BE CIVIL ENGINEERING

PROJECT REPORT

ANALYSIS AND MANAGEMENT OF A BUILDING USING BUILDING INFORMATION MODELING (BIM) TOOLS

Project submitted in partial fulfillment of the requirements for the degree of

BE Civil Engineering

Submitted By

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MILITARY COLLEGE OF ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY

RISALPUR CAMPUS, PAKISTAN

(2015)

Syndicate members with Advisor

This to certify that the

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Has been accepted towards the partial fulfilment of the requirements

for

BE Civil Engineering Degree

Lecturer Rana Mamoon Ahmad

Syndicate Advisor

Dedication

Dedicated to our parents, our friends and all faculty members

for their support and encouragement……….!

ACKNOWLEDGEMENT

First of all thanks to Allah for His blessings Who has enabled us to complete our project. Efforts have been taken by syndicate members however, it would not have been possible without the kind support and help of many individuals and instructors to whom we are greatly obliged.

We would like to express our deepest gratitude towards our beloved parents and our project advisor Lecturer Rana Mamoon Ahmad for his kind cooperation and encouragement which helped us in completion of project.

We would like to extend our sincere thanks to Dr. Muhammad Irfan and college staff for giving us such attention and time. Our thanks and appreciations also go to our colleagues in developing the project and people who have willingly helped us out with their abilities.

(All Syndicate Members)

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LIST OF ABBREVIATIONS

2D	2-Dimensional
3D	3-Dimensional
AEC	Architectural, Engineering and Construction
AIA	American Institute of Architects
BIM	Building Information Modeling
CAD	Computer Aided Design
CI	Construction Industry
CM	Construction Management
FM	Facility Management
HVAC	Heating Ventilation & Air Conditioning
IP	Intellectual Property
IPD	Integrated Project Delivery
MEP	Mechanical Electrical & Plumbing
n-D	n-Dimensional
RFI	Request for Information
UK	United Kingdom
USA	United States of America

LIST OF FIGURES

EXCETIVE SUMMARY

Handling, management and flow of data is very complex on construction projects due to uncertainties, ambiguities and lack of information technology applications. New advancements in Construction Industry (CI) have introduced Building Information Modeling (BIM) that gained attention in the Architectural, Engineering and Construction (AEC) industry. BIM is a methodology used for generating, exchanging and managing data throughout the project lifecycle. BIM processes are for development and use of computer generated n-dimensional (n-D) models to simulate the planning, design, construction and operation of a facility and for clash detection in design, construction or operation of any facility.

Current project path involves the discussion on acceptance of BIM as a new innovative technology, its effectiveness and the problems associated with the adoption of this thriving technology. In this project, a building in Peshawar is selected for case study and BIM tools are applied to model the building in the virtual environment. Flow of the project involves the creation of 3-Dimensional (3D) Model of selected building using a BIM tool Autodesk Revit 2013 that includes architectural and structural model. Later on this model is used for different kind of analysis. Firstly, the model is exported to Autodesk NavisWorks 2015 for the simulation of the activities of the project and the estimation of quantities in the building model. After quantification, structural analysis and wind simulation is carried out in Robot Structural Analysis Professional 2015. Preliminary energy analysis is also carried out using Autodesk 360 Service Green Building Studio. All these studies are compiled in this report to understand and set a path for application of BIM in CI of Pakistan.

Chapter 1

INTRODUCTION

1.1 Background

The CI is a project-based industry and is known for its lower efficiency and decreased labor productivity, compared to the manufacturing industry that has continuously increased its productivity. The major causes of low labor productivity is due to fragmented nature of traditional CI, conventional use of 2-Dimensional (2D) Computer Aided Design (CAD) technology and the size of the construction firms (Teicholz, 2004).

Traditionally, the project drawings and specifications designed by architect and engineer are delivered to the client with a warranty that the design is complete and free from defects. The client then puts up the project for bidding, and after the bidding process a low responsible bid is selected. The construction documents are handed to the contractor and a distant relation start with the architect and engineer. For each problem in the project documents, contractor Requests for Information (RFI), each RFI takes sufficient duration of the project which results in lower productivity and sometimes leads to bitter relations between the stakeholders.

The traditional CI is a ‘document-centric’ in which project information is prepared and stored predominantly in documents, i.e. technical specifications and 2D CAD drawings. Although such information is produced in electronic form, but the project information is distributed among multi-disciplinary teams. Traditional 2D CAD drawings does not promote collaboration among the teams. Architects and engineers produce their own fragmented 2D CAD documents. The drawings are not integrated and the quantity estimator has to count and produce his own material take-offs based on CAD documents. In addition, the 2D CAD drawings has no capability of promoting the integration of the drawings with the project schedule and cost. This fragmented nature of the industry, poor integration of drawings and less coordination between the stakeholders, results in poor efficiency and performance of the industry. During design phase with 2D-based communication, sufficient time and expense is required to produce critical assessment information of the design, including cost estimates, structural detailing, energy analysis etc. Errors and poor coordination in paper documents results in unseen field costs, delays and sometimes lawsuits between the stakeholders. These problems cause friction, extra financial expenses and project delays.

In order to address these issues certain methods were adopted i.e. changing the organizational structure of the industry such as Design-Build method, Construction Management (CM) at Risk; using real-time technology such as sharing plans and documents on project web sites; and by implementing 3D CAD tools. Although these methods helped in improving the project coordination, but ineffective in reducing the severity and number of conflicts which are caused by paper documents and their electronic equivalent.

Now, a unique approach 'BIM' is the most discussed topic in the AEC industry. BIM comprises of multiple software tools that produce digital representation of building to improve design, construction, operation; and also to improve lifecycle functions of the building (Eastman *et al.*, 2011). BIM is not just a technological change but a process change. BIM is a process of developing computer generated models to simulate the design, planning, construction and operation of a project.

The 2D CAD drawings describe a building by independent 2D views such as plans, sections and elevations. Changing one view needs to change and update all the views, which is an error-prone process and one of the main cause of poor documentation. While a BIM model is a 3D digital representation of a building and its intrinsic characteristics. These models are made of intelligent building elements and systems such as beams, floors, columns, spaces etc. For example, a window of specific material and dimension is parametrically related and hosted by a wall. Further, BIM provides views consistent and coordinated with each other. A Building Information Model has all information related to the project, including its physical and functional characteristics and project life cycle information, in form of 'smart objects'.

This study includes the critical literature review of BIM. Then potential problems in the traditional AEC industry are discussed, followed by the BIM contribution to the architectural and engineer design teams, its coordination capabilities and detailed planning and simulation of the model for the contractor. Different aspects of the BIM are then discussed. Finally a four story Commercial Plaza in Peshawar is analyzed as a case study. Its 3D architectural and structural model, scheduling, quantity estimation and simulation models are discussed.

1.2 Objectives

- Development of virtual 3D Architectural and Structural Model of Sardar Khan Plaza, Peshawar using BIM tool; Autodesk Revit 2013
- Quantity Take off and Scheduling timeline in Autodesk NavisWorks 2015
- Structural analysis of structural model and Wind Simulation in Robot Structural Analysis Professional 2015
- Energy analysis of the prepared model using Autodesk 360 Service Green Building Studio

1.3 Justification Of The Topic

Since BIM is one of fastest growing techniques in CI, and its wide spread effects on the industry, this research area is selected. The CI has evolved from hand drawings to 2D digital CAD drawings then to 3D models and now is the era of intelligent based multi-dimensional modeling. Now with the development of powerful computer technologies things are changing quite faster. BIM is an innovation in the CI and is implementing in the industry with an exponential growth rate. Hence, one must be acquainted with the recent developments in the industry. In the economic world of today, two things are most important the time and project cost. Project cost is of concern to the owner while contractor has the aim to finish the project within time. With effective coordination and integration of the construction documents BIM has reduced the project time and cost. Keeping in view the impacts of BIM on the local CI this topic has been selected.

1.4 Advantages

BIM has following potential advantages:

Better Performance through Collaboration: Since all the partners on a project such as designers, contractors, clients, and customers use a single 3D shared model, it results in collaborative work that certainly increases efficiency of the project.

Enhanced Performance: BIM makes possible swift and accurate comparison of different design options, enabling development of more efficient, cost-effective and sustainable solutions.

Faster Project Delivery: Time savings of up to fifty (50) percent can be achieved by agreeing the design concept early in project development to eliminate later stages design changes using; standard design elements when practicable; resolving complex construction details before the project goes on site; avoiding clashes; taking advantage of intelligence and automation within the model to check design integrity and estimate quantities; producing fabrication and construction drawings directly from the model; and using model data to control construction equipment.

Reduced Safety Risk: Asset managers can use the 3D models to enhance the operational safety. Contractors can minimize construction risks by reviewing complex details or procedures before going on site.

Chapter 2

LITERATURE REVIEW

2.1 BIM

According to United States of America (USA) National BIM Standard, BIM is a digital representation of physical functions and characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during life-cycle; defined as existing from earliest conception to demolition stage.

Autodesk Incorporation defines BIM as an intelligent model-base that provides insight into planning, designing, construction, and management of buildings and infrastructure.

BIM is the process and practice of virtual design and construction throughout the project life-cycle. It serves as a platform for sharing knowledge and communicate between project teams.

2.2 Traditional 2d Cad to BIM

Architects started using CAD in early 1980s. CAD system became very familiar within a couple of years and shop drawings plotted by computers almost replaced the paper based manually drafted sheets. Gradually innovations were introduced to this system and it became easier to use and exchange of data in drawing files rather than physical drawing and construction documents. 2D drawing files also represented building data along with simple graphics through its layer structure. Building data was represented by vectors, associated lines, arcs, and points called entity based modelling. Through layer system in CAD, same graphical entity represented different objects in different layers as; a circular solid fill in one layer represented a column but on alternate layer a circular duct or any specific circular object other than column. With advancement in internet technology file sharing through internet increased. With further development CAD files became electronic files which not only store graphical data but also the non-graphical additional information and associated text. More complex tools and data blocks were included to CAD with the advancement of new 3D modelling. As CAD frameworks became more advanced and intelligent, clients needed to impart and share information and data linked with a given design, the center moved from drawings and 3D graphics to the information and data itself. But till 1990s all the innovations introduced in CI driven by Information and Communication Technology (ICT) effected the design stage only and rest all construction stages remained same.

All this development continued resulted in introduction of Object-Oriented CAD also called object based modelling in 1990s. In object based modeling, instead of graphical representation of building components like walls, doors, windows, roofs etc. with lines and areas, built asset elements called objects were used to store non graphical data about a building along with graphical representation in a logical structure and were adequate to represent the behavior of common building elements. The advanced factor of this technology was, the building objects could have non-graphical data associated to them, and link between the elements of a built asset to be made (Batcheler and Howell, 2005). CAD drawings lacked interactivity which make the work more laborious like building layout section drawing and change in one view was not automatically reflected in other views but with the advent of BIM based architectural software have produced intelligent models which allowed automatically updating of all other views once change is made in one view. BIM model is not only a simple graphical 3D model created with graphical elements rather it is generated from a linked data base comprising of information related to the elements of structures and their relationships. BIM models also support data integration and design analysis. BIM software defines objects and adjust their positioning or proportion due to utilization of parametric intelligence which make it less labor intensive and provide maximum protection against creating any inaccuracy or inconsistency in models.

