLAN	DESIGN	CONSTRUCT	OPERATE
Existing Conditions Modeling			
Cost Estimation			
Phase Planning			
Programming			
Site Analysis			
	Design Authoring		
	Design Reviews		
	Mechanical Analysis		
	Structural Analysis		
	LEED Evaluation		
	Other Eng. Analysis		
	Code Validation		
		3D Coordination	
		Construction System Design	
		Site Utilization Planning	
		3D Control and Planning	
		Digital Fabrication	
			Building System Analysis
			Asset Management
			Record Model
			Maintenance Scheduling
			Disaster Planning
			Space Mgmt./Tracking

2.4 BIM for Different Stakeholders:

2.4.1 BIM for Owners:

Owners can feel a lot of advantages by projects using BIM processes and tools to deliver better performing and energy efficient buildings. As we know, BIM facilitates integration of different project participants, removing errors and generating a more efficient result. BIM can contribute a lot in areas where information is needed to be provided to owner, which would create a more desirable and environment friendly project. Currently, following benefits are available and recognized by owners:

2.4.1.1 Reduction of Financial Risk:

Improved collaboration of project team results in better cost estimates at earlier stages, empowering the owner to decide about his construction project. Reliable results on which owner can trust are obtained through BIM.

2.4.1.2 Reliable Cost Estimates:

Quantity Takeoff of the building model, gives decision a great impact. Automatic Quantity Takeoff results in timely feedback by the owner. Giving engineer the confidence to go for the reliable estimates and avoid conflicts at the end.

2.4.1.3 Facility Management and Maintenance:

Properly organized information about all the systems in the building, which are used in life cycle analysis of the facility. Exporting as built and equipment information to all the stakeholders.

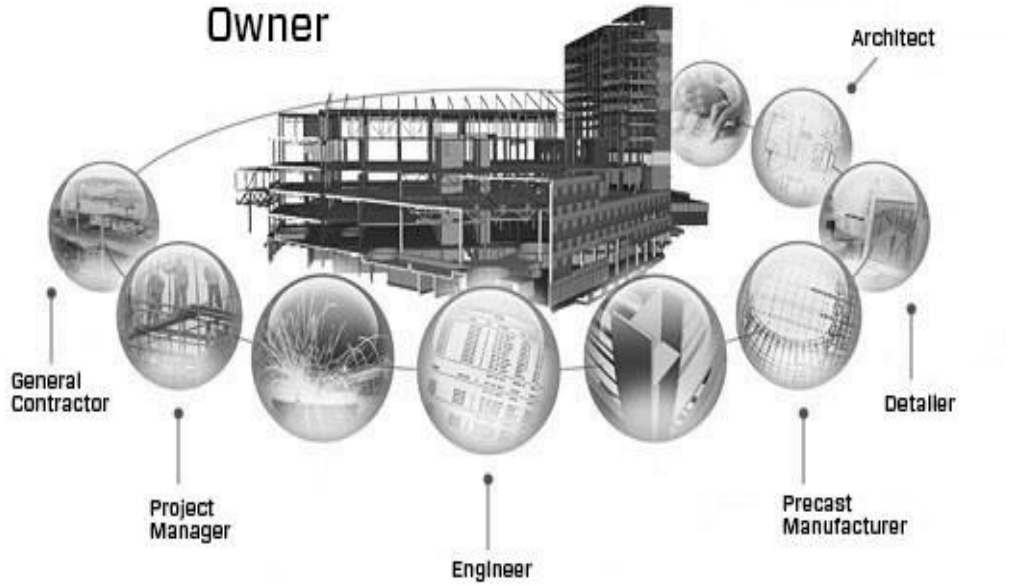
2.4.1.4 Better building performance:

BIM based energy systems and other systems, building performance is enhanced to a great extent.

2.4.1.5 Proficient Project Schedule:

BIM allows pre-scheduling and coordination of models and people to reduce labor time. Better coordination of on field and off field personals to meet the time constraint.

Figure 2-2 Owner's Relationship with the Project and other Stakeholders



2.4.2 BIM for Architects:

The value of BIM is well recognized by the architects in decision based perspectives. Using less time to work out their designs, productivity of architects can be greatly enhanced, which is actually the basic concern of other stake holders involved in the project. Taking these concerns out of the question, BIM also adds new dimensions to add to creative designs and details of study and communication. BIM as renowned for design purposes, got its early reputation in regard of that. But architects actually see an opportunity to get more communicated with other stake holders through a new design commodity. Efficiency is one of major benefits as architects presume it to be. Talking about benefits, the top regarded benefit of architects is the improved integrated design and coordination of documents and drawings via BIM. This can be highly regarded by architects as it lets them to be more innovative in their approach rather than being dull minded by documentation bulk. The work done by architects once handed to next team member of construction project, architects started recognizing that by using BIM they can

reduce their work load and save their time as less time is wasted in error reduction and ROI's that is required by the next member to work out the schedule.

The quality to decreasing time and hence improving productivity of people by using BIM is being top ranked by the architects to improve the request for information with use of this tool. Almost three by four of architects have reported this feature to be the most important one than other stakeholders i.e., contractors and owners. The job of an architect is to convince their customers and work on their demands to create an idea and work on it. BIM allows them to do their job with most ease. Visualization of architectural design and their presentation to their customers are the most important benefits for architects achieved through BIM. Users of BIM can create models of expanded levels of detail, but the three dimension part of this technology is still a very important and key factor which adds value for architects.

Architects say:

■ Communication among different parties involved in the project has been greatly improved and 3D visualization has been never this much detailed and data rich, which firms see as best ROI resolving benefit of BIM. 79% of the architects in the construction industry rate it as highly important.

■ Improvement in the collective understanding of the construction project by all team members in the design phase is the best way BIM adds value to it. More than two third of architects rank it as very important. [1]

2.4.3 BIM for Contractors:

Contractors are the ones who perform the actual job on the ground after the design phase. And recently contractors have reported a lot of admirable and dramatic benefits of BIM for them. Most of the finances are being utilized in the construction phase, actual savings of time and money can be experienced in the field. Contractors face a lot of clashes, scheduling and sequencing issues. The pre-planning of these problem causing factors can save a lot of time and budget. Change

is bad—at least during construction. The piled up change orders during construction greatly affects the budgets and schedules. So, contractors eye up this benefit that BIM can assist in reducing the errors before they lead to amendments in constructed works on the field. Clash detection is one of the product of BIM, which has proven its utility between contractors and subcontractors communication. It has been highly efficient. According to contractors, reduction in conflicts and avoiding change orders are the top ways through which we can be efficient in time and financially stable. [1]

Avoiding conflicts in the construction field is regarded as the best method to achieve profits from BIM, as reported by contractors. More than 80% of the contractors agree with this idea. Contractors feel that spatial communication between building members shows the most value of BIM. More than 78% rated this at a high level of significance for contractors. BIM design brings more detail along with simplicity to a complex project. From the fact that coordination and better communication increases value, contractors tend to see more significance as the level of complexity in a construction project increases. Scheduling is one of the basic issues for contractors. If they have confidence over designed systems with clashes resolved, they can ease out their schedules. Contractors rate "Project complexity" as the top rated factor affecting the progress of a project for contractors in construction phase.

Seven in ten of the contractors graded this as highly main factor influencing the construction phase. Contractors want their complex parts to be pre-planned more accurately, which will be expected from BIM by them in the near future. In coming five years, contractors (78%) are expecting prefabrication to add value. However numerous contractors utilizing BIM see enormous advantages, functioning as a group can be a test. As soon as contractors who realize significant savings can be done through BIM will start using it, regardless of taking into account others can use BIM or not. An integrated environment is the best place where BIM can be effectively used. Hence these issues need to be resolved. According to the major majority of contractors (82%) say that better multi party

communication and understanding from 3D visualization are top ways that BIM add significance to its value. Improving interoperability between software applications is the top way that contractors say they could increase the business value of BIM. Eight in ten contractors (78%) ranked it as highly important. [2]

2.5 Benefits of BIM:

BIM covers a vast area. Its advantages are numerous. It has certain limitations as well. But with time, it is being improved for better project delivery. BIM offers a lot assistance to AEC industry. Here, we will restrain ourselves to those aspects which we will adhere the benefits performed through our project.

2.5.1 Better visualization of project:

BIM develops 3D model directly, rather than many 2D views. Hence, it is very effective in being consistent in every view. It can be analyzed at any stage of the project providing accuracy.

2.5.2 2D Drawings of any section of the design:

2D drawings are generated any time required. This removes a lot of errors as it can create these 2D drawings for every design aspect. Comparing these drawings with specification removes a lot of ambiguity.

2.5.3 Cost Estimation:

Cost estimation with is more clear and accurate. Like 2D drawings, cost can be extracted at any stage of the design phase or building phase. The benefit with BIM is that every stake holder involved in the project is kept update about the cost implications related to the project.

2.5.4 Emission of errors prior to construction:

A construction project is a vast project. Different field personals are working in collaboration to complete a project. BIM provides models for all disciplines in time, which can be analyzed and compared to check their consistency. Conflicting points and other problems are easily detected prior to construction and removed.

2.5.5 Energy Analysis:

BIM provides energy analysis over 3D design of the project. It can be carried out more accurately with a 3D design rather than 2D. Changes can be suggested in the early phase. However, carrying out the same work with 2D views takes a lot of time, and is performed at the end which is only a formality.

2.5.6 Sustainability:

BIM offers better sustainability options. Various types of analysis tools help generate better alternatives regarding sustainability. It gives a lot of options for choosing different types of results after analysis. These tools create a better and efficient building which is environment friendly and sustainable.

2.6 BIM Tools:

BIM has become a widely used application. People in AEC industry and even other industries are working on it. Different software developers, looking at the use of BIM are putting their input to BIM. A lot of tools have been developed and more are lined up in the queue, adding to the efficiency of BIM phenomenon. A summary of BIM tools of different organizations are shown in following table:

