Assessment of benefits of BIM application with Traditional Project Delivery Method

A thesis submitted in partial fulfillment of
the requirements for the degree of

Masters of Science
in
Construction Engineering and Management

by

Waqas Ather

(2012-NUST-MS-CE&M-04)

Department of Construction Engineering and Management
National Institute of Transportation (NIT)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences and Technology (NUST),
Islamabad, Pakistan.

January, 2015

This is to certify that the
thesis titled

Assessment of benefits of BIM application with Traditional Project Delivery Method

Submitted by

Waqas Ather
(2012-NUST-MS-CE&M-04)

has been accepted towards the partial fulfillment
of the requirements for the degree of
Masters of Science in Construction Engineering and Management

____

Dr. M. Jamaluddin Thaheem
Supervisor,
Department of Construction Engineering and Management,
NIT, SCEE, National University of Sciences and Technology (NUST), Islamabad

DEDICATED
TO
MY FRIENDS

(Who helped and guided me in completing this thesis)

ACKNOWLEDGEMENT

The completion of this thesis would not have been possible without the guidance, help and patience of a number of people, who in one way or the other extended their valuable assistance in the continuation and completion of this research. First and foremost this piece of work would never have been accomplished if it wasn't for the benevolence of one above all of us, the all-pervading Allah, for answering my prayers and for giving me the strength to keep moving despite several hurdles and hiccups , thank you so much Dear ALLAH.

Further I would like to pay debt of gratitude to my advisor Dr. Jamal Thaheem, for his fathomless guidance, valuable time and encouragement, to complete this research work. I am also extremely grateful to the committee members, Dr. Hamza Gabriel, HOD water, Dr. Waheed, (Assistant Professor, NICE) and lecturer Ma'am shahnila for their sincere guidance to complete this research work. I owe my special thanks to Asst.Professor Zia-ud-Din for his help and support throughout my course work and during my research work which contributed much in fine tuning of this research work. I also owe my special thanks to the respondents for their valuable contribution to this research. I would also like to pay my earnest gratitude with sincere sense of respect to my father and family for their unending support, encouragement, prayers and patience.

Waqas Ather

ABSTRACT

BIM is a latest tool facilitating the project managers to achieve higher performance. Not only that it helps the client to go through the model to confirm project needs, it also helps the designer to perform constructability analysis and make a realistic design. Such a design, duly approved by the client, would allow the contractor to quote more realistic bid which will ultimately help avoiding change orders, disputes and enhance the quality of the project.

In Pakistan, the construction professionals are familiar with the potential benefits of BIM adoption but its implementation in the industry is limited. The situation is further worse when talking about the public sector. One of the reasons is prevalent traditional project delivery method which hinders the early collaboration of designer and contractor. This research focuses on finding the opportunities and challenges of BIM implementation on Design-Bid-Build (DBB) projects. The issues of BIM model development and ownership are also researched. It was found that (47%) of the total respondents are of the view that main difficulties in adopting the BIM are related to the cost of adoption in the company/project and (38%) of the respondents are of the view that the lack of awareness towards new technology is the main cause. Although the professionals understand that BIM implementation will help in achieving the project within the stipulated time and cost. Moreover the realistically constructed and updated as-built model will help the facility management operations as well. Regarding the ownership of the BIM model all the stakeholders are of the view that it should be managed by the PM of the consultant and it should be handed over to the client at the handing over of the project. The cost should be reimbursed to them on a fixed rate or on the actual cost basis. A case study conducted on a running project revealed a number of benefits in terms of estimation and clash detection. In conclusion, it can be stated that the construction sector needs a major overhauling in contracting documents and in the skills to adopt the BIM. Educating the clients and modifying the contracts could make things easier and will help all the stakeholders to perform project with less cost and more benefits

Table of Contents

Table of Figures

LIST OF ABBREVIATIONS

AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
2D	Two Dimensional
CAD	Computer Aided Design/Drafting
ACM	Agency Construction Management
DB	Design-Bid
DBB	Design-Bid-Build
MEP	Mechanical, Electrical and Plumbing
PEC	Pakistan Engineering Council
VDC	Virtual design and construction
USA	United States of America
UK	United Kingdom
SPSS	Statistical Package for Social Sciences
ANOVA	Analysis of Variance
CI	Construction Industry

CHAPTER 1

INTRODUCTION

1.1 Brief Description

The construction sector is not new to humans, it took years to construct a single house earlier but now the skyscrapers and bridges are being constructed in months just due to the advancement of the technology (Azhar, 2011). Building Information Modeling (BIM) is one of the most promising and recent developments in the construction industry. BIM is a process which starts with digitally built model(s) in which buildings are built virtually before they actually get built on site. BIM is an interlinked database of coordinated information for which different stakeholders participate throughout the project life cycles. Firms that adopt BIM in their early stage, now have the justification that the projects are being completed in more time and cost effective manner (Becerik-Gerber et al., 2012). When BIM will be used with the traditional project delivery system it will improve the growth and increase the competitiveness among the construction industry by eliminating waste and inefficiency and stimulate higher level of innovations, which in a result will make construction more affordable and cost effective and create better opportunities for the stakeholders (Office, 2011). Therefore the international industry is speeding inevitably towards n-Dimensional virtual modeling and away from paper based drawings (Tenku and Noumbissi, 2008).

The Design-Bid-Build (DBB) project delivery system is being used extensively in public sector to get the competitive bidding for public money. The DBB is a very popular project delivery system and for this reason it is also called ‘Traditional’ method (Molenaar et al., 2009). In DBB the designer is directly in contract with the client to provide the design whereas the contractor is on board for the execution of the design only. So different stakeholders are involved for design and construction and drawings have already made when the contractor is selected. So the bidders estimate the cost on the basis of the drawings available and usually the contractor who wins the contract is the one who submitted the lowest BID (Bolpagni, 2013). Generally the contractor is being selected on the cost basis and due to the errors in project itself and the changes being made by the client the scope of works increases because the BIM usage in the tender stage is very limited (Finne, 2012). The usage of BIM in the earlier stages is not wide spread and the late participation of the contractor makes this delivery method not much conducive for the BIM adoption. To add on this the tender documents usually not contain complete drawings for the potential bidders to figure the quantities which results in inaccurate estimation and low or high bid prices. The study is planned to make the construction firms in general and public sector in particular aware of the benefits of BIM and how useful it can be in achieving improved performance on their DBB projects. A frame work for BIM implementation in the public sector projects mainly in DBB project delivery system would be suggested. Advices on the ways for smooth implementation of BIM in DBB projects would be sought. Furthermore, this study also attempts to show the BIM 5D model on Overseas Employment Corporation (OEC) project to assess the benefits of the implementation of the BIM. The data was collected from the project site and main office. The research will identify the changes that are necessary to meet the industry's performance requirements.

1.2 Background

A lot of research has been carried out on BIM in the world. Now most of the American construction companies demand submission of BIM model as mandatory in their program requirements (Suermann, 2009). Liverpool School of Architecture has started B.Sc in BIM program. Professor Steve Lockley, Research Director of the BIM Academy, Northumbria University has done extensive work in BIM for its application in facility management (http://collab.northumbria.ac.uk/bim2/about-us/team).

But no significant research work is available in Pakistan on the proposed subject. Last year one MS thesis was carried on the BIM related topic by Kifayat Hussain (2013) at the NIT-SCEE, NUST. Some promising work in Pakistan, however, has paved way for early research; the takeaway lesson is that *"*BIM can aid in performing complex building performance analyses to ensure an optimized sustainable building design*"* (Azhar, Brown et al. 2009;). In UK *Client BIM Mobilization and Implementation Group* has been set up in year 2011 to see the opportunities and strategies of BIM implementation (Office, 2011).

*"*BIM can be well used in all the phases and life cycle of project: the owner can use it to go through the project needs; the designer can analyze the design; the contractor can manage the construction and the facility managers can use it for the operational and decommissioning phases*"* (Bryde, Broquetas et al. 2013). Another study proposed that BIM provide a better opportunity to achieve project objectives. It involves the development

of computer generated n-dimensional models to analyze the constructability and operational aspects of a project. It helps all the project participants to detect the issues at the beginning levels (Azhar, Nadeem et al. 2008).

In DBB projects the use of BIM can be very useful as mentioned by Azhar (2011) "BIM can help in getting improved quality of the product and getting more sustainable design of buildings". Porwal and Hewage (2013) (Porwal & Hewage, 2013) worked the possibility of the coexistence of the BIM model and traditional 2D drawings with the issuance of property of documents. (Yan & Damian, 2008) published the possible benefits and barriers of BIM implementation on the basis of literature review and questionnaire survey.

The highlights of this study are that the biggest benefit of BIM is that it saves construction time and the biggest barrier in its implementation is that it requires skilled human resource to operate and manage. Researcher carried out several studies on Implementation of BIM in public sector study in USA, Singapore, Finland, UK, etc. and they found that some countries have made mandatory the usage of BIM and they have made guidelines as well (Wong, Wong, & Nadeem, 2010)

1.3 Justification

In the last 5 years, the idea of BIM has gained considerable attention in Pakistan. Most of the architectural firms from medium to large scale have now a basic understanding of BIM. The major reason behind this is the exchange of technical workforce between Pakistan and surrounding countries, such as United Arab Emirates and Malaysia, which are progressing at a faster pace and where technical knowledge within the Architecture Engineering and Construction (AEC) industry has grown by leaps and bounds. Professionals who went for work in these countries they brought back with them a widened and broad understanding of BIM and its applications.

BIM in Pakistan is thought as a design approach, in which data sharing between all the stakeholders is possible and can be used to develop BOQ's and Schedule . But the usage of construction and/or procurement details, environmental data in BIM or its use in project management and facility management is understood to a lesser degree and to add insult to the injury it is understood least in the public sector. Paper based procurement approaches result in miscarried and misinterpreted information (Eastman et al., 2011). Similarly it's not being used in the initial phase of procurement, whereas it is understood that the adaptation of BIM in the tender phase can improve the overall work flow (Finne, 2012). Similarly (Horton, 2000) said making the use of BIM mandatory in public sector will create economic benefits. As stated by (Bolpagni, 2013) that the client can get more accurate and reliable bid, if the implementation of BIM in tender is ensured. Furthermore, it would help avoiding change orders and the issuance of revised drawings again and again. This is the dilemma with public sector clients that they opt for the lowest bid often missing the best value from the potential bidders eventually resulting into cost and time over runs.

When BIM would be used in early stage in bidding process the contractors would work out exact quantities and therefore can give good bid price to the client. Whereas it has seen that normally in projects without BIM the contractor who bids the low gets the project irrespective of how unrealistically he quotes. Therefore it would help the contractors to visualize the complex projects fully; it will help them to estimate correctly and suggest any improvements. Moreover during construction they would be able to avoid doing rework and variation orders to a great extent because of the clarity of the scope. Furthermore they can perform the safety analysis and Hazard analysis more easily for different tasks. It will help them planning work more efficiently and the space and overlapping clashes of subcontractors can be then managed easily, which will boost the morale of the overall project team. On the other hand it will help avoiding disputes during the execution of the project and at the closeout. On the top of all; the BIM model after the project completion can be handed over to the client who can then use this model for the facility management and can take the facility management and operation phase to a next level. Through case study, it will be investigated how much benefits can be achieved through the implementation of BIM and the suggestion to avoid the deviations from the baseline and to reduce the wastage and extra price.

1.4 Objectives

The objectives of this study are:

- To find the benefits of BIM on the DBB projects and the obstacles in achieving them.
- To develop a framework that how BIM can be implemented in different phases of construction on DBB projects.

- To measure the benefits of BIM applications on a running project through case study.

1.5 Relevance to National Needs

Pakistan construction sector is in developing stage and currently it is facing the scarcity of professional skills and technology. Most of the contracts in public sector are Design Bid and Build. These contracts at one hand are to obtain best value for public money but on other hand due to its structure they do not give the desired results to public sector clients. Due to the late involvement of contractor and limited data provision related to the project at initial stage there exist too many problems in executing such projects which needed to be addressed.

On public projects we observe contractual clashes arise very frequently due to the lack of communication channel and slow coordination process. The request for change orders is often exercised which requires noh age to get it approve from the top management. Often the chairman of the institution is the project sponsor and when that project sponsor is transferred to some other department. The project being constructed suffers a lot of submittals and elevation approval issues. The projects due to late participation of contractor and limited data face cost and time slippages.

Sharing of the benefits of BIM with the construction industry participants will help the industry to a great extent. The contractors will be able to perform cost and schedule control measures more effectively. They would be able to give best price to the client. The client will visualize the project in true sense, they can estimate the project cost more accurately and hence it will help them to reduce the change orders. Similarly the consultants who are responsible to manage and administer contract will be in a better position to detect and avoid clashes arising due to the schedule overlap and work performance. This will eventually improve the end product. The constructability analysis will be easier and we can have the zero accident projects in Pakistan as well.

1.6 Advantages

The construction industry in a developing country like Pakistan needs much effort to excel in technology. The use of technology has proved all over the world the benefits in achieving project goals in lesser time and lesser costs. Its almost 40% less cost involved in constructing a secondary school in UK now due to the inclusion of new technology and improved contracting systems (Office, 2011).

The subject study will help us to find the benefits of using BIM with the traditional project delivery method. The projects will be performed safer because the designer can see the constructability of the project. When adopted in tendering the contractor can quote price for all the components making the bids more realistic and the benefit over cost ratio of construction projects can be justified. Because of the model the input of client and contractor can be incorporated at very beginning so less change orders will be generated. Due to the model development lesser time will be required for the as built drawings and submittal processing so the construction project will be completed within the stipulated time. As the subcontractor can coordinate well and foresee the construction activities well before execution so clashes of any sort can be avoided. Secondly due to its editable features no revision of drawings would be needed, which creates hassle during the execution phase .Moreover all the stakeholders can communicate and coordinate better, so as a result fewer disputes would arise and value engineering could be well practiced. This study will improve the DBB project delivery system for public sector to a larger scale as then the prices being quote by the contractor will have the justification. Moreover now the as built data will be most accurate and can be used for the facility management and operational phase, which will in a result, will improve the quality of life of the inhabitants.

1.7 Areas of Application

The area of application of this research is Construction Engineering and execution and in facility management as well.

CHAPTER 2

LITERATURE REVIEW

2.1. Building Information Model

The Building Information Model is a n-dimensional digital depiction of a project and its basic characteristics. BIM gives consistent and coordinated views with reliable data for each view. This helps the designer to save a lot of time for correction as each view is interlinked. According to the National BIM Standard (2010), 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"*.

2.2. Building Information Modeling

Building Information Modeling (BIM) is the tool for executing the virtual design into real time construction. It's a medium for the project stakeholders to share and coordinate information throughout the project life cycle (Hergunsel, 2011).

2.3. Types of BIM Model

There are several building Information Model (Hergunsel, 2011).

2.3.1. "Hollywood" BIM

When a 3-D model is developed only to better understand the BIM concept and the contractor doesn't use the information in this model to develop the Building information Model then this is known as Hollywood BIM

2.3.2. "Lonely" BIM

When BIM model is used internally within a single Organization and doesn't share it with other stakeholders then this type of BIM is called "lonely BIM". Therefore this would hurdle the participation of the construction manager (CM) unless a new model is created by the CM (Vardaro, 2009)

2.3.3. “Social” BIM

The social BIM is the one of the best model out there. The model is shared among the engineer, architect, construction manager and the sub-contractors for the collaboration purpose. During design phase all the stakeholders can give their expert opinion about the construction to design team.

2.3.4. “Intimate” BIM

Intimate BIM is another best Model for the coordination and collaboration purpose. In this model the owner, design team and construction manager share risk contractually and get reward. Both Intimate” and “social” BIM make teams to collaborate better to produce better drawings in a cost and time effective manner.

2.4. Project Delivery Methods and BIM

No matter which delivery approach is chosen, the general contractor or the construction manager can use BIM (Sebastian, 2011). BIM can be used to make realistic cost estimates by extracting quantities from the model. The contractors can obtain powerful rendering out of it. The construction schedule can also be integrated in BIM called a 4D model, which is then used for safety analysis and to make site logistics plans. The costs and schedule can be updated through BIM. Last but not the least the model with as-built changes can be handed over to the facility management team for the operation phase.

2.5. BIM for Construction Managers

On a project the construction manager’s job started as soon as the project is awarded. The construction delivery approach is dependent on the timeline given to the construction manager and the organizational structure of the project (Ahuja, Dozzi et al. 1994). In Building information modeling the construction delivery approach and the organizational structure of the project impacts the participation of the construction managers.

