BUILDING INFORMATION MODELLING

A CASE STUDY OF NUST SCHOOL OF SOCIAL SCIENCES AND HUMANITIES (N3SH)

By

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A report submitted in partial fulfillment

Of

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Bachelors of Engineering

In

Civil Engineering

NUST Institute of Civil Engineering (NICE),
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Islamabad, Pakistan.

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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

Bachelors of Engineering in Civil Engineering

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DEDICATED

TO

OUR PARENTS &

TEACHERS

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ABSTRACT

Since construction industry is very rigid to new changes because the people involved in it are used to all the previous methods and ways. However the new advancements introduced in the industry are obviously for the betterment of the industry. One of the modern technology the use of which has helped in the industry is Building Information Modeling (BIM). It is the method of documenting all the data of the construction project in such a manner that it integrates all the phases and handling the data has been very much effective. The technology is so attractive that according to certain studies it has been able to reduce the costs and time taken of the project as well AIA (2007). In the construction industry the two main stakeholders the contractor and the client are in search of these things. The contractor wants the project time taken to be reduced and the owner wants to spend as less as possible. Along with it certain models are prepared prior to the execution of the project during the planning phase, which gives detailed visualizations of the project that given that at the very start of the project all the stakeholders are having a very good idea of what the end product would be.

The flow of the project involves creation of 3D model of NUST School of Social Sciences and Humanities using the tools of Autodesk Revit 2013 which included Architectural model, Structural model and MEP model. Later on this model was used for different kind of analysis. The model was exported to Autodesk QTO to estimate the quantities in the building model. Autodesk Naviswork was used for the clash detection of all the three models within themselves and also for the simulation of the activities of the project. Preliminary energy analysis was carried out using Autodesk 360 service Green Building Studio. All these studies are compiled in this report to understand how BIM could be useful to the construction industry.

LIST OF ABREVATIONS

AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
CAD	Computer aided design
IAP	Institute of Architects Pakistan
IBC	Institute for BIM in Canada
IPD	Integrated Project Delivery
MEP	Mechanical, Electrical and Plumbing
PCATP	Pakistan Council of Architects and Town Planners
P & D	Planning and Development
R & D	Research and Development
RFI	Request for information
VDC	Virtual design and constructio

LIST OF FIGURES

Chapter 1

INTRODUCTION

In traditional 2D design a lot of thinking process was involved and most of the things were misinterpreted. The documents were too much prone to mistakes. No imagination of actual picture in the start of the project was there. BIM is a proactive technique which gives in advance and at the very early stage of the construction the actual visualization of the construction project. Interpretation of the traditional documents involved thinking process, which made it more prone to errors, and these mistakes give chances to increased cost of the project, these mistakes occurred because the documentation was not in an organized manner. BIM gives a chance of an integrated documentation.

The National Building Information Model Standard (NBIMS) defines BIM as ―a digital representation of physical and functional characteristics of a facility and it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward"(Smith and Edgar 200)

There is famous statement about the construction industry which describes what the construction industry actually is and how difficult it is to bring a change in the process of construction. “Construction industry is historically notorious for being resilient to change." Bringing about a change or innovation in the construction process or the documentation of a construction process is very difficult to achieve. People are used to conservative methods and resist in adapting to the new methods. The new methods introduced obviously has some impact, it certainly benefits the process of construction and always a new thing is introduced in the industry for more advanced and latest technique, which at the end reduces the cost and time taken for the execution AIA (2007).

Building information modeling is a new, innovative and easy way of documenting a construction project (Silver 2000). It has been introduced in the construction industry and is being developed at exponential rate. The words being heard in the industry virtual building, parametric modeling, and model based designing are kind of synonyms of Building Information Modeling. Building information modeling is an integrated technique which involves the development and use of a computer generated model to simulate the planning, design, construction and operation of a facility. Presently this methodology is not very common in the local construction industry and it certainly would take some time for the industry to adopt these techniques.

Due to lack of visualization of the facility at the start of the project the owner, whose money is at the stake is not able to realize or not able to convey to the consultants what end product is desired. The problem that arises during the construction is that during construction a lot of change orders are issued, and since a construction engineer is of the knowledge that higher the number of change orders would definitely increase the cost of the construction project. Thus benefiting the owners, engineers and each and every one in the construction industry, BIM is a technology, the use of which is exponentially increasing in construction industry.

1.1 OBJECTIVE

The main objectives of this exercise are:

- Development of virtual 3D model of NUST School of Social Sciences and Humanities project using Building Information Modeling tools; Autodesk Revit 2013.
- Take off the quantities from the model prepared using Autodesk QTO.
- Develop a 5D model of the construction, which includes the 3D visualization of the project, the cost and the schedule of the project.
- Energy Analysis of the model of the using Autodesk 360 Green Building Studio.

1.2 REASON FOR SELECTION OF BIM AS RESEARCH AREA

Since it is one of the growing techniques in the construction industry, and to be capable to adapt to the industry and work in according to the latest techniques available, this research area has been selected. It is the world of innovation; things are changing at faster rate now that ever. One has to be competitive and at the same time should know about the latest things happening in the industry. Since the adaption rate of BIM is exponential, and for making oneself competent enough in the faster growing and competitive industry this knowledge area has been selected. BIM is a huge technique. Adequate information needs to be present with an engineer who is going to be new in the industry. Secondly BIM has a lot to give to the industry as well. As discussed in the introduction of the report, BIM techniques in various ways has been able to reduce costs and time of the project. And these are the two things that are taken care of, the most in construction industry. The owner is always worried about the cost of the project and the contractor wants to complete the project as soon as possible. Introducing BIM in local industry would certainly revolutionize the construction process in the local industry, benefiting everyone whose stakes are involved in the construction industry.

1.3 ADVANTAGES AND EDUCATIONAL OUTCOMES

The growth of BIM is phenomenal in the construction industry. At the end of previous century, with the advent of computers and its involvement has certainly played a role in the development of the construction industry. At start various tools named as Computer Aided Drawings (CAD) were used for benefiting the construction industry. It made work certainly easier from all the previous methods yet it had certain limitations. 2D CAD is very much error prone and the data present in it can be misinterpreted at various occasions. Also CAD tools do not allow you to interrelate data between different departments involved in construction process.

It though was Huge advancement that draftsmen shifted from handmade techniques to using the computer aids, it also helped the engineers and all the people directly involved in the construction, but as it is said, with the advancement of technology new sets of information is available and new techniques are introduced. People think different with advancements. It is need of the industry to integrate all the documentation process, otherwise the same repeated mistakes would occur and it would make the life of people directly involved in the construction industry more difficult. It happens in the industry that certain changes are made in the plans of the execution but due to lack of integration of the documentation the message is not conveyed to all the people involved in the process. In BIM techniques due to integration, the changes are easily made, and are done all at once in all the documents. BIM certainly is more advanced way of documentation of a facility.

Along with documentation of the documents of the project, some of the efforts would be made for the introduction of the latest technology in the local industry. Since the development of local industry reflects the role of engineers involved in the industry, for that purpose a questionnaire would be circulated among the construction firms about their knowledge of the technology on BIM. After that a handbill would be distributed among the industry people, letting them realize the importance of the latest available techniques and at the end of the project, certain recommendations would be issued in a form of report.

1.4 AREA OF APPLICATION

BIM is one of the exponentially growing techniques in formulating the documents of construction project. It is already been used in certain countries like Sweden, USA, UK and Canada. In the following lines it is explained that in which areas BIM has been adopted by different stakeholders to optimize their profitability and performance.

1.4.1 Visualization of a Project in Early Stages.

BIM models are prepared in 3D space to scale and all major systems are visually checked. It is assured that there has been no major overlap between the objects of the building. For example it could be assured during the planning phase of the project that piping does not overlap with steel beams, ducts or walls (Azhar at el, 2008).

After the models are created in 3D and incorporated into BIM, these systems are then merged. All the objects in the building like fixtures, pipes, conduits, structural members, cable trays and other building machinery are checked through ―clash detection" tools to find out and resolve clashes before systems are constructed in the building. Some studies have shown 80% decrease in field-related questions and clashes due to this ―clash detection" tool of BIM. As shown in Figure 1 all mechanical, electrical, plumbing, fire protection, structural, and architectural systems are integrated before they are made-up and fitted in field (Leon L. Foster, 2008).