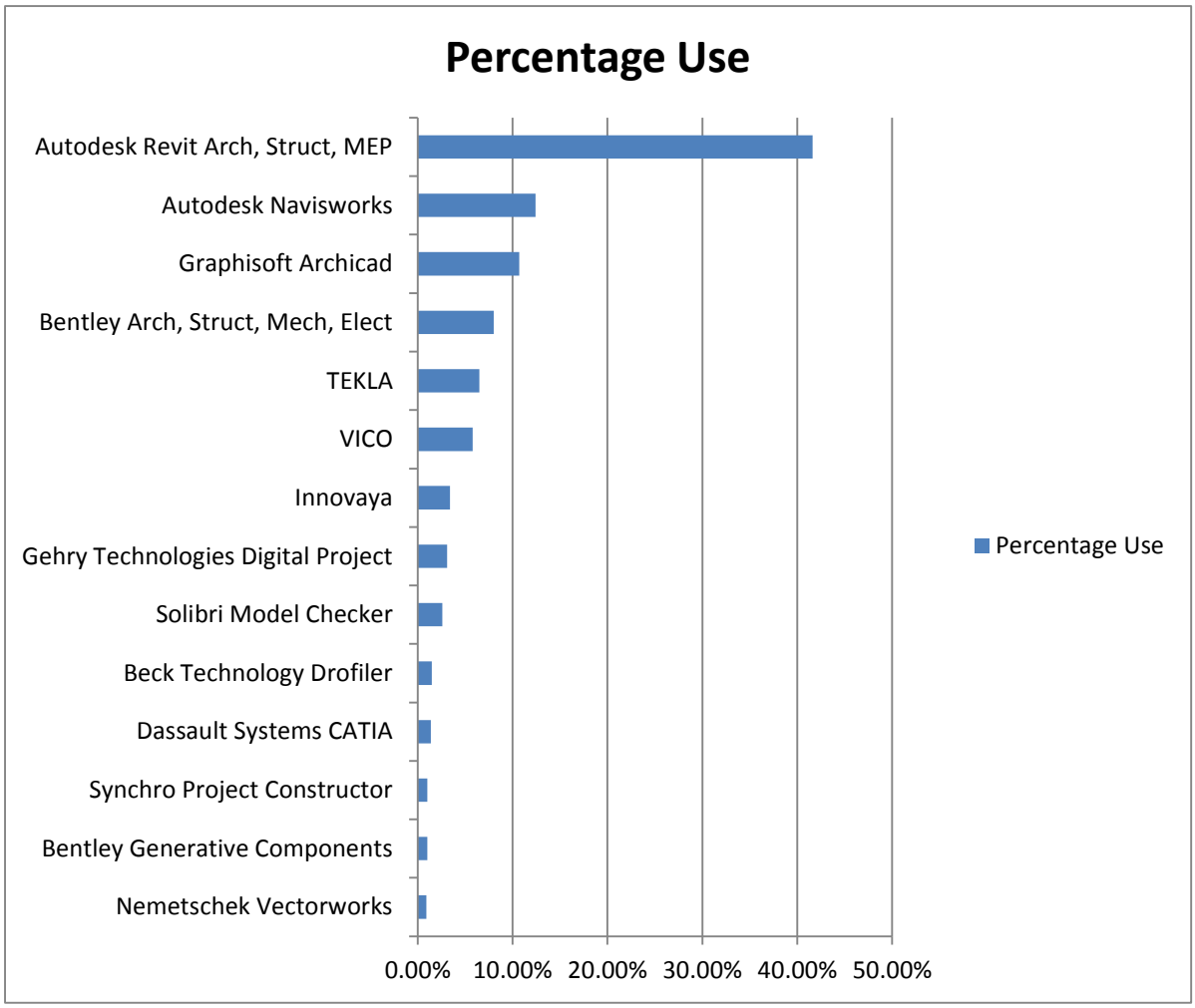
Table 2-4 Products of BIM by different vendors

Company	Software	Use
Autodesk	Revit	BIM Modeling
	Naviswork	Clash Detection
	Quantity Takeoff	Quantity Takeoff
Graphisoft	ArchiCAD	BIM Modeling
	Estimator	Estimation
Bentley	Bentley Architecture	BIM Modeling
	Project Wise Navigator	Analysis tool
Tekla	Tekla Structures	Structural Modeling and Detailing

Vico	Vico Control	Scheduling from resource, cost, location based BIM
	Takeoff Manager	Quantity Takeoff
Synchro	Synchro Professional	Scheduling application (Primavera or MS Project)
Innovaya	Visual 4D Simulation	3D Modeling joined with Scheduling applications
	Visual Estimating	Estimation
	Visual Quantity Takeoff	Quantity Takeoff
U.S. Cost	Success Estimator	Estimation
On Center	On Center	Quantity Takeoff
Exactal	Exactal	Quantity Takeoff

A survey conducted by Burcin and Samara (2010) of 424 construction firms in United States shows that various BIM tools have already been adopted in the construction Industry. Following figure shows the percentage use of these tools by these 424 firms.

Figure 2-3 Percentage Use of BIM products in AEC Industry, USA



The buying of these tools is different as we do for regular software purchases. As each software has its own operation, limitations and shortcomings. The user must determine his requirement, identify the most useful software required and purchase that particular one.

2.7 BIM and Energy Efficiency:

Building information modeling (BIM) is an integrated process for generating a project's important structural and architectural parts digitally even prior to its construction. The dependable, synchronized data used throughout the

BIM process assists engineers, architects, owners and contractors to see, prior to physical building structure, that what design features will the project possess and more significantly, performance characteristics of building. When used on present buildings, we can create the basic model using given information of previously built building using various BIM based modelling software i.e. REVIT and used that model for gathering necessary information needed to conduct energy performance analysis of any existing building. Those BIM based energy performance results can aid us in improving the existing facility and make that building more energy efficient.

With a building information modeling (BIM) concept, any AEC firm can use BIM based energy analysis software to perform analysis on their designs and create different alternatives for greater energy efficiency. Using BIM based results design professionals can quickly and easily provide various alternatives to the clients. Those results include suggestions to improve energy efficiency of the facility and can also provide the conceptual data of energy usage by the building over its whole life cycle. With the simple energy models, design professionals can give the clients different design alternatives, based on cost benefit analysis owners can then choose the suitable design based on their budget and future savings values, hence creating the long lasting and sustainable buildings.

Conducting analyses on the design model is critical; in fact, some studies show that when a design team uses whole building energy analysis, they can save an average of 20 percent on energy use. For retrofit projects, the potential for energy savings is even greater because older buildings tend not to have had any tenant or system improvements over the years. This creates an opportunity for greater reductions in energy consumption—reductions that can be calculated using whole building energy analysis as part of the BIM process. [4]

2.8 Clash Detection:

With BIM, AEC professionals are well positioned to ensure sustainability and energy efficiency throughout the life of the building, whether it is a new design or an existing building. During construction process, it is possible that building

elements are in conflict with each other with respect to their location like a beam being cut by an HVAC duct. These clashes can be numerous and usually result in slowing down progress of a project thus increasing the duration and cost of a project. Navisworks provides a clash detector tool to detect these conflicting building elements. Clash reports can be generated and managed to resolve clashes. These interactive reports not only tabulate the clashes but also provide an effective tool to resolve the clashes. Each clash can be assigned a status of resolved or not. Navisworks has the flexibility to either clash detect whole models or specific elements in a model. To carry out clash detection test, the structural model and the HVAC model were first imported to Navisworks after which beams from the structural model and HVAC ducts from the other model were selected for clash detection. After the test type had been defined, clash tests were run and reports were generated. For future use and clash resolution, statuses were assigned to the clashes which would be automatically updated once the clashes would be resolved. Same procedure was repeated to run clash detection tests on other building elements like beams and plumbing pipes etc.

2.9 BIM and Sustainability:

Physical models and drawings which are created through conventional means and then building performance evaluated depending upon graphic representations of traditional CAD requires a lot of interference and intervention by people with related knowledge. This Interpretation of data requires great cost and time which are limited on all projects. A survey was conducted at the Stanford University by Center for Integrated Facility Engineering (CIFE) concluded that primary cause that hinders the implementation of sustainable designs and construction procedures is failure to provide enough finances or such related economic problems(CIFE, 2004).

BIM signifies the structure as an integrated database of synchronized information. Apart from the realistic representation of project, much information is taken from the procession of design of project. All this information is used to support the sustainable design of building. In addition to that, by integrating BIM with Performance Analysis tools, many analyses have been simplified. It also

gives feedback to architects about any possible design alternates that can be used to make building more effective and attractive.

Following indicates that BIM can aid in the following aspects of sustainable design.

- Building orientation (to select the best building orientation that results in minimum energy costs)
- Building massing (to analyze building form and optimize the building envelope)
- Daylighting analysis
- Water harvesting (to reduce water needs in a building)
- Energy modeling (to reduce energy needs and analyze renewable energy options such as solar energy)
- Sustainable materials (to reduce material needs and to use recycled materials) [5]

2.10 GLOBAL STATE OF BIM:

Building Information Modeling system and software are now being utilized throughout the world. BIM is now famous worldwide and is stable in many multinational and international construction firms. Nine of the world's 10 largest construction markets Australia and New Zealand, Canada, Brazil, Germany, Japan, France, the U.K., South Korea, and the U.S are currently working on BIM and a majority of their projects are built on integration of several software.

Contractors in Germany, Japan and France report the largest return on investment in BIM, while those in the U.S, South Korea and the U.K. report the lowest. ROI metrics are principally financial – higher profitability, reduced cost, and higher productivity – and are being supported by other metrics for project submission –fewer unplanned changes, fewer Requests for Information (RFIs), less process disruption and higher customer satisfaction,. Across the globe, more than 60% of the contractors surveyed indicate that improved BIM cooperation as outcome of visualization increments would positively affect their BIM ROI.

The major project profits seen by contractors are collaboration with owners and design firms (35%), reduced errors and omissions (41%), and reduced rework (31%). Respondents point to shorter cycles for workflows, also better predictability and cost control, and approvals, as key construction process rewards of BIM.

The Hong Kong Institute of Building Information Modeling (HKIBIM) has been established to develop and enhance the field of Building Information Modeling.

2.10.1 SITUATION IN ASIA:

BIM is recognized in India under the name VDC (Virtual Design and Construction). India is a rising market for BIM with a considerably large construction market and it has a large potential for scale inhabitation and money making development due to huge population and economic expansion. In India there are many highly educated and skilled professionals with experience who are implementing this technique in Indian construction projects and also supporting project management teams in Australia, United States, Gulf, United Kingdom, Africa and Singapore to plan and deliver construction project using Building Information Modeling.

Iran Building Information Modeling Association (IBIMA) provides information resources to improve CEM (construction engineering management) decision making.

The Building and Construction Authority (BCA) in Singapore has introduced BIM for structural, architectural and M&E submissions. South Korea has also developed its BIM industry to a whole new level.

2.10.2 EUORPE:

In France, the FFB (Fédération Française du Bâtiment), and the French arm of building are working on the development of Building Information Modeling.

Lithuania is starting to apply BIM infrastructure by starting an organization named "Skaitmeninėstatyba.

Major idea behind this proposal is to take up the following in Lithuanian construction industry as standard:

• BIM (Building Information Modeling)

• Industry Foundation Classes (IFC)

• National Construction Classification

ETH Zurich is also working to develop BIM in Switzerland.

Netherland has also introduced RGD BIMnorm through Rijksgebouwendienst, the agency within the Dutch Ministry of Housing, Spatial Planning and the Environment.

In United Kingdom, representatives of major UK industry institutions has created the Construction Project Information Committee (CPIC), accountable for delivering best practice assistance on construction fabrication information. Research by CPIC has produced the same definitions as National Building Information Modelling Standard Project Committee in Unites States.

National Building Specifications (NBS), owned by Royal Institute of British Architects, is publishing research into BIM adoption in UK. They have carried out four surveys now. There are several websites in UK that host BIM objects along with a large number of construction product manufacturers.