2.6. Design Bid Build Approach

In the traditional project delivery, the design, bid, and build phases comes after one another. The architect is usually the lead designer in building projects and construction manager works directly for the owner due to separate contract binding. The engineering consultants or sub consultants are in the designer’s team. Ideally the engineer/architect designs the building at first stage. After, the completion of the design, the construction managers/ general contractors bid for the project. Once the contract is awarded, then the construction work commences. Due to its arrangement this delivery method is not a fast track method. In other words, this method bars the early participation of the construction team in the design phase (Gu & London, 2010), or in other words a 3D parametric model generated by the designer for the project, will be in short of critical information of the contractors during the early phase. So the DBB method eliminates the benefit of introducing the construction input in the design phase when the impact of cost is the highest as shown in figure 2-1. Furthermore the designer due to risks of unauthorized reuse and the misinterpretation of the information provided may not want to share their model.

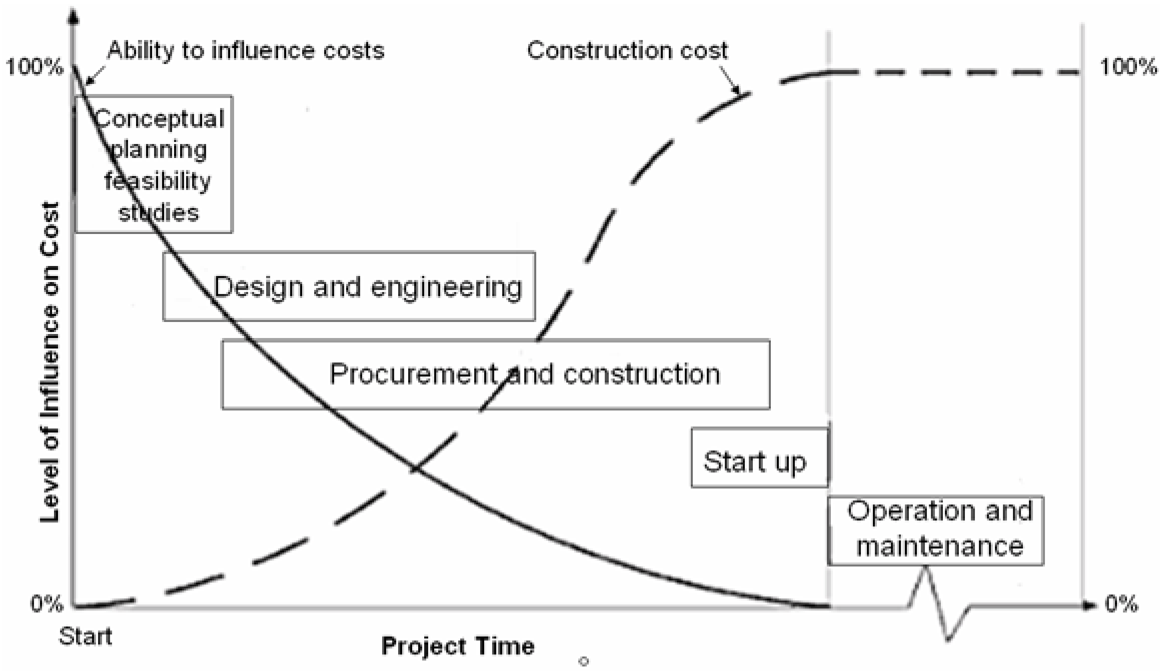


Figure 2- 1 Project Life Cycle - ability to influence cost (Eastman, 2008)

2.7. Construction Management at Risk

When, both the designer and the construction manager are in separate contracts with the owner, than this is known as Construction Management at Risk delivery method. In this approach they can collaborate and help in each other's work and report the owner. When BIM is used in this approach their lies the same risk like in the traditional project delivery method (Hergunsel, 2011). Due to early appointment of the Construction manager in Construction Management at Risk approach in the early stage. This enables the input of the construction team during the design phase in the BIM model. This can be used for both private and public fast track projects.

2.8. Design/Build Approach

When a single body takes over the responsibilities of the design and the construction for the owner than this is known as DB project Delivery Method. In this delivery method the BIM can be used from beginning of the project. The strong collaboration of the designer and the builder can make the use of the Building Information modeling as a strong and effective tool. In addition, as described by (Foulkes, 2010) that BIM creates other efficiencies such as there is great potential of lowering the cost of rework because of clash detection functions. At the completion of the design phase a fully developed model is available which helps the contractor to save time and money on site.

On complex projects BIM can bring more clarity and confidence in the co-ordination process. It would help contractors to go for the prefabrication options to help managing schedules. BIM would help minimizing waste on site because of relatively accurate ordering and take offs. Due to BIM the concepts of modern procurement techniques can be well implemented on site i.e. Just-in-time.

Through the implementation of BIM on DB projects. The contractor can for see the potential safety risks well, perform constructability analysis. BIM helps getting fast regulatory approval and can improve commissioning and project close-out. So using the BIM will help saving as built data well and can be extracted when needed. This will eventually lessen the issues being blamed on contractor after completion.

2.9. Integrated Project Delivery (IPD)

The structure of integrated project delivery (IPD) method requires designers, construction manager, subcontractors and owners to share the project risks. If the project stays within budget, then all the project participants receive their share of profits. Otherwise, they all lose their fee. This incentive promotes all the participants to work together towards a common goal. The share all the Building Information Model, share decision making, and share the responsibility. This joint project management approach results in pure collaboration and no litigation. Overall, Building Information Modeling makes IPD achievable (Handler, 2010).

2.10. Shortcoming for DBB and its Remedy

The Building Information Modeling is a process of virtual design of the project and its construction (Büchmann-Slorup & Andersson, 2010). Due to the involvement of

General Contractor after the completion of Design phase, so therefore the traditional approach will not be best method to reap the benefits of BIM in contrarily to other Delivery methods.

As Salmon (2012) stated that the structure of DBB delivery system is itself hinder to reap its potential benefits. As (Bolpagni, 2013) has advised to obtain potential benefits at 1st place the number of offers must be increased and to obtain more realistic bids some risks are to be shared by client. He suggested that the quantities should be worked by client and these quantities should be provided to the contractors with the Model, who then submit the bid.

2.11. BIM and Project Phases

There are many uses of Building Information Modeling for each project participant. Figure 2-2 shows these uses for the planning, design (preconstruction), construction and operation (post construction) phases.

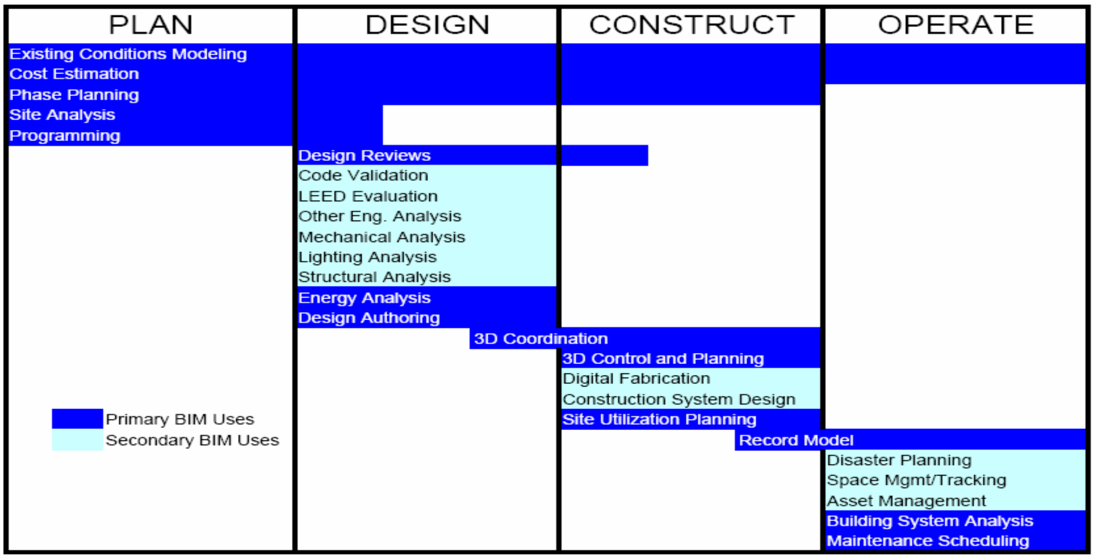


Figure 2- 2 BIM Uses throughout a Building Lifecycle (Messner, 2009)

During the design phase, the use of BIM can maximize its impact on a project since the ability to influence cost is the highest. The team can creatively come up with ideas and provide solutions to issues before problems become high cost impacts to the project. This can be realized through the cooperation and coordination of the entire project staff. Therefore, it is extremely important to have a good collaboration. The use of BIM especially enhances the collaborative efforts of the team. The architect and engineer can test their design ideas including energy analysis. The construction manager can provide constructability, sequencing, value and engineering reports. They can also start 3D coordination between subcontractors and vendors during early stages of design. The owner can visually notice if the design is what he is looking for. Overall, the BIM promotes the collaboration of all of the projection participants.

There are beneficial of using BIM during the construction phase. However, the ability to impact the cost in a project reduces as depicted in figure 2-1 as the construction progresses. Several uses include sequencing, cost estimation, fabrication and onsite BIM. These uses are later discussed in detail.

During the post construction phase, maintenance scheduling, building system analysis, asset management, and space management and tracking, disaster planning, and record modeling can   a record model can help to maintain the building throughout its lifecycle. Ideally, the building automation systems (BAS) which controls and monitors the use of mechanical and electrical equipment can be linked to the record model to provide a successful location based maintenance program. Furthermore, building system analysis including energy, lighting, and mechanical can be used to measure building's performance. Moreover, upgrades may be initiated to various equipment and components of the building.

2.11.1. Visualization

BIM is a great visualization tool. It provides a three dimensional virtual representation of the building. During the bidding phase of the project, the construction manager can provide renderings, walkthroughs, and sequencing of the model to better communicate the BIM concept in 3D.

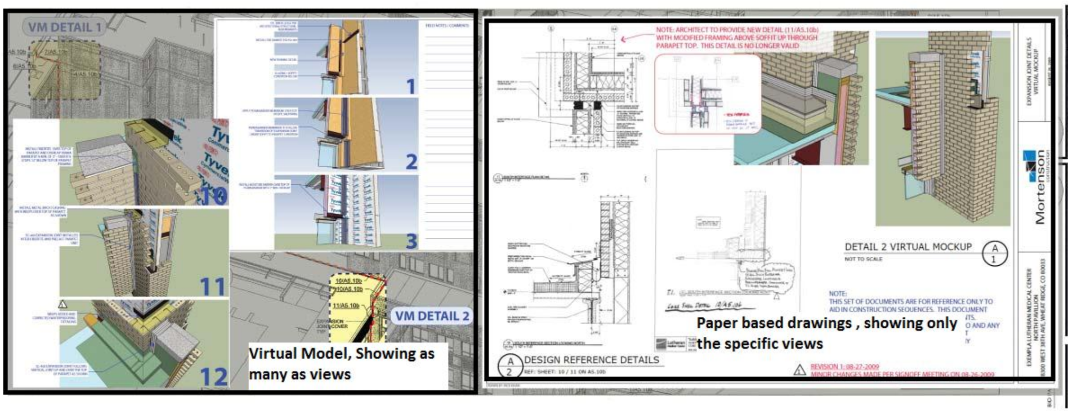


Figure 2- 3 Exterior Envelope Virtual Mock up for 3D Shop Drawing Review (Khemlani, 2011)

2.11.2. 3D Coordination

The Building Information Modeling shall immediately be implemented at the start of the design phase so that collaboration of the construction team with the architect, engineer and the owner is started. In BIM based construction the 2D drawings provided by the architect must be then converted into 3D intelligent models. This 3D model will help to coordinate the work of sub-contractors. The 3D coordination can then be conducted right after the model development to avoid any hard clashes (space interference) and soft clashes (clearance clash) conflicts. This is shown below in figure 2-4.

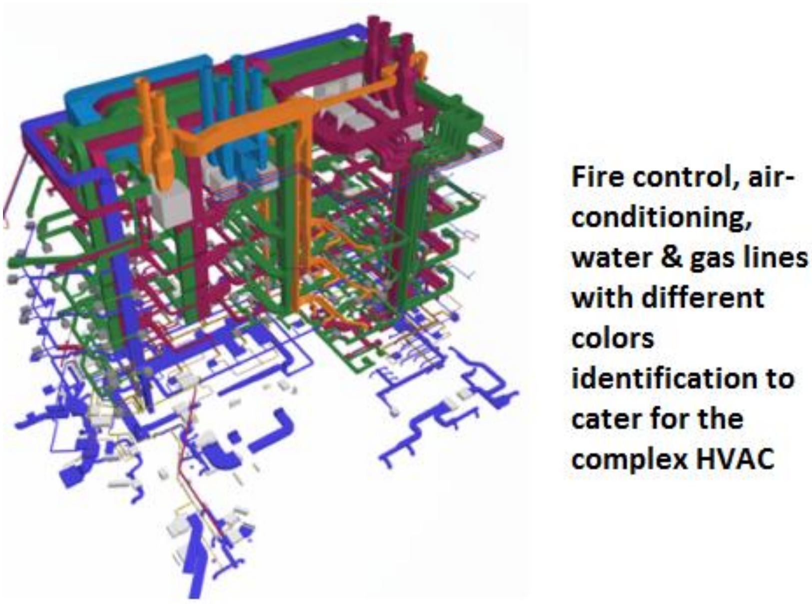


Figure 2- 4 Layers of Complex Systems

2.11.3. Prefabrication

Field labor cost and time can be reduced by using prefabrication moreover it increases accuracy in a good quality construction. In prefabrication there is a controlled environment, where more tools and options readily available to finish work more precise taking less time in more cost effective manner. By including the specs, activity sequencing, finishing details and 3D visuals of each component can provide a Building Information Model this level of accuracy can be achieved.

2.11.4. Construction Planning and Modeling

The work schedule of any project can be integrated within the Virtual 3D model. By adding the schedule into BIM the planning will be improved which will enhance the site utilization and space coordination

2.11.5. Cost Estimation

The Quantities can be extracted from a Building Information Model to a cost database.

2.11.6. Record Model

A model after incorporating the as-built drawings into the BIM model can be handed over to owner. The owner can use this model to manage security and safety of the building by extracting information such as emergency lighting, emergency exits, fire extinguishers, fire alarm, smoke detector and sprinkler systems (Liu, 2010).

2.12. Benefits of Building Information Modeling

The hardcore benefits of BIM were presented in a paper by (Bryde, Broquetas, & Volm, 2013) are "BIM puts the paper-based tools used on construction projects onto a virtual environment that enables an improved level of communication and collaboration that exceeds than those of conventional construction process ".

Similarly, one more benefit explained by (Grilo & Jardim-Goncalves, 2010) is that BIM can be used at all stages throughout the project life cycle; the owner can use it to apprehend project needs, the designer can analyze the design, the contractor can manage the construction activities and the facility manager can use it for operational and decommissioning phases. A most important benefit is its use by project managers; BIM can be used as a catalyst by Project Manager to redesign their processes to better involve different stakeholders participating in construction projects.

2.13. Importance of the selection of appropriate Project Delivery System (PDS)

Most of the authors agree that for a particular project there may be a PDS that is most suitable but not a single PDS can be used on every project. As the project size, complexity and the level of risk increases and if the owner is Public sector then the client persuade towards the PDS selection with more care. Similarly (Gordon, 1994) has mentioned that "There is no exact science to select an appropriate contracting method. There is no single best method, but several that are appropriate. Similar thing more concisely explained by (Ibbs, Kwak et al. 2003) that over many years the construction Industry is looking for effective project delivery approach for better performance. There are several project delivery approaches such as DBB, DB, BOT, etc. But not any one approach is best appropriate for any general project.

So Selection of the most suitable PDS may significantly affect the project success parameters, such as its stipulated time, cost, and quality objectives and will lower the contractor consultant's claims and disputes.

2.14. Current status of PDS in different countries

Currently the three main PDS being used in America as stated by (Konchar & Sanvido, 1998) that Construction management at risk, design build and design bid build are three principal project delivery systems used in the United States today. Furthermore they did an empirical research and found that projects being performed on Design-Bid approach achieve significant advantages as far as cost is concerned and schedule. In addition to this DB projects when compared with CM@R and DBB projects produce more desirable quality products.

The current status in America's school building procurement about the PDS is studied by (Rojas & Kell, 2008) and concluded that in United States during the 20th century most of the school projects of public sector were procured with DBB, whereas CMR is now an alternative method being used increasingly.

The statistics (Rojas & Kell, 2008) presented are The Pacific Northwest School database PNWSD includes the Oregon and the Washington data sets which was consisted of 8%CMR projects and 92% of BDD projects. Similarly they concluded further that there are very few studies that compare the performance of different project delivery methods.

The status regarding the rework cost and the selection of the project delivery system (Love 2002) concluded that rework costs do not differ relative to project type or procurement method.

As far as the status of most used PDS is in Australia (Love 2002) concluded that in Australia the lump-sum methods are the most popular form of procurement. Though now there is a major shift in the adoption of integrated methods such as design & build.