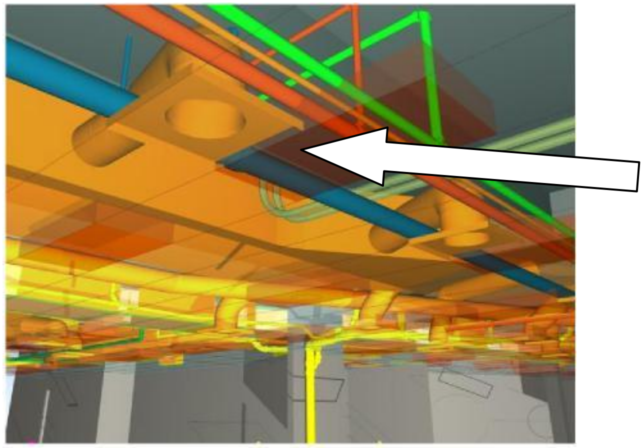

Figure 1 Systems co-ordination (Mortenson 3D Image)

1.4.2 "4D" Scheduling and Sequencing

Traditionally the planning has been carried out always. It is done by using a Gantt chart in which various activities are linked with each other under certain logics. But in huge projects as the activities would increase the understanding of the construction phase time plan will decrease. This in turn can lead to complexities to see which collision a certain work task has on the project. BIM however connects the construction phase time plan to the BIM model. The different construction components will have different internal pecking order. This in turn increases the understanding of the construction phase time plan.

1.4.3 "5D" Cost Estimating

BIM software(s) have built-in cost estimating features. Material quantities are extracted automatically and changed when any changes are entered in the model (Salman Azhar at el, 2008).

The two main rudiments of a cost estimate are quantity take-off and pricing. Quantities from a Building Information Model can be exported to a cost database or an excel file. However the limitation of a model is that it cannot estimate the costs and it is carried out using different estimating tools. Mehmet F. Hergunsel (2011)

1.4.4 "6D" Procurement

Through BIM one can make a lot of different kind of models shaped for several subcontractors. The major part of complete data that is included in BIM model comes from fabricators, subcontractors, suppliers and vendors. The accuracy of the data acquired from the data is the same as the accuracy provided in making the model. Since the BIM model contains all the vital details of every element in the construction, this facilitates off-site prefabrication.

1.4.5 Lighting Analysis

Certain models could be simulated about the lighting of the building which in turn could provide a cost effective model of what type of lighting to be provided and where to be provided.

Chapter 2

LITERATURE REVIEW

2.1 BIM ADOPTION BARRIERS

Due to the advancement of construction industry a lot of research has been carried out in regard to understanding and implementing BIM to the industry. The growth of BIM is phenomenal and exponential in advanced construction industry and people are making more efforts to make it according to the desires and needs of people involved in the construction industry. The introduction of computers at the end of 20^{th} century revolutionized almost every real life process, and with the advancement and more and more research now the involvement of computers is integral and important part of the industry. People started using different tools of computers in construction industry as well. Advancements in the tools are certainly done and people are trying to make life more comfortable for the people involved in construction industry.

2.1.1 CAD Modeling

Computer-Aided Design (CAD) is an essential tool for the production of drawings in the construction industry. Since the introduction of CAD some 20 years ago, there have been a number of studies on the downstream applications of CAD drawings, such as automated quantity measurement (Tse & Wong 2004). However, the majority of these applications have not been widely adopted. The core problem is that CAD is mainly used as a digital drafting board rather than as a design tool. The upstream CAD data remains mainly in the form of 2D geometry data, compiled by entity-based CAD software such as AutoCAD and MicroStation. The whole building model is therefore simply represented by raw graphic entities or primitives (e.g. lines and arcs), which cannot provide rich semantic meaning about the building. Although several kinds of building information can be encapsulated using layering, line types, color, blocks and extended data, this would unavoidably increase the drafting time or involve a lengthy post-drafting standardization process (Tse & Wong 2004). Apparently, entity-based CAD software is not the appropriate agents for forming building models with rich semantic meaning. In the marketplace, there is another line of CAD products referred as to object-based or object-oriented

CAD modeling. These products construct a building model with parametric objects such as walls, columns and windows. Nemetschek Allplan and GraphiSoft ArchiCAD, introduced in 1980 and 1984 respectively, were notable as the pioneers in object-based modeling in the construction industry (Nemetschek 2004 and GraphiSoft 2004a). Within the same period, the first versions of Autodesk AutoCAD and Bentley MicroStation were also shipped in 1983 and 1984, respectively (Autodesk 2004a and Bentley 2004a). This indicates that the development of object-based modeling and entity-based modeling began at a similar point in time.

2.1.2 Entity Based Modeling

Before going into the detail the terms "entity based modeling" and "object based modeling" would be explained. Entity based modeling is one of the type of modeling that attempts representing the meaning of the data. In involves three basic concepts, entity sets, relationships sets and attributes. Entity is any particular group of object that can be distinguished from any other set of objects on any ground. Attributes are the sets explaining about the entities and at the same time distinguishing it from the objects of other entities. A relationship associates objects in different entities. Now this is the model being used by the people of the industry which certainly was helpful to people involved in industry and adding to their comfort. People used to link objects and convey their meaning by using its attributes and also compared it with different objects using the feature of relationship at same time.

2.1.3 Object Based Modeling

On the other hand object oriented data model is kind if adaptation if the object oriented programming language paradigm to database systems. The basis of object oriented model lies on encapsulating data and code that operates on the data. As we used entities in entity based modeling, here objects are used and the attribute values are represented by instance variables within the object. The value that is in the instance variable itself is an object. For describing this relationship the terminology if containment relationship is used. Benefits of containment relationship are that it has the ability for objects to be shared among several containing object. An object is able to send a message to another object which executes a "method" in response. Methods are procedures. Which are being written in the general purpose programming language that manipulates the object‘s local instance variables and may send messages to other objects? This encapsulation of code and data has proven useful in development of modular systems. Objects that contain same types of values and same methods are grouped together into classes. A class is viewed as a type definition for objects. Classes are organized into an inheritance hierarchy each class inherits attributes and methods from classes those are above it in the hierarchy. This combination of data and code into a type dentition is similar to the programming language concept of abstract data type. This hierarchical structure facilitates code sharing among classes. Taking full advantage of both the code and object sharing features is an important aspect of object oriented data modeling.

2.1.4 Need of New Modeling Product

According to DSC (2000) in 1994, the top three best-selling CAD products were all entity-based models, including AutoCAD (1,000,000 copies sold), Cadkey (180,000 copies sold) and MicroStation (155,000 copies sold). There were certain reasons behind the use of entity base modeling. A huge gap existed between what was available and what was required in the hardware and software capability; therefore practitioners did not opt for object based modeling. Provided the processors at that time and the level of expertise present at that time certainly object oriented modeling was hard to master. Object oriented modeling required more graphics, higher memory and higher expertise. Since computers were newly introduced in the industry and the personal use computers was increasing rapidly with very less training available, people focused on what was easy and adaptable at that time. Given the quality of processors available at that time and graphics required the use of object oriented modeling certainly had a disadvantage.

However the importance of object oriented modeling could never be overlooked and despite the disadvantageous use, efforts were made to make it available to people. With the technological advancements and the decreasing cost of systems people started shifting from entity based modeling to object based modeling. By the start of 21st century the companies that were selling entity based modeling software‘s started focusing on object oriented modeling and subsequently launched the Bentley MicroStation Triforma and Autodest Architecture Desktop. However one of the disadvantages of this was that this software‘s were mainly targeted at small to medium scale developments (two to three stories house designs) for relatively low software costs.

2.1.5 Autodesk Rivet Modeling

In 2000, Revit Technology Corporation launched a new parametric model called Revit.

Revit was a new product in the construction industry and its use increased because of its advantages. In 2002, Bentley revamped the MicroStation Triforma into a new line of products called Bentley Building Information Modeling, which include sub-modules in Architecture, HVAC and Structure (Bentley 2004a). This object-based CAD software is now commonly known as Building Information Modeling (BIM), although Virtual Building, Parametric Modeling and Model-Based Design also refer to the same line of products.

One of the main advantage of Revit was it had 17 families of predefined building objects which was listed in the modeling pallet. This made the use of Revit very popular, because objects were inserted into the documents with a lot of details in quick succession of time. This provides the mechanism for creating building objects with rich embedded information. One of the other advantages of Revit was that it also supported Open Database Connectivity (ODBC). This allows synchronization between BIM and database. This is certainly a valuable approach in certain circumstances. The example of this can be quoted as if a completed BIM is passed on by design team to quantity surveying team, who then can use a standalone application to generate bill of quantities (BOQ‘s) to the required format. The workflow is in line with the current practice where quantity surveyors take off the quantities from blueprints furnished by designers.

