INFORMATION MODELING
OF ATC TOWER, NEW ISLAMABAD INTERNATIONAL AIRPOT (NBBIAP) ALONG WITH RISK ASSESMENT

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Bachelor of Engineering in Civil Engineering

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This is to certify that the

Report entitled

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Has been accepted towards the partial fulfillment of

the requirements for

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ABSTRACT

Although Building Information Modeling (BIM) is emerging in the construction industry in Pakistan, it is viewed as the new incipient technology in the world of building industry in most developed countries. BIM maybe inexistent as yet in most of the underdeveloped countries but such countries are darning their ways to become more suited to adopt this attractive technology. BIM offers a better ability to plan, simulate, manage and execute the complete project life cycle consuming powerful BIM tools. The main objective of this project is to develop BIM model of Air Traffic Control (ATC) tower of NBBIAP and to run analysis such as QTO, clash detection and to create a model WBS using appropriate BIM tools for each task. A 3D BIM model of the building was made first, comprising of an architectural model and a structural model. This all was accomplished using Autodesk Revit 2013 and Autodesk Revit 2015 software. QTO of the model for cost estimation purposes was generated using Revit and Navisworks. Clash detection of our model was done by using Autodesk Navisworks. The results reinforced the belief that BIM tools provide better ability in planning and managing large building projects.

DEDICATION

We would like to dedicate our efforts and this report to all the construction workers of Pakistan, on whose 'shoulders' stand the nation. They are the ones who bring dreams into realization and to whom we owe the gratitude for taking on the harder and unacknowledged part of the job. We would also like to dedicate this report to children of Army Public School martyred in cowardly attack by terrorists

ACKNOWLEDGEMENT

We would like to express our gratitude to all those who gave us the possibility to complete this project. We would like to thank our project adviser Dr. M. Jamaluddin Thaheem who encouraged us to go ahead with our project and for his conscientious guidance and encouragement. His comments reflected his experience as a counselor and as an engineer; his actions manifested his willingness to devote his time and energy to help us, by always being available despite his busy schedule.

We also want to thank the Pakistan Civil Aviation Authority for giving us such a golden opportunity to commence this project in the first occurrence.

Most importantly we would like to give special thanks to our parents whose patient, love and prayers enabled us to complete this work. And at last but not the least, we would like to thank God for the successful completion of our project

LIST OF ACRONYMS

AEC	Architecture, Engineering and Construction
AHU	Air Housing Unit
BIM	Building Information Modeling
CAD	Computer aided design
FEM	Finite Element Method
LAN	Local Area Network
LOD	Level of Detail
NBIMS	National Building Information Modeling Standard
NBS	National BIM Survey
MEP	Mechanical, Electrical and Plumbing
ROI	Return on Investment
BOQ	Bill of Quantities
HVAC	Heating, ventilation and air conditioning
IFC	International Finance Corporation
RFI	Request for information
API	Application Programming Interface

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CHAPTER 1

INTRODUCTION

Widespread works have been done to make the most out of ever growing technological advances in all arenas of science; the harvests of such works are nothing less than wonders, from space investigation to Nano technology, from internet to curing diseases and from erecting magnificent skyscrapers to building mammoth dams. Technological advances have made possible what was only fanaticized half a century ago. Engineering fields have specifically seen a boom and their productivity as well as innovation have shot sky high with technological advances. In the case of civil engineering, technology has led to the construction of 30-storey building in merely 15 days (Ark Hotel in the Chinese city of Changsha, Hunan province). You can effectively cure concrete working in Antarctica's subzero temperatures (Korhonen 2003) or in the Sahara's blazing hot weather (Hampton 1981) with the right mix design and the appropriate technology employed to provide suitable curing conditions. There are now tunnel boring machines to cut through earth with pace which could have never been imagined before. In short technology has provided construction industry with amazing tools and methods to build dreamlike structures. However it has been noticed that construction industry has not experienced the same increase in productivity which other disciplines experienced due to technological advance (Teicholz 2004). The level of uncertainty associated with a construction process is usually high (Hendrickson 1998). Limitations in the planning process lead to delays during construction. These limitations are mostly due to the fact that collaboration and information sharing between different team members has been poor. Stakeholders involved usually are not on the same page with regard to the methodology to achieve the final outcome of the project (Sequeira 2007). Also the inability to foresee the issues that could arise in field such as working space limitations, collision of building elements, clash of working schedules of different project teams etc. was another major factor affecting the productivity of a construction process (Emmitt, Gorse et al. 2003). Thus it was the need of time to develop tools which provide better collaboration between stakeholders and a virtual environment able to imitate the real building process providing enhanced visualization for the issues which could arise during construction process. Building Information Modeling (BIM) promises to overcome the above mentioned issues. It is a process envisaging the complete building life cycle from its conceptual design to facility management and demolition phases. BIM utilizes different tools for different purposes. All these tools are compatible with each other thus not only reducing the repetitive work and allowing focus to be more on planning than on modeling but also providing a robust link for collaborative work between different team members of a construction project. BIM modeling tools generate parametric 3D models which possess all the information related to a project (Carmona, Jorge et al. 2007). These BIM models are imported to other tools for different purpose like QTO, simulation (scheduling), structural analysis, energy analysis, clash detection etc. Studies have shown BIM to be rapidly growing trend in construction industry with more construction firms preferring it (Sattineni and II 2011) and states like the UK encouraging the adoption of BIM given vast application and benefits its promises.

1.1 Objective

The objectives of this project are following:

- To learn about BIM.
- To create a BIM Model of building in order to do quantity estimation, create a model WBS and run clash detection between different building elements.
- To explore the areas where BIM can help improve efficiency of a building design process.

1.2 Reason/justification

The reason for selection of this project is to facilitate the introduction of BIM in local industry where it is least known among professional engineering firms by providing an insight into the possibilities a BIM process provides and to bring to light the advantages and limitations of BIM in a third world country such as Pakistan.

1.3 Advantages and educational outcomes

The project provides a document that will help the engineering firms analyze the BIM process, its tools, work and the benefits. The document provides insight to encourage firms to go for BIM.

1.4 Area of application

The outcomes of our project are applicable on the broader scale of construction industry. The BIM model developed is utilized throughout the life cycle of a building from estimation, creation of WBS and clash detection in the design phase to the generation of construction and shop drawings as well as providing better visualization for the risks assessment and mitigation during construction phase. The same model can be utilized in facility management operations.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

2.1.1 Construction Productivity

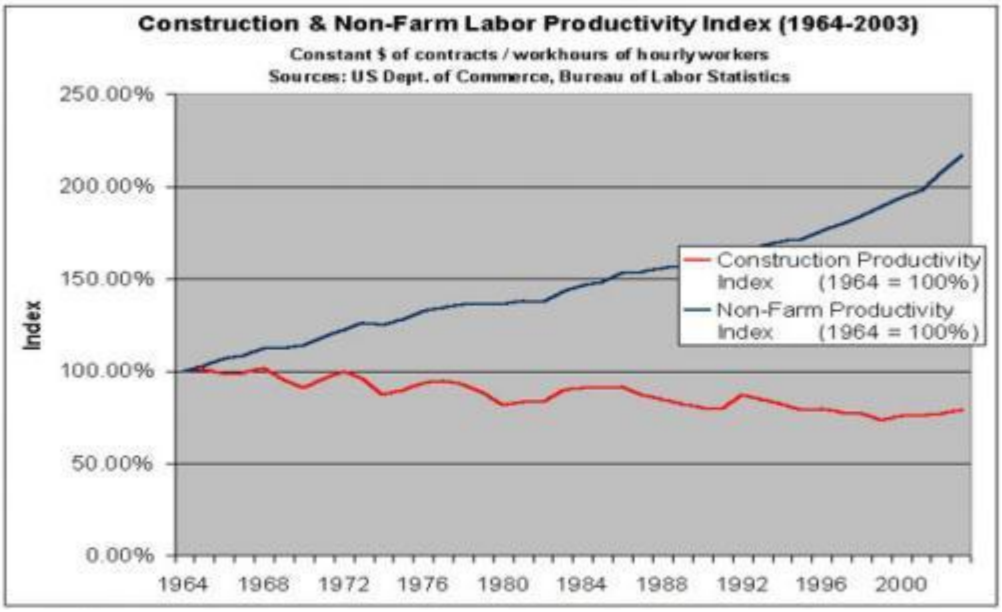

Figure 1 Construction and Non-Farm Labor Productivity Index (Teicholz, 2004)

The construction industry of the world is experiencing a gradual decline in its productivity since 1960's while other industries are improving their productivity at a considerable rate. This trend is visible in Figure 1

Fragmented nature due to traditional project delivery approach, use of traditional 2D Computer Aided Drafting (CAD) technology and the size of constructions are the main cause of lack of labor productivity in the construction industry (Teicholz 2004).

Traditional construction project delivery methods like Design-Bid-Build hinders the collaborative involvement of project stake holders during the design phase of the project. Use of traditional visualization and project planning techniques like two dimensional nonintegrated CAD drawings and scheduling techniques usually pose conflicts of information which result in construction delays and inefficiency in labor productivity.

Moreover many researchers and practitioners have identified that poor performance such as scope changes, lack of proper planning and scheduling, design errors and omissions, improper management of equipment, tools, labor and materials among many other factors are due to poor management practices currently practiced in construction industry (PEng 2009).

2.1.2 Importance of Communication in Construction

Communication is an important topic in the construction industry. Many problems in construction are referred to as communication problems (Emmerson 1962) ; (Higgin and Jessop 1965); (Latham 1994) ; (DETR 1998).The industry forms a complex communication environment due to its specific nature. Construction is a fragmented and dynamic sector with a project based nature. The efficiency and effectiveness of the construction process strongly depend on the quality of communication.

Talking about the construction site, it is the job of Project Manager to organize the information arriving on site, often it happens that workers are not notified or the accidental use of old drawings lead to larger or smaller occurrence of mistakes. (Richter and Koch 2004). A study conducted in 2004 by NCC and DTU shows that 61% of errors made during construction were due to lack of communication and cooperation. Table 1 shows the percentage shares of all tumbling stones.

Table 1: Percentage-Share of all Tumbling Stone in the Case Study

Weakness in	Percentage share
Communication & Cooperation	61
Design Activities	45
Work Organization & Planning	42
Project Review	36
Execution of work on site	34
Process and work control	29
Weather and Theft	20
Access to skilled labor	15

(Richter & Koch, 2004)

2.1.3 Development of 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

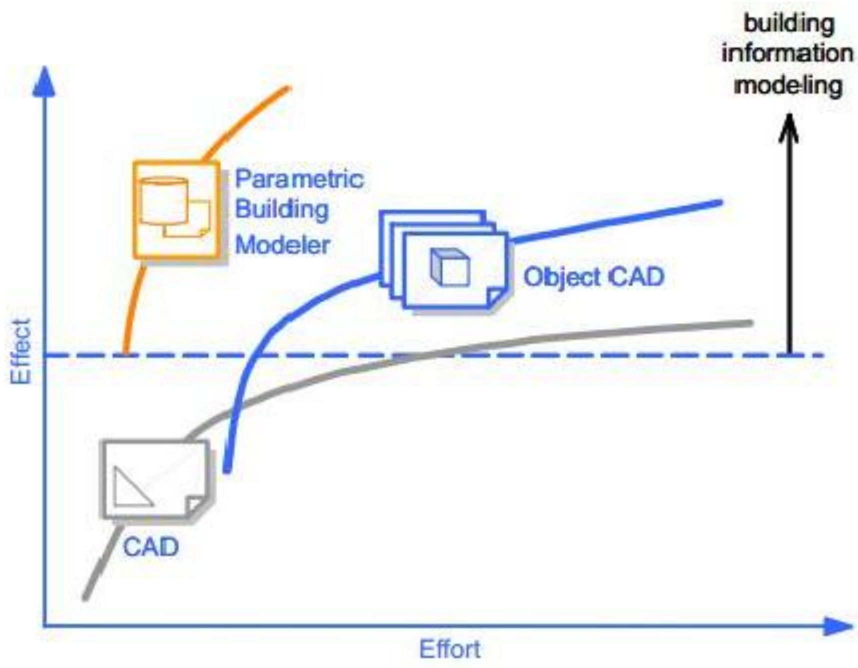

Figure 2 Effectiveness and effort required to achieve technology (Autodesk- Whitepaper) (Autodesk 2003)

In the figure 2 provided the vertical axis represents the effectiveness of the three mentioned technologies while the horizontal axis shows the effort required to achieve that level of benefit or effectiveness. The horizontal dashed line shows the minimum degree of effectiveness that can be termed as building information modeling. Below this building information modeling threshold are traditional industry processes while above this line are increasing degrees of building information modeling effectiveness. The three solid lines represent the level of benefit achievable at a given level of effort using these three different technologies.