In India a research was made by (Jeelani, Karthikeyan, & Aldosary, 2012) where he studied the effects on project constraints in DBB project with and without the ACM (Agency Construction Management) projects delivery method the Cost Growth and Time Growth are more in the case of Design- Bid-Build Projects where Agency CMs are not used than the Design-Bid- Build Projects where Agency CMs are used.

2.15. Popular PDS in Pakistan

In Pakistan generally traditional project delivery system is adopted due to its simplicity and procurement agencies rules and regulations. But this system is not conducive as concluded by Farooqui (2008) the conventional low-bid approach has proved in promoting the adversarial relationship, rather than the coordination among the stakeholders. Moreover the owner faces increased vulnerability to contractor's claims over design and constructability issues".

Further Farooqui (2008) has drawn the results of selecting the low-bid price criteria. The outcomes of the research stated that the selection of low-bid criteria has developed a vast range of negative consequences on many projects causing the effect on work environment, team relationship and an overall effect on project performance parameters. Most of the times on a project the low-bidder contractor has put irrelevant claims, employing of low grade human resource, generation of fake disputes, displaying the technical, managerial and financial incompetence".

In other research, Saqib (2008) studied the critical factors that lead to project success on that list he rated the *"appropriate selection of project delivery system"* on 3rd number out of five numbers.

2.16. Comparison between BD and DBB with respect to BIM System

Research on the Empirical Comparison of DB and DBB project Delivery approaches was conducted by Hale, Shrestha et al. (2009) in which he states that DB is more suitable method as compared to DBB in terms of BIM usage. Similarly Roth (1995) took six DBB and six DB projects and compared. He concluded that the DB projects significantly reduce costs associated with design and construction.

Ibb et al. (2003) concluded that DB projects are better than DBB projects in terms of completion time but not in cost. They further stated the project performance mostly depends upon the skills of project management team and the experience of the contractor.

Songer and Molenaar (1996) concluded that the projects procured with DBB have more chances of schedule changes as compared with DB projects.

2.17. Readiness study of the industry for BIM

(Yan & Damian, 2008) researched on the basis of literature review and a questionnaire survey and published the benefits and barriers of BIM implementation as shown in Figure 2-5.

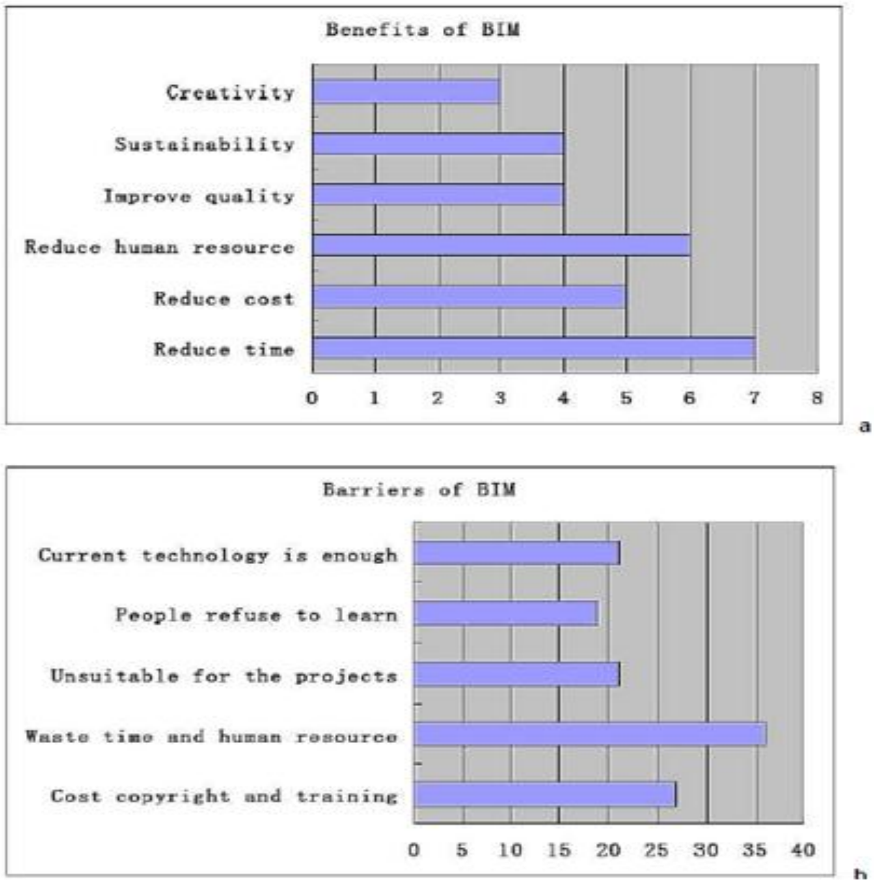


Figure 2- 5 Benefits and Barriers of BIM by Yan and Damain (2008)

CHAPTER 3

RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

This chapter discusses and presents the procedures of research design and methodology for this study. It involves the study tools used, methods of data collection, and the tools used for data analysis. The research is focused around a pyramid of research procedures i.e. questionnaire survey, interviews with the professionals, and a case study. A three page questionnaire was formed for the construction industry's main stakeholders i.e. designer/client, contractor/constructor and facility manager regarding the benefits of BIM application and then the interviews with the construction industry professionals regarding the framework for the BIM implementation with the traditional project delivery system were carried out and lastly the case study for measuring the benefits of BIM application on a running project was performed.

This study was conducted to assess and measure the benefits of BIM application with traditional project delivery method. There are three parts of the research that are; the obstacles in implementing the BIM, the framework for BIM implementation, and the study BIM usage ongoing project. The questionnaire survey was conducted to show the possible benefits and the obstacles in implementing BIM. Interviews are the main source for gathering the suggestions regarding the BIM implementation framework which were conducted with the construction experts. Along with a BIM model was developed for a High rise building projects on which manual and calculations through BIM software was made and important benefits are calculated. The schematic plan of the research is shown in Figure 3.1. First of all a comprehensive literature review was conducted followed by the case study. Publications related to BIM implementation were studied. Based on the literature study, the questionnaire for this study and framework for BIM implementation were formulated.

The following sections provide the details of the research method adopted in this thesis.

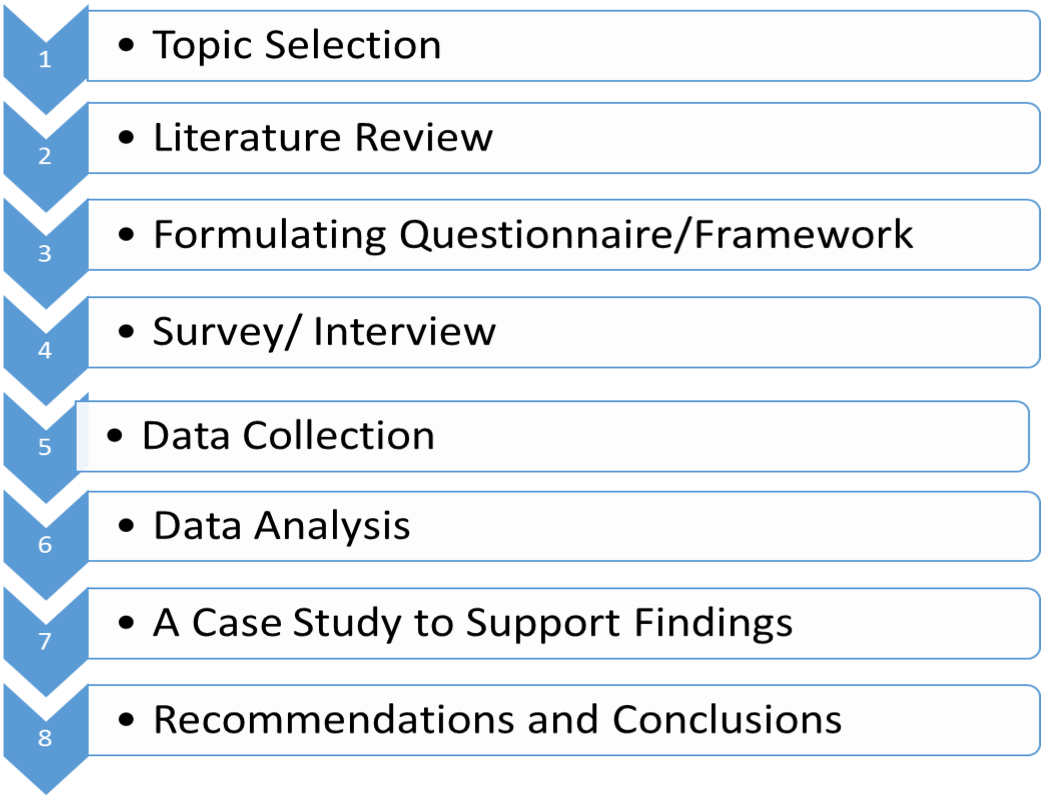


Figure 3- 1 Showing the pictorial view of research design

3.2 Choosing the Approach

3.3.1 The Research Design

There are number of ways to a research. The research design is the strategy to gather information on the subject Topic. The research design is chosen on the basis of problem statement (Ghauri and Grønhaug, 2010).

An exploratory nature of research design is adopted for the reason that our research problem is somewhat unstructured. Although we know the areas needed to consider to answering our research problem but we still do not know the following questions:

- What are the main barriers for effectively implementing BIM in Traditional Project Delivery system?
- How could be BIM can implemented easily in the Traditional Project Delivery System?
- What are the possible benefits of BIM implementation on a Project Procured on Design Bid Build Method?

These questions set the frame for the kind of reasoning that should be applied and the kind of research method and techniques that should be used.

3.3 Setting the Scope

3.3.1 Study Design

The research strategy provide a structure for designing a systematic way that address the study's goals, objectives, and questions. The study design explains the logical flow from the preliminary activities that started the research and the formation of the questionnaire with the help of the data collected and analysis of the data to refine the conceptual model and development of the working hypothesis.

3.3.2 Preliminary activities

To justify and start the research, an in-depth literature review of the publications on BIM implementation in construction sector has been carried out. Moreover previous research on BIM implementation, theoretical frameworks and models relevant to the research topic has also been reviewed. This insight supported the conceptual model and the need of the research in this area. To confirm the need, several interviews were also conducted with the experts. These experts not only advised to conduct the study, but also identified the potential issues that might relate to BIM implementation with traditional project delivery method.

3.3.3 Development of preliminary conceptual model

Based on experiential knowledge, review of literature and experts' advice, a preliminary conceptual model was presented.

3.3.4 Data collection, data reduction, and data analysis:

By the use of multiple data collection methods and different sources of evidence, sufficient data has been gathered for this research, the gathering of data was an iterative process, which then coded to reduce the extra data.

3.4 Setting the Sample Size

The question regarding the selection of the population for the research was a major task. To have every stakeholder's participation in the research Random sampling was conducted. As this is the only technique through which the probability of getting a representative sample is higher than any other method.

Kothari (2004) in his book states that for making proportionate, meaningful comparisons between sub-groups in the population stratified random sampling is an appropriate method.

Consequently Robson (1993) tells that in stratified random sampling the mean of the sample is likely to fall close to the population mean, so this is why it's an effective way of sampling. Finally, Leary (1995) tells that a sample selected stratified randomly will show the attributes of the complete population.

Targeting the wrong population can result in inconclusive or misleading data, therefore, in order to get accurate results, selection of participants has been given extensive consideration, to ensure that they are familiar with the topic under discussion.The number of sub-categories included in the study will control the total size of sample needed for guaranteeing statistical validity. Regardless of the possibility that the total population is constant, e.g. the size of the industry is fixed, the bigger amount of sub-population, will result in the bigger sample size (Naoum 2007). This implies that for keeping the sample size down, less number of sub- categories should be considered in the study. Therefore, the scope might be narrower.

3.5 Sample Selection

The purpose of statistics is to have summary measure about some characteristics of the population through sampling. For good results sampling should be a true representative of population. As BIM is a new technology generally and people in Pakistan's construction industry not know much about this latest technology. The sample for this research is selected from a population of civil engineers working in construction organizations/firms in Pakistan. But the technique of focused group is adopted because the BIM technology is pretty new for the construction sector of Pakistan. For this research, random sampling and stratified technique partly is adopted by selecting the civil engineers at random all over the Pakistan but those who have some construction experience. Moreover many respondents were reluctant to fill the questionnaire and some did not responded actually due to unawareness of the recent advancements in the constructional technologies.

3.5.1. Sample Size

As mentioned earlier since the BIM adoption is new for the Construction Industry of Pakistan. So the “convenience sampling” technique (Castillo, 2009) adopted for this research purpose. A good number of experts from all the groups were selected to answer the questionnaire and some open ended questions.

Total of 60 respondents in total responded back with the answers.

3.6 Data Collection

After defining the choice of approach, setting the scope and setting the sample size, the following approach is selected for data collection:

- Surveys/questionnaires
- Interviews
- Statistics

The decision of selecting the tool often turns into a compromise between what was defined in theory (ideal information) and restrictions forced by reality, e.g. time, expense, access to information and the dedication of participants to contribute (reasonable information) (Flanagan 2005).The strategy for this research is to collect qualitative and quantitative data, supporting the evaluation of opinion or perception of the respondents towards various factors of BIM implementation with traditional project delivery system. Therefore a questionnaire based survey followed by an interview technique is adopted for collection the factual information along with opinions, because interpersonal contact is necessary to clarify and illustrate the framework of BIM implementation and the ownership of BIM model in different stages of construction.

3.7 Research Design

In chapter one the objectives of this research have been established. The approach for attaining these goals will be outlined in this section. In order to comprehend the BIM implementation, all the prime stakeholders are kept in considerations with the preparations of different sections for each stakeholder to establish the obstacles and benefits for adoption of BIM. Moreover, a frame work for BIM implementation in construction sector is suggested. In the BIM implementation study, a set of factors regarding construction industry environment, supporting factors, flexibility, potential, construction business environment and, economics and finance are recognized after a detailed literature review. To achieve our objectives, we require an investigation technique:

a) Bibliographical research

b) Discussion with appropriate experts and construction management professionals;

c) Conducting a questionnaire;

d) Analysis of the information collected.

3.8 Survey Specifics

The questionnaire was divided into the following sections**:**

1. **The Covering Letter** (it had the information about the researcher, researcher's university, dissertation topic and the purposes for this research study.)

2. **Respondent's Profile** (The introductory information of respondent to make sure that it was qualified to answer the questions)

3. **Body of the Questionnaire** (the Body of Questionnaire includes questions related to BIM implementation and the suggestion on possible scenario)

4. **Questions related to designer/Owner** (10 Questions Regarding the benefits of BIM implementation in Traditional Project Delivery System were asked from the Point of View of Designer/Owners were grouped here)

5. **Questions related to Constructor**(9 Questions Regarding the benefits of BIM implementation in Traditional Project Delivery System were asked from the View of Constructor were grouped here)

6. **Questions related to Facility Manager**(5 Questions Regarding the benefits of BIM implementation in Traditional Project Delivery System were asked from the View of Facility Manager were grouped here)

7. **Scenario** (it's a sub objective and the research variables regarding the implementation of BIM in Traditional Project delivery system, where 03 scenarios were grouped in this part of the questionnaire)

8. **BIM Implementation Strategies / Framework** (a suggestion for BIM implementation were proposed)

The purpose of this survey was to begin to gather information about BIM Implementation and its benefits and the barriers in the adoption and a frame work for its implementation in Traditional Project Delivery System.

After the pilot study, the questionnaire was further reviewed and adjustments were made to refine it further.

3.9 Reliability and Validity of Survey

The reliability and validity of a study determine that the research instrument fulfills its intended purpose. "Reliability refers to the consistency of a measure and to the probability of obtaining similar results if the measure is to be duplicated" (Oppenheim, 1992). Reliability can be measured in various ways however most commonly used method in researches is internal consistency. "Validity determines whether the score or question can measure what it is supposed to measure" (Oppenheim, 1992). To ascertain the reliability and validity of a questionnaire, researchers use numerous methods. As such, some will refer to the research instrument used in previous studies already been proven valid and reliable.

3.10 Test for Normality

An evaluation of the data normality is a pre-condition for the use of numerous statistical tests. It is performed to know whether data is normally distributed or not, i.e the data parametric or non-parametric in nature. A more thorough test of normality, suitable for data sets of about two thousands (2000) elements or less is presented by the Shapiro-Wilk test. To count as sufficiently normal, the Significance (Sig.) value should be non-significant (i.e. it should be larger than 0.05). For the data set more than 2,000 values, Kolmogorov-Smirnov test, also known as K-S Lilliefors, is more suitable. Hence in this study Shapiro-Wilk test is used to check the normality owing to the limitation of sample size.

3.11 Guided Interviews with Stakeholders

The question regarding that how many qualitative interviews are enough? According to a source (Baker & Edwards, 2012), it depends upon the interviewer that how much he think is right. Similarly *"there is no rule of thumb for the quantity of qualitative interviews"* (Boeije, 2002).

