

Chapter 1: Introduction

1.1 Preface

In response to the fast growth in construction industries worldwide, design and construction firms, and professionals in Architecture, Engineering and Construction (ACE) sector, have great challenges to adopt more efficient and effective building tools to achieve client's satisfaction by providing accurate and easier information and data more than traditional assembled 2D. Since 1992 the term of Building Information Building(BIM) appeared and started using widely as concept for digital representation of the physical and functional characteristics of a building displayed as a 3D model, with the added capability to integrate a whole array of design, and the term is changing from one developer to another such as Virtual Building by GraphiSoft and Integrated Project Models by Bentley Systems.

According to The National Building Information Model Standard (NBIMS), Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle. In 2004, the National Institute of Standards and Technology (NIST) published a report stating that poor interoperability and data management costs the construction industry approximately \$15.8 billion a year, or approximately 3 -4% of the total industry .A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM process to support and reflect the roles of that stakeholder (Suremann, 2009)

Addition to that, new dimension elements have been added to 3D concept such as 4D for time and 5D for cost to enhance the capability for life cycle management. Stakeholders with access to BIM information can use it to look back or to look forward in the lifecycle of a building or facility, and to do so from a very detailed level to a

summary view (IBirna, 2011). Standards are now taking shape to support this approach so that stakeholders involved in the building lifecycle can access and apply information from the smallest part of a facility up to the worldview, from the beginning of a project to hand over to client and even beyond completion for operation and maintenance. BIM Standard efforts in the US, Europe and elsewhere around the world assume that this digital information is shareable among different stakeholders' information systems, is based on open standards, and is capable of being defined in contract language mentioned by National Building Information Model Standard (NBIMS).

1.2 Problem Statement

The Sudanese construction industry has been criticized for inefficient and low rate of productivity. On other words, the construction industry has been slow in adapting to new technology, such as BIM and used as it should be. BIM suggested by professionals, developers and researchers in construction industry to addresses this problem, still there is lack of knowledge of using BIM in construction management to facilitate to deliver a project and obtain high degree of client's satisfaction.

1.3 Aim of the Study

The aim of this research to study the capability of building information modeling from the prospective of Construction management and focusing to evaluate the performance of Building information modeling (BIM) in Construction industry and increase the usage of BIM by construction companies and finding the obstacles that might face the full implementation of BIM.

1.4 Objectives and Research Questions

This research will try to find answers and solution for the problem stated above by achieving these objectives:

- To Study the literature review and understand how construction industry use BIM
- To explore the benefits of BIM implementation.
- To find out why organizations are not adopting BIM
- To find out the challenges and barriers of BIM implementation

1.5 Scope of the Research

This study will focus to investigate the impact of BIM on construction industry and study advantages and limitations of BIM. The study will conduct based on qualitative method such as questionnaire survey from those who participates in construction industry and study the literature review about Building information modeling.

1.6 Methodology

This research will conduct questionnaire survey and study data from past studies the questionnaire will be conducted from well recognized companies, both methods will analysis in order to achieve the objectives of the research and result will present in chapter four to come out with the final conclusion and recommendation in chapter five.

1.7 Organization of the Research

This research is divided into five chapters in order to achieve the objectives and answer the questions have been set in Chapter 1 section 1.4 (Objectives and Research Questions), and the structure of the chapters will be carried out as

Chapter 1: Introduction; this chapter provided descriptions of research aim and objectives and clarification on how research will try to find key of success for problem stated.

Chapter 2: Literature Review; presents a review of the literature regarding BIM and potential benefits and drawbacks from past researches and articles

Chapter 3: Methodology; describes the research methodology including discussions on the challenges and methods will be used to collect data.

Chapter 4: Analysis and discussion; demonstrates the data collection that will be conducted from the qualitative methods such as questioners, interviews and survey.

Chapter 5: Conclusion and Recommendation; concludes the final statements from the results studies as well as identifies future implications and recommendation.

Chapter 2: Literature review

2.1 Introduction

Building Information Modeling (BIM) has recently attracted attention in the Architectural, Engineering and Construction (AEC) sector. BIM represents the development and most technological uses of computer generated (N) dimensional (n-D) models to simulate and facilitate the planning, design, construction and operation of a facility. It helps architects, engineers and contractors to visualize what is to be built in simulated environment and to identify potential design, construction or operational problems and risks might face the team during implantation phase .

With the rapid adoption of BIM in the construction industry by developed countries, and its gradual beneficial impact on implementation in the design industry, careful considerations have to be taken in order to change from the traditional method of creating construction documents to use building information methods in projects. There are some advantages and limitations and unknowns regarding implementing BIM approach must be considered when adopting this change. This chapter will discuss research that was done about the background of BIM, and positive and negative effects, on construction industry and highlight the effects and features and most used software and their advantages and disadvantages plus the challenges and barriers that has been discussed in past studies

2.2 Building Information Management (BIM)

The technological advancement in the construction industry has been introduced and provides frequently new concepts and software to enhance the productivity and project delivery as well. One of the most exciting advances in construction today is the ever increasing use of a technology known as building information modeling (BIM).

Fundamentally, BIM adds a three dimensional modeling component to traditional two dimensional plans and specifications, with an added features. Every element of the design displayed in the building information model also carries with it data to support a whole array of construction management tasks and activities

According to (Barbara, 2010) building information modeling is 3D digital representation of the physical and functional characteristics of a building. And difference between a typical CAD-generated 3D model and a building information model is that the BIM can save all vital information about the entire building process and all of its components. In other words, the power of this technology is that the virtual model is also a database in which to load every bit of electronic data that can be collected. That means specification data about materials (weight, size, color, fire rating, maintenance data, and others), installation instructions for assembly, product warranties, maintenance requirements, including productivity and price information. Also, BIM is a CAD model linked to a database in which you can enter just about any information you want. BIM model serves as a shared knowledge resource for the entire design and building team. On other words, BIM focuses on the integration of information that inevitably adds efficiency to the design and construction process, reduces waste and error, and improves quality which is help to complete project successfully. Building information modeling can be defined as the process that is focused on development and use of computer generated model to stimulate the planning, design, construction and operation of facility (Azhar, 2008).

It is also defined as a digital representation of physical and functional characteristics of a facility according to (NBIMS Committee, 2007). BIM is a visualization tool that enhances communication between architectural, engineering and construction industries. The concept is to build a building virtually, prior to building it physically, in order to work out problems and simulate and analyze potential impacts (Suremann, 2009)

2.3 Evolution of BIM

BIM is a revolutionary technology started with the market need for more accurate and fast tool that facilitate and help in process of transforming the buildings and designed, planned, constructed and managed more accurately. It is also regarded as an approach to assist the construction industry to develop new ways of thinking and practice. The construction industry and researchers have a number of views as to define BIM, figure 2.1 describes the three words of building information modeling BIM separately and the definition for BIM when it combined together

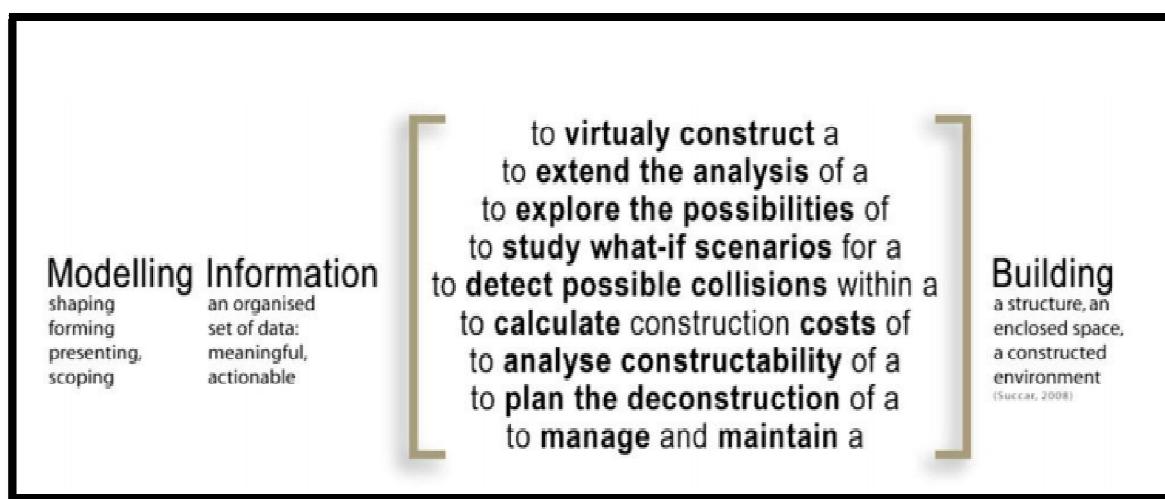


Figure 2.1:Explains BIM Concept, ((BIM Project Execution Guide, 2009)

(Smith, 2007) stated in his report BIM is a digital representation of the physical and functional characteristics of a facility. It provides a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. Since its inception, a number of systems and tools have been made available, among which is Virtual Prototyping (VP) technology, a computer aided decision tool through digital product models and realistic graphical simulations. Because of the novice nature and a huge potential, BIM is a widespread and popular subject of research and application in the AEC community.

BIM was originated from the concept of semantic data models in machine engineering in the 1970s. These semantic data models were designed for connecting logical and physical information. Example of early BIM development in AEC industry include the Building Design System (BDS), which was generated under a funded research project by the UK government in mid-1970s. Another early BIM is Really Universal Computer Aided Production System (RUCAPS), a computer aided design (CAD), which was developed by John Davison, and John Watts from the Liverpool University. These two building modeling systems were used by early adopters in the UK and U.S. through the mid-1980s (Wong el.al 2010)

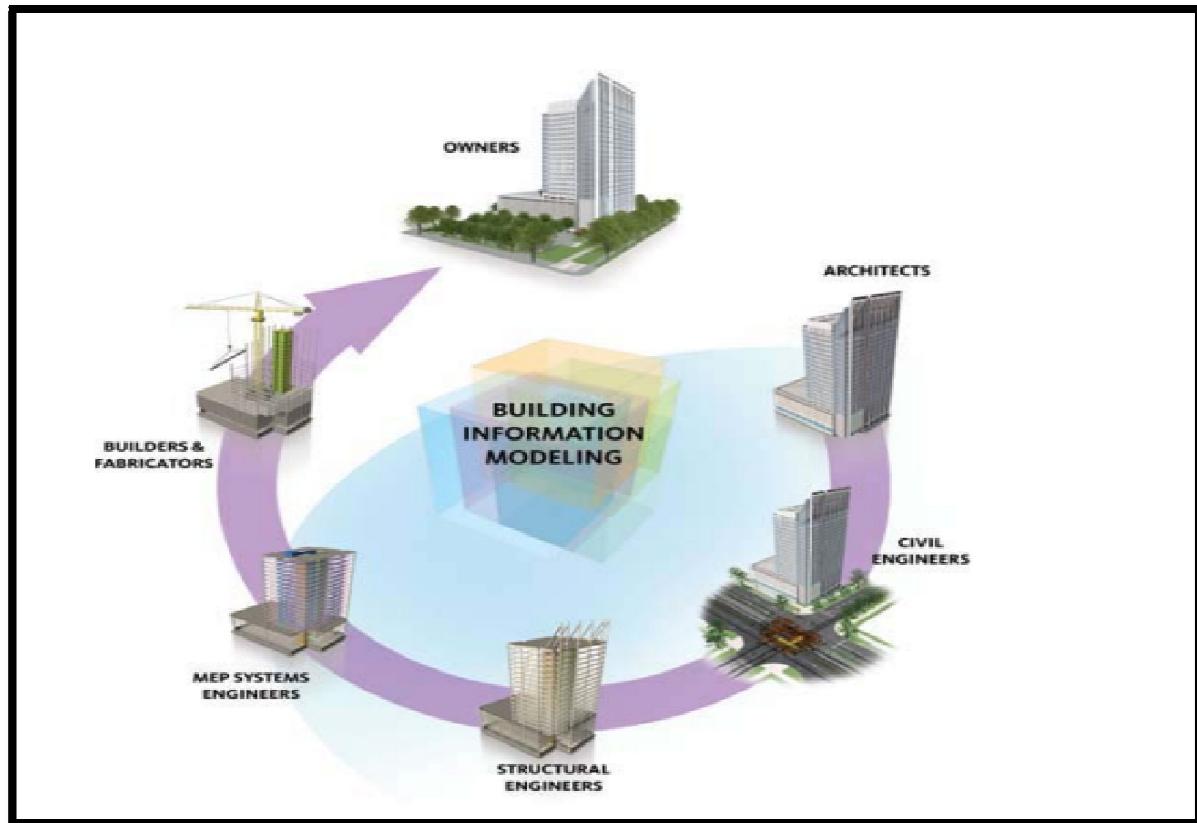


Figure 2.2: Shows lifecycle of a building using BIM (Source: Autodesk Revit brochure 2010)

2.4 Differences between CAD and BIM

Before 40 years ago, architectural plans were created with normal pen, pencil, and paper, change to some part of a document if needed, Means changing the other parts that effected. Thus redrawing was very tedious and stressful. In the early 1970s, computer-aided drafting (CAD) started appear the marketplace. As exciting as this technology was, at first it was able to run only on graphic terminals connected to mainframe computers. But in the early 1980s, CAD programs that were able to run on personal computers began to emerge, in the offices of some architects. On other words CAD changed the architecture community (Barbara, 2009).

Designers were able to draw and erase lines by electronic means and insert text to create 2D plans and specs and changes become more easily. CAD allowed architects to produce better designs much faster. Complex shapes that in less time. Typical items and details could be drawn once and then stored for future insertion into other drawings. Once retrieved, could be copied, rotated, and oriented into position in seconds.

Eventually the technology advanced to include basic 3D modeling capabilities, and all of the 2D line drawings were now able to be represented as 3D objects. Once animation was added, such functions as walk through and bird's eye view can be involved.

CAD was a major breakthrough for the architectural community, and contractors benefited from the breakthrough as well. All of those big rolls of paper plans and specs were now able to be transmitted to them electronically, and with 3D modeling they could get a glimpse of what the project was supposed to look like when it was finished .But as wonderful as CAD is, even with 3D modeling capabilities, it isn't BIM. In other words, the model that is produced via CAD isn't intelligent. It is simply a 3D representation of a 2D design. For example, the 3D model is not able to detect errors on its own and correct information from one part of the model to another part of the model automatically. The CAD lines simply configure to create 3D objects.

The concept of BIM goes way beyond CAD. With BIM the design process begins by building a model made up of intelligent objects that represent all the elements of the project walls, roof, windows, beams, stairs, air conditioning units, and so on and shows what relationship have with the other objects in the model. Therefore instead to look in different places plans, sections, elevations, and schedules for information regarding a particular item, all the pertinent information is built into the window in the BIM. The object shows size, frame material, properties and even information about manufacturer and when changing the design, each object will adjust itself to fit the new scheme.

In addition to communicating design intent, BIM allows the designers to run a variety of studies, simulations, and “what if” scenarios in a virtual environment, keeping track of the different databases that comprise the project, thereby tracking the various impacts those scenarios have on everything from energy. Furthermore, as other design professionals get involved with the model, such as structural engineers, mechanical engineers, and electrical engineers, figure 4 shows the collaboration work by different engineers for one building using BIM, also can add their project elements and run design scenarios to see how they interface with the architectural components of the model.