2.1.4 CAD Technology

The gray line in the chart represents CAD-based technology that is in use traditionally for decades. 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.

2.1.5 Object CAD Technology

The blue line on the chart represents software based on Object CAD which 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.

2.1.6 Parametric Building Modeling Technology

The orange line on the chart shows parametric building modeling technology which is equivalent to the decision support systems adopted in the financial 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 Building Information Modeling (BIM)

2.2.1 Definition

The National Building Information Modeling Standards (NBIMS) committee of USA defines

BIM as follows: "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. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (NBIMS, 2010)."

The US General Service Administration (GSA) BIM Guide (2007) defined Building Information Modelling (BIM) and Building Information Model as follows: Building Information Modeling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views appropriate to various users' needs can be extracted and analyzed to generate feedback and improvement of the facility design.

BIM also provides consistent and interlinked views of the digital model including reliable data for each view. This is a time saving feature for the designer as coordination of views is done through programmed intelligence of the model. According to the National BIM

Standard, Building Information Model is “A digital representation of physical and functional characteristics of a facility and 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” ("About the National BIM Standard-United States", 2010). Building Information Modeling (BIM) is a platform for data sharing between project stakeholders while carrying out design and construction throughout project’s life cycle process and practice of virtual design and construction throughout its lifecycle.

2.2.2 Types of BIM

2.2.2.1 Hollywood BIM

BIM being used only for developing 3D models and other features of BIM, not utilizing the advanced features of BIM. Contractors may use it to win contracts without utilizing full potential of BIM.

2.2.2.2 Lonely BIM

BIM being adopted internally within a single organization and data not being shared with rest of stakeholders.

2.2.2.3 Social BIM

It is a more inclusive approach which allows for data sharing related to project plans between the engineer, architect, construction manager, and subcontractors.

2.2.2.4 Intimate BIM

When the designer, owner and contractors share the risk and reward through integrated project delivery using BIM. Intimate as well as social BIM encourages the production of better drawings, reduce time and cost, collaboratively (Hergunsel 2011).

2.3 BIM Application Areas

A building information model can be used for the following purposes:

2.3.1 Visualization

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

2.3.2 Fabrication/Shop Drawings

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

2.3.1 Code Reviews

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

2.3.2 Forensic Analysis

A building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans, etc.

2.3.3 Facilities Management

Facilities management departments can use BIM for renovations, space planning, and maintenance operations.

2.3.4 Cost Estimating

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

2.3.5 Construction Sequencing

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

2.3.6 Conflict, Interference and Collision Detection

Because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences (Azhar, Nadeem et al. 2008).

2.4 Advantages of BIM

The efficient and accurate 3D representation of the building parts of a project is the main advantage of BIM (Innovation.2007). Other benefits of implementing BIM are explained in the Table 2:

Table 2: Advantages of BIM Implementation

Life Cycle Phase	Benefits
Planning	• Provide easy and quick alternative analysis • Facilitates analysis of the building. • Provide easy quantity and cost estimates • Facilitates specifications development
Design	• Improves coordination • Provide easy information exchange • Provide auto code checking • Facilitates easy tracking of design changes

Construction	• Reduce interpretation problems • Improves coordination among various trades • Reduces Request for Information (RFI) • Reduces material value • Reduces Constructability problems • Facilitates proper equipment selection • Provide more safe work environment
Operation and Maintenance	• Reduces down time • Provides easy access to maintenance records, warranties, installation and operation manuals • Reduces rework and wastage • Resolves space management issues • Facilitates emergency evacuation planning

(Meadati, Irizarry et al. 2010)

Stanford University Center for Integrated Facilities Engineering (CIFE) survey showed following statistics concerning BIM benefits (CIFE. 2007)

- As much as 40% termination of unbudgeted change.
- Cost estimates with accuracy within 3% range of actual cost.
- Up to 80% time saved to generate QTO.

- Due to conflict detections, savings of up to 10% of the total contract value can be made.

- Project Time period reduced by an amount as much as 7%.

2.5 BIM in Construction Industry around the World

BIM is rapidly developing among Construction and Architecture Industry. By 2016 all British Public Sector Projects will be carried out using BIM. According to NBS- National BIM Report 2013, 95 percent people of construction industry of Britain are now aware of BIM i.e. now almost a common word, 54 percent are aware and currently using BIM, while a very small amount 5 percent neither know about it nor they are using it (NBS 2013).

Similarly in North America adoption of BIM increased rapidly in the past few years. (McGraw- Hill Construction SmartMarket Report), 2012 that BIM adoption in North America is increased to 71% in 2012 from 49% in 2009 and 28% in 2007 respectively.

This rapid increase in adoption is happening because of the following reasons mentioned in Figure 3.

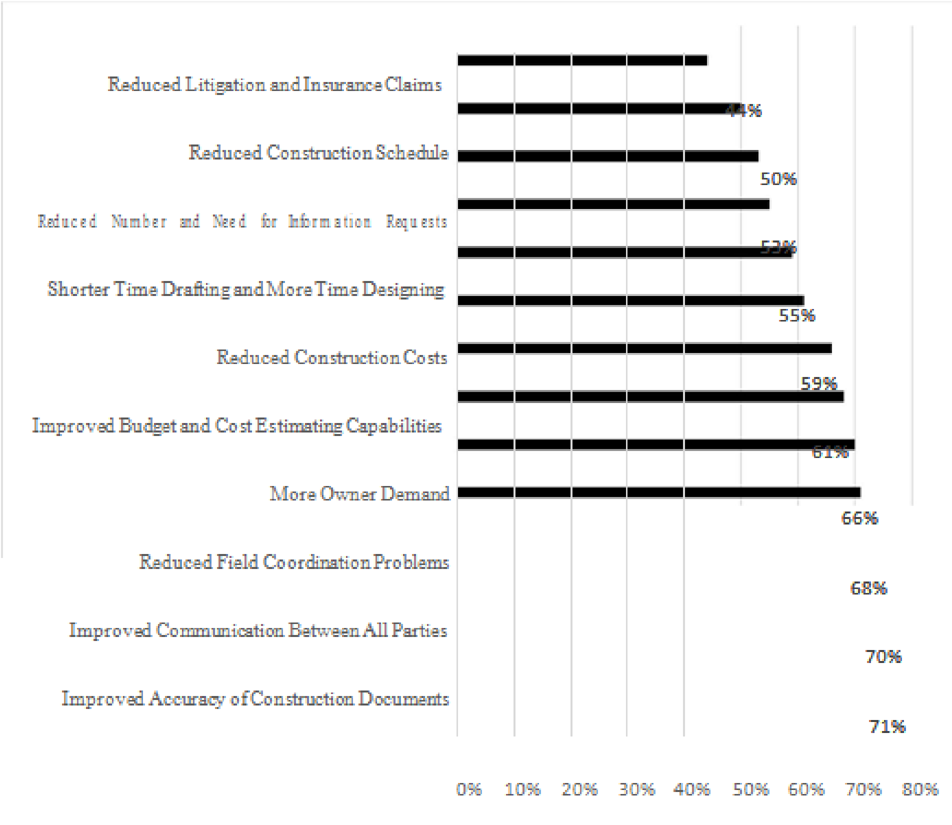

Figure 3: Factors Influencing Non Users to Adopt BIM (McGraw-Hill Construction 2012)

2.6 BIM Tools

Various software are used across the construction industry as Building Information Modeling tools, they are summarized in Table 3.

Table 3: BIM Tools

Company	Software	Primary Usage
Autodesk	Revit	BIM Model generation
	Navisworks	Clash Detection, 4D Scheduling, Quantity Takeoff
	Robot Structural Analysis	Structural Analysis
	Green Building Studio	Energy Analysis
Graphisoft	ArchiCAD	BIM Model generation
	Estimator	Estimation
	EcoDesigner	Energy Analysis
Bentley	AECOsim	BIM Model Generation
	Project Wise Navigator	Review and Analysis
Tekla	Tekla Structures	Structural Model generation and Detailing
	Tekla BIM sight	Review and Analysis
Vico	Vico Control	4D Scheduling
Synchro	Takeoff Manager	Quantity Takeoff
	Synchro Professional	4D Scheduling

Innovaya	Visual 4D Simulation	4D Scheduling
	Visual Estimating	Estimation
	Visual Quantity Takeoff	Quantity Takeoff

2.7 Project Life Cycle and BIM

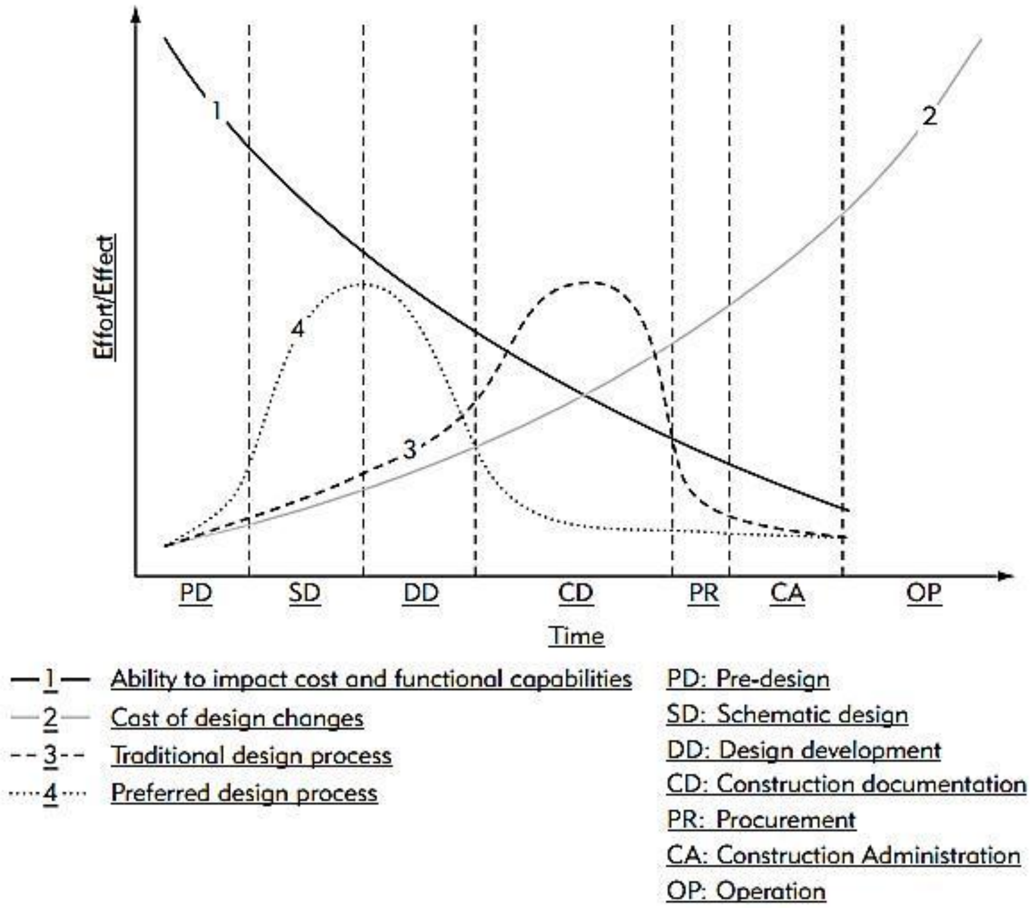

Figure 4: Value added, cost of changes, and current compensation distribution for design services. (Patrick Mac Leamy, CURT (2007)

BIM automates standard forms of detailing, thus significantly reduces the amount of time required for producing construction documents. The general relationship between design effort and time is illustrated in Figure 4. Line 3 shows the effort traditionally distributed and effect on it by application of BIM is shown by Line 4. The change in the distribution by BIM aligns effort more closely with the value of decisions made during the design and build process shown in Line 1, and the growth in the cost of making changes within the project lifetime shown in Line 2.

Early design decisions highly impact on overall functionality, costs and benefits of a building project, emphasized in the Figure 4. This change in distribution of effort is also affected by the delivery method and contracting. This change is resulting in the change of fee structure of design firms reflecting the value of decisions made during the schematic design and the reduced amount of effort required for producing construction documents (Eastman, Teicholz et al. 2008).