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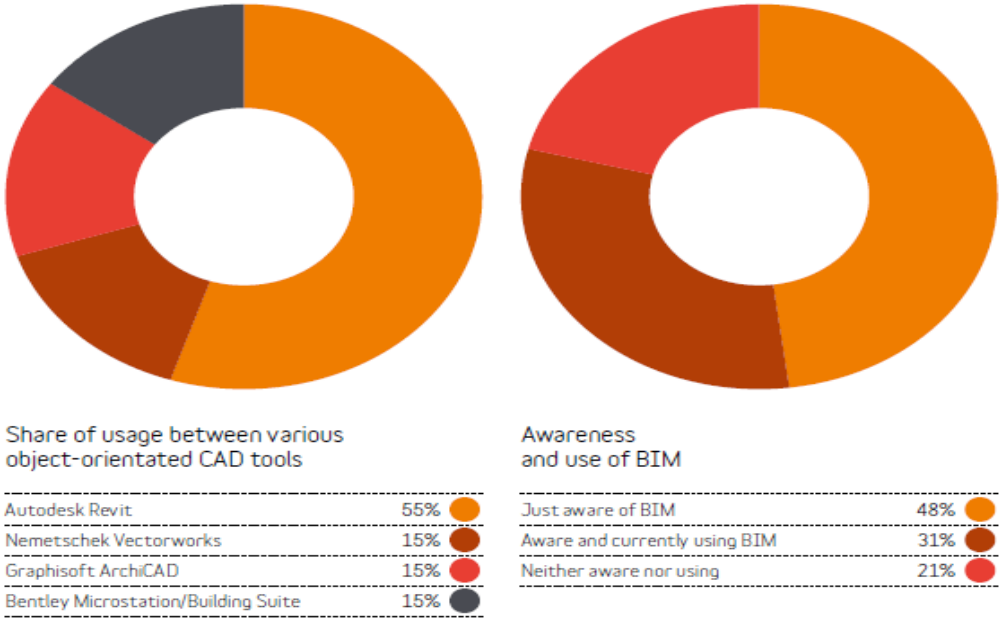
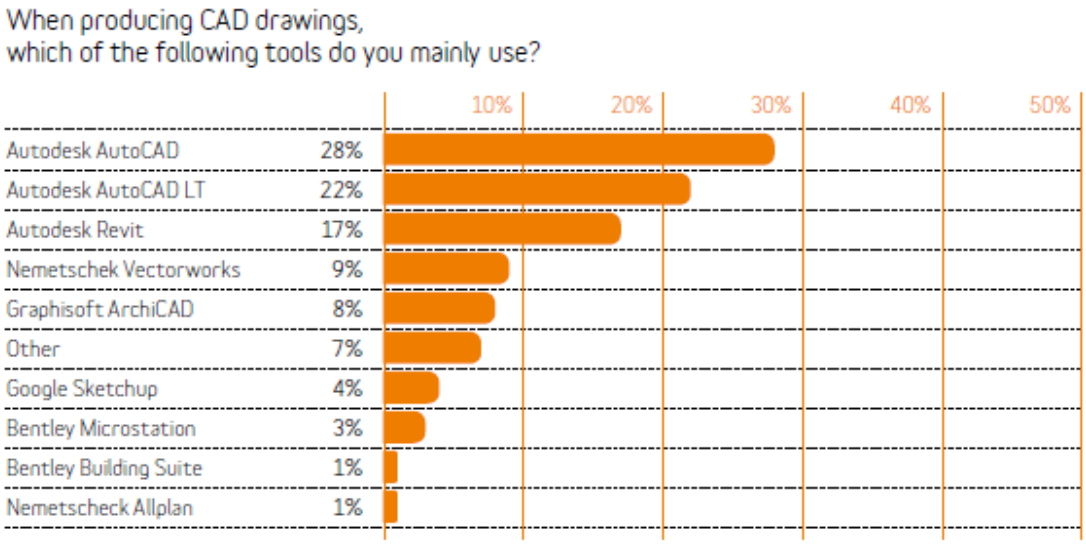
Figure 2-4 Share of Usage and Awareness of BIM



1000 Respondents from a range of business sizes, with a quarter coming from very small organizations (one or two employees) and 14% coming from very large businesses (more than 500 employees). A majority, 52%, of respondents came from organizations with 15 or fewer employees. [10]

Figure 2-5 Producing CAD drawings



An opinion poll was set up (Survey by Department of Civil and Building Engineering, Loughborough University, UK Han Yan and Peter Damian). There were two major purposes of this questionnaire. The first purpose was to study the relation of AEC companies of using BIM in the US, UK, and other countries. The second aim was to recognize the benefits to the companies who are utilizing this drawing expertise. In addition, for the companies who were not using BIM, what were the hindrances to take on this tool can also be analyzed through survey

The survey questionnaire was delivered in paper form and electronic form to about 100 AEC scholars and professionals. Participants were randomly chosen using personal contacts. Response turnover rate was about 70%. Many responses contained inappropriate answers and were disregarded. Hence, 67% valid responses were taken in account, 21 from UK, 23 from USA and 23 from other countries. The results showed that BIM has not been yet accepted as the new design tool. 24 respondents claimed that they knew nothing about BIM. 31 organizations said that they are only familiar with the name and knew very little about the real concept of BIM. The total responses that showed adequate information about BIM was only 13. USA was thought to be the biggest host of BIM but it also showed similar results. Only 26% of companies in USA, as compared to 14% in UK and 5% in other countries, said that they were using BIM as a design tool. This result also shows that reduction of construction time is the most significant benefit of BIM. On the other hand, most of the companies that do not use BIM think that the BIM training would cost their companies too much time and other resources. This is the biggest barrier to BIM application. Figure 2-6 shows that BIM's reduction of construction time is the most important benefit. Figure 2-7 shows that the time and human resource cost of BIM training is the largest barrier to their adoption.

Figure 2-6 (Advantages of BIM) [3]

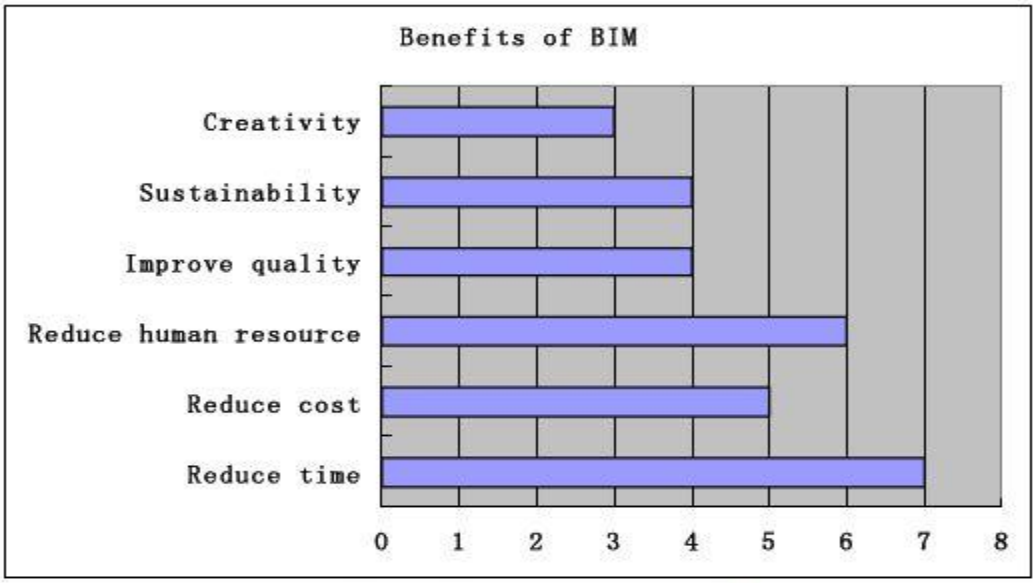


Fig. 1 Advantages of BIM

Figure 2-7(Drawbacks of BIM) [3]

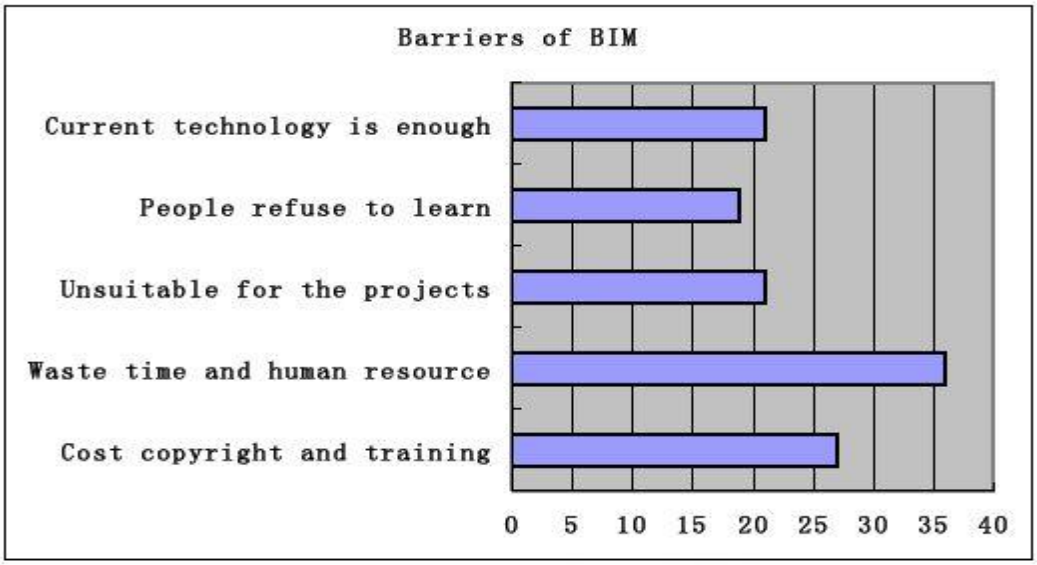


Fig. 2 Drawbacks of BIM

2.10.3 NORTH AMERICAN STUDY:

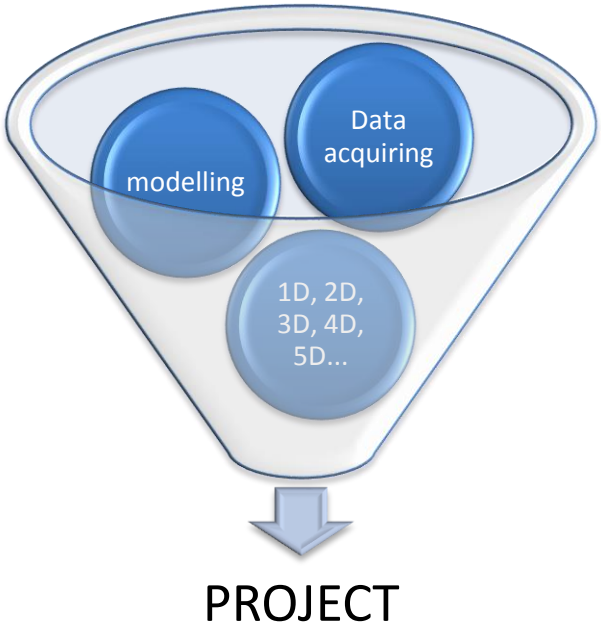
The Canada BIM Council is a referendum and team motivated association for BIM used in Canada created by industry runners to regulate the practice of models in engineering, planning and building. The Associated General Contractors of America and U.S. contract companies have established diverse fields of BIM. BIM is being viewed as closely related to Integrated Project Delivery (IPD) where the main intention is to get the teams together early on in the project. A complete realization of BIM also demands the project teams to work together from the commencement stage and devise model sharing and ownership contract documents. In the time period of 2007 to 2012, BIM acceptance in North America popped up from 28% to 71%. The contractors carry on to BIM modernization, metrics and value throughout the Canada and U.S.

Chapter 3

METHODOLOGY

In this section, we are going to discuss that how we are going to carry out our task that is assigned to us.