As argued by (Wong el al. 2010) with BIM, the opportunity to integrate every aspect of the design is a real possibility because all of the physical and functional characteristics of every element of the project are captured in a database format. It's easy to share project information with other members of the team. Addition to that contractor issues such as constructability, productivity, fabrication, and installation can also be considered while the design is being developed

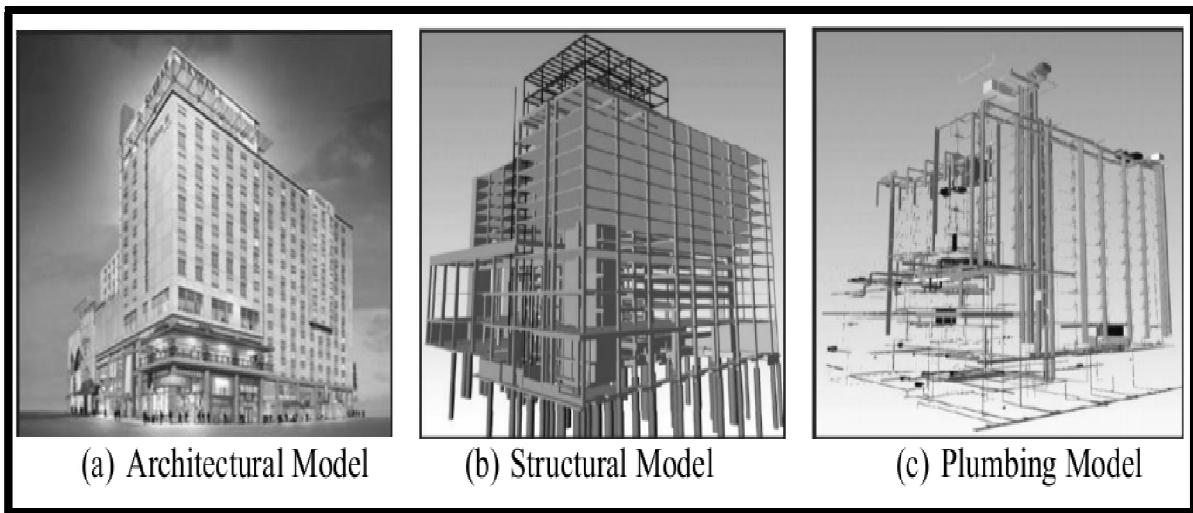


Figure 2.3: shows the collaboration between different engineers using BIM (Sources: Holder Construction, Atlanta, GA, 2011)

2.5 Dimensions of BIM

Traditionally, buildings have been designed in two dimensions, (plan, elevation, and section) and detail drawings to define and visualize more accurately the building form by third dimension 3D. BIM has introduced more dimensions to presents the cost and time and even operations and maintenance of facility after hand over to the client.

i. Fourth Dimension for Time (4D)

The planning and scheduling functions represent one of the most important aspects of the construction management process. These efforts continue through-out the building process and are constantly being monitored to keep the project on track. By adding schedule data to a 3D building information model, you can create a 4D information model, where time is the fourth dimension reported by (Barbara, 2010)

Adding the fourth dimension to the building information model helps everyone involved in the project visualize the schedule and understand how important proper sequencing of activities is to the overall success of the project. 4D schedules are stereoscopic projection a 3D video display of a computer generated virtual reality environment.

Developed tools for phasing, coordinating, and communicating and planned work for subcontractors, designers, owners, and other project stakeholders helps to optimize the sequence of construction and manage project logistics.

ii. Fifth Dimension for Cost (5D)

One of the major benefits of BIM is that each object within the model includes information about its length, width, and height which is needed by the estimator in order to develop quantities for the project. BIM enables accurate quantity takeoffs of materials and building components that can be linked directly to cost databases to create an accurate estimate for the project. Furthermore, the design and the estimate are connected in such a way that any cost impacts associated with changes in the design can be seen immediately by all parties associated with the project (Barbara, 2010)

iii. Sixth Dimension for Facility Management(6D)

The sixth dimension is still under dispute whether it exists or not. For those that believe that the sixth dimension exists it is about lifecycle cost, facilities management, and environmental impact. So actually the sixth dimension is about aspects which have an impact on the building and how the building has an impact on its surroundings.

2.6 BIM for Design, Planning and Construction

BIM has a great deal of research efforts has been placed on the development of innovative BIM systems in the aspect of design planning and construction of building projects. Li et al. (2009) explained two key purposes for applying BIM in pre-construction planning. First, it aims to allow project planners to view their static realistic images and check for design errors and collisions by using information embedded in 3D models. Second, BIM is adopted as a detailed building component model to act as a design check and to develop a detailed construction activity.

(Wong el al. 2010) reported that a conceptual framework consisting of four levels of abstraction and functionality which facilitates the recording of the intent behind

construction project decisions, thereby providing a complete project history. Despite these efforts, the problems of these early works are associated with insufficient attention to the real productivity rate of different machineries and manpower in their model design (Li et al. 2009). A more recent development of BIM technologies involves the use of visual representations in the project schedule and associated information combined with visual representations of the project in progress such as 4D. these tools assist project teams to identify effective construction strategies for shortening project duration, examine their workability, and review overall schedule quality. Figure below show the percentages of usage for BIM technology and what function is used for. According to Marcus,(2012) architects and engineers can take advantage of BIM applications at different stages of project design namely schematic design (SD), detailed design (DD) and construction detailing (CD). Table 2.1 illustrates specific BIM applications in each stage of project design.

Table 2.1 BIM applications in project design phase, (2011)

| Schematic design | Detailed design | Construction Detailing |
|--|--|--|
| <ul style="list-style-type: none"> ▪ Options Analysis (to compare multiple design options) ▪ Photo Montage (to integrate photo realistic images of project with its existing conditions) | <ul style="list-style-type: none"> ▪ 3D exterior and interior models ▪ Walk-through and fly-through animations ▪ Building performance analyses (e.g. energy modeling) ▪ Structural analysis and design | <ul style="list-style-type: none"> ▪ 4D phasing and scheduling ▪ Building systems analysis (e.g. clash detections) ▪ Shop or fabrication drawings |

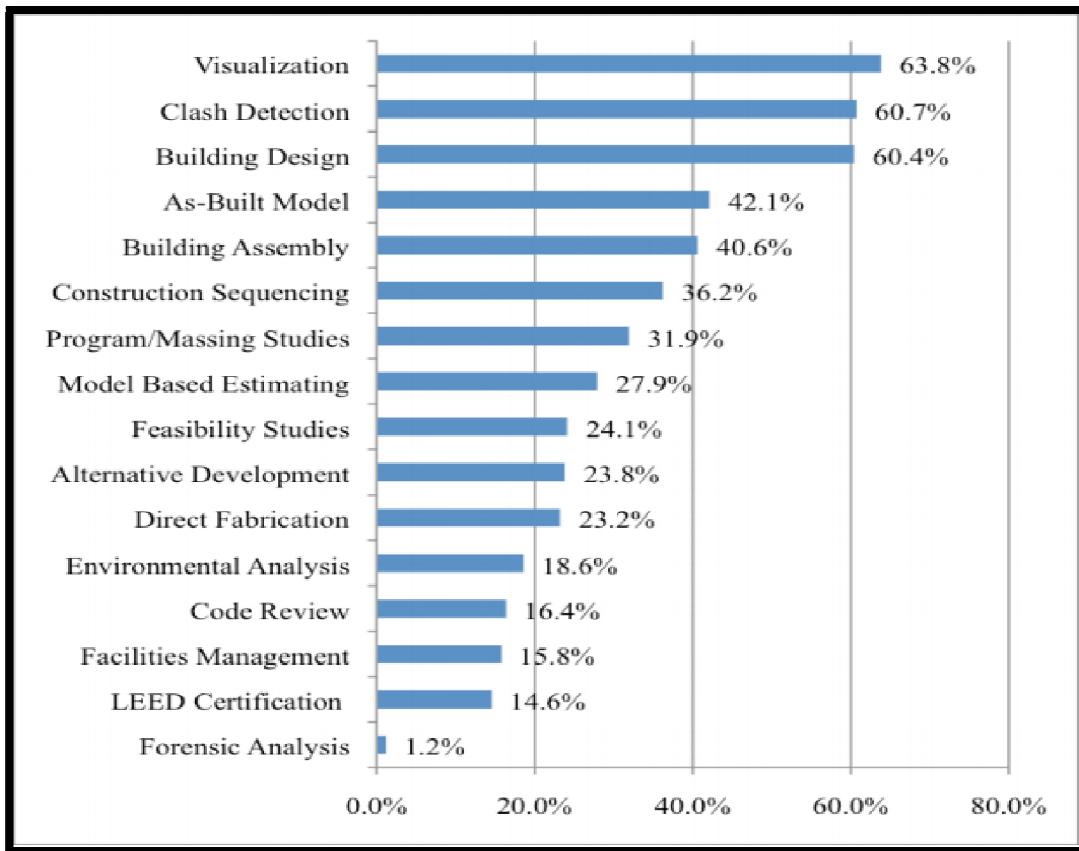


Figure 2.4: shows the percentage of task used by BIM (Azahr 2011)

2.7 BIM Capabilities

A building information modeling is developed concept of constructing project in simulation environment before implementing it in the real world. BIM also can be used for the following purposes as indicated by (Azaher, 2008) in his report: Visualization: 3D renderings can be easily generated in facility with little additional effort.

- i. Fabrication or shop drawings: it is easy to generate shop drawings for various building systems, for example, the sheet metal ductwork shop drawing can be quickly produced once the model is complete.
- ii. Code reviews: fire departments and other officials may use these models for their review of building projects.

- iii. Forensic analysis: a building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans, etc.
- iv. Facilities management: facilities management departments can use BIM for renovations, space planning, and maintenance operations.
- v. Cost estimating: BIM software have built-in cost estimating features. Material quantities are automatically extracted and changed when any changes are made in the model.
- vi. Construction sequencing: a building information model can be effectively used to create material ordering, fabrication, and delivery schedules for all building components.
- vii. Conflict, interference and collision detection: because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences. This process can verify that piping does not intersect with steel beams, ducts or walls

2.8 Application of BIM

From first phase of planning for project through handover the project, BIM application could be applied for every single phase of the project. According to BIM Project Execution Planning Guide by The Pennsylvania State University, there are twenty-five uses of BIM for consideration on a project as stated by (Marshall et al. 2009) as can be seen in Figure 4, And as the guide suggest, it is not appropriate to implement all of the application of BIM. The most importantly is to understand the main reason why BIM is used in the project and to set objectives of adoption. Only then, the use of specific BIM application can be selected.

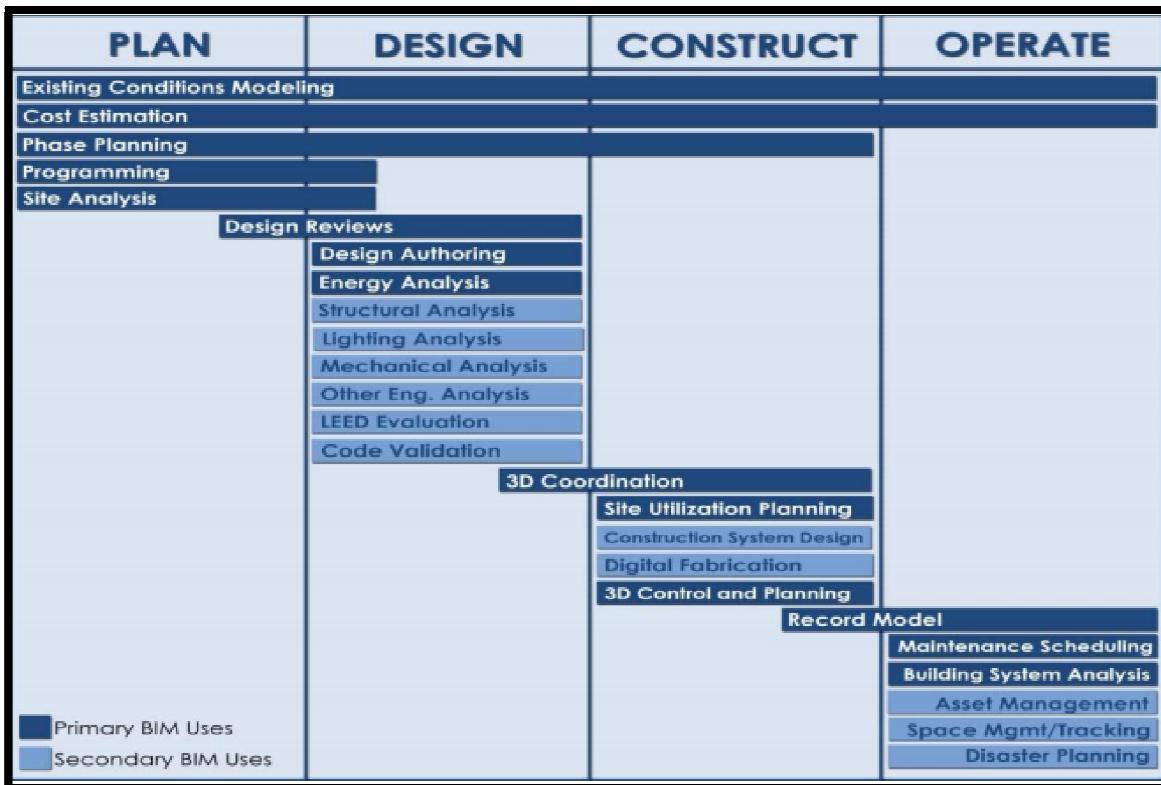


Figure 2.5: shows BIM application in project life-cycle (BIM Project Execution Guide, 2009)

2.9 BIM Benefits

The most important benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data. (Azaher, 2008) mentioned in his report some other benefits can be as such:

- i. Faster and more effective processes; information is more easily shared, can be value-added and reused.
- ii. Better design; building proposals can be rigorously analyzed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions.
- iii. Controlled whole life costs and environmental data; environmental performance is more predictable, lifecycle costs are better understood.
- iv. Better production quality; documentation output is flexible and exploits automation.

- v. Automated assembly; digital product data can be exploited in downstream processes and be used for manufacturing and assembling of structural systems.
- vi. Better customer service; proposals are better understood through accurate visualization.
- vii. Lifecycle data; requirements, design, construction and operational information can be used in facilities management.

According to Stanford University Center for Integrated Facilities Engineering (CIFE) found based on 32 major projects using BIM indicates benefits such as:

- i. Up to 40% elimination of unbudgeted change.
- ii. Cost estimation accuracy within 3%.
- iii. Up to 80% reduction in time taken to generate a cost estimate.
- iv. A savings of up to 10% of the contract value through clash detections.
- v. Up to 7% reduction in project time.