2.8 Level of Detail in BIM

As defined by (Bedrick 2008), Level of Detail (LOD) is *"the steps through which a BIM element can logically progress from the lowest level of conceptual approximation to the highest level of representational precision"*. There are five levels of detail to describe the BIM models, which are named from Level 100 to Level 500: Conceptual, Approximate Geometry, Precise Geometry, Fabrication and As-built. Different LOD in different project phases are defined in Table 4 (Bedrick 2008; Leite, Akcamete et al. 2010) LOD of the models moves to higher level and richness of information improves as the project progresses. Cooperation of all parties involved in the project like architects, engineers, estimators and scheduler is require to embed the information in model according to its requirement.

Table 4: LOD Definitions (Bedrick 2008; Leite, Akcamete et al. 2010)

Project Phase	LOD 100	LOD 200	LOD 300	LOD 400	LOD 500
Design	Conceptual Non-geometric lines, areas or volume zones	Schematic /Preliminary Three dimension-generic elements	Detailed Specific elements with dimensions, capacities and space relationships	Construction Shop Drawing/fabrication With manufacture, installation and other specified information.	As built
Scheduling	Total Project Construction duration	Time-scaled, ordered appearance of major activities	Time scaled ordered appearance of detailed assemblies	Fabrication and assembly detail including construction means and methods	
Cost Estimation	Conceptual cost estimation	Estimated cost based on measurement of generic element	Estimated cost based on measurement of specific assembly	Committed purchase price of specific assembly at buyout	As built cost
Energy Analysis	Strategy and performance criteria based on volumes and areas	Conceptual design based on geometry and assumed system types	Approximate simulation	Precise simulation based on specific information	Commissioning and recording of measured performance

2.9 BIM in Construction Management

The decisions made by the contractor directly influence the progress and cost of a project. As much as 30% of the cost of construction is wasted in the field due to coordination errors, wasted material, and labor inefficiencies and other problems in the current construction practice (CURT 2002). BIM reduces above mentioned inefficiencies consequently enhancing the productivity and decreasing the cost of the project. According to (Gallaher, O'Connor et al. 2004), the estimated "cost of inadequate interoperability in the U.S. capital facilities industry is $15.8 billion per year" and the AEC industry are targeting to reduce this $15.8 billion losses by providing a more integrated project life-cycle. The utilization of BIM in estimating and project controls to increase efficiency of a plan is described as follows:

2.9.1 Cost Estimation in BIM

Decision making in any project is solely dependent upon cost and environmental impacts. Both of these factors require quantities of the material being used in the project. Considering the dynamic nature of such construction projects, accurate quantities are required in a timely manner.

Traditionally, estimators used the 2D drawing sheets to perform the quantity takeoff. Alder (2006) described the challenges of this method as follows: "Unfortunately for large projects, manual takeoff can be a very time consuming and tedious task. An estimator must use a well-organized systematic method of takeoff to avoid missing or double counting items. An estimator must also take special care when transferring measurements to their ledger by verifying that each measurement is recorded correctly. Additionally, the ledger must be organized in a way that when changes occur or measurements must be verified the estimator can easily review the calculations performed" (Alder, 2006).

Using BIM technology quantity takeoffs can be generated directly from the model. The most effective thing about this process is that the information remains consistent throughout the project and the changes can be accommodated easily. BIM has the capability to support complete project lifecycle and can be beneficial for the integration of costing efforts throughout the project phases. The different phases of the project determines what type of information is required in a model and type of cost estimate needed i-e from high level schematic drawings during the pre-programming stage to the detailed working drawings as construction is about to start, the data can easily be extracted out from the model saving a lot of hectic calculations and time consumed (Sabol 2008). Figure 5 shows the manual estimating process compared with model based estimating.

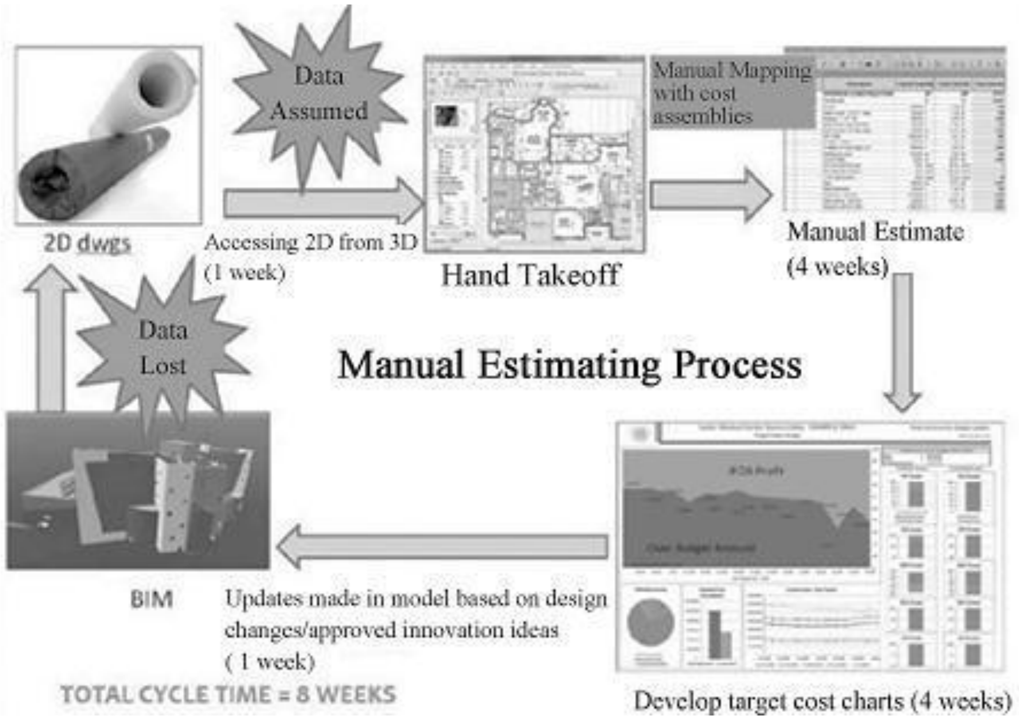

Figure 5: The manual estimating process compared to the model based estimating Tiwari S et al., (2009)

2.9.2 Methods of Cost Estimation in BIM

As BIM tools generate a model that is object based and coordinated with parametric functions, it is convenient to quantify the objects used in BIM model with less inefficiencies. The QTO process is also enhanced saving 50% to 80% of an estimator's time on a project (Rundell 2006)

BIM can be used in three ways for cost estimation namely:

- Export quantities to estimating software ∴
- Link the BIM tool directly to the estimating software

- Use a BIM quantity takeoff tool (Jiang 2011)

2.9.2.1 Export Quantities to Estimating Software

Once BIM model has been completed and the quantities have been extracted off the model, the QTO data can then be exported to an external database such as Microsoft Excel for estimation. This method needs standardization and efficient setup to obtain reliable quantities of the model so that more accurate QTO lists are created (Jiang 2011).

2.9.2.2 Directly link BIM Components to Estimating Software

A BIM model can be directly linked to a built in or external tool for quantifying the objects and estimating the costs. Many software tools provide capabilities to generate QTO data directly off the Model without having to first quantifying the data and then importing the data to a third party estimating tool (Jiang 2011).

2.9.2.3 Quantity Takeoff Tool

Another method for estimating in BIM is to use a BIM tool specifically designed for cost estimation. Users can easily carry out QTO process without requiring learning all of the features in a given BIM tool. After assembling the data in a BIM tool, the dimensional data can be transferred to the QTO list for further pricing. The simulation of the objects being taken off reduces the chances of estimator missing out on items, thus producing an accurate estimate with insignificant effort. Also, when a change is made in the model, the estimated quantities are automatically updated (Khemlani 2006).

2.10 BIM and Clash Detection

In the construction business, members need to work together to effectively complete a venture. In numerous ventures, the members create their outlines as indicated by the accompanying request. The architect creates a few designs focused around the necessities of the owner. After the owner picks and endorses one plan, a structural specialist creates a structural framework which compares to the architectural design. At the point when these two framework plans are prepared, the establishment counsel creates an establishment framework plan which incorporates with the other two system designs.

As indicated by Plume, J. also J. Mitchell (2007), numerous system coordination issues emerge on the grounds that members create their design independently and have an individual centering. Along these lines, customarily, work preparators think about and control the distinctive specialty plans for clash circumstances. As a rule, work preparators are in charge of the planning exercises for the execution arrange as structuring contract with foremen, buying materials, and guaranteeing a great coordination and gathering request of the diverse frameworks of an undertaking. As per Khanzode et al (2006), guaranteeing a great coordination by analyzing and controlling drawings is an awkward procedure, in which work preparators effectively make disappointments since they don't have a reasonable diagram of the outlines and their coordination identified with one another. Missed clash circumstances between diverse frameworks in the outline stage, bring about change requests which cost a great deal of cash and reason delay.

A Building Information Model gives a finer visualization by consolidating the strength framework plans in one 3D model. This makes it less demanding for preparators to contrast the distinctive forte systems to attain great framework coordination. BIM organizers can utilize the Navisworks Clash Detective device to lead a Clash Detection to understand a great framework coordination.

2.10.1 The Clash Detection Process

Throughout a Clash Detection, work preparators utilizing 2D drawings, and BIM facilitators in the event of 3D Designs, look at the different plans for clashes. In both cases, not all clashes are applicable to discover, however clashes which cause change requests throughout the execution stage, work preparators/BIM organizers must find. An important clash is a clash which happens between no less than two components and brings about a change request in the execution stage, on the off chance that the BIM organizer does not locate the clash, and/or the capable member does not settle the clash. To discover these pertinent clashes, work planners and BIM organizers center at focuses in the plans where distinctive frameworks meddle with one another.

These clashes will result in change requests which postpone the task and cost additional cash. Regularly, project coordinators recognize these clashes past the point of no return, and need to illuminate the clash in situ. In addition to postponement and additional expenses, these pressurized choices bring about unsatisfied results. Hence it is important for work preparators and BIM organizers to evade these clashes by discovering them throughout the design stage leading a Clash Detection. In the wake of discovering the significant clashes, work planners and BIM facilitators can give forte members the task to modify their design at the crash area. (S. Gijezen, T. Hartmann, N. Buursema and H. Hendriks)

2.10.2 Types of Clash

Some BIM organizers utilize the expression "clash" to allude comprehensively to one of a few sorts of spatial clashes uncovered in a BIM, that is, they portray the clash focused around the way of its presence. Case in point, they separate 'hard clashes' from 'soft clashes,' and 'time clashes' (e.g., Mangan 2010). Other BIM facilitators highlight clashes focused around their presence, as well as focused around the procedure used to follow up on them. For instance, Gijezen et al. (2010) utilize a work breakdown structure and characterize 'important crashes' as those that prompt change requests. Whichever is the situation, clashes point at conflicts that request the consideration of last designers and, as required, likewise of others in the venture conveyance process.

A description of the terms used for types of clashes is as follows

- A 'hard clash' alludes to one building part physically yet unintentionally entering an alternate building segment; that is, two (there could be more) segments seek the same physical space (volume). Figure 2.6 outlines a hard clash between pneumatic tube (purple) and waste and vent (W&v, red).

- A 'soft clash' (otherwise known as a 'clearance clash') alludes to parts (subsystems) that are closer than a certain separation (a base leeway) from each other (e.g., separation in-between outer cylindrical surfaces of two funnels). Figure 6 shows a delicate clash between pneumatic tube (purple) and blaze funnel (red).

- A 'time clash' alludes to spatial difficulties (segments conceivably involving the same space) expected when considering constructability or operability of the office. A time clash may be displayed as a sort of freedom necessity, however one that has a worldly part.