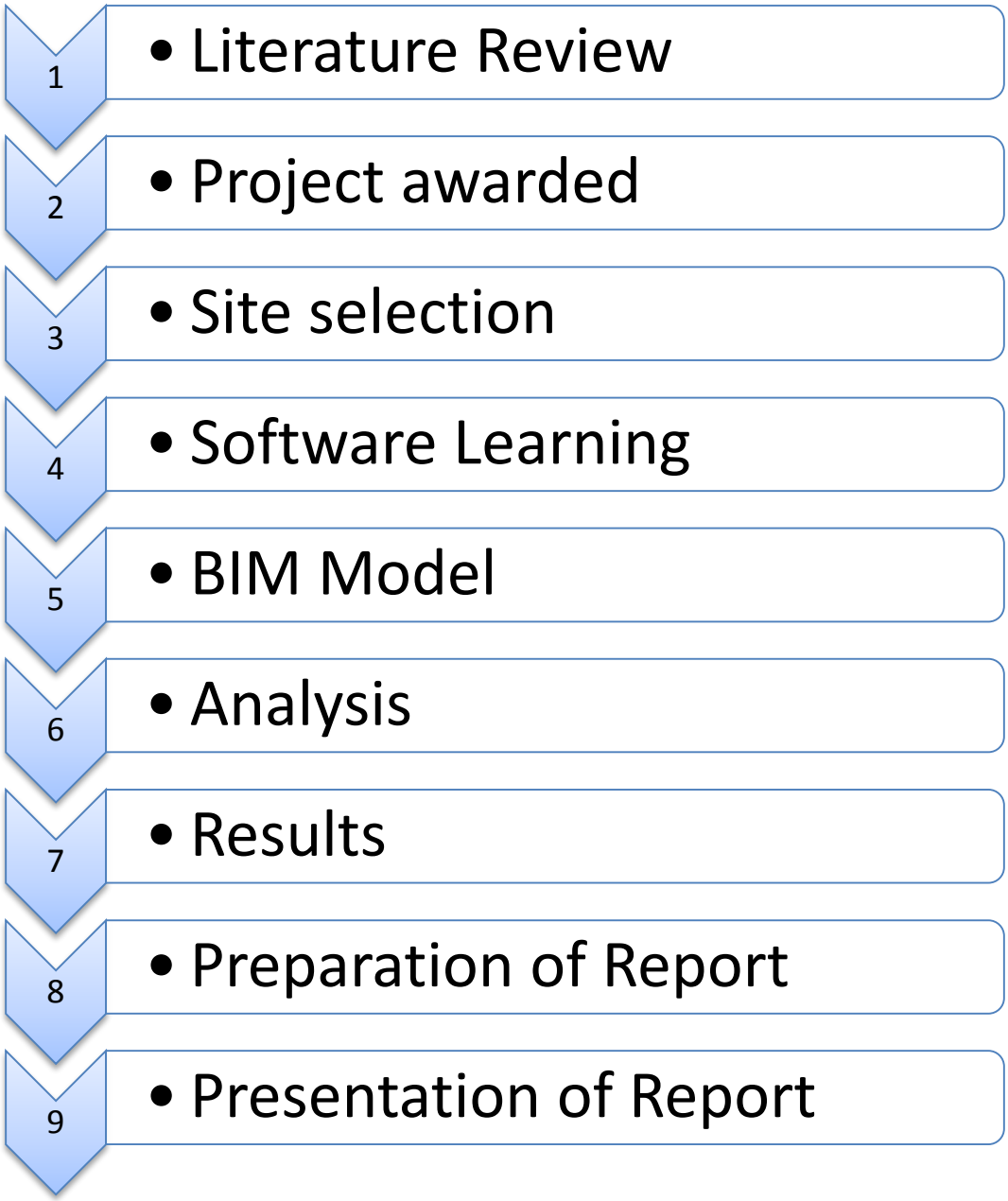
Figure 3-1 Methodology



Outlining the project methodology is basic task for carrying out any project. Activities and tasks are assigned to each and every member to efficiently carry out work. Timely completion of a successful project requires outlining the deliverables and dividing the work among all the group members.

The following flow chart gives a brief overview of the methodology adopted for the conduction of the project. Each phase of the flow chart has been described in the following lines:

Figure 3-2(Methodology steps)



3.1 Literature Review:

To have a deep understanding of the application of BIM, a thorough study of the literature related to BIM, which was deemed to be useful in carrying out our

project, was done. General definition of BIM and its usage in wide area was studied. This literature review lead us to the fact that in order have command on the subject regarding our project, we should focus on one specific aspect of project planning to better understand the benefit of BIM in that area compared to the traditional method being used there. Energy Efficiency and Sustainability were the areas where we decided to focus on.

3.2 Project Awarded:

A specific site is required to perform the project topic, which would be compared after analysis and results. As per instructions, Energy Efficiency and Sustainability project was undertaken as a case study which was designed. This was under taken in the 7^{th} semester.

3.3 Software Learning:

Since, the modeling work required use of parametric software which are relatively new and not taught in undergraduate courses. So, all software were self-learned through video tutorials. A sample theoretical project was made in order to have grip on the software before the start of main work. Following Software were learned and used in the project:

- Autodesk Revit 2013 and 2015
- Autodesk Naviswork
- Autodesk QTO
- Autodesk Green Building Studio
- MS Project
- Ecotect
- Robot Structural Analysis

3.4 Site Selection:

After deciding the specific area of BIM, a site was to be selected to perform the required task and obtain results. Our advisor, recommended PMO, NUST Building for our case study. He asked the authorities to provide us with the

necessary data we required for our project. Hence the double story already constructed building of PMO was selected as the case study. All data required (drawings, specifications, BOQ) and assistance was provided by the firm.

3.5 BIM Model:

An architectural, structural and MEP BIM as planned model was generated through the as planned drawings on Autodesk Revit 2013, 2015 and 2016. The model was then exported to Autodesk QTO for Quantity estimation and Autodesk Naviswork for the Scheduling and Clash detection. Energy analysis was performed through Autodesk Green Building Studio and Ecotect. Structural Analysis was performed through Robot Structural Analysis.

3.6 Analysis:

Quantities obtained from different model based quantity generation software will be compared to check the difficulty associated with the process and benefits. Clash detection results, scheduling, Structural analysis and Energy Analysis results will also be analyzed and compared to know the advantage they offer compared to the approach used in building.

3.7 Results:

After thorough analysis and expert opinion from project sponsor, a result is deduced in the form of a documentation which could justify the use of either technique, traditional or BIM, for planning and executing a building project. It could also be used for other educational purposes.

3.8 Preparation of Report:

After results have been compiled, a comprehensive report of the entire project describing in detail the different phases our project and the methodology adopted to achieve the required results. The report will also envisage the hurdles and setbacks faced during project execution.

3.9 Presentation of Report:

Finally, we will be presenting our findings, conclusions, the knowledge gained and the project execution details in the form of a report and power point presentation to the project sponsor for evaluation and approval.

Chapter 4

CASE STUDY

In this main part of the project, PMO NUST Building, sector H-12, was studied in order to make a BIM model of the building. This building is the central management office of NUST. All NUST contracts are made through the PMO office. It is an essential building of NUST. Moreover, analyzing a building in a certain area adds to the information record. A project was thus launched by our group in collaboration with NUST with the aim to understand BIM, its advantages and limitations in a third world country such as Pakistan. The main objectives of the project were to explore the use of BIM tools in quantity take-off, scheduling, clash detection and collaboration between stake holders. Later it was decided to include energy analysis and structural analysis in the scope of the project to further explore the possibilities in BIM. The BIM model was developed using Revit 2013, 15 and 16 while to determine QTO (quantity take-off) of the building, Autodesk Quantity Takeoff BIM tool was used. A clash detection report of the BIM model was generated with Autodesk Navisworks 2013. Its purpose was the visualization of collisions between different building elements to help resolve conflicts. Sequencing of the model i.e. linking the schedule of the building construction with the BIM model elements to virtually simulate the building construction process, was also done using Navisworks 2013. The purpose of simulation is to check space availability and smooth workflow during construction. A preliminary Energy Analysis of the building was done using the online Autodesk 360 service Green Building Studio and Ecotect to understand the energy requirements and environmental impact of the building. Structural Analysis was done using Autodesk Robot Structural Analysis software to show the structural engineer's role in a BIM process.

4.1 Description:

The development of a BIM model for PMO NUST Building required a different approach than what could be expected from the BIM process for a new construction. The building was already constructed through traditional design approach and tools. Using this new technology of parametric modeling required a set of new techniques and processes. The building is already constructed through traditional approach. We planned to start with modeling a professional approach. Quantity takeoff was to be calculated based on that model and it was to be compared with the quantity takeoff values generated by Engineer through traditional approach. "As-Planned" Architectural drawings of PMO were provided. They consisted of a Site Plan, Floor Plans of all floors and 2 cross-sections. Instead of importing the CAD files to the Revit 2013 software to develop the model, we started from scratch with minimum set of architectural drawing needed to aid us with the modeling and built a complete LOD 400 (as-planned) architectural model. This Model was then imported to Autodesk Quantity Take-off to carry out a detailed quantity take off of the building which was then compared with the traditional calculated quantities. Complete Structural and MEP drawings of PMO building were prepared. Structural and MEP models were first built in Revit 2013. These models were then exported to Autodesk Navisworks to generate a clash detection report of different building elements. For sequencing, the architectural model was imported to Navisworks and linked to the primavera schedule of the building to visualize the progress of building process in harmony with the scheduled timeline. This helped in visualizing optimum space utilization as the project progressed. For energy analysis, the architectural BIM model was imported online to green building XML to generate a preliminary energy analysis report of the building. For Structural Analysis, the structural model was exported to Robot Structural Analysis and Finite element model analysis was carried out with applied loads and boundary conditions specified to check the structural safety of the model and to design the structure elements such as beams and columns, automatically generating the reinforcement details. These design changes including the reinforcement detail were updated back in the Revit model utilizing

the robust bidirectional link between Revit and Robot. The process was impeded due to several problems. Acquiring computer systems that could run BIM tools smoothly and learning to use the BIM tools was a tedious and time consuming process. The difference between as-planned drawings of the building and how the building actually exists is NOT negligible. There were several errors, omissions and ambiguities in the CAD drawings provided to us by PMO.

After all the architectural and structural work, Energy Efficiency and Sustainability aspects were to be determined. Green Building Studio and Ecotect tools were used to analyze the building with respect to these parameters. Alternatives are suggested and comparison among different alternatives is discussed.

4.2 Approach:

The following is a brief overview, in chronological order, of our approach to develop the BIM model of the PMO Building NUST:

- Development of generic Architecture model.
- Centralizing the file for collaborative workflow.
- Creation of customized Revit families.
- Replacing generic elements with customized families and addition of materials to the generic architectural model.
- Development of Structural model.
- Generation of Clash Detection Report of different building elements with Autodesk Navisworks.
- Generation of Energy Analysis Report with Green building XML and Ecotect.
- Determination of quantity takeoff (QTO) using Assemble software.
- Comparison between QTO determined through BIM and through traditional approach.
- Determination of estimated cost of the building (subject to availability of time).

- Sequencing of building.

4.3 Model Building Process:

At first we opted to create the generic architectural model according to the as planned drawings. We used the families already provided in the standard Revit software. Modifications were made to bring the model in coherence with the specifications provided to us later. The structural and MEP models were to follow the completion of architectural model.

4.3.1 Architectural Model

4.3.1.1 Frame Structure:

Basic frame structure consisting of beams and columns were modelled in the first stage due to the fact that we required a reference for further modelling. The beams and columns were generic i.e. without rebar details. Materials were assigned to the beams and columns after the frame structure was completed.

4.3.1.2 Walls and Shafts:

As the work progressed we added walls and elevator shafts to the model. The consideration of walls, after the successful creation of basic structure, was due to the fact that the addition of windows and doors require a host family to be placed in. We started with the exterior walls and then moved to interior walls and shafts. The walls used were generic brick walls. Layers and materials were assigned to the walls after the completion of Architectural walls. This was a hectic job as adding a layer would move the wall from its position by a distance equivalent to the thickness of layer added, it would be therefore preferred to assign layers and materials to the walls while drafting them in the model if the wall section detail is available. Structural walls were placed according to the drawings as well.

4.3.1.3 Windows:

Windows were the next element to be added. They required walls to host them and are easy to place through a drag and drop operation. Window dimensions were assigned according to the specifications provided. Different families were thus used.

4.3.1.4 Curtain walls:

Curtain walls were placed according to as-planed drawings and the drawings were clear enough to aid us to model the curtain walls. Mullions were provided as per the drawings and Glass Units were used for the curtain walls. Place wall command was used to place curtain walls.

4.3.1.5 Doors:

Doors like windows also require a host family to be placed. Doors and openings were placed next in the model, again by simple drag and drop operation. Dimensions and material were set as per the specifications.

4.3.1.6 Slabs:

The slabs were expected to be the same on the upper floors and it would have been easier to copy the floor of ground floor onto the upper floors but slab on each floor was slightly different due to difference in dimensions thus each floor's slab had to be modeled separately. Layers with different materials were defined after the model had been completed. Floor by sketch command was used to model slabs.

4.3.1.7 Roof

Placement of roof is almost the same as placement of a slab in Revit. Layers with different materials were assigned to the roof after the completion of model. Roof by sketch command was used and the boundaries were manually sketched.

