Damascus University
Faculty of Civil Engineering
Department of Engineering Management and Construction

Utilization of Building Information Modeling in Construction Project Planning

BY

Modar Saad

Supervised By

DR. Shukri Baba

A THESIS SUBMITTED TO
DEPARTMENT OF ENGINEERING MANAGEMENT AND CONSTRUCTION
FACULTY OF CIVIL ENGINEERING
(DAMASCUS UNIVERSITY)

FOR
THE DEGREE OF MASTER OF SCIENCE
IN
MANAGEMENT OF IT IN CONSTRUCTION

DAMASCUS 2014

Abstract

Construction Project Planning, as one of the key processes in project lifecycle, shapes the empirical foundation of the project success and plays a primary role in optimizing and managing construction development. The traditional techniques and resources in the current construction planning practice still face several limitations and challenges. Most of construction projects are still planned based on the cumulative and personal experiences of planners or managers. Therefore there is an important need to enhance the traditional construction planning approach in order to improve the project performance and minimize the overrun costs and delays.

Building Information Modeling BIM provides a digital representation of physical and functional characteristics of the building model and serves as a shared knowledge source for information about the building. 4D Building Information Modeling, the addition of time to the 3D model environment, was being developed as a virtual construction tool.

This thesis aims to review the traditional planning process and technique in order to address the different limitations and challenges that facing the current construction planning practice. Then, the impacts of utilizing the 4D building information modeling technology are discussed.

The study concluded 4D building information modeling as a promising tool for construction planning. The most significant determined benefits of this technology are improving the construction works visualization, producing reliable construction documents and achieving accurate construction plans.

Acknowledgment

This thesis would not have been achieved without the help, support and patience of my supervisors, Dr. Shukri Baba, who was beside me whenever I needed his instruction, which makes me extremely grateful.

I am deeply thankful for all the people who trust in me, who supported me verbally or by action.

Finally I will proud to dedicate this work to my family; My Father Abdeen Saad, My Mother Jamila Altal, My Sister Reem Saad and My Brother Moayad Saad.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

Chapter 1 Introduction

The background and the motivation of this research are represented in this chapter. This chapter includes the problem statement of the research, an explanation of the main aim and objectives and demonstrates the structure of the thesis. It also provides the reader with clarity and directions.

1.1 Background

Construction industry is one of the largest sectors in the European Market representing around (7-10) % from country's GDP (Voordijk et al. 2000). This industry is complex, covers wide range of companies and skills. The typical construction project, the center of construction industry, is a short term partnership including the owner, designer, contractor…etc collaborating together to deliver the final product. Construction industry, comparing to other manufacturing industries has low rate with productivity and efficiency and more problems with quality.

Many reports had referred to the nature of complications in construction industry. This includes conflicts in design and implementation, restricts on the information flow and differences in estimations (Olatunji et al. 2010). According to Teicholz, the main causes of the lack of the labor productivity in construction projects are: the traditional project delivery approaches, the dependency on the 2D Computer Aid Design (CAD) technology and the size of the construction companies (Teicholz, 2004).

Several studies indicated that there is a lot of waste in construction projects including the spent cost on redoing errors and waiting for information which prevents the productivity development (Josephson 1994).

As the Construction Planning form the empirical foundation of optimization and success of the construction project, special attention was given to improve this key process which will subsequently improve the overall construction development.

The analysis of current planning processes will indicate essential discrepancies between the overall and the detail level of scheduling. Most of the planning processes represent the personal experience of planners and managers with limited and unsystematic share of information among the construction team which prevents continuous improvement of the plan during the project lifecycle (Büchmann and Andersson.2010). The traditional construction planning and control system are, based on the classic Critical Path Method CPM, suffering from low productivity and high production cost (Dawood and Sriprasert 2002).

The emergence of Building Information Modeling (BIM) technology had a significant influence on the development of construction industry. From the 2007, publication of the National BIM Standard (NBIMS) defined BIM as “a digital representation of physical and functional characteristics of a facility” (NBIMS 2007). BIM offers an efficient assistance within the construction management aspects including project planning.

1.2 Problem Statement

Construction planning is considered as an important and essential activity in the execution and management of construction projects (Hendrickson, 2000). Effective planning is one of the most significant factors which influence the success of the construction projects (Heesom and Mahdjoubi, 2004). However there is emerging evidence indicates a shortage of skill in the construction planning area, with a decreasing number of experienced planners having the ability or knowledge to produce efficient construction plan.

A wide range of planning methodologies have been researched and implemented but they are not qualified enough to satisfy the desire of construction parties. There is still an enormous disparity between execution and plan (Allen and Smallwood, 2008).

Currently, the construction planning process depends mainly on 2D charts and drawings with the absence of spatial features of actual construction (Wang, et al, 2004). The Critical Path Method CPM has been known as the most used technique for construction planning. Construction planners split up the construction project into a number of small activities and all the activities re represented as bar in the final bar chart. Using computers to produce CPM schedules helped planners to produce efficient construction plans. However, the major limitations of utilizing CPM in construction project still influencing the efficiency of the construction plans.

The reliability of the construction documents and the dependency on the imagination of the construction planners and managers also affect the construction planning process.

All such circumstances affect the performance of the construction projects negatively. The construction industry needs to adopt a new technology to improve working practices and efficiencies in order to make construction more attractive to both investors and potential recruits. Given that planning has a significant impact on the ability of any organization to achieve this, the focus of their attention should be on using technology to improve the construction planning process.

1.3 Objective and Main Aim

The objective of the research is to address the most common challenges that facing the current construction planning practice and investigate the impacts of utilizing Building Information Modeling (BIM) technology in construction planning.

The main aim of my research is to provide a justification of using 4D building information modeling technology.

1.4 Thesis Structure

The thesis includes 8 chapters. The remaining chapters are as following. Chapter 2 presents an overview of the traditional planning approach with a brief description/evaluation of planning techniques. It also reviews the current construction planning processes. Chapter 3 goes through the concept of BIM and explains the special characteristics of BIM. Then, it shows the benefits of utilizing BIM in construction industry. Chapter 4 provides an overview of the research methodologies and research types/approaches, presents the way of collecting data for this research, demonstrates the main stages of the research and clarifies how the study has been achieved. Chapter 5 contains descriptive statistics of the collected data from the interviews and survey which have been conducted with professional construction planners. Chapter 6 describes the process of building the sample model beginning with the 3D Building Information Model and presenting the 4D sample model. Afterwards, in chapter 7 the discussion, the findings and the reflection are presented respectively. The thesis finishes with the conclusion and recommendation in chapter 8.

1.5 Conclusion

While the construction industry is growing, there is an essential necessity for assistance from computer to accomplish an effective construction management and planning. This thesis addresses the common challenges that facing the traditional planning approach and introduces the benefits of utilizing the building information modeling technology in construction planning in order to improve the performance of the construction project.

Chapter 2

Construction Planning

Chapter 2 Construction Planning

This chapter presents an overview of project and construction planning including a brief description/evaluation of used planning techniques. It also describes the construction planning processes.

2.1 Introduction

Planning plays a primary role in project management. The significance of planning could be shown through the following definition: “Planning is the process of determining appropriate strategies for the achievement of predefined project objectives”.

Construction projects run through various stages, therefore it is quite important to use a good planning technique to produce a realistic construction plan which contains all the required activities from the board activity to the detailed one in the right sequence in order to deal with all changes occurring through the project cycle.

Due to the complexity and multi-party involvement in constructions projects, construction planning was represented as key process in the success of such projects. Many researches were carried out to categorize construction planning problems, challenges, and the possible methods to improve/optimize the traditional construction planning approach.

2.2 Construction Planning Techniques (Scheduling Types)

The construction plan could range from a simple list of activities to a complex program which depends on the degree of project complexity.

To show activities relationships/dependencies, graphic techniques are used. In the presence of several planning methods, selecting the most appropriate technique is influenced by various factors such as: the complexity of the project, construction period, type of project…etc.

Planning techniques could be classified according to the basis of each. As indicated by kenley and Seppanen, there are two types of planning techniques: 1). Activity based planning techniques, 2). Location based planning techniques (Kenley and Seppan, 2009).

Generally, there are four scheduling types in common use: Gantt or bar chart, the milestone schedule/ chart, the network schedule, and the Linear scheduling (Line of Balance). (Scheduling Guide for Program Managers, 2001)

2.2.1 Gantt and Milestone Charts

Gantt Charts were the first developed scheduling technique and have been formally used since the early 20th century. Activities are represented as horizontal bars showing the planned start and finish dates with possibility to provide more information about tasks progress and schedule slips or gains.

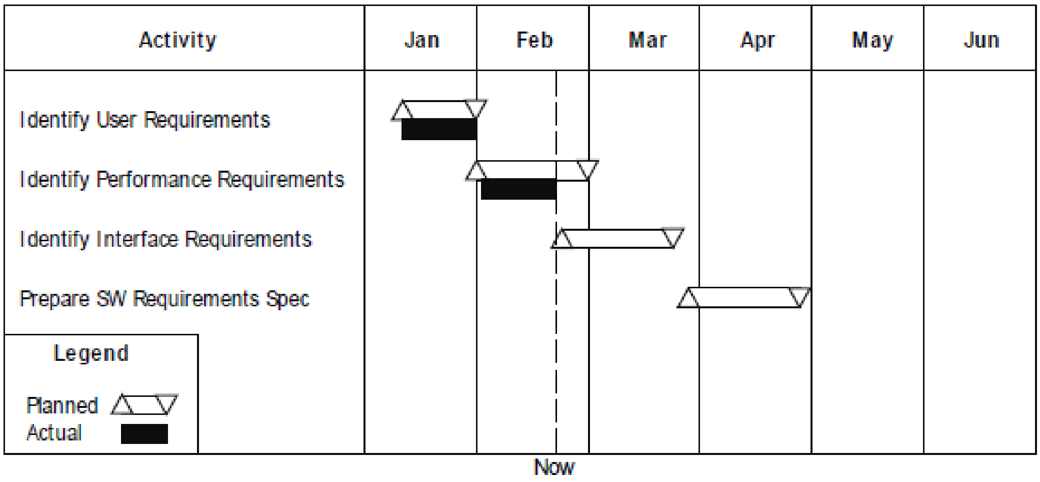

Figure 1 Gantt Charts Example

The main shortcoming of both types could be briefed in their inability to carry out a detailed schedule analysis.

2.2.2 Network Schedules

Due to the development of planning processes and the need to overcome Gantt Chart shortcoming, there was a need to adopt a new technique with more advanced graphical presentation to clarify relationships between activities, dependencies, and constraints across the project. Program Evaluation and Review Technique "PERT" was the first developed network scheduling technique that helped managers to visualize and control the program, monitor tasks relationships, and define which activities are more important than others.

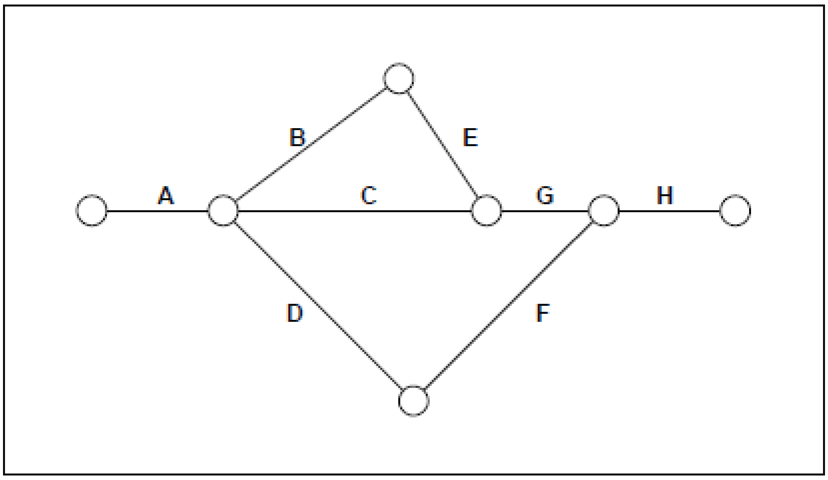

Figure 2 Network Schedule Example

Parallel to the development of PERT and based on the concept of the critical path, construction industry developed a network planning system called Critical Path Method “CPM”.

Critical Path Method CPM has been widely used in construction industry. Most of construction projects have been scheduled based on that traditional planning technique. The reasons behind this extensively usage vary from firm to firm and from project to another. Generally, most of contract documents direct contractors to submit CPM analysis with their proposals. The combination of CPM and Gantt Chart has formed the corner stone of the present commercial planning software (kenley, 2004).