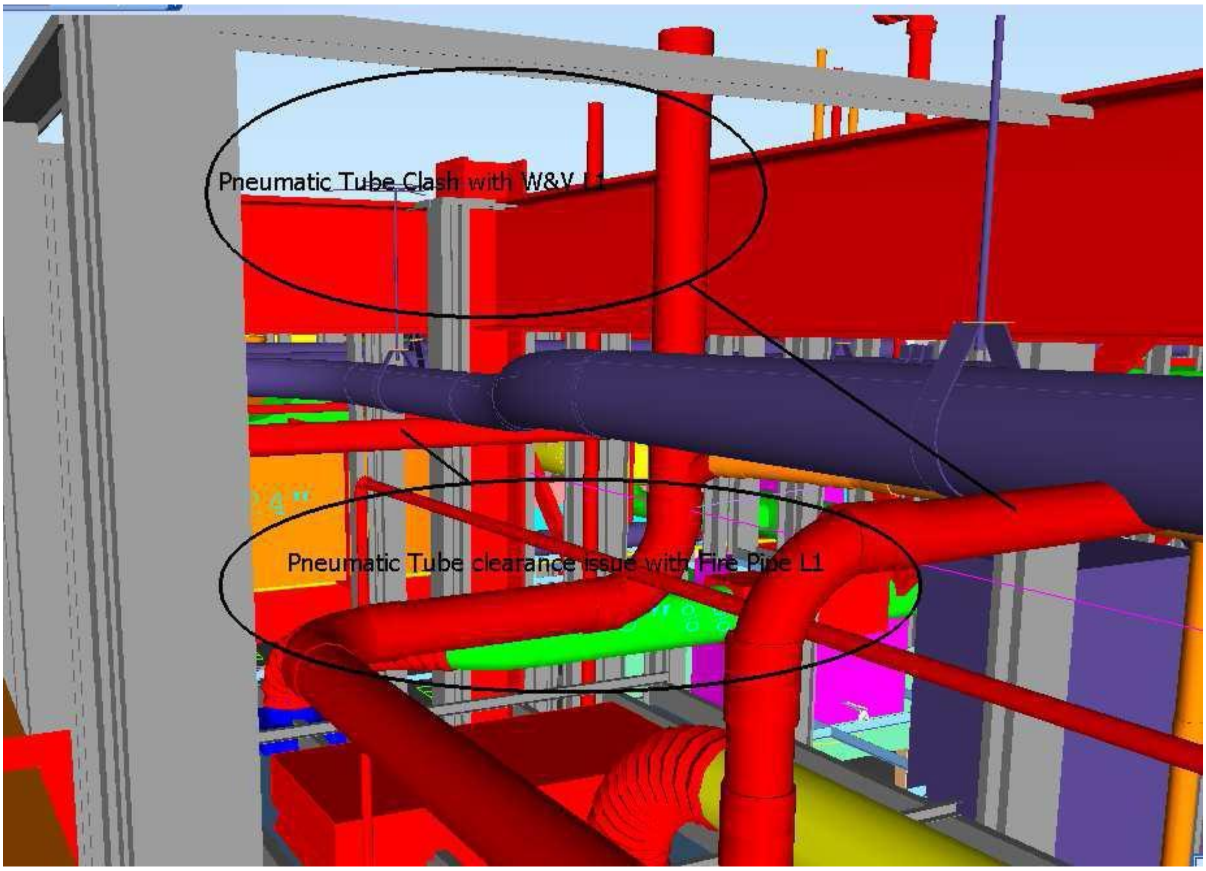

Figure 6: Hard Clash between Pneumatic Tube (purple) and Waste and Vent (W&V, red), and Soft Clash between Pneumatic Tube (purple) and Fire Pipe (red) (Eric Osterling, Unger Construction)

2.11 Structural Modeling and Analysis in BIM

2.11.1 Structural Modeling

The Architects generally concentrate on the creative statement of the structure and the association between the structure and the environment in every sense. Some structural components may be shown in the architect's design but they do not hold associated structural data.

Modelers develop a model working with space, mass surface and shapes which implies they work with articles in an alternate path as compared to engineers who work with structural elements of a model in the structural modeling (Robinson, 2007).

Structural Model being a subset of BIM can contain vital data for structural engineers i.e. loads, load combinations, geometry, boundary conditions, material properties, sectional properties, etc. As a result Structural model could be utilized for structural analysis and for drawing and report creation (Robinson, 2007).

An illustration of the contrast between Architectural Model and Structural Model is indicated in Figure 7. The Architectural Model incorporates data about geometry, rooms and area of openings which e.g. is significant to the architect. Further, data about the general ornamentation and the introduction of the building which e.g. is important to the HVAC specialist is incorporated. Extra, data about non-structural components and materials which e.g. is applicable to the structural specialist is incorporated. In the structural model, data about the framework, structural components, quality parameters etc. are incorporated. This data is included by the structural designer and is just significant to the structural engineer

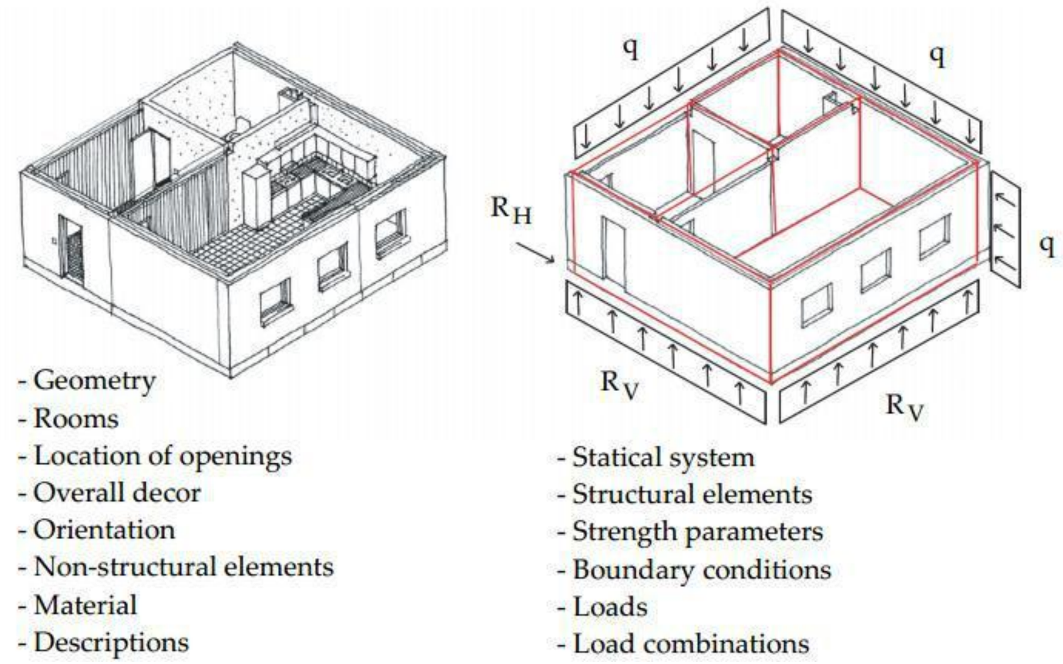

Figure 7: Left: Architectural Model, Right: Structural Model. (Bips 2006)

2.11.2 Structural Analysis

The Architectural Model– holding data from numerous members of the building procedure – is given over to the structural engineer, e.g. through the IFC position. In the Structural Modeling programming the engineer can relegate pertinent data to the model. This could be particular data about e.g. geometry, material properties, burdens and limit conditions, which e.g. the architect did not characterize. From the Structural Modeling programming the specialist can perform structural examination through structural BIM instruments.

The data streams from the BIM (model) to the aftereffects of the computations are demonstrated in Figure 2.8 where Architectural Model is referred to by the BIM (model), S-BIM refers to the structural BIM modeling, FEM is the analysis software while Results might be coefficients of use and deflections etc.

In Figure 2.8 the procedure with structural add-on tools is indicated in the top. This procedure gives the most run data stream from Structural Modeling to the results. The procedure with an immediate connection is indicated in the middle and the methodology with an indirect connection e.g. by means of IFC is indicated in the bottom. These techniques hold an additional step contrasted with the methodology with the add-on tools

In the incorporated design process the progressions to the structure acquired from the consequences of the structural analysis are upgraded in the Structural Model and thus in the fundamental model. In connection to Figure 8 separate sorts of software might be utilized as a part of the distinctive stages. Cases of Structural Modeling software are Tekla Structures and Autodesk Revit Structure.

Samples of FEM software which might be utilized for analysis and design within connection to BIM are Bentley Staadpro and Autodesk Robot Structural Analysis. In this undertaking Autodesk Robot Structural Analysis Professional 2013 [autodesk, 2010b] is utilized. The reason behind this choice is that there is an immediate connection from Revit Structure to Robot Structural Analysis. Utilizing Robot Structural Analysis makes it conceivable to test both this immediate connection and the roundabout connection.

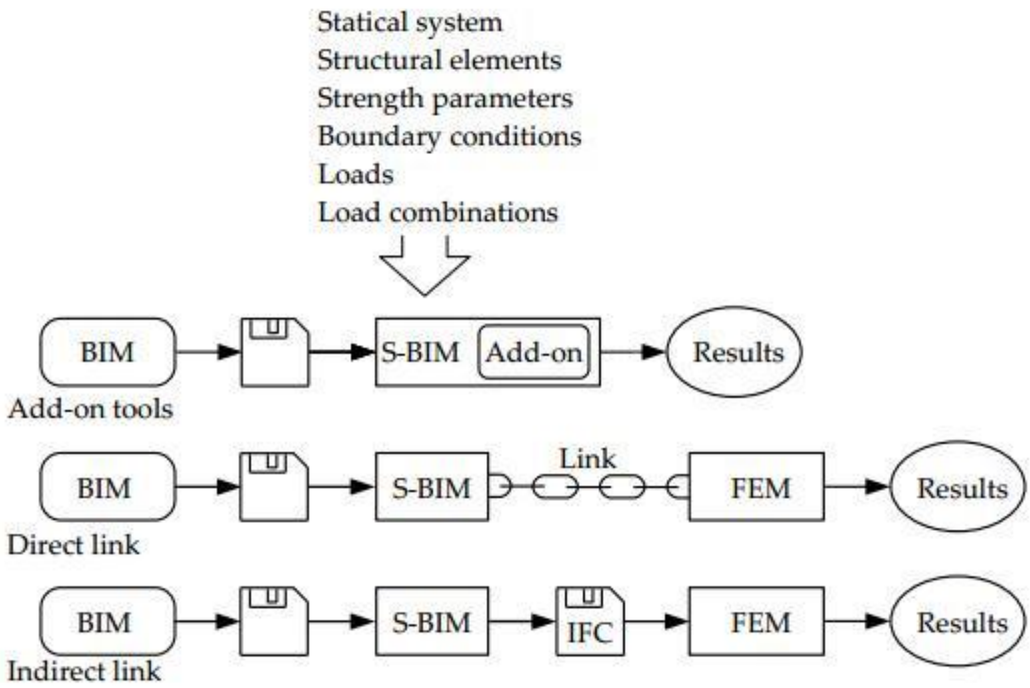

Figure 8: The information flow from the BIM (model) to the results of calculations

2.12 BIM & Role of Different Project Stakeholders

What can be deduced from BIM model is basically a well-coordinated method of keeping all the processes coordinated i.e. engineering, designing and developing and essentially maintaining a building focused around the Building Information Model. It can be stated safely that the Building Information Model needs to be developed in order to use the model as a procedure. After the development of the procedure, the model can be used as part of the traditional workplace culture for the different people involved in the building process, as shown in Figure 9. This interpretation of the Building Information model is put forward as ‘BIM as a vision’ by Coenders (2009).

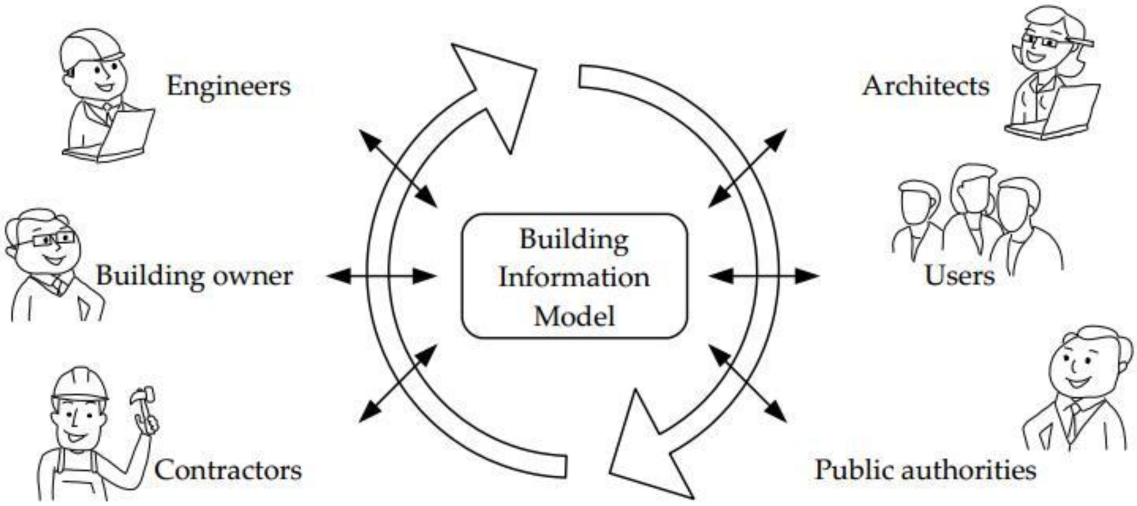

Figure 9: The BIM (model) and some of the participants of the building process

There are many benefits of utilizing the Building Information Model in the workplace since it leads to better cooperation and coordination between the people working on a project which results in a smoother flow of work. Another major benefit is that there is less repetition i.e. the same data isn't entered multiple times. This is basically because instead of cluttered data that is provided by all the members, the raw data is fed into a typical model. Utilization of the Building Information Model also leads to minimization of errors that appear in the form of construction and design failures. Different fields of engineering all have varying models, i.e. there could be models focusing on components related to structure, or those that are primarily used in mechanical or electrical engineering related fields, models that are made to analyze ventilation systems or models that are used for environmental design and so on. In the Building Information Model application, designers and sketchers cooperate and since all the parts of the various orders are brought together, the number of errors (relating to construction and design) are marginally reduced since all the components that 'clash' are easy to spot and mistakes are easy to rectify there and then. 'BIM as a software technology' is also put forth by Coenders (2009) and there it is inferred that the state of programming that is currently being used is a far cry from the vision and the current requisitions are over simplified.