4.3.1.8 Stairs

Adding stairs to the model was more tedious than we imagined. It was partially due to some errors in the drawings and partially due the complex nature of the way the stairs were designed in the planned structure. Spiral stairs were placed inside the building. Both stair by component and stair by sketch command were utilized in this process.

4.3.2 Structural Model

Unlike the previous versions of the software, Revit 2013 integrates architecture model, structural model and MEP models into a single design suite and therefore we don't require different segments of the same software. After the

completion of architectural model, it was linked to a new .rvt file which had a structural template assigned to it. Structural elements of the architectural model such as columns, slabs, structural walls etc. were copied from the architectural model into the structural model keeping center to center alignment between both models. These elements were also monitored so if any change was made to them the owner of the architectural model would be notified.

4.3.2.1 Structural beams:

It's worth mentioning here that beams are not capable of being copy/monitored which could be termed, in our humble opinion, as a built in shortcoming of the software. Beams could either be copied manually without using the monitor command or modeled from scratch in the structural model. We chose to model them from scratch using the structural drawings provided by PMO. Materials were assigned to them while modeling. It was noted that the beam placement in the architectural drawings was a lot different from the placements in structural drawings. Beam command under the structural tab was used for this process.

4.3.2.2 Structural Columns:

Structural columns same as beams were not copied. They were designed according to the specifications. Architectural Model acted as delineator and structural columns were raised from the base made from the architectural model. Irregularities were seen in the structural model. Hence, to satisfy the design of the buildings, required adjustments were made.

4.3.2.3 Structural Slabs:

Like structural columns these were copy/monitored from the architectural model and afterwards their coherence with the structural drawings was ensured.

4.3.3 Work Sharing:

Work sharing was practiced for collaborative workflow. Work sharing is a real time process where multiple users are working on the same file at the same time but on different work sets. The main idea is to share a central file between

multiple users, assign each user its work set where work set is a collection of building elements. Assigning a work set to a user defines the elements editable to the user. Any element not included in the work set is not editable to the user. However if the owner (assigned user) of a work set grants access to another user, that user can then edit the elements in that work set. The central file can be shared through various means i.e. cloud, LAN etc. The choice should be made depending upon the accessibility to the server, a robust connection established with the server ensures smooth work sharing. It was decided to share the central file through LAN. 3 users made their local files from the central file and worked simultaneously on the architectural model. Each user had a work set assigned to them. When a user needed to work in another work set, a request was placed with the owner of that work set to be granted which would immediately pop up in the owner's interface. The access would be granted with a note to keep specific information in mind while working on that element or denied if the owner did not want the element to be edited.

4.4 Quantity Takeoff:

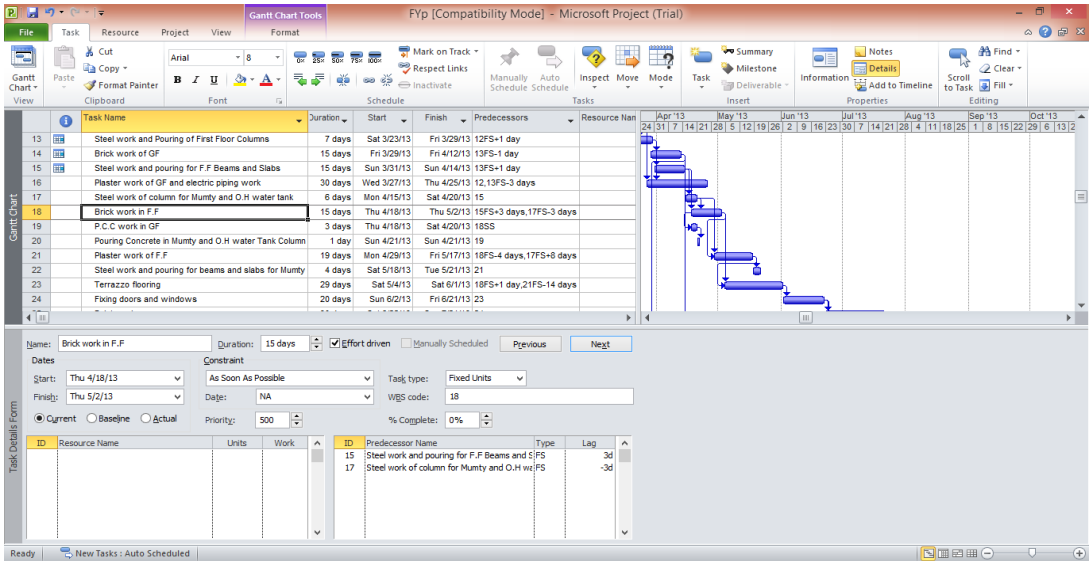
When architectural and structural models were completed, both the files were linked together using Revit link feature. In this way both models i.e. architectural and structural models were combined in a single file. After combining both files, these were exported into DWF/DWFx file format because Autodesk QTO uses DWF/DWFx file format. Then these files were imported into our project's QTO and perform a quantity take off process which was completed after the software did three base runs. QTO gives us the results in the form of tables in which we have to select the options for calculations i.e. whether you want the quantities of the slab in the form of area or volume. It also depends upon the material costs you were provided whether those costs are in the form of sq. meter or cubic meter. After selecting the options for all the values QTO gives us all the quantities and then we exported that file into excel format and perform necessary formatting to turn that file in more presentable form. The problem with BIM based estimating is that you have to be careful about material types used during modelling, because QTO gives you only the quantities of those materials you have

used in the REVIT model. The accuracy of the estimates depends upon your modelling skills and the care you have taken during the use of material while modelling.

4.5 Scheduling:

Software was acquired through School of Mechanical and Manufacturing Engineering, NUST. It was installed using key provided by them. Schedule that was actually made and used by PMO, while construction of this very building was used by us. Activity names, duration, start date and finish date was provided to us through PMO. All activities were enlisted. Duration of every activity along with start and finish date was entered. Relationships between different activities were developed on our own. Task which was completed in two different steps were split using split task command. Task having any lag or lead on its predecessor activity was given in predecessor tab e.g. 13FS-3 days mean finish to start relation with its predecessor activity which is 13th activity on the list and having lag of -3 days or lead of 3 days.

Figure 4-1 Schedule of PMO on MS Project



4.6 Clash Detection:

During construction process, it is possible that building elements are in conflict with each other with respect to their location like a beam being cut by an

HVAC duct. These clashes can be numerous and usually result in slowing down progress of a project thus increasing the duration and cost of a project. Navisworks provides a clash detector tool to detect these conflicting building elements. Clash reports can be generated and managed to resolve clashes. These interactive reports not only tabulate the clashes but also provide an effective tool to resolve the clashes. Each clash can be assigned a status of resolved or not. Navisworks has the flexibility to either clash detect whole models or specific elements in a model. To carry out clash detection test, the structural model and the HVAC model were first imported to Navisworks after which beams from the structural model and HVAC ducts from the other model were selected for clash detection. After the test type had been defined, clash tests were run and reports were generated. For future use and clash resolution, statuses were assigned to the clashes which would be automatically updated once the clashes would be resolved. Same procedure was repeated to run clash detection tests on other building elements like beams and plumbing pipes etc.

4.7 Energy Analysis:

Energy Analysis was key deliverable for our project. Sustainability and Energy efficient designs were to be proposed. Alternatives were to be suggested after analysis of our project. For the given objectives, following two software were used:

1. Ecotect 2011
2. Green Building Studio

4.7.1 Comparison:

Table 4-1 Comparison between ECOTECT and Green Building Studio [8]

	Ecotect Analysis Desktop Tools (Visualize and Stimulate Design Performance)	Green Building Studio (Analyze Multiple Design Alternatives)
Whole building energy Analysis		X

Carbon-Emissions Estimates		X
Water Use and Cost Estimates		X
ENERGY STAR Scoring		X
LEED Daylighting Credit Potential		X
Natural Ventilation	X	X
Wind Energy	X	X
Photovoltaic Collection	X	X
Thermal Performance	X	X
Solar Radiation	X	
Visual Impact	X	
Shadows and Reflections	X	
Daylighting	X	
Shading Design	X	
Acoustic Analysis	X	

4.7.2 Green Building Studio:

The Revit architectural model was saved in gbXML format and was exported to Green Building Studio for detailed analysis. Several settings must be defined in the Revit model before it can exported as a gbXML file. You must log in to Autodesk 360 account to use these settings. Revit gives us two options to create an energy model.

1. By using conceptual mass
2. By using building elements

The energy model was created by using basic building elements. In energy settings, the real life location of the building was selected and the building type was specified e.g. hospital, school, office etc. You can select either ‘rooms’ or ‘spaces’ as export category. Rooms are selected to run energy simulations based on architectural elements of the building. Spaces are selected to run MEP elements based energy simulations. Rooms was selected as our export category. All the floors of the building were divided into rooms. Default thermal properties and systems properties were used since the details were not available. Care must be taken that

there are no open spaces left in the building and the building forms a whole closed figure. Open spaces will lead to errors that will not allow the model to be exported as a gbXML file. All the open spaces were closed and the model was exported to Green Building Studio. Energy simulations were run on Green Building Studios and detailed reports were created as an output.

4.7.3 Ecotect Analysis:

For Ecotect analysis the Revit model was exported into UTF 16 format. But the Ecotect software used the format UTF 8 so we have to convert between UTF 16 and UTF 8. After conversion we imported our file into Ecotect. The first thing that we need is to get hold of weather data. It doesn't need to be exactly where the site is, but the nearer the better. After acquiring the data using Ecotect weather manager import that weather data into your project. The second thing is to place your project on the map and give proper coordinates so that it matches your original building position and orientation. Before starting any analysis check for the material of walls, ceilings, floors and roofs. Sometimes while conversion into different formats the settings gets altered. Manage all the zones using Ecotect zone management for putting all the related information related to your project like HVAC systems, lightening values, building type, building schedule and occupancy percentages of the building. After all the input parameters we performed the solar access analysis which gave us the values of irradiance absorbed by exterior surfaces of the building during day time which tells us that which portion of the building is exposed to maximum amount of sunlight for the maximum amount of time. Other values contains hourly gains, monthly gains, yearly gains, passive gains breakdown, temperature gains and temperature distributions.

Chapter 5

RESULTS AND ANALYSIS

5.1 Introduction:

To learn about BIM tools and applications and know benefits and issues involved in the process a case study was done. Architectural and Structural models of PMO Building NUST, a 10,640 ft. square area building with 2 stories.

5.2 Errors in Drawings:

BIM tools provide enhanced visualization enabling the designer to rectify any awkward and inappropriate features of the building which only become visible after execution and sometimes even complete construction of the building due to limited visualization capability of CAD or any 2D tools. With BIM these mishaps can be rectified easily beforehand and the change is reflected automatically in all drawings (plans, sections, 3D views etc.) Of the project eliminating possible inaccuracies. Following two accuracies were seen in drawings:

- In our project's 2-D CAD drawings, provided to us by PMO NUST, first floor had two plan drawings, wall plan and floor plan, but one of them showed that building is uniform while other had errors in certain dimensions which disturbed the uniformity of whole building.

- Similarly there was another error in drawings showing details of stairs which contradicted heights shown in a section view of the same area. These kinds of errors are a non-occurrence in 3-D modelling using BIM tools as it generates all drawings from the same model having similar dimensions.

5.3 Clash Detection:

5.3.1 Navsiwork:

Both architectural and structural model were linked in Revit. This linked file was then exported to .dwfx file format. We then opened the Navsiwork and imported that .dwfx file which brought both architectural and structural model in one Navsiwork file.

