

A Suggested Solution to Improve the Traditional Construction Planning Approach

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ABSTRACT

Construction Project Planning, as one of the key processes in the project lifecycle, shapes the empirical foundation of the project success and plays a primary role in optimizing and managing construction operation. Dependence on the traditional techniques and documents in construction planning and scheduling still faces numerous difficulties and obstacles.

Recently, research efforts have tried to enhance planning capabilities with improved and even new methods and techniques.

This paper reviews the current planning techniques utilized in the construction industry, inspects the current construction planning approach challenges and suggests an integrated solution for better construction plans.

This research paper is divided into three main stages. In the first stage, a comprehensive literature review was conducted to identify the construction planning processes, construction planning techniques and the major limitations and challenges facing the current planning process. Then, a survey was carried out in order to verify the construction planning challenges found throughout the literature review. Based on the extracted facts from the survey, the suggestions were introduced as an integrated approach starting from adopting new project delivery methods toward using improved planning techniques.

KEYWORDS: Construction planning, Building Information Modeling (BIM), 4-D modeling.

INTRODUCTION

The construction planning process is considered as the most substantial part of construction management (Najjar et al., 2004). Preparing appropriate construction plans is one of the most important experiments within the construction industry. The traditional planning approach still faces several challenges, including the fragmentation nature of the construction industry and the dependence on

the traditional planning techniques which have proven a disability to deal with the spatial constraints in the construction site and to communicate the construction plan effectively among the construction team (Sriprasert and Dawood, 2004). Planners have to rely on their imagination and experience to explore the construction sequence and come up with an appropriate construction method. Therefore, there is an essential necessity to have high planning capabilities form the broad activity to the detailed one in order to deal with all changes occurring

through the construction project cycle. Many researches have been carried out in order to categorize construction planning problems, challenges and possible methods to improve/optimize planning processes.

This research aims to:

- 1- Study the current construction planning approach and its techniques.
- 2- Define the limitations and challenges of the current planning processes and techniques.
- 3- Highlight the areas which need to be improved and recommend a supportive technology to enhance the construction planning.
- 4- Introduce an integrated approach to improve the planning process in order to produce more qualified construction plans.

Traditional Construction Planning Techniques

Planning techniques could be classified according to the basis of each. As indicated by Kenley and Seppanen (2005), there are two types of planning techniques: 1) Location-based planning techniques. 2) Activity-based planning techniques.

1- Location-based Planning Techniques

As the construction project is characterized by continuous work where construction activities are performed in different locations of a building, construction schedules appear to be a group of repetitive activities. Liner scheduling methods have proven to be a successful scheduling technique of a project with repetitive nature. Adopting liner scheduling method could assist in ensuring the uninterrupted usage of construction resources in order to improve the resource performance and productivity. Schedules prepared by such techniques are represented graphically as a series of production lines with each line representing a repetitive activity.

2- Activity-based Planning Techniques

These techniques rely on the construction of a network of activities and relationships in three forms; activities on arrows, activities on nodes and logical

dependency constraints (Dawson and Dawson, 1995).

The Critical Path Method (CPM), as an activity-based planning technique, is a common technique for analyzing and managing task sequences in construction projects. Based on calculating how long it takes to complete essential activities and analyzing how those activities are interrelated with each other, CPM provides a visual and mathematical technique to plan, analyze, schedule and monitor construction projects.

Traditional Planning Approach Challenges

Proceeding from the fact that the planning process can be considered the backbone of construction management, improving the credibility of planning is necessary in order to achieve stable construction flow, high productivity and improved quality (Chua et al., 1999).

Therefore, there is a real need to determine limitations of current planning techniques and the challenges facing their capabilities.

1. Fragmented Nature of the Construction Industry and the Traditional Building Process

The construction industry is a fragmented industry (Alashwal et al., 2011). The construction project is divided into various disciplines, parties and stakeholders working separately most of the time. Through the traditional Design-Bid-Build, the project is designed separately from the parties actually constructing the project (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.

The project delivery process within the construction industry depends mainly on paper-based communications (Arnorsson, 2012). Therefore, any errors or conflicts 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.

2. Applying Constructability Concept

Constructability as 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” (Construction Industry Institute, 1986).

The achievement of a good constructability depends on both of the designer and builder. Thus, implementing the constructability concept requires a continuous integration of knowledge and experience of the construction project parties; i.e., the designer, contractors and subcontractors. Applying constructability has a great impact in minimizing the gap between the design and the 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 planners to consider constructability issues during the preconstruction planning stage (Dawood et al., 2006).