2.12.1 Architect

Architects have picked up the value of Building Information Model in ways that are quantifiable and that improve the final outcome. Productivity is increased exponentially since there is less clutter and less repetition and designers spend less time rekeying information or coordinating and dealing with any apprehensions that the team members might have. The model essentially creates a new dimension for the designers and increases interaction and creativity at all levels. The Building Information Model was initially recognized only as a program used for design but with increased usage and awareness, the architects have realized that there is a growing need for more and more team members to use the model.

Architects have realized that BIM leads to efficiency. Through the Building Information Model there is vast improvement in the management and coordination of documents and drawings. There is substantial time conservation since the processes are simplified and efficient and that leads to increased creativity since they have to spend minimal time on making and analyzing various documents and reports. When the work flows down the process chain, there are minimal errors and that get passed down, and since all the information is made available to all parties through the model, there are minimum requests for information and less hassle.

The primary benefit that architects derived from the BIM was that they could improve their return on investment through its application. 74% architects report that this factor is more important than all the other ones (Construction 2009).

Communication of a vision or an idea is the most important part of an architect’s job. After coming up with a creative idea, they have to sell that idea to the client and then be a part of the execution in order to transform the idea into reality.

BIM helps present and visualize the various designs which is one of the major selling points of the model. There are various models that serve that criteria but the 3 Dimensional aspect of the model sets it apart and creates unparalleled value.

It has been said by various architects that:

- Through BIM there is better communication in the case of more than one party, there is better comprehension through the three dimensional visualization; and it has been realized as one of the best ways to see the ROI. Seventy nine percent architects rate this aspect as very significant.

- Through BIM there is an improvement in the collective overall understanding of the design intent and since there is more understanding, more value is derived. Sixty five percent architects rate this dimension as highly significant (Construction 2009).

2.12.2 Civil Engineers

In addition to Architects, BIM is also highly beneficial for Civil Engineers. It is the belief of many that application of the model can prove beneficial in many ways since successful application can give them an edge with respect to the competition, as it is easier to report challenges and improve processes. Incomplete or flawed software leads to issues arising that create chaos, thereby reducing value. Many engineers, who are not proficient in the application have reported flaws in the model and also that there is no application of it in their work.

Engineers that are proficient in BIM know that they can add value to the overall project due to increased efficiency, creativity and accuracy. They, who have the ability to add value to a project, know that they have acquired a skill that will help the project in terms of both the short run and the long run and help them, compete.

It has been said by Engineers:

- BIM helps to market business to potential clientele. Forty three percent view this aspect as highly important.

- BIM helps in providing new services – Thirty eight percent see this aspect as highly important.

- Positive ROI is determined mainly by a significantly positive influence on marketing. For Engineers the equation is crystal clear. More problems, less efficiency and less profit. Fewer problems, more efficiency and more profit.

- BIM significantly minimizes the errors in documentation and this benefit is ranked at third most important.

- BIM also results in minimal conflicts and digression during the actual constructing of the building.

To maximize the value derivation from the Building Information Model, engineers have to realize the importance of improvements in software and their inter-operability. The major aspects that maximize the ability of the engineers to realize the benefits of the business are:

- Improvements in inter-operability of different software applications. 83% ranked this factor as vital.

- Improvements in the functions of the Building Information Model. 78% rated this factor as vital

- Building Information Model Deliverables that are clearly defined are rated as an important factor by 65% of the engineers

- Tasks that provide the most benefits through BIM:

- Presenting the architectural design and helping others visualize it

- Analysis of the Structure

- Spatial Coordination

- Factors of the project that may affect the value derived:

- The level of complexity in the project

- Design professionals that are proficient in the usage of BIM

- Inter-operability b/w software applications being used by different group members (Construction 2009).

2.12.3 MEP Engineer

The MEP engineers i.e. engineers belonging to the mechanical, electrical and plumbing disciplines are involved hands on the in project since they have to study the planning and construction in minute detail.

In the 2008 Smart Market report pertaining to the BIM, research led to the knowledge that a large number of BIM users use it to make models of ventilation systems, duct systems, diffusers while twenty percent used it to model energy conservation control and management systems. Only a tiny percentage of electrical engineers used the BIM to model elements.

MEP engineers who are proficient in the use of BIM also recognize that the model can lead to distinct competitive advantage.
The benefits derived from the model for the MEP engineers are:

- The BIM helps in marketing business to potential client
- It helps in providing new service offerings
- The mechanical, electrical and plumbing engineers realize the benefits of cost estimation more than engineers or people from other disciplines
- Similar to the other engineers, the MEP engineers rate the presenting of the architectural design through superior visualization as one of the top benefits provided by the Business Information Model.

2.12.4 Contractor

Since contractors are mostly deeply involved with the project, they get to see the major benefits that the Building Information Model provides. Since the major chunk of cost is associated with the initial construction phase, the contractors can easily see the benefits that the BIM provides in terms of cost and time savings. Since through BIM the sequence of activities is planned out thoroughly, and clashes are minimized, changes that come up in construction are also minimized and that consequently leads to no errors as far as the budgets and scheduling is concerned.

Change is normally preached but when there are changes made during construction it means major setbacks and setbacks in construction mean money wastage. Scheduling and budgeting has to be re done according to the changes and that brings the whole process to a halt. Contractors have realized that the model leads to error reductions and that means that there is no reworking required during the construction. Clashes are taken care of in the planning phase and coordination is maximized which ensures that all parties including the sub-contractors, are on the same page. The contractors are of the opinion that conflict management and reduction in changes are the top two ways to maximize value from the BIM.

- Conflict reduction and management is one of the top benefits of the BIM and around eighty three percent say that this factor maximizes value derived.
- Seventy eight percent of the contractors are also of the opinion that there is a major improvement in spatial coordination and they believe that maximizes the value derived from BIM.

The model can simplify even the most complicated projects by bringing in un-parallel clarity. There is improved coordination that ultimately leads to value maximization. And since coordination and interaction is highly difficult in a complex project, if it is done right the advantage is clear for everyone to see. Since there is visible improvement in the coordination, contractors can afford to ask for systems being pre-fabricated and building elements that improve scheduling.

- Projects that are complex in nature affect value in a major way as noted by seventy two percent of the contractors and they rated this aspect as vital.
- Prefabrication of the bigger parts that have more complexity are the areas that require the most improvement and seventy eight percent contactors expect that this area will lead to maximum value in the future and rate this as vital.
- Contractors that have used BIM know that there are problems that arise in any large project; mainly pertaining to communication, coordination and repetition of

information. If BIM is to be implemented in an integrated environment with people from varying backgrounds working together, certain needs need to be fulfilled mainly.

- Most of the contractors, i.e. eighty two percent are of the opinion that communication improvements throughout the diverse team and the three dimensional visuals that aid comprehension are the best methods to derive value from the BIM.

- Improvements in inter-operability between differing applications of different software are considered to be one of the best ways to derive value from BIM. Nearly seventy eight percent of the contractors rate this aspect as vital in deriving value (Construction 2009).

2.12.5 Owners

Owners have the liberty of not being involved wholly in all the steps of the project and they have a holistic view about it. This is why they look for value maximization in the overall costs decreasing, the delivery time decreasing and the work being done efficiently and effectively. Even though the benefits of the BIM are visible in operations and even in the maintenance, few owners focus on the parts rather than the whole.

The primary need of an owner is being kept aware. Since the BIM is an integrated information system, with information from all levels fed into it, the owners have access to all kinds of information from all the diverse team members working on the project. This leads to saving time, effort, hassle and money and better coordination throughout the project.

The owners are of the opinion that:

- Presenting and helping potential clients visualize the designs that the architects have produced is one of the major benefit of the BIM and sixty six percent view this as one of the top benefits.

- The improvement in combined understanding of the design is also one of the major ways that a project can achieve value throughout the life of the project. Sixty six percent rate this as one of the major benefits.

- BIM makes the coordination and interaction better between diverse individuals from varying backgrounds who are working as a team since the three dimensional visuals make comprehension better and improve ROI. Seventy six percent see this factor as one of the most vital.

However, owners think in terms of profitability, and they will always look at numbers before anything else and after a through cost benefit analysis they come up with their decisions.

Owners have said that:

- Since it is easy to spot clashes through BIM and repetition is avoided, there is time saved and money earned.

- Since the cost of the project is substantially lower, the value of BIM is even higher.

- Despite the individual benefits that BIM gives to various team members, the big picture can only be judged by the owner.

- So if the final outcome is an improved construction through BIM, forty eight percent owners state that this is the top benefit. If the construction work throughout the project is improved and the outcome is considerably better, BIM gives them a winning combination and forty eight percent owners think this is one of the most important aspects.

- The improvements in the final result i.e. minimal RFIs and better cooperation and interaction is one of the best ways to improve value through BIM according to fifty two percent of the owners.

- Projects with improvements in design and buildings that perform better in the long run are the two value creating elements that owners hope to achieve through the Business Information Model (Construction 2009).

2.13 Risk Assessment

Risk management is the systematic process of identifying, analyzing and responding to project risks. It includes maximizing the probability and consequences of adverse events to project objectives *(PMBOK).* Risk management is a collection of different steps arranged in a sequence to allow effective evaluation and mitigation of risks. The steps are as follows:

- Plan Risk Management
- Identify Risks
- Qualitative Risk Analysis
- Quantitative Risk Analysis
- Risk Response Planning
- Controlling Risks

Interactions of above six processes make up the risk management plan for a certain project. Project's risk is an uncertain event which can have either a positive or negative impact on the deliverables of project. A risk can be due to one or more causes and, if it occurs, can have one or more impacts. Sometimes organization's environment can also contribute to the project risk, like an immature project management team, multiple projects running side by side, or dependency on external parties which are outside the project control office.

Positive and negative risks are commonly known as opportunities and threats, respectively. A firm should develop a consistent approach to risk for an individual project, and communications and its handling should be open and honest. An organization should be committed and consistent in risk management proactively throughout the project.

2.13.1 Plan Risk Management

Planning means how risk management activities for a project will be undertaken. It is always important to plan for risk management processes to ensure that the level, nature and visibility of risk management are proportionate with both the risk and importance of the project to the association. The inputs, the tools & techniques and the outputs of this step are summarized below in the figure 10.

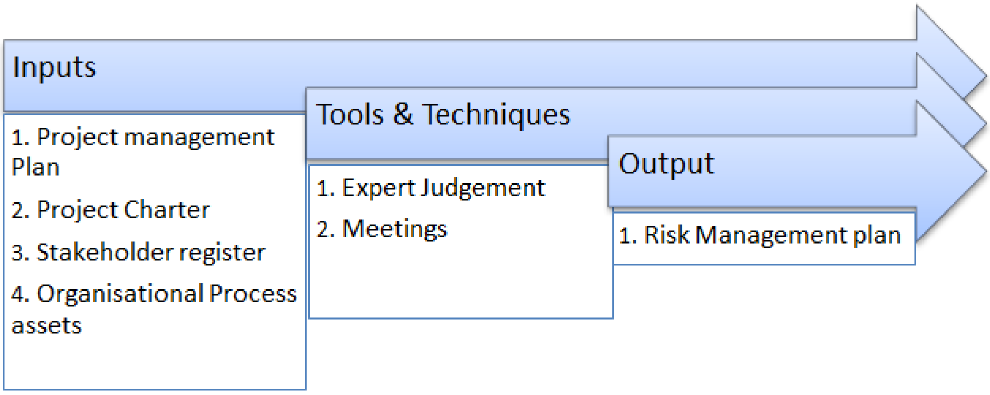

Figure 10: Plan Risk Management

2.13.2 Identify Risk

Identifying risk means evaluating which risk may affect the project. The key benefit of this process is that we get the risks documented and, in turn, the knowledge and ability of the project team to anticipate or mitigate the risks. The inputs, the tools & techniques and the outputs of this step are summarized below in the figure 11.