5.3.2 Clash Detection:

In Navsiwork first thing we did was clash detection. Clash detection detects all the clashes in model. Clashes are defined as any two objects having same snap points. In the tab of clash detection, first we selected architectural model only and found 320 clashes. Most of clashes were clash of slab and wall, intersection of walls and furniture clashes. When we selected structural model only, there we no clashes in it. When we checked architectural model against structural model total number of clashes were 710 consisting of clashes between walls and columns, columns and floors, beams and floors etc. Total number of clashes was 1030. All clashes were reviewed and reduced to about 350.

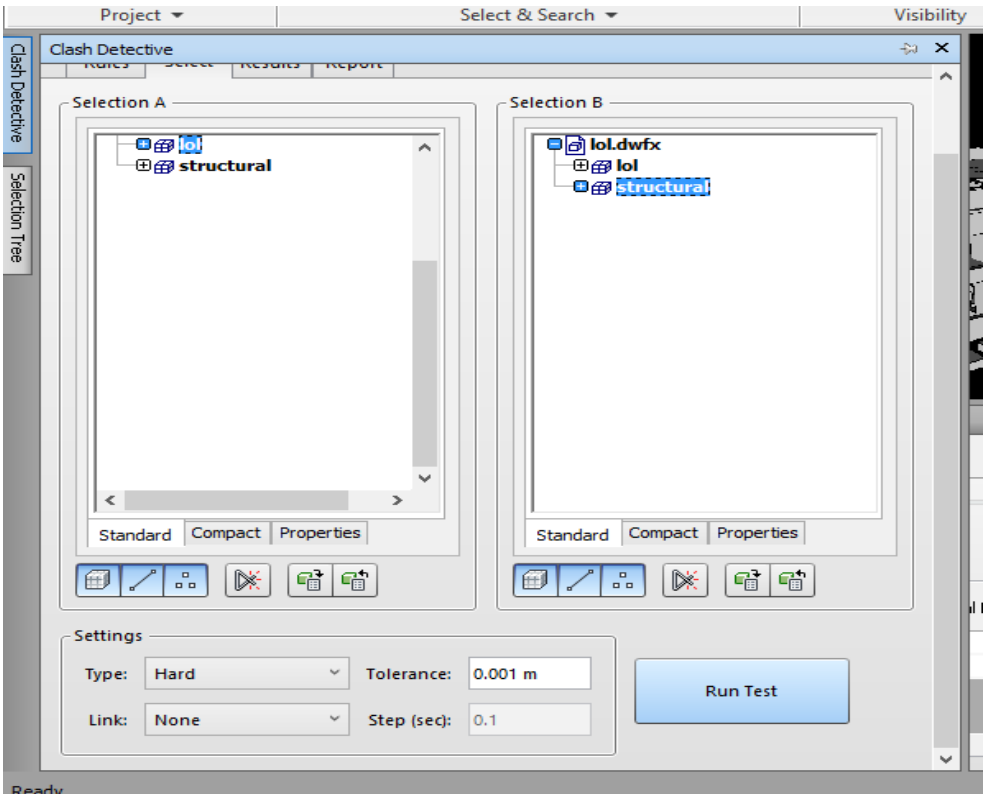
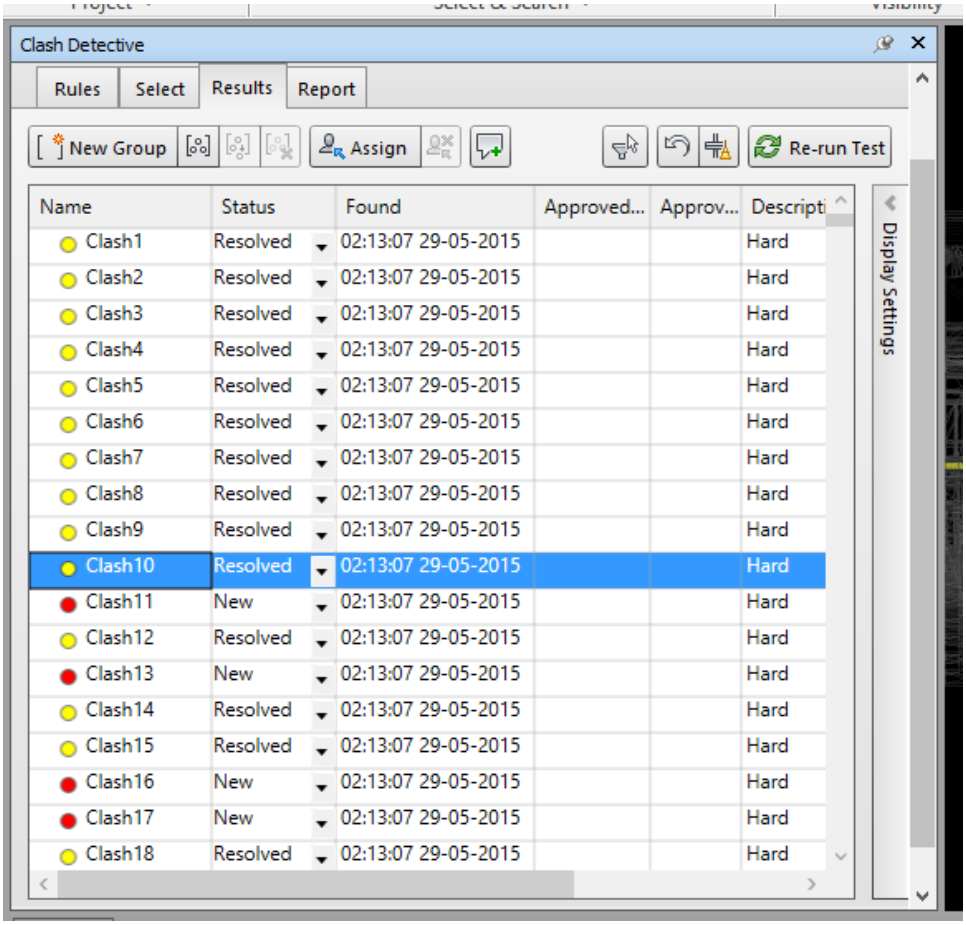


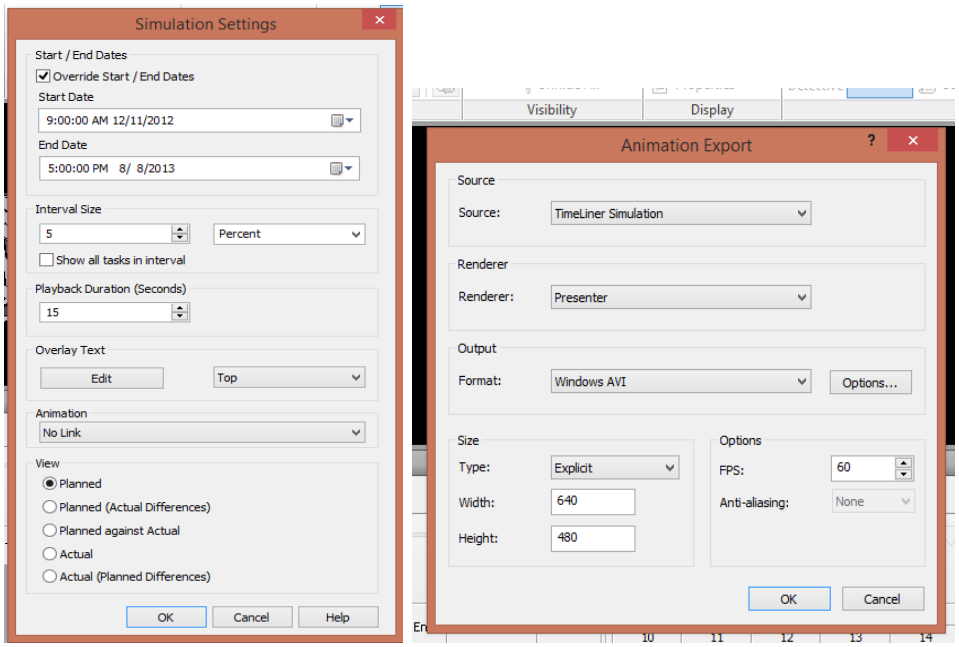
Figure 5-1 Navisworks steps



5.3.3 Simulation:

Schedule made on MS project 2010 was linked to Navsiwork and task hierarchy was built under that link. All tasks were linked with its respective component of building. Task type was allotted to all tasks as Construct, Demolish or temporary. Under simulate tab, Simulation was played. Under settings in simulate tab, interval size, playback duration, Overlay text and dates to be used to create simulation was selected according to our project. Simulation was played to see any component of building to be missed or any other mistake. When finalized, view was checked through which the video should be exported. Simulation was exported using export animation tab, keeping source as Time Liner Simulation, format as Windows AVI. Size was selected for exported video and then hit OK. We browsed where we wanted to save the simulation.

Figure 5-2 Navisworks Simulation method

- 

5.4 Energy Analysis:

5.4.1 Green Building Studio:

Green building Studio is a cloud based software. Our design which was architectural and structural model was upload which yielded us a lot of results. Alternatives were suggested by the software after analysis. 94 people were assumed to be working in the building.

Input Parameters that were assigned to Green Building Studio are as follows:

1. Location: Islamabad, Pakistan
2. Currency: PKR
3. Time Zone: Pakistan Standard Time.
4. Electricity & Gas Rates.
5. Weather Station: GBS_06M12_12_111265
6. Distance from Project: 1.5 miles (2.3 kilometer)

Results are based on number of people using the utilities of the building. Those are summarized in the following tables:

Table 5-1 Energy Consumption Results

Alternatives	Annual Energy Consumption	Life Cycle Energy Consumption(30 years)	Annual Fuel Consumption	Life Cycle Fuel Consumption (30 years)	Carbon Emission
Base Run	97,435 kWh	2,923,058 kW	682 Therms	20,473 Therms	29.1 tons
Double Glass LowE HP Windows	82,865 kWh	2,485,947 kW	970 Therms	29,087 Therms	24.7 tons
Continuous Insulated Roof	98,195 kWh	2,945,839 kW	436 Therms	13,094 Therms	28.0 tons
Occupancy Sensors	94,239 kWh	2,827,169 kW	704 Therms	21,121 Therms	27.9 tons
Orientation 180 degree	93,395 kWh	2,801,863 kW	942 Therms	28,270 Therms	28.9 tons

Looking at the summarized tables of the results, one can use the alternatives to improve the efficient design of the project. Using alternatives reduces the carbon emissions by sufficient amount.

Table 5-2 Water Usage & Photo Voltaic Results

- Water Usage:

	Base Run	Grey Water Reclamation Rainwater Harvesting Vegetation Landscaping
Indoor	92,380 Gal / yr	92,380 Gal / yr
Outdoor	26,100 Gal / yr	10,458 Gal / yr
Net utility	**118,480 Gal / yr**	**33,849 Gal / yr**

- Photovoltaic Analysis:

Installed Panel Area	Annual Energy Production
2217 sq. ft.	31,383 kWh

Water usage can be also reduced greatly using alternatives provided. These photovoltaic analysis shows that by using these, one can reduce the energy usage and can get back the money within 9 years.

5.4.2 Ecotect:

The Input Parameters that were assigned to the software were:

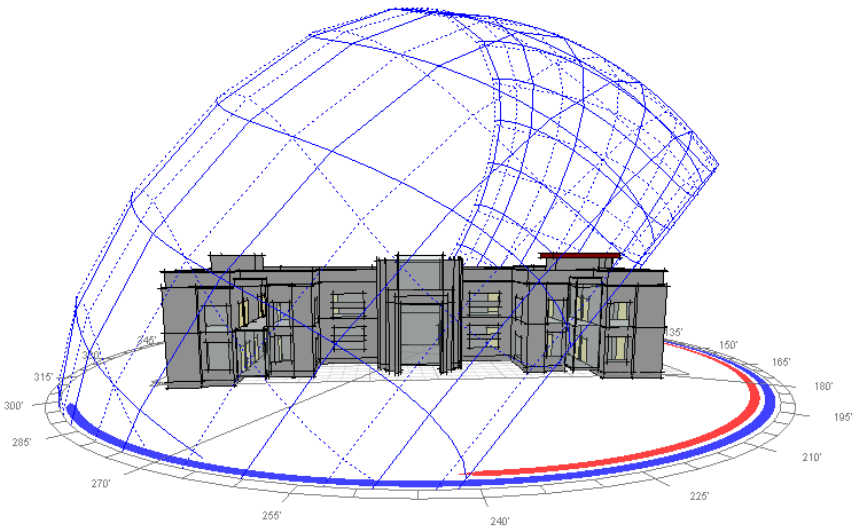
- Data range: year
- Time range: 9 to 5
- Location: Islamabad, Pakistan.
- Type of HVAC system: Mixed
- Thermostat Range: 18 to 26 degree Centigrade.