However, several researches have discussed the suitability of CPM and criticized three major drawbacks which could be summarized in the difficulties to evaluate and communicate the plan and the inability to deal with real world constraints and provide details required during the construction phase.

2.2.3 Linear Scheduling (Line of Balance)

Utilizating of uninterrupted resource became an extremely important issue that was not addressed by the critical Path Method CPM. Linear scheduling technique was proposed to support the progress of repeating activities against time in projects with repetitive nature such as building projects.

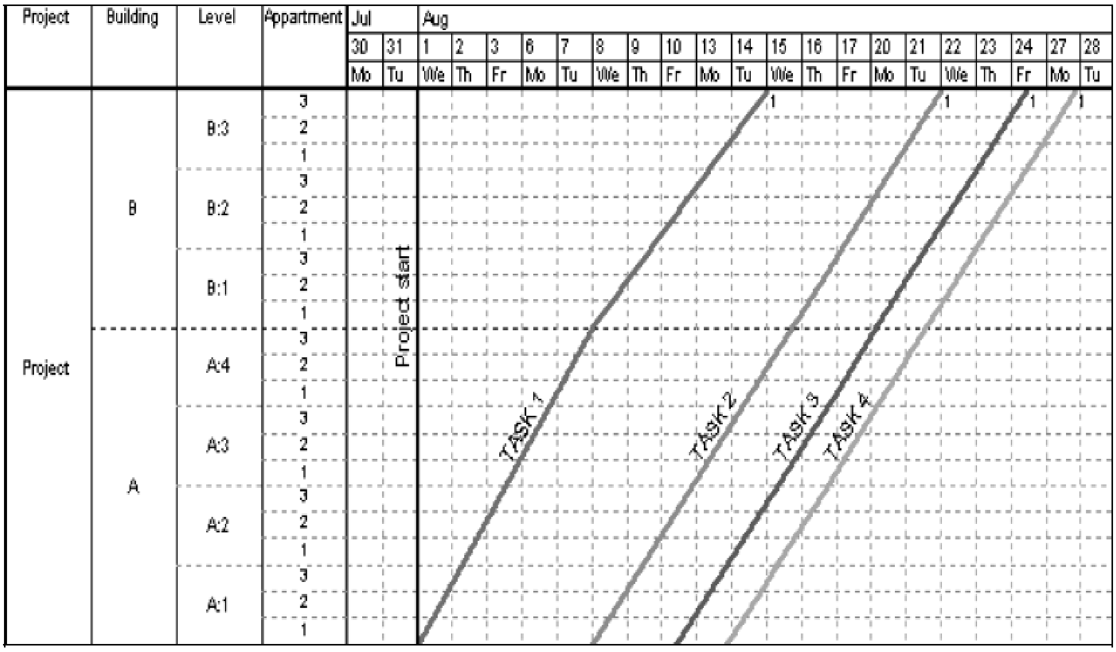

Figure 3 Linear Scheduling Example

Line of Balance technique consists of four major elements: 1). Contract schedule, 2). Production plan chart t, 3). Project status char and 4). LOB chart.

Many researches have addressed the potential value of Location Based Scheduling for its ability in allowing management of projects according to Lean concepts and merging interdependent tasks together in summary activities in order to achieve a master schedule where activities are balanced in relation to production rate, locations and continuity (kenley, 2004).

2.3 Construction Planning Processes

Developing a construction plan is an important task in construction project management as it involves in defining work tasks and construction technologies, estimating tasks durations/dependencies and demonstrating the resource required for each task. A successful construction plan should be evolved throughout the following processes:

2.3.1 Information collection

Before commencement of any planning preparation, there is required information to be obtained in order to form a comprehensive understanding of the project. Project information could be classified as

I. Contract Information

Contract information is the combination of construction documents (Bill of Quantities, Specifications) and contractual information (contract form, tender form).

II. Design Information

Design completion depends on the project delivery method adopted by the client. Design information should be self-explanatory and include the following information: detailed drawings, explanatory schedules, Specific instructions and ground investigation reports.

III. Site Information

The planner should review the existing conditions in the site which may have influence on the construction progress.

IV. Specialist information

There is a second type of information which is not less important than the project information and it plays a major role in planning processes such as production information, factual information and reference information.

2.3.2 Work Breakdown Structure and Construction Activities Definition

A Work Breakdown Structure (WBS) is a hierarchic decomposition or breakdown of a project or major activity into successively levels, where each level is a finer breakdown of the preceding one. In final form, a WBS is very similar in structure and layout to a document outline. Each item at a specific level of a WBS is numbered consecutively (e.g. 10, 20, 30, 40, and 50). Each item at the next level is numbered within the number of its parent item (e.g. 10.1, 10.2, 10.3, 10.4)" (Martin E. M., 1996).

The purpose of Work Breakdown Structure WBS is to divide the project into manageable elements to facilitate controlling/monitoring activities, estimating durations and approximating budget. WBS structure can be arranged in variety of formats as it depends on the complexity of project. According to NASA Work Breakdown Structure Reference Guide, WBS consists of three levels and they are

I. Level 1 is the entire program/project.
II. Level 2 elements are the major product segments or subsections.
III. Level 3 contains definable components, or subsets, of the level 2 elements.

WBS forms the source for activities definition as it gives the ability to divide construction activities into detailed ones in order to enable fix correct duration estimation and resource allocation.

2.3.3 Construction Method Selection

Construction planners/managers coordinate and work with other construction parties to select the appropriate construction methods in order to calculate cost and duration estimations. The selected construction methods will identify the required resources which generally consist of materials, equipment and labor.

Defining construction methods requires collaborative work among the construction management team and specific knowledge about the available resources. One of the main concerns of the planner during the planning process is the productivity of the selected resources which will have a great impact to duration and cost of the construction activities.

Construction methods selection should take into consideration the following aspects (planning and programming in construction, 1991):

1. Organization: define how the project will be managed.
2. Methods: Describe the sequence of the work flow
3. Material handling: define the required resources and facilities
4. Accesses: provide accesses to/out of the construction site
5. Site establishment: provide accommodation requirements and material storage.
6. Safety, Quality management and Environmental factors

2.3.4 Construction Activity Sequencing

The main aim of this process is to define the accurate constraints/relationships among schedule activities to establish the sequence which the activities will be accomplished accordingly.

According to Scheduling Guide for Program Managers, construction activities sequencing process input are:

- The activity list developed in the activity definition step,
- The product description and characteristics,
- Mandatory constraints/dependencies, such as the fact that a prototype must be fabricated before it can be tested,
- Discretionary constraints/dependencies developed by the program management team based on "best practices" or specific sequences desired by management,
- External dependencies, such as availability of test sites, and
- Other constraints and assumptions.

All of the mentioned inputs form a foundation to determine the dependencies for the construction activities.

2.3.5 Resources Allocating

After finalizing the definition of construction methods for construction activities and completely defining the required resource types, construction manager/planner has to allocate a suitable quantity of resources for each activity. Resources availability and capability are not less important than the time of activities (Ming and Heng, 2003). Even though many researches have indicated that increasing the allocated resources to construction activities would improve project performance; other studies stated that investing in construction planning beyond the optimal point would lead to deterioration in project performance (Olusegun et. al, 1999).

Based on the resources availability\ limitation and the project duration flexibility, there are two scenarios for resources management:

Resource Allocation

Generally, resources allocation scenario is often utilized when resources are limited and there could be a possibility to extend the project duration beyond the completion planned date.

Resource Leveling

When resources are not completely limited and the project duration was already fixed regardless the resources constraints, it would be effective to exploit the resource leveling strategy in order to smooth resource utilization and reduce the required amount of any type of resource in any given time.

2.4 Current Planning Approach Challenges

Proceeding from the fact that planning process can be considered the backbone of construction management, improving the credibility of planning could be efficient to achieve stable construction flow, high productivity and improved quality (Chua et al, 1999). For this purpose, i.e. improving the credibility of planning, it is important to demonstrate the major challenges that facing the traditional planning processes:

2.4.1 Fragmented Nature of the Construction Industry and the Traditional Building Process

The construction industry is fragmented (Alashwal, 2009). The construction project is divided into various disciplines, parties and stakeholders working separately most of time. Most of the common procurement strategies like the

Design-Bid-Build DBB within construction industry are based on the total separation between design and construction process i.e. the main contractor and subcontractors have no design responsibilities or involvement in the preparation of the design (Latham, 1994). In light of this fact, the main contractor can't commence any of the construction works unless the full design has been already carried out by the architect/engineer. This separation had led to lack in performance in many construction projects (Alashwal, 2009).

The project delivery process within the construction industry depends mainly on paper based communications. Therefore any error or conflict within the paper documents will cause delays, over costs and eventually claims between the construction project team. As the construction industry is a project oriented industry, improving the coordination among the different parties of the project will assist in reducing the negative impacts of the fragmentation problems. Figure 4 illustrates the conceptual process of a construction project form the concept stage to the construction stage.

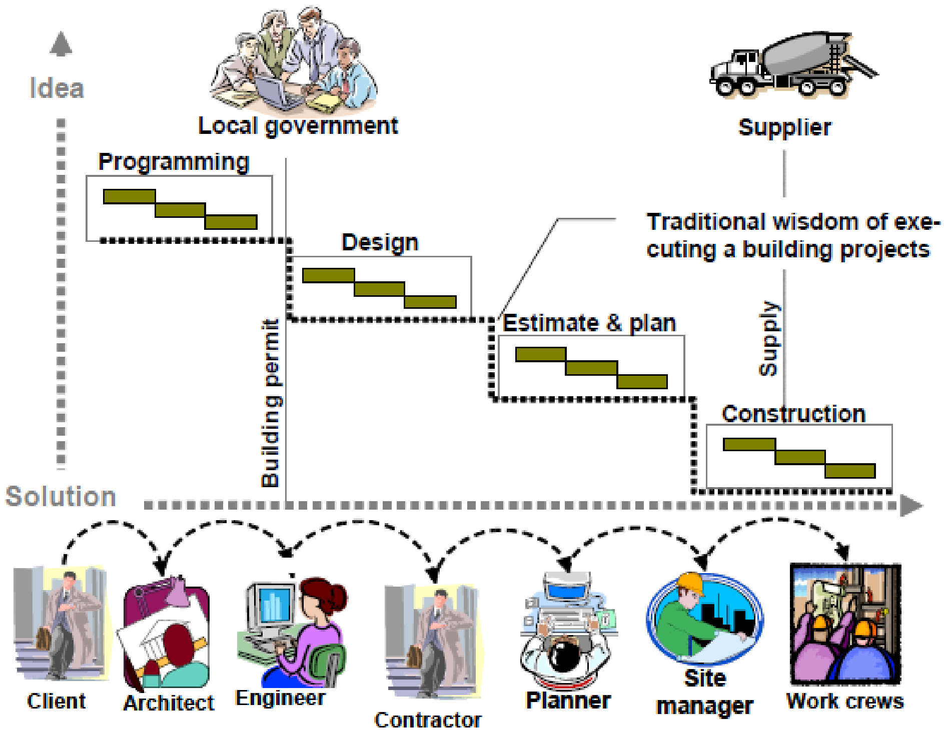

Figure 4 The conceptual image of a building project (Jongeling et al, 2007)

2.4.2 Constructability and Buildability

The constructability as it has been defined by the Construction Industry Institute CII is "The optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives". Nevertheless the buildability involves mainly in the design stage and constructability is applied to overall development of the project (Wong et al, 2007), many researchers have used the two terms for the same meaning.

The achievement of a good constructability depends on both of designer and builder so; the constructability concept requires a continuous integrating of knowledge and experience of the construction project parties' i.e. designer, contractors, subcontractors…etc. Applying constructability has a great impact in minimizing the gap between design and execution phases in the traditional procurement method DBB, increasing the productivity rates and reducing costs (Hijazi et al, 2009). The traditional planning approach, depending on the CPM technique, does not assist planner to consider constructability issues during the preconstruction planning stage (Dawood and Sikka, 2009)

2.4.3 Dependency on the Personal Experience

Generally, the construction planner should have many specific skills and experiences like the ability to liaise with different parties and imagine how the project will be constructed, having a practical experience in construction technologies and construction laws and understanding the design considerations. A lot of personal experience is required in order to select the right construction method statement (Tulke and Hanff, 2007). Büchmann and Andersson (2010) stated that producing the construction plans is basically depend on the personal experience of the planner and the construction manager rather than standards and well founded figures (Büchmann and Andersson.2010). Planners and construction managers have to imagine the construction process in their mind while the preparing process of the construction plans. The overload of the construction documents, including the 2D drawings, specifications, BOQ…etc, produces serious difficulties to understand the project characteristics and extract the required information for scheduling purpose (Büchmann and Andersson, 2010).