According to Marcus,(2012)BIM can be viewed as a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing all team members (owners, architects, engineers, contractors, subcontractors and suppliers) to collaborate more accurately and efficiently than traditional processes. As the model is being created, team members are constantly refining and adjusting their portions according to project specifications and design changes to ensure the model is as accurate as possible before the project physically breaks ground . BIM has tremendous benefits for project stakeholder, Before discussing benefits of BIM for project owners, designers, constructors and facility managers, it is useful to summarize BIM applications for these stakeholders. Table2.2 provides this summary

Table 2.2 BIM applications for project stakeholders, (2010)

| BIM Application | Owners | Designers | Constructors | Facility Managers |
|-------------------------------|--------|-----------|--------------|-------------------|
| Visualization | X | X | X | X |
| Options analysis | X | X | X | |
| Sustainability analyses | X | X | X | |
| Quantity Survey | | X | | |
| Cost Estimation | | X | X | |
| Site Logistics | X | X | X | |
| Phasing and 4D scheduling | X | | X | |
| Constructability analysis | | X | X | |
| Building performance analysis | | X | X | X |
| Building management | X | | | X |

I. Project Owners

Owners can achieve significant benefits on projects where BIM technology and processes are applied. Eastman et al. (2011) and Reddy (2011) summarized the following benefits of BIM for project owners: (1) Early design assessment to ensure project requirements are met; (2) Operations simulation to evaluate building performance and maintainability; (3) Low financial risk because of reliable cost estimates and reduced number of change orders; (4) Better marketing of project by making effective use of 3D renderings and walk-through animations; and (5) Complete information about building and its systems in a single file. Due to these and other tangible and intangible benefits of BIM, large project owners in the USA (such as the General Services Administration (GSA), the U.S. Army Corp of Engineers(USACE), are increasingly requiring designers and contractors to utilize BIM in all projects

I. Project Designers

The project architects and engineers can take advantage of BIM in schematic and detailed design; and construction detailing phases as summarized in Table 2.2. Following are some of the main benefits of BIM for project designers:(1) Better design by rigorously analyzing digital models and visual simulations and receiving more valuable input from project owners; (2) Early incorporation of sustainability features in building design to predicts its environmental performance; (3) Better code compliance via visual and analytical checks; (4) Early forensic analysis to graphically assess potential failures, leaks, evacuation plans and so forth; and(5) Quick production of shop or fabrication drawings. The early design and preconstruction stages of a building are the most critical phases to make decisions on its sustainability features. Traditional Computer-Aided Design (CAD) planning environments typically lack the capability to perform sustainability analyses in the early stages of design development. Building performance analyses are typically performed after the architectural design and construction documents have been produced. To assess building performance in the early design and preconstruction phases realistically, access to a comprehensive set of data regarding a building's form, materials, context and systems is required. Since BIM allows for multi-disciplinary information to be superimposed within one model, it creates an opportunity for sustainability measures to be incorporated throughout the design process.

Azhar et al. (2011) found that information for up to 17 LEED (Leadership in Energy and Environmental Design, a green building rating system used in the USA. It means a building information model can be used as a by-product for LEED analysis thereby saving substantial time and resources.

II. Project Contractor

In the United States general contractors are the early adopters of BIM among all stakeholders Azhar et al., (2008). The contractors and subcontractors can use BIM for the following applications: (1) Quantity takeoff and cost estimation; (2) Early identification of design errors through clash detections; (3) Construction planning and constructability analysis; (4) Onsite verification, guidance and tracking of construction activities; (5) Offsite prefabrication and modularization; (6) Site safety planning; (7) Value engineering and implementation of lean construction concepts; and (8) Better communication with project owner, designer, subcontractors and workers on site. Through these applications constructors can achieve the following benefits: (1) High profitability; (2) Better customer service; (3) Cost and schedule compression; (4) Better production quality; (5) More informed decision making; and (6) Better safety planning and management.

III. Facility Managers

In the past, facility managers have been handed over the building with boxes and piles of owner's manuals and warranties. The use of BIM provides two major benefits: (1) The same critical information is present in a single electronic file; and (2) the facility managers do not have to sift through the piles of information to gather data. As mentioned by Marcus (2011), with the BIM database, any information about equipment is just one-click away. The facility managers can click on any equipment or fixture to obtain information on product, warranties, life cycle of the product, maintenance checks, replacement cost, installation and repair procedures, and even place order for a replacement online.

2.10 Challenges for BIM Adaptation

Implementing BIM approach is consider one of the challenging task in construction industry, some factors must be considered is definitely has negative effect

for the construction industry if it's not well considered. There are still many challenges and barriers in BIM, which still needs to be resolved, argued by (Ningappa, 2011) in his research such as:

i. Ownership

Who owns the ownership of model; Legal concerns are presenting challenges as to who owns the multiple design, fabrication and construction datasets, who pays for them and who is responsible for their accuracy. Some Professional groups and research bodies are developing guidelines to cover issues raised by the use of BIM technology.

ii. Responsibility

Another issue in BIM is it is not clear who has to control the entry of data and be responsible for the inaccuracies. Taking the responsibility can be extremely risky as it may lead to major legal liability issues (Azhar, 2008). Thus, before BIM technology can be fully utilized, the risks of its use must be identified and allocated and the cost of its implications must be paid for as well

iii. Collaboration and Teaming

According to (Eastman, 2008) stated in his paper architectural firm may not use the BIM software, which leads to general contractor outsourcing the entire model. This is not only is time consuming but also costly. Also, if members of the project used different modeling software, collaborating with them might be difficult and might cause some loss

iv. Implementation Issues

Implementing BIM requires more attention through understanding and a plan for implementation before the conversion can begin to avoid any misunderstanding during exchange the information (Eastman, 2008).

2.11 BIM Future Challenges

Previous studies have been done to highlight the barriers that face the implementation of BIM in Construction industry to benefit from all BIM technology as it increase productivity and has great economic effect by reducing cost Furthermore, the technology to implement BIM is readily available and rapidly maturing. Regarding to that, some issues started arisen for slow BIM adoption more than anticipated (Azaher 2010).

The issues for implementation and use of BIM there is no clear consensus as how to implement or use BIM, there is no document or treatise on BIM that instructs on its application or usage. There is a need to standardize the BIM process and to define the guidelines for its implementation. Another contentious issue among the AEC industry stakeholders, owners, designers and constructors is who should develop and operate the building information models and how should the developmental and operational costs be distributed (Azaher 2010).

The researchers and practitioners have to develop suitable solutions to overcome these challenges and other associated risks. As a number of researchers, practitioners, software vendors and professional organizations are working hard to resolve these challenges, it is expected that the use of BIM will continue to increase productivity in the AEC industry.

Moreover In the past facilities managers have been included in the building planning process in a very limited way, implemented maintenance strategies based on the as-built condition at the time the owner takes possession. BIM modeling may allow facilities managers to enter the picture in the future at a much earlier stage, where they can influence the design and construction. The visual nature of the BIM allows all stakeholders to get important information before the building is completed. This includes tenants, service agents as well as maintenance personnel. Finding the right time to include these people will undoubtedly be a challenge for owners.

2.12 Benefits of BIM Technology

Nowadays BIM technology is considered one of the most important technological tools that support all the processes of the project life cycle starting with feasibility study stage and continuing through whole facility. Benefits presented by (Eastman, 2008) for each building project lifecycle in four phases discussed as following:

i. Pre-construction phase

In feasibility stage client tries to determine the size of the project which would meet his budget. The estimation of the project at this point is very rough. But it is still not desired to spend a lot of time on cost estimation which at the end appears to be significantly over budget. Using BIM tools approximate building model can be linked to cost database and project price would be calculated instantly along with model creation or modification process. In early stage when only schematic model is available it is possible to evaluate building functionality and sustainability using analysis and simulation tools. This allows defining right project development directions in early stage which increases the overall quality of the building.

ii. Design phase

Entering the design phase 3D model is already available from previous stage. There is no need to generate model from 2D drawings. Models might be just ready for updates. If objects are assembled using parametrical constraints probability of error occurrence while design is changing is minimized. There is possibility to extract accurate and consistent drawings for any set of objects or specific view of the project. What is more, after each modification of 3D model all the 2D visual representations are modified respectively. It is possible to perform automatic evaluations of 3D models in terms of satisfaction of set requirements like “Area of certain type room has to be of particular size”. Estimators using BIM can extract quantities and spaces which can be used for cost estimation. At the beginning estimations are made based on available quantities like areas. When more detailed design is done more accurate estimations can be performed. It helps to make better design decisions along project development process as project price can be monitored continuously.

iii. Construction and Fabrication

Using 4D BIM it is possible to simulate the construction process, visualize how building will be constructed day by day, and reveal potential problems on the site and opportunities for improvements.

BIM technology allows identify clashes between systems from different disciplines before construction takes place. This speeds up construction process, reduces risk for project cost raise due to clashes and need for solutions to fix mistakes, minimizes probability of legal disputes. In case design changes appear during construction, modified model, which is set with parametric rules, will update also cost estimate and schedule instantly. BIM technology also facilitates fabrication process. 3D elements from the model can be sent to factories where element production process is fully automated.

iv. Post-construction phase

BIM models are full of information which can be useful for building operation processes. It is desired that models support real time monitoring of control systems, provide a natural interface for sensors and remote operating management of facilities.

2.13 Technical Aspects of BIM

i. Clash controls

By clash controls, the building information models of different disciplines are brought together and checked for geometrical design inconsistencies. Points where the models of different disciplines overlap each other when brought together are detected and can then be corrected. Moreover, visual errors which can lead to poor esthetical quality can be discovered and corrected (Eastman 2008).

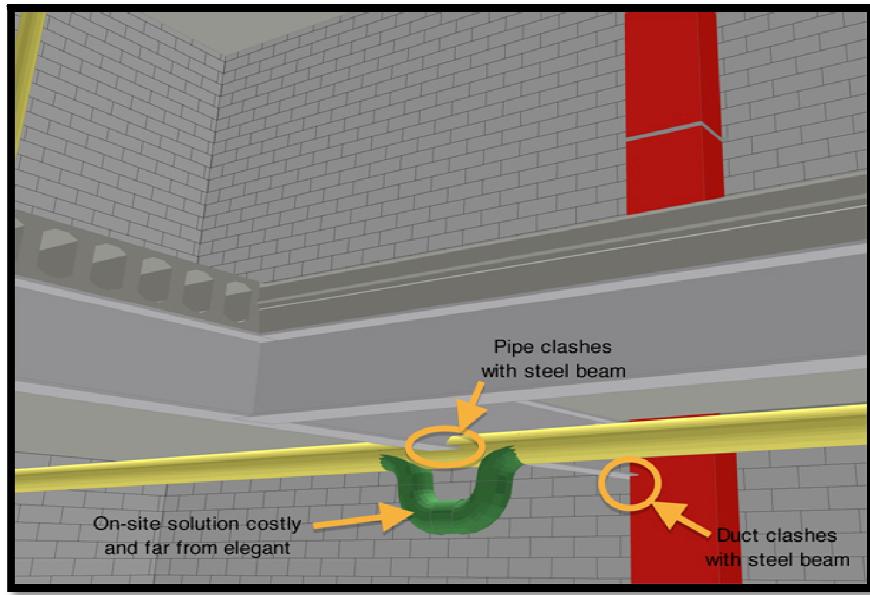


Figure 2.6: Shows clash detection during design phase and before implementation phase (Source: Building design expert website, 2011)

ii. Analysis

Energy analyzes can be performed by linking a building information model to tools which analyzes the isolating ability of a building and measures energy usage for heating and cooling during peak periods. Energy analyzes enable production of buildings that consume less energy during its lifecycle (Eastman, 2008).

iii. Time estimation (4D)

With time estimation, or fourth dimension 4D, objects in a building information model are linked to the time plan. The linkage to time plan makes it possible to graphically visualize the projects schedule and users can simulate the building site and construction at any point in time. This type of simulation provides considerable insight and allows for early detection of planning errors. Instead of realizing planning mistakes later on in the construction phase, and having to resolve problems on site which can be very costly, mistakes can be eliminated already in the design

phase (Eastman,2008). Moreover, time estimation can be utilized to optimize the logistical aspects. Figure 5 below show the time estimation with construction process on site with accordance to bar chart that presents the daily activities.

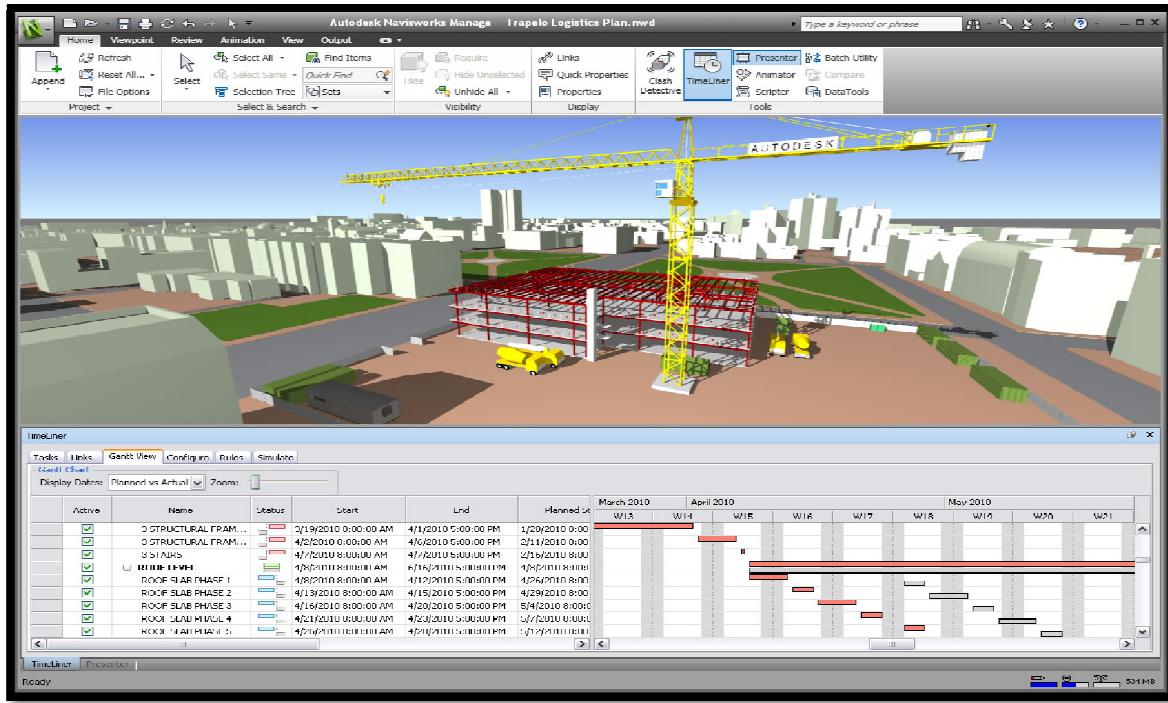


Figure 2.7: shows the 4D process from Autodesk Naviesworks Manages software (Source: mrasbuilt.com, 2011)

iv. Cost estimation (5D)

With cost estimation, also referred as 5D, the objects in a 3D design can be connected with price lists for different materials. The price lists are mainly based on volume cost of materials, but can also include labor and equipment costs for more detailed cost estimates. This enables accurate cost estimation at any point in the design phase and creates understanding regarding financial implications of design decisions. (Eastman, 2008).

v. Record Model

Construction and design firms can provide a record Building Information Model to the owner at the end of a project. The model includes the integration of the as -

built from the subcontractors. Furthermore, each object property in the model can also include links to submittals, operations and maintenance, and warranty information. Centralized database can help the facilities department to find information easier.