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 an understanding of the design considerations. Selecting the most proper construction method is one of the most important decisions requiring a lot of personal experience to be made correctly (Tulke et al., 2008). Büchmann and Andersson (2010) stated that producing construction plans depends basically on the personal experience of the planner and the construction manager rather than standards and well-founded figures. Planners and construction managers have to imagine the construction process in their minds during the preparation process of the construction plans. The overload of the construction documents, including the 2-D drawings, specifications, bill of quantity

documents, produces serious difficulties to understand the project characteristics and extract the required information for scheduling purpose (Büchmann and Andersson, 2010).

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 (O’Brien and Plotnick, 2006). Defining the major limitations and challenges facing the Critical Path Method was a very important subject for numerous investigations and researches in order to achieve a development in the construction planning field. Most of those challenges could be categorized as follows:

I. The Interrupted Usage of Resources

Many contractors require ensuring the continuous usage of resources during 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 and Ioannou, 1998). 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. Ignoring the activities flow would consequently lead to inability to succeed in managing the construction resources (materials, equipment, labor) which is one of the most important elements in the planning process (Najjar et al., 2004). The guarantee of the uninterrupted usage of the construction resources, especially labor, would improve the performance and the productivity of such resources.

II. The Spatial Conflicts

Construction spaces are classified into three categories: resource spaces, topology spaces and process spaces (Akinici et al., 2002). Usually during the preconstruction planning processes, the main concerns are all about the construction durations and construction activities constrains related to time,

regardless the spatial constraints (Sriprasert and Dawood, 2002). 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.

III. Schedule Evaluation and Communication

Many construction schedules have numerous contraries which are difficult to be found out, and the only ones having been detected are during the execution stage (Huhnt, 2006). Although CPM technique has been widely adopted throughout the construction industry, having full understanding of the construction plan from reviewing the CPM schedule was easier said than done even to the civil and architectural engineering students (Messener and Horman, 2003). It has been proven that it is difficult to evaluate and communicate the CPM schedules among construction project participants (Huhnt, 2006).

IV. Repetitive Construction Project

In repetitive projects, the network diagram for x units will be established for one unit and then repeated x times and linked together, which will result in a huge network with a great number of activities. Although CPM technique has a remarkable effect on complex projects, it has been doubtlessly shown that CPM has limitations when applied to projects with repetitive activities such as roads and high rise building projects (Yamin and Harmelink, 2002). 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.

V. The Usage of Buffer Time

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

PRACTICAL STUDY

Data Collection and Analysis

In order to verify the construction planning challenges found within the literature review, a questionnaire was designed consisting of two parts:

The first part aimed to collect general information about the respondent's experience and the current planning approach including the planning methods and software.

The second part aimed to seek the respondent's agreement on the derived facts from the previous review of the construction planning approach challenges and their impacts on the construction plan.

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

Respondents were asked to report their agreement on a 5- point Likert scale. For each question, the respondents were asked whether, and how strongly, they agree or disagree to each question using a point rating scale.

Table 1. The Respondents' Experience in the Construction Planning Filed

Position	Frequency	Percentage
Planning engineer	26	74%
Construction manager	3	9%
Contract manager	1	3%
Site manager	1	3%
Project engineer	4	11%

Table 2. Years of experience in the construction planning field

Years of experience	Frequency	Percentage
Less than three years	4	11%
Between 3 and 6 years	20	57%
More than 6 years	11	32%

Table 1 shows a record of the respondents' experience in the construction planning filed.

Table 2 shows the percentage of the respondents participating in the survey according to their experience in the construction planning field.

Table 3. The commonly used project delivery method

Project delivery method	Frequency	Percentage
Design-Bid-Build	21	60%
Design-Build	9	26%
Integrated Project Delivery	0	0%
CM at Risk	2	6%
Other	3	9%

As shown in Table 3, Design-Bid-Build was ranked as the common project delivery method that has been used within the construction projects, whereas the Design-Build method was ranked as the second one.

Figure (1) shows that 17% of the respondents agreed that selecting the planning method is one of the contractor's responsibilities, whereas 43% assumed that the client is the one who is responsible of selecting the planning method. Just 34% of the respondents thought that the project manager shall decide on the used method.