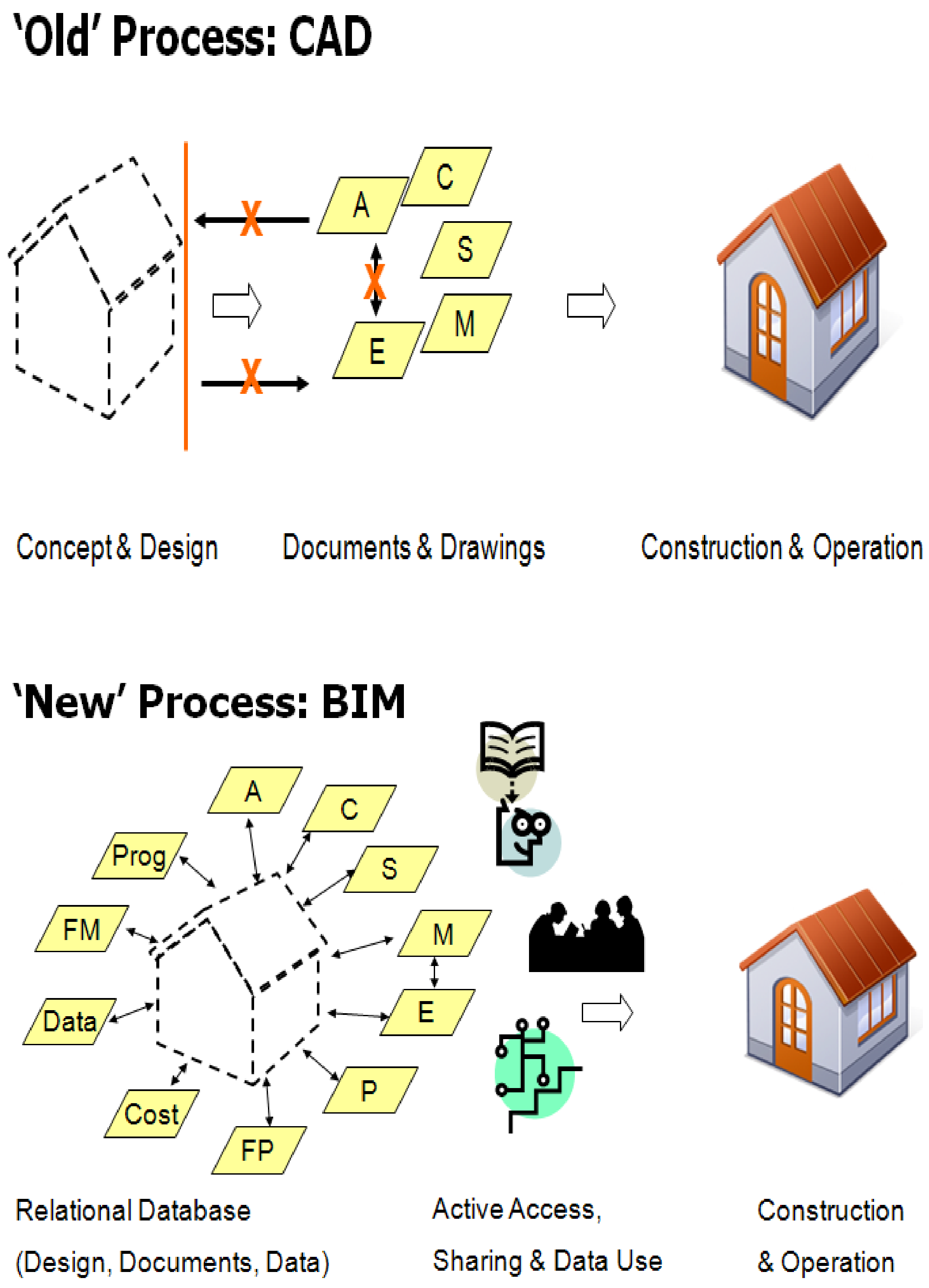

Figure 2.1: A comparison between conventional CAD and new BIM approach

2.3 BIM Applications

Apart from 3D designs, BIM has 4D to n-D applications in CM and AEC industry. BIM process is readily adopted in developed countries like Australia, USA, Canada, Germany and Finland. Results of BIM applications are interpreted as cost and time saving, better performance, optimized design and profitability to the stake holders. BIM is applicable to all the construction phases right from preliminary design to demolition phase.

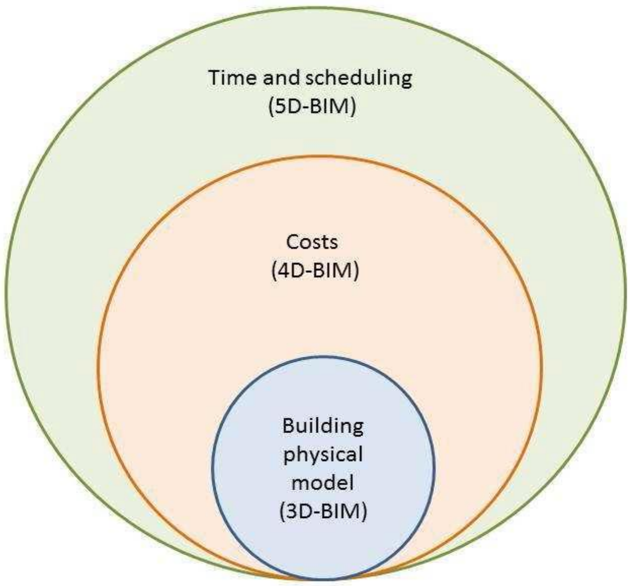

Figure 2.2: Dimensions of BIM

2.3.1 BIM Utilization in Construction Phases

3D Visualization: Semantic visualization of end product and coordination of visual interface checking with Mechanical Electrical & Plumbing (MEP) integration for any conflicts and omission of these clashes at design phase. At design stage identification and omission of errors would save cost and time rather at construction phase.

4D Scheduling and Sequencing: Sequencing of activities along with visualization and simulation of time frame along with construction and also incorporates the scheduling of resources.

5D Cost Estimation: Cost estimation can be done, as in BIM models material quantities are extracted automatically in different material schedule formats and changed when any changes are introduced in the model. Micro and macro cost estimation models can be formed during design and construction phase.

6D Procurement: Details and data about the subcontractors and vendors can be integrated in separated models. Optimization of prefabricated components, structural analysis for loading, lightning analysis for efficient and cost effective lightning system can be done. In mechanical analysis such as Heating Ventilation & Air Conditioning (HVAC) clashes, conflicts and overlapping can be identified in computerized visualization. Energy analysis, delighting, solar analysis, orientation and wind pattern analysis can also be done in virtual environment.

7D Operation and Maintenance: It involves Facility Management (FM) for repairs, renovations, future planning and operation maintenance. Emergency management and safety equipment such as fire extinguishers, fire alarms, smoke detectors, sprinkler system and emergency lighting and power.

2.4 BIM Adoption Benefits

BIM is the new recognized ICT for integrated project documentation and information hence minimizing the data conflicts and better productivity in CI. Bryde *et al*. (2013) carried out the analytical study on twenty (20) projects to sort out the benefits of BIM and formulated the following: control or reduction in cost and time, coordination improvement, collaboration and communication improvement and quality control. Furthermore, many researchers addressed the potentials of BIM for explicating financial and ecological implications simultaneously at early design stage (Z. Ma *et al*., 2012 & J. Basbagill *et al*., 2013). Current benefits of BIM as per United Kingdom (UK) government report (2012) are; about thirty eight (38) percent reduction in total construction project cost and nineteen (19) percent to forty (40) percent cost saving is expected from the design stage alone. BIM survey report (2013) states that the current BIM adoption rate in UK construction sector is thirty nine (39) percent.

Stanford University Center for Integrated Facilities Engineering (CIFE) identified the few noteworthy benefits based on thirty two (32) major projects using BIM (CIFE, 2007):

- Up to forty (40) percent elimination of unnecessary work and unbudgeted change
- Cost estimation accuracy within three (3) percent
- Up to eighty (80) percent time saving in creation of cost estimate
- Up to ten (10) percent contract value saving due to clash detection
- Up to seven (7) percent reduction in construction time

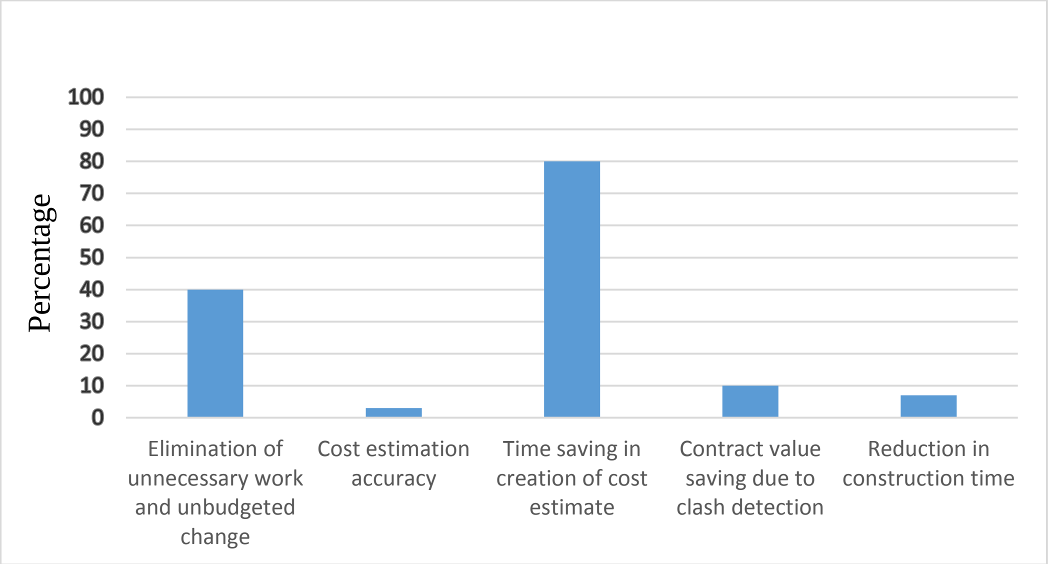

Figure 2.3: Benefits of BIM (CIFE, 2007)

BIM benefits from earlier conceptual stages through design, construction, lifecycle operation and maintenance are greatly recognized for all the three stakeholders i.e. owner, consultant and contractor.