Most of the times, it is good to have limited number of interviews, selected , crafted and interpreted well than a larger number where the researcher falls short of time to analyze them in detail (I.Seidman, 2012).

Furthermore as Baker and Edwards (2012) said that the researcher should stop conducting interviews when he is sure that the interviews and observations acquired coincide with the conclusions.

As described by Becker and Geer (1957) that interviews are best when the researcher cannot directly observe things regarding a particular area. He further states that interview is beneficial within a particular subject area as it establish a conversational style which helps to explore information regarding a particular subject area.

For the suggestion on the Frame work for BIM implementation a closed end interview was planned with Construction Industry experts. Interviewees were asked first on a phone call and after introducing the description of the study and the motivation about the significance of the meeting with the particular respondent. In some cases an email was also sent describing the purpose of study and asked them to comment on the proposed frame work. During interviews, the BIM implementation issues were openly discussed.

Interviews turned out to be extremely helpful in gathering information on the BIM Implementation frame work and the suggestions in implementing the BIM in the traditional project delivery method.

3.12 Case Study

The case study of OEC Tower Project was taken in consideration. A BIM model of the Project had been made of the project. After making a 3 D model of the building calculations were made both manual and automatic, which were compared generally.

3.12.1 Why a single Case Study is sufficient?

A single–case design is appropriate if the subject study is revelatory (Yin, 1989). He further explains that a revelatory case is one for which there is a belief that the problems discovered in a particular case are common to other cases as well.

3.12.2 Benefits of case Study:

During a case study multiple methods for data collection and analysis are being used for data collection. The primary sources in this study were BIM model and documentary evidence, interviews with key participants, and observation of the work executed. Each of these data sources provided the study with specific types of information.

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1. Questionnaire

Several questions were asked from the construction industry personnel related to the benefits and barriers of BIM implementation on traditional project delivery system. Total of 115 numbers of questionnaires were dispatched to the construction industry experts and 60 were received, making a response rate of 52%. Different interesting trends of these responses were observed during the analysis.

4.2. Normality Test

This was a pre-condition to evaluate the normality of collected data for the application of statistical tests. It was conducted to know whether the data was normally distributed or not and to check whether the collected data was parametric or non-parametric in nature. Shapiro-Wilk test is a more thorough test of normality suitable for the collected data of about two thousands (2000) elements or less. The Significance (Sig.) value should be non-significant to be counted as sufficiently normal and this means it should be larger than 0.05. Kolmogorov-Smirnov test, also known as K-S Lilliefors, is more suitable for the dataset more than 2,000 values. Hence in this research study Shapiro-Wilk test was applied to check the normality owing to the size of sample.

These trends are as follows:

➢ **How long it takes to define the complete detailing of a high-rise building project?**

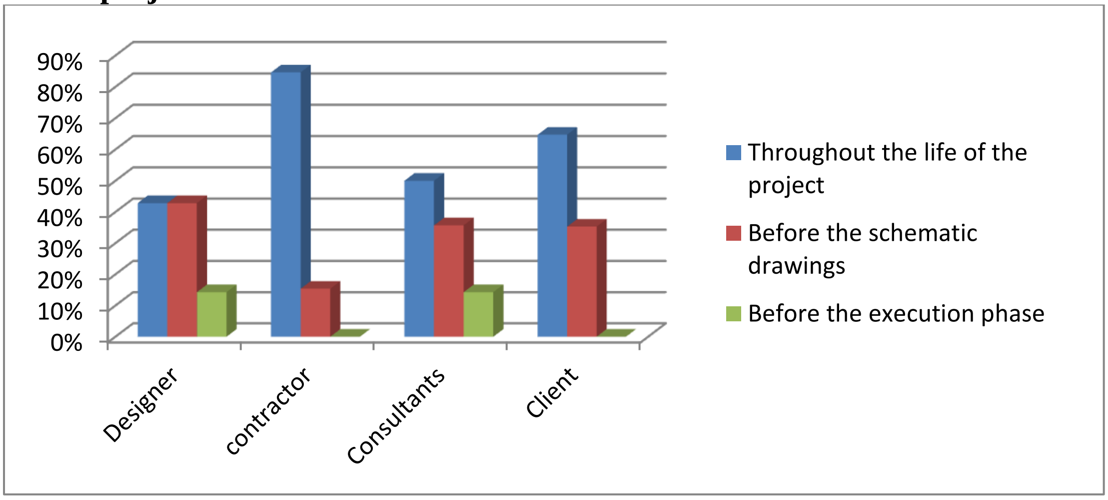


Figure 4- 1 Perception of stakeholders on defining complete detailing of a project

Results: In Figure 4-1 the majority of the respondents are of the view that in traditional project delivery method without BIM, it requires the whole life of project to completely define project detailing. Nevertheless a sizeable number of designers, consultants and clients think that scope is well understood before the schematic drawings are issued.

This truly favors the implementation of BIM for scope finalization. If BIM is being implemented, the project participants can go through the project needs and output thoroughly by visualizing it in 3D. It will definitely control the Change Orders resulting in reduction of time and cost overrun risks.

As (Foulkes, 2010) said that usually the client specifically the government is not experts in construction process and it is not necessary for them to have all the skills to interpret all the details in 2D CAD drawings. So, when a client receives design proposal as a BIM model, they can see the design in 3D and walk through the model to confirm that the desired results would be met when the construction is completed.

<u>Normality Test</u>

The significance values were found 0.418 for variable A, 0.162 for variable B and .067 for variable C indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.1.

Table 4.1 Normality Test for the reasons for the scope creep

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	By having 3D model like BIM	.929	4	.589	insignificant
2	By spending more time on planning	.852	4	.231	insignificant
3	By working on Design Build methods	.729	4	.024	significant

Results: It shows that all the stakeholders give different weightings to the reason behind the scope creep if BIM is not being implemented on DBB projects. The designer and clients strongly believes that the scope creep can be minimized only either by developing BIM model or by spending more time on planning in DBB system.

- **How much drawings discrepancies are expected on a traditional project?**

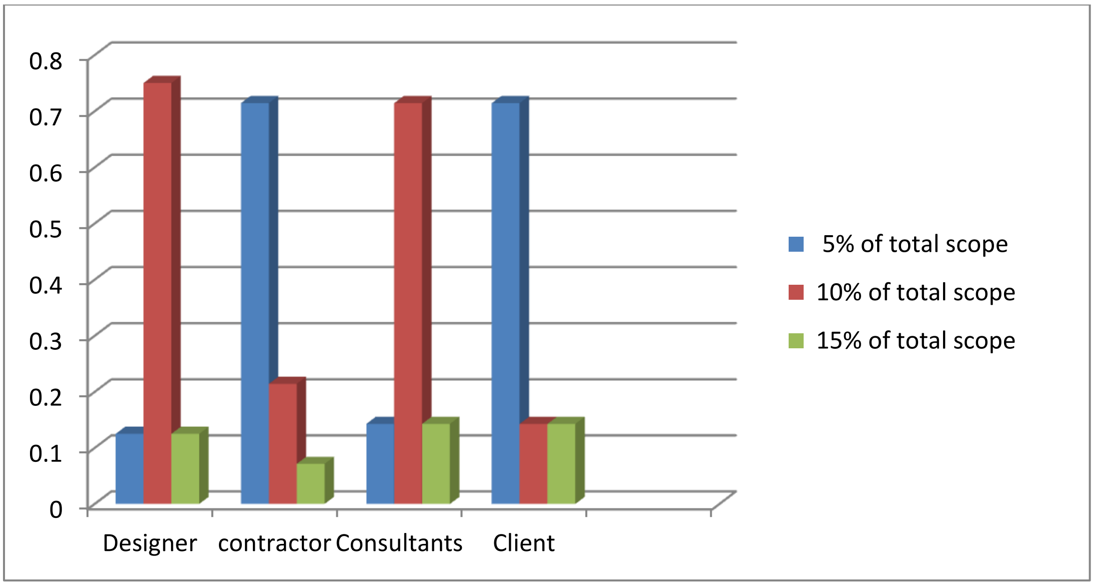


Figure 4- 2 Perception of stakeholders on defining the percentage of discrepancies on a DBB project

Results: As depicted in Figure 4-2, majority of the respondents are of the view that in traditional project delivery method without BIM, it usually has drawings discrepancies from 5 to 10 %. These discrepancies sometimes caught before execution which hampers the smooth execution of the activities and even worse is the case when these discrepancies highlighted after the execution resulting into the re-work. So if having a 3D Model of the project, the cost incurred and time consumed in correcting the errors would be saved.
As Foulkes (2010) suggested that the contractors working with BIM in the USA confirmed that the greatest benefits of BIM implementation is improved collective understanding of design intent.

Normality Test

The significance values were found 0.697 for variable A, 0.712 for variable B and .065 for variable C indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.2.

Table 4.2 Normality Test for the discrepancies found in traditional drawings

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	5% of total scope	.947	4	.697	insignificant
2	10% of total scope	.982	4	.712	insignificant
3	15% of total scope	.630	4	.065	insignificant

Results: This shows that all the stakeholders give different weightings to the reason behind the discrepancies in drawings if BIM is not implemented on DBB projects. The clients and contractors strongly believe that it is 5 % whereas the designers and consultants believe that it is 10% in DBB projects.

➢ **How much a project is usually delayed due to shop drawings preparations and approval of the submittals?**

Figure 4- 3 Perception of stakeholders a DBB project delayed due to shop drawings and submittals

Results: In traditional project delivery method, all the respondents/stakeholders are of the view that it would require a time of 6 months to approve different submittals and shop drawings as shown above in Figure 4-3. As the site office after reviewing sends the submittals to the main office or prime consultants for their comments which will delay the decision for some more days. So if a Model would have been developed earlier, this significant time could be saved and the completion time of the project could be reduced.

<u>Normality Test</u>

The significance values were found .048 for variable A, .119 for variable B and .021.for variable C the values indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.3.

Table 4.3 Normality Test for the time requires approving the submittals and shopping drawings.

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	2months	.760	4	.048	significant
2	4 months	.809	4	.119	insignificant
3	6 months	.723	4	.021	significant

Results: It shows that all the stakeholders give different weightings to the reason behind approval of submittals and shop drawings if BIM is not implemented on DBB projects. All of them are agreed that it requires more than 2month in DBB projects.

- **If you have 3D model are you going to give it to Facility Managers in the end?**

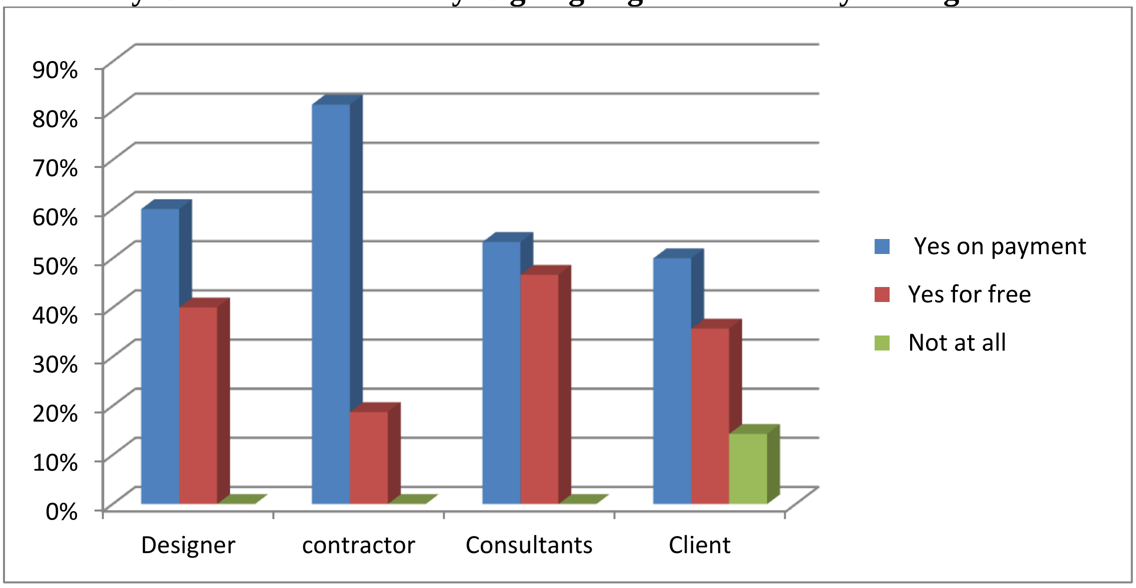


Figure 4- 4 Perception of stakeholders on handing over of 3D model on a DBB project

Results: Contractors in traditional project delivery system have to submit the As-Built drawings at the project completion as per the contractual obligations. A modeler and sophisticated computer accessories required to make and update the model, majority of them think that the cost incurred in making BIM model should be paid back as shown in Figure 4-4. Which is a positive thing as it will create the professionalism amongst the stakeholders. As at the end of project everyone will know nothing they have done for free and the responsibility could be fixed for any discrepancy.

Normality Test

The significance values were found 0.266 for variable A, 0.610 for Variable B and 0.001 for Variable C. For the variables "A" and "B" the values indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.4.

Table 4.4 Normality Test for the handing of BIM model to facility manager

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	Yes on payment	.862	4	.266	insignificant
2	Yes for free	.933	4	.610	insignificant
3	Not at all	.630	4	.001	significant

Results: It shows that all the stakeholders are on board that it requires cost to develop BIM model when BIM is implemented on DBB projects. This also was highlighted in the interviews that the Project manager of consultant should hand over this model to the facility manager either on lump sum cost or for free (cost included in unit rates) in DBB projects.

- **Do you think owner should pay for the BIM model?**

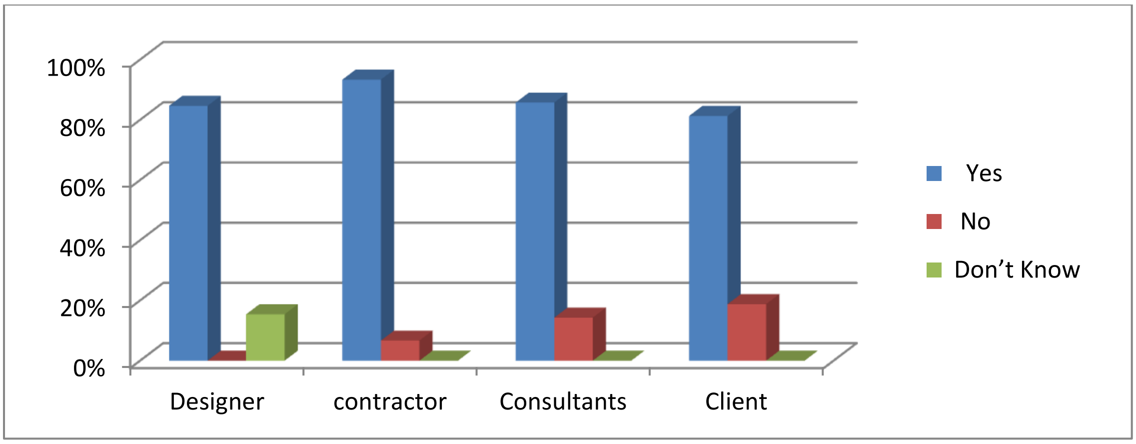


Figure 4- 5 Perception of stakeholders on paying of BIM model on a DBB project

Result: When it was asked that whether the owner should pay for the BIM model, all the stakeholders replied that the Owner should pay for the Model as explained in fig 4-5. This is right as he is the one who reaps most of the benefits such as improved quality, safe man-hours to finish the project and timely completion of the project.

Normality Test

The significance values were found 0.697 for variable A, 0.913 for Variable B and 0.001 for Variable C. For the variables "A" and "B" the values indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.5.