2.1.6 BIM Acceptance Survey

In a survey conducted in Hongkong the various reasons for shifting from traditional CAD documents to BIM were given as the respondents agreed or even strobgly agreed that creating views and schedules dynamically and automatically was the most salient reason for using BIM, Nearly two thirds (62.5%) and slightly more than one-thirds (38%) respectively saw reflecting changes instantly in all drawings and schedules and single project file as two other driving forces.

Three quarters held a neutral view on the Toolbars oriented operation. A respondent elaborated in Question that it is faster to type commands than to click toolbars, provided that one is familiar with the command oriented operation. This could explain why the remaining quarter had opposite views on this reason. In marked contrast, around two-thirds clearly indicated that required by clients and required by other project team members" were not reasons for using BIM, simply

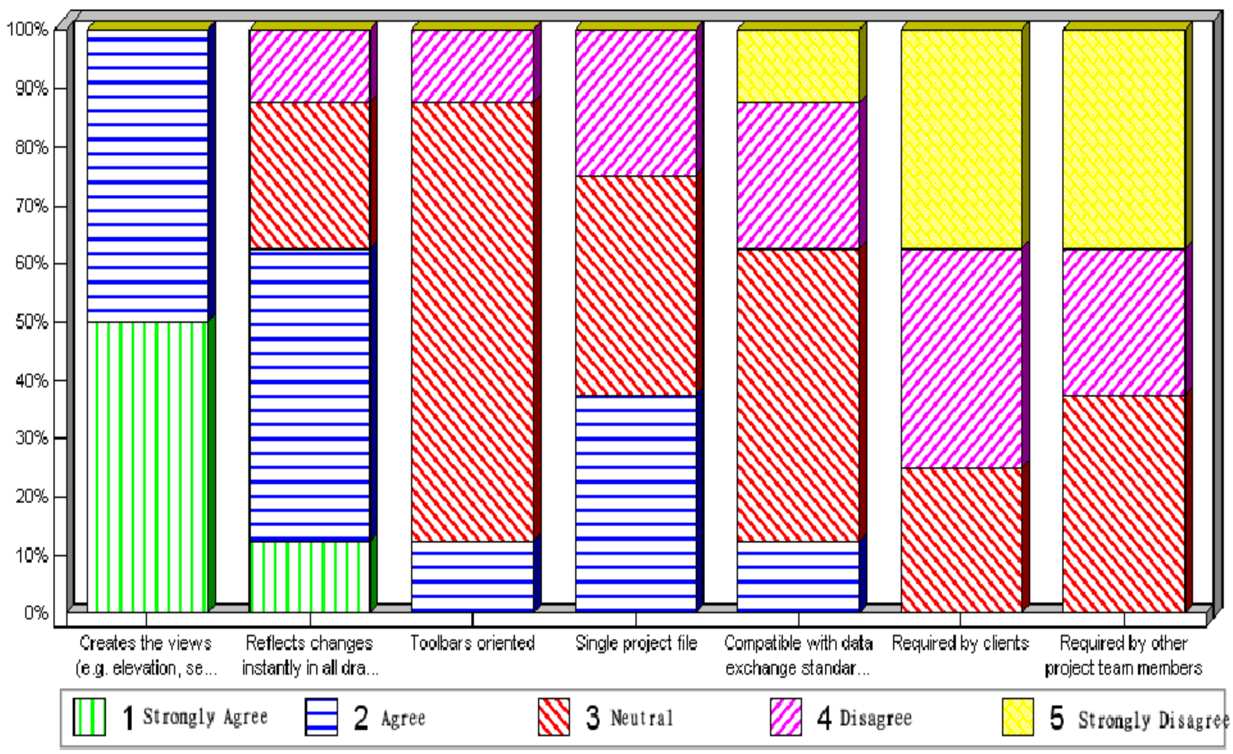

Figure 2 The results of survey being carried out

because there were actually no such requirements in the industry.

Regarding compatibility with data exchange standards", more respondents disagreed than agreed with this reason Similarly in same survey the reason for people not willing to use BIM was also investigated and the results suggests .According to the results obtained in one of the Question, around two-fifths (43%) of the respondents had never used or tested any of the six listed types of BIM software. It was further revealed that slightly more than half (54%) of them had never heard of these BIM software. Another question was answered by all of those respondents who were not using BIM but who recognized its existence. As shown in Fig., the major reasons for not using BIM were the fact that clients and other project team members did not require it to be used. Two-thirds of the respondents agreed that existing entity-based CAD systems can fulfill the design and drafting needs. Regarding the time issue, half indicated that BIM cannot reduce the drafting time and the other half were neutral. One-thirds of the respondents agreed that inadequate skills/training and BIM features/flexibility were two other reasons. The other two-thirds were all neutral towards these factors rather than opposed to them. There were divergent views on whether cost was a consideration for not using BIM. In the additional reasons obtained in one of the Question, one respondent suggested that the prices of BIM software should be reduced significantly in order to increase the incentive to adopt this new technology. (Tse TK, Wong KA and Wong KF (2005))

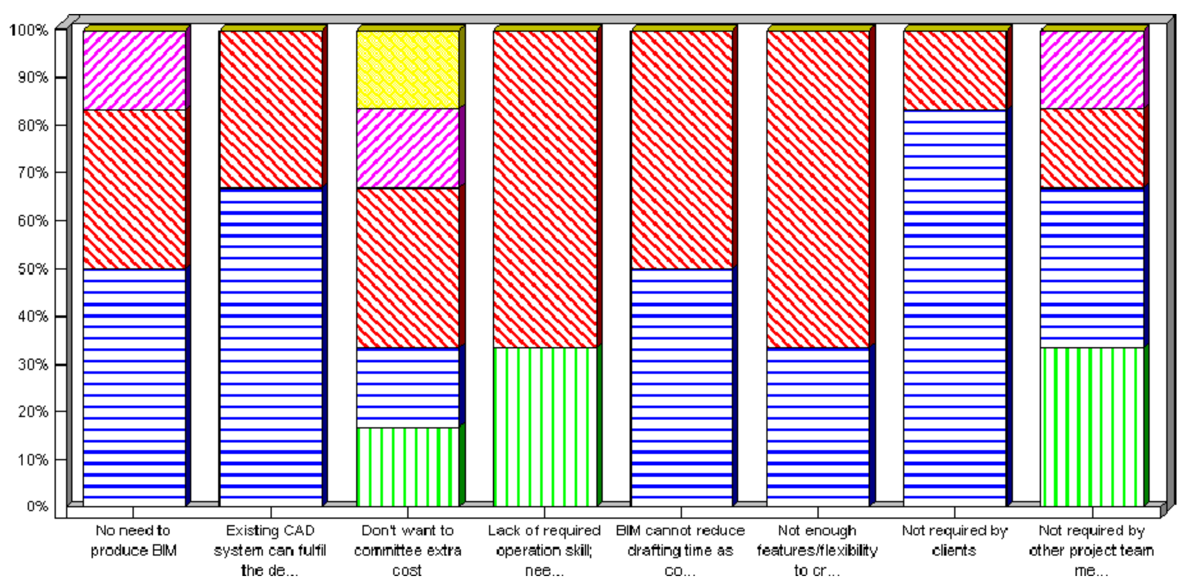

Figure 3 the results of survey being carried out

2.2 INTEGRATING CONSTRUCTION PROCESS DOCUMENTATION INTO BUILDING INFORMATION MODELING

Currently 3D CAD tools act as mode of communication between planning and design phases. These 3D models serve to solve certain other issues like constructability problems, conduct interference analysis and to perform scheduling and hazard analysis. Still the information is collected and transferred to the owners in boxes or file cabinets. The information, including requests for information (RFI), schedules, submittals, change orders, or as-built, specifications, rarely serves as a reliable database for future decision making and would be more effective if incorporated into the BIM.

In traditional 3D modeling only the visualization was provided. However in 5D model facilitates the impact of changes on the project and assists decision making for owners, project engineers, or managers (Tanyer and Aouad 2005). These benefits are seldom realized post construction due to the breakdown in continuity of data collection. The losses due to inadequate interoperability in the United States capital facility Industry were estimated to be $15.8 billion (Gallaher et al 2004). Thus the technological advancements done in the industry facilitate digital information exchanges among various project participants and replace the traditional paper based information exchange (Hjelt and Bjork 2006).