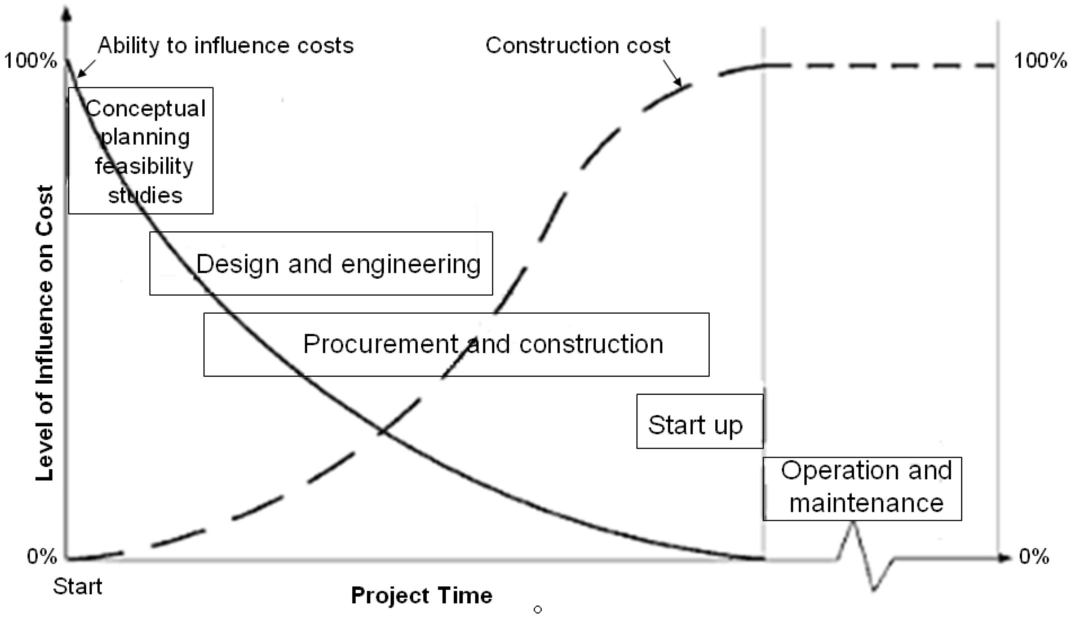

Figure 2.4: Project life cycle - ability to influence cost (Eastman, 2008)

2.4.1 Accurate 3D Visualization of Design

Parametrically accurate and consistent 3D model can be designed directly in BIM software which can be used for visualization at any stage of project. Earlier visualization of project is very important to owner, who is the main stake holder and whose money is involved in all stages of construction. By 3D model visualization he can actually see the final product which is going to be handed over to him. By 3D visualization he can make changes if he wants to do, in earlier stages of design, results in less change orders which ultimately save unbudgeted cost and time. 3D model visualization gives a very little room for any kind of misinterpretation by the stakeholders involved in the project and it also helps them to re-align their expectations (Salazar *et al*., 2006).

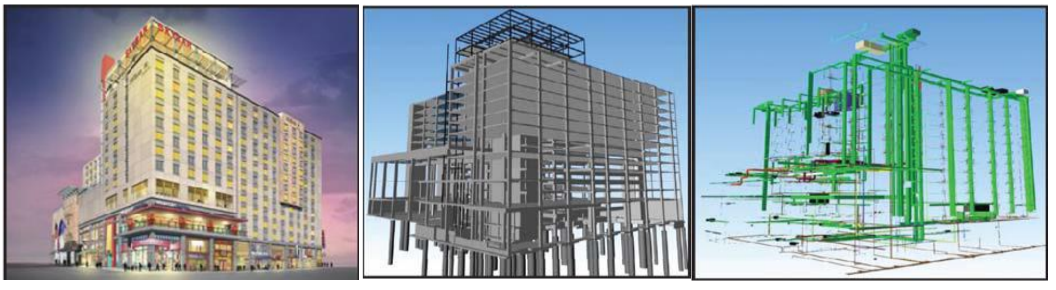

Figure 2.5: Architectural, structural and plumbing models of BIM

2.4.2 Interoperability: Collaboration across Multiple Disciplines and Organizations

BIM facilitates the simultaneous working of different design disciplines. For working in a team BIM have the ability to work on a single model saved as central model and the working models assigned to team members connected to the server. Any work done in working model is automatically updated to central model and at the end of the day one can extract the central model containing all the work. BIM allows the collaborations of coordinated models which shortens the design time and greatly reduces the design errors. As contractors and consultants work on the same model and this model plays a mediating role between the two and designers can act more rapidly on engineering problems faced by contractors and vice versa. Construction organizations are able to more clearly formulate their knowledge of construction problems and ask changes to the model that otherwise would have had to be worked out in the field during construction or later 'with a hammer' (Taylor and Levitt, 2007). BIM gives the solution to minimize the disputes between the design and construction phase by providing a single digital environment in which both designer and contractor working their own way round. Computer model containing the rich information data of project can be handled from one contractor to the other in contracting out regimes.

In common situation, an architect would extract information from the model such as HVAC pressure, wind direction, lighting analysis, and emergence under emergency situations, structural performance and budgetary feasibility, specialized skills and information would no longer be required for data input and result interpreting creating a closer linkage between design process and analysis (Autodesk, 2003).

2.4.3 Clash Detection and Minimizing Conflicts

Clash detection is significant tool of BIM which can reduce the project time and cost efficiently. As coordination between designer and contractor enhanced which lead to less chances of errors results in reduction of legal disputes and a smoother process for whole project team. Major hard and clearance clashes can be detected and highlighted by integrated all the key models together and checked for multisystem interfaces. Major and minor internal conflicts between the structural and MEP design systems can be detected and rectified at early design stages before field construction which can be a difficult challenge at construction phase. The solution can then be checked to ensure that it resolves the problem and to determine if it creates other, unintended, consequences (Ashcroft, 2006).

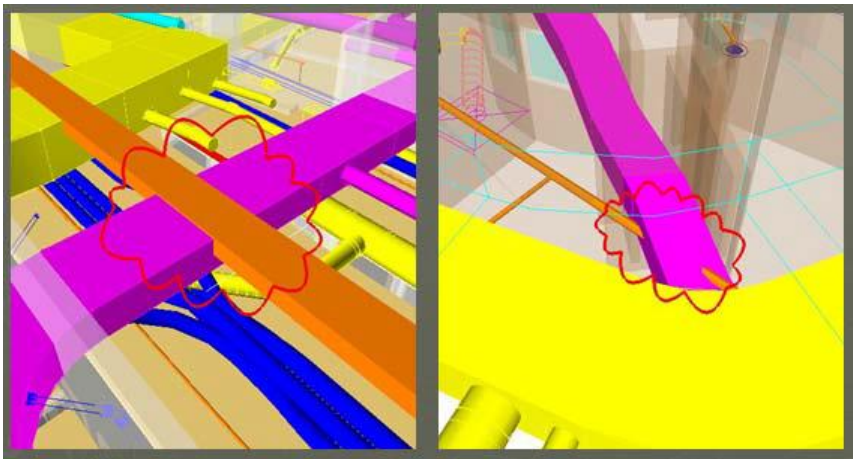

Figure 2.6: An illustration of clash detections via BIM

2.4.4 Quantities and Cost Estimation

BIM technology can be used to extract the Bill of Quantities (BOQs) at any stage of design. Quantities can be automatically take off in BIM software tools by using simple commands and used for cost estimation in design stages. BIM allows the automatically updating of quantities once change is made in model. As the design progress more detail quantities are generated and can be used for more detailed and accurate cost estimates. As stated earlier, up to eighty (80) percent cost saving can be achieved by using BIM technology. Final cost estimate with in the accuracy of three (3) percent, can be prepared based on quantities for all objects contained in the model at final design stage. This helps in making better decisions regarding cost and financial approaches to the project by using BIM technology rather than paper work.

2.4.5 Energy Efficient and Sustainable Design

BIM allows one step ahead green building design by linking the created model to energy analysis tools for evaluation of energy. The capability to link the building model with various analysis tools can give more opportunities to increase the building's energy performance. Solar study carried at early design stages helps in elimination of modifications at construction stage and improves building quality. Lightning analysis can be done for energy efficient design and efficiently save the lightning cost by reducing electricity load.

2.4.6 Construction Sequence and Planning

4D scheduling and sequencing in BIM allows the simulation whole construction process by linking the 3D objects in the design model with a construction plan. The simulation is done in a manner to show what building and construction site would look like at a particular point in time and provides considerable insight how the building will be constructed day by day and reveals the potential problems during construction related to cast and crew, equipment, safety problems and so forth. This type of simulation cannot be done with ordinary 2D and 3D software or paper work. Moreover temporary construction objects like cranes, scaffoldings etc. can be linked with the schedule activities and can be reflected in simulation.

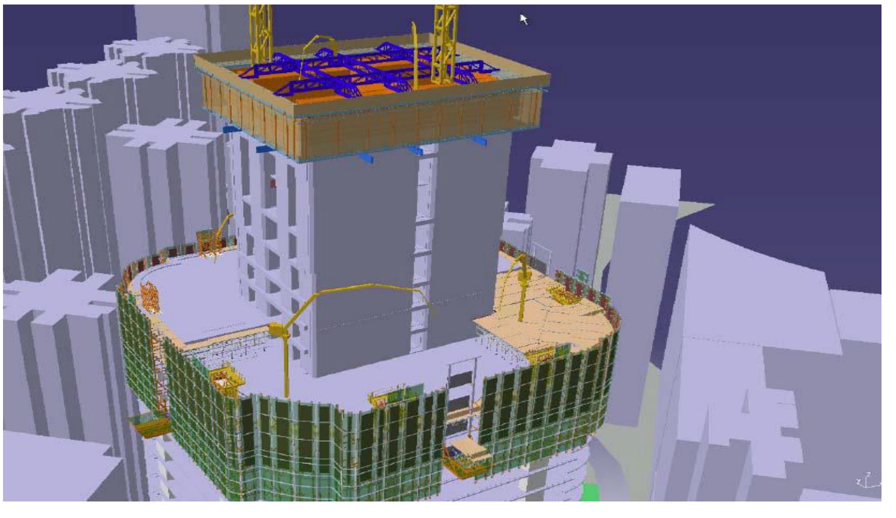

Figure 2.7: Construction sequencing model

2.4.7 Procurement of Materials

BIM can be used to design different kind of models shaped for product vendors and contractors. The quantities, specifications and properties provided for all materials and objects contained in complete building models can be used to procure materials from subcontractors and contractors. The major part of complete data that is included in BIM model comes from fabricators, subcontractors, suppliers and vendors. The accuracy of the data acquired from the data is the same as the accuracy provided in making the model. Since the BIM model contains all the vital details of every element in the construction, this facilitates off-site prefabrication.

2.5 BIM Adoption Barriers and Challenges

BIM is a thriving technology in AEC industry ready to bring huge change in whole construction process. As CI is very resilient to changes and very slow in adoption of any new technology. Initially BIM was not adopted by CI at a rate at which it was expected though now a days it is increasing exponentially. Barriers to the adoption of BIM can be categorize as business and legal issues, technical issues and organizational issues.