Table 4.5 Normality Test for the thought that owner should pay for the BIM model

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	Yes they should	.947	4	.697	insignificant
2	No they should not	.982	4	.913	insignificant
3	Don't know	.630	4	.001	significant

Results: this shows that all the stakeholders are on board that it requires cost to develop BIM model when BIM is implemented on DBB projects. This also was highlighted in the interviews that the client reaps the most benefits if BIM is implemented in DBB projects. So he ultimately pays for the BIM implementation

➢ **How the facility management work can be improved?**

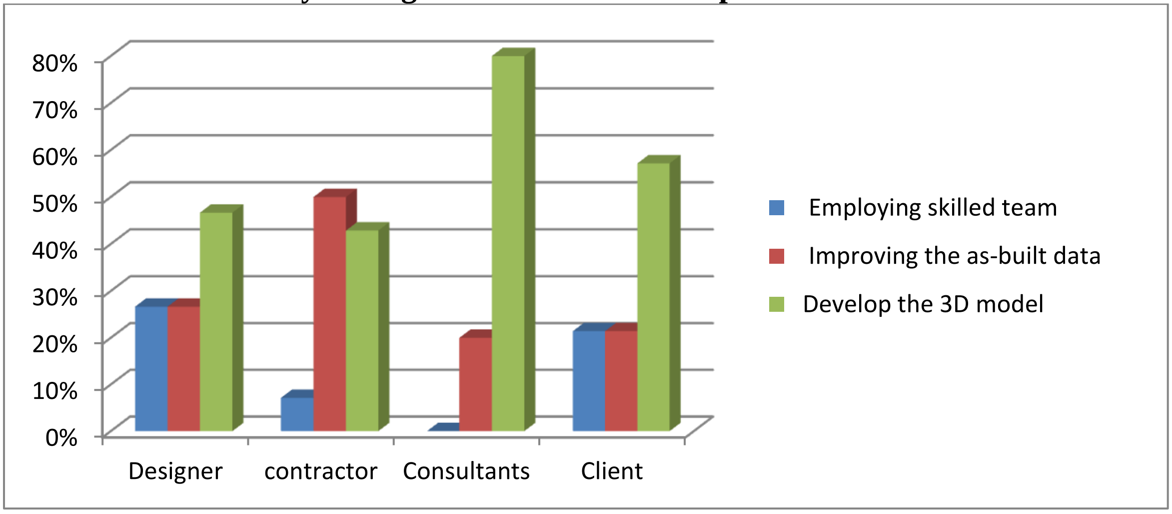


Figure 4- 6 Perception of stakeholders on improvement in Facility management work on a DBB project

Results: When it was asked that how the facility management work can be improved, as in Figure 4-6 The Clients, Consultants and a significant number of Designers strongly believe that a 3D model should be developed, whereas on the other hands more than half the Contractors think that the as-built data should be improved for the better facility management.

This shows that most of the Contractors are reluctant to adopt BIM for the facility management works because of the risk of loss of data as BIM model is to be managed by BIM expert only with upgraded software and hardware.

Normality Test

The significance values were found 0.670 for variable A, 0.091 for Variable B and 0.383 for Variable C. The values indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.6.

Table 4.6 Normality Test for the improvement of the facility management work

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	Employing skilled team	.943	4	.670	insignificant
2	Improving the as-built data	.793	4	.091	insignificant
3	Develop the 3D model	.890	4	.383	insignificant

Results: This shows that all the stakeholders give different weightings to the suggestions for the improvements in facility management if BIM is not implemented on DBB projects. All of them are agreed that if the as built data is improved or the 3D model is made on the DBB projects then the facility management work can improve.

- **Intelligent Building model cannot be deployed due to?**

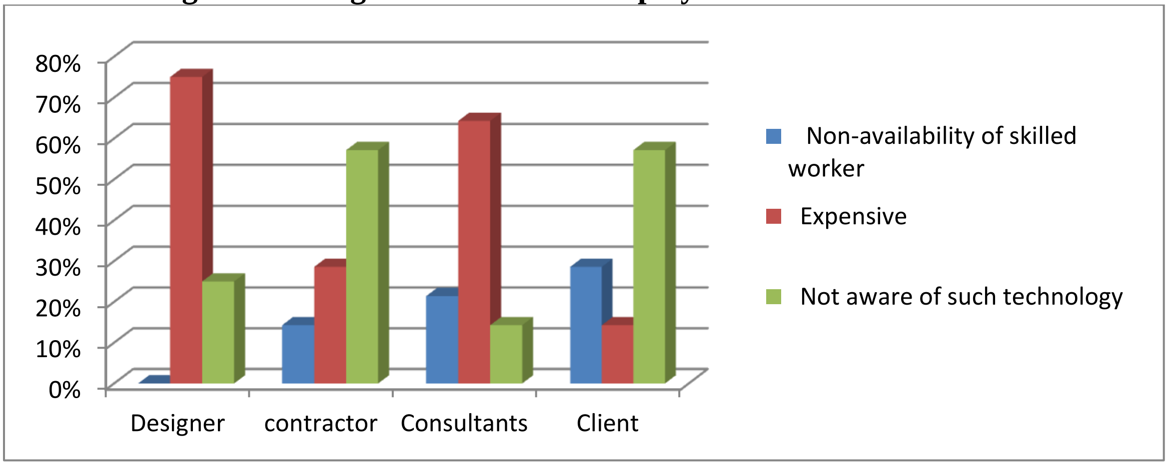


Figure 4- 7 : Perception of stakeholders on the reason of not deployment of intelligent model on a DBB project

Results: When asked about the main barrier in deploying a digital model, a pattern revels that the Clients and Contractors mostly are un-aware of this technology whereas the Consultants and Designers think that it is very costly to deploy such model as shown in fig 4-7. So, the Clients and the Contractors are required to be literate in terms of BIM , secondly the Consultants and Designers are to be educated that the life cycle cost of such model is justifiable .

Normality Test

The significance values were found 0.963 for variable A, 0.585 for Variable B and 0.473 for Variable C. The values indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.7.

Table 4.7 Normality Test for the reason behind BIM being not implementing

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	df	Sig.	
1	Non-availability of skilled worker	.991	4	.963	insignificant
2	Expensive	.928	4	.585	insignificant
3	Not aware of such technology	.908	4	.473	insignificant

Results: It shows that all the stakeholders give different weightings to the reasons behind the BIM barriers on DBB projects. Most of the stakeholders think that the biggest barrier is BIM adoption cost and the 2nd reason is that many stakeholders still are not familiar with BIM.

- **Quality of the service for building occupants can be improved by deploying anyone of technique?**

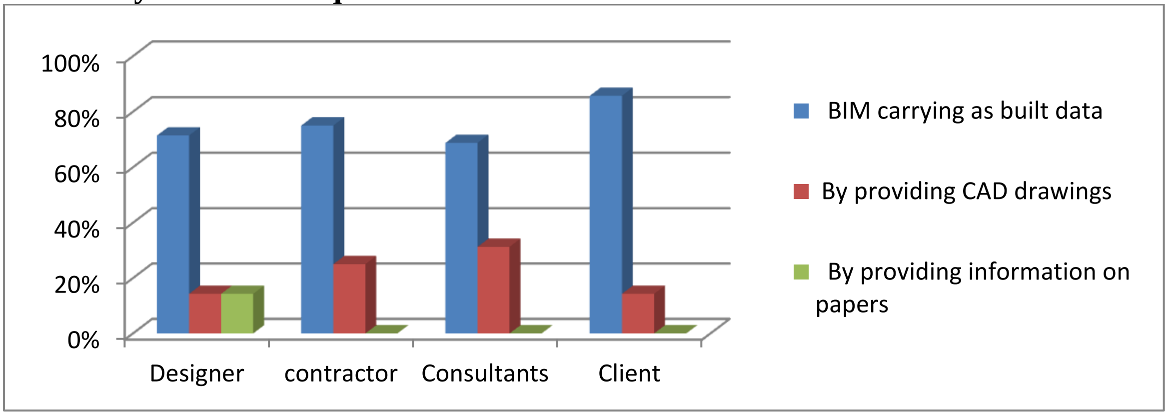


Figure 4- 8 : Perception of stakeholders on how the quality of the service for occupants can be improved on a DBB project

Results: When it was asked that what should be adopted to improve the quality of living of the occupants, almost all the stakeholders were of the view that if BIM model is designed and implemented, the facility management can be improved so as the living of the inhabitants as shown in fig 4-8. And this will lead to the fast identification of faulty work.

Normality Test

The significance values were found 0.350 for variable A, 0.237 for Variable B and 0.001 for Variable C. The values indicating that the collected data for is normally distributed. Regarding the normality of the data by ShaprioWilk test the details are shown in Table 4.8.

Table 4.8 Normality Test for the reason of improving the quality of occupants in operations phase

Sr. No	Research Variable	Shapiro-Wilk			Remarks
		Statistic	**df**	**Sig.**	
1	BIM carrying as built data	.883	4	.350	insignificant
2	By providing CAD drawings	.853	4	.237	insignificant
3	By providing information on papers	.630	4	.001	significant

Results: It shows that all the stakeholders give different weightings to the suggestions behind the improvements in the quality of life of occupants if BIM is implemented on DBB projects. All the stakeholders are strongly believes that by adopting the conventional method i.e. having 2D traditional drawings the quality of living can't be improved on DBB projects.

4.3. Reliability Analysis

If a measurement that produces the same result when repeated then it is considered a reliable measurement (Carmines et al. 2009). Leech et al. (2005) argued that the reliability test is done to check whether each item in the scale is free from error of measurement. Hinton et al. (2004) have also defined reliability as a questionnaire tested to study any topic at different times and across different populations, if produces same results, the questionnaire is a 'reliable one'.

Different methods are used to assess the reliability. Test-retest method is used to ideally measure the reliability. In this method, the measurement is done on the same object twice and comparing the results. If the results are same, the measurement is reliable.

However, practically this method is quite difficult to establish the reliability (Hinton et al. 2004).

In SPSS, widely used methods for assessing reliability include Cohen's Kappa Coefficient for categorical data and Cronbach's Alpha for continuous data (Likert-scale type items). Among them, Cronbach's Alpha is most popular method (Hinton et al. 2004 and Leech et.al. 2005.

Table 4.9 Reliability Test

Cronbach's Alpha Value	No of items
-393.450	39

Results: When the greater values of one variable mainly correspond to the smaller values of the other, i.e., the variables tends to show opposite behavior, the covariance is negative. The reason for this is that for each stakeholder the hick-ups in implementing BIM and the resulting benefits are different.

4.4. Scenarios

4.4.1 Scenario # 1

In scene 01 as shown in figure 4-9, the model is being developed by the designer and it's updating and use of this model by contractor in the execution phase and the then the handing over of the model to facility managers in the operational phase.

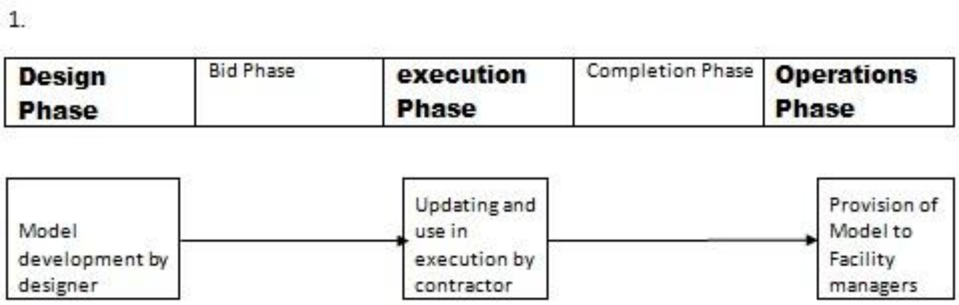


Figure 4- 9 Scenario 01 (contractor updating the model)

Results: 43% of the respondents agreed that the designer should develop the model as per the client requirements and it should be update and use by the contractor in the execution phase. After execution this updated model is hand over to the facility managers for the operations phase.

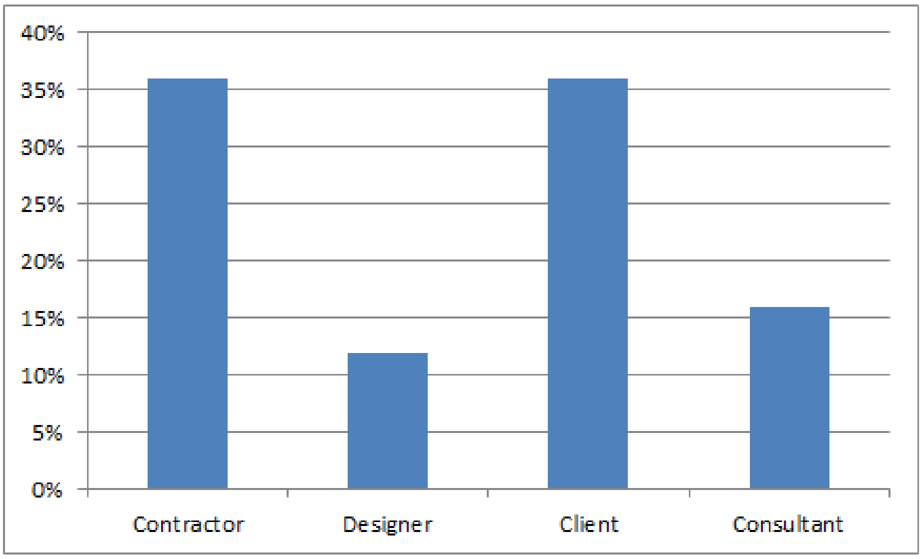


Figure 4- 10 Stakeholders perception about the scenario 1

As shown in Figure 4-10 the contractor and clients are more comfortable with the model being developed by the designer. But the designers consider this scenario as the least acceptable amongst all because due to the ownership and responsibility.

4.4.2 Scenario # 02:

In scene 02 as shown below in figure 4-10, the model's development, it's updating and the use in execution phase is the responsibility of contractor and then the handing over of the model to facility managers in the operational phase.

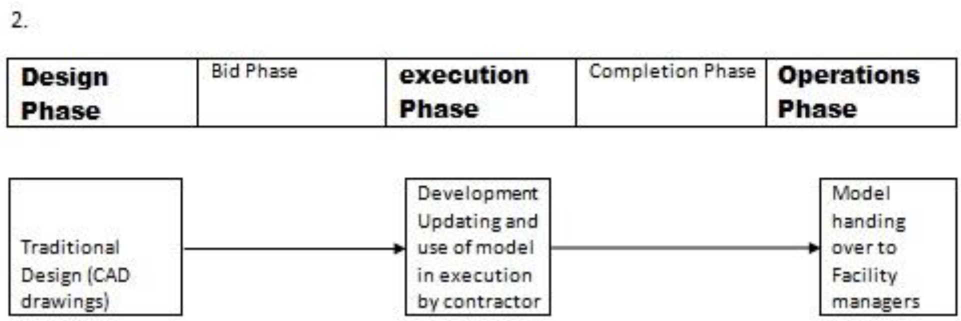


Figure 4- 11 Scenario 02 (contractor developing and updating the model)

Results: 14% of the respondents are of the view that the designer should provide the traditional drawings to the contractor, who develops the model as per the drawings provided and update and use this model in the execution phase. After execution this updated model is hand over to the facility managers for the operations phase.

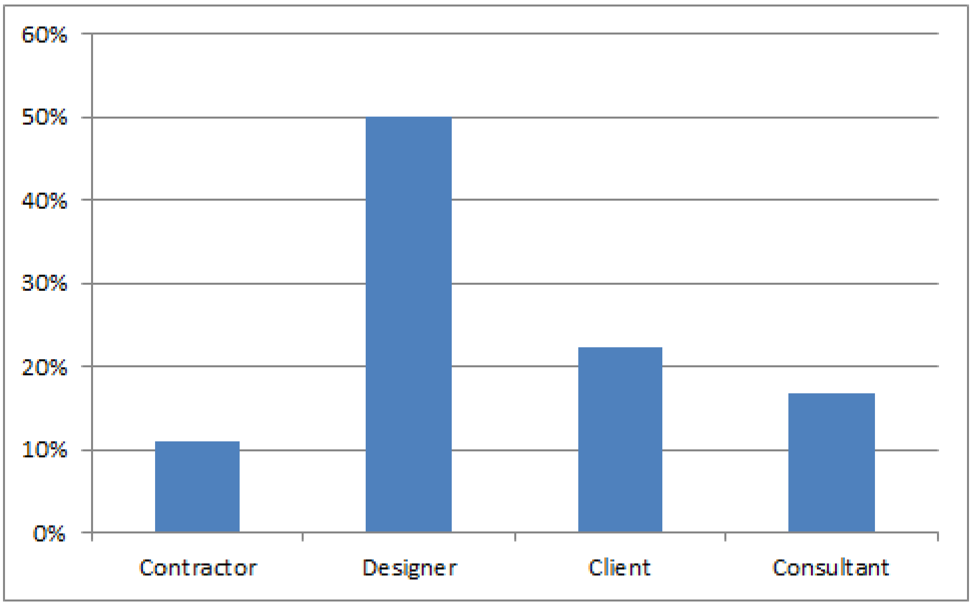


Figure 4- 12 Stakeholders perception about the scenario 2

Similarly in the Figure 4-12 the designers are happy to make the conventional drawings but considering the discrepancies in the drawings the contractors are reluctant to adopt this scenario.

4.4.3 Scenario # 03:

In scene 03 as shown in figure 4-11, the model is being developed and updated by the designer; contractor would only use it in the execution phase and then the handing over of the model to facility managers in the operational phase.