Here a case study is discussed in which the tools of BIM were applied. The project was extension to an existing child development center. The research project ran in parallel to the traditional methods used by the contractor and owner as neither was prepared to rely on the unproven methodologies. The process is discussed step wise in the following lines.

2.2.1 Capture 3D As-built Data into BIM Model

Traditionally the same 2D As-built drawings are developed for the owner. This certainly is time consuming, inaccurate and not very useful. The efficient management of the facility, preconstruction, depends on the availability of accurate as-built drawings. The Data required for the modeling was obtained by using built robotic laser rangefinder system. The data from it was obtained in xls format and incorporated in Revit.

2.2.2 Document Actual Construction Schedule.

Bentley products were used for developing the 4D as-built model since it already had the features necessary to integrate the 3D model with the schedule were readily available. The actual construction schedule depicting progress as recorded on the daily site progress reports were created in MS Project. Then the 3D as-built model and actual construction schedule were linked to generate the 4D as-built model using Bentley Navigator.

2.2.3 Use BIM to Capture and Store Construction Documents.

In traditional practices the facility manager is required to search 2D as built drawings for dimensional details and multiple construction documents to obtain information regarding a building component. The new shared parameters include specifications, RFI, change orders, submittals and shop drawings. They were created as instance parameters and assigned to all categories like walls, windows, doors, and columns. The URL data format was used for each parameter. This format is useful to establish the link between the respective files and component. The link between the documents through the path stored in the parameter allows easy access

to the required information. The ease of integration depends upon the availability of information in digital format. This project used traditional practices so most of the information was in paper format. Paper based information was scanned and converted into digital format. The information was then attached to the BIM model by creating shared, instance parameters as described previously. The specifications, submittals, shop drawings, and RFIs were integrated by linking the file path location to the respective parameter. BIM facilitates any time access to query and retrieve information by the stakeholders throughout the life cycle. The information like specifications, submittal, shop drawings, and RFIs can be retrieved by accessing the respective instance parameters of a particular element.

2.2.4 Outcomes.

This research project ran in parallel with the traditional method and did not directly influence the project outcome. The primary benefit is that the owner now has access to a BIM model with the full range of project information. The quantitative as well as qualitative benefits may result from the availability of such information throughout the life cycle of the project. With continued research and development of software and protocol the cost associated with capturing the construction process information could be reduced substantially.

2.2.5 Conclusions

The conclusions drawn by the author of this research were that the software’s employed in BIM should be more enhanced. To properly use it, it requires more modifications, so that the clichés of BIM are satisfied. Interoperable software that link a daily progress report to the model would reduce redundancy. A manager could simply click on each component and update the status as installed. Other features could include the same information provided in a standard daily report.

The integration of construction process documents is done by selecting each component and linking the documents by specifying the documents storage path. The files could be placed in a pre-assigned path with automated links if the storage location was standardized. Much has been done through the NBIMS effort but even more is necessary. The standards will help the manufacturers as well as BIM and other software developers reduce the burden of interoperability.

BIM has the potential to substantially change the way construction is performed and documented. The transition requires a complete paradigm shift through all phases of the life cycle. BIM could eventually become the sole source of information including facilities management and planning. There are a number of advantages including productivity improvements associated with BIM. Future research will be necessary, as is currently being funded through the AIA LFRT, to develop metrics to measure the value of BIM in construction.

2.3 EXPERTS' VIEWS ON STANDARDISATION AND INDUSTRY DEPLOYMENT

To make it clear, using the latest techniques is not only called BIM. It has been called BIM since very beginning, even using the traditional ways. But it involved very complex processes. The goal was to establish single Building Information Model in which all the data is incorporated at the same time and the data is in integrated manner. With the advancement of research and the development of technology initiatives were taken by scientist, software developers and standards committees. Now the owners of projects are convinced and desire the use of these latest techniques of building information model, which benefits him in domains of cost and time.

As discussed in previous chapters the traditional ways for formulating an information model was complex, conservative and error prone. Certain standards needed to be established to make the data available more understandable, therefore committees were formulated to establish the standards. Standards are critical when communication between different specialists, internationally and over long periods, takes place. There is now an awareness of the cost of not having interoperability and some major building clients are starting to encourage their teams to use the standards compliant tools that are becoming available. All the information models prepared needs to be specific, able to be conveying messages in a standardized way and allowing the data to be retained throughout the process. A survey carried out in Finland in January 2007 has shown that use of manual drafting by designers is falling by 55% while that of 2D computer drafting is falling by 32%. BIM is planned to grow by 85% but is defined as any CAD system using 3D data and includes the use of 3D visualization.

Referring to one of the study being carried out among the stakeholders of the industry an encouraging answers were acquired. When asked about the possibility of creating comprehensive building information models, a huge number of answers were in the category of ―Yes, but ...'and ‗No. but ...'which certainly gives encouragement and hope at same time. And the conclusion drawn from the question was that BIM is not something new. Not only construction industry but all the engineering studies involve preparing and simulating models prior to the execution of the project, why isn't construction industry given a chance. Another question being asked in the same questionnaire was whether the standards of BIM already exist? If not who should be developing implementing and promoting it? The conclusion drawn was that a framework is needed into which all BIM standards can be incorporated, including defining the data. Another question; is anyone benefited the answered can be summarized as BIM certainly has a lot of advantages depending upon the type procurement and the responsibility for operation of facilities. Question: any changes needed to ensure BIM benefits, the answer may be phrased as Changes to the process are already starting but there may need to be a special role to manage BIM, and special education.

The information collection in the survey certainly raised more questions but at the same time gave answers to a lot of questions, which certainly is based on the experience of introducing a new technique to the industry. (Howard and Björk 2008)

2.4 BUILDING INFORMATION MODELLING FRAMEWORK: A RESEARCH AND DELIVERY FOUNDATION FOR INDUSTRY STAKEHOLDERS

BIM is continuing its proliferation in both industrial and academic circles as the new CAD paradigm‘

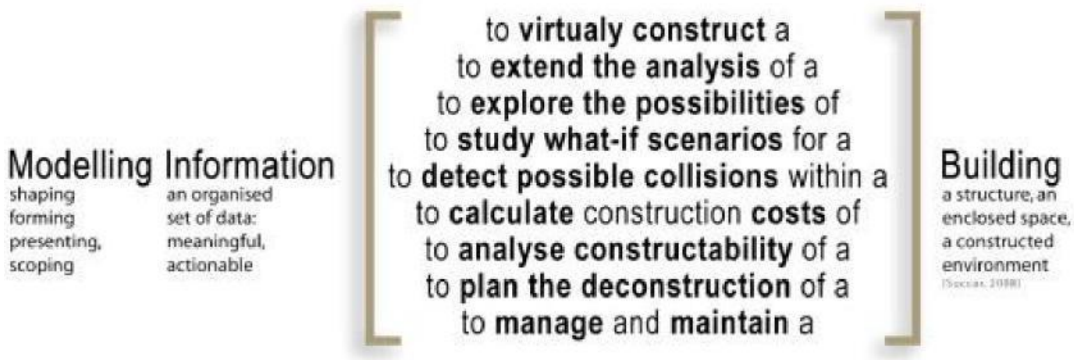

Figure 4 Some common connotations of multiple BIM terms

When a new item is introduced in the community or the slogan of change is given, it certainly attracts people. ―BIM" is a word being heard in seminars and workshops and is considered at the same time a catalyst for change poised to reduce industry‘s fragmentation, improve its efficiency and effectiveness and lower the higher costs of inadequate interoperability.

BIM activity can be divided into three interlocking fields, (figure given) namely ―The BIM Technology Field involves the people specializing in software, hardware, equipment and networking systems needed to increase efficiency, productivity and profitability of AECO sectors.

The second field is named as ―The BIM Processes Field" clustering a group of people who procure, construct, design, manufacture, use, manage and maintain structures. The third field is named as ―The BIM Policy Field" the players involved in this group are focused on preparing practitioners, delivering research, distributing benefits, and allocating risks and minimizing conflicts within AECO industry. These overlaps occur when a deliverable is requiring players from many fields.