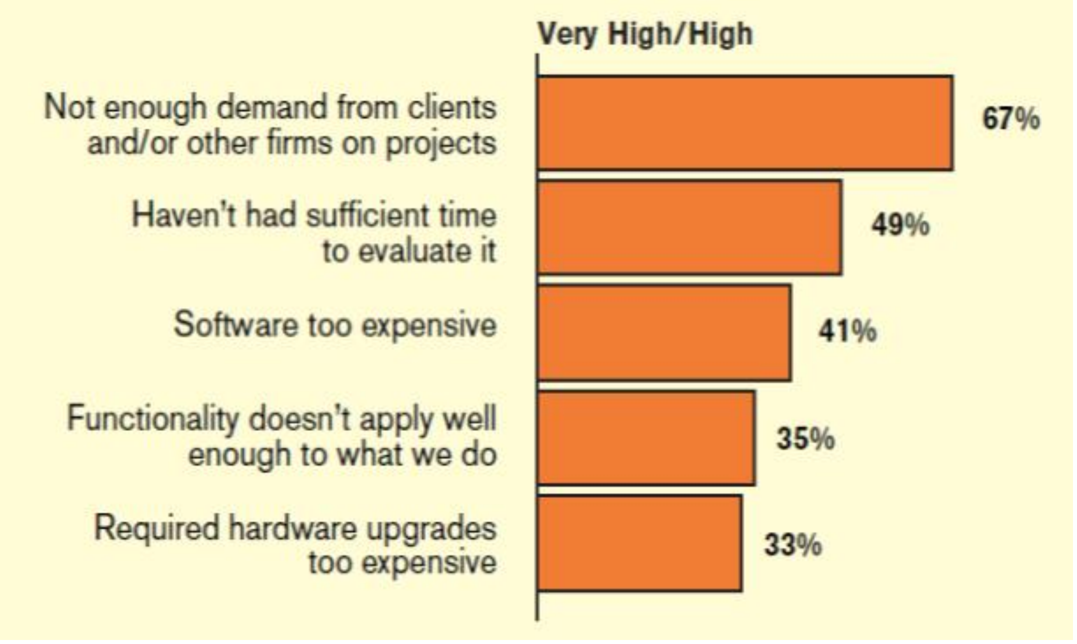

Figure 2.8: Most important obstacles to BIM adoption

2.5.1 Business and Legal Issues

2.5.1.1 Data ownership and risk liability

Due to single complex project file, the legal issues involved with BIM and between working organizations are; who owns the multiple design, fabrication and datasets?, who financially support them?, and who is legally responsible for a faulty design?. The legal issues associated to BIM are identified by Ashcroft (2006) are risk allocation, standard of care, privacy and third party reliance, economic loss doctrine, who is the designer?, Intellectual Property (IP), etc.

As BIM typically involves various architects and design professionals who contribute their expertise and IP to the creation of rich data model. This raises the question of ownership of the IP of model. Other issue is the risk and liability, who is responsible for any defect in the model and failure. As architects creating the seeds for whole BIM model, so Frazer (2006) evokes that it is possible to hold the architects responsible for any defect in the model as architects have IP rights.

Architects have shown reluctance in sharing their models due to risk and liability concerns. This made some contractors to develop their own construction phase models (Batcheler and Howell, 2005). At later stages if there is any model that turns out to be defective, all the professionals would blame the original creator of work. This leads to unusual scenario that the architect initially creates the model would receive immediate benefits but greater risk and liability (Ashcroft, 2006).

2.5.1.2 Data privacy and contractual issues

As a single BIM model is a data rich database which leads to the issues of data privacy and secrets. The problem is also recognized by Drogemuller *et al*. (2006) who states that an auxiliary issue is the ability of firms in construction and FM to manage the shared data and databases. As the data in BIM model relates to the numerous parties involved in its development so contract must address the risk related to the databases in BIM model (CURT, 2006).

Ashcroft (2006) argues that these new approaches will have to be developed to support the collaborative process within a system able to maintain design integrity and discipline.

2.5.1.3 Lack of standards and high cost

BIM standards are in stage of development and no particular standards were defined. So lack of standards lead to ambiguities and legal issues but now people are working and some standard sets are defined and available to cover the issue raised in CI. Professional groups like American Institute of Architects (AIA) and Associated General Contractors are establishing new standard guidelines for contractual forms and language. Also the lack of client demand or market demand due to ignorance and low knowledge of technology and its benefits.

People in industry are not trained as professionals of BIM. If an organization tries to adopt the BIM technology they certainly have to train their employs and also have to buy the BIM software tools and highly efficient computer systems. All these approaches lead to high initial cost and investment. The process to obtain a high level of knowledge and expertise of this software is often very difficult and prohibitively expensive (Bazjanac, 2004).

2.5.2 Technical Barriers

2.5.2.1 Interoperability

In BIM technology a shared building model is intensively used in all construction phases. As a base for whole construction process and collaboration, a set of coordinated building models is used during the process of design, construction and fabrication processes. In order to make a BIM project successful immense inter organizational coordination is needed. Taylor and Levitt (2007) identified the same problem and states that for all construction firms it is important to implement 3D CAD and to adopt and work with same software tools or at least the same standards.

In CI the software vendors launch new and different innovative software tools in order to compete in industry. This make different design and construction firms to work with different software. Once the organizations using BIM, they have to coordinate because of using a single electronic design file throughout the construction process and this collaboration demands the same software by a single vendor or same standard software by any other vendor otherwise the whole structure of collaboration will fail. Files produced in one software format may not be able to open in other software tool which will lead to the failure and delay at any stage of construction. File converter software tools are available in market but actual file is viable to corruption or loss of any crucial data during conversion. So it is important for participating firms and organizations to switch to the same software before working on a project using BIM. Each organization should have the specialized software to perform BIM functionalities because inconsistent adoption pattern will lead to budgetary problems for participating organizations (London and Bavinton, 2006).

2.5.3 Organizational Barriers

2.5.3.1 Lack of initiative and training

Lack of initiative and training can be named as socio-technical issue related to the introduction of BIM. Taylor and Levitt (2007) also recognized this problem and stated that there is a little work in the way of providing guidance to the organizations, working in collaboration, about how to implement the BIM which requires a change in whole process.

Also there is no implication of BIM in educational community which results in untrained staff and graduates. Less or no knowledge about the BIM and cost associated with training is also a major factor.

2.5.3.2 Resistance of AEC industry to change

CI is very resistant and slow to accept any change. It has been number of years people are preparing 2D drawings, manually and by using CAD programs, and working with it. They have their own expertise in this regard and they think they can easily learn and adopt current technologies while learning of new technology is very difficult and hectic work. Most of them are of opinion that if they are good with already available technologies and working satisfactorily then there is no need to learn and implement new technology. Due to these skill issues they are reluctant to any change in industry. For implementation of BIM organizations have to recruit trained and professional personal or existing staff have to be trained to the appropriate level which results in more cost. Construction firms will only able to successfully implement 3D CAD after they obtain sufficient training (Taylor and Levitt, 2007).

2.6 BIM In Education

Support required for advancement and development of BIM comes from more professionals and experts trained in BIM applications and such a support has generally lacked in recent years (Young *et al*., 2008). Essential training in this regard and incorporation of BIM in advanced educational institutes will not only serve the increasing demand of BIM professionals, but also open the new door for students to build their carrier by dealing with occupational challenges and to achieve high efficiency by applying BIM. Some institutes have included BIM in their existing curricula or as a separate course and adopted the integrated approach in line with the requirements of AEC industry. In USA, a number of educational institutions are introducing BIM in their curricula. For example, Auburn University started offering BIM with a one-week tutorial, which was followed by a one-semester introductory course on BIM (Taylor *et al*., 2008).

University of New South Wales, Australia, Queensland University of Technology, Australia, Aalborg University, Denmark, Tampere University of Technology, Finland are examples of some major universities which offer multidiscipline and modeling courses.

2.7 BIM Adoption Survey

In 2014 a questionnaire survey was carried out from the stakeholders of AEC industry in all over Pakistan. Different professionals responded to this survey that included architects, consultants / engineers, general contractors, trade / specialist contractors, design builders / project managers and academicians / researchers. Respondents were asked to rank their level of knowledge related to BIM. Only twenty (20) percent respondents considered that they have no knowledge related to BIM. It is established in this survey that only twenty seven (27) percent organizations are using BIM or involved in BIM adoption process in any capacity whereas seventy three (73) percent organizations are neither using BIM nor involved in BIM adoption process in any capacity. The positive point is that most of AEC professionals are very optimistic about the future of the BIM. Ninety six (96) percent professionals are in favor of implementing BIM in the CI of Pakistan. For future of BIM in Pakistan fifty three (53) percent respondents said ‘Definitely Yes’ whereas only two (2) percent respondents considered ‘No’.