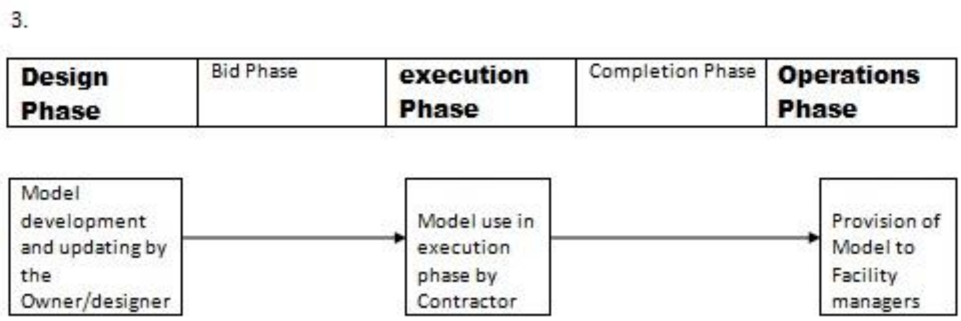


Figure 4- 13 Scenario 03 (contractor using the updating model)

Results: Similar to the 1st scenario 43% of the respondents are of the opinion that the designer should develop and update the model through-out the construction period, this model should be shared with the contractor to use in the execution phase. After execution this updated model is hand over to the facility managers for the operations phase.

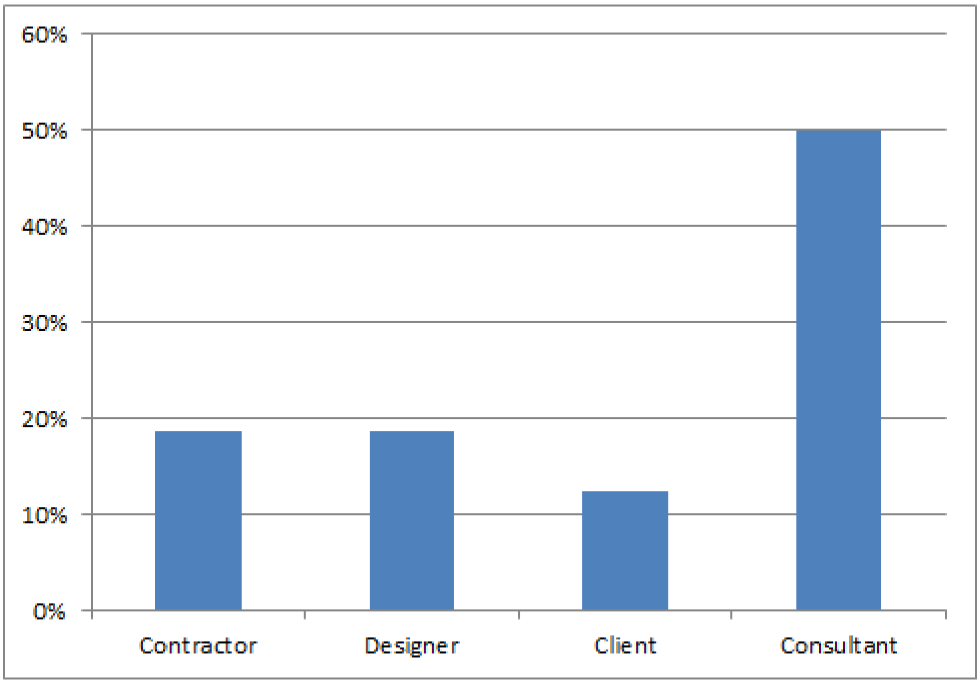


Figure 4- 14 Stakeholders perception about the scenario 3

Similarly in the Figure 4-14 consultants are happy if the model is being developed and updated by the designer as in this way the point of contact of the consultants related to BIM model will remain same and it will help them executing the work.

In the nut shell majority of the construction experts knew that BIM yields more benefits if used in the design phase and the development and updating of the model should lies with the designer. But all the stakeholders are reluctant to take the responsibility related to the ownership and managing of model at this point of time.

4.5. Interviews

Several construction experts were contacted personally to discuss certain issues related to the ownership of BIM model. The following section explains the areas discussed and the summarized answer to each question.

4.5.1 Distribution of the ownership of the BIM model in different stages of a project.

Overall the ownership of the Model should lie with the Project Manager (Consultant's) but with proper coordination with the all the main stakeholders as advised by most of the respondents. A few although explained in terms of the ownership that it should be owned by the client in the design phase and then handed over to the project manager (Consultant's) during the execution phase.

4.5.2 Distribution of responsibility of managing the BIM model

While asking the question regarding the management of the Model, all the respondents spelled that it should be managed by the project manager (Consultant's). Although some of the respondents went specific and said the client should create a post of BIM manager, who must manage the Model in coordination with Project manager (Consultant).

4.5.3 Who should bear the Cost of BIM model? (You can advise full cost or partial cost stage wise as well)

The respondents when asked that who should bear the cost of the Model updating during different stages of project. All the respondents were of the view that it should be borne by all the stakeholders (i.e. client, contractor and consultants) as it would yield benefits to all of them. Whereas, some of the experts suggested that the cost should be borne by the Project Manager (Consultant's) initially and then it could be sold to client or facility manager on actual cost basis or lump-sum cost incurred.

4.5.4 Your suggestions to best implement BIM in Design Bid Build Contracts.

Most of the experts suggested that by putting BIM in tender documents, and in particular conditions of contract it would ease the implementation of the BIM. Similarly the contractors/consultants having past experience of using BIM should be preferred. Few contract experts were of the view that the contract clauses asking contractor to submit 2D as-built drawings at the end of project can be modified and can be read as "the contractor will submit the as-built BIM Model.

CASE STUDY

5.1 Project Introduction

All phases of BIM are to be implemented in the Government Project of Employees Old age Benefit Institution (EOBI) in G-9/4 sector, Islamabad named as Overseas Employees Corporation (OEC) Tower (figure 5-1). The total covered area of the project is 190,000 square feet. The plot size of the project is 120 X 300. Floor area ratio of the building is 1:3. The build floors consist of two basements, one ground floor and nine floors.

Figure 5- 1 OEC Tower East Artistic View

Builders Associates is the firm contracted to build the project. This was designed by Sohail A. Khan Associates (SAKA). Pakistan Real Estate Investment & Management Company (PRIMACO) is a firm which represents the client (EOBI) and handles the queries regarding construction. The MEP consultants of the projects are Fahim, Nanji and Desouza Pvt. Ltd. The project was started in April, 2012 and was to be completed by November, 2013. But due to some reasons the project was not completed at the targeted date but the latest date proposed for its completion is 20 November, 2014. The detail about the stakeholders can be extracted from Table 5.1.

Table 5.1 Project stakeholders

Stakeholder	Role	Information
EOBI	Client	*www.eobi.gov.pk*
PRIMACO	Construction Manager	*www.primaco.com*
SAKA	Consultant	*saka.net.pk*
Builders Associates	Contractor	www.buildersltd.com
Fahim, Nanji & desouza Pvt. Ltd.	MEP consultant	www.fnd.com.pk

5.2Special Features of OEC Tower

A few distinct and sustainable features of the building which make it different from other building are:

- Vertical Plantations
- Solar Panels at the roof
- Rain water storage and harvesting
- Re-use of building waste water for external irrigation
- Drip irrigation
- Impulse Ventilation system for car park area
- Smoke management system
- Water based Fire Suppression system including fire sprinkler system
- Dedicated fire water storage to provide 60 minutes of fire suppression capability
- Supervision and Monitoring of fire suppression system at fire alarm panel
- Waste Management system
- Emergency exit tunnel
- Storm water drainage system for roof and plot.

The view of the project can be seen in the Figure (5-2 and 5-3).

Figure 5- 2 Architectural view of OEC

Figure 5- 3 Under construction View of OEC

5.3 Area of OEC Tower

Initially at the time of tender, in June 2011, the project was supposed to be a 10+3 story building. Consisting of 10 floors of office building and below it had to be 3 basements for parking facilities etc. at that time the total covered area was estimated to be 220,000 sft. But due to lack of funds, the scope of project was changed and a basement was removed from the scope of project leaving behind 190,000 sft covered area divided upon a 10+2 story building.

Table 5.2: Floor Areas

AREAS OF OEC TOWER		
AREA DESCRIPTION	**DIMENSIONS (Ft)**	**APPROX. AREA**
TOTAL PLOT AREA	120X300	36,000 sft
BUILT UP AREA	- (Covered area of building & lawns etc)	200,000 sft
COVERED AREA	- (Building area)	190,000 sft

5.4 3-D Model

Project yielded a 3-D Model of a Building facility. Using conventional methods, architects are only able to draw a Two-Dimensional Model of the facility whether by Manual Drafting or by using AutoCAD. The end product i.e. the integrated 3D model of the building was of the exact same dimensions and features. Autodesk Revit was used for this task. Models from different disciplines were integrated to develop an integrated 3-D model. The integrated model was used for material takeoff which was used in estimating costs. The clashes between different models were also detected. So the integrated 3-D model was essential for other features of BIM. The integrated 3-D model consisted of following models.

5.4.1 Architectural Model

During the project the architectural model was developed initially. In the process of developing of architectural model different components of the building were involved including walls, floors, stairs, roof, elevators, openings, doors, columns and curtain wall etc. The components involved in the model are as follows:

5.4.1.1 Grids

First of all the grids were drawn in order to provide reference to other building components. The vertical grids were given the notation in the form of numbers whereas the horizontal grids were given the notation in the form of alphabets. The same grid was used for other building models.

5.4.1.2 Levels

The levels were drawn in the model after the drafting of grids. Levels depict the elevations of different building floors. Every level was given a specific elevation as provided in the building drawings. The levels were handful in the development of multi storey building. The level 0 in the building depicts the ground level of the building. The ground floor of the building was four feet above the ground level that’s why it was termed as level 0+4 and the levels go on from level one to roof level, with the twelve feet elevation from the relative previous level. The two basements were given negative elevation as they were below the ground level.

Table 5.3 Floor levels

Level	Elevation(ft)
T.O Footing	-24
Basement 2	-18
Basement 1	-7
Level 0	0
Level 0+4	4
Level 1	16
Level 2	28
Level 3	40
Level 4	52
Level 5	64
Level 6	76
Level 7	88
Level 8	100
Level 9	112
Roof	124
Elevator	134

5.4.1.3 Plan Views

Using levels plan views were generated. The plan views consist of floor plans and structural plans. Using the floor plans reflected ceiling plans were also generated. These plan views provide the platform to for the building components. The Area plans were also generated which determine the area of rooms and floors.

5.4.1.4 Walls

The walls were drawn on the plan views. The dimensions and properties of the walls were similar to the walls in the actual project. Different types of walls were used in the project. Concrete walls, block masonry and curtain walls were used. Different materials and finishes were applied to different walls in the project. Walls also differ in the thickness. The walls were given the base constraint and top constraint in order to control their heights.

5.4.1.5 Floors

The floors were provided on every level of the building. The floors were made on the plan view by drawing the boundary of the floors. The floors were assigned the materials as in the actual project. The interior floor was assigned lavender blue marble. Marble sills were used on the projection slab of each floor. Nearro granite was used in the lavatory. The top level of the floor was three inches above the respective level.

5.4.1.6 Openings

Different openings were provided on the floors. The openings included elevator shaft opening, stair opening, smoke shaft opening and other openings. The openings could be made either by providing inner boundary or using opening tool. Both processes were used to provide openings on the floors.

5.4.1.7 Doors and Windows

Doors and windows are hosted families. They can only be made when there is a suitable host for them. Walls act as the host to the doors and windows. Different type of walls and windows were used. They have different sill levels. The doors and windows families were downloaded from the internet and loaded into the project.

5.4.1.8 Ceilings

Using the ceiling plans, ceilings can be made either by drawing them i.e. by giving a boundary or by automatic ceiling option in Revit. Both processes were used to provide ceilings in the project. There were two types of ceilings used in the project which differ in height as well as in material.

5.4.1.9 Ramps

Two different types of ramps were made in the project. One ramp was a simple straight ramp whereas the other one was curved ramp. Both were provided in the basement. The ramps were made by outlining their boundaries and setting their top and base constraints.

5.4.1.10 Columns

Twelve different types of columns were made in the project. Some columns required the new families to be made. Columns had different heights and thicknesses. As these were structural columns so finishes could not be given to them.

5.4.1.11 Other Components

Other than basic building components other components were also included in the model such as solar panels, aluminum louvers, water body, entrance gate, elevators, topography, plumbing fixtures etc. Different plug-ins and families were downloaded from the internet and loaded into the project.

5.4.1.12 Structural Model

The components involved in structural model are:

5.4.1.13 Floors Slabs

Reinforcement was added in floor slabs as given in the drawings. To add reinforcement in floor slabs area reinforcement tool was used in Revit. This process was done in structural plan. Reinforcement bars #3 and #4 were used. Both top reinforcement and bottom reinforcement were added in each floor of the building according to the given drawings. X-axis was chosen as major axis while Y-axis was minor axis and maximum spacing between the bars were added.

5.4.1.14 Beams

Reinforcements were added to the structural framing of beams by using rebar tool in Revit. Cover of 1.5" was provided. Stirrups were also included of #3 and #4 bars and they were added by using maximum spacing option. Rebar of #6, #7 and #8 bars were provided. Rebar were placed by using the fixed no. option in rebar tool. Firstly all the rebar and stirrups were added to horizontal (along X-axis) section later there length was improvised by cutting a vertical (along Y-axis) section.

5.4.1.15 Columns

Reinforcements to columns were also added in structural plan. Firstly stirrups of the column according to the drawing were added and then rebar were added. These reinforcements were then stretched accordingly. Stirrups were added by using the maximum spacing option.

5.4.1.16 Walls

When adding the reinforcement to the walls both area reinforcement and rebar option of Revit was used. Later the sections of the walls were created and lengths were adjusted accordingly.

5.4.1.17 Stairs

Reinforcements were also added to the stairs. Firstly longitudinal section across the Y-axis was made and reinforcements were added by using the rebar tool. Further reinforcements were also added by area reinforcement tool.

5.4.1.18 Foundations

In foundation reinforcements were added by area reinforcement tool. Cover of 4" was used. This process was also done in the structural plan**.**

5.4.1.19 HVAC Model

Creating a HVAC model in Revit was neither difficult nor very different from architectural modeling. It had similar user interface and same basic modeling techniques as in architectural modeling. However video tutorials available on internet provided further helped to create an efficient HVAC model.

5.4.1.20 Loading 'system template'

Unlike architecture modeling which uses 'architectural template', modeling of HVAC systems required 'System template' to be loaded while starting a new project in Revit. In order to see if template is successfully loaded or not, plans and elevations of Mechanical and HVAC were checked.

5.4.1.21 Linking architectural model

In next phase before actual modeling starts, Architectural model was linked with the project. From linked architectural model, Grids, levels and basic wall structure was copy monitored and pasted into HVAC project file. This provided a reference to HVAC components needed to be installed.

5.4.1.22 Creating work space

Plans were created in accordance with the levels copied from linked architectural file. By using the plans of each and every floor and the linked model was made hidden. HVAC components were installed as per detailed specifications, dimensions and locations provided by client.

5.4.1.23 Pipes and ducts

Three types of pipes and five types of ducts of different diameter and width were used in model. Three types varying size ducts having varying diameter after regular intervals were used on each floor.

5.4.1.24 Pipe and duct fittings

While joining two or more parts of a duct or pipe, Revit required information about the joints and bends for example if they needed to be sharp edged, smooth edged or rounded. In model smooth edged and rounded bends were preferred.

5.4.1.25 Mechanical equipment

Equipment like water tanks, ventilation and exhaust fans etc. were also installed on their specified locations.

5.4.1.26 Electrical Model

To understand the method of installing electrical fixtures, switches and different electrical equipment as well as creating an electrical circuit system, tutorials and training videos were found through the internet. Installing different electrical fixtures and connecting them through wires and circuits was not very difficult, although it was a long and tedious process. This was due to the fact that wiring had to be installed for each and every fixture on all floors individually since unlike in architecture, one cannot simply copy/paste the circuit from one floor to rest of floors.

5.4.1.27 System template:

To start off any MEP systems work, such as electrical system in this case, a 'systems template' needed to be loaded. This was done by creating a New Project in Revit and loading the system template file usually named 'Systems-Default.rte'. It could be checked that the file is correctly loaded by viewing the project browser to see if tabs containing floor plans for Mechanical, Lighting, Power etc are showing. If so, then things are good to go.

5.4.1.28 Linking Revit architectural model:

In Revit, all types of modeling (such as HVAC, electrical etc) are done over the architectural model. The new project in systems template is linked with the Revit architectural file of the project through Insert>Link Revit and loading the model. After that, all the grids, levels, floor plans and architectural elements were copy monitored to the new project file. This was done through the tab Collaborate>Copy Monitor>Select Link and copying all the levels.

5.4.1.29 Creating work space

For electrical systems, plan views were created in the following manner: View> Plan views> Floor Plan>Edit Type and electrical template was selected in 'Template applied to new views' and the required floor plans were added.

For smooth working in electrical systems, the Project Browser should contain the following plan views under electrical category:

Lighting:

- Floor Plan (of all floors): To install electrical fixtures/equipment mounted next to walls.
- Ceiling Plan (of all floors): To install electrical fixtures on the false ceiling.