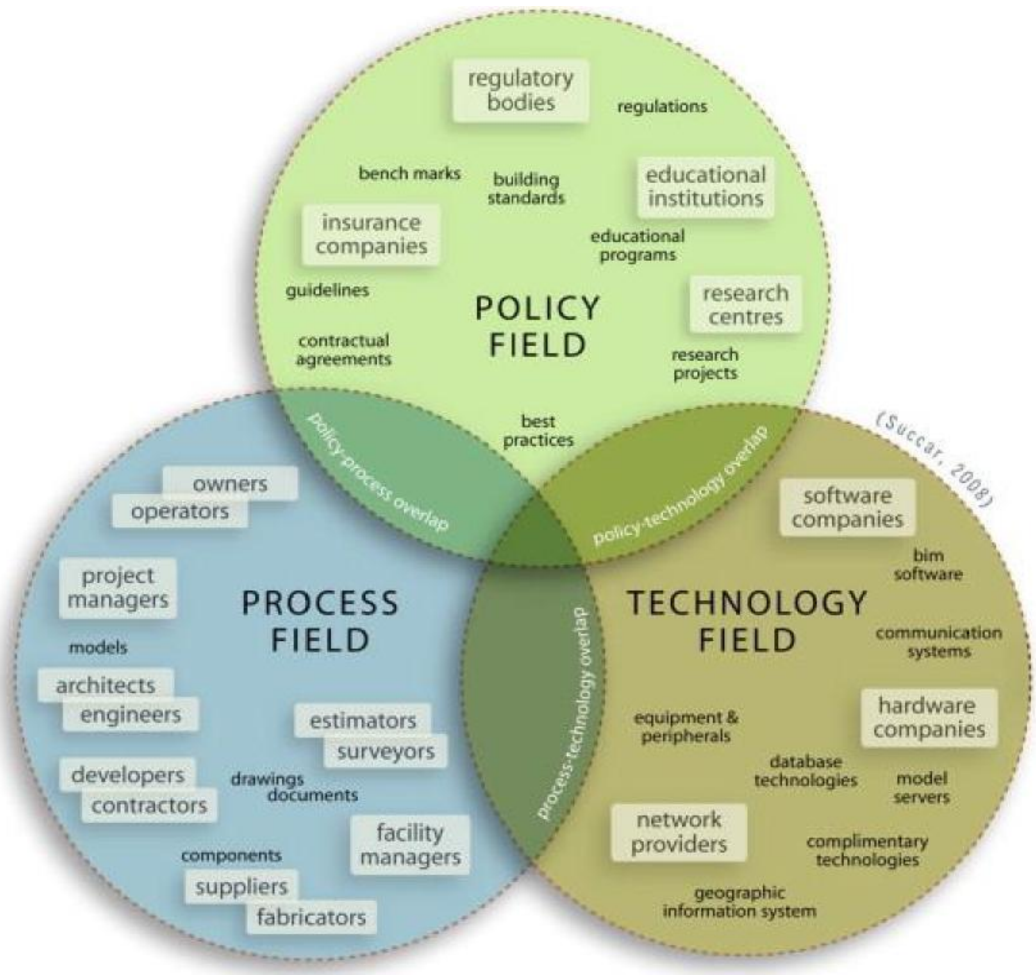

Figure 5 Three interlinked Fields of BIM activity — Venn diagram (Succar 2009

2.5 SPECIFYING PARAMETRIC BUILDING OBJECT BEHAVIOR (BOB) FOR A BUILDING INFORMATION MODELING SYSTEM

To express what actually is desired by the owner a proposal of parametric drawing was given to inculpate domain expertise in models of buildings. With the advancement of the modern technology all complex and sophisticated models are easily incorporated in the building models. The availability of more detailed and more advanced tools for building modeling ensures more detailed version of the desired outcome. BIM is also defined as a ―process‖ which generates and manages the information related to the model of a building in an interoperable and useable way. As discussed in previous chapters the main problem of previous data models was that no integration between different departments existed. BIM provides an integrated and interoperable model, which certainly provides comfort to the people involved in the industry.

With the advancements in technology a lot of new software‘s are developed helping the people in the construction industry to create three dimensions, abundant with knowledge parametric modeling systems. These include ArchiCAD, Bentley Architecture and Structure, Revit Building and Revit Structure, Tekla Structures, Digital Project (CATIA-based) and StructureWorks (Solidworks-based). Using the tool of BIM a lot of things can be modeled with its range limiting from principles based on material and fabrication properties, safety factors, available production machinery, good design practice, aesthetics, generative rules, construction sequences, non-geometric properties of building objects but a lot of other things as well.

In the heading of the chapter the term building object behavior was used. To describe this term it means the behavior of any object, like beams, columns, walls, etc. the software‘s involved in Building Information Modeling are at same time intelligent as well, by studying the behavior of the objects, this model is so advanced that it would be able to provide you the details of the functionality of the object. The intelligence such as providing windows with in a wall, providing an opening in any particular closed chamber, providing details about the supports needed by a beam and even the details of reinforcement for the sustainability of the building is present in the model. (Lee, Sacks et al. 2006)

Chapter 3

METHODOLOGY

In this chapter the method by which we are going to carry out the project is discussed.

3.1 SELECTION OF TOPIC

This step has already been carried out. The topic selected for Final Year Project FYP) is Coordination on Construction Project Using Building Information Modeling(BIM). This topic emphasizes on the new advancements made in construction industry in regard to documentation of a construction project. With the advent to latest technologies a lot of research has been carried out to formulate an integrated way of documenting the details of the project. Now in market various soft wares are available benefiting the stakeholders of construction industry and eventually reducing the time taken and cost of the project.

3.2 LITERATURE REVIEW

Since this technique is not very much popular in the industry, yet its use is increasing exponentially because of its advantageous use. Thus to understand the actual process and carry out our work, thorough study was carried out during the 1st period of the project. Certain research papers issued in various journals by leading universities of the world were studied. Some booklets written were also read out to develop the understanding of the newly growing technique in the industry.

3.3 SITE SELECTION

This was one of the hardest jobs to be done in the project. Some sites were selected but their data was not available to us. At last with the help of the NICE administration the site selected was the under construction building of NUST School of Social Sciences and Humanities. The client of this site is NUST, whereas the contractor for the construction is Izhar Constructions ltd. It is a four story building consisting of a good number of classrooms, computer labs, research labs and a library. The classrooms are wide and open and can accommodate approximately 60 students at a time. The offices of the faculty members and school deans are also in the same building along with the administration department. The building is very artistically designed with good architectural symmetry.

3.4 DATA COLLECTION

The data collection task was carried out with the help of NICE administration from the PMO NUST. The PMO provided us the architectural, structural and MEP drawings of the project which were required for the completion of the project.

3.5 MAKING OF 3D MODEL USING REVIT & ANALYSIS

All the information acquired from the project site has been modeled using the software AutoDesk Revit 2013. Revit is relatively new software in the industry and the expertise of that is not available to the extent in the market. The tutorials of the software were acquired with the help of instructors and the operation of the software was learnt. The detailed architectural, structural and MEP models of the building are prepared. The model prepared on Revit were exported to AutoDesk Quantity Take off (QTO) and AutoDesk Naviswork for quantity takeoff and scheduling respectively. These softwares were thoroughly learnt and the results of the project were generated which are attached in the Appendix. Along with these softwares some online tools like Autodesk Green Building Studio was also learnt and its applications were also incorporated in the project.

3.6 PREPARATION OF THE REPORT

After all the process of modeling and its analysis was carried out a detailed report was generated which tells in detail about what the project was all about. The literature review about BIM is shared clarifying about the various concepts of BIM and removing most of the misconceptions and describing how the technology has evolved with the passage of time. The report also contains the step wise process of how the project was carried out and how the work flow had been. At the end of the report the case study of NUST School of Social Sciences and Humanities is discussed giving information about the preparation of modeling and applications of tools of BIM in the real life project and all the difficulties faced during the work flow of the project.

3.7 ANALYSIS AND RESULTS

The results obtained from the applications of the tools of BIM were found. A comprehensive study about the applications has been given at the end of report and the comparison have been made between traditional and BIM techniques. The analysis about the clash detection, quantity take off, visualization of the project at the planning phase of the project has been done and is written thoroughly in the report, which would allow the reader to decide which technology is more favorable and advantageous to be used in the industry.

3.8 FINAL PRESENTATION

At the end of the project, the presentation would be given to the project sponsor for the approval. This presentation would contain the details about how the project was carried out and what were the outcomes of the project and how BIM could be advantageous to AEC industry. The knowledge gained in the working phase of the project and the problems faced during the project would also be shared in the presentation. The models prepared and the results obtained from BIM tools would also be shared in the presentation.