Record model can be used to manage security and safety information such as emergency lighting, emergency power, egress, fire extinguishers, fire alarm, smoke detector and sprinkler systems (Li et al. 2009). Furthermore, the facility team can analyze energy efficiency of a virtually built model. In addition to that, facilities team can plan with record model to maintain and renovate buildings by tracking spatial information such as furniture, equipment, and MEP (mechanical, electrical, and plumbing) connections. Finally, the facilities department can use the model to generate cost and schedule impacts for maintenance and renovation projects.

Overall, a record model can be utilized to optimize facility management and maintenance. Generation of Building Information Model as a record model is an area in the process of development. The interoperability of the record model with various applications could potentially be a challenge. Furthermore, the owner needs to be willing to allocate funding to train employees, up date and maintain the record Building As the benefits of the record model are realized, the owners will be more demanding of the record Building Information Model. An accurate record model that contains the scope of the project and the needs of the facilities department can help the owner manage and maintain the building tremendously.

vi. Site Planning and Site Utilization

Proper site planning and utilization is a critical job site management task that has significant impact on the project's overall success. With BIM, the superintendent and project manager can study the existing and proposed utilities, site access options, safety and evacuation concerns, excavation plans and shoring requirements, dewatering issues, crane placement and hoisting schemes, and choices for temporary lay-down storage areas. A number of scenarios can be tested and confirmed, and once

decisions have been made as to how to proceed, the contractor can communicate the plan to subcontractors, the owner, and even neighbors if needed. (Barbara, 2010)

2.14 BIM Tools

Regarding to the fast growth forBIM and attention for this new technology in construction industry, more software developers produce and applying their products into the prospective area in BIM.

According to(Burcin and Samara, 2010) in their report 424 construction firms in United States show that various BIM tools have already been adopted in the construction industry. Figure 3 shows the market share of various BIM tools which are used by these 424 construction firms. Autodesk BIM tools are the most widely used BIM solutions in U.S with 54% of those construction firms using them; and Graphisoft with ArchiCAD software follows with 10.7% and Bentley BIM tools with 8%. Tekla and Vico BIM tools used by 6.5% and 5.8% of the construction firms based respectively.

The other software tools such as Innovaya, Dprofiler, Vectorworks, etc. are also being utilized by a small portion of the construction firms (Burcin et al. 2010). The software tools have been used in different phases during the project lifecycle such as Preliminary Design and Feasibility Study, Shop Drawing and Fabrication, Estimating, Scheduling, and File Sharing & Collaboration. The purchase of the software package is different from regular purchases, since the buyers need to consider the capabilities of each software tool in the package. This section provides general information about BIM software packages which are widely adopted by users

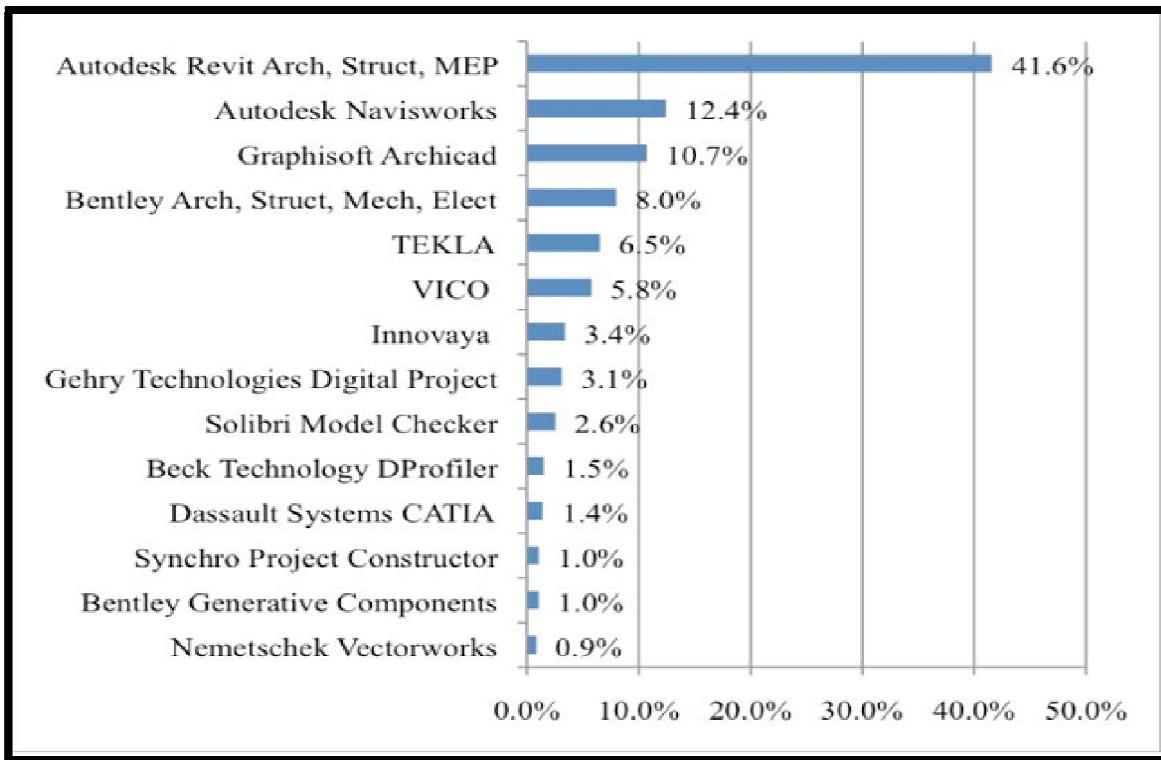


Figure 2.7: shows percentages of market share of BIM tools used by construction firms (Source: from Burcin and Samara, 2010)

There are many Tools of Building Information Modeling produced by different companies. Table below will identify these products. The following table 2.3 depicts the BIM tools and their primary functions. The list includes MEP, structural, architectural, and site work 3D modeling software. Some of this software are also capable of scheduling and cost estimation.

Table 2.3: BIM Tools (Reinhardt, 2009)

| Product Name | Manufacturer | Primary Function |
|----------------------|------------------|--|
| Cadpipe HVAC | AEC Design Group | 3D HVAC Modeling |
| Revit Architecture | Autodesk | 3D Architectural Modeling and parametric design. |
| AutoCAD Architecture | Autodesk | 3D Architectural Modeling and parametric design. |
| Revit Structure | Autodesk | 3D Structural Modeling and parametric design. |
| Revit MEP | Autodesk | 3D Detailed MEP Modeling |

| | | |
|------------------------------------|------------------------|--|
| AutoCAD MEP | Autodesk | 3D MEP Modeling |
| AutoCAD Civil 3D | Autodesk | Site Development |
| Cadpipe Commercial Pipe | AEC DesignGroup | 3D Pipe Modeling |
| DProfiler | Beck Technology | 3D conceptual modeling with real time cost estimating. |
| Bentley BIM Suite | Bentley Systems | 3D Architectural, Structural, Mechanical, Electrical, and Generative Components Modeling |
| Fastrak | CSC (UK) | 3D Structural Modeling |
| SDS/2 | Design Data | 3D Detailed Structural Modeling |
| Fabrication for AutoCAD MEP | East Coast CAD/CAM | 3D Detailed MEP Modeling |
| Digital Project | GehryTechnologies | CATIA based BIM System for Architectural, Design, Engineering, and Construction Modeling |
| Digital Project MEPSystems Routing | GehryTechnologies | MEP Design |
| ArchiCAD | Graphisoft | 3D Architectural Modeling |
| MEP Modeler | Graphisoft | 3D MEP Modeling |
| HydraCAD | Hydratec | 3D Fire Sprinkler Design and Modeling |
| AutoSPRINK VR | M.E.P. CAD | 3D Fire Sprinkler Design and Modeling |
| FireCad | Mc4 Software | Fire Piping Network Design and Modeling |
| CAD-Duct | Micro Application | 3D Detailed MEP Modeling |
| Vectorworks Designer | Nemetschek | 3D Architectural Modeling |
| Duct Designer 3D, PipeDesigner 3D | QuickPen International | 3D Detailed MEP Modeling |
| RISA | RISA Technologies | Full suite of 2D and 3D Structural Design Applications |
| Tekla Structures | Tekla | 3D Detailed Structural Modeling |
| Affinity | Trelligence | 3D Model Application for early concept design |
| VicoOffice | Vico Software | 5D Modeling which can be used to generate cost and schedule data |
| PowerCivil | Bentley Systems | Site Development |
| Site Design, Site Planning | Eagle Point | Site Development |

Various BIM construction management and scheduling tools are available as depicted in table below. Tools that support coordination are Navisworks Manage, ProjectWise, Digital Project Designer, and Vico. Furthermore, Vico, NavisworksTimeliner, Innovaya and Synchro support BIM and schedule integration.

Table 2.4: BIM Construction Management and Scheduling Tools (Reinhardt, 2009)

| Product Name | Manufacturer | BIM Use |
|--------------------------------|---------------------|---------------------------------------|
| Navisworks Manage + Scheduling | Autodesk | Clash Detection Scheduling |
| ProjectWise | Bentley | Clash Detection and Scheduling |
| Digital Project Designer | Gehry Technologies | Model Coordination |
| Visual Simulation | Innovaya | Scheduling |
| Solibri Model Checker | Solibri | Spatial Coordination |
| Synchro | Synchro Ltd. | Planning & Scheduling |
| Tekla Structures | Tekla | Structure-centric Mode |
| Vico Office | Vico Software | Coordinate ,Scheduling and Estimating |

Autodesk Navisworks Manage is well known for its clash detection feature. However, it comes with a feature called Timeliner to simulate construction schedules. Timeliner can link Microsoft Project, and Primavera project planner with various BIM (ie. Revit), CAD and Laser Scan formats. Unfortunately, Timeliner is only a unilateral information exchange platform. Similar to Autodesk Navisworks Manage, TeklaBIMsight runs clash detections. The user can combine models and add comments. This brand new product developed by Tekla is likely to be quickly adopted throughout the world since it is a free product to use and share .There are several very powerful middleware software. The two most common are Innovaya and Synchro. Both are capable of providing integration services between the common scheduling software (Primavera or Ms Project) with various types of BIM software. Vico Software Inc. provides BIM software packages geared more towards the construction management industry. Its construction software package includes Constructor, Estimator, Control and 5D presenter. Building Information Model is developed in Constructor. Quantities and

costs are estimated in Estimator. The data is imported from Constructor 3D model to Estimator. Vico's Estimator software features include processing of quantities, tracking of model revisions, addition of margins, and creation of bid packages. Location based scheduling is used via Vico's Control software. This is an approach that optimizes the productivity of works by using line of balance method. Simulations are available through the Presenter. Vico's Control software can also integrate with other scheduling software. Control has a bidirectional link to Primavera or Microsoft Project. Project schedule in Controller can be exported to Primavera or Microsoft Project and vice versa.

There are some companies are consider pioneered in producing this tools with featured functions. This research will highlight and focus in the most famous and most used one by ACE sector such Autodesk ,Graphisoft, Bentley and Tekla.

Autodesk BIM software package is the best known and most popular among BIM users, 93% of buildings stakeholders know it and 73% of them are using this package. (Burcin and Samara, 2010)

Same report stated that 54% of the respondents (contractors) are using Autodesk BIM products in their projects. First BIM product from Autodesk Company is Revit Architecture was introduced to the industry in 2002 for the architectural design purpose and was quickly adopted by most architecture firms.

After years of development, the Revit package has evolved into a product which can support multiple functions during the construction process such as Revit Architecture for architectural design, Revit MEP for electrical engineering and plumbing design and Revit Structure for structural design.

For the schedule and cost controls, Autodesk has Navisworks which allows users to simulate and manage the construction process and Autodesk Quantity Takeoff Software that supports cost estimating function. Other than these, Autodesk also developed software tools such as Autodesk 3ds Max for model visualization.

Also the company Inventor for data exchange to benefit the users from higher control level. Most of the software tools from Autodesk can support multiple file formats

which include: DGN, DWG, DWF, DXF, IFC, SAT, SKP, AVI, ODBC, gbXML, BMP, JPG, TGA, and TIF. The multiple file formats supporting function allows these software to be compatible with products from other software developers.

Graphisoft is one of the earliest companies to market BIM capabilities. Its main product ArchiCAD is marketed since 1980s and is the only object model oriented architectural CAD system running on the Apple Macintosh (Burcin and Samara, 2010). Moreover, ArchiCAD can serve both Apple Platform and Windows. One special feature of ArchiCAD is the Virtual Building Explorer, a real -time 3D navigation which is enhanced with gravity, layer control, fly-mode, egress recognition and pre-saved walkthroughs. ArchiCAD also includes a built -in analysis tool to conduct the energy analysis function on its BIM model. ArchiCAD supports a range of direct interfaces: Maxon for curved surface modeling and animation, ArchiFM™ for facility management .It also contains object libraries for users with an Open Database Connection (ODBC) interface.

MEP modeler is another key product from Graphisoft, the extension to ArchiCAD , which is used for MEP modeling pipes, fittings, ducts, and others . Graphisoft embeds large object libraries in its product. However, the software tools have some limitations in parametric modeling capabilities. As an example, automatic update to related objects is not supported.

Bentley is another company that offers products major software for architecture, engineering and construction. The architectural designing tool in BIM, Bentley Architecture, introduced in 2004, can be integrated with other software tools such as: Bentley Structural Modeler, Bentley Building Mechanical Systems, Bentley Building Electrical Systems, Bentley Facilities, Bentley Generative Components and Project Wise Navigator (Jiang, 2011).

Bentley offers a broad range of BIM software tools which are involved in almost all stages of building lifecycle. Its products can deal with almost all aspects of AEC industries such as Bridge design and engineering, Building analysis and design, Plant operations, Rail design and operations, Transportation operations, Water and Wastewater

Network analysis and design and others. Currently, Bentley products are in version V8i and according to Bentley, the "i" stands for five key new capabilities and enhancements: more intuitive conceptual modeling capabilities; interactive dynamic views; intrinsic geo-coordination capability; incredible project performance and speed; and finally, a high degree of interoperability.

Its supported file formats include: DGN, DWG, DXF, PDF, STEP, IGES, STL, and IFC. The supported file formats are not as diverse as Autodesk BIM software tools which limit the interoperability capabilities of Bentley software tools.

Tekla is a Finnish company founded in 1966 which has multiple several divisions include Building and Construction, Infrastructure and Energy. The main product of Tekla is Tekla Structures which was formerly named Xsteel in mid 1990s. The basic functionality of Tekla Structures is for structural design. It allows users to create a complete digital model that depicts the structure combined with both physical model and analytical model, and then this structural model can be used for different types of structural analyses.

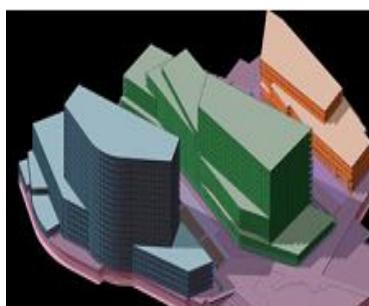
Tekla Structures is also used by detailers, fabricator and manufacturers for generating detailed information for steel, precast and rebar detailing. Tekla Structures supports interfaces with: IFC, DWG, CIS/2, DTSV, SDNF, DGN, and DXF file formats. It links with various systems through Tekla Open API (Application Programming Interface) that is implemented using Microsoft .NET technology.