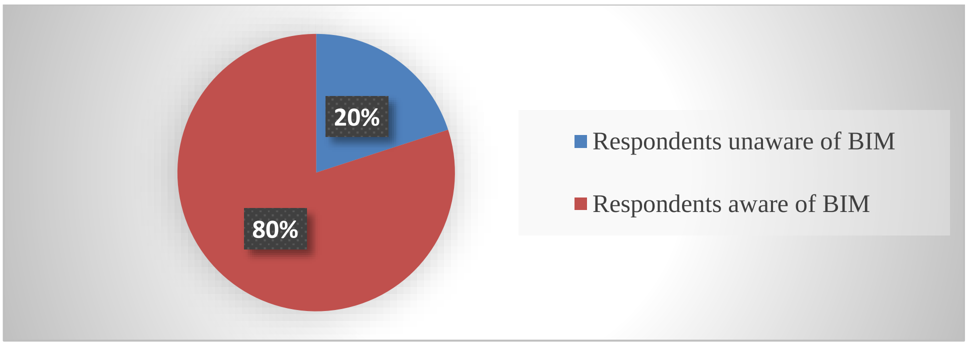

Figure 2.9: Awareness of BIM in Pakistan

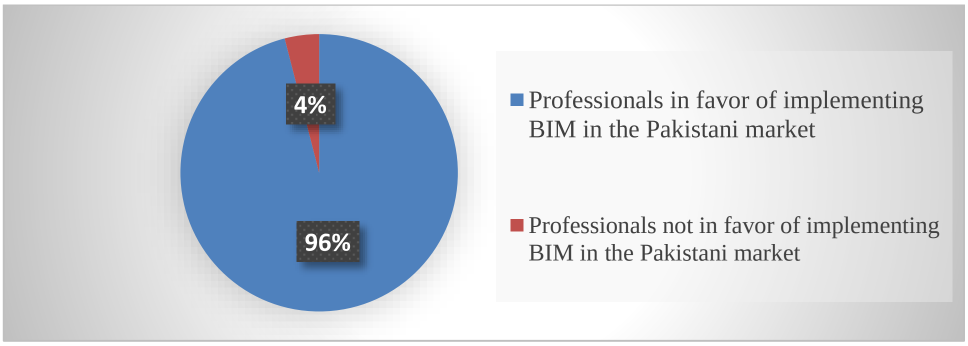

Figure 2.10: Professionals' views on BIM in Pakistan

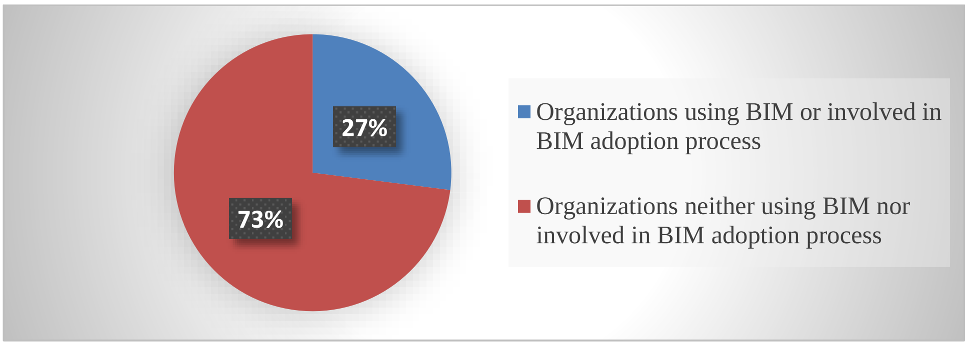

Figure 2.11: Organizational statistics of BIM

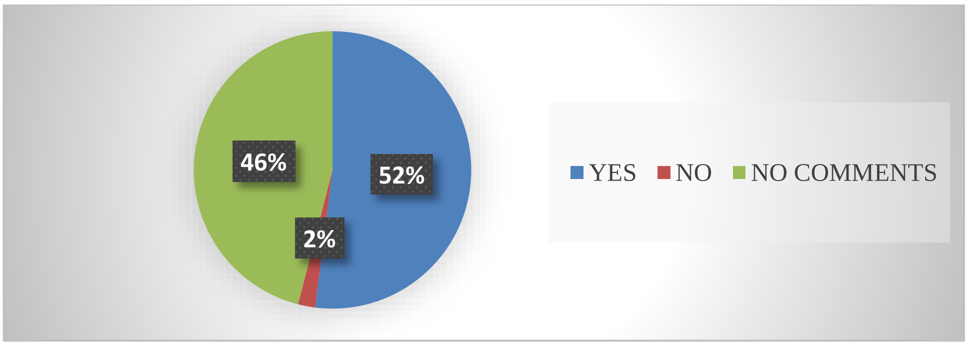

Figure 2.12: Future use of BIM in Pakistan

According to a 2006 survey conducted by the AIA, sixteen (16) percent of AIA member-owned architecture firms have acquired BIM software, and sixty four (64) percent of these firms are using BIM for billable work (Riskus, 2007).

A survey carried out in Finland in January 2007 has shown that use of manual drafting by designers is falling by fifty five (55) percent while that of 2D computer drafting is falling by thirty two (32) percent. BIM is planned to grow by eighty five (85) percent but is defined as any CAD system using 3D data and includes the use of 3D visualization.

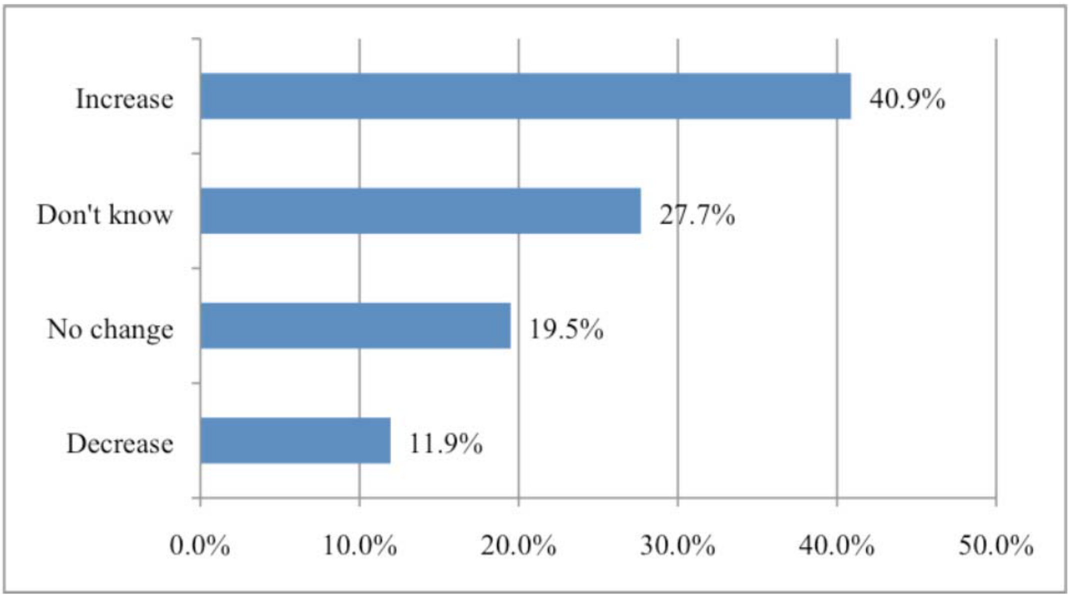

Figure 2.13: Effect of BIM use on project profitability

2.8 Integrated Project Delivery (IPD)

IPD is a relatively new procurement process that is gaining popularity as the use of BIM expands and the AEC FM industry learns how to use this technology to support integrated teams.

BIM is now considered the ultimate in project delivery within the AEC industry (Azhar *et al*., 2008), and has the potential to revolutionize the industry (Gerrard *et al*., 2010).

There are multiple approaches to IPD as the industry experiments with this approach. The AIA (2010) has prepared sample contract forms for a family of IPD versions. They have also published a useful Guide to IPD (AIA, 2010). In all cases, integrated projects are distinguished by effective collaboration among the owner, the prime (and possibly sub-) designers, the prime (and possibly key sub-) contractors.

This collaboration takes place from early design and continues through project handover. The key concept is that this project team works together using the best collaborative tools at their disposal to ensure that the project will meet owner requirements at significantly reduced time and cost. Either the owner needs to be part of this team to help manage the process or a consultant must be hired to represent the owner's interests, or both may participate. The tradeoffs that are always a part of the design process can best be evaluated using BIM cost, energy, functionality, esthetics, and constructability. Thus, BIM and IPD go together and represent a clear break with current linear processes that are based on paper representation exchange of information. Clearly the owner is the primary beneficiary of IPD, but it does require that they understand enough to participate and specify in the contracts what they want from the participants and how it will be achieved.

Chapter 3

METHODOLOGY

3.1 Introduction

Research methodology is a systematic way to solve a research problem. These methodologies may include experiments, surveys, case studies etc. In our study, we have selected a building in Peshawar for case study. The methodology of our project is shown in the following flowchart.

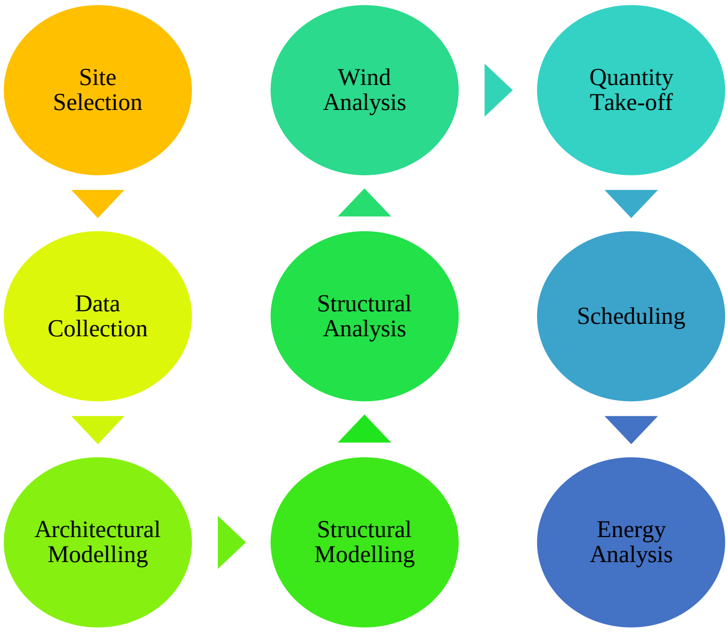

Figure 3.1: Research methodology

3.2 Case Study

For implementation of BIM in Pakistan to small buildings, we have selected an under construction building to apply all BIM tools to know about advantages of BIM and articulate them in a descriptive manner. The building selected is Sardar Khan Plaza which is a commercial building/hotel situated at Grand Trunk (GT) Road, Peshawar. The building is four (4) storied and also have a basement. Ground floor comprises of shops and upper stories are used for hotel or residential floors so designed accordingly. The main objective of the project was to construct the 3D model of this building using the tools of Autodesk Revit and visualize the project in an efficient way. Then to take off the quantities by using Autodesk Revit and

Autodesk NavisWorks 2015. In Autodesk NavisWorks 2015 the schedule was also incorporated and the sequencing of the activities was also done. This sequencing would help in smooth flow of the project and also used to provide the required space for the machinery to be used in the construction phase. Basic energy analysis of the building was also conducted using the online tools of Green Building Studio.

3.3 Project Description

Sardar Khan Plaza is located at GT Road, Peshawar. Client of the project are owners, Sardar Khan and Sher Mohammad S/O Adam and contractor is a private firm and the drawings were provided to us by Project Manager. The total area covered by the building is around 3130 square feet and the building has four stories and a basement. The purpose of building would be to provide the commercial facilities to the people of that area. An elevator is also provided for the purpose of cross level movement. The salient features of the building are:

- It is RCC structure with raft foundation. The load is transferred to the soil through two (2) feet raft
- In basement six (6) inches monolithically cast retaining walls are provided with columns to retain the soil and stand with soil pressure
- Various openings are provided in each room of the building to ensure good cross ventilation and make less use of energy to make it sustainable
- There is a central opening in each floor slab to ensure good light during the day and roof opening is covered with a frame sloped glass

The selected building is now complete and being constructed with the traditional techniques. Parametric model of this building was developed and the study is conducted to compare the two systems and apply the applications of BIM to the buildings to make it more economical and also energy efficient to ensure the demands of sustainable development as well. The building is chosen because the purpose of the project is to set a path for the implication of BIM to the small commercial and residential buildings of Pakistan. It is a typical commercial building and almost 90% of commercial buildings in Pakistan are of same type with a few changes. This indeed was a good project for the consideration of the study of BIM techniques.

The architectural, structural and electrical drawings were provided by Project Manager for the development of parametric model of the building. The architectural drawings included the floor plans of all the floors, the schedule of openings, site details and few sections and elevations of the building for detailing purpose. According to the plans provided in the drawings the model of the building was prepared using Autodesk Revit 2013. After that, structural model was prepared. It included foundations, columns, beams and slabs. The reinforcement was also provided in the structural model as well. Accordingly the electrical layout was also incorporated in the model and false ceiling was provided in architectural model. The model was then exported to Autodesk NavisWorks 2015 for sequencing of the activities and quantification. The model was then exported to Autodesk Service Green Building Studio for its basic energy evaluation.

The process of developing a BIM model of the building was not an easy task. It required a lot of research and we had to pass certain rigorous hurdles to be able to achieve an effective BIM model. Starting with the limitation of the computer memory available, (since BIM model software tools demand high memory on the RAM of the computer) to certain limitations of the software and we had to add certain plugins to overcome those limitations. Along with that the CAD drawings are very prone to errors and proper understanding and deletion of those errors took a lot of time. There was no expert available to guide about the contingencies and ambiguities during the work. So with all these hurdles, one need a shear will, cool temperament and consistent hard work to complete all these tasks.

3.4 Work Flow

In the following lines the phases of the development of the model are described.