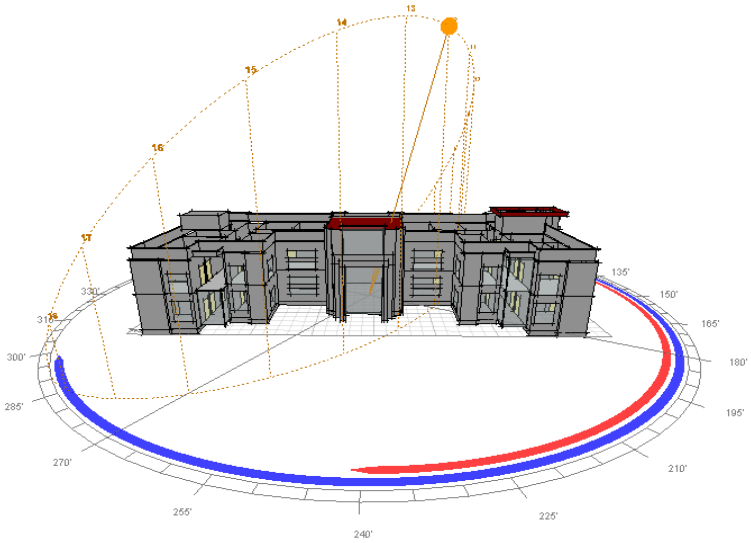
Following analysis were performed by Ecotect on our model:

5.4.2.1 Sun Path:

Following figure, extracted from ECOTECT, shows sun path according to the orientation of our building. First figure shows annual sun path while other shows sun path for a single day in the month of May.

Figure 5-3 Ecotect Sun path (yearly and daily respectively)





5.4.2.2 Orientation:

Figure below shows that the best orientation for the building is almost 180°, whereas our building is oriented at 242°. Figure also illustrates best orientations under different heat conditions and an average orientation.

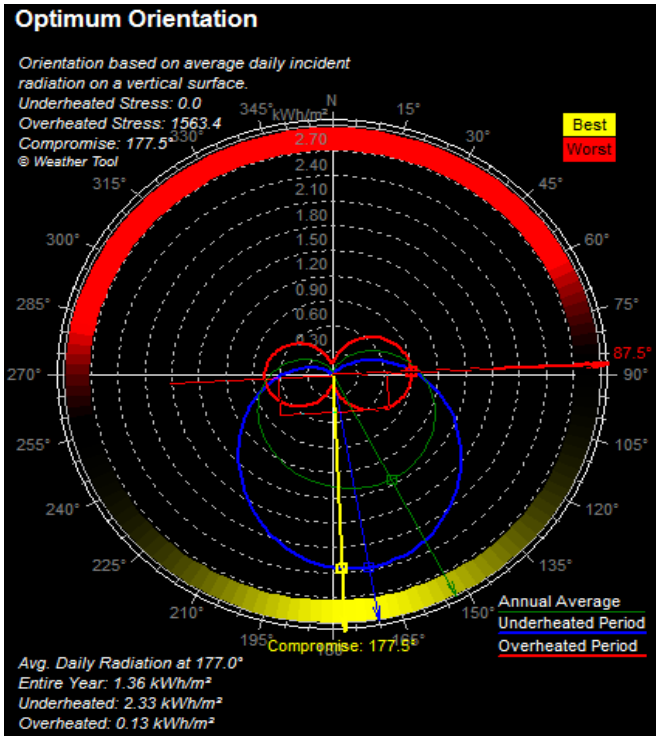
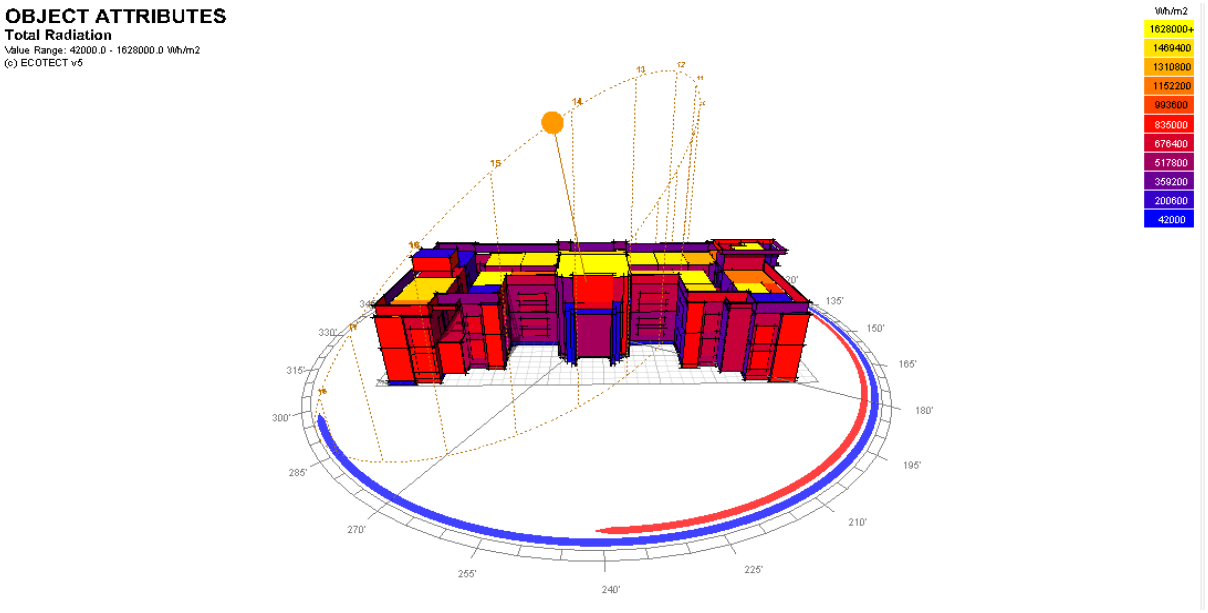


Figure 5-4 Ecotect Orientation

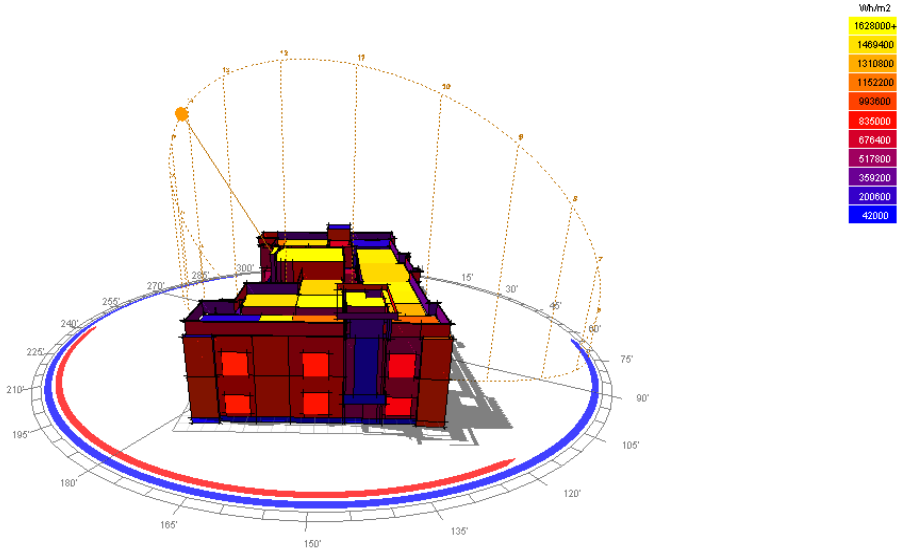
5.4.2.3 Radiation Analysis:

A radiation analysis is also a tool in ECOTECT that shows Irradiance of a building's exterior. Irradiance is the radiant flux received by a surface per unit area (Wikipedia). Following figures shows the results extracted from radiation analysis that shows irradiance of different surfaces of our building.

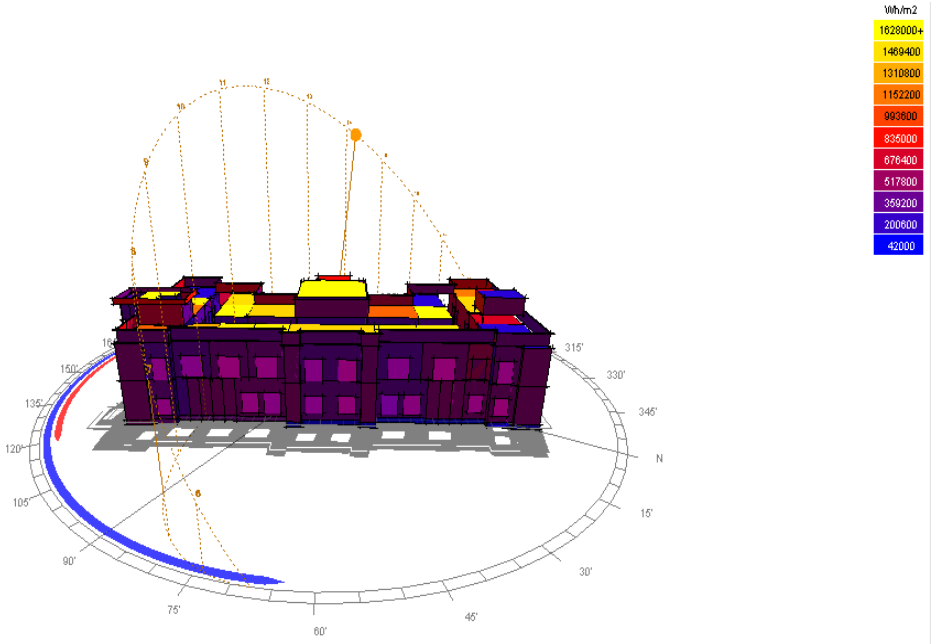
Figure 0-5 Ecotect Radiation Analysis

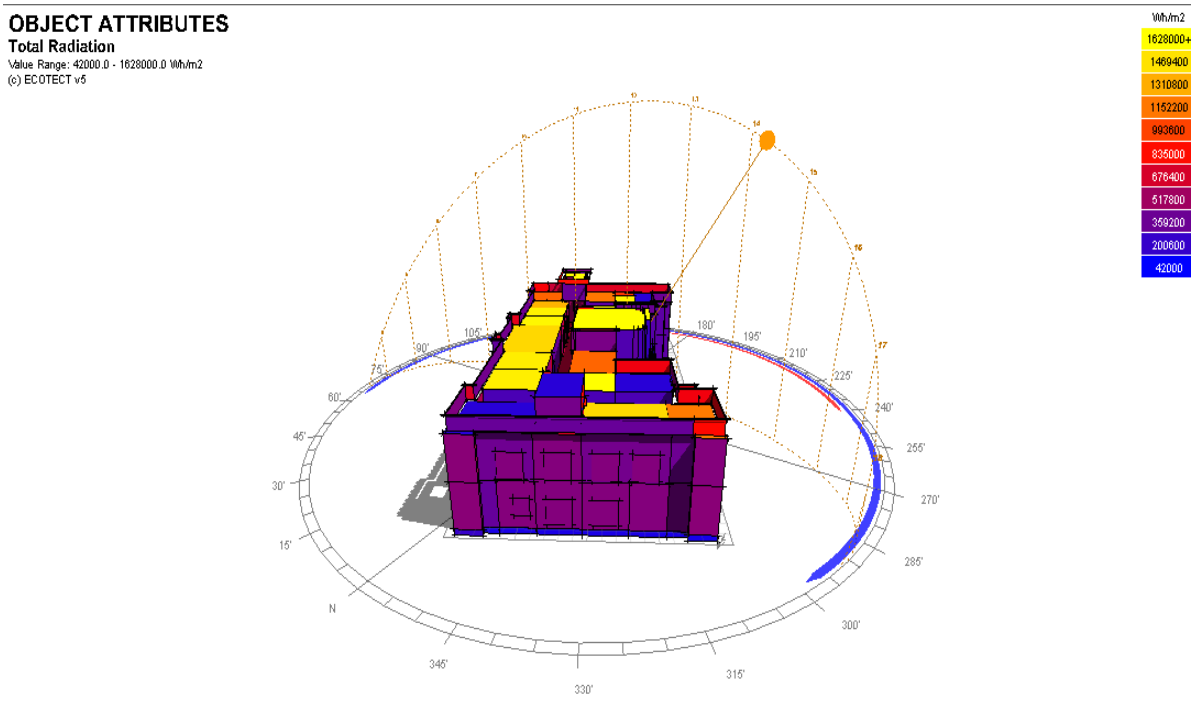


OBJECT ATTRIBUTES
Total Radiation
Value Range: 42000.0 - 1628000.0 Wh/m2
(c) ECOTECT v5