Tekla Structures is capable of supporting large models, even with multiple users operating concurrently by its Multiuser Server. This Multiuser Server is developed by Tekla Corporation and can support a maximum of 40 users operating simultaneously. However, since the concurrent operation from multiple users is more complicated than a single user operation; these users need to be highly skilled to fully utilize the complex functions of this software (Jiang, 2011)

2.15 Implementation Cost of BIM

Building information model costs and savings depends on many factors. Costs are based upon the level of detail (LOD) of the model, complexities of the project and the expertise of modeling team in the technology. The level of detail (LOD) can be categorized thru system published by American Institute of Architects (AIA). LOD 100 is conceptual stage. LOD 200 is approximate geometry stage. LOD 300 is precise geometry stage. LOD 400 is fabrication stage. LOD 500 is as-built stage (Bedrick 2008). The main functions of BIM in construction management industry for visualization, 3D coordination, prefabrication, construction planning and monitoring, quantity take offs, and record model. Project savings are considerably high if the Building Information Modeling is used during the early design phase. This is mainly due to coordination efforts that yield to minimization of trade conflicts in the field. The owner, architect, and engineer can eliminate some of the coordination issues in LOD3 via BIM. Later, the subcontractor can provide more detailed shop and fabrication drawing as LOD 400. Lastly, record Building Information Model can be achieved in LOD 500 (Jiang ,2011).

The scale of LOD rises from a low detailed level to a high detailed level. Usually, several Virtual Building Models (VBMs) are represented in a design and construction process and the LOD is representative to single entities within the VBM or a smaller section of the model. LOD is suited to the parametric abilities which BIM related software has to offer and supports the progress of the programmatic task. Below four images represents and shows the capabilities and details that can be available in different level of details



*(Photo taken from Mats,
2011)*

LOD100 is equivalent to the conceptual design phase, involving whole building types of analysis in overall design purposes. It is based on building volumes and orientations. At this stage the preliminary goal is to define the overall form-expression and functionality of the design; making sure that the design holds the spatial requirements and that light and shadows are harmonic



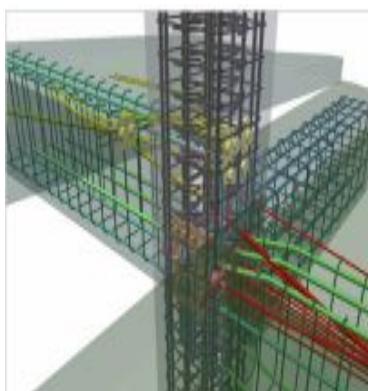
*(Photo taken from Mats,
2011)*

LOD200 is more related to the schematic design of the building. The model now contains geometry and functionality of building objects, including spaces, base, walls, decks and roof. Objects do not need to involve design specific data, but relates to more object based design purposes including modular systems, approximate quantities, size, shape, location and orientation. LOD200 also include early analysis of selected systems and design performance in terms of sustainability, technical systems, structure, cost indications etc.



*(Photo taken from Mats,
2011)*

LOD300 is a precise description of the geometry where model elements become suitable to generate traditional construction documents and shop drawings. It includes confirmed 3D object geometries, precise definitions of wall thicknesses with engineered dimensions, times scaled ordered appearances of detailed assemblies, precise quantities of materials and related aspects



*(Photo taken from Mats,
2011)*

LOD400 is the industrial level of building construction, shop and fabrication drawings for purchase, manufacturing, installation etc. This includes details of assembly, purchase prices, precise simulations based on the specific manufacturer and their detailed system components. Often this stage will be conducted by manufacturers and contractors with specific knowledge within the fields

2.15.1 Level of Details

According to Bedrick (2008), Level of Detail (LOD) of BIM models are defined as “the steps through which a BIM element can logically progress from the lowest level of conceptual approximation to the highest level of representational precision”. Five levels of detail are determined to describe the BIM models, which are named from Level 100 to Level 500: Conceptual, Approximate Geometry, Precise Geometry, Fabrication and As -built . Table below provides LOD definitions in different project phases as the project progresses, the LOD of the models will be going to a higher level and the richness of the information will also be improved. It requires the cooperation among all parties involved in the project such as architects, estimators and schedules.

Table 2.5: LOD definitions in different project phases, (2011)

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

2.16 BIM in Construction Management Industry

Construction management (CM) is process of planning, scheduling, evaluation and controlling of construction tasks or activities to accomplish specific objectives by effectively allocating and utilizing appropriate labor, material, and time resources in a manner that minimizes costs and maximizes customer or owner satisfaction as stated by (Barbra.J,2010). On other words, Construction management is wide operation combined more than one activity together in order to accomplish one objective or specific project within the three successful keys, Cost, Time, and Quality.

As argued by (Barbra.J, 2010) the function of construction management is not just a single task or activity. It comprises several tasks and is usually delivered by a construction management team. It has been widely accepted that construction management skills of the contractor is the hub of the construction process, and any activities and decisions made by contractors during the construction phase will influence the productivity and cost of the whole project. It has been reported that as much as 30% of the cost of construction is wasted in the field due to coordination errors, wasted material, labor inefficiencies and other problems in the current construction practice (Jiang 2011). One of the benefits in BIM is to limit the above inefficiencies, thus enhancing the productivity and reducing the project cost by using sophisticated tools in BIM that help to manage the construction projects such as different Revit packages that promoted by Autodesk Company and others .

2.17 Previous researches and case studies

Many researches and studies has been done in BIM to measure the tangible the benefits of BIM and also case studies conducted in developed countries where BIM has been used widely. In this research several cases has brought to explore and show the cost of BIM, acoording to Salman 2011 McGraw-Hill Construction (2008) published a comprehensive market report of BIM's use in the AEC industry in2008 and projections for 2009 based on the findings of a questionnaire survey completed by 82 architects, 101 engineers, 80 contractors, and 39 owners (total sample size of 302) in the United States. Some of the key findings are as follows:

- i. Architects were the heaviest users of BIM 43% used it on more than 60% of their projects while contractors were the lightest users, with nearly half(45%) using it on less than 15% of projects and only a quarter (23%) using it on more than 60% of projects.
- ii. Eighty-two percent of BIM users believed that BIM had a very positive impact on their company's productivity.
- iii. Seventy-nine percent of BIM users indicated that the use of BIM improved project outcomes, such as fewer requests for information (RFIs) and de-creased field coordination problems.
- iv. Sixty-six percent of those surveyed believed use of BIM increased their chances of winning projects.
- v. Two-third of users mentioned that BIM had at least a moderate impact on their external project practices.
- vi. Sixty-two percent of BIM users planned to use it on more than 30% of their projects in 2009.

The report predicted that prefabrication capabilities of BIM would be widely used to reduce costs and improve the quality of work put in place. As a whole, BIM adoption was expected to expand within firms and across the AEC industry.

Kunz and Gilligan (2007) conducted a questionnaire survey to determine the value from BIM use and factors that contribute to success. The main findings of their study are as follows:

- i. The use of BIM had significantly increased across all phases of design and construction during the past year.
- ii. BIM users represented all segments of the design and construction industry, and they operated throughout the United States.
- iii. The major application areas of BIM were construction document development, conceptual design support, and planning services.
- iv. The use of BIM lowered overall risk distributed with a similar contract structure.
- v. At the time of the survey, most companies used BIM for 3D and 4D clash detections and for planning and visualization services.
- vi. The use of BIM led to increased productivity, better engagement of project staff, and reduced contingencies.
- vii. A shortage was noted of competent building information modelers in the construction industry, and demand was expected to grow exponentially with time.

The results of these surveys indicate that the AEC industry still relies very much on traditional drawings and practices for conducting its business. At the same time, AEC professionals are realizing the power of BIM for more efficient and intelligent modeling. Most of the companies using BIM reported in strong favor of this technology. The survey findings indicate that users want a BIM application that not only leverages the powerful documentation and visualization capabilities of a CAD platform but also supports multiple design and management operations. BIM as a technology is still in its formative stage, and solutions in the market are continuing to evolve as they respond to users' specific needs. In the above-mentioned surveys, the AEC industry participants indicated that BIM use resulted in time and cost savings. However, no data were provided to quantify and support these facts. The following case studies illustrate the cost and time savings realized in developing and using a building information model for the project planning, design, preconstruction, and construction phases. All the data reported in this section were collected from the Holder Construction Company (HCC), a midsize general contracting company based in Atlanta, Georgia.

Case Study: Aquarium Hilton Garden Inn, Atlanta, Georgia the Aquarium Hilton Garden Inn project comprised a mixed-use hotel, retail shops, and a parking deck. Brief project details are as follows:

- i. Project scope: \$46 million, 484,000-square-foot hotel and parking structure
- ii. Contract type: Guaranteed maximum price
- iii. BIM scope: Design coordination, clash detection, and work sequencing
- iv. BIM cost to project: \$90,000, or 0.2% of project budget (\$40,000 paid by owner)
- v. Cost benefit: Over \$200,000 attributed to elimination of clashes
- vi. Schedule benefit: 1,143 hours saved.

Although the project had not been initially designed using BIM technology; beginning in the design development phase, the GC led the project team to develop architectural; structural; and mechanical, electrical, and plumbing models of the proposed facility. These models were created using detail-level information from subcontractors based on drawings from the designers. After the initial visualization uses, the GC began to use these models for clash detection analysis. This BIM application enabled the GC to identify potential collisions or clashes between various structural and mechanical systems. During the design development phase, 55 clashes were identified, which resulted in a cost avoidance of \$124,500. Just this stage alone yielded a net savings of \$34,500 based on the original building information model development cost of \$90,000. At the construction documents phase, the model was

updated and resolved collisions were tracked. Each critical clash was shared with the design team via the model viewer and a numbered collision log with a record of individual images of each collision per the architectural or structural discipline. The collision cost savings values were based on estimates for making design changes or field modifications had the collision not been detected earlier.

More than 590 clashes were detected before actual construction began. The overall cost savings based on the 590 collisions detected throughout the project was estimated at \$801,565. For calculating net cost savings, a conservative approach was adopted by assuming that 75% of the identified collisions can be detected through conventional practices (e.g., sequential composite overlay process using light tables) before actual construction begins. Thus, the net adjusted cost savings was roughly considered to be \$200,392. During the construction phase, subcontractors also made use of these models for various installations. Finally, the GC's commitment to updating the model to reflect as-built conditions provided the owner a digital 3D model of the building and its various systems to help aid operation and maintenance procedures down the road. Aquarium Hilton Garden realized some excellent benefits through the use of BIM technology and certainly exceeded the expectations of the owner and other project team members. The cost benefits to the owner were significant, and the unknown costs that were avoided through collaboration, visualization, understanding, and identification of conflicts early were in addition to the reported savings. After this project, the architect and GC began to use BIM technology on all major projects, and the owner used the developed building information model for sales and marketing presentations (Azhar and Richter 2009).

For this study, detailed cost data from 10 projects were acquired from Courtesy of Holder Construction Company, Atlanta, GA (HCC) to show BIM cost and BIM saving if were used in Project. The results are shown in Table 2.3. In some projects, BIM savings were measured using real construction phase, direct collision detection and cost avoidance, and in other projects, savings were computed using planning or value analysis phase cost avoidance.

| Year | Cost (\$M) | Project | BIM Scope | BIM Cost | BIM Saving(\$) | Net BIM Saving (\$) |
|------|------------|-------------------------|--------------|----------|----------------|---------------------|
| 2005 | 30 | Ashley Overlook | P/PC/CD | 5,000 | 135,000 | 130,000 |
| 2006 | 54 | Progressive Data Center | F/CD/FM | 120,000 | 395,000 | 232,000 |
| 2006 | 47 | Raleigh Marriott | P/PC/VA | 4,288 | 500,000 | 495,712 |
| 2006 | 16 | GSU Library | P/PC/CD | 10,000 | 74,120 | 64,120 |
| 2006 | 88 | Mansion on Peachtree | P/CD | 1,440 | 15,000 | 6,850 |
| 2007 | 47 | Aquarium Hilton | F/D/PC/CD | 90,000 | 800,000 | 710,000 |
| 2007 | 58 | 1515 Wynkoop | P/D/VA | 3,800 | 200,000 | 196,200 |
| 2007 | 82 | HP Data Center | F/D/CD | 20,000 | 67,500 | 47,500 |
| 2007 | 14 | Savannah State | F/D/PC/VA/CD | 5,000 | 2,000,000 | 1,995,000 |
| 2007 | 32 | NAUSciences Lab | P/CD | 1,000 | 330,000 | 329,000 |

Table 2.6 Building Information Modeling BIM Cost (Source: Holder Construction Company, Atlanta, GA, 2011).

Note: CD = construction documentation; D = design; F = feasibility analysis; FM = facilities management; P = planning; PC = preconstruction services; and; VA = value analysis

Chapter 3: Research Methodology

1.1 Introduction

Aim of this thesis is to investigate the challenges and potential use of BIM in the AEC industry and how it can improve productivity and profitability for construction firms after implementing BIM in their operations. BIM It is a computer model that fulfills the needs of all parties involved in the AEC industry, offering CAD services, cost calculations, energy simulations, building code checking, life cycle analysis, and it is formatted to be interoperable with other programs that are specific to the AEC industry. Productivity improvements and challenges, barriers and benefits related to BIM for the construction industry were discussed in chapter two from literature review such as articles, journals, book, and theses to understand effect of Building Information Modeling ACE Sector. History of BIM was researched to determine the purpose of the program and the limitations that it may have. Objective of this thesis is to study both negative and positive effects of BIM and limitations/complications with implementing a BIM program in the construction industry in Sudan. With knowledge of the program and how it works; the benefits of how BIM can increase productivity in the construction industry. With this objective, interviews were conducted with local and international large and small construction companies, to determine the possibility of implementing BIM into their daily operations. Their perspectives will also be attained about using BIM on projects, it benefits to productivity and its disadvantages. Scope of this thesis involves doing research on what Building Information Modeling actually is, based on its core components. Research on BIM will make the benefits and limitations more readily understood. More importantly, how BIM can influence the construction industry. How BIM is being used in the AEC industry is revealing difficulties that have to be addressed. Limitations are encountered because historical data is not readily available due to the lack of recordkeeping. This software is still in its infancy, and although most experts consider BIM to be the future of the construction industry, the change over by architects and engineers is very slow. In the construction industry, BIM is more widely accepted because of the ways that it links with currently used scheduling and estimating software.

3.2 Conducting Questionnaire for Construction Practitioners

The questionnaire was developed through a review of literature on BIM. These questions reflected the concerns highlighted in the literature review in chapter two and the questionnaire derived out from the objectives of this thesis. Questionnaire will circulate to the industry representatives and participants from construction industry.