- Development of the architectural model
- Converting the generic model into material specified model. All the original materials used in the construction of the building were incorporated in the building
- Certain families that were not available in the Revit predefined libraries were developed and accordingly incorporated in the model

- The structural framing of the building was done and the reinforcement was placed in the framed structure
- The architectural and structural models were then exported to Autodesk NavisWorks 2015 for quantification and scheduling of activities
- Structural model was then exported to Robot Structural Analysis Professional 2015 for structural analysis and wind simulation
- The model was exported to online Green Building Service Analysis tools for energy analysis

3.5 Modelling Procedure

Commencement of parametric model preparation set forth with the start of architectural model which later on followed by the structural and MEP model. The architectural model was prepared as per the drawings provided by the Project Manager. Drawings consisted of 2D AutoCAD plans, sections, and elevations along with electrical and plumbing drawings. First of all the generic model was developed and later on addition of materials, fixtures, and families were incorporated.

3.5.1 Architectural Model

Architectural model was made in Revit Architecture. Steps used to develop an architectural model are:

3.5.1.1 Grid establishment

In Revit, grid is first to be established to specify the boundary of the model and to complete the building within the bounds of grid. The vertical lines of the grid were named in alphabetic order and the horizontal in numeric order. The intersection points of vertical and horizontal lines of grid were mostly the points where columns were situated. Establishment of grid made our work easy as there was no use of scale afterwards because the grid lines effectively dictated the room and extreme boundaries.

3.5.1.2 Frame structure

As the grid intersection points were providing the column’s location, so as specified in the drawing the columns of appropriate dimensions, (given in the design) were placed in Revit. To complete the frame of the building, beams were placed above the columns. As this was a generic architectural model so the frame developed was without any reinforcement.

3.5.1.3 Floor levels

Addition of floor levels is an example of Revit being so user friendly. Revit made it just a matter of clicks. In any of elevation north, south, east or west, levels can be created at appropriate height and floors of specific thickness can be incorporated at these levels. So the floor levels were created and the grid, columns and beams already generated were copied to the selected floor levels. In this way, the maximum height of the building was reached.

3.5.1.4 Raft and retaining walls

Building consists of a basement containing retaining walls all along the perimeter and raft foundation. Generic concrete raft of two (2) feet depth was created at level zero (0). Retaining walls six (6) inches wide all along the perimeter joined with columns were also created to form a basement.

3.5.1.5 Walls and shafts

As per the specifications the walls were incorporated in the building. We started off with the exterior walls of the building followed by the partitions among the shops and rooms of the building. The shaft for the elevator and stairs was also incorporated in the model. There was one thing that required to be taken care of while making the walls. While we were working on the architectural model, the section details of the walls were not already incorporated. Later on when we added the material layers to the walls, the interior spacing of the room was shortened and was not matching the already designed spacing. Thus it is advisable to generate the walls in a way that all the wall section details are already incorporated in the structure, to avoid the hectic work of dimensioning the spacing of the rooms again.

3.5.1.6 Openings

In Revit, openings are among the component family which always need a host family to install them. As Revit is parametric intelligent software so all openings need a host like walls to place them in drawings, so you cannot create an opening without a host although there is a procedure to form a pseudo host. In Revit adding an opening is just drag and drop system. Select a door or window family (also can edit the family and save it in any special cases), adjust dimensions and place it on a wall.

3.5.1.7 Slabs

Revit makes it very easy to place a slab at any level selected with addition of choice of materials. Slab families are available and can be edited, you just need to select a slab of particular material and define the boundaries by picking up the walls (can also draw boundary lines) and done. In our case material of the slabs were same for each floor (six (6) inches concrete slab + two (2) inches terrazzo) so we selected six (6) inches generic concrete slab and edited to add two (2) inches finishing material (terrazzo) and copied this slab to other levels.

3.5.1.8 Roof

Roof placement is very much similar to the slabs but difference lies in materials. Roof materials were different like insulation and roof tiles and all the materials were added to the roof as per drawing specifications. Of course roofs are provided with a slope in order to drain the rain water out of it, these slopes can be defined during the generation of roof. Besides flat roof slabs in Revit, sloppy roofs can also be constructed virtually with different material applications.

3.5.1.9 Stairs

Stairs in Revit can be generated by one of the two methods: by sketch or by component. We have generated the stairs by using sketch method, defined the riser, tread and top and bottom level. Landing was formed automatically and the top finishing material was terrazzo and one-fourth (¼) of an inch nosing was provided. The sketch ends automatically when the predefined height is reached.

3.5.1.10 Railings

Railings were consisted of hand rail, guard rails and we can also edit its path and material by our choice whether we like glass or steel railings. In order to provide railing with stairs, we have to check the railing option during the generation of stairs. Railings other than stairs can also be created by railing option and defining the path.

3.5.1.11 Glass roof

Opening in the center of the building was covered with sloped glazed glass roof. Aluminum mullions of rectangular shape were used in which glass was fit. Its main purpose was to provide the light in the building during daytime. It was created by using glazed glass curtain roof and slope was defined in addition to the panel sizes, mullions and materials.

3.5.1.12 Site

Site topography can be created in Revit by using topo surface tool and picking the point at desired level. We can also define the materials like grass, soil, asphalt or concrete. We have generated the topographic surface at GT Road level and it comprises of some parking components, GT Road asphalt strip, and one link road passing besides the building.

Figure 3.2: Architectural modeling in Revit

3.5.2 Structural Physical Model

For starting structural model the architectural model was linked in the Revit structure template. The shared elements between architectural model and structural model (such as Grids, columns, beams, floors) were copied. The remaining structural details were then added to the model. This is also required for combining the models for 4D simulation and material takeoff.

3.5.2.1 Raft foundation and basement retaining wall

First step was adding foundation to the model. Using slab-on grade tool raft foundation with beams was laid. A retaining wall around the basement is added up to the ground floor.

3.5.2.2 Structural columns

From top of foundation structural columns were added up to the roof level. The column dimensions changed above the ground level, so column dimensions were changed accordingly.

3.5.2.3 Structural beams

Beams of different dimensions were first defined and then beams of particular dimensions were placed at their respective levels and locations. The advantage of Revit is that at any moment during modeling we can change any element, its properties and locations etc.

3.5.2.4 Structural slabs

The structural slabs of particular dimensions and materials were drawn along the perimeter of the story. In order to show all concrete elements as monolithic the alignment tool was used to make the elements aligned.

3.5.2.5 Shafts and openings in slabs

Openings of specific dimensions for open to sky places and for stairs and elevators are drawn at respective positions and slabs. This can be done very easily in Revit. As same openings are repeated on the upper floors, so the shaft and openings were copied up to top roof level.

3.5.2.6 Placing of reinforcement in the model

Manual placement of reinforcement in Revit was difficult compared to other work that was done in the software. There were bars, stirrups and tie bars of specific shapes available in the software, but bars of different shapes and with different hooks were to be edited and sketched manually which was a cumbersome process. In slabs and raft foundation reinforcement bars with specific spacing can be easily done using area method. For retaining wall path method of reinforcement placement was used. But for columns and beams cross-sections must be taken at respective location and reinforcement placed according to the drawing. But it can also be made easy by placing reinforcement in a beam or column and then copied and placed in similar beam or column. Revit gives better visualization of reinforcement. Fig. 3.3 shows reinforcement detail of a typical beam-column joint.

But real advantage of Revit is that the structural model prepared in it was exported to an analysis and design software where after final designing, the model was imported into the Revit and the model updated accordingly. For example Robot Structural Analysis Professional 2015 was linked with Revit model. The analytical model was sent to Robot Structural Analysis Professional 2015 where the model was analyzed and reinforcements were generated automatically according to ACI code specifications. The model was then updated in Revit and the reinforcements were automatically placed.

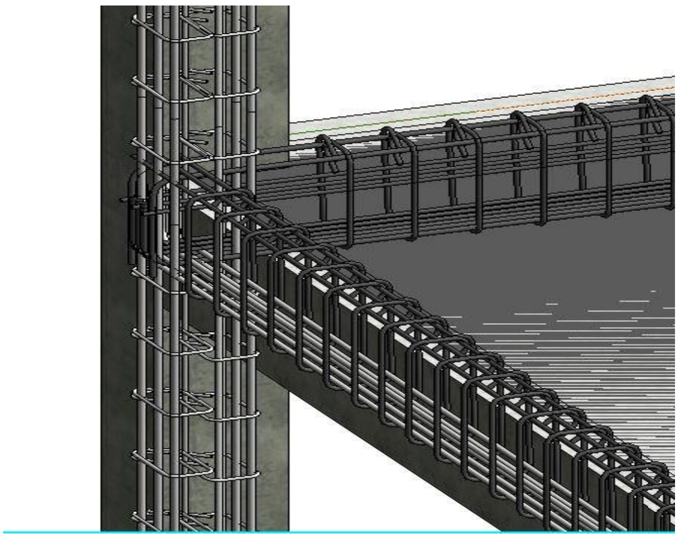

Figure 3.3: Reinforcements at typical beam-column joint

3.5.3 Analytical Model

With physical modeling of building in the Revit, the software automatically generated an analytical model (as shown in Fig. 3.4) corresponding to the physical model. The model showed beams and columns as lines and slabs and walls as lines along the perimeter. This analytical model is the central model for the structural designer, which they use for different analysis and design in different software. Otherwise, in traditional designing the structural engineer prepares separate analytical model for each software which is a laborious work and prone to more mistakes and errors. The ability of Revit to interoperate with a number of software like ETABS, SAFE, STAAD Pro, Robot Structural Analysis Professional 2015 etc. makes it more suitable for structural designing. For designing, the analytical model is prepared in Revit by applying required loads and applying suitable boundary conditions. The model is then exported to the particular software where the model is analyzed and each structural element is designed and then the model is imported back in the Revit. The model is automatically updated in Revit with any changes to any element done in other software.

The main advantage is that the design and documentation process is integrated in BIM. The structural designing process is a trial and error base process. During the designing of model its detailing is also done simultaneously. But if after some work the structural designer make some changes to the structural elements, the corresponding structural drawings must also be manually changed, which is a laborious process and is one of the error prone process. By integration of designing with documentation it results in smooth design process, increases efficiency and reduces errors. The changes made to the model e.g. change in the element dimension, change in reinforcement etc. will automatically update in all views related to the element. Another main advantage is that structural drawing sheets can be prepared in Revit with all details required by a contractor.