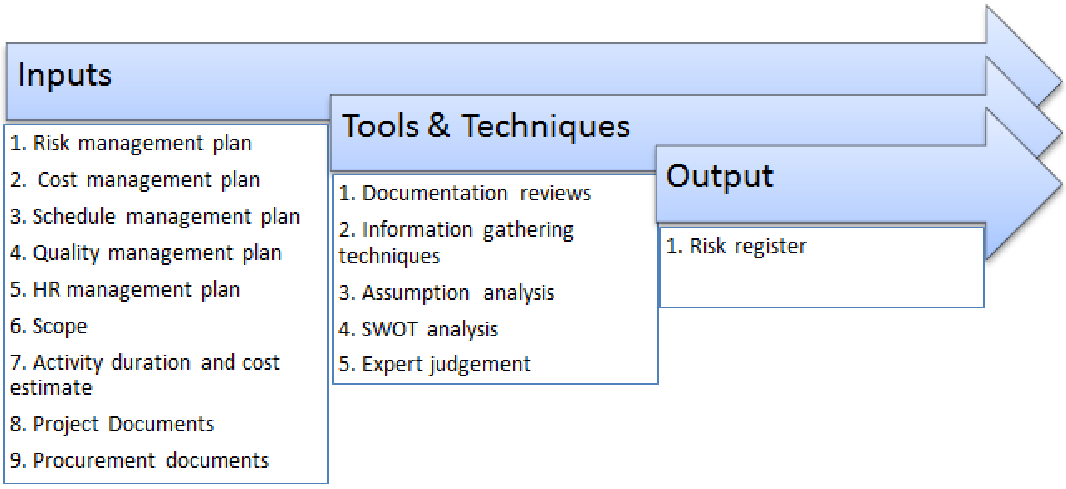

Figure 11: Identify Risk

2.13.3 Qualitative Risk Analysis

Qualitative risk analysis is the analysis in which we evaluate the probability of occurrence of risks along with their impact on the project. The key benefit of this process is that it enables project managers to reduce the level of uncertainty and to focus on high-priority risks. The inputs, the tools & techniques and the outputs of this step are summarized below in the figure 12.

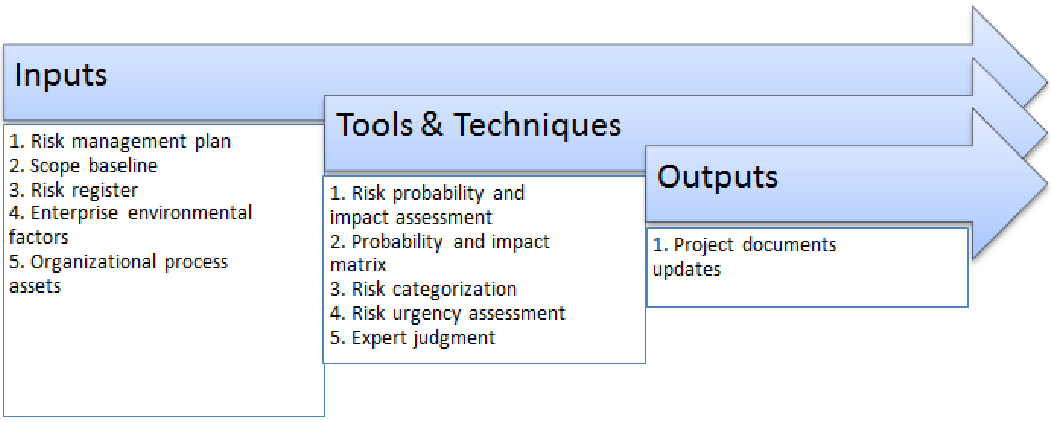

Figure 12: Qualitative Risk Analysis

2.13.4 Quantitative Risk Analysis

Quantitative analysis is the numerical analysis of the identified risk on the overall objectives of the projects. Quantitative risk provides with the information to support decision making in order to reduce project uncertainty. The inputs, the tools & techniques and the outputs of this step are summarized below in the figure 13.

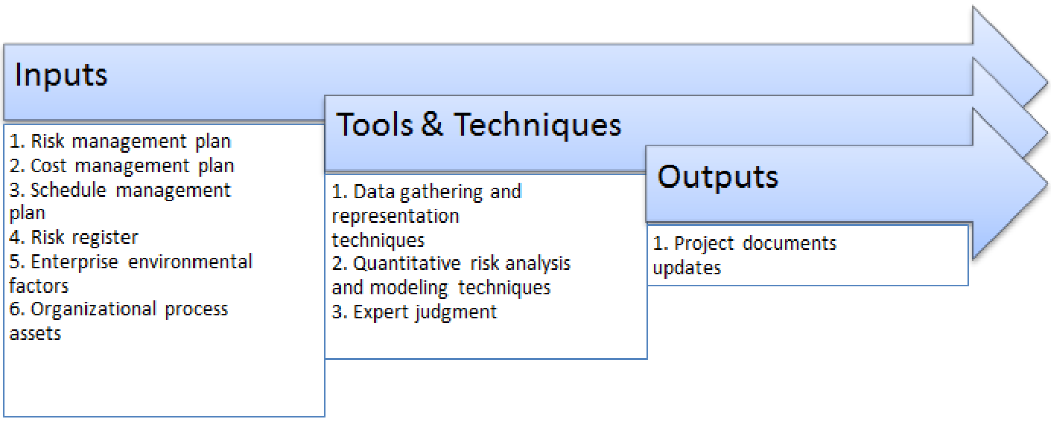

Figure 13: Quantitative Risk Analysis

2.13.5 Plan Risk Responses

Plan risk responses are the method of developing options and actions to enhance chances and to shrink threats to project goals. The major advantage of this process includes that it addresses the risks by their significance, introducing resources and activities in the budget, schedule and project management plans where needed. The inputs, the tools & techniques and the outputs of this step are summarized below in the figure

14.

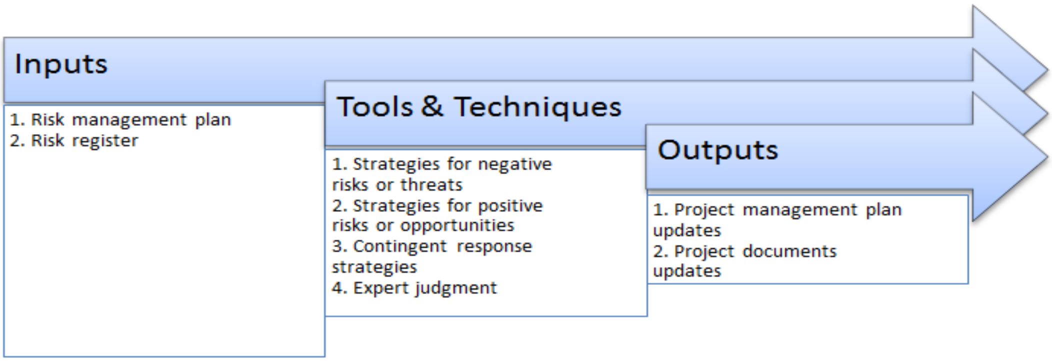

Figure 14: Plan Risk Responses

2.13.6 Controlling Risks

Control Risks is the process of implementing risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness throughout the project. The key benefit of this process is that it improves efficiency of the risk approach throughout the project life cycle to continuously optimize risk responses. The inputs, the tools & techniques and the outputs of this step are summarized below in the figure 15.

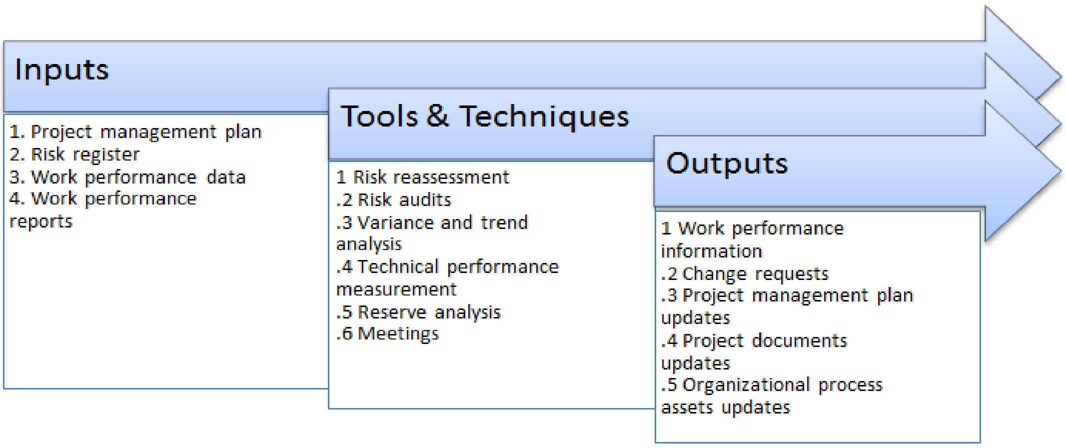

Figure 15: Controlling Risks

CHAPTER 3

METHODOLOGY

The following flow chart, figure 16, gives a brief overview of the methodology adopted for conduction of the project. Each phase of the flow chart has been described in the following lines.

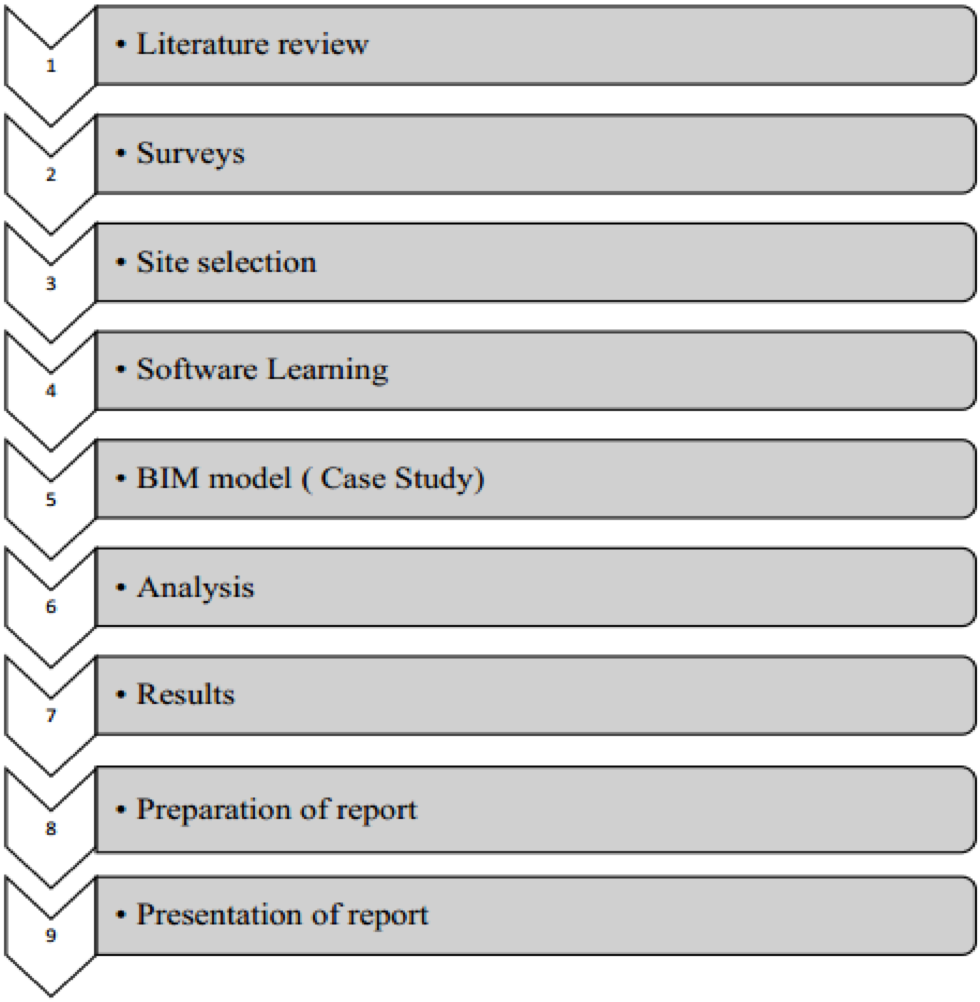

Figure 16: Research Methodology

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 the project, was done. This literature review enforced the thought that in order to have command on the subject regarding the project, each component of a BIM process that is part of the project needs to be studied thoroughly.