3.9 FLOW CHART OF PROJECT

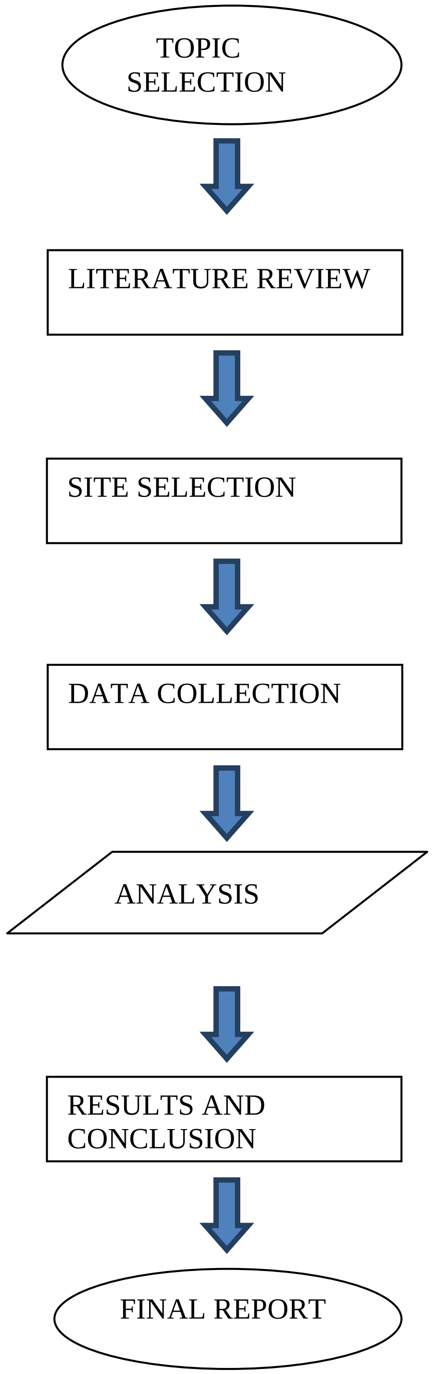

Figure 6. Flowchart

Chapter 4

CASE STUDY

The main part of the project was to select an under construction building, apply the techniques to BIM to that building and know about the advantages of BIM and formulate them in a descriptive manner. For this purpose the building of NUST School of Social Sciences and Humanities was selected due to the reason that it was easily accessible and the administration of NUST Institute of Civil Engineering and Project Management Office NUST provided the support to work in detail on the project. NUST is state of the art institute of Pakistan and has always been focusing in providing quality education with extra ordinary facilities to make the students feel home and concentrate to continue their endeavors in the competitive modern world. The NUST School of Social Sciences was also designed keeping in view the future needs of the students and better education environment to its students. For this purpose an ample area building, which accommodates the students to take classes, do research in the modernly equipped labs and informative library providing the student's nice and peaceful environment for its students is included in the building of NS3H. The building is four storied having classrooms on the ground floor and second floor. The third and fourth floor consists of language and research labs, the library, the offices of the administration, faculty and Dean and the conference room for meetings. The main objective of the project was to construct the 3D model of this building using the tools of Autodesk Revit and visualize the project in an efficient way. The model of the building was then exported to Autodesk QTO to obtain quantities of the building. The clash detection report of model was prepared which would be helping the contractor and field engineer to know about clashes among the objects to be placed in the building and start planning about them right from the beginning. For this purpose Autodesk Naviswork was used. In Autodesk Naviswork the schedule was also incorporated and the sequencing of the activities was also done.

This sequencing would help in smooth flow of the project and also us to provide the required space for the machinery to be used in the construction phase. Basic energy analysis of the building was also conducted using the online tools of Green Building Studio.

4.1 INTRODUCTION

The site of NUST School of Social Sciences is located at NUST H12 campus. The client of the project is PMO NUST, and the contractor is is Izhar Constructions Pvt. Ltd. Different consultants are hired for various purposes. The design consultants are SC consultants, Shami consultants for HVAC and Universal Associates for Plumbing. The total area covered by building is around 11550 square feet and the building is four storied. The total cost of the project is estimated around 150 million PKR and the purpose of building would be to provide the education facilities to the students of NS3H. The building is four storied and elevator is also provided for the purpose of cross level movement. The salient features of the building are:

- It is RCC structure with piled foundations. The load is transferred to the hard surface through piles and rectangular column footings are provided at NSL of the area.
- The building is centrally air conditioned, the plant of HVAC placed at the top of the roof of the building, with air ducts of cold air and exhaust provided in all the rooms. The operation of HVAC is entirely automated.
- Various openings are placed in each room of the building to ensure good cross ventilation and make less use of energy to make it sustainable.
- The building includes firefighting system, security cameras, fire alarm systems and stand by generators.

4.2 DESCRIPTION

The building of NS3H is still under construction and being constructed with the traditional techniques. The parametric model of any of the building of NUST is prepared for the very first time and the study is conducted to compare the two systems and apply the applications of BIM to the buildings to make it more economical and also energy efficient to ensure the demands of sustainable development as well. This building is chosen because NUST always provide state of the art facilities and the infrastructure development of NUST incorporates the future needs of the competitive education environment and sustainable development. This indeed was an ideal project for the consideration of the study of BIM techniques.

The architectural drawings were provided by PMO NUST for the development of parametric model of the building. The architectural drawings included the floor plans of all the floors, the schedule of openings, the schedule of doors, site details and few sections of the building for detailing purpose. According to the plans provided in the drawings the as it is model was prepared using Autodesk Revit 2013. The model was then exported to Autodesk QTO for the purpose of quantity estimates of the building.

This all work was completed by December 2013 and now we had to advance towards a more detailed model of the building, so that we can have something tangible for the purpose of analysis. The PMO NUST was approached for acquiring the Architectural and MEP drawings of the building. PMO provided the drawings to us without any resistance and further work for the preparation of structural and MEP model was started right away. First of all the structural model of the building was prepared. It started with foundations, then columns, beams and finally slabs. The reinforcement was also provided in the structural model as well, which indeed was the most hectic part of the preparation of the model. After that the MEP model was made. Firstly the air ducts bringing in the cold air and exhaust air ducts were placed and properly dimensioned in the model to avoid any kind of clashes with the false ceiling provided and the structural members of the building. Accordingly the plumbing and electrical model was also incorporated in the model. The model was then exported to Autodesk Naviswork for detection of any kind of clashes among the different components of the building and also the sequencing of the activities was done accordingly. The model was then exported to Autodesk Green Building Studio for its basic energy evaluation.

The process of formulating a BIM model of the building was not an easy task. It required a lot of research and we had to pass certain rigorous hurdles to be able to achieve an effective BIM model. Starting with the limitation of the computer memory available, (since BIM model softwares demand high memory on the RAM of the computer) to certain limitations of the software and we had to add certain plugins to overcome those limitations. Along with that the CAD drawings are very error prone and proper understanding and deletion of those errors took a lot of time.

4.3 WORK FLOW

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

- Development of the architectural model.
- Converting the generic model into material specified model. All the original materials used in the construction of the building were incorporated in the building.
- Certain families that were not available in the Revit predefined library were developed and accordingly incorporated in the model.
- The structural framing of the building was done and the reinforcement was placed in the framed structure.
- Development of the MEP model of the building.
- The MEP model was then exported for the generation of the clash detection report.
- The model was exported to online Green Building Analysis tools for energy analysis.

- The QTO report was generated and compared to original BOQ of the building.

4.4 MODELING PROCESS

The preparation of parametric modeling took off with the preparation of architectural model in the start. The architectural model was prepared as per the drawings of the building provided to us by PMO. Firstly the generic model was made and then the additional of materials and various families was incorporated into the project. The MEP and structural models were to follow the architectural model.

4.4.1 Architectural Model

4.4.1.1 Grid Establishment

The first task to make the model was to establish a grid, in the bounds of which the building was to be completed. The vertical lines of the grid were named in alphabetic order and the horizontal in numeric order. The horizontal and vertical lines of the grid would intersect each other at the point of any column in most of the cases and at the extreme boundary points in other. The advantage of making the grid at the start of the model was that there was no use of scale afterwards. The grid lines effectively determined the boundaries of rooms etc.

4.4.1.2 Frame Structure

Since the intersection of grid lines was providing the location of the columns in most of the cases so as per the drawing the columns with appropriate dimensions, (as given by the design) were place in the drawings. The beams were placed above the columns completing the frame of the building. This frame was a generic one, without any addition of steel bars into it.