Power:

- Floor Plans

5.4.1.30 Types of electrical equipment installed:

The electrical equipment installed are:

- Lighting fixtures (two types)
- Emergency Lights (Three Types)
- Switches
- Distribution Panels (Two Types)
- Heat/Smoke Detectors
- CCTV cameras
- Fire Alarm system
- Wiring

Each electrical equipment was installed on all the floors according to the specifications given in drawings. To do this, first the systems tab was used and the required object family was loaded. If a required object was not pre-loaded in Revit, it could be searched and download from websites like seek.autodesk.com or revitcity.com. Furthermore objects and families can also be created in Revit, but this was more difficult in case of electrical objects than it was for architectural elements. Once the correct family is loaded, we can proceed to install fixtures/alarms/cameras/switches etc first according to the specified elevations.

All fixtures mounted on the ceiling were by default given the elevation height of the false ceiling from the floor i.e. 7' 9".

5.4.1.31 Creating a circuit system:

To create a circuit system, each fixture was highlighted and their default switch and power option appeared. The switch option was selected and the required switch was connected with the fixtures by 'select the switch' option. Moving the cursor over the switch and pressing tab key showed a set of dotted lines projected towards all the connected items, hence confirming that the switch was connected right. After this, the switch was connected to the type of distribution panel board required, depending upon the power usage of the electrical item.

In this project, two types of distribution panel boards were used.

- Lighting and Appliance Panel board 208V
- Lighting and Appliance Panel board 480V

After placing the distribution panels on the all the floors, each panel was highlighted and their distribution system was defined. There are two types of distribution systems needed for the project:

- 120/208 Wye Distribution system
- 480/277 Wye Distribution system

Once the distribution system was selected, the switch already connected to a set of fixtures was highlighted and its power option was selected. In the power option, the switch was connected to the panel board. The switch connected to small energy savers required less voltage and was connected to 120/208V panel board while the larger, more power consuming tube lights were connected to 480/277V panel board. This process was repeated for all the floors until all fixtures were connected with the right panel board. Once a switch was connected to the panel board, Revit allowed it to be ‘wired’ directly with the panel board and showed it on the plan views (with an arrow pointing towards the connect panel), unlike in case of fixtures connected with switches (which does not show wires, only dotted lines). The wires could be connected automatically in any one of the following types:

- Arc wiring
- Chamfered wiring
- Manual wiring

5.4.2 Plumbing Model

The different views of plumbing model can be seen in Appendix-6. Plumbing model was prepared by following the steps given below:

1. System template was opened.
2. Revit Architectural model was linked to provide the host and reference to the fixtures.
3. The floors and walls were copied by using copy/monitor tool.
4. The plan views were generated.
5. Various families were downloaded from the internet.
6. New pipes were made by creating duplicate pipes and editing according to mentioned in drawings.
7. View range of floors was set to work properly on them.
8. Fire pipes were made in mechanical pipes plans whereas other plumbing pipes were installed in plumbing floor plans.
9. Plumbing units like toilets, sinks etc were installed and connected with pipes using a connector.
10. Connecter itself as a family which was downloaded from the above mentioned source.

Screen shot of the model can be seen in **Figure: 5-4**

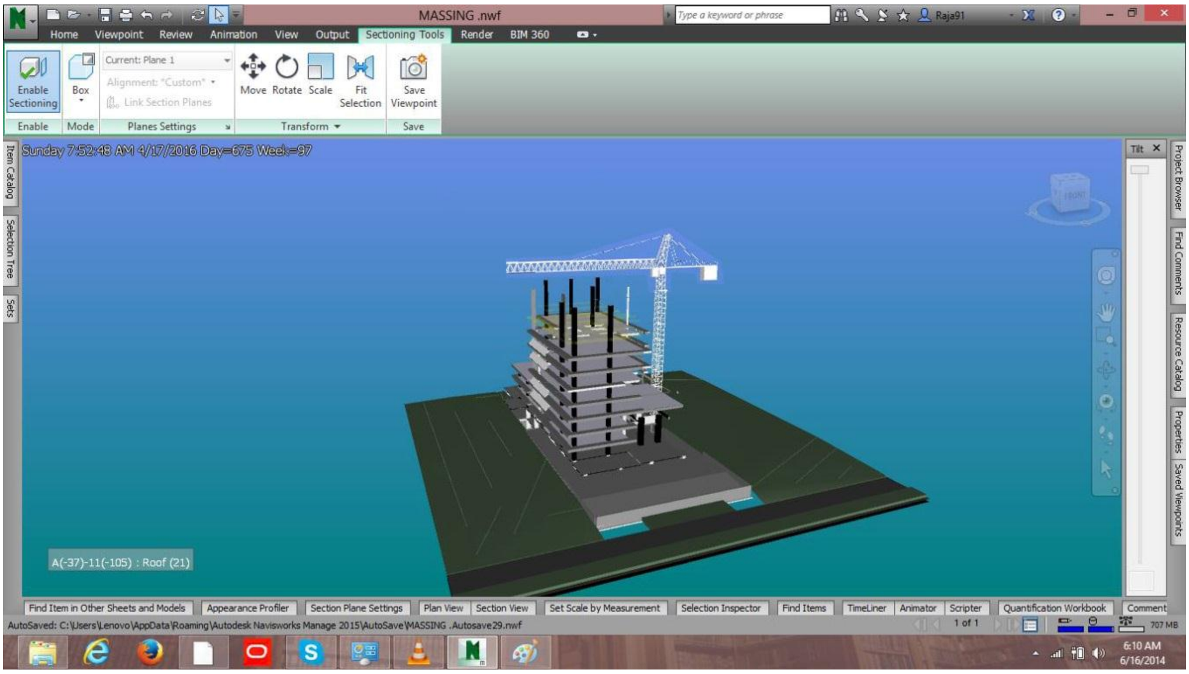


Figure 5- 4 Model

5.5 Quantity Takeoff

Using BIM tools quantity estimate can be generated automatically without the use of manual calculations. Autodesk Quantity takeoff was used to estimate the cost of the project and the results were analyzed.

The models were exported from Revit in DWG format. The models were imported into Autodesk Quantity Takeoff. The whole model was selected and using the "calculate material" option the total number of quantities was estimated. The reports were generated automatically using a feature provided by Autodesk Quantity takeoff. Autodesk Revit was also used for estimating quantities. The total reinforcement was estimated using Autodesk Revit. The detailed estimate can be seen in the Appendix-7. The summary of estimated quantities can be seen from Table 5.4.

Table 5.4 : Quantity Estimation table

Item	Volume (CF)	Area (SF)	Count (ea)	Weight (tones)
Concrete	343,802.274	-	-	-
Reinforcement	9724.38	-	-	2165.88

Curtain wall	-	42106.727	-	-
Doors	-	-	325	
Windows	-	-	67	-
Ceiling	-	91323.456	-	-

5.6Clash Detection

The software used for clash detection was Autodesk Navisworks Manage. The different models were exported from Autodesk Revit in NWC format. The architecture model was imported into Autodesk Navisworks. The other models were imported into Navisworks by using append tab to develop an integrated 3-D mode. The clash detective tool of Navisworks detected the clashes between different models. All the rules regarding clash detection were checked and tolerance of 0.001m was allowed. The reports of the clashes were generated due to the use of report generating feature of Autodesk Navisworks. The detailed report of the clashes can be seen in the Appendix-8. The summary of clashes can be seen in the table 5.5. Some clashes detected between HVAC and Plumbing models are shown in figure 5-4 and figure 5-5.

Table 5.5 Clash detection summary

Model 1	Model 2	No. of clashes	Clash Type
Plumbing	Structure	712	Hard
Plumbing	HVAC	26	Hard
Structure	HVAC	206	Hard

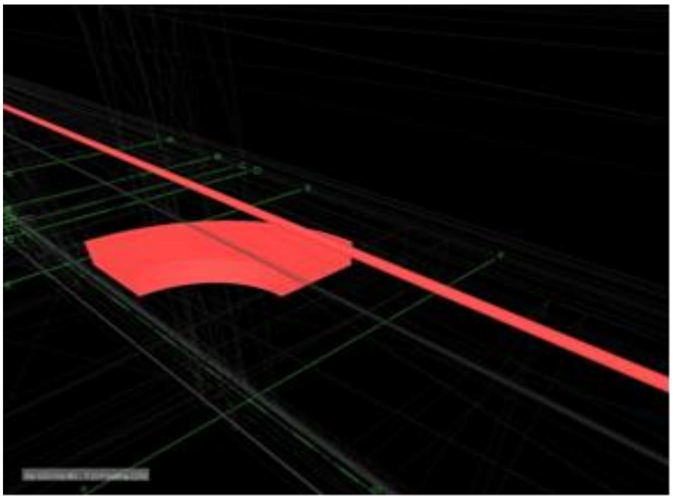


Figure 5- 5 Duct bend and Plumbing pipe clash

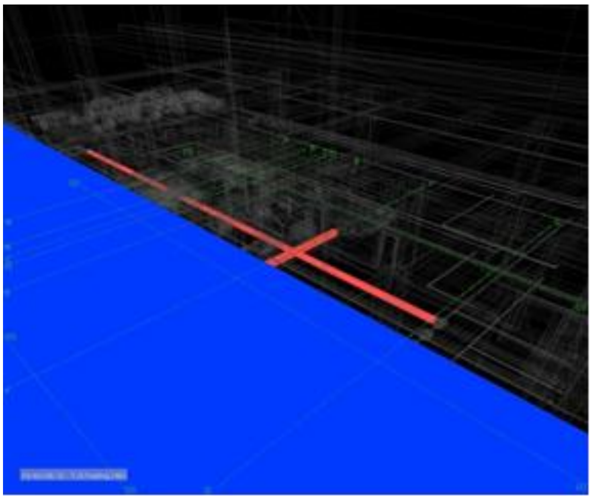


Figure 5- 6 HVAC and Plumbing pipes clash

5.7 Quantity Comparison

Quantities calculated from the manual estimation from the Project officials were compared to the quantities calculated using BIM tools. This process was done in order to check the accuracy of BIM tools and the reliability of the data obtained from the tools. The quantity comparison of some quantities can be seen in table 5.6.The difference in the quantities was due to the manual calculation errors, incomplete drawings and lack of detailing.

Table 5.6 Quantity comparison

Item	Manual Estimation	Automatic Estimation	Difference
Concrete (foundation)	120,000 CF	116,790.523 CF	-3209.47 3% of total
Concrete (columns)	37,300 CF	36,017.709 CF	-1282.291 3% of total
Reinforcement	1800 tones	2165.88 tones	365.88 20% of total
Ceiling	115278 SF	91,323.456 SF	23954.544 21% of total
Curtain wall	36,500 SF	42,106.361 SF	5606.361 15% of total

The Manual estimation is basically as per the BOQ quantities and the Automatic Estimation is the software output. The quantities which are lesser in Manual Estimation for instance steel are less estimated than the need of the project. In traditional projects delivery system it is very tough to approve the variations .so if the model would have been used the bidding/design stage construction cost would be rationale and secondly the quantities would have been exact, which would save variation orders.

5.8 Difficulties encountered in modeling

During the project several problems were confronted. The problems faced regarding the project were mostly related to the software used. No assistance regarding the use of software was available. Most of the software used was available on a free student license provided by Autodesk, limited features of the software were available. The system requirement of the software used was very high. So the process of development of model sometimes got slowed down. The software sometimes crashed and the data was lost. Autodesk Revit was not suitable for the structure model as it slowed down the system very much. Autodesk Quantity Takeoff was not suitable for quantity estimation as it crashed a lot of times during the process and useful data was lost. So systems with high specification must be used to develop the models and license of different software must be purchased. The search for alternatives should be performed so that the software limitations could be catered.

The blueprints of the project were not clear as there was a lot of vague detail present in it. The other details were not clear. The specifications were too generalized, which could not provide the required detail to understand the blueprints. Lots of change orders led to many changes in the original blueprints which were accommodated as the project continued.

5.9 Unclear drawings

Some of the discrepancies found at the time of developing model are as follows:

1. The main problem faced while drafting the basement was the inadequate information of the reinforcements of the floor slab and foundation slab. The details of the retaining wall reinforcements were not available. The drawings had inadequate details. The detailing of floors was missing with lots of useful information. The information regarding materials used was not available. The detailing of doors and windows was not adequate. The curtain wall details were inadequate. The reinforcement of shear walls and stairs was not available.

2. The electrical wiring details regarding their path were not available, their connections and power supply were also missing. The HVAC pipes were not detailed as if the drawings were incomplete. So a lot of things had to be assumed. The detailing of the reinforcement of columns was very confusing. The change in reinforcement was not identified.

3. There were many errors identified in the drawings. The difference between the walls and building frame was difficult to understand. The detailing of the joints and the laps was not given due to which there was a difference between the total calculations of the reinforcements.

4. The details of septic tank were not available. Many drainage pipes were having open ends. The slope of the floors was not identified in order to drain the water to the pipes. The details of railing were not provided. The material used in the stairs was not identified. The details of the water body were not available.

CHAPTER 6

CONCLUSION AND FUTURE RECOMMENDATIONS

6.1 The benefits of BIM on the DBB projects and the obstacles in achieving them

It can be concluded along the lines of the data and information shared above that the industry can reap the benefits of BIM in full extent if the Clients are well educated about this technology, secondly the life cycle cost of BIM adoption can be justified. So the benefits are for both the Public and Private Clients as stated by As Foulkes (2010) mentioned that the client and the contractor from both the public and private sectors have the clear benefits from using BIM. Secondly the cost should be compensated by client so that the ownership of BIM model should be addressed properly.

When talking its use with traditional project delivery method, almost 86% respondents agree that the BIM implementation should be started at the early stage i.e. during design phase to yield more benefits which was supported by the case study.

6.2 A framework that how BIM can be implemented in different phases of construction on DBB projects

A frame work also designed with the help of experts opinion and literature review to implement BIM in traditional project delivery method.

Construction phase/ Stakeholders	Project Inception	Design	Execution	Project Operations
Owner's PM	Scope Definition	Coordination with Consultants	Progress Monitoring	Facility Management
Supervisory Consultants	-	Coordination with BIM Implementation Team/Constructibility Analysis	Technical inspections	Preparation of As built Model with BIM Implementation Team
BIM Implementation Team	Schematic Design/Contract Documents preparation	Model Evaluation/full Design Model build-up	Model updation	Handing over to facility manager
Contractor	Bid Submission	Coordination in Model building and contract documents	Construction	As built data to BIM Implementation Team

LEGEND:

One Way Communication

Two Way Communication

Figure 6- 1 BIM implementation frame work on DBB project

As shown above in the Figure 6-1 a BIM implementation should be involved from the inception phase to better implementing BIM. This team may be contracted separately or may be the part of the consultants. The main role of this team would be to develop the BIM model after discussions and coordination with Project Manager of client. The role during the construction would be to update the model as per the changes during the execution. This team would be consisted of a BIM manager, an expert modeler and a site inspector to record the site changes. The updated as-built model can then be handed over to the facility managers at the project completion.

6.3The benefits of BIM applications on a running project through case study.

- Due to the clashes and some changes in the specification of MEP works, change orders and planning issue arose. The HVAC change order almost caused rupees 10.1 Million extra.
- Quantities calculated from the manual estimation from the cad drawings were compared to the quantities calculated using BIM tools. This process was done in order to

check the accuracy of BIM tools and the reliability of the data obtained from the tools. The quantity comparison of some quantities can be seen in table 6.1. The difference in the quantities was due to the manual calculation errors, incomplete drawings and lack of detailing.

Table 6.1 Quantity comparison

Item	Manual Estimation	Automatic Estimation	Difference
Concrete (foundation)	120,000 CF	116,790.523 CF	-3209.47 3% of total
Concrete (columns)	37,300 CF	36,017.709 CF	-1282.291 3% of total
Reinforcement	1800 tones	2165.88 tones	365.88 20% of total
Ceiling	115278 SF	91,323.456 SF	23954.544 21% of total
Curtain wall	36,500 SF	42,106.361 SF	5606.361 15% of total

Results: The Manual estimation is basically as per the BOQ quantities and the Automatic Estimation is the software output. The quantities which are lesser in Manual Estimation for instance steel are less estimated than the need of the project. In traditional projects delivery system it is very tough to approve the variations .so if the model would have been used the bidding/design stage construction cost would be rationale and secondly the quantities would have been exact, which would save variation orders.

Autodesk Revit is not a tool which could be recommended for the structural reinforcement details of the large scale building. For this Autodesk Robot structure analysis or Etabs should be used in order to lower down the work force. For Quantity estimation Autodesk Quantity Takeoff is not a suitable tool. It is not user friendly and it crashes while process of quantity takeoff. The simulation of construction generated by Autodesk Navisworks is pleasing to the eye but it has no effect on the technical side. Autodesk Green Building Studio is very useful software for Energy Analysis as it generates a detailed energy report of the building. Autodesk Revit model is a platform which connects with all other BIM tools to perform other functions. The drafting of reinforcement details is very hectic in Autodesk Revit.