2.4.4 Traditional Construction Planning Techniques

Critical Path Method (CPM) has been widely used in the construction industry as the main tool for construction planning and scheduling since its invention in 1950 (CPM in Construction Management, 2010). Many surveys around the world agreed that Critical Path Method (CPM), forming the corner stone of the common construction planning software, had proven to be a helpful technique for planning, scheduling and controlling construction projects. In spite of its extensive usage, the suitability of the CPM has been widely criticized due to its major shortcoming and limitation especially in the construction planning field.

Defining the major limitations, drawbacks and shortcomings of the Critical Path Method was a very important subject for numerous investigations and researches in order to achieve some development in construction planning area. Most of those drawbacks and challenges could be categorized as following:

1. The interrupted Usage of Resources

Many contractors require ensuring the continuous usage of the recourses during the construction which is difficult to be ensured by applying the Critical Path Method because only resource availability constraints are shown in the CPM network (Harris et al, 1998). Ignoring the activities flow would consequently lead to inability to succeed in managing the construction resource (material, equipment, labor…etc) which is one of the most important element in the planning process (Najjar et al, 2004). Commonly, during the preparation of the CPM schedule, the main concern is about activities and their relations regardless the limitation of resources available for executing the work (Büchmann and Andersson, 2010). The guarantee of the uninterrupted usage of the construction resource, especially labors, would improve the performance and increase the productivity.

2. The Spatial Conflicts

Construction spaces are categorized into three classifications: resources spaces, topology spaces and process spaces (akinci et al, 2002). Usually during the preconstruction planning processes, the main concerns are all about the constriction durations and construction activities constrains related to time, regardless the spatial constraints. Since the construction schedule contains hundreds of activities requiring different locations with different spaces, it is quite difficult for the construction manager to illustrate the spatial requirements for the construction resources i.e. the spatial locations and the physical components are not directly related to the schedule activities. Nevertheless its wide usage in the construction management filed, the stand-alone CPM technique still has no ability to represent the spatial and temporal aspects of construction (Sriprasert and Dawood, 2002).

3. Schedule Evaluation and Communication

Although CPM technique has been widely adopted throughout the construction industry, having fully understanding of the construction plan from reviewing the CPM schedule was easier said than done even to the civil and architectural engineering students (Messner et al, 2003). Many construction schedules have numerous contraries which is difficult to be found out and they only been detected during the execution stage. It has been proven that it is difficult to evaluate and communicate the plan among construction project participants (Sriprasert and Dawood, 2002).

4. Dealing with Repetitive Construction Project

Although CPM technique has a remarkable effect on complex projects, it has been shown beyond doubt that CPM has limitations when applied to projects with repetitive activities such as roads and high rise building projects (Yamin and Harmelink 2001). In repetitive projects, the network diagram for x units will be established for one units and then repeated x times and link together which will be resulted in huge network with great number of activities (Cheng, 2006). As most of the construction projects have several repetitive activities, there will be extra advantages to deal with them in order to produce an agile construction plan.

5. The usage of buffer time

Within the CPM scheduling method, the main attention is given to the critical activities which lead to less efficient usage of the buffer time and could causes risks as the critical path changes during the execution stage.

2.5 Conclusion

Construction planning is playing an important role within the development of construction industry. The aim of planning is to generate required activities as well as their interdependence and thereby ensuring that the project will be completed within the best manners of economics, safety and environmental acceptance.

Through construction planning process, suitable technologies are selected; work tasks are assigned; resources are allocated and project participants as well as the interaction between them are identified.

There are several of methods implemented in construction planning such as Gantt chart, Critical Path Method, and linear scheduling.

The traditional construction planning approach is facing a numerous challenges that affect the efficiency of the construction plan.

Chapter 3

Building Information Modeling

Chapter 3 Building Information Modeling

This chapter will go through the concept of BIM and it will explain the special characteristics of BIM. It will also review the benefits of utilizing BIM in construction industry.

3.1 Introduction

BIM (Building Information Modeling): “Digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. ” (National Building Information Model Standard NBIMS).

Basically, the concept of Building Information Modelling technology is to illustrate the building before it is physically built in order to solve potential problems, enhance communication between different parties and enable simulation.

Building information modeling has the capacity to include all construction documents, which facilitate the work of construction managers, detect errors and avoid the extra costs resulting from such errors.

By utilization of BIM technology from the early stages of construction project, the concept of constructability/ buildability could be incorporated during the building design process to form more informed decisions making process and positively impacts overall project efficiency and quality.

3.2 BIM Characteristics

Building Information Modeling provides architects with a detailed/integrated expression about project information and it supplies a scientific simulation/analysis platform for engineers and designer in order to utilize the 3D model to carry out design, construction and management works.

According to M.A. Mortenson Company, BIM as “An inelegant simulation of architecture” could be characterized by the following: Digital, Spatial, Measurable Comprehensive, Accessible and Durable.

However, Jianhua and Hui had mentioned more general characteristics/capacities of BIM technology (Jianhua and Hui, 2010):

- Visualization: Visualization is a fundamental characteristic of BIM as it is a digital representation of the project information. This main attribute could assist communication, design, construction and decision making processes.
- Coordination: Construction project is a multi-disciplinary project. BIM can support project managers in solving coordination problems as coordination is an essential task in project management.
- Simulation: When design changes, there is a need to repeat analysis and then to simulate results accordingly to facilitate decision making.
- Optimization: Better optimization could be done by the utilization of BIM as it provides the rational results.
- Documentation: All kinds of plans, sections, elevations…etc. could be carried out throughout the BIM environment.

3.3 Justification for BIM

Unlike other kinds of industry, construction industry has recorded low rates of productivity in recent decades. This indicates that construction suffers from a lack of development and adoption of modern ideas. Figure 5 shows the gap between and construction industry and labor productivity in USA market.

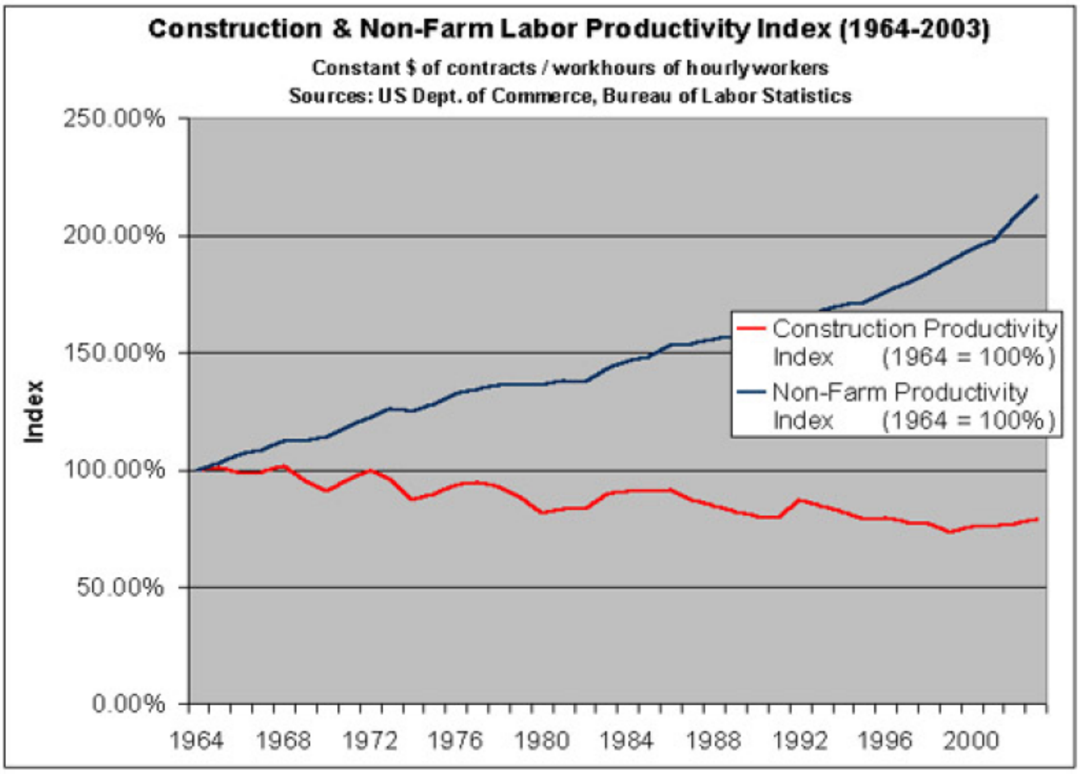

Figure 5 Labor productivity index for US construction industry and all non-farm industries (Teicholz, 2004)

As indicated by Teicholz, the underlying root causes of the lack of productivity in the construction industry are due to (Teicholz, 2004):

- Using of traditional projects delivery approaches such as Design- bid – build and their disadvantages due to the separation of design and construction phases which often lead to more changes/conflicts
- The adopted information technology has not improved collaboration among project team as it works independently

- Large number of project stakeholders
- The low rates of investments in research, development and training in construction industry
- Way of paying construction workers salaries

BIM provides great opportunities in order to improve construction industry productivity facilitate project management application and support decision making processes.

3.4 Building Information Modeling (BIM) Benefits

Beside its major benefit regarding the accurate representation/visualization of building in an integrated environment, BIM has several benefits: (Azhar et. al, 2006)

- Faster and more effective processes: ability to share/reuse information among the project team.
- Better design: assist in preparing proposals, better analyzing and simulation, enabling innovative solutions
- Controlled whole-life costs and environmental data: provide a powerful mean to evaluate the environmental performance and estimate the project lifecycle cost.
- Automated assembly: provide information could be used for assembling the structural system.
- Lifecycle data: operational data could be used for facilities management and later maintenance.

3.5 3D Building Information Modeling and Parametric Modeling

From the beginning of 60s, construction industry started to adopt the Computer Aided Design (CAD) systems in order to speed up the processes of preparing 2D drawings. Depending on 2D drawings during the design phase has led to large number of conflicts due to the co-ordination difficulties among the design disciplines.

Despite the presence of 3D modeling applications, their use was limited to the major engineering offices due to financial and technical considerations (Jongeling et al, 2007). At the present time, CAD system could be used for more than 3D modeling and it could be extended to be utilized with more efficiency within the AEC (Architecture, Engineering and Construction) industry.

The development of the virtual model depends on the purpose of model and the required amount of information in the model. 3D virtual models are classified into two groups: 1) Surface models and 2) Solid models.

Surface Model is a model with just a visualization purpose. In spite of acting like a soiled model, surface model is made up of only form elements without thickness or volume characteristics as it contains only visualization information. Surface model could be used particularly for marketing, presentation and communication purposes. Software programs such as SketchUp, Maia, etc., make surface models faster and simpler than modeling by solid modeler software programs.

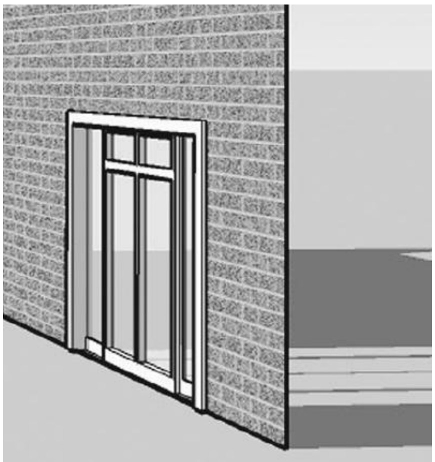

Figure 6 The Most Basic Surface Model

However, solid models (Smart models) are the real representation of objects in 3D space. They contain more detailed information about the building and allow for simulation in addition to their significant assistance in producing 2D views, preparing traditional construction documents and developing shop drawings.

Intelligence model consists of two kinds of information, physical information including dimensions and project location, while parametric information could assist in identifying a particular element and discriminating it from others. Such information could play a useful role in estimating cost of a project.