4.4.1.3 Floor levels

Revit has always been user friendly. The creation of floor levels was just a click of the mouse. The heights of the floors were accordingly incorporated in the parametric model. The grid, columns and beams already generated were copied to the selected floor levels. By now the maximum height of the building is reached.

4.4.1.4 Walls and Shafts

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

4.4.1.5 Windows

Revit is intelligent software and thus generating a window in Revit would always require a host for it. There is no way a window can be made in the open space of the window. Adding the windows was just a drag and drop task. You just need to adjust the dimensions of the window, the sill level, edit the family if required (families are made in case of any special type of windows) and place it on the wall.

4.4.1.6 Doors

Similar to the windows the doors were also placed in the model. Doors also require the host i.e., walls. The dimensions of doors were set according to the specifications and materials were also incorporated accordingly.

4.4.1.7 Slabs

Placing of slab is very easy in Revit. You just need to select the slab, define the boundaries of the slab and the materials of each slab. Since in our case the materials of slab was not same on all the floors so what we did was to make a generic concrete slab was made and copied to all the levels. The slab materials were then edited for each floor later on.

4.4.1.8 Roof

The placing of roof is very similar to that of slabs but the roof materials are different and obviously some slope is given on the top of the roof to allow the flow of rain water, which needs to be defined while generation of the roof in the model. All the insulation materials were added in the roof as per the specifications given in the drawings.

4.4.1.9 Stairs

The generation of stairs in the model is done by defining the height of riser and the width of tread and the top and bottom level of the stairs. The stairs were placed by using the sketch method, providing the landing in the specified space. The sketch ends automatically when the predefined height is reached.

4.4.2 Structural Model

Since the new version of Revit has the capability to link the revit files at the later stage, a separate structural model was prepared. The file was first linked to the architectural model and then the centering of the model was done. The structural elements from the model were copied in the structural model and the structural details were added to the model.

4.4.2.1 Foundations

At the start of the structural model the foundations were added to structural model. The structural model was started from the natural surface level, below which the piling for the foundations was done. Beneath each column rectangular footing was provided which was incorporated in the model as per the specifications. The base of the column lies in the footing at the Natural Surface Level, which extends to the top of the building.

4.4.2.2 Structural Columns and Shear Walls

Starting from the natural surface level the columns of given dimensions were extended to the top of the building, which is the roof level in this case. In some of the cases the columns were not continuous till the top floor. The cross section of the column changed above the first floor, which was accordingly incorporated in the model. The building also included some shear walls. The shear walls were incorporated accordingly in the model.

4.4.2.3 Structural beams

There were different kinds of beams in the model. 21 types of beams were present in the model. The dimensions of beams were defined and the required beam was placed at the allocated place as per the drawings. It is worth mentioning that the beams command from the structural tab is to be selected, otherwise while doing the analysis of the building it will not be regarded as structural element.

4.4.2.4 Structural Slabs

The slabs were accordingly made from the drawings using the bounds of the building and accordingly copied to the aligned levels.

4.4.2.5 Reinforcement

This was the most hectic part of the project. And to reduce the productivity of BIM in AEC industry the placement of reinforcement manually would play the main role. Revit provides various methods of placing the reinforcement, but each and every element needs to be done separately which is very rigorous process. In our model what we did was that in slabs the reinforcement was placed using the area methods. For beams and columns separate sections for each beam and column was made. To place reinforcement in the beam both the section and side view of the beam was on, and the reinforcement was placed accordingly. Similar methodology was adopted for the columns as well.

The foundation reinforcement was placed using the area methods.

This was a tiresome job and at the end if this has been done nothing would be achieved. This is very unproductive method. There has been a new tool introduced for the placement of beams named as Robot Structural Analysis. What happens in Robot Structural Analysis is that you place the loading on the slabs as per the original conditions and the tool would automatically generate the reinforcement details in the model as per the ACI specifications. But this tool has certain limitations and also requires high memory processing.

4.4.3 MEP Model

NUST School of Social Sciences and Humanities has been equipped with modern infrastructure and to cope with extreme weather conditions the building is centrally air conditional. Since HVAC is under the scope of mechanical engineering therefore problems were faced in understanding the details of the drawings and specifications. With help of some professionals the drawings detail was understood.

Afterwards the architectural model was imported to systems template and the MEP model was prepared accordingly.

4.4.3.1 HVAC Model

The main system of the HVAC is placed at the roof of the building. It is linked to all the fixtures in the building through the ducts provided in the building.

4.4.3.1.1 Fixtures

The first thing we did in making the MEP model was to place the fixtures in the ceilings of all levels. All kind of openings to take in cold air and bring out the exhaust air were provided in the ceiling plan.

4.4.3.1.2 Duct Layout

The ducts that would be connecting the HVAC central system to the fixtures in the ceiling plans were placed in the building. The layout of the duct system was made and all the network of the ducts was formed with the fixtures provided in the ceiling plans.

4.4.3.1.3 Duct Sizing

As per the requirements of the fixtures and the air loads the size of the ducts change. It is uneconomical to have ducts greater than their required sizes. So as per the specifications the duct sizes was changed. One needs to be careful in doing this because the connections may disconnect while sizing the ducts.

4.4.3.1.4 Vertical Ducts

There is a shaft provided in the all the roof levels allowing the ducts to be interconnected and at the end joined to the main HVAC system. A section of building at the region of shaft was cut out to efficiently place the vertical duct and provide connections to the supplier ducts without any errors and at proper bending, otherwise the efficiency of the system could be lost.

4.4.3.2 Plumbing model

Separate plumbing template was used to produce this model. The Revit architectural and structural model was imported to the template and accordingly the plumbing fixers, pipes etc were added to the model for further analysis.

4.4.3.2.1 Fixtures

Plumbing fixtures like pipes, sink, Indian flush, Commode, Water heaters etc. were placed in their respective locations.

4.4.3.2.2 Piping System

There were different kinds of pipe systems introduced in the model. For the collection of rainwater a pipe system was placed connecting the roof top to the base collection and the main holes were placed at the ground level. Those were the collection points and connecting it to collect all the water at one place.

Underground water tank is also placed in the building and along with that it is connected to the overhead water tank. A separate pipe system is provided for this connection.

Another connection is for the supply of hot water to the washrooms in the building. The pipe system linking the overhead water tank to the water heaters and then from water heaters to the washrooms is provided.

Another system for supply of cold water is provided directly from the overhead water tank to the washrooms. Most of the water used in the building is supplied through this system.

The last system is for the sewerage collection of the building. It is connected to the main hole and the sewerage water is disposed of accordingly.

4.4.3.3 Electrical Model

The electrical fixtures provided in the drawing were placed in the model. The electrical connections were beyond the scope of civil engineering therefore not provided in the model.

4.5 QUANTITY TAKE OFF

The model was exported to Autodesk QTO for the generation of reports for cost estimate. In our scope we have determined the quantities of the all the materials used in the building. These quantities are then combined in the form of detailed report and attached in the appendix of this report.

4.6 SCHEDULING

The model was exported to Autodesk Naviswork for the simulation of sequencing of activities during the construction phase of the building. The primavera schedule was linked to the model of the building and the virtual simulation of the building process was visualized with respect to the associated schedule.

4.7 CLASH DETECTION

During the construction process one of the main problem for the contractor is the clashing of different elements if they were constructed according to the drawings and specifications provided. This actually slows down the process of construction at the site and is cause of headache to the contractor at the site. If these issues are resolved at the planning phase of the project, a lot of work would be reduced and no rework would be required to be done by the contractor at the site. It is the ability of BIM that it has been providing us this kind of facilities and has been making us make the construction industry more innovative in performing the tasks of the construction at the site.

For the purpose of clash detection the architecture and structure model was been linked to one another on the basis of origin-to-origin. When the harmony was established between architecture and structural model it was linked to the MEP model of the building and this linked file was then exported to Autodesk Naviswork for the purpose of clash detection. Naviswork after processing all the models and comparing them generated a detailed report of the clashes among the models. There were around 285 clashes in the model which then grouped to 35 on the basis of similarities and repetition of same kind of clashes among the models. The status of these clashes can accordingly be updated to "resolved" or as it is when the clash has been removed. Same clash detection tests were run again for the detection of clashes among the plumbing and structural model as well. Some of the clashes were resolved, while resolving the rest was beyond the scope of the project because that would change the size of the air ducts which would ultimately affect air load handling of the building.