The questionnaire comprise of 13 questions, which were developed to evaluate the participants point of view and understand how the construction industry sees BIM for future. There questions mainly are seeking to collect information about five parts which are:

1. background of participant and their organization
2. To recognize the understanding of BIM,
3. Barriers and challenges to BIM use,
4. BIM services offered,
5. future estimates for BIM use and implementation

Data obtained from the questionnaire will be analyzed graphically and the results and conclusion will presents in chapter four and five respectively

3.3 Sample Size and questionnaire distribution

The questionnaire will distribute to consultancy firms and the size of sample will be determined from equation 4.1 in order to find out the number of the consultant offices that will participate in this study. According to the Organizing Council for Consultancy Firms, there are 208 consultant offices, size of sample was in this study are 53 firms. Kish reprobated that to achieve 94% confidence the following equation can be used

$$n= n'/ [1+(n'/N)]$$

Equation 4.1

Where:

- N = total number of population
- n= sample size from finite population
- $n' = \text{sample size from infinite population} = S^2/V^2$; where S^2 is the variance of the population elements and V is a standard error of sampling population. (Usually $S = 0.5$ and $V = 0.06$)

The questionnaire was developed with information derived from objectives, research, and literature reviews. A first stage of questionnaire was distributed in area of center of Khartoum where number of firms are there, in the date between July 14, 2014 to July 24. The second Stage of distributions was short and it was between 3, August 2014 to 7 August 2014. A total of 70 questionnaires were distributed in 53 firms. Some firms received more than one questionnaire due the large number of qualified respondents found in the organization. Additional questionnaire has distributed in order to obtain more information from more than one respondents in each organization, this producers conducted randomly only on large organization, finally 68 respondents where completed and considered while 2 respondents were rejected.

The questionnaire is broken down into four main areas with a total of 13 questions. The first section focused on general questions related to the type of firm, personal experiences and position of respondents in their organization. The second section focused on recognizing and definition of BIM and how respondents understand the term of BIM .Sections three and about software used in construction industry and their functions. Fourth section concentrated on barriers and challenges of BIM.

Chapter 4: Result and Discussion

4.1 Questionnaire Findings

4.1.1 Respondent Profiles

The number of questionnaires distributed are 70, in 53 firms according to the formula mentioned in chapter 3, and 68 questionnaires were collected and two questionnaire are rejected by researcher as the information provided was inaccurate, table 4.1 shows general information about questionnaire distribution.

Table 4.1: Shows percentage of respondents

| Respondents Position | Senior manager / Director | Civil Engineer | Architect | Project Manager | Other | Total |
|-----------------------|---------------------------|----------------|-----------|-----------------|-------|-------|
| Number of Respondents | 11 | 13 | 24 | 16 | 4 | 68 |
| Percentage | 16% | 19% | 35% | 24% | 6% | 100% |

Figure 4.1 categorizes the total respondents by discipline; from the figure 4.1 can be shown that most of the respondents are architects followed by project manager's .This could be attributed to the high number of architects hired by consultancy firms as they needed for most of architectural design purpose.

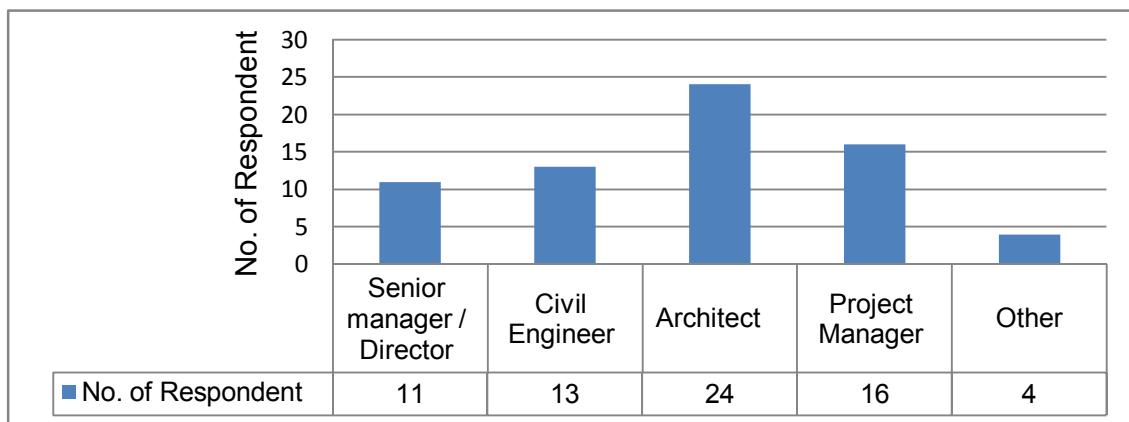


Figure 4.1: Shows the Respondents profile

4.1.2 Personal Experience of the Respondents

As shown in Figure 4.2, respondents reflect a broad variation in their number of year of experience. While 28 people have more than 20 years of experience in the industry, 16 people have experience less than 5 years and they are consider as graduates. And 15 respondents have experience between 11 to 20 years, On the other hand, there nine respondents who has experience between 6 and 10 years. This means that the overall questionnaire results are dominated by the people who have substantial experience and understanding about the development and progress of the construction industry over the last two decades.

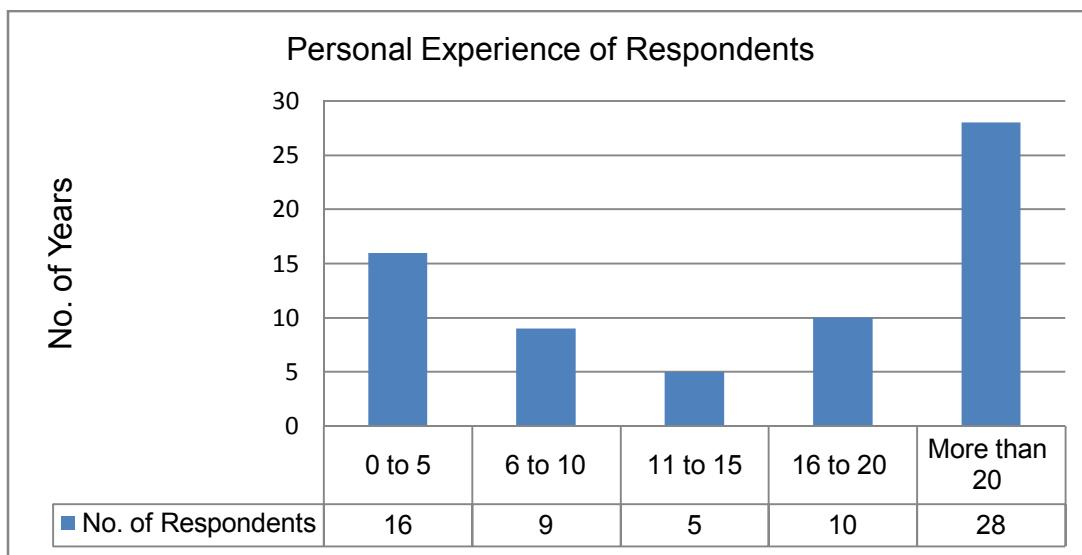


Figure 4.2: Shows the personal years of respondents

4.1.3 Understanding of BIM in Construction industry

Responses to the question about whether their organization use BIM or not, a direct questions has been formulated in this questionnaire to investigate about respondents understanding for concept of BIM and supported with another question to identify the most appropriate definition for BIM to make sure that the respondents had the enough understanding about BIM and rely on their provided response, those questions allowed the researcher to find out which response can be consider or reject.

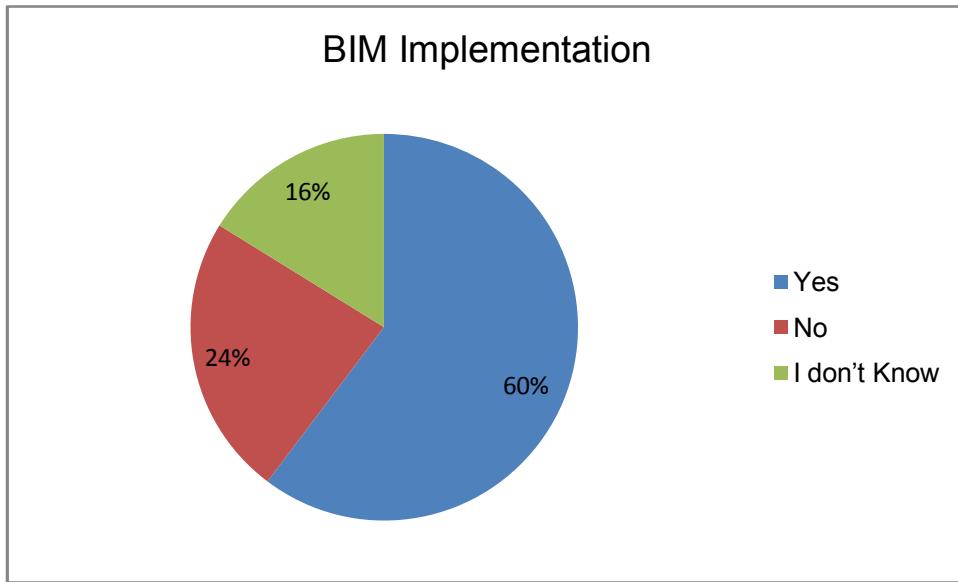


Figure 4.3: shows the response implementing BIM `

Around 60% of the respondents Indicated that BIM is used in their organization, while 16% and 24% of the respondents showed negative answer on using BIM on their organization as showed in figure 4.3. On other word, 40% of the respondents they are not familiar with BIM. Another question has been added for this purpose to examine the reliability of the answer provided by 60% of the respondents; the question objective was to investigate how those 60% of respondents identifies the term of BIM.

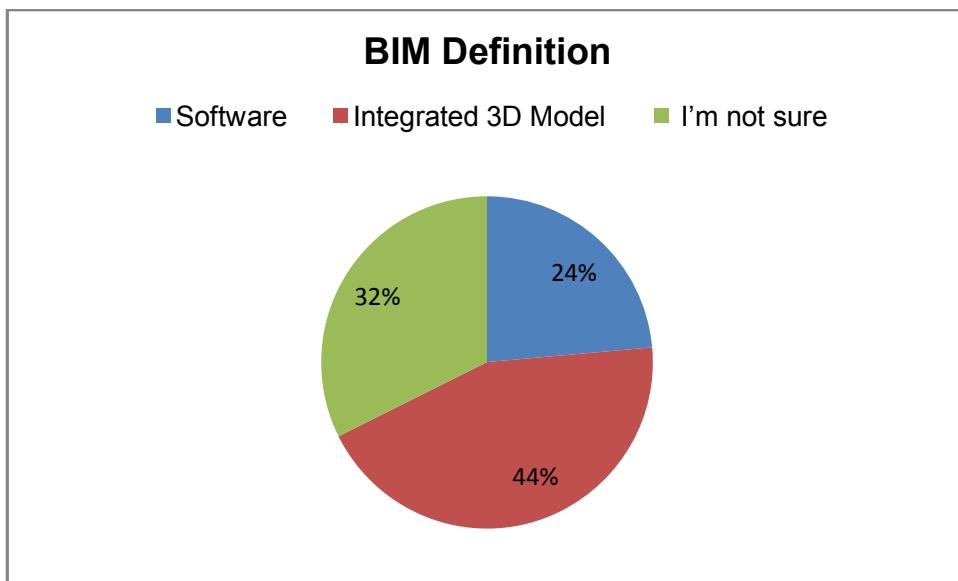


Figure 4.4: the percentage of respondents who defined BIM Concept

Figure 4.4 shows the result from the question has been asked to respondents to identify the correct definition for BIM. As shown from chart above, 44% of the respondents answered that BIM is integrated 3D Model which is the most suitable answer, it can be noticed that the percentage of respondents has mentioned that their organization using BIM has reduced from 60% to 44% according to the question asked about the definition of BIM, this reduction indicate that only 44% of respondent are familiar with BIM according to the answer provided in second question about BIM definition. According to the result shown above in figure 4.3 and 4.4 can be summarized that an acceptable percentage of the respondents have enough knowledge to start implement BIM in construction industry. BIM Definition

4.1.4 Existing Software used in Construction Industry

Today, there are numerous of BIM authoring and analysis tools available to the building industry. Generally any software can present the building in 3D modeling can be categorized under the family of BIM as well as any tools that help to create 4D and 5D model from the 3D model. On other word, BIM has many tools and software has been used widely in construction industry. In order to implement the BIM in construction industry and make it techniques that enhance the construction industry by increasing the productivity and reduce cost, BIM needs to be used with all the features and capabilities available. For example integrated model must include all the demission such as 3D, 4D, and 5D to achieve the maximum advantages of using BIM in construction management. In this study three questions has been asked to find out the existing software that use in construction industry regarding to (architectural, structural, project management).

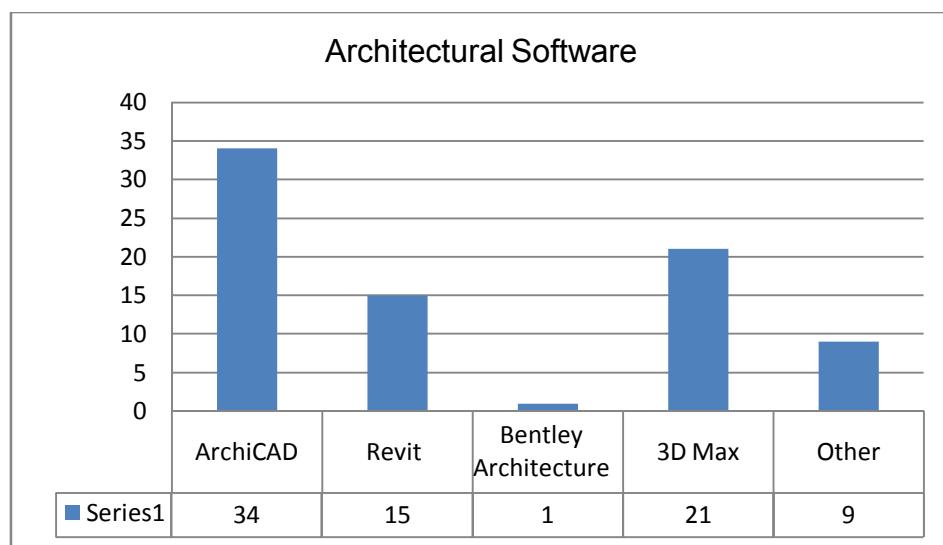


Figure 4.5: Different type of architectural Software used by respondents

figure 4.5 shows the response that obtained from the questionnaire indicates the construction industry use ArchiCAD and 3D Max the most preferred software and also the result shows that there adoption for Revit in construction industry, also the respondents reported that some other tools is also used based on the survey results. On other word, the result shows increment on the Revit which is considering one of the most used software in BIM.