So in general the complete overhaul of the contract documents are required. The consultants and clients are needed to be presented the workshops and literature on BIM implementation strategies and benefits.

6.4 Recommendations for Future Research

The following are the general recommendations for future research work:

a) A study may be conducted to explore the potentials of BIM usage in early stages on public sector projects.

b) A case study may be conducted to evaluate the life cycle cost of a DBB project considering all the pre-construction, construction and post construction phases.

c) A study may also be carried out to measure the performance of BIM on two projects being procured with traditional project delivery method.

References

Ahuja, H. N., S. Dozzi, et al. (1994). Project management: techniques in planning and controlling construction projects, John Wiley & Sons.

Azhar, S., J. Brown, et al. (2009). BIM-based sustainability analysis: An evaluation of building performance analysis software. Proceedings of the 45th ASC Annual Conference.

Azhar, S., A. Nadeem, et al. (2008). Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects. Proc., First International Conference on Construction in Developing Countries.

A Langley. (1999)."Strategies for theorizing from process data" -. Available on http://amr.aom.org/content/24/4/691.short.Last accessed on: 22 OCT 2014.

A Porwal, KN Hewage. (2013). "Building Information Modeling (BIM) partnering framework for public construction projects", Available online at: http://www.sciencedirect.com/science/article/pii/S0926580512002439. Last accessed on : 24 Nov 2014

AKD Wong, FKW Wong, A Nadeem. (2010). " Attributes of building information modelling implementations in various countries"Available online at: http://www.tandfonline.com/doi/abs/10.3763/aedm.2010.IDDS6. Last accessed on : 24 Nov 2014

"About the national BIM standard-United States".National institute of building sciences.2010 web. Apr. 2010.<www.buildingsmartalliance.org>

Bolpagni, M. "The implementation of BIM within the Public Procurement."

Bryde, D., M. Broquetas, et al. (2013). "The project benefits of Building Information Modelling (BIM)." International Journal of Project Management 31(7): 971-980.

Baker, S. E. and R. Edwards (2012). "How many qualitative interviews is enough."

Becker, H. S. and B. Geer (1957). "Participant observation and interviewing: A comparison." Human Organization16(3): 28-32.

Boeije, H. (2002). "A purposeful approach to the constant comparative method in the analysis of qualitative interviews." Quality and quantity36(4): 391-409

Chen, Y. Q., J. Y. Liu, et al. (2011). "Project delivery system selection of construction projects in China." Expert Systems with Applications 38(5): 5456-5462.

Carmines, Edward G., and Richard A. Zeller, eds. Reliability and validity assessment. Vol. 17. Sage, 1979.

Eastman, Chuk, Paul Tiecholz, Rafael sacks, and Kathlean Liston. BIM Hnadbook. New

jersey: john wiley & sons, 2008.print.

Farooqui, R. U. (2008). "AN ASSESSMENT OF GENERAL TRENDS ADOPTED FOR BIDDING AND

PROCUREMENT IN THE CONSTRUCTION INDUSTRY OF PAKISTAN."

Flanagan, R. J., Carol Ericsson, Stefan Henricsson, Patrik (2005). Measuring construction competitiveness in selected countries. UK, Univ. of Reading.

Finne, C. (2012). "The Finnish COBIM project–common national BIM requirements." eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2012: 471.

Foulkes, J. (2010). "Design and build procurement in the context of BIM. Available online at:http://www.fgould.com/uk-europe/articles/design-and-build-procurement-context-bim-and-gover/. Last accessed on: 29 OCT 2014

Moselhi, O. and Z. Popic "MULTI-TIERED PROJECT DELIVERY SYSTEMS SELECTION FOR CAPITAL PROJECTS."

Gordon, C. M. (1994). "Choosing appropriate construction contracting method." Journal of Construction Engineering and Management120(1): 196-210.

Grilo, A. and R. Jardim-Goncalves (2010). "Value proposition on interoperability of BIM and collaborative working environments." Automation in Construction19(5): 522-530.

Han Yan and Peter Damian (2013)."Benefits and Barriers of Building Information Modeling ". Available on http://www.hetnationaalbimplatform.nl/files/pages/294_benefits-and-barriers-of-building-information-modelling.pdf.Last accessed on: 27 NOV 2014.

Hale, D. R., P. P. Shrestha, et al. (2009). "Empirical comparison of design/build and design/bid/build project delivery methods." Journal of Construction Engineering and Management135(7): 579-587.

Hergunsel, M. F. (2011). Benefits of building information modeling for construction managers and BIM based scheduling, Worcester Polytechnic Institute.

Hussain, K. and R. Choudhry "BUILDING INFORMATION MODELING (BIM) USES AND APPLICATIONS IN PAKISTAN CONSTRUCTION INDUSTRY."

Handler, Laura. "Benefits of IPD". Tocci. 2010 Web. Sept. 2010. <tocci.com>.

Ibbs, C. W., Y. H. Kwak, et al. (2003). "Project delivery systems and project change: Quantitative analysis." Journal of Construction Engineering and Management129(4): 382-387.

JEELANI, S. A. K., J. KARTHIKEYAN, et al. (2012). "EVALUATION OF DESIGN-BID-BUILD (DBB) PROJECTS WITH AND WITHOUT AGENCY CONSTRUCTION MANAGEMENT." Research and Development (IJCSEIERD)2(4): 71-86.

Jiang, X. (2011). "Developments in cost estimating and scheduling in bim technology."

Kothari, C. R. (2004). Research methodology: methods and techniques, New Age International.

K Molenaar, N Sobin, D Gransberg. (2009). " Sustainable, high performance projects and project delivery methods: A state-of-practice report", Available online at: http://www.holderconstruction.com/KnowledgeCenter/Documents/Project%20Delivery%20Research/Sep2009ReportPankowDBIA.pdf. Last accessed on : 24 Nov 2014

Khemlani, Lachmi. " AGC's Winter 2011 BIMForum, Part 1."AECbytes"Building the Future"(2011).web. 22 Mar. 2011 <aecbytes.com>

Konchar, M. and V. Sanvido (1998). "Comparison of US project delivery systems." Journal of construction engineering and management124(6): 435-444.

Love, P. E. (2002). "Influence of project type and procurement method on rework costs in building construction projects." Journal of Construction Engineering and Management128(1): 18-29.

Liu, Zijia. Feasibility Analysis of BIM Based Information System for Facility Management at WPI.Thesis.WPI, 2010.Electronic Thesis and Dissertations. web. 30 Marc. 2011 <wpi. edu/Pubs/ETD/>.

Matthews, O. and G. A. Howell (2005). "Integrated project delivery an example of relational contracting." Lean Construction Journal2(1): 46-61.

Naoum, D. S. G. (2007). Dissertation Research and Writing for Construction Students.

PC Suermann. (2009). " Evaluating the impact of building information modeling (BIM) on construction", Available online at: http://etd.fcla.edu/UF/UFE0024253/suermann_p.pdf. Last accessed on : 24 Nov 2014

Rojas, E. M. and I. Kell (2008). "Comparative analysis of project delivery systems cost performance in Pacific Northwest public schools." Journal of Construction Engineering and Management134(6): 387-397.

R Büchmann-Slorup, N Andersson. (2010) BIM-based scheduling of Construction–A comparative analysis of prevailing and BIM-based scheduling processes. Available online at http://itc.scix.net/data/works/att/w78-2010-113.pdf. Last accessed on: 24 NOV 2014.

Roth, M., (1995) " An empirical analysis of United staes Navy Design/Build contracts". Masters thesis , University of texas , tex.

Saqib, M. (2008). "Assessment of Critical Success Factors for Construction Projects in Pakistan."

Sebastian, R. (2011). "Changing roles of the clients, architects and contractors through BIM." Engineering, Construction and Architectural Management18(2): 176-187.

S Azhar. (2011). " Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry", Available online at: http://ascelibrary.org/doi/abs/10.1061/(ASCE)LM.1943-5630.0000127. Last accessed on : 24 Nov 2014

S Horton. (2000). "the competency movement: its origins and impact on the public sector", Available online at: http://www.emeraldinsight.com/doi/abs/10.1108/09513550010350283. Last accessed on : 24 Nov 2014

Seidman, I. (2012). Interviewing as qualitative research: A guide for researchers in education and the social sciences. Teachers college press.

Vardaro, Michael j., James Vandezande, William Sharples, Jonathan Mallie, and John A.

Rapaport."Weighing the issues on BIM Technology."

Appendix 1

(Covering Letter)

Research Survey for Assessment of benefits of BIM application with Traditional Project Delivery Method in Pakistan

---

Dear All,

Subject: Dissertation – Construction Engineering & Management

I am currently undertaking a Master's of Science Degree in Construction Engineering Management at NUST H-12 campus. In fulfillment of this dissertation I am required to research a topic area and produce a dissertation. The topic I have chosen is "Assessment of benefits of BIM application with Traditional Project Delivery Method", and I am investigating the following aspects:

1. The benefits of BIM on the Design Bid Build Projects and the obstacles in achieving them
2. To develop a framework that how BIM can be implemented in different phases of construction on Design Bid Build Projects.
3. To measure the benefits of BIM applications on a on a running project through a case study.

I would be very grateful, if you could analyze the framework attached to this email and suggest your valuable comments to improve the framework in your own time. Needless to say, the information provided will be treated with strict confidence and individual firms will not be identified. Equally, a copy of the summary report will be available to the co-operating firms/Individuals.

Yours Truly,

Waqas Ather
MS CEM Student,
NIT, NUST, Islamabad.

Appendix 2

(Questionnaire)

Section 1: Respondent profile.

1. Name of respondent : ____

2. Email address: ______________________ Contact No.(Optional)______________________

3. Name of Firm/Organization/Company: ____

4. Please indicate your qualification (*Tick one box only*)
   - ☐ Doctorate (PhD)
   - ☐ Master Degree (MS/M Phil)
   - ☐ Bachelor Degree
   - ☐ Diploma Holder
   - ☐ Other

5. Please indicate your profession (*Tick one box only*)
   - ☐ Architect / Designer
   - ☐ Engineer / MEP Consultant
   - ☐ Contractor / MEP subcontractor
   - ☐ Developer / Facility owner
   - ☐ Academia
   - ☐ Others

6. Please indicate your role / designation in your Firm / Organization (*Tick one box only*)
   - ☐ Managing Director
   - ☐ Project Director / Manager
   - ☐ Project Architect / Engineer / Planner
   - ☐ Contract Manager
   - ☐ Site Manager
   - ☐ Site Supervisor
   - ☐ Facility manager
   - ☐ Professor / Lecturer
   - ☐ Other

7. Please indicate your professional experience (in years) (*Tick one box only*)

0-5	5-10	10-15	15-20	>20
☐	☐	☐	☐	☐

8. Please indicate the experience (in years) you have with BIM technology. (*Tick one box only*)

No experience	0-5	5-10	10-15	>15
☐	☐	☐	☐	☐

9. Please indicate the level of knowledge about BIM you have. (*Tick one box only*)

Little	General	Working	Expert
☐	☐	☐	☐

A questionnaire survey from different stakeholders is being conducted for the Assessment of benefits of BIM application with Traditional Project Delivery Method:

Designer and owner

1. *How long it takes to define the complete scope of a high-rise building project?*

☐ Throughout the life of the project
☐ Before the schematic drawings
☐ Before the execution phase

2. *How much cost you think is required for defining the scope of a project?*
- ☐ Less than 10% of design fees
- ☐ More than 10% of design fees
- ☐ Not recorded ever

3. *How much scope creep develops in the traditional project delivery system?*
- ☐ 10 % of total scope
- ☐ 15% of total scope
- ☐ More

4. *Do you agree with the inclusion of construction safety in the design phase of a project?*
- ☐ Strongly Agree
- ☐ Agree
- ☐ Don't Know

5. *What is to be added for sustainability of the building while in the design and scope phase?*
- ☐ New Technology
- ☐ experienced Workers
- ☐ creativity

6. *If you have 3d model like BIM, do you think value engineering will be more effective:*
- ☐ YES
- ☐ No
- ☐ Don't Know

7. *If you have 3D model like BIM, do you think constructability of the building components can be improved?*
- ☐ YES
- ☐ No
- ☐ Don't Know

8. *Do you think development of 3D or n-D model is very expensive and through its cost-benefit ratio of it can't be justified?*
- ☐ Agree Not agree Don't Know

9. *The model development should be owner during design phase?*

Yes No

10. *The model should be handed over to the contractor for further updating?*

Yes No

Constructor

1. *How much time is needed for planning the construction activities with the traditional drawings?*
- ☐ Less than 10% of execution phase
- ☐ More than 10% of execution phase
- ☐ Not recorded ever

2. *How could be scope creep syndrome minimized during the construction phase?*
- ☐ By having 3D model like BIM
- ☐ By spending more time on planning

- By working on Design Build methods

3. *Is pre-task planning of project activities conducted?*
- Frequent
- seldom
- never

4. *If seldom or No in question # 3, what is the reason*
- Skills not available
- No contractual requirement
- No tools available

5. *How much drawings discrepancies are expected on a traditional project?*
- 5% of total scope
- 10% of total scope
- 15% of total scope

6. *How much a project is usually delayed due to shop drawings preparations and approval of the submittals*
- 2months
- 4 months
- 6 months

7. *If you want to develop 3D model, do you think it would be cost effective?*
- Yes
- No

8. *If you have 3D model are you going to give it to Facility Managers in the end?*
- Yes on payment
- yes for free
- Not at all

9. *Do you think owner should pay for the BIM model?*
- Yes
- No
- Don’t Know

Facility mangers

1. *How much discrepancies you find in as built drawings while performing the maintenance operations?*
- Very much
- Minimal
- Not any

2. *How the facility management work can be improved?*
- Employing skilled team

☐ Improving the as-built data
☐ Develop the 3D model

3. *Intelligent Building model can not be deployed due to?*
☐ Non-availability of skilled worker
☐ Expensive
☐ Not aware of such technology

4. *BIM model can be helpful in providing early warning/notification of the failure of different elements of the buildings*
☐ Very much
☐ To some extent
☐ Don't Know

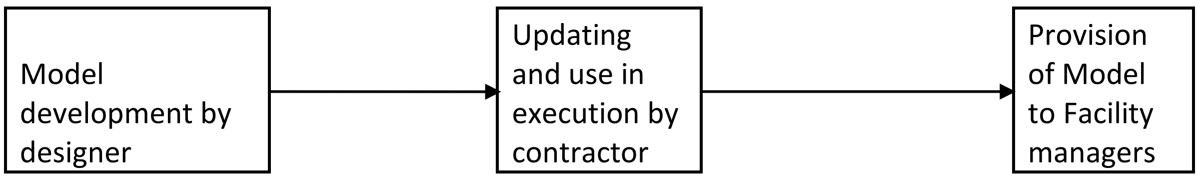
5. *Quality of the service for building occupants can be improved by deploying anyone of technique*
☐ BIM carrying as built data
☐ By providing CAD drawings
☐ By providing information on papers

<u>Scenarios:</u>

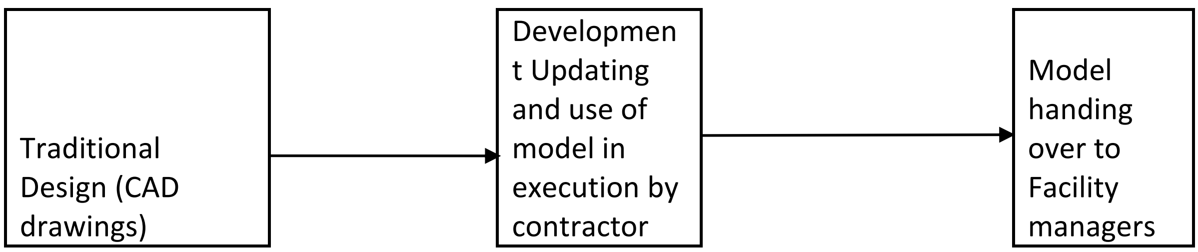
Choose the best option among the scenarios, if you are project manager of a project:

Design Phase	BID PHASE	**execution Phase**	COMPLETION PERIOD	**Operations Phase**

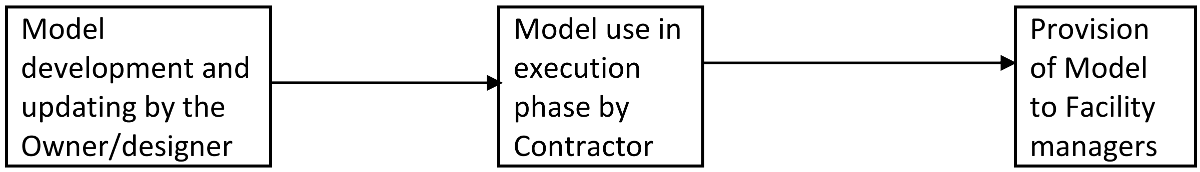
1.



2.



3.



Thank you so much for your help and time you spent. All responses will be held in strict confidence and will be used for academic purposes and for this research work only.