3.2 Surveys

To execute the project, a real life building was required as case study whose construction data generated through traditional methods was available. Surveys were done in the local construction industry for this purpose.

3.3 Software Learning

Since the modeling work required use of a BIM tool which are relatively new and not taught in undergraduate courses therefor the learning of BIM tools was done through video tutorials and online blogs. 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 Navisworks 2013 and 2015
- Lumion 3D

3.4 Site Selection

The surveys lead us to the air traffic control complex of New Benazir Bhutto International AirPort. The building is under construction and the consultant (CAA) agreed to provide the all the information required.

3.5 BIM Model (Case Study)

An architectural and structural BIM as planned model was generated through the as planned drawings on Autodesk Revit. Revit built in tools for material takeoff as well as Navisworks was used for Quantity estimation. Lumion 3D was used for rendering purpose.

3.6 Analysis

Quantities obtained from BIM model were compared with those obtained by traditional approach. Clash detection results and WBS results were analyzed and compared to know the advantage they offer as compared to the approach used in building.

3.7 Risk Assessment

To identify the risks associated with the project, we did survey the project site and found out the major risks that were related to the project by all the main stakeholders.

3.8 Results

After analysis and expert opinion from project coordinator, results were deduced in the form of a documentation which are to be used as a comparative study of traditional and BIM approach, for planning and executing a building project. It could also be used for other educational purposes.

3.9 Preparation of Report

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

3.10 Preparation of Presentation

Finally, the findings, conclusions, the knowledge gained and the project execution details were compiled in the form of a power point presentation and presented.

CHAPTER 4

CASE STUDY

In this main part of the project, control tower of New Benazir Bhutto International Airport, was studied in order to make a BIM model of the building. Civil Aviation Authority (CAA) is the client, Louis Berger Group being the consultant and Beixin-Gammon JV is the prime contractors. The main objectives of the project were to explore the use of BIM tools in 3D modeling, quantity take-off, clash detection and collaboration between stake holders. The BIM model was developed using Revit 2013 while to determine QTO (quantity take-off) of the building, built in material take off tool of Revit as well as Navisworks 2015 were 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.

4.1 Introduction

Pakistan Civil Aviation Authority (CAA) is a public sector autonomous organization operational under the Federal Government of Pakistan through Aviation Division Cabinet Secretariat. CAA was founded on 7th of December, 1982 through Pakistan Civil Aviation Authority ordinance 1982. The purpose of establishing this organization was to provide for the promotion and regulations of Civil Aviation activities and to develop an infrastructure for safe, competent, adequate, cost-effective and properly coordinated Air Traffic Services in Pakistan. Currently CAA is monitoring and controlling more than ten airports throughout the Pakistan.

New Benazir Bhutto International Airport, being the most highly equipped airport, has an area of 3200acres. The project selected consists of a total area of 4465 square meter of all the nine floors. First two being the complex floors consisting of offices, kitchens, washrooms, generators rooms and above 6 floors consist of tower, whereas on the top floor, 9^{th} one, is the control center for air traffic controllers.

The contract of this project was signed-off on 11th December 2010 with a notice to commence on 4th of July 2011. Total contract price of the building was Rs. 1,470,169,597. The physical progress of the work till March was 69%. Some salient features of the building are:

- RCC frame structure with a collection of combined and separate footings, making it a complex foundation design
- RCC Titled walls for aesthetics and specially modified beam structure to make it earthquake resistant.
- Façade consists of special aluminum panels for the insulation and aesthetics
- Flooring entirely consists of high grade porcelain tiles with marble elements.
- Tower has a lift for the air traffic controllers.
- The building is equipped with firefighting systems, alarm systems, security cameras and stand-by generators

4.2 Description

For the development of a BIM model of ATC Tower, NBBIAP, Islamabad a different approach was required as compared with what could be expected from the BIM process for a new construction. The building was already undergoing the process of construction through traditional design and build approaches and tools. The building was chosen owing to the challenge it represents due to its complex, modern and sustainable design and it gave a chance to work with one of the finest design and consultancy firm from the world.

Since the building is already under construction through traditional approach, it was planned to start with modeling an LOD 400 (As planned) model of the building. "As-Planned" Architectural drawings of ATC tower were provided. They consisted of a Site Plan, Floor Plans of all floors, section and all elevations. Instead of importing the CAD files to the Revit 2013 software to develop the model, modeling started from scratch and a complete architectural model was developed. This Model was then imported to

Autodesk Navisworks to carry out a detailed clash detection of the building, Revit built in tools were used for QTO.

Complete Structural drawings of ATC Tower were also provided by the CAA, which were also translated into a Revit model by us. It was then used for clash detection, along with Architectural Model.

4.3 Approach

The following is a brief overview, in chronological order, of our approach to develop the BIM architectural model of the ATC tower.

- Development of generic Architecture model.
- Centralizing the file for collaborative workflow while developing architectural model.
- Creation of customized Revit families.
- Replacing generic elements with customized families and addition of materials to the generic architectural model.
- Development of Structural model.
- Clash Detection of different building elements with Autodesk Navisworks.
- Determination of quantity takeoff (QTO) using Revit 2013.

4.4 Model Building Process

At first the grids were marked to give us a starting point. Then generic architectural model and structural model was developed according to the as planned drawings. The families already provided in the standard Revit software were utilized as well as some families were developed from scratch. Modifications were also made to some features of families to bring the model in coherence with the specifications provided after the generic models were completed. Both the models were prepared side by side.

4.4.1 Architectural Model

4.4.1.1 Revit Families

Families in Revit are components that are needed to create a model. They include doors, windows, stairs, walls, floors, etc. A family can have many variations. They can have differences in size, building materials or other parameters. A change made to a certain family type is updated throughout the project where ever that type may have been used. For instance, if we change the wall thickness of a wall type, all the walls with that wall type are changed automatically.

Revit provides a wide range of default families. In most cases, these families are not enough to develop a detailed Revit model. We can create our own families by the following methods:

- Edit an existing family according to our needs.
- Create a new library from scratch by choosing any of the family templates Revit provides.
- Download families online from different resources.

In our model, most of the default families were edited to suit our modeling needs e.g. walls, windows, doors, stairs, etc.

Some families were downloaded from online resources such as ‘Autodesk Seek’ and ‘Revitcity’. These families were edited according to our needs

4.4.1.2 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. The beams and columns in the drawings provided to us were at times incorrectly placed. Ambiguities had to be cleared with the representatives from CAA.

4.4.1.3 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.

4.4.1.4 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.

4.4.1.5 Curtain walls

Curtain walls in the as-planned drawings were different from the as-built structure but the drawings were clear enough to aid us to model the curtain walls. Mullions were provided as per the drawings. Place wall command was used to place curtain walls.

4.4.1.6 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 were set as per the specifications.

4.4.1.7 Slabs

The slabs were expected to be the same on all the 9 floors and it would have been easier to copy the floor of ground floor onto the upper floors but slab on each floor was completely different due to slanting walls and difference in dimensions thus each floor's slab had to be modelled separately. Layers with different materials were defined after the model had been completed. Floor by footprint command was used to model slabs.

4.4.1.8 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 footprint command was used and the footprint was manually sketched.

4.4.1.9 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. Different types of stairs, including spiral staircase, dog-legged staircase etc., were placed inside the building. Both stair by component and stair by sketch command were utilized in this process.

4.4.2 Structural Model

Unlike the previous versions of the software, Revit 2013 integrates architecture model, structural model into a single design suite and therefore different segments of the same software are not required. Structural elements such as columns, slabs, structural walls etc. were modeled into the structural modeling template keeping center to center alignment between both models

4.4.2.1 Structural beams

There were more than 80 different types of beams in the building and all of them were modelled them from scratch using the structural drawings provided by CAA. 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

4.4.2.2 Structural Columns

There were 24 different columns in the building and all were modelled from the scratch. It was found that column placements like beam placements is also not the same in architectural and structural drawings. This showed that the structural engineer made changes to the architects plan and architects plan was not updated, probably because of lack of coordination. The column placement was then updated accordingly to bring in harmony with the structural drawings.

4.4.2.3 Structural Slabs

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

4.5 Quantity Takeoff

4.5.1 Quantification by Revit

Schedule/Quantities and Material Takeoff commands were used to generate quantities schedules of different items. The latter is used to generate quantities according to material assigned in layers of different items while former for the whole component. The schedule generated can then be later exported as editable Excel file by using Revit extensions. BIM Coder Suites was used in this project, a free extension to export the schedule as editable excel files.

4.6 Work Breakdown Structure

Due to the unavailability of baseline schedule, we were not able to make a workflow sheets. So in order to get some understandings of how the work will progress step by step an approximate WBS was created. The WBS is shown below.

4.7 Clash Detection

During construction process, it is possible that building elements are in conflict with each other with respect to their location. 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 viewed, approved, 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 architectural model were first imported to Navisworks. After defining the test type, clash test was run.

As Navisworks encourages collaboration environment, so for future use and clash resolution, statuses were assigned to the clashes which would be automatically updated once the clashes would be resolved.

4.8 Risk Assessment

Risks are inherent to a project of building construction. They sometimes pose serious threats and sometimes they also come as opportunity. In order to get the project successfully, one needs to understand the risks and all the dimensions associated with the risk, take advantage from opportunity risks and abstain from threat risk. So in order to identify the risks associated with our project we made some questionnaires. We get them filled from the Client, the Consultant and the Contractor. We tried to figure out what the risks are and what differences lay in the project form different stakeholders' point of view.

CHAPTER 5

RESULTS & ANALYSIS

5.1 Introduction

To learn about BIM the tools and the applications and to know benefits and issues involved in the process this case study was done. Architectural and Structural model of ATC complex of NBBIAP were made. This chapter includes Results of the Case Study.

5.2 Errors in Drawings

The drawings we were provided were the tender drawings which were with the client. Those drawings were the initial drawings so they had a lot of issues and were not updated. We had to face difficulty in sorting out the errors and mistakes and therefore we asked the CAA to provide us the updated version of the drawing. Those were completely different from the one initially provided to us.

5.3 Quantity Takeoff

The quantity takeoff was done using Revit 2013. The sample results are shown below in figure 17:

	A	B	C	D	E	F	G	H
2	Family and Type	Material: Name	Material: Area	Material: Cost	Cost of Item	Count	Complete Cost	
3			SF				in dollars	
4	Acoustic Ceiling Tile 24 x 24							
5	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474	$1.75	$829	1		
6	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474 SF	$1.75	$829	1		
7	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474 SF	$1.75	$829	1		
8	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474 SF	$1.75	$829	1		
9	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474 SF	$1.75	$829	1		
10	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474 SF	$1.75	$829	1		
11	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	474 SF	$1.75	$829	1		
12	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	482 SF	$1.75	$844	1		
13	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	654 SF	$1.75	$1,145	1		
14	Compound Ceiling: 2' x 2' ACT System	Acoustic Ceiling Tile 24 x 24	758 SF	$1.75	$1,327	1		
15	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	1026 SF	$1.75	$1,796	1		
16	Compound Ceiling: 2' x 2' ACT System	Acoustic Ceiling Tile 24 x 24	5614 SF	$1.75	$9,824	1		
17	Compound Ceiling: 2' x 2' ACT System	Acoustic Ceiling Tile 24 x 24	7317 SF	$1.75	$12,805	1		
18	Compound Ceiling: 2' x 2' ACT System	Acoustic Ceiling Tile 24 x 24	7472 SF	$1.75	$13,076	1		
19	Compound Ceiling: 2' x 2' ACT System	Acoustic Ceiling Tile 24 x 24	13685 SF	$1.75	$23,948	1		
20	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	16851 SF	$1.75	$29,490	1		
21	Floor: 3" LW Concrete on 2" Metal Deck	Acoustic Ceiling Tile 24 x 24	25536 SF	$1.75	$44,688	1		
22	Acoustic Ceiling Tile 24 x 24: 17		82713 SF		$144,748	17		
23	Aluminum, Anodized Blue							
24	Basic Wall: Generic(AL) - 8" 2	Aluminum, Anodized Blue	20 SF	$8.00	$160	1		
25	Basic Wall: Generic(AL) - 8" 2	Aluminum, Anodized Blue	20 SF	$8.00	$160	1		
26	Basic Wall: Generic(AL) - 8" 2	Aluminum, Anodized Blue	20 SF	$8.00	$160	1		

Sheet1 Sheet2 Sheet3

Ready 100%

Figure 17: Quantity Takeoff Sheet

5.4 Clash Detection

If BIM tools are utilized in design process the quality of construction documents increases as well as RFI (Request for Information) orders from site also decreases as drawings are well detailed and have less errors due to the improved tools used in design process. Clashes between different elements while designing can be spotted and removed.