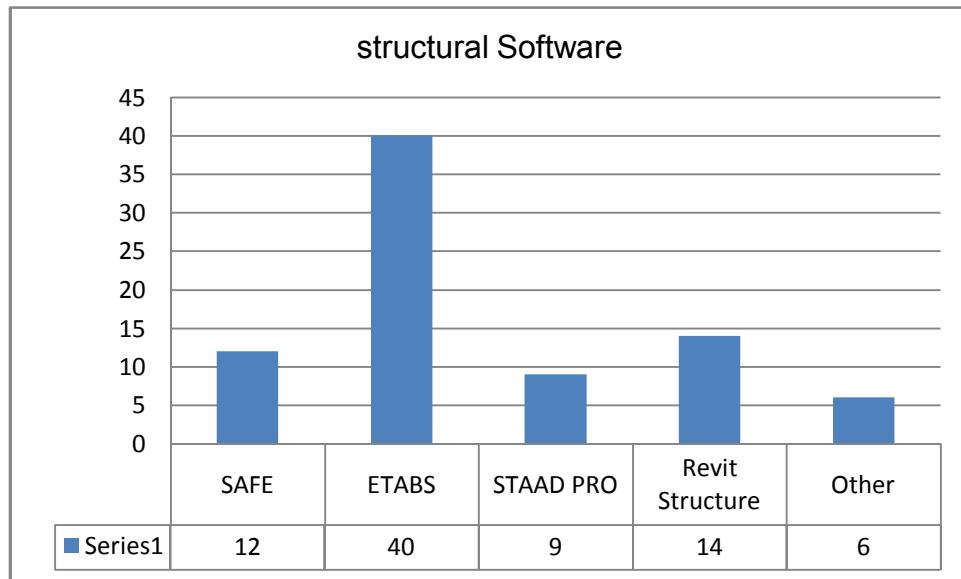


Figure 4.6: Different type of Structural Software used by respondents

Regarding to the software used in civil structure design, the study shows that construction industry biased to the ETABS as most used software for structure design followed by SAFE then Revit structure for shop drawing tools based on its capabilities on provide more detailed on the structures components. The result shows some resistant to shit for BIM tools and that attributed to the accuracy provided by ETABS and SAFE for structure analysis and design for Building as is showed in figure 4.6

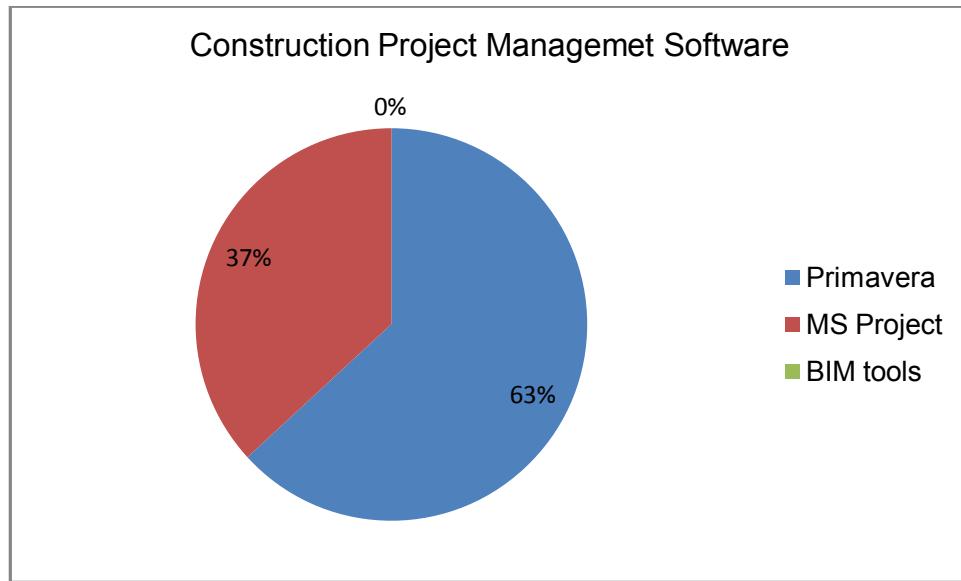


Figure 4.7: Different type of Construction Project Software used by respondents

Based on the result from this study regarding to the project management tools, 63% of the respondents mentioned that Primavera is used and MS project followed by 37% which is consider perfect result as those software is the first steps for 4D modeling. Generally, the steps involves importing the existing 3D BIM model into the BIM software tool, importing the schedule created by another scheduling software tool such as Primavera and Microsoft Project and then linking the schedule with its relevant objects in the BIM model, which mean the imported schedule will be linked to the objects of the building model information. On other word, the construction industry showed great result as by using this tools (Primavira and MS project) and that's the first steps for creating 4D model. The following illustration in figure 4.8 explains how 4D model can be created.

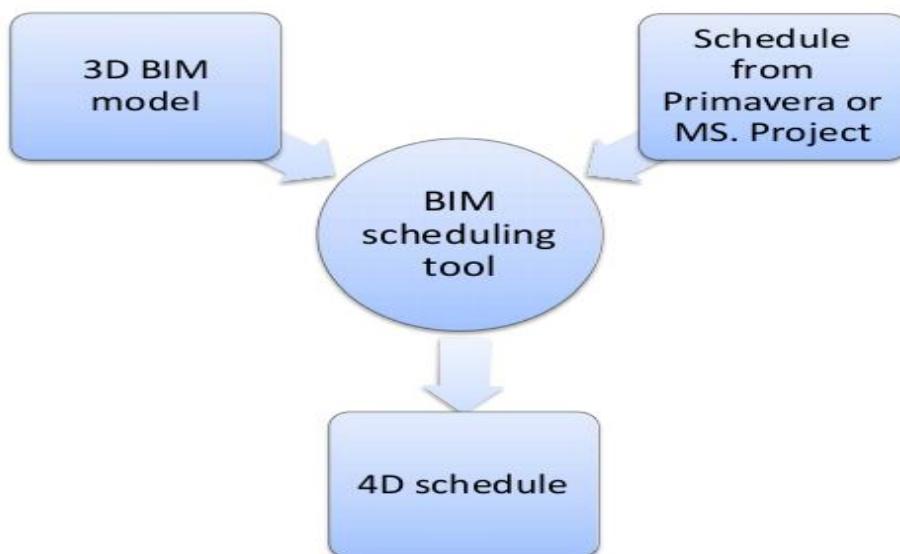


Figure 4.8 shows how to create 4D model

Also in this research respondents were asked which tasks they used BIM for in their organization. Visualization (rendering, 3D presentations, model, etc.), and building design and other architectural purpose were the top three tasks BIM is used for, with roughly equal rates of use. Architecture firms use BIM heavily for design - related functions such as building design, visualization. Others BIM use areas such as clash detection, visualization, and cost estimating and automated quantity take off, construction site management and analysis of building performance are related to contractor work which is not considered in this questionnaire because only consultancy firms are involved in this research as shows in figure 4.9.

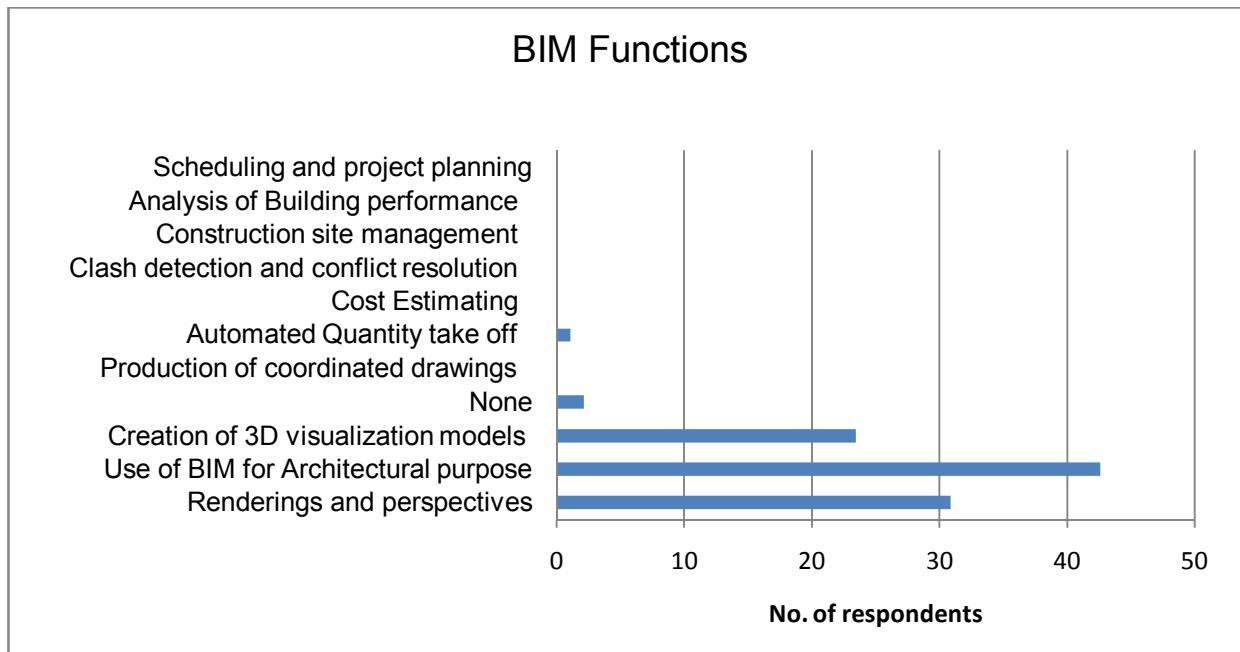


Figure 4.9 BIM Function

4.2 Adoption of BIM

Figure 4.10 below represents the result from question has been asked to respondents when their organization are looking to implement BIM, from the result 62% of the respondents indicated that they are considering BIM for near future, while 15 % of them stated that they are in early stage of BIM implementation. On other word, 77% of respondents are willing to shift for BIM, meanwhile 23% of the respondents are not interested in BIM, this resistant in changing or considering BIM maybe attributed to many reasons such lack of knowledge about BIM benefits or cost of implementing it or BIM still is a

new technology to many users. These results might be a representation of where the construction industry stands in terms of BIM implementation.

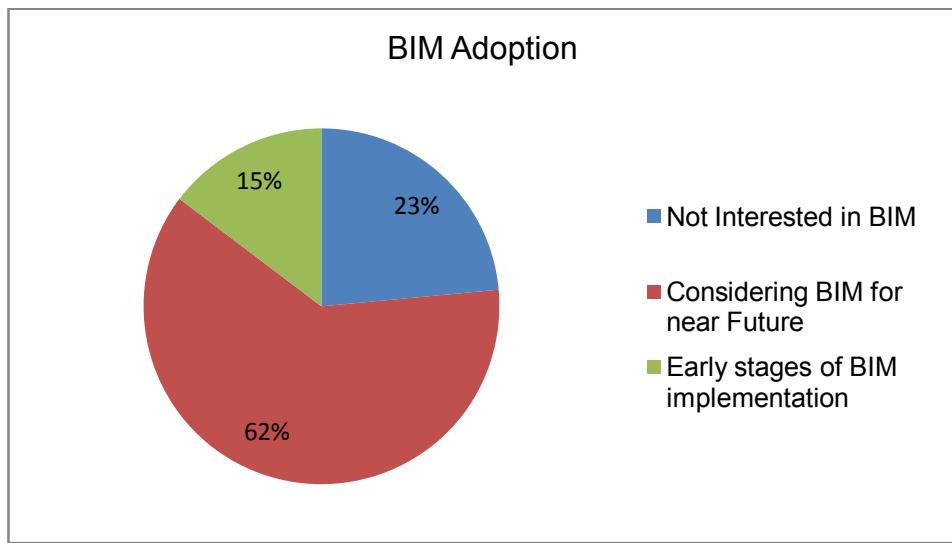


Figure 4.10: shows the percentage of the respondents' adoption for BIM

Additionally, another question formulated in this questionnaire to support the answer above whether the organizations are really interested in BIM also to give those who are not currently implementing BIM to participate and provide their comment on whether they are planning to adopt it or not. The result shows in figure 4.11 below indicates that 97% are planning to adopt it while only 3% are refusing to adopt.

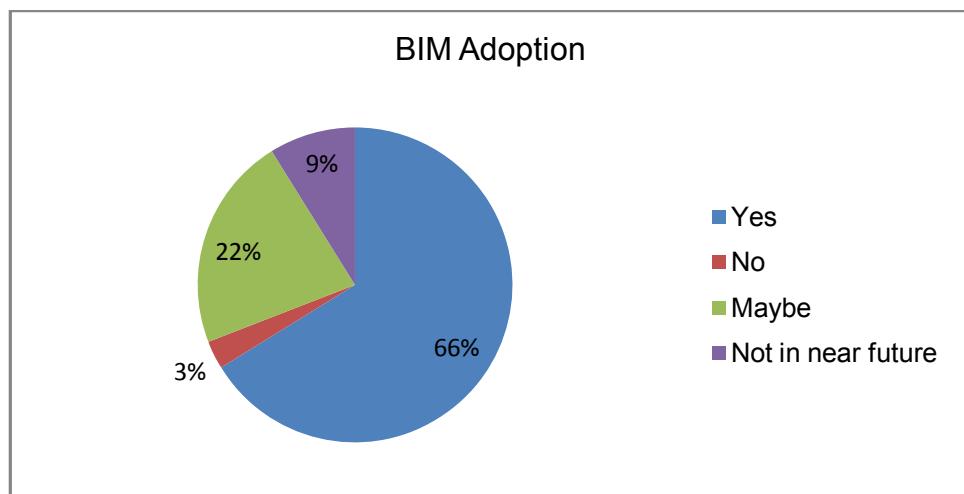


Figure 4.11 the percentage of respondents who are planning use BIM

4.3 Obstacles of BIM

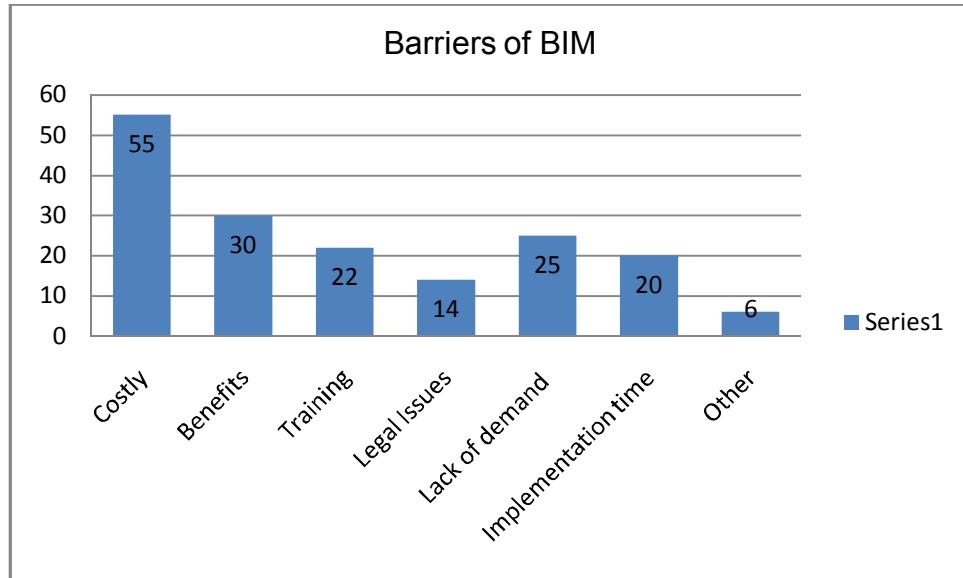


Figure 4.12: the barriers of Implementing BIM

From the survey results, it is understood that primary reasons and barriers for not to fully implement BIM and adopt it in construction industry are those , costly, benefits, lack of demand , lack of training ,implementation time, legal issues, and other , those reasons ranked based on the respondents answer , on other word , from the result can be summarized that firms are not ready yet to fully shift to BIM or not familiar enough with BIM use also they are reluctance to initiate new workflows in their organization or train staff on BIM and may consider that Benefits from BIM implementation do not outweigh the costs to implement it

4.4 Challenges of BIM

It is promising that respondents stated that they are planning to adopt BIM. But when organization decide to do that, some challenges will face the BIM implementation and must be consider to implement BIM successfully. Hence this questionnaire asked the respondents about the factors that can encourage the BIM implementation. Figure 4.13 shows that ongoing training courses on BIM will help to increase uses of BIM which is count as promising factor that indicates the willingness of construction industry to adopt a new technology such as BIM if the enough and professional training provided.