4.8 ENERGY ANALYSIS

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

1. By using conceptual mass 63
2. By using building elements

The energy model was created by using basic building elements. In energy settings, the real life location of the building was selected and the building type was specified e.g. hospital, school, office etc. You can select either 'rooms' or 'spaces' as export category. Rooms is selected to run energy simulations based on architectural elements of the building. Spaces are selected to run MEP elements based energy simulations. Rooms were selected as our export category. All the floors of the building were divided into rooms. Default thermal properties and systems properties were used since the details were not available. Care must be taken that there are no open spaces left in the building and the building forms a whole closed figure. Open spaces will lead to errors that will not allow the model to be exported as a gbXML file. All the open spaces were closed and the model was exported to Green Building Studio. Energy simulations were run on Green Building Studios and detailed reports were created as an output.

Chapter 5

RESULTS AND ANALYSIS

5.1 INTRODUCTION

The purpose of this project was to learn the application of BIM to the construction industry and accordingly establish the advantages of BIM tools to the AEC industry. The case study of NUST School of Social Sciences and Humanities was taken. NS3H is a new and under construction department at NUST H12 campus. It covers the area of 11550 square feet and is a four storied building providing state of the art facilities to its students. It is modernly equipped with the latest technology available providing its students an excellent opportunity to excel academically. It was an ideal project for the case study of BIM. This chapter includes the results of case study. Quantity estimation, clash detection, scheduling, and energy analysis.

5.2 ERRORS IN DRAWINGS

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

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

There were some errors in the drawings in which the structural components of the building were clashing with the openings i.e., windows in the project. What happened in our project was that the column was passing through the window in the east wall of the building. The project manager was contacted for the clarification of the error. What happened at site was that the location of window was changed as the column location would result in the structural design change in the building and could cause more problems. Since traditional CAD models were incorporated in the building and it could not have been updated in the model. If it had been BIM model, the changes in the model would have been applied in the project accordingly. This is one of biggest advantage of BIM technology that the drawings could be updated at any stage of the project without any extra efforts.

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

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

5.3 QUANTITY TAKE OFF

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

5.4 CLASH DETECTION

One of the important features of BIM technique is that it allows us to detect the clashes among the different objects of model. This allows us to plan right at the planning phase of the project how to construct all the different components without any clash detection. This thought process in the start of the project makes us to reduce the RFI's on the project and the rework to design the components at the later stage and in in-situ conditions.

5.4.1 Clash Detection in Revit

The 3D visualization in Autodesk Revit allows us to visualize all the clashes among the objects of the model. However this is an empherical method and one has to go through the rigorous process of looking in detail each and every part of the project. This was not possible in the traditional CAD modeling and BIM allows you to do it, and effectively carry out the process of construction in the industry.

The following figure gives the overview of one of the clashes detected in the project while working on it.

5.4.2 Clash Detection through Naviswork

The linked structural and MEP model was exported to Navis work. The Naviswork detected all the clashes among the different components of the building. The reports were generated in the software and are attached in the appendix of the report.

5.5 ADVANTAGES OF BIM TO PROJECT PARTICIPANTS

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

5.5.1 Architect

- A designer needs to be very experienced to visualize the tools available and a considerable amount of time is required to its applications, however in BIM model the designer could work in multiple views at the same time and the automatic generation of 3D model enhances the visualization ability of the designer.
- As these tools are incorporated in the project, separate plans, sections and elevations of the same object needs to be prepared which is not linked to each other in any way. In BIM model making the sections and elevations is just a click of mouse away. These sections and elevations are as per the plans and the separate human effort induced is reduced while the use of BIM model.
- The work gets cumbersome and is prone to a lot of errors. The model generated by the use of traditional tools is only for the purpose of visualization and no information about the materials used or section properties are provided in that model. The model generated by BIM tools is intelligent and can be used for further applications of BIM tools like energy analysis or structural analysis.
- If at any stage of the project the designer desires to bring about any kind of change into the project, he needs to do that separately in all the views related to that object. However in BIM model any change can be made at any time in the project. Since the views are interlinked, so any change in any of the view would automatically change the properties of the objects in the simultaneous views.
- The cost estimation is done manually and they are prone to a lot of errors, since a lot of things could be missed out in the manual estimation however BIM provides an accurate quantity take offs form the model prepared.

5.5.2 Structural Engineer

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

5.5.3 HVAC Engineer

- In the traditional designing tools only the layout of the ducts was given, no details about the thickness of the duct, about the places where the connections would be provided was given due to limited capability of the 2D CAD tools. Due to the 3D modeling available the plan as well the elevation of the layout is also made.
- Traditionally the contractor decided about the details of the section of the ducts on site after reviewing all the spaces available, making the job more difficult, however in BIM model detailed sketches are made at the planning phase of the project.
- There is huge chance of a lot of clashes among the different components of the building however in Revit 3D model the clashes are reduced due to better visualization of the model and also a clash detection report is generated which would remove any missed out clashes in the project. This would allow the work on site to pace up.
- If at any stage of the project the designer desires to bring about any kind of change into the project, he needs to do that separately in all the views related to that object. However in BIM

model any change can be made at any time in the project. Since the views are interlinked, so any change in any of the view would automatically change the properties of the objects in the simultaneous views.

5.5.4 Plumbing Engineer

- Lack of ability to identify conflicts due to the 2D representation of the designs. However revit would let you identify and let you decide what to be done about it if any kind of clash arises.
- The lack of identification of conflicts results in the construction process. The BIM tools provides the solution for clashes and the time is saved.
- The designer is always having a fear in his mind that whether or not his design would fit into the system, thus he provides only the layout; however in revit the designer designs with confidence with removal of any kind of errors or conflicts in the design.
- A lot of rework is needed to remove the clashes on site, which is not needed in case of BIM modeling.
- If at any stage of the project the designer desires to bring about any kind of change into the project, he needs to do that separately in all the views related to that object. However in BIM model any change can be made at any time in the project. Since the views are interlinked, so any change in any of the view would automatically change the properties of the objects in the simultaneous views.
- The conflicts are identified after the budgets are approved, which is ultimate cause of conflict between designer, contractor and owner and in this case a lot of RFI's would be generated for the cause, which is reduced in case of BIM modeling.

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

5.6 PROBLEMS AND 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 applying various solutions to our problems posted on the internet. This was a time taking process.

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

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

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 PROJECT OBJECTIVES

The objectives of this project were following:

- To learn about BIM.
- Create a BIM Model of a building to Estimate Quantities, do Scheduling, generation of Clash Detection reports of different building elements, Energy Analysis and Structural Analysis using BIM tools.
- To explore the areas where BIM can help improve efficiency of a building design process.

6.2 CONCLUSIONS

After applying the technology of BIM to a real life model, we have drawn the conclusion that this technology must be adopted by the AEC industry due to the benefits it has been providing. The following conclusions are drawn from the research we have conducted.

- BIM allows you to produce high quality drawings and the errors are reduced in it and less time is consumed, so this should be adopted for producing high quality drawings in less time.
- The use of BIM should be made by the architects for their design because it allows them to make better designs and visualize the end product in better way. This gives the architect the opportunity to interact with the owner and designer and all of them could draw better conclusions from the model at the planning phase of the project.
- BIM must be used for the design of HVAC system of the building because it makes it accurate, efficient and less prone to clashes with the other components of the building.
- Greater coordination could be established among the piping systems if BIM tools are used for the purpose of Plumbing design.

- BIM should be used in quantity take off of the building, but care should be taken while modeling to ensure the accuracy of the quantities.
- The important tool, by which the contractor should be convinced for the use of BIM technology in building, is clash detection. The clashes among the different components of the building could be reduced using this tool. This would make the life of contractor easier since no site re work would be required from him during the construction process.
- Sustainable development is one of the requirements of the developing technologies. BIM facilitates you in performing the energy analysis of the building, thus making the greener and environmentally friendly buildings.
- High computation power computers are recommended for BIM model preparation and the use of more than one screen would enhance the productivity of the model.

6.3 RECOMMENDATIONS

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

Since BIM allows you to visualize the end product at the very beginning phase of the project it removes the ambiguities of the project participants about the project. BIM allows you to remove errors in the drawings, remove clashes between components and getting detailed sections giving the benefits to the project participants, it is highly recommended to efficiently use this technology.

High memory computers should be made available before the application of BIM for the design process.

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