5.4.1 Clash Detection through Navisworks

Some clashes in the model due to errors in the drawings are as follows:

1. As shown in the figure 18 the tilted column of the top floor of tower not fitting in the beam.

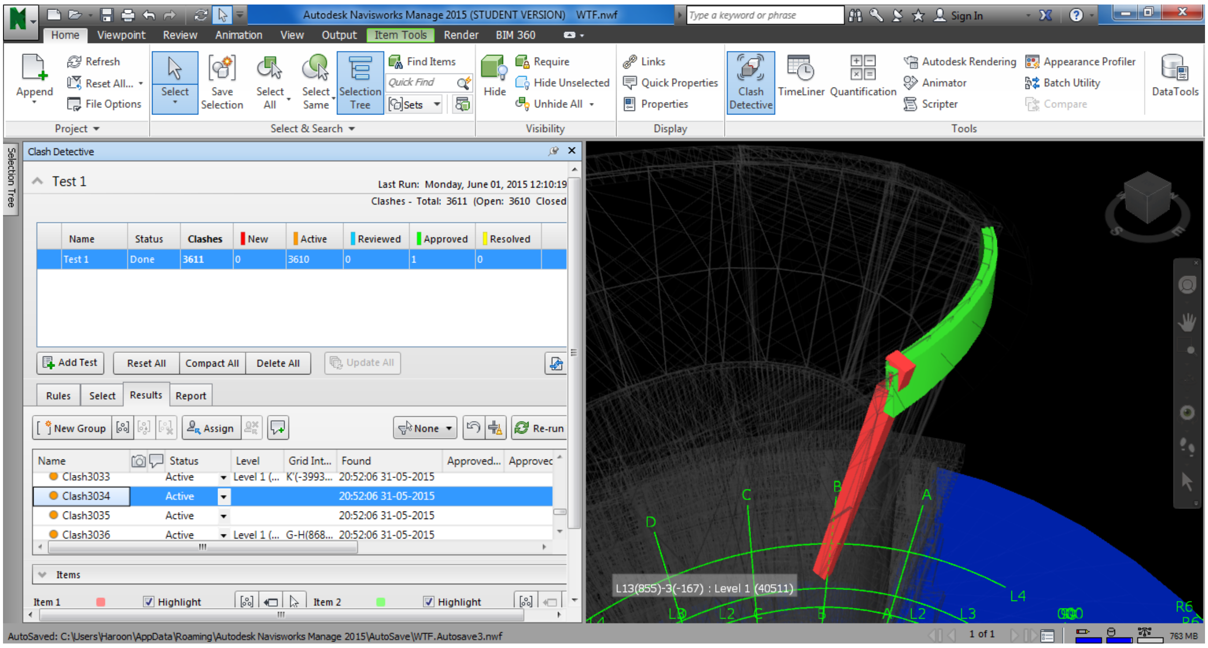

Figure 18: Navisworks Clashes

2. As shown in the figure 19 wall cutting and going under the slab

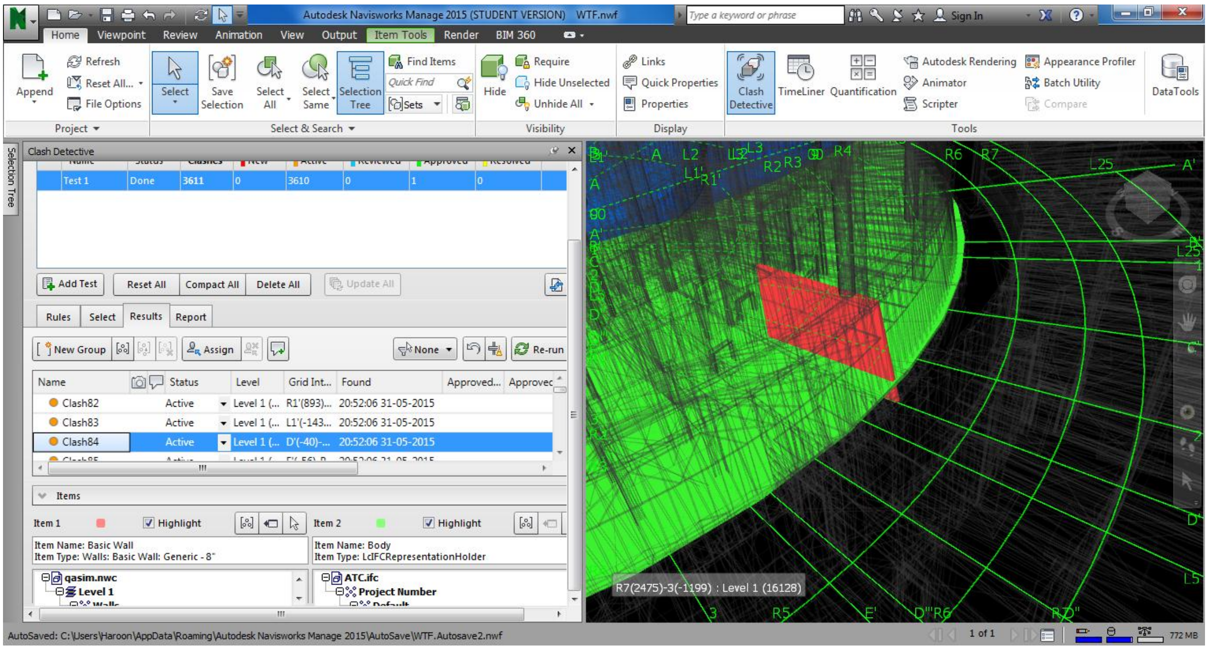

Figure 19: Navisworks Clashes

5.5 Risk Management

5.5.1 Risks associated with the project

Following table 5 shows the risks that were identified by the contractor, consultant and client.

Table 5: Risks Identified by Stakeholders

Contractor	Consultant	Client
Design failure	Design freeze	Unskilled manpower
Construction Methodology	Delayed procurement	Fluctuation in foreign currency
Delays in approval	Slow progress	Poor Co-ordination
Delay in land acquisition	HSE risks	
Sub-Standard material	Unskilled labor	
Sub-standard equipment	Poor co-ordination between Civil and E&M	
Unskilled manpower		
Delayed Decisions		

5.5.2 Steps to Mitigate the Risks

Following table 6 shows the steps that were taken by the main stakeholders in order to mitigate risks;

Table 6: Mitigation Techniques

Contractor	Consultant	Client
Organized Procedure	Strict Adherence to HSE policy	Proper co-ordination between different contracting
Project Management involves controlling design process, cost, quality and administration within contractual limits in order to make sure that risks involved in project and contract are minimized.	Use of design tools (CAD, primavera and 3D software were used during design phase particularly for combined services layouts to minimize issues during construction phase.	Retention money
Efficient co-ordination between contractor, client and consultant in order to reduce potential risks.	Construction schedule to strictly follow to avoid delays, claims and disputes.	

5.6 Effect & Benefits for Design Participants

Adoption of BIM helps all stakeholders involved in Design process. During the case study by working with the BIM tools and observations of the current process revealed following observations.

5.6.1 Architect

The improvements BIM can offer to an architect are summarized in table 7 below:

Table 7: Improvement in Architect's work by BIM

Traditional	BIM
Visualization mostly depends upon designer experience and tools available takes a considerable time.	Work in multiple views support designer imagination as well as simultaneous generation of 3D model support visualization and helps designer communicate design to owner.
Cumbersome work due to separate generation of plans, section and elevation.	Sections, elevations etc are automatically generated therefore time is not wasted in drawing generation and generated drawings are error less since human factor is reduced.
Conceptualization model prepared by current in use tools (3D studio max, Rhino etc.) are not object attributable so they are only used for Visualization purpose.	Conceptual model generated can be used for other analysis purposes along with visualization like structural analysis, energy analysis.
If a change is made in one drawing all other subsequent drawings (plans, elevations, sections) will have to be updated manually which can cause error.	All drawings and other data is interlinked which automatically change in all places if change is made in one place thus time is saved as well as chance of error is reduced.

Preliminary cost estimates generation takes time and effort and may contains errors. In case of change quantity takeoff tables need to be separately adjusted.	Preliminary Quantity takeoffs can be generated directly from the model more accurately. Changes are automatically adjusted in QTO thus time is saved as well was chance of human error reduces.

5.6.2 Structural Engineer

To aid the structural engineer, BIM has advantages shown in the table 8 below:

Table 8: Improvement in Structural Engineer's work by BIM

Traditional	BIM
The designer has to create separate model for analysis which is time consuming	Analysis model is automatically generated along with physical model so time is saved.
Analysis model has no link with 2D CAD drawings. Recreation in case of change is time consuming and may cause error.	Analysis model is linked with the drawings and physical model thus in case of change regeneration of analysis model is not required.

When a change is made in one drawing all other subsequent drawings (plan, elevation, sections).	If a change is made anywhere in a model it will be automatically be addressed in all other subsequent drawings making this process efficient by saving time and a lot of hectic work.

5.7 Problems & Hurdles

Lack of knowledge and experience about BIM and the use of its tools in the construction industry 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 or go through the websites like YouTube for searching the required tutorials and applying various solutions to our problems posted on the internet. This was a time taking process.

Acquisition of computer systems with high specifications which have the capability to run the Revit Software smoothly. 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 CAA. Several beams and columns were misplaced in the plans, sections and plans had contradicting information. The dimensioning differed a lot when compared the initial tender drawings and the drawings we got afterwards. This hampered our progress and was cleared by discussions with the contractors working on the project and by examination of the as-built structure.

Time and schedule has always been against us. The monotonous and hectic schedule made has also hindered our progress in some way

CHAPTER 6

CONCLUSION

6.1 Review of Research Objective

The objectives of this project were following:

- To learn about BIM.
- Create a BIM Model of a building to Estimate Quantities, generation of Clash Detection reports of different building elements and to evaluate the major risks associated with the project.
- To explore the areas where BIM can help improve efficiency of a building design process.

6.2 Conclusions

After studying of this new process, it is concluded that this must be adopted by the AEC industry because of the benefits it offers. Following conclusions are made through this study.

- Since drawing quality and errors are greatly reduced and time is saved in the process BIM should be used in the design process of the building to make quality drawings in less time.
- Use of BIM tools by Architects since allow them to make better designs in less time and help them to communicate them to owners as well as it gives the ability to easily increase energy efficiency of their design therefore it must be used by them.
- 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.
- Clash Detection tools greatly help in reduction of clashes therefore they must be iteratively used in the design process in collaboration with other disciplines.

- BIM allows easy energy analysis in less time thus the process can be used to ensure greener and environmentally friendly buildings.

- Manual Structural detailing is a time taking process. BIM can be used by structural engineers if whole BIM process is followed i.e. BIM analysis and automatic detailer tools are used.

- Since all BIM tools require heavy computation power therefore in order work and get maximum from BIM tools heavy workstations must be used with 2,3 screens to fully utilize the visualization capabilities of these tools.

6.3 Recommendations

Due to the benefits provided by BIM as mentioned in the above section. It is recommended that steps must be taken by design firms to fully implement Building Information Modeling in their organization.

To get familiarize with the process as a first step towards implementation BIM tools can be used in the current design process to get specific benefits like removing errors from drawings, removing clashes between different disciplines, getting extra sections for detailing etc. High spec computer infrastructure must be built before starting any BIM project.

6.4 Recommendations for Future Study

Further studies should be done in the following areas:

- Comparison of efficiency between various BIM quantity takeoff tools
- Use of Structural BIM Model for analysis with different FEM Analysis tools.
- Use of BIM in procurement management.

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