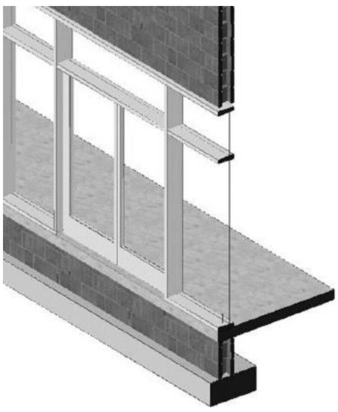

Figure 7 Section in a Solid Model

Recently, BIM has been widely adopted by the CAD vendors such as Autodesk and Bentley. Beside the fact that a building information model serves as a visualization tool, it also contains information about the building construction, management, operation and maintenance which could assist in supporting the building lifecycle. Using BIM technology requires modeling components with their real attributes (sizes, specifications, materials. etc) with their relationships to other components. The more information provided during the modeling process by using parametric objects would enable the automated utilization of the product model in extracting the required information such as quantities and schedules.

There are several software which adopt the concept of Building Information Modeling derived from several programming companies such as Autodesk and Bentley. The following table lists some of the BIM tools with their functions:

Product Name	Manufacturer	Primary Function
Cadpipe HVAC	AEC Design Group	3D HVAC Modeling
Revit 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 Civil 3D	Autodesk	Site Development
DProfiler	Beck Technology	3D conceptual modeling with realtime cost estimating.
Bentley BIM Suite (MicroStation, Bentley Architecture, Structural, Mechanical, Electrical, Generative Design)	Bentley Systems	3D Architectural, Structural, Mechanical, Electrical, and Generative Components Modeling
Affinity	Trelligence	3D Model Application for early concept design
Vectorworks Designer	Nemetschek	3D Architectural Modeling
Tekla Structures	Tekla	3D Detailed Structural Modeling
MEP Modeler	Graphisoft	3D MEP Modeling

Table 1 BIM Authoring Tools (Reinhardt, 2009)

3.6 4D Modeling Scheduling Technique

With the rapid development and the explicit successes of the Building Information Modeling technology within the Architecture, Engineering and Construction industry, many studies has discussed the contribution of the Virtual Reality (VR) in general and the BIM concept especially for better visualization and analyzing the building design through its construction. Beside the support provided by BIM during the design stages, there were many areas that BIM could assist like the construction planning and monitoring, and the cost estimation.

As discussed previously, the most common scheduling methods are the Critical Path Method CPM and the Line of Balance LoB. In CPM schedule, the listed activities are linked to each other with assigned duration and the longest path is defined as critical path which represents the predicted duration of the project. In contrast, LoB uses locations as basis for scheduling which could be helpful within projects with repetitive nature.

The 4D BIM (4D Building Information Modeling) refers to the intelligence linking of the 3D building information model with time schedule. There are several ways to create the 4D BIM model by using BIM tools with 4D capability or exporting the 3D BIM to a 4D BIM tool and then import the time schedule. Creating the 4D model with specialist 4D BIM tools could enhance the production of the 4D model and provide the planner with multiple options to build the 4D BIM model with particular specifications. Figure 6 shows the 4D model building process.

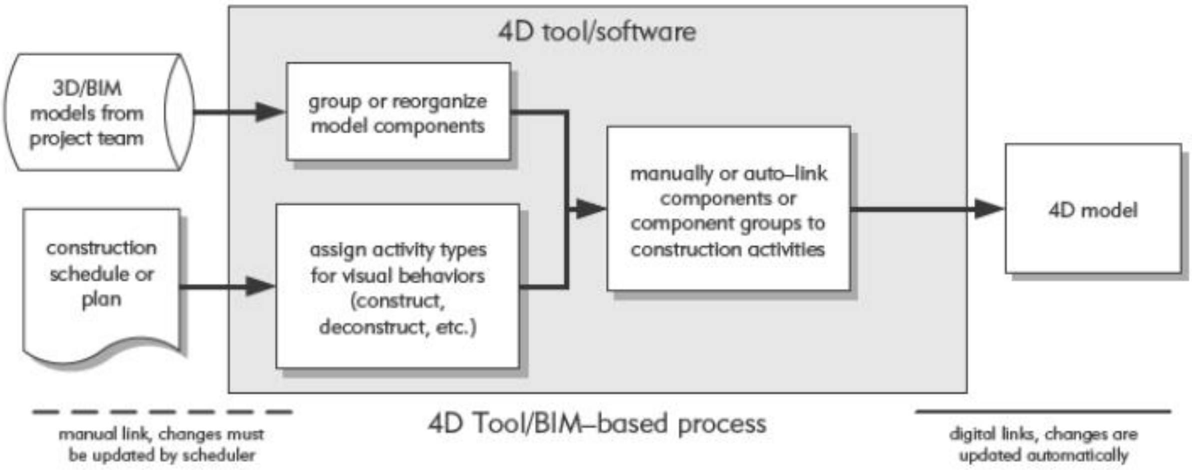

Figure 8 4D Model Building Process (Eastman et al, 2008)

The usage of the 4D modeling could improve the construction planning in many areas as follows:

3.6.1 Visualization of the Construction Process

4D modeling provides a visual solution to illustrate the construction works better than which could be done with the 2D drawings and documents such as Gantt charts and linear schedules. The 4D model shows how the 3D model components are being constructed step by step with the progression of time. There is no further need for 2D drawings and schedules to conceptualize the construction process because the 4D model allows viewing the two separate documents through one single source.

3.6.2 Communication of the Construction Plan

As been mentioned previously, the construction project is divided into various disciplines, parties and stakeholders, the results of the 4D modeling allow project participants to view the planned construction and review the actual status of the project without difficulties (Norberg and Olofsson, 2008). The 4D model also could reduce the time for communicating the schedule to the sub-contractors and enhance their feedback (Norberg and Olofsson, 2008).

3.6.3 Solving and Detecting Spatial Conflicts and Detecting Clashes

Using the 4D modeling technology could greatly improve the coordination process as it has the ability to detect the spatial conflicts within the construction plan that are very difficult to be identified when the coordination performed based on the 2D drawings (Coyne, 2008). By the implementation of the BIM tool, there was an ability to detect clashes that couldn’t be found by the design team when using the traditional method of overlaid drawings on light table. On the other hand, utilizing the 4D modeling technique gives support in detecting clashes resulted from the movement of the construction equipment within the construction site and assessing the temporal constrains of the construction resources.

3.6.4 Constructability

Implementing the constructability/buildability concept within the construction industry will affect advantageously the return of investment of the construction projects. The most appropriate way to assess constructability of a building project is to simulate and visualize the construction activities before it take place in reality. 4D modeling based on BIM technology provides a helpful tool to figure out what will go wrong and go right before the commencing the execution (Hijazi et al,2009). Aranda-Mena et al (2008) found that BIM could improve the buildability of the design in compliance with its functionality.

3.6.5 Construction Site Planning

To increase the productivity in the construction site, it is important to ensure a continuous flow of the allocated resources and preparing a suitable site layout to ease the movement of workers and other facilities (Jongeling et al, 2008). 4D building information allows producing a reasonable site layout with proper storage areas and site access.

3.7 Conclusion

With the rapid development in the construction industry, there was a necessity need to adopt a new technology to comply with the modern project management methodologies.

Building Information Modeling extends beyond being just a digital representation of a facility to establish a stable platform for sharing information and provide novel concepts about managing construction projects. Visualization, as a main feature of the BIM, provides the construction project participants a better look to the project more than the 2D drawings and documents could ever do. Using BIM offers a better design, improved coordination, collaboration and communication between the project team and reliable data platform which could be used through the project lifecycle.

Construction planning could also be enhanced by linking the construction schedule to the building components in order to animate the construction process. Illustrating the execution process before it begins could reduce on site errors and conflicts, help planners and construction manager to communicate the schedule clearly and provide a reliable site plan.

Chapter4

Research Design and Methodology

Chapter 4 Research Design and Methodology

This chapter provides an overview of the research methodology and research types/approaches and presents the way of collecting data for this research. Also, it demonstrates the main stages of the research and clarifies how it has been achieved.

4.1 Introduction

According to the Concise Oxford Dictionary, research is ‘careful search or inquiry; endeavor to discover new or collate old facts etc. by scientific study of a subject; course of critical investigation” .However, the Encyclopedia of Social Sciences defines research as “the manipulation of things, concepts or symbols for the purpose of generalizing to extend, correct or verify knowledge, whether that knowledge aids in construction of theory or in the practice of an art.”

Despite the fact that there are several definitions for the term “research” it is believed that most of the definitions, according to Rusk, George J. Mouly, Francis G. Cornell, Clifford Woody of the University of Michigan, C.C. Crawford, C. Francies Rummel, W.S. Monroe and R.M. Hutchins, agreed that the research could be defined as “seeking for knowledge through a systematic and scientific investigation for relevant information on a specific topic in order to achieve a contribution to knowledge” (Monroe and R.M. Hutchins, 2006).

In spite of mutual understanding of the main aim of research from Singh, Y.K. and Kothari, C.R., the former outlined research objectives to the following(Monroe and R.M. Hutchins, 2006):

- Theoretical Objective: Explain the relationships between several factors in order to formulate novel laws and theories.

- Factual Objective: Describe events happened in the past.
- Application Objective: Provide an improvement n practice.

While Kothari, C.R thinks that research objectives could be grouped to the following (Monroe and R.M. Hutchins, 2006):

- To gain more information regarding specific phenomenon.
- To identify exactly the characteristics of a particular situation.
- To determine the frequency of a phenomenon.
- To test a theory against different factors.

4.2 Research Types

According to Kothari, C.R, researches are classified to the following:

- Descriptive vs. Analytical: the analytical research aims to establish relations between several attributes of the research subject, whereas the descriptive research provide and description of a phenomena
- Applied vs. Fundamental: hence the main objective of pure research is to discover novel natural laws, develop theories and gather knowledge for knowledge’s sake, the applied research aim is to find solutions for practical problems. Academic researches, in many cases, are pure researches. However industrial and business researches are almost applied researches due to the needs of work development. Some sectors, such as construction sector, prefer to adopt a combination of pure and applied researches-theory and application.

- Quantitative vs. Qualitative: the quantitative research is an objective research depends on stable evidences and facts, but the qualitative research is a subjective research dealing with individuals and opinions.
- Other types including: Longitudinal research, Laboratory research, Diagnostic research.

However, Singh, Y.K addressed two basic outlined researches classes based on the research objective (Monroe and R.M. Hutchins, 2006):

- Applied Research or Action Research
- Fundamental or Basic Research

Discussion:

Quantitative vs. Qualitative

Quantitative research depends basically on numbers and analyzing the data with statistical procedures to verify a hypothesis or a theory. The main aim of the quantitative studies is either to test the hypothesis or to reflect whether the theory is confirmed or not. Qualitative researches have a subjective nature as it is dealing with personal experiences and opinions. In contrast with the quantitative studies, the theory could be the end product of the qualitative study. There are two classification of the information gathered in the quantitative research: explanatory research and attitudinal research. Naoum (2007) quoted that Bryman presented a list that shows the main differences between the two strategies. Table 3 shows those differences that been presented by Bryman

		Quantitative	Qualitative
1	Role	Fact findings based on evidence or records	Attitude measurement based on opinion and views
2	Relationship between researcher and subject	Distant	Close
3	Relationship between theory and research	Nomothitic Testing/confirmation	Idiographic Emergent/development
4	Nature of data	Hard and reliable	Rich and deep

Table 2 The Main Differences between the Quantitative and Qualitative Research Methodologies (Naoum, 2007)

4.3 Design of the Study

The methodology adopted for this research was a combination of qualitative and quantitative approaches. In spite of the fact that academic researches are pure researches, the adaption of the mixed approach was aimed to produce a novel research which could be a guideline to utilize the BIM in order to improve the construction planning processes.

Regarding the fact that using the Building Information Modeling technology is still limited and in the absence of understanding the needs of it, it is difficult to review a full 4D planning case study based on BIM in real practice. Therefore, the study is divided into the following stages to provide the required data for the research:

4.3.1 Stage 1: The Literature Review

Literature review is a great matter of importance in scientific reports. The aim of the first stage was to identify the construction planning processes, construction planning techniques and the major limitations and challenges that facing the current planning process. Also the literature review aimed to investigate the concept of the Building Information Modeling, usages, characteristics and its contribution to the construction planning.

For this purpose, a comprehensive literature review was carried out in order to collect the data, fill the gap of information and establishing a reliable platform for the next stages.