OBJECT ATTRIBUTES
Total Radiation
Value Range: 42000.0 - 1628000.0 Wh/m2
(c) ECOTECT v5





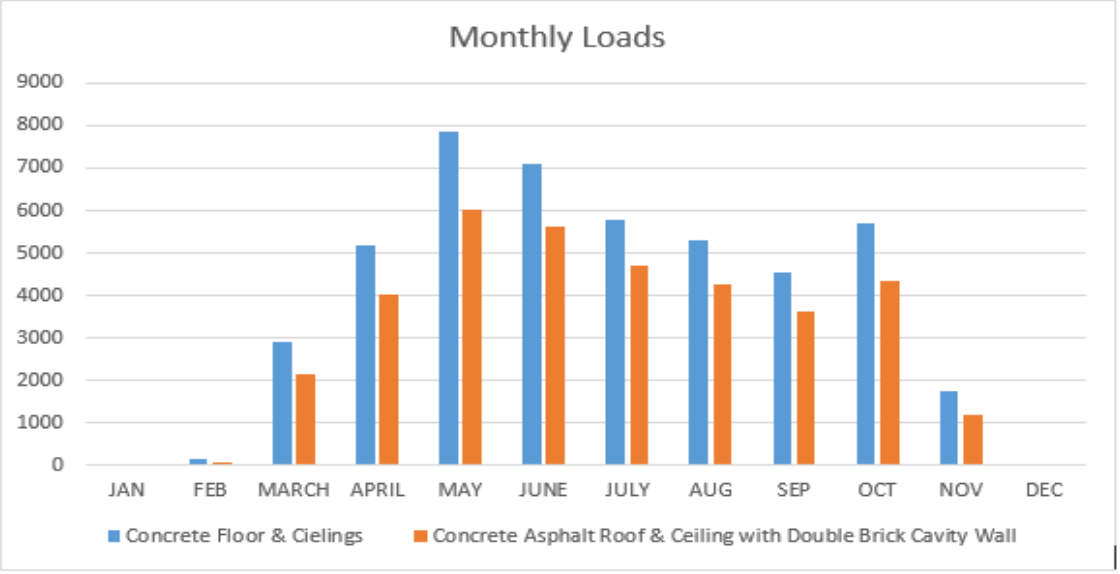
5.4.2.4 Heating and Cooling Loads:

Analysis showed the heating and cooling load for different months with and without design alternatives.

Originally no insulation was provided in roof or walls that caused increased loads overall. Afterwards we performed another analysis with certain design alterations i.e. concrete asphalt roof and ceiling plus double-brick cavity walls. This caused a remarkable decrease in loads thus providing more energy efficiency.

Following figure shows result comparisons of with and without design alternatives.

Figure 5-6 Monthly Loads Reduction after applying alternatives

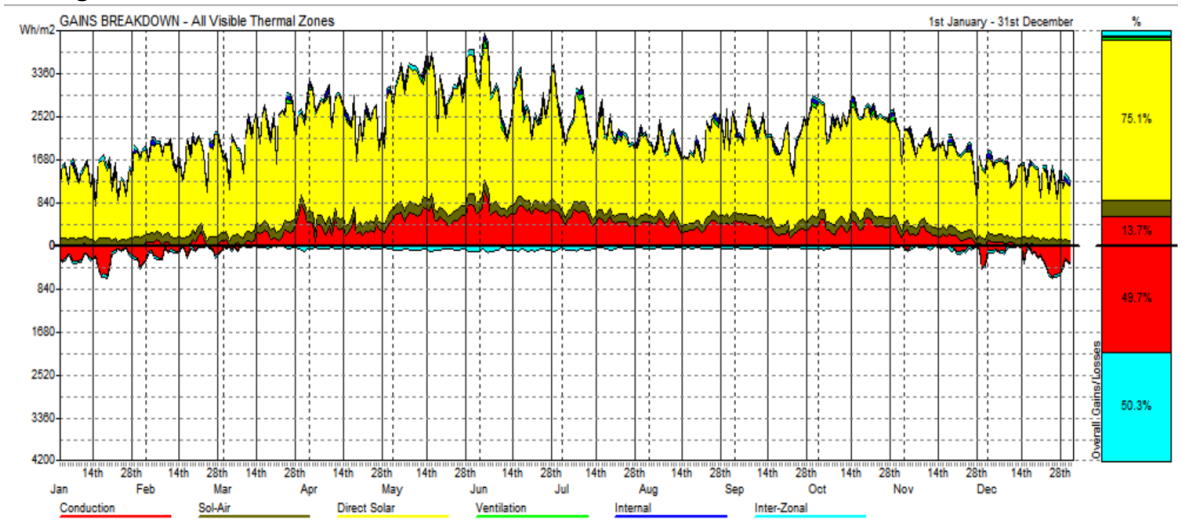


All values on Y-axis are in KWh.

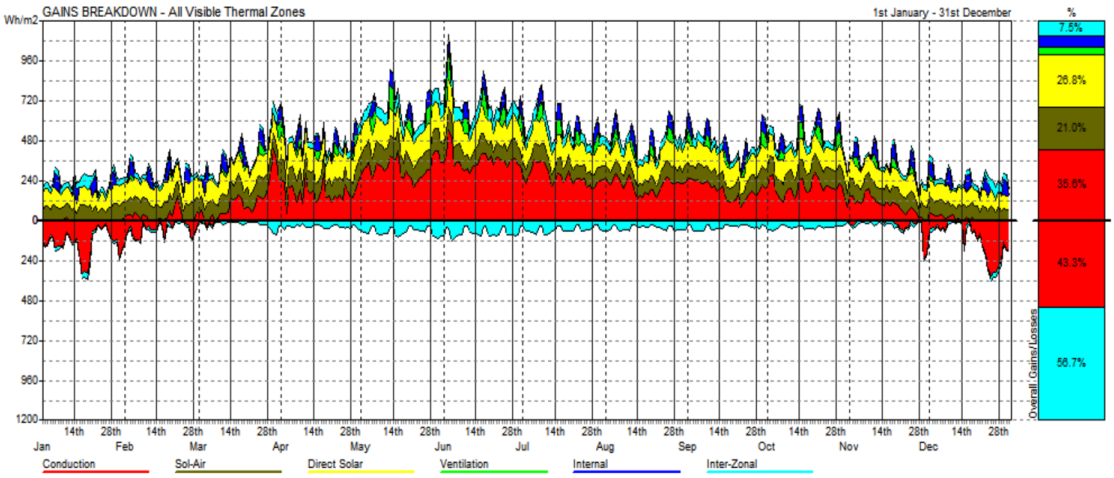
The following figure shows Passive Gains Breakdown of our Building that represents where our building is gaining heat and where it is losing heat.

This analysis is performed for both conditions (with and without design alternatives).

Figure 5-7 Passive Grain Breakdown



With concrete roof and simple brick walls



With asphalt concrete and double-brick cavity walls.

These passive gain breakdown charts shows what percentage of gains and losses in heat are coming from conduction, solar radiation, infiltration, and internal loads. Energy flow patterns in specific zones is shown and these patterns can be tracked over the course of the year.

5.5 Problems & Issues:

Need of learning and experience about BIM and the use of its devices in the development Industry was a noteworthy obstacle. We were fundamentally by and by when it came to taking in the utilization of BIM apparatuses. At whatever point there was an issue in demonstrating, we needed to apply hit and trial methodology applying different arrangements to our issues posted on the web. This was a time taking process. Procurement of PC frameworks with substantial determinations with capacity to smooth run the Revit programming. As the measure of the undertaking records builds the framework virtual RAM prerequisite increments. Rendering process uniquely requires the need to get such PC frameworks. There were a few equivocalness/mistakes/oversights in drawings gave to us by PMO. A few shafts and sections were lost in the arrangements, areas and arrangements had repudiating data. This hampered our progress and were cleared by discourses with the senior draftsman and by examination of the

as-manufactured structure. Time and calendar has dependably been against us. The dull and chaotic calendar made has likewise frustrated our advancement somehow.

Chapter 6

CONCLUSIONS

6.1 Review of objectives:

The objectives of our project were following:

- Integration of construction processes of client requirements, designs, construction and operation using tools of BIM.
- Develop a 5D model of the construction, which includes the 3D visualization of the project, the cost estimation, scheduling and simulation.
- Applying BIM, focusing on aspects of Energy efficiency and Sustainability.
- Suggesting alternatives based on analysis of sustainability factors and energy consumption.

6.2 Conclusions:

After designing and performing all the analysis of the project, following conclusions were drawn from our study:

- BIM is an extremely useful tool but it should be viewed with caution. An immediate change from the traditional approach to Building Information is not recommended as the dynamic working environment in software such as Autodesk Revit takes some time to get used to. An interim phase, where both methods are simultaneously used should be implemented in order to ensure that the information obtained is accurate. A complete shift should only be made when the appropriate personnel working in a company have familiarized themselves with the working environment of BIM.
- Quantity takeoff process from BIM since takes very less time therefore it must be used but care should be taken while modeling to ensure accuracy of the quantities.
- BIM allows easy energy analysis in less time thus the process can be used to ensure greener and environmentally friendly buildings.

- After acquainting yourself with the working environment of Revit, it is not hard to develop 3-D models. Learning the software itself is a tedious task, however, it promises great benefits in the long run as you can use knowledge gained from one project and apply it to the next one. After the first few projects, you can greatly improve your efficiency and develop even the more complex models in a timely manner.
- Ecotect and Green Building Studio are both handy software. Both come with their limitations. One must determine his requirement like time, cost etc., to decide which software to use.
- Applying Energy Analysis gives us alternatives to use which would result in better environment with less carbon emissions.

6.3 Recommendations:

The problems we faced, technical issues, professional incapability helped us in guiding us towards following recommendations:

- There must be a PC framework of high specification for performing BIM operations.

- One must counsel some approved individual, so he can get any sort of information needed for the correct and effective execution of BIM procedures.

- Without getting all the information about project we can't get all the advantages of BIM in the way it should be.

- We must get the correct information of BIM related instruments and programming projects before executing our work so that subsequent to realizing all the devices which can perform the work in a fitting stream and get the powerful results.

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