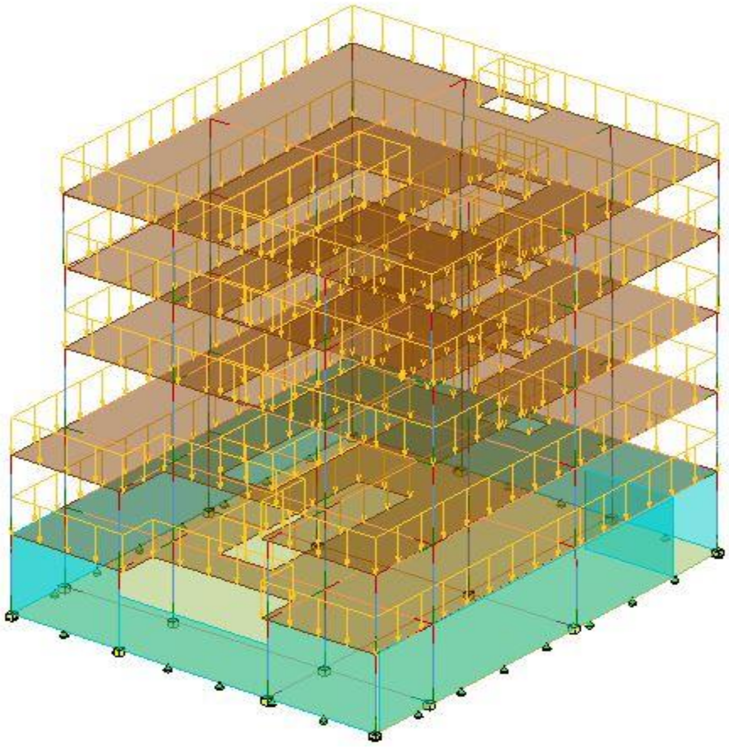

Figure 3.4: Analytical model in Revit Structure showing loads and boundary conditions

3.6 Structural Analysis

After structural model was completed in Revit, it was sent to Robot Structural Analysis Professional 2015 for analysis. The analytical model was adjusted and checked for consistency. After that suitable boundary conditions were applied to the foundation and general live load value for hotel/plazas was applied to the model using area loads. After model was prepared in Revit it was sent to the Robot Structural Analysis Professional 2015. The material properties and loadings defined in Revit can be exported to the software, it can also be easily defined in Robot Structural Analysis Professional 2015. When model transfer was completed, it was then analyzed. Robot Structural Analysis Professional 2015 creates automatic meshing for slabs and walls. Different colorful results for moments, reactions, stresses, soil pressure, deflections etc. can be obtained (Fig. 3.5 & 3.6 shows deflection map and bending moment diagram respectively). Values at all nodes can also be obtained in tabular form which is an added advantage for structural designer. The results can be easily exported to other file formats.

Designing of individual element in Robot Structural Analysis Professional 2015 can be done easily. Select a beam or column, it will give the loads and moments acting on the element. Select a suitable building code and desired configuration for the reinforcement, Robot Structural Analysis Professional 2015 gives the area of reinforcement for an element and places the reinforcement in the element according to code specifications and desired configuration. Structural drafting can be done in Robot Structural Analysis Professional 2015 and structural drawing sheets can be obtained. The designed model can also be imported back to Revit, the model is updated and it will import all the reinforcement for all the elements.

Similarly, Revit can also interoperate with other software like ETABS, where the model is analyzed and designed and imported back and updated in Revit. This collaboration makes the designing process error free, quick and smooth.

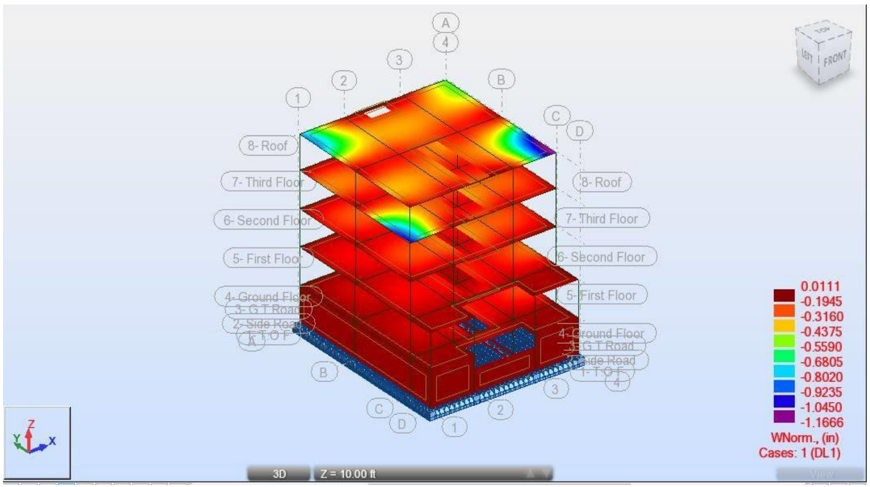

Figure 3.5: Deflection map in Robot Structural Analysis Professional 2015

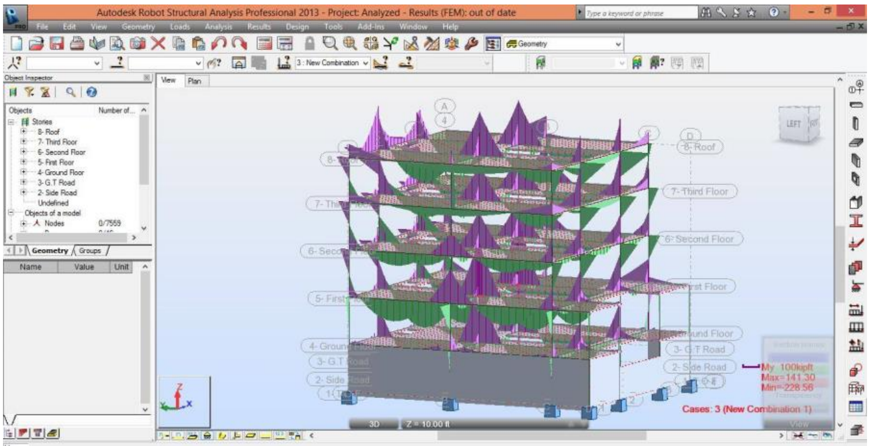

Figure 3.6: Moment diagram in Robot Structural Analysis Professional 2015

3.7 Wind Simulation

For high rise structures wind loads are an important design factor. Wind load depends on the geographical location where the building is located, influence of nearby structures, topography and the proposed building orientation. Robot Structural Analysis Professional 2015 has wind simulation tool which can be used during the designing process. The wind simulation tool in Robot Structural Analysis Professional 2015 enables the structural engineers to determine the wind load effects earlier in the design phase, and any design changes to the building can be made early, preventing from the repeated analysis and design process. Wind load parameters such as: wind direction, wind velocity, terrain elevation, load generation requirements, and the wind profile along the height of the building are entered in the wind simulation dialog box. These parameters enable the users to customize the analysis to fit the building and site characteristics. Once the analysis is started the program generates automatic wind loads according to ASCE 7 code provisions. It shows the wind pressures produced in the building due to wind loads. The results of analysis can be viewed in tables, figures, equations and moving simulation.

For wind simulation the model was exported to the Robot Structural Analysis Professional 2015, where necessary loads were defined and applied. For wind effects claddings were used on the outer parameter of the building to resist the wind load and transfer its effects to the main structural elements. Once the model was prepared, wind simulation tool was started. Hypothetical values for wind direction and wind velocity were applied. The software automatically generated wind loads and calculated the pressure values for the structural elements. Fig. 3.7 shows the pressure on elements with wind direction in (X+Y+).

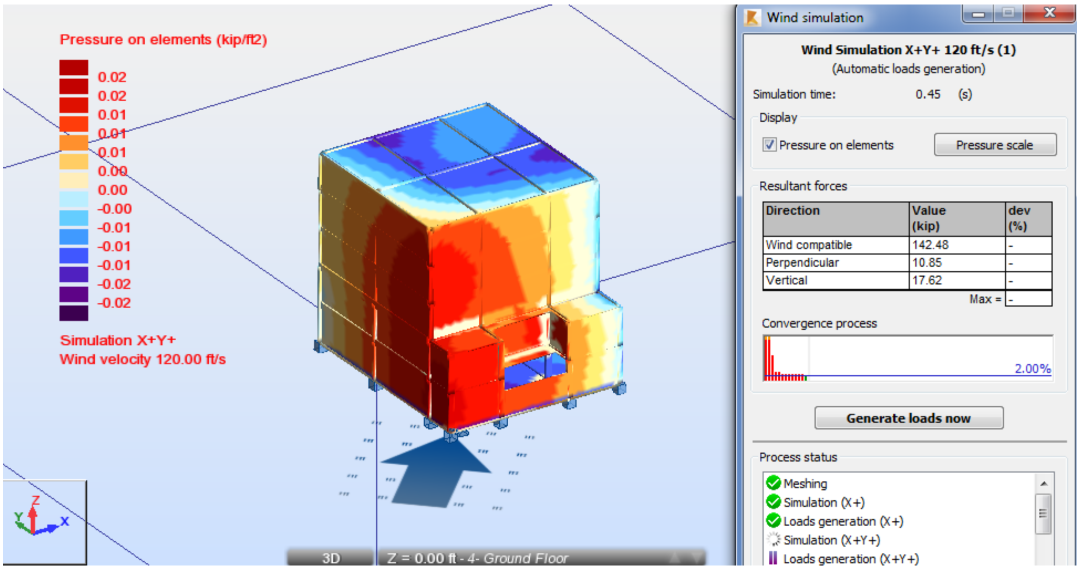

Figure 3.7: Wind analysis in Robot Structural Analysis Professional 2015

3.8 Quantity Take Off

Detail sheets and material take off was done in Revit. Revit produces document sheets which cannot be further worked upon. For quantification, the model was exported to Autodesk NavisWorks 2015 for the generation of reports for quantities. These reports can be exported to excel and can be further worked upon. In our scope we have determined the quantities of the all the materials used in the building. These quantities are then combined in the form of detailed report and attached in the appendix of this report.

3.9 Scheduling

The model was exported to Autodesk NavisWorks 2015 for the simulation of sequencing of activities during the construction phase of the building. All the activities were scheduled in Autodesk NavisWorks 2015 itself and a timeline was created showing the completion of activities in a sequence. Activities can be scheduled in Excel or Primavera and linked in the Autodesk NavisWorks 2015 as a CSV file. The Excel or Primavera schedule can linked to the model of the building and the virtual simulation of the building process can be visualized with respect to the associated schedule.

3.10 Energy Analysis

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.

- By using conceptual mass 63
- 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 is selected to run energy simulations based on architectural elements of the building. Rooms were 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. Study for illumination (as shown in fig. 3.8) was carried out using the Autodesk 360 Green Building Studio and rendering was done to give the architectural and realistic view. Also night artificial lights and solar study was carried out by using the same tool.

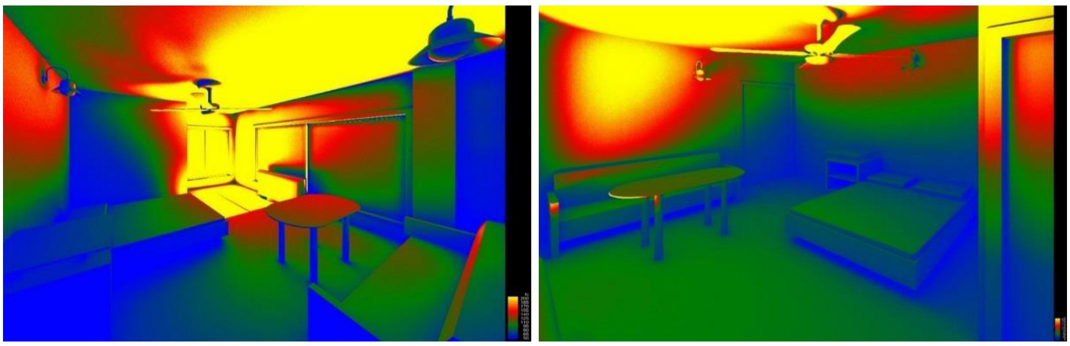

Figure 3.8: Illumination study of solar light

Figure 3.9: Night artificial light analysis

Chapter 4

RESULTS AND ANALYSIS

4.1 Introduction

The purpose of the project was to learn, set a path of the application of BIM to the typical small buildings of Pakistan and accordingly formulate the advantages of BIM in AEC industry. Building selected for BIM application was an under construction commercial building depicting all the typical constructions in Pakistan. It is a four story building and covers an area of one hundred and ten (110) square feet providing the commercial facilities to the people of area. Building consists of a basement formed by concrete retaining walls and located on a corner plot. This chapter comprises of the results of case study which includes 3D modelling, quantity estimation, scheduling, structural analysis and energy analysis.