4.3.2 Stage 2: Assessment of the Identified Facts in the First Stage

By the end of the first stage there was need to assess the information conducted in order to ensure the compliance with the real practice and to prioritize the factors which will be adopted through the following stages. A tow parts questioner were sent to construction planning professionals to explore their viewpoints regarding the current construction planning challenges and the areas which need to be improved in the planning process.

4.3.3 Stage 3: Building a 4D Model Sample

A sample of a 4D model was built in order to explore the contribution of BIM in the construction planning field.

Building the 3D building information model was carried out based on the 2D architectural drawings using the Revit software and then it has been linked to the construction schedule by the Naviswork software in order to establish the 4D building information model.

4.3.4 Stage 4: Evaluating and Validating the Findings

To validate the results extracted from building the 3D and 4D models, interviews with a group of construction planning personnel and construction managers were conducted to represent the findings and gather feedback from them.

4.3.5 Stage 5: Summarization and Recommendations

In light of the feedbacks and the facts been gathered and founded in the previous stages, the recommendations were verified and the results were documented.

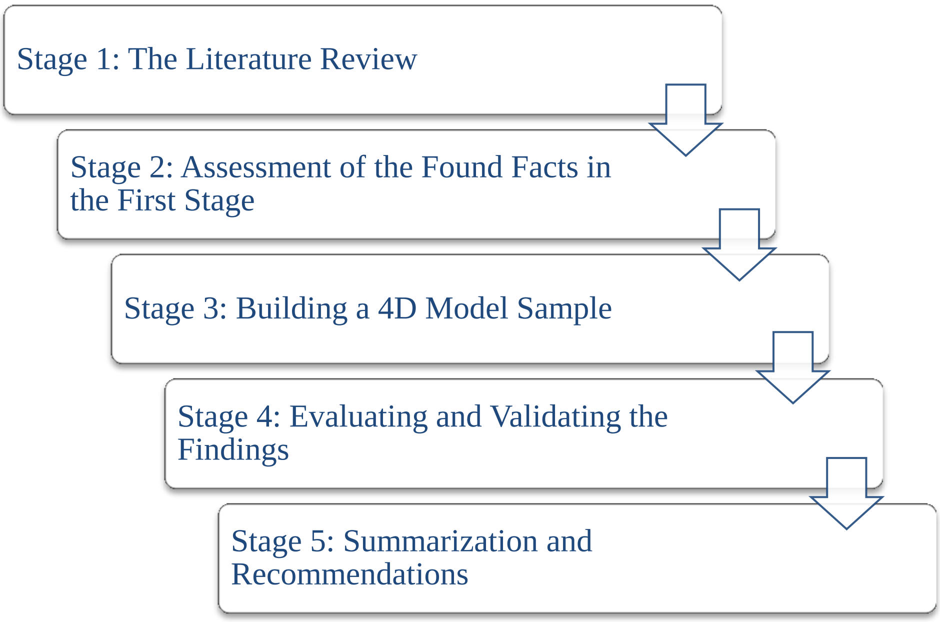

Figure 9 Research Stages

4.4 Data Collection Procedures

There are two approaches for data: primary data and secondary data (Naoum, 2007).

The secondary data for this study was acquired from several international publications, scientific journals, conferences. Noting that, the available documents on the Internet did not contain the correct page number which makes it difficult to create a formal reference list.

The primary data was assembled from a questioner sent to construction planning specialists and then analyzing their feedback.

4.5 Questionnaire Structure

The questionnaires structure framed based on three types of answering techniques, namely rating-based, selective based and open-ended format. Within the rating-based format, respondents were instructed to rate their opinion for a specific fact by making a 5-point scale ranging from Strongly Disagree to Strongly Agree. Hence within the selective-based questions, it only required respondents to tick in the appropriate box.

The structure of questionnaire for this study had covered 3 sections:

Section 1: Building a background about the respondents such numbers of years of experience, his/or position in the company.

Section 2: The second part target was to gather general information about the construction planning process including the most common project delivery method, the traditional used planning techniques and software .

Section 3: The second part comprises the questions the indicating the possible challenges those face the construction planning.

In this study, the address of the web-based questionnaire has being distributed to selected group of 45 respondents, with various ages group, level of experience, organizations, working nature and responsibilities as their involved in planning construction project.

4.6 Analysis Method

The data were analyzed partly by using the Statistical Package Social Science (SPSS) software and Microsoft Office Excel. Average index was calculated to reflect the effectiveness of aforementioned criteria. The analysis has ranked the challenges based on the frequency analysis and the average index. This index was calculated as follows (Abd Majid and McCaffer, 1997):

Average Index Formula:

$$\text{Average Index} = \frac{\sum \mu \, \mathbf{X}\mathrm{n}}{N}$$

μ = Weighting given to each factor by respondents (1 to 5);

n = Frequency of the respondents;

N = Total number of respondents

Whereby the application of Average index in questionnaire for instance would be:

μ1 = 1, frequency of “Strongly Disagree” response

μ 2 = 2, frequency of “Disagree” response

μ 3 = 3, frequency of “Neither agree nor disagree” response

μ 4 = 4, frequency of “Agree” response

μ 5 = 5, frequency of "Strongly Agree" response

With the rating scale as below: (Abd Majid and McCaffer, 1997)

- 1 = Strongly Disagree (1.00 ≤ Average index < 1.5)
- 2 = Disagree (1.50 ≤ Average index < 2.5)
- 3 = Neutral (2.50 ≤ Average index < 3.5)
- 4 = Agree (3.5 ≤ Average index < 4.50)
- 5 = Strongly Agree (4.5 ≤ Average index < 5.00)

4.7 Reporting Results

All possible challenges that affect the traditional construction planning approach were listed and ranked according to the rating scale by respondents. These challenges were divided into 4 categories:

(1) The Fragmented nature of the construction industry

(2) The Dependency just on the personal experience

(3) The construction planning method

(4) The reliability of the construction documents

4.8 Conclusion

Combined between the qualitative and quantitative research methodologies was chosen to carry out this study.

This study was gone through several stages in order accomplish the main objectives. The beginning was performing a literature review to collect general information about the research subject and then doing an assessment of the found facts. A sample architectural building information model was built and then linked the construction schedule in order to visualize the construction process and extracting the potential benefits of utilizing the BIM concept within the construction planning.

Chapter5

Data Analysis

Chapter 5 Data Analysis and Findings

This chapter provides an assessment of the found facts in the first stage of the study. Also it contains descriptive statistics of the collected data from the interviews and survey which have been conducted with professional construction planners.

5.1 Data Collection

The qualitative data generated from the questionnaire survey was analyzed using the frequency analysis and relative index technique as explained before. The summary of data analysis for questionnaire survey was tabulated in the next section. The result will be used as the basis for further discussion in the next chapter.

The questionnaire was sent as a web-page link to a group of 42 construction planners and construction managers form 7 construction and consultation firms in the private construction sector. The survey was supported by personal interviews. The total number of responds was 35 with full answers for all questions.

5.1.1 Demographic Profile of Respondents

The demographic profile of respondents through the questionnaire shows that the respondents were from top management of the company. The positions held were planning engineers, construction managers and project engineers. This shows and proves that the data collected for the purpose of this analysis is deemed to be strong and appropriate, as they comes from the main field of the study. Figure 10 shows the demographic profile of respondents

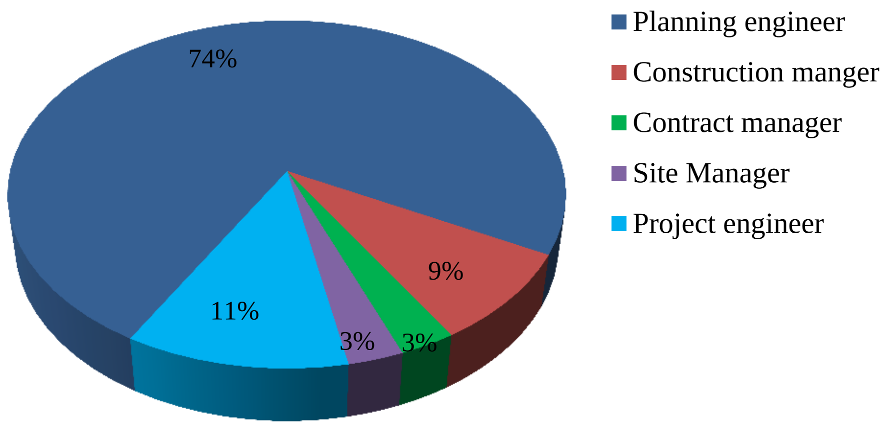

Figure 10 Demographic Profile of Respondents

5.1.2 Respondent's Experience

Figure 11 shows the respondents' working experience in the construction planning field. A majority of them, 57% have 3 to 6 years of experience. 31% of the respondents have more than 6 years of working experience. Only 11% have less than 3 years of. This proves that the respondents have a tangible experience in construction planning field.

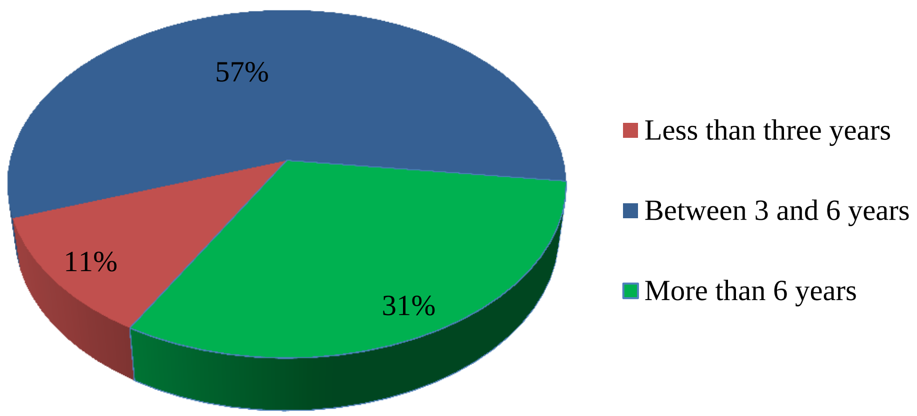

Figure 11 Working Experience of Respondents

5.1.3 Project Delivery Method

Figure 12 illustrates the common used project delivery method within the construction industry based on the respondents' experience. A high percentage of the respondents (60%) agree that the "Design-Bid-Build" delivery method is the most common method. However, none of the respondents have used the Integrated Project Delivery method.

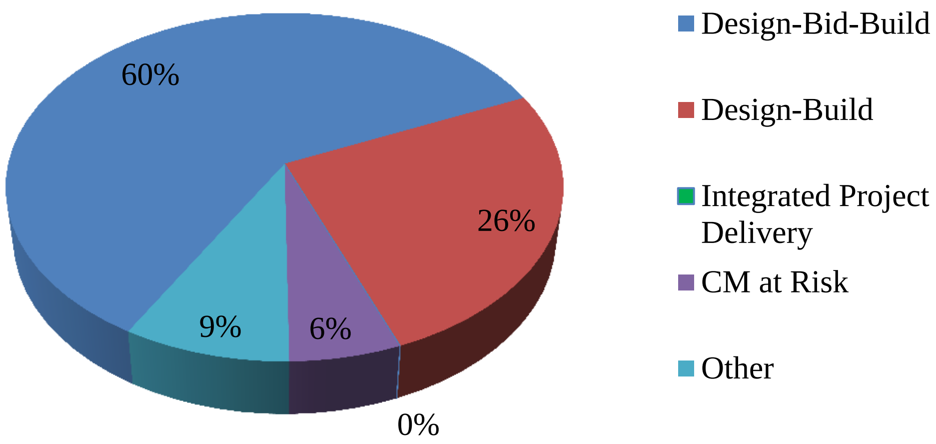

Figure 12 Project Delivery Method

5.1.4 Selecting the Planning Method and Software Responsibility

Figure (13) shows that just 17% of the respondents agreed that selecting the planning method is one of the contractor responsibilities, whereas 43% assumed that the client is the one who is responsible to select the planning method. On the other hand, 34% of the respondents thought that the project manager should decide on the used method.