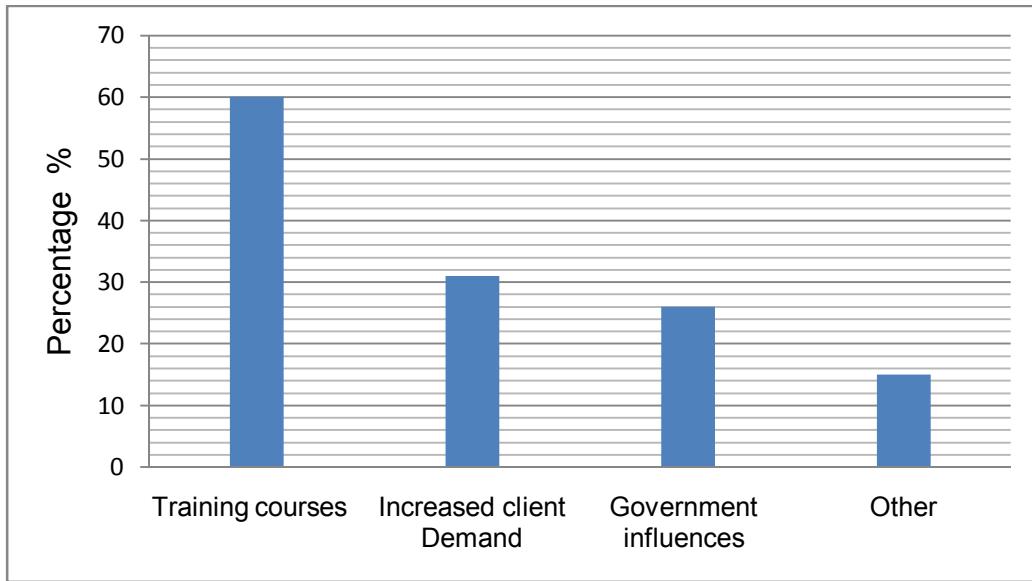


Figure 4.13: reasons that encourage on BIM uses

Finally it can be concluded from this result, construction industry needs to put a roadmap as first step on Implementation of BIM such as Training staff on new process and workflow, training staff on new software and technology, effectively implementing the new process and workflow, establishing the new process, workflow, understanding BIM enough to implement it, Realizing the value from a financial perspective and Purchasing software.

Chapter 5: Conclusion and Recommendation

5.1 Introduction

BIM is most technological method to digital design and construction. It is a model based dynamically linked to database of project information for coordination that has a real time. BIM change the way projects are built and how project stakeholders communicate with each other through the unlimited transfer of information between the project stakeholders, Architects, Engineers and all construction personnel.

BIM is designed to be as a hub and mediating program between the specific programs used by architects, engineers, contractors and suppliers and venders. It moves towards a completely universal and interoperable program working with computer based models in 3D, 4D and 5D. The 3D capabilities of the program will visually solve any questions about material and spatial relationships. This makes conflict resolution easier to detect as well. Engineers can design their respective systems (i.e. plumbing, HVAC and fire sprinkler) and coordinate with each other. Once the model is composed, models can then be created in 4D so contractor s can both visualize construction before it actually takes place, and predict the best locations for construction equipment and lay down areas. Progress can also be monitored to ensure that productivity levels are being maintained.

Future of BIM in the construction industry will be just as important as traditional computer aided drafting (CAD) programs. It will require many years to fully adopt, once it's done, productivity will begin to improve, and through continuing education, more opportunities for improvement will begin to reveal themselves. Perhaps the most important issue to remember BIM can only be helpful if used with knowledge and trained engineers.

5.2 Conclusions

The research studied the various objectives; advantages of BIM and how organization uses BIM and obstacles face the BIM implementation. This research focused on the use of BIM mainly in construction industry and found out the barriers that could slow the adoption. Studies and researches from literature review (Journals, articles, books, paper, conferences and theses) and questionnaire survey showed the benefits as well as the challenges of BIM. The research concludes that the use of BIM will be an advantage for construction industry and will present tremendous benefits for construction firms. The major advantages for BIM implementation in quick and accurate visualization, better construction planning and monitoring and conflict resolution, scheduling and quantities takeoff and led to improve profitability, better time management and improved customer client relationships.

Successful implementation of BIM will allow project stakeholders to re-engineer and streamline their processes to take full advantage of BIM and is helping to make the fabrication of increasingly complex building assemblies and subassemblies economically and technologically feasible. BIM represents a new paradigm within AEC sector. On the other word, BIM can improve productivity and reduce cost if the project team decided to use integrated Model that use 3D, 4D, and 5D. Early involvement of all the project participants in BIM is extremely important for a successful collaborative process.

The way the BIM movement is progressing, it is not very far that BIM will replace CAD systems. As the market continues to adopt BIM as a standard, BIM will continue to take over instead the traditional CAD. The advances in technology such as Smartphone and tablet technologies will allow users to instantly use BIM models for communications and quick decisionmaking on site. Other great advantages can't be denied from BIM is sixth Dimension (6D) which is facility management that allow project owners and facility managers to operate efficiently their buildings , this features didn't studied in this research deeply due the lack of information provided in construction industry and researches centers. Professionals bodies and experts still conducting researches in 6D because they believes that feature might be expensive to consider because the project team needs to use high level of details(LOD500) which is consider very expensive for small projects.

The respond and feedback collected from the questionnaire indicated that BIM is started to be implemented and the concept being used but in small range as most of responded stated that BIM needs some times to be fully implemented and use. On other hand, result derived out from the questionnaire showed that companies start shifting and adopt more professional software such Rivet architectural as they mentioned that the features for this software is much greater than other software has been used already in the construction industry. Questionnaire also showed that some resistant in shifting from existing structural software to adopt new one due the accuracy that they examined from the existing one such as ETABS , SAFE , STADDPRO ,SAP2000 and detailing using AUTOCAD. Some respondents mentioned complete shifting to BIM maybe adopted if ongoing training and workshops and seminars and professional courses has been conduct to raise the awareness and knowledge of BIM. In construction project management, questionnaire showed that Primavira and MS project taking the lead in managing construction projects and other techniques related to BIM may use in near future if enough training provided to engineers

5.3 Recommendation

While this questionnaire represents a first step towards understanding and benchmarking the realized value associated with the use and implementation of BIM, there are several avenues that should be pursued further. Some were not addressed in the questionnaire at all, for example, the costs associated with BIM, these benefits would be better examined in detailed case studies and another questionnaire with extensive interviews. Additionally, some objectives maybe studied in further research, for example, which types of projects would be better to design , planning construct and manage using BIM and which one is more profitable and why? What other costs are being reduced to see the overall reduction in projects costs? In addition, it would be worthwhile to distribute the questionnaire internationally to analyze use and value of BIM for different world regions. Finally, questionnaire, researches and survey should be conducted at future points in time to observes the changing in construction industry weather is accepting the BIM or not and measure the performance and level of adoption to help and facilities the implementation.

Moreover, some points noted by several respondents and commented that is too early to adopt the BIM to replace the traditional process, as the industry is still at its early stages of changes as they believed that intensive training and practice maybe needed before the full adoption. Many firms are still working on initial deployment of BIM, and even though there is some efficiency achieved such as consistency, accuracy, there are still huge and steep learning curves. Many believe that as BIM use is still limited, the true value of BIM has yet to be achieved.

5.3.1 Recommendation for further Researches

For future research on BIM and how to increase productivity and reduce cost in the construction industry, a set rules and standards have to be adopted, that will help to shift from CAD to BIM. Once this takes place, case studies, experiences and historical data will become more readily available, and surveys can be conducted to compare the traditional method of construction against the BIM methodology. This kind of information will be essential in figuring out the challenges face the implementation of BIM. Future research needs to be done on various programs that are essential to the

AEC industry to see how well BIM can be integrated compatible with other software. Surveys should be conducted to determine how well BIM is improving productivity, and how productivity levels compare against other industries. This will become more readily available once more historical data is gathered from construction and design firms that have implemented the program.

5.3.2 Vision and Recommendation for BIM Implementation in Sudan

From the questionnaire result; some points can be recommended to improve BIM Implementation in construction industry such as consultancy and support from professional bodies related to construction industry by conducting ongoing training for successful BIM adoption. On other word, firms involved in construction industry need to be enlightened about BIM benefits and encourage them to adopt it to achieve a good return on the company's investment.

Therefore, Education and Training are considered vital factor and plays important part of BIM implementation due to the process and technological changes within the organization. In order for the implementation to be successful, all users required to be skilled and those who are in specific positions may require gaining certain standards of education and training. Moreover Professional Certifications maybe needed for the concept of " BIM Implementation map" in order to achieve successful plan towards full adoption of BIM and those who could complete such certification program will engage and administer organizational process and technological changes that are initiated through BIM implementation appropriately. Therefore a growing need for such educational program needs to be hosted by academic organizations on BIM to provide graduates with the basic concept to make them ready for full implementation. Finally some points can be concluded and highlighted in order to adopt and implement BIM such as:

1. Clear understanding of benefits that outweigh the cost and other factors
2. Required training and know-how transfer to their firm and staff
3. Attending workshops to discuss BIM uptake and further info
4. Recommendation of a way forward with regards to software and hardware
5. Research centers and educational institution need to conduct more researches on BIM.
6. New rules and regulation need to be issued by related bodies and agencies to encourage to adopt BIM

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Appendices

بسم الله الرحمن الرحيم



جامعة السودان للعلوم والتكنولوجيا

كلية الدراسات العليا – كلية الهندسة – قسم الهندسة المدنية

برنامج الماجستير بالمقررات و البحث التكميلي

ماجستير ادارة تشييد

M.Sc in Construction Management

الموضوع : استبيان

عنوان : نمذجة معلومات المباني في ادارة التشييد ، دراسة تأثيرات و معوقات تنفيذها في صناعة التشييد

الطالب : منذر خالد قسم الخالق

المشرف: د. عوض سعد حسن

يهدف هذا الاستبيان للتعرف على فوائد و تأثيرات تطبيق بما يعرف تقنية نمذجة المعلومات على صناعة التشييد و مدي انعكاسها على ادارة المشروعات , كما يهدف ايضا للطرق على مشاكل و معوقات تطبيقها ان وجدت و ما هي السبل التي تؤدي الي تسهيل تطبيق تلك التقنية .

تعرف نمذجة معلومات المبني على انها التمثيل الرقمي للمبني في شكل ثلاثي الابعاد مع وجود كل الخصائص الفيزيائية و الوظيفية للمبني في مع امكانية دمج و ربط بيانات التصميم و التخطيط و التشييد في مجسم واحد, مثل (المدة الزمنية و التكلفة و الكميات و المواد او ما يعرف بالبعد الرابع و الخامس...)

Name (Optional) :.....

Contact details (Optional):.....

1. What is the best description for your organization??

| | |
|---------------------------------------|---|
| <input type="checkbox"/> Consultancy | <input type="checkbox"/> Contractor |
| <input type="checkbox"/> Architecture | <input type="checkbox"/> Project management |

2. What is best describes your position?

| | |
|--|--|
| <input type="checkbox"/> Senior manager / Director | <input type="checkbox"/> Civil Engineer |
| <input type="checkbox"/> Architect | <input type="checkbox"/> Owner /Client |
| <input type="checkbox"/> Other..... | <input type="checkbox"/> Project Manager |

3. How many years of experience do you have?

| | |
|---|--|
| <input type="checkbox"/> 0 – 5 Years | <input type="checkbox"/> 6- 10 Years |
| <input type="checkbox"/> 11 – 15 Years | <input type="checkbox"/> 16 – 20 Years |
| <input type="checkbox"/> More than 20 Years | |

4. Does your organization use Building Information modeling (BIM)?

| |
|---------------------------------------|
| <input type="checkbox"/> Yes |
| <input type="checkbox"/> NO |
| <input type="checkbox"/> I don't know |

5. In your opinion, what is the best description for the concept of “Building Information Modeling (BIM) “?

| |
|---|
| <input type="checkbox"/> Software |
| <input type="checkbox"/> Integraded3D Model |
| <input type="checkbox"/> I'm not sure |

6. What software are you using for Architectural Design? (Check all that apply)

| | |
|---|-------------------------------------|
| <input type="checkbox"/> ArchiCAD | <input type="checkbox"/> Revit |
| <input type="checkbox"/> Bentley Architecture | <input type="checkbox"/> Other..... |

7. What software are you using for Structural Design? (Check all that apply)

| | |
|------------------------------------|--|
| <input type="checkbox"/> SAFE | <input type="checkbox"/> Revit Structure |
| <input type="checkbox"/> ETABS | <input type="checkbox"/> Other..... |
| <input type="checkbox"/> STAAD PRO | |

8. What software are you using for Construction Projects Management?

| | |
|-------------------------------------|--|
| <input type="checkbox"/> Primavera | <input type="checkbox"/> 4D and 5D Model |
| <input type="checkbox"/> MS Project | <input type="checkbox"/> Other..... |

9 Which of the following functions do you use BIM technology in your organization?

| | |
|--|--|
| <input type="checkbox"/> Use of BIM for marketing purposes | <input type="checkbox"/> Clash detection and conflict resolution |
| <input type="checkbox"/> Production of coordinated drawings | <input type="checkbox"/> Construction site management |
| <input type="checkbox"/> Creation of 3D visualization models | <input type="checkbox"/> Analysis of Building performance |
| <input type="checkbox"/> Automated Quantity take off | <input type="checkbox"/> Scheduling and project planning |
| <input type="checkbox"/> Cost Estimating | <input type="checkbox"/> Renderings and perspectives |

10. When is your company looking to implement BIM?

- Not Interested in BIM
- Considering BIM for near Future
- Early stages of BIM implementation

11. What are the barriers to implementing BIM?

| | |
|---------------------------------------|--|
| <input type="checkbox"/> Cost. | <input type="checkbox"/> Lack of demand |
| <input type="checkbox"/> Benefits | <input type="checkbox"/> Implementation time |
| <input type="checkbox"/> Training | <input type="checkbox"/> Other..... |
| <input type="checkbox"/> Legal Issues | |

12. What measures can be taken to encourage BIM implementation?

| | |
|--|-------------------------------------|
| <input type="checkbox"/> Training courses | <input type="checkbox"/> Other..... |
| <input type="checkbox"/> Increased client Demand | |
| <input type="checkbox"/> Government influences | ... |

13. Are you planning to adopt BIM?

- Yes
- NO
- Maybe