4.2 Errors In Drawings

BIM is an ideal visualization tool for the AEC industry. The traditional design methods had been very much intermingled, so prone to errors and require a lot of thought process for understanding it. Due to the limited capabilities of CAD technology important features of the building has to be ignored and no details of those features can be provided at the planning phase which causes a lot of problems at the planning phase of the project, because the owner is not able to visualize what the original outcome would be. Due to this reason a lot of change orders during the construction phase of the project need to be issued and it causes a lot of contractual misconceptions among the project stakeholders and conflicts arise at the later stage of the project.

These errors could also be result of inexperienced CAD operator or may be some kind of mishap, as CAD tools are not intelligent and you are not able to realize what you are making in the CAD window. Another disadvantage of CAD system is that it has been drawing each and every object as a separate entity and the concept of interoperability is not available in CAD, however while working on BIM technology we know that all the objects are interlinked by parametric relations and any change in one view would result in the change of properties in all the corresponding views of the objects. Thus the chances of errors in BIM model are reduced to a very less level. We had to deal with a lot of errors in the drawings and those drawings were accordingly adjusted after consultation with the field engineer and the project manager of the project.

There were some errors in the drawings in which the structural components of the building were clashing with the openings in the project. What happened in our project was that the column sizes were different and their placement in drawing was so intermingled which caused a lot of problem in modelling. Project manager was contacted and asked about the column locations. Site was visited to know the proper location of particular columns and it was a drawing mistake. Since traditional CAD models were incorporated in the building and it could not have been updated in the model. If it had been BIM model, the changes in the model would have been applied in the project accordingly. This is one of biggest advantage of BIM technology that the drawings could be updated at any stage of the project without any extra efforts.

Another change in the project was that the north east corner of the building was changed originally, however the drawings were still the same and modifications were not added to the base drawings. BIM provides the facility of applying any change in the project at the later stage and automatically all the project stakeholders at any stage of the project.

BIM also ensures enhanced collaboration between different team members of a project e.g. architect and engineer, this enhanced collaboration and work sharing allows coherent working of the team members. All stake holders are on the same page and disparities are eliminated. However in this case, due to lack of collaboration between the architect and the engineer there were numerous ambiguities and inaccuracies in the architectural and structural drawings. At times the location of beams and columns in structural drawings would differ from that in architectural drawings. BIM tools would have provided a robust collaboration between the two team members and the difference in their drawings would have been negligible or none at all.

4.3 Quantity Take Off

For the purpose of quantity take off a number of software tools are available. The Revit model can be exported to these software tools and accordingly the quantities of the materials can be estimated. Assemble has been one of the effective software available for commercial use in the market. Since it was not freely licensed for the students as the products of Autodesk are, we could not use it in our project and we had to shift ourselves towards Autodesk QTO. We found that Autodesk QTO is now incorporated in Autodesk NavisWorks 2015 as its tool named as Quantification. We downloaded Autodesk NavisWorks 2015 and used it to take off quantities. We have also generated material quantities and schedule sheets in Revit but the Revit documents cannot be further worked upon. So we have quantified the material quantities in Autodesk NavisWorks 2015 and it is a good estimation software but it also has certain limitations in its applications and therefore has been a cause of headache to us during the estimation process. In Autodesk NavisWorks 2015 quantification tool has the ability to estimate the quantities after you determine to calculate it linearly or in volume form. The further information available, like productivity, labor force available, the resources available could then be incorporated in Autodesk NavisWorks 2015 and then the report would be generated which would be a detailed report in the form of BOQ of the project. This BOQ is provided in the excel form. The quantities determined from the QTO were then compared to the original BOQ of the building manually generated by the contractor of the project. The quantities estimated had been almost accurate with the slightest of errors. This allows us to motivate the AEC industry to adopt BIM technology in their construction process because it is more easiest way to be incorporated in the design and would get more accurate as further advancements in the software is available.

4.4 Advantages Of Bim To Project Participants

During the case study certain advantages had been established for all the project participants which are described here in detail.

4.4.1 Architect

A designer needs to be very experienced to visualize the tools available and a considerable amount of time is required to its applications, however in BIM model the designer could work in multiple views at the same time and the automatic generation of 3D model enhances the visualization ability of the designer.

As these tools are incorporated in the project, separate plans, sections and elevations of the same object needs to be prepared which is not linked to each other in any way. In BIM model making the sections and elevations is just a click of mouse away. These sections and elevations are as per the plans and the separate human effort induced is reduced while the use of BIM model.

The work gets cumbersome and is prone to a lot of errors. The model generated by the use of traditional tools is only for the purpose of visualization and no information about the materials used or section properties are provided in that model. The model generated by BIM tools is intelligent and can be used for further applications of BIM tools like energy analysis or structural analysis.

If at any stage of the project the designer desires to bring about any kind of change into the project, he needs to do that separately in all the views related to that object. However in BIM model any change can be made at any time in the project. Since the views are interlinked, so any change in any of the view would automatically change the properties of the objects in the simultaneous views.

The cost estimation is done manually and they are prone to a lot of errors, since a lot of things could be missed out in the manual estimation however BIM provides an accurate quantity take offs form the model prepared.

4.4.2 Structural Engineer

The structural model is separately prepared for analysis which is time consuming, whereas Revit automatically generates the analysis model along with physical model.

Since the analysis model prepared has no link with the CAD model of the project generated so this model generated is time consuming and also prone to a lot of errors. However in BIM modeling the analysis model is directly linked with the physical model and any change there would automatically be incorporated in the drawings. This is subsequently time saving technique as the change in any view changes the properties of entire family rather than changing the properties in all the concerned views as happening in the traditional modeling.

4.4.3 HVAC Engineer

In the traditional designing tools only the layout of the ducts was given, no details about the thickness of the duct, about the places where the connections would be provided was given due to limited capability of the 2D CAD tools. Due to the 3D modeling available the plan as well the elevation of the layout is also made.

Traditionally the contractor decided about the details of the section of the ducts on site after reviewing all the spaces available, making the job more difficult, however in BIM model detailed sketches are made at the planning phase of the project.

There is huge chance of a lot of clashes among the different components of the building however in Revit 3D model the clashes are reduced due to better visualization of the model and also a clash detection report is generated which would remove any missed out clashes in the project. This would allow the work on site to pace up.

If at any stage of the project the designer desires to bring about any kind of change into the project, he needs to do that separately in all the views related to that object. However in BIM model any change can be made at any time in the project. Since the views are interlinked, so any change in any of the view would automatically change the properties of the objects in the simultaneous views.

4.4.4 Plumbing Engineer

Lack of ability to identify conflicts due to the 2D representation of the designs. However Revit would let you identify and let you decide what to be done about it if any kind of clash arises.

The lack of identification of conflicts results in the construction process. The BIM tools provides the solution for clashes and the time is saved.

The designer is always having a fear in his mind that whether or not his design would fit into the system, thus he provides only the layout; however in revit the designer designs with confidence with removal of any kind of errors or conflicts in the design. Lot of rework is needed to remove the clashes on site, which is not needed in case of BIM modeling.

If at any stage of the project the designer desires to bring about any kind of change into the project, he needs to do that separately in all the views related to that object. However in BIM model any change can be made at any time in the project. Since the views are interlinked, so any change in any of the view would automatically change the properties of the objects in the simultaneous views.

The conflicts are identified after the budgets are approved, which is ultimate cause of conflict between designer, contractor and owner and in this case a lot of RFI"s would be generated for the cause, which is reduced in case of BIM modeling.

Traditional designing requires a lot of site supervision to effectively carry out the works, since a lot of ambiguities occur in the design. The Revit design is mostly clear and no extra explanations are needed.

4.5 Problems and Hurdles

Lack of knowledge and experience about BIM and the use of its tools in the CI was a major hurdle. We were basically on our own when it came to learning the use of BIM tools. Whenever there was an issue in modeling, we had to apply hit and trial approach applying various solutions to our problems posted on the internet. This was a time taking process.

Acquisition of computer systems with heavy specifications, with capability to smoothly run the Revit software was a major problem. As the size of the project files increases the system virtual RAM requirement increases. Rendering process specially necessitates the need to acquire such computer systems.

There were several ambiguity/errors/omissions in drawings provided to us by Project Manager. Several beams and columns were misplaced in the plans, sections and plans had contradicting information. This impeded our progress and was cleared by discussions with the colleagues working on same project and by examination of the as-built structure.

For online rendering and energy analysis process high speed internet availability is required which is also a major problem and causing delay in project.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Application of BIM to a real life project helped us to draw the conclusion that due to its efficiency and advantages BIM should be adopted and implemented in AEC industry in Pakistan. Conclusions drawn from the project are following:

- BIM can be used to produce high quality drawings with less errors and in less time with minimum effort. BIM drawings are less viable to errors and can be updated at any point of time in project. So BIM should be adopted to produce high quality drawings
- Architects should adopt BIM because it gives them more flexibility to visualize the end product in early stages and can introduce changes with greater flexibility. Architects can make different designs in less time and can proceed with one selected and can modify the design according to owner's wish in design stage, omitting the chances of change orders during construction
- BIM includes the documentation process and simulation of activities in a dynamic timeline in association with time of activities which is impressively beneficial for a project manager to compare its work whether he is on schedule or lacking behind
- Since BIM provides a single analytical model for all the structural design process, so it reduces errors in design and increases efficiency of the design team
- Same model is used in quantity take off of the building, therefore it creates detailed takeoff based on the intelligent model. Care should be taken while developing the model to ensure accuracy in quantities
- Now a days, energy efficiency is more concerned part in building constructions. BIM allows and facilitates the performing of energy analysis of model which results in energy efficient and ecofriendly design

5.2 Recommendations

The advantages of the BIM modeling have been discussed in detail in the report. It is highly recommended that steps must be taken for the adoption of this technology in the AEC industry. The adoption of BIM would certainly benefit all the project stakeholders and also reduce the time taken and cost of the project.

- Since BIM allows you to visualize the end product at the very beginning phase of the project it removes the ambiguities of the project participants about the project. BIM allows you to remove errors in the drawings, remove clashes between components and getting detailed sections giving the benefits to the project participants, it is highly recommended to efficiently use this technology.
- High memory computers should be made available before the application of BIM for the design process.
- The scope of this project only covers the typical 4 to 5 story buildings in Pakistan which involves no HVAC system. Work can be done on high rise buildings which also includes the complex HVAC systems and plumbing facilities. High rise buildings can be modelled in BIM tools and clash detection can also be done (which is an important BIM tool) to check the clashes between structural and MEP model. Autodesk Revit and Autodesk NavisWorks 2015 can be used for clash detection. Moreover there is more scope of work in using different analysis tools like shadow analysis, HVAC load calculations and energy efficient design.

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APPENDICES