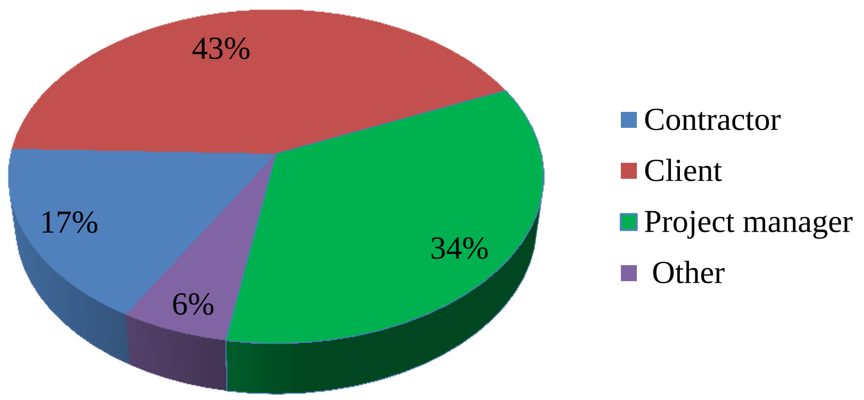

Figure 13 Selecting the Planning Method and Software Responsibility

5.1.5 Construction Planning Method

Figure 14 and table 3 demonstrate the construction planning method used by respondents. All of the respondents (100%) used Critical Path Method (CPM) as main planning method. In contrast, 80% of respondents did not know the 4D Modeling.

	Not used		Occasionally		Always		Unknown	
	f	%	f	%	f	%	f	%
Simple Bar Chart	23	66%	12	34%	0	0%	0	0%
Critical Path Method (CPM)	0	0%	0	0%	35	100%	0	0%
Line of Balance	22	63%	0	0%	0	0%	13	37%
To Do List	9	26%	26	74%	0	0%	0	0%
4D Modeling	7	20%	0	0%	0	0%	28	80%

Table 3 Construction Planning Method

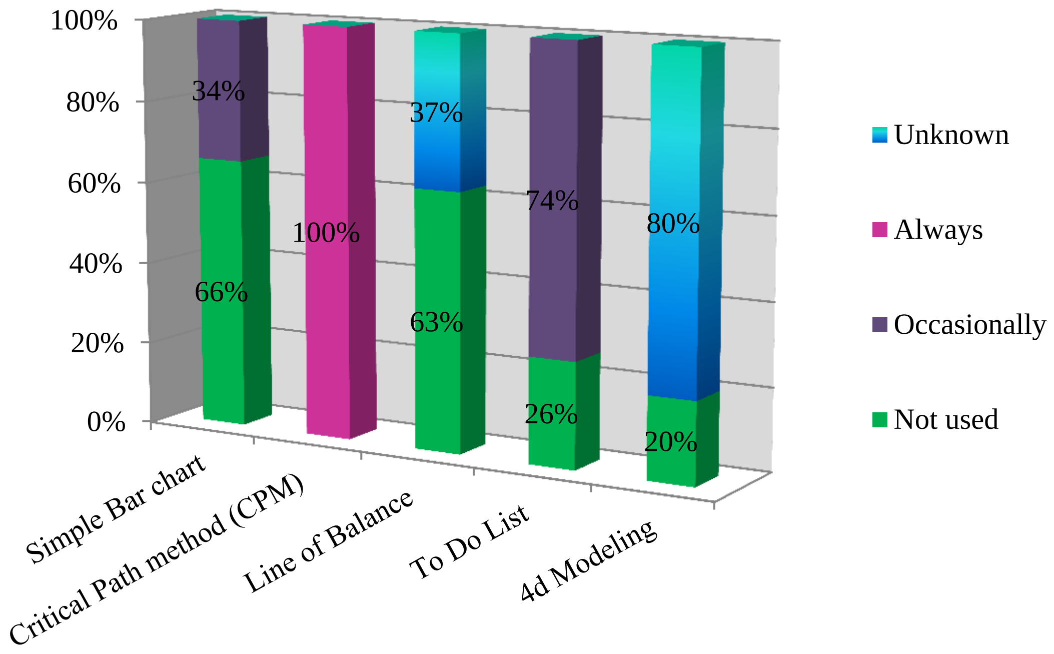

Figure 14 Construction Planning Method

5.1.6 Construction Planning Software

Figure 15 and table 4 demonstrate the construction planning software used by respondents. The majority of the respondents (89%) used Primavera as main planning software. In contrast, 86% and 91% of respondents have not any idea about Navisworks and Schedule Simulator (4D modeling software).

	Not used		Occasionally		Always		Unknown	
	f	%	f	%	f	%	f	%
Primavera	0	0%	4	11%	31	89%	0	0%
MS project	0	0%	10	29%	25	71%	0	0%
Naviswork	5	14%	0	0%	0	0%	30	86%
Synchro Professional	3	9%	0	0%	0	0%	32	91%
Other	5	14%	30	86%	0	0%	0	0%

Table 4 Construction Planning Software

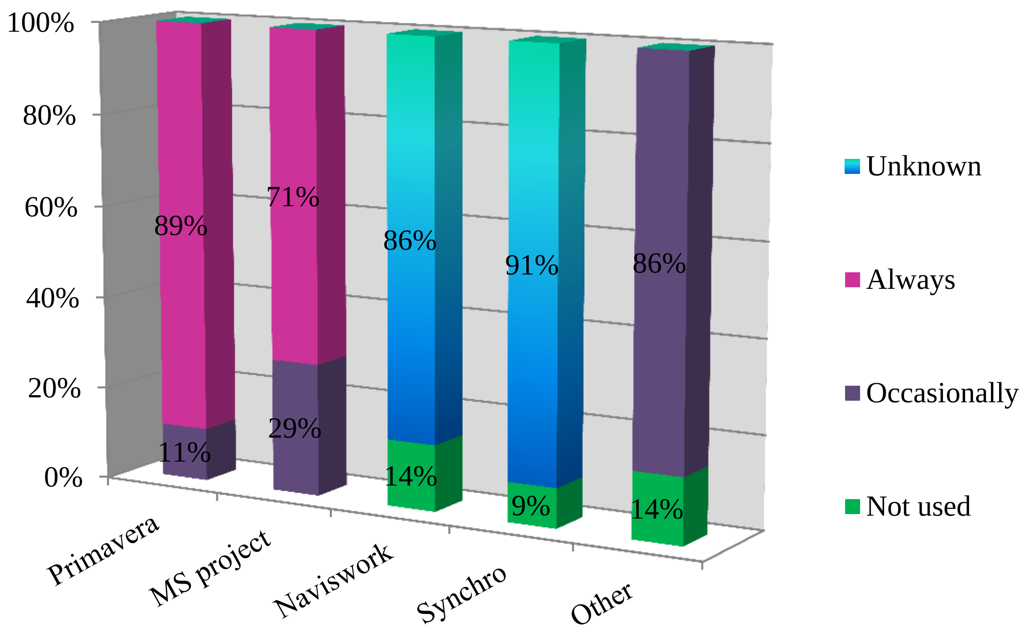

Figure 15 Construction Planning Software

5.1.7 Traditional Planning Approach Challenges

The analysis for this section will cover the evaluation of challenges and factors that have been asked in the questionnaire. In addition to that, these challenges have been discussed earlier in the literature review. Through the SPSS software, analysis was automatically done by inserting the data, and hence the analysis was then tabulated. The challenges were classified into four groups which are:

1) The Fragmented nature of the construction industry
2) The Dependency just on the personal experience
3) The construction planning method
4) The reliability of the construction documents

Level of Consideration		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Average Index	Description
Respondent's frequency		%	%	%	%	%		
The Fragmented nature of the construction industry	Sharing information with the contractor and sub-contractors during the design stage	57%	43%				4.57	Strongly agree
	The utter separation between the design and the construction stages	31%	60%	9%			4.23	Agree
Dependency just on the personal experience of the planner	Obtaining all the required information for scheduling purposes from the construction documents	57%	37%	6%			4.51	Strongly agree
	Estimating the activities durations	51%	43%	6%			4.46	Agree
	Selecting the construction method	43%	40%	11%	3%	3%	4.17	Agree
	Defining the construction activities sequence	20%	74%	6%			4.14	Agree
	Extracting the required information for scheduling purposes from the construction documents	37%	43%	14%	6%		4.11	Agree

Table 5 -1 Traditional Planning Approach Challenges

Level of Consideration		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Average Index	Description
Respondent's frequency		%	%	%	%	%		
The used construction planning method	Consider the constructability issues	66%	28%	6%			4.6	Strongly agree
	The disability to provide uninterrupted Usage of Resources	68%	26%	3%	3%		4.6	Strongly agree
	Disability to represent the spatial and temporal aspects of construction	51%	49%				4.51	Strongly agree
	Difficult to communicate the schedule to the project team and foremen	37%	54%	6%	3%		4.26	Agree
	Disregarding the spatial and resources constraints.	36%	46%	9%	9%		4.11	Agree
	The main concern is about activities and their relations	26%	60%	11%	3%		4.09	Agree
	Difficult to evaluate the construction plan	43%	28%	23%	6%		4.09	Agree
	Difficult to communicate the schedule to the client and other stakeholders	11%	54%	26%	9%		3.69	Agree
	Weakness to deal with repetitive projects	15%	46%	28%	11%		3.63	Agree

Table 6 -2 Traditional Planning Approach Challenges (Cont)

Level of Consideration		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Average Index	Description
Respondent's frequency		%	%	%	%	%		
The reliability of the construction documents	The reliability of bill of quantity BOQ documents	66%	28%	6%			4.6	Strongly agree
	The reliability of the construction drawings	23%	68%	6%	3%		4.11	Agree
	The Coordination between the design disciplines	34%	40%	23%	3%		4.06	Agree
	The level of detail of the construction drawings	22%	46%	26%	6%		3.86	Agree
	The availability of a 3D model of the building	19%	46%	26%	9%		3.77	Agree

Table 7 -3 Traditional Planning Approach Challenges (Cont)

5.2 Results Discussion

The data collected through the questionnaire survey has been analyzed and presented in section 5.1. Based on the analysis that have been made the following discussion are made:

From the results obtained from the survey, it was possible to create a clear image of the current planning approach. Most of the construction plans are prepared after the design stage is being completed as the most used project delivery method used is “Design-Bid-Build”.

The Critical Path Method could be classified as the main planning technique that has been used according to the respondents and the software that adopt the CPM concept (Primavera and MS Project) are the most used planning software. On the other hand, there is an evident absence of utilizing the 4D modeling technique through the respondents’ answers.

In this study, twenty one (21) possible challenges facing the preparation of better construction work schedule were investigated. These challenges were divided into four (4) main categories:

1) The Fragmented nature of the construction industry
2) The Dependency just on the personal experience
3) The construction planning method
4) The reliability of the construction documents

From the challenges listed, six (6) of them scored an average index between 4.50 to 5.00 rating scale, fifteen (15) have average index between 3.50 to 4.5 rating scale, and there is no one that has average index less than 3.5. This means that most of the respondents have fairly high degree of consideration of the situation of the traditional construction planning approach, the challenges faced and the limitation of the current construction planning methods and techniques.

Chapter6

Building the Model

Chapter 6 Building the Model

This chapter describes the process of building the sample model beginning with the 3D Building Information Model and the Presenting the 4D sample model.

6.1 Introduction

In order to investigate the contribution of Building Information Modeling to construction planning, a sample 4D Building Information Model created.

Creating the 4D model was developed

1.) Building the 3D model based on the 2D drawings using the BIM software

2.) And then developing the 4D model by linking the construction schedule to the 3D model.

6.2 Building the 3D Model

The 3D model was created based on the 2D drawings by using the BIM software Revit Architectural. The adopted method of transforming the 2D drawings into 3D BIM model consisted of several stages as following:

1. Setting up the project environment.

Setting up the project environment will assist in reducing errors, maintaining standards and keeping users working efficiently. There are several processes involved in setting up the project environment:

a. Developing a custom template:

Templates could offer a start point and contain many things that a normal project could have like the project information, project setting, lifestyles, line weights, projects views…etc. A pre-designed template was used to start up the project.

b. Setting the project information, parameters, units and precision display

Project information is data relating to a project that typically doesn't change. Project units are defined typically based on the project region and the traditional measurement units that are used. There are three disciplines of units: Common, Structural and Electrical. Metric units were selected to be used within the project.

c. Organizing the project browser
d. Transferring standards into the project

Some of standards were transferred from other project in order to reduce the required time for re-creating process.

2. Start modeling the project.

a. Importing plan layouts:

As the building CAD drawings are available, plan layouts were imported to be used as a platform to start modeling the project. Gridlines and levels were created.

b. Building the 3D model by using the Revit built-in elements and customized elements:

Elements in Revit are organized into categories, families, types and instances.

- Categories represent different parts of the building such as floors, walls, columns…etc.
- Each category contains different families. Column category may include round column family and rectangular column family for example. Families are also divided into components, in place, and system families.

- Within each family there are several types of the sane object. The rectangular column families could have several types based on each type dimensions, material and other type parameter.
- When a type is placed in a project it turned into an instance of a type. There could be two columns from the same type but the first is one-story column however the other is three-story column.

Modifying any type parameter would be reflected to the all instances of the same type whereas instance parameters affect only the selected instance.

During the modeling process, Revit built-in elements were used and new families were created, when needed, to meet the study requirement.

3. Modifying the model.

After the completion of building the 3D model, many modifications were performed to correct the errors during the modeling process.

4. Exporting the 3D Model to Naviswork.nwc File

Revit Architectural provides an excellent tool to export the 3D model directly to the Naviswork environment. This plug-in is installed within Naviswork installation process. Noting that it is not a standard export option but it was developed by Autodesk to save the 3D model as Naviswork.nwc in order to open the file directly by Naviswork software. This tool provides many options for exporting the model.

5. Static Clashes Detections

Clash detective is a tool provided by Naviswork software that allows for effective inspection and reporting interfaces in the 3D model. This tool could assist in reducing the human errors during the 3D modeling process and it also used as a checking tool to test the completion and coordination of the design.

A total 214 clashes were found during the static clash detection process, some of them were design related and the others were model related. Naviswork provides reports which contain information about the clashes statuses and the clashed elements IDs.

6.3 Developing the 4D Model

Presenting and linking the 3D model to the time schedule was divided into several steps. Figure 11 shows the overall process of presenting and linking the 4D model.

1. Developing and Linking the Time Schedule

The time schedule could be established with the TimeLiner tools within the Navisworks environment, or it could be separately developed by different planning software and then linked to the Navisworks Model.

Autodesk Navisworks supports a variety of scheduling software like Primavera planning software and Microsoft Project.

In this study, the time schedule was developed independently by Primavera project manager P6. A direct link between Primavera and Navisworks was established in order to achieve a direct access to the activities from the TimeLiner tool. This direct link allows the schedule to be updated once it is updated from Primavera software which provides more flexibility for the schedule tracking changes.

2. Creating the Task Types

Each task in the schedule needs to be associated with a ‘Task Type’, which specifies how the 3D objects attached to the task are treated (and displayed) at the start, the end of the task and during the duration of the task. Therefore, a number of ‘Task Types’ need to be defined for each 4D simulation.

Navisworks allows creating new Task Types supported by multiple colors to achieve more understandable construction simulation.

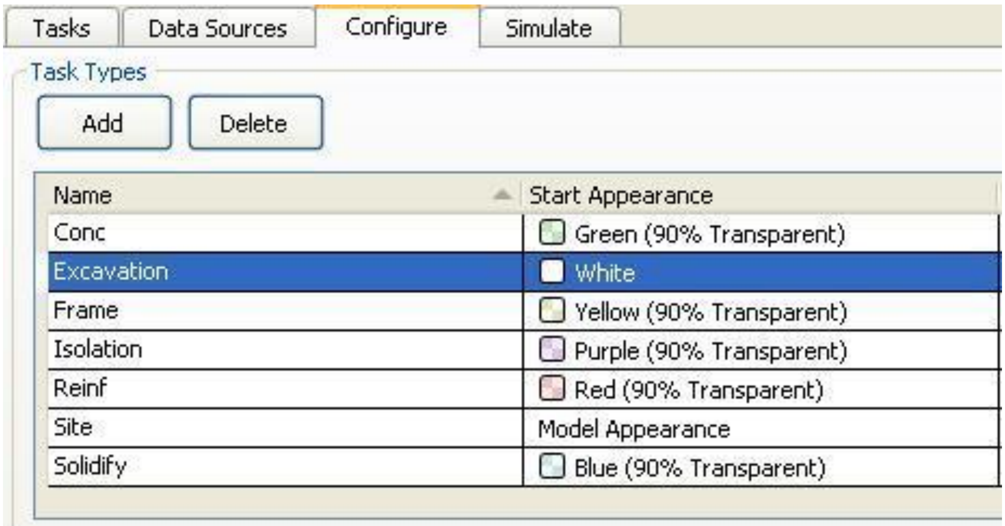

Figure 16 Task Types

3. Creating the Selection Set Structure

It is common to develop a suitable ‘Selection Set’ Structure that represents the same Work Breakdown Structure WBS of the time schedule to ease attaching the geometry elements to the schedule activities.

‘Selection Set’ Structure was created according the levels of the schedule WBS.

4. Creating 'Selection Sets' with Respective Geometry for 'Tasks'

After the 'Selection Set' folder structure representing the WBS structure of the schedule has been created, the next step was to create 'Selection Sets' that contain the 3D geometry items that correspond to the 'Tasks' in the schedule. The respective 3D geometry that needs to be represented with each tasks needs to be selected first.

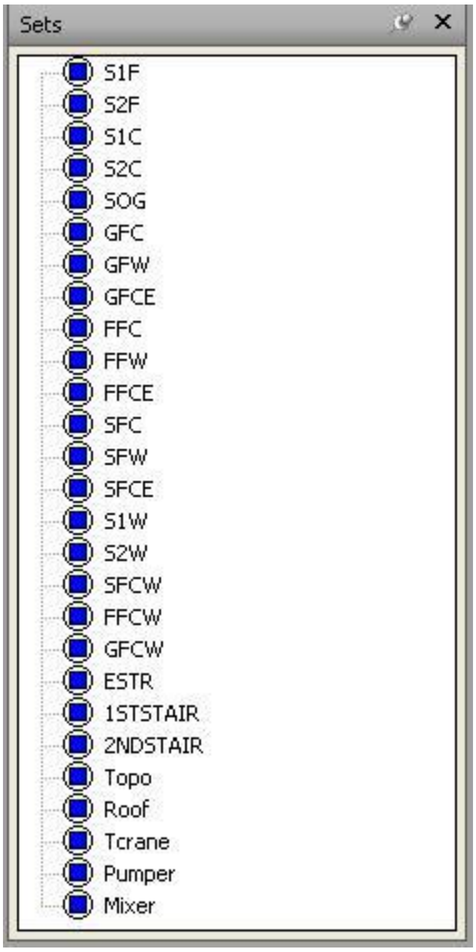

Figure 17 Created Selection Sets

5. Linking 'Selection Sets' with 'Tasks'

The linking process could be automated by adding a unique column in the time schedule that complied with the geometry selection sets. This automated process reduces the required time to attach the tasks in the time schedule to the model elements and minimize the human errors during the linking process.

6. Creating ‘Viewpoints’ that Show the Construction Sequences and setting the Simulation Settings

After the ‘master’ 4D model has been created that links the schedule activities to 3D geometry, in a next step several ‘4D scenarios’ should to be created. One of the scenarios shows an overview over the whole construction project and several scenarios show in details several important construction sequences. The overall play back duration and the Start and End dates of the simulation could be modified to produce an understood simulation.

Chapter7

4D BIM Contribution

Chapter 7 The Contribution of Building Information Modeling to Construction Planning

This chapter demonstrates the findings of the research based on developing a sample 4D Building Information Model and disuses the opportunities of adopting the BIM based scheduling methodology. Section 5 dealt with the questionnaire survey analysis and section 6 explained the process of creating the 3D model and developing the 4D model.

7.1 Introduction

The Sample 4D Building Information Modeling was introduced to a group of construction personnel in Go Green Syria Company in order to validate the contribution of building information modeling to construction planning and .

The feedback was recorded as following: There are six major benefits of BIM based scheduling approach for construction planning. They were identified after developing a sample 4D building information model

7.2 Benefits of Adopting BIM Based Scheduling Approach

The six major benefits of BIM based scheduling approach for construction planning identified after developing a sample 4D building information model

7.2.1 Improving the Construction Works Visualization

One of the most significant benefits of 4D building information modeling is that it improves the construction work visualization and provides a better presentation of the construction schedule more than could be done by 2D drawings and documents such as Gantt chart. The advanced visualization assists the planner to select the most appropriate construction method statement by developing several construction scenarios and choose the most applicable one.

With the usage of 4D building information modeling, the planners and construction managers do not have to imagine the construction process in their minds while the construction activities sequence and their relations can be simulated to check the authenticity of the schedule and to enhance the planning process.

By using the traditional methods of planning like CPM, it is very possible to miss some activities during the planning process in the construction plan due to lack of visualization provided by such planning methods. Whereas, 4D building information modeling provides a very effective tool to visualize the construction works and identify all the possible construction activities leading to an accurate and detailed work plan and play a major role in evaluating the compatibility of the construction plan.

7.2.2 Planning Professionally

4D building information modeling enables the planners and project teams to achieve a very effective and efficient planning of construction works.

BIM could be used for constructability analysis and design consistency check in order to eliminate unpredicted problems and reduce rework during the construction phase. This will lead to improve the reliability of the construction plan and increase the percentage of the activities that start and finish on time.

4D building information modeling also assists the planners in allocating resource in order to utilize minimum resources in the construction phase with maximum benefits and in minimum time.

7.2.3 Reliable construction documents

With the overload of the traditional construction documents including the complete set of 2D drawing covering all the design disciplines, specifications and BOQ documents, it is a quite difficult mission to obtain all the required information for the planning process form those documents. Building information modeling provides the construction team with full support of producing an organized, reliable construction documents.

7.2.4 Improving Communication

4D building information modeling provides an effective tool among different project stakeholders. Project communication based on the traditional 2D documents and drawings can lead to misunderstanding as they do not provide a clear picture of the construction project.

With 4D building information modeling, construction teams including the client, contractor and subcontractors, can successfully understand the project details and the overall sequence of the construction works.

7.2.5 Construction Site Planning

Construction works face several kinds of physical and logistical constraints (i.e. site accesses, storage areas and temporal structures) which is difficult to represent by the traditional scheduling methods.

4D building information modeling enables the planner to manage and plan the storage areas and the access to them more efficiently with the aid of better visualization of the construction site.

The modeling of the temporary structure including tower crane, concrete mixers and pumpers provides enhanced understanding of the construction works sequence and lead to more efficient construction plan.

7.2.6 Static and Dynamic Clash Detection

Entire BIM models can be checked for static and dynamic interferences and clashes. 4D building information modeling enables planners to detect the expected conflicts and clashes in the construction phase during the planning process.

As observed in the mock up 4D model, there were 214 static clashes. They were detected during the 3D modeling process.

Three types of dynamics clashes are detected by using Navisworks software. They are time-based clashes, soft clashes and time-based soft clashes.

- **Time-based clashes**

Project models can include a static representation of temporary items, such as work packages, ships, cranes, installations, and so on. Such static objects can be added into the TimeLiner project, and scheduled to appear and disappear at particular locations, over specific period of time. As these static package objects move within the project site, based on the TimeLiner schedule, it is possible that some static package objects could, at some point in the schedule, take up the same space, that is 'clash'.

- **Soft clashes**

The Animator window to create animation scenes with the temporary items in the construction site, so that they will be moving around a project site, or change their size, and so on. It is possible that some moving objects could bang into each other.

- **Time-based soft clashes**

Time-based soft clashes are combination of time-based clashes soft clashes.

Chapter8

Conclusion and Recommendations

Chapter 8 Conclusion and Recommendations

Based on the preceding chapters, this chapter encloses the most important conclusions of the thesis. Moreover, suggestions for further research on this topic will be proposed.

8.1 Conclusions

There are two objectives of this study which have been achieved. The first objective is to analyze the problems and challenges faced by the construction practitioners in current project planning and scheduling practice, and to identify and assess the benefits of utilizing building information modeling in order to improve the traditional construction planning approach.

8.1.1 The Challenges Faced by the Current Construction Planning Approach

The first objective of the study has been successfully identified. A total of twenty one challenges were classified under four groups; the Fragmented nature of the construction industry; the Dependency just on the personal experience; the construction planning method; the reliability of the construction documents. Analysis of the data showed that there is a total agreement that the traditional construction planning approach is facing many serious challenges and there is an essential need to improve the current construction planning practice in order to produce better, efficient and more realistic construction plans.

8.1.2 4D Building Information Modeling for Construction Planning

The study investigated the contribution of building information modeling to the current construction planning practice. There are many positive impacts of utilizing BIM in the construction planning process discovered which are not possible to be achieved through traditional planning methods being used. The most significant benefits of 4D building information modeling are found out to be better visualization of construction work, better communication among project teams and increased planning efficiency. In addition, 4D building information modeling assists in achieving detailed and accurate work plans, planning of temporary structures, quantity takeoffs and managing site logistics.

With the help of better visualization and communication, the planners, project team and client can achieve a better understanding of the project scope and objectives, which can improve the construction planning and execution process significantly.. Implementing 4D building information modeling allows planners to detect the problems prior to construction phase which lead to reduction in the amount of rework and clashes. Therefore, a more reliable and detailed work plan can be obtained which assists the project to complete within prescribed time and budget.

With the absence of the 4D building information modeling concept within the Syrian construction market as per the results from the conducted survey, it is recommended that 4D building information modeling should be widely adopted into construction industry. Implementing 4D building information modeling technology could be promising development for construction firms and could help mitigating the most common challenges faced in the construction projects with efficient planning.

8.2 Recommendations for Further Research

After conducting this study, it has been shown that 4D building information modeling is advantageous for the construction planning process.

.In future research, the validity and reliability of the study could be increased by applying the 4D building information modeling technology on a real construction project in the Syrian market.

Furthermore, the building information modeling technology and its contribution to the different aspects of the construction industry including cost and procurement could be a rich subject for many researches.

References

1. Abd. Majid, M.Z., and Mc Caffer, R. (1997). “Assessment of Work Performance of Maintenance Contractors in Saudi Arabia”. Journal of Management in Engineering, ASCE, Vol. 17.
2. Akinci, B., Fischer, M., and Kunz, J. “Automated Generation of work spaces required by construction activities.” Journal of Construction Engineering and Management. 6 (2), pp. 124-135, 2002.
3. Ali Mohammed Alashwal, Hamzah Abdul Rahman and Abdul Mutalib Beksin. (2011). “Knowledge sharing in a fragmented construction industry: On the hindsight”. Scientific Research and Essays Vol. 6(7), pp. 1530-1536, 4 April, 2011.
4. Allen, C., and Smallwood, J. (2008). “Improving construction planning through 4D planning.” Journal of Engineering, Design and Technology, 6 (1), 720.
5. Aranda-Mena, G., Crawford, J., Chevez, A amd Froese, T. (2008). "Building information modeling demystified: does it make business sense to adopt BIM?", CIB W78 International Conference on Information Technology in Construction Santiago, Chile.
6. Azhar, S., Hein, M., and Sketo, B. (2008). “Building information modeling: Benefits, risks and challenges.” Proc., 44th Associated Schools of Construction National Conference.
7. Chua, D. K. H., Jun, S. J. & Hwee, B. S. (1999) Integrated production scheduler for construction look-ahead planning. 7th Annual Conference of the International Group for Lean Construction. Berkeley, California, USA.
8. Coyne, Kevin T. (2008). “Leveraging the power of 4D models for analyzing and presenting CPM schedule delay analyses”, AACE International Transactions; p1, June 2008.
9. Dawood, N. N., Sriprasert, E. & Mallasi, Z. (2002), Development of an integrated information resource base for 4D/VR construction processes simulation, Automation in construction journal, 12(2), 123–33.
10. Dawood, N., and Sikka, S. (2009), “Development of 4D based performance indicators in construction industry”, Engineering, Construction and Architectural Management, Vol. 16 No. 5, 2009 pp. 438-458
11. Eastman, Chuck, Paul Tiecholz, Rafael Sacks, and Kathleen Liston.(2008). BIM Handbook. New Jersey: John Wiley & Sons.
12. Eknarin Sriprasert and Nashwan Dawood. (2002). “Next generation of construction planning and control system: The Lewis approach”. Proceedings IGLC-10, Gramado, Brazil.

13. H.J. Wang, J.P. Zhang, K.W. Chau and M. Anson. (2004). “4D dynamic management for construction planning and resource utilization”. Automation in construction, 13, pp575- 589
14. Håkan Norberg and Thomas Olofsson. (2008). "A process model for construction synchronization using time-space planning methods and field force automation ", CIB W78 International Conference on Information Technology in Construction Santiago, Chile.
15. Harris, R.B. and Ioannou, P.G. "Scheduling projects with repeating activities." Journal of Construction Engineering and Management, ASCE, Vol. 124, No. 4, 269-278, July-August 1998.
16. Heesom, D., and Mahdjoubi, L. (2004). Trends of 4D CAD applications for construction planning. Construction management and economics, 22, 171–182.
17. Hendrickson, C. (2000). “Project management for construction fundamental concepts for owners, engineers, architects and builders.” Retrieved February 27, 2012, from http://pmbook.ce.cmu.edu/09_Construction_planning.html
18. Hijazi, Wissam; Alkass, Sabah; Zayed, Tarek. (2009). “Constructability assessment using BIM/4D CAD simulation model.” AACE International Transactions; pBIM.04.1.
19. James J. O’Brien, Fredric L. Plotnick, (2010). “CPM in Construction Management” Seventh ed. The McGraw-Hill.
20. Jianhua et al, (2010), Application and Popularizing of BIM Technology in Project Management, International Conference on E-Product E-Service and E-Entertainment (ICEEE).
21. Jongeling, R. and Olofsson, T. (2007). A method for planning of work-flow by combined use of location-based scheduling and 4D CAD. Automation in Construction Vol 16(2), pp. 189-198.
22. Josephson, P. E. & Hammarlund, Y. (1999) “The causes and costs of defects in construction: A study of seven building projects.” Automation in construction, 8, 681-687.
23. Kenley, R. (2004).”Project micromanagement: practical site planning and management of work flow." IGLC-12, 12th Con. of the Int. Group for Lean Construction, Helsingor, Denmark, 194-205.
24. Latham, M. (1994). “Constructing the Team” UK Govermennt, London, United Kingdom.
25. Martin E. M. (1996). A Professional's Guide to Systems Analysis, 2nd. Ed. McGraw Hill.
26. Messner, J.I. and Horman, M.J.(2003). "Using advanced visualization tools to improve construction education," Proceedings of CONVR 2003, Conference on Construction Applications of Virtual Reality, Blacksburg , VA , pp. 145-155.

27. Ming Lu and Heng Li. (2003). “Resource-activity critical-path method for construction planning”. Journal of construction engineering and management © ASCE. pp 412-420.
28. Min-Yuan Cheng, Ming-Hsiu Tsai, Zhi-Wei Xiao. (2005). “Construction management process reengineering: Organizational human resource planning for multiple projects” Automation in Construction. Vol (15). pp 785-699.
29. Monroe and R.M. Hutchins. (2006). Fundamentals Of Research Methodology And Statistics.
30. Olusegun O. Faniran, Peter E. D. Love and Heng Li. (1999). “Optimal allocation of construction planning resources” Journal of Construction Engineering and Management, Vol. 125, No. 5, September/October, 1999
31. Planning and Programming in Construction. (1991). Published by The Charted Institute of Building.
32. Reinhardt, Jan. (2009). " BIM Tools Matrix." The Contractor's Guide to BM.” 2nd ed. AGC of America. pp. 57-67.
33. Rolf Büchmann-Slorup, Niclas Andersson, (2010). ” BIM-based scheduling of construction – a comparative \ analysis of prevailing and BIM-based scheduling processes.” Proceedings of the CIB w78 : 27th International Conference –Cairo, Egypt, 16-18 November.
34. Russell Kenley and Olli Seppänen. (2009). “ Location-based management of construction projects: part of a new typology for project scheduling methodologies” Proceedings of the 2009 Winter Simulation Conference, 2563-2570
35. Scheduling Guide for Program Managers, (2001). Published by The Defense Systems Management College Press Fort Belvoir, VA 22060-5565.
36. Shamil Naoum. (2007).” Dissertation Research and Writing for Construction Students” 2nd ed.
37. Teicholz, E. (2004). “Bridging the AEC/FM technology gap.” IFMA Facility Management Journal, Apr/Mar 2004.
38. Tulke J., Hanff J. (2007). “4D construction sequence planning – new process and data model”, CIB W78, 24th Conference, Maribor.
39. Voordijk, H., de Haan, J. and Joosten, G.-J. (2000). “Changing governance of supply chains in the building industry: a multiple case study”. European Journal of Purchasing & Supply Management 6(3-4), pp. 217-225.
40. Wong, F.W.H., Lam, P.T.I., Chan, E.H.W., and Shen, L.Y. (2007). “A study of measure to improve constructability”. Int. Journal of Quality & Reliability Management, 24(6), 586-901.
41. Yamin, R.A., Harmelink, D.J. (2001). “Comparison of linear scheduling model (lsm) and critical path method (CPM)”. Journal of Construction Engineering and Manaqgement, Vol. 127, No. 5, pp. 374-381.

42. Z. J. Al-Najjar, Z.M. Saco and A.A. Al-Azzawi. (2004). “The impacts of production theories on construction planning efficiency.” Emirates Journal for Engineering Research. Vol 9.

BIM and construction planning

1. Job Title / Specialization:

2. Years of experience in the construction planning field:

- less than 3 years
- between 3 and 6 years
- more than 6 years

3. Generally, What type of project delivery method is used (contract type)?

- Design-Bid-Build
- Design-Build
- Integrated Project Delivery
- CM at Risk
- Other

4. Who is responsible for selecting the planning method and software?

- Contractor
- Client
- Project manager
- Other

5. How could you rank the following planning method based on its utilization in construction projects (if known)?

	not used	occasionally	always	unknown
Simple Bar chart				
Critical Path method (CPM)				
Line of Balance				
To Do List				
4d Modeling				

6. How could you rank the following planning software based on its utilization in construction projects (if known)?

	not used	occasionally	always	unknown
Primavera	○	○	○	○
MS project	○	○	○	○
Naviswork	○	○	○	○
Schedule Simulator	○	○	○	○
Other	○	○	○	○

7. The Fragmented nature of the construction industry could affect the efficiency of the construction plan within the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The utter separation between the design and the construction stages	○	○	○	○	○
Sharing information with the contractor and sub-contractors during the design stage	○	○	○	○	○

8. Dependency just on the personal experience of the planner could affect the efficiency of the construction plan within the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Selecting the construction method	○	○	○	○	○
Estimating the activities durations	○	○	○	○	○
Construction activities sequence	○	○	○	○	○
Extracting the required information for scheduling purposes from the construction documents	○	○	○	○	○
Obtaining all the required information for scheduling purposes from the construction documents	○	○	○	○	○

9. The used construction planning method could affect the efficiency of the construction plan within the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Interrupted Usage of Resources	○	○	○	○	○
The main concern is about activities and their relations	○	○	○	○	○
Disregarding the spatial and resources constraints.	○	○	○	○	○
Disability to represent the spatial and temporal aspects of construction	○	○	○	○	○
Difficult to evaluate the construction plan	○	○	○	○	○
Difficult to communicate the schedule to the client and other stakeholders	○	○	○	○	○
Difficult to communicate the schedule to the project team and foremen	○	○	○	○	○
Weakness to deal with repetitive projects	○	○	○	○	○

10. The reliability of the construction documents could affect the efficiency of the construction plan within the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The reliability of bill of quantity BOQ documents	○	○	○	○	○
The reliability of the construction drawings	○	○	○	○	○
The level of detail of the construction drawings	○	○	○	○	○
The Coordination between the design disciplines	○	○	○	○	○
The availability of a 3D model of the building	○	○	○	○	○

Ministry of Higher Education & Scientific Research
Jordan University of Science and Technology

Jordan Journal of Civil Engineering

An International Refereed and Indexed Research Journal

Irbid,
1st Jul. 2014

Dear *Eng.* Modar Saad
I am very pleased to inform you that your paper entitled:

Suggested Solution to Improve the Traditional Construction Planning Approach

has been accepted for publication and it will appear in the coming issues of the *Jordan Journal of Civil Engineering, (Vol. 9, No.2, 2015)*.

Thank you again for your contribution to the Jordan Journal of Civil Engineering (JJCE).

With best regards,

Jordan Journal of Civil Engineering
Editor-in- Chief
Fouad Gharaybeh

Prof.Fouad Gharaybeh

Issued by: The Scientific Research Fund, Ministry of Higher Education & Scientific Research, Amman-Jordan
Published By: Deanship of Research, Jordan University of Science and Technology, Irbid 22110, Jordan

Tel. (962-2) 7201000 Ext. 22104, Fax. 0096227201073, P.O.Box, 3030, Irbi