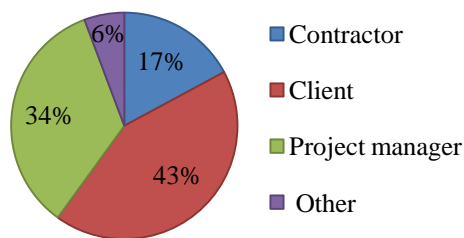


Figure (1): Planning method selection

Critical Path Method CPM has been chosen as the most utilized planning method within the construction projects (100% of the respondents agreed that they always use the CPM for construction planning). 4-D Modeling has not been used in construction planning within the

studied sample. Figure (2) illustrates the ranking of the planning methods based on their utilization.

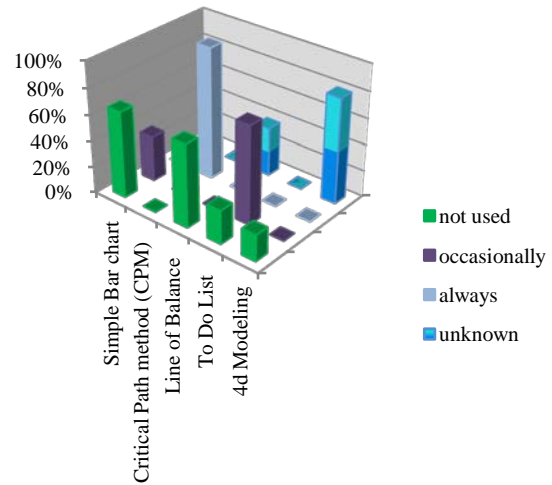


Figure (2): Planning methods ranking

Based on the extensive usage of the CPM, it has been shown that Primavera and MS project software have been widely used. On the other hand, the software adopting the 4-D modeling concept has been classified as not used or unknown software. Figure (3) shows the ranking of the planning software based on their utilization.

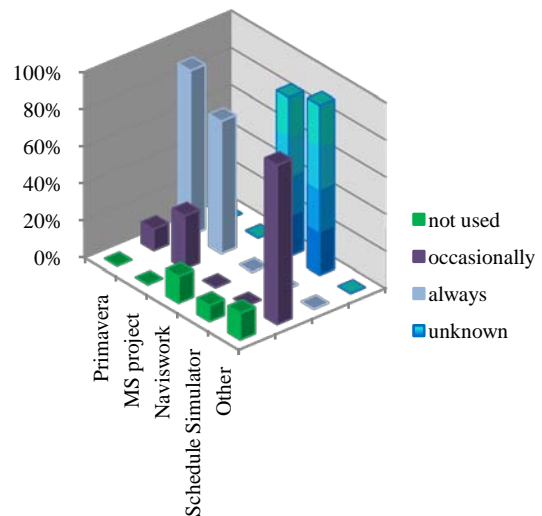


Figure (3): Planning software ranking

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

Average Index Formula:

$$\text{Average Index} = \frac{\sum \mu X_n}{N}$$

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

n = Frequency of the respondents;

N = Total number of the respondents.

The application of the Average Index in the

questionnaire would be for instance:

$\mu_1 = 1$; frequency of “Strongly Disagree” response.

$\mu_2 = 2$; frequency of “Disagree” response.

$\mu_3 = 3$; frequency of “Neither agree nor disagree/neutral” response.

$\mu_4 = 4$; frequency of “Agree” response.

$\mu_5 = 5$; frequency of “Strongly Agree” response.

With the rating scale as shown below (Abd Al-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).

Table 4. The Traditional planning approach challenges classification

Level of Consideration		Strongly agree		Agree		Neutral		Disagree		Strongly disagree		Average Index	Rating	Description
		%	f	%	f	%	f	%	f	%	f			
The fragmented nature of the construction industry	The utter separation between the design and the construction stages	28%	10	60%	21	9%	3	3%	1	0%	0	4.14	4	Agree
	Sharing information with the contractor and sub-contractors during the design stage	51%	18	43%	15	6%	2	0%	0	0%	0	4.46	4	Agree
Dependency just on the personal experience of the planner	Selecting the construction method	43%	15	40%	14	11%	4	3%	1	3%	1	4.17	4	Agree
	Estimating the activities durations	51%	18	43%	15	6%	2	0%	0	0%	0	4.46	4	Agree
	Defining the construction activities sequence	14%	5	74%	26	6%	2	6%	2	0%	0	3.97	4	Agree
	Extracting the required information for scheduling purposes from the construction documents	20%	7	43%	15	31%	11	6%	2	0%		3.77	4	Agree
	Obtaining all the required information for scheduling purposes from the construction documents	48%	17	37%	13	9%	3	6%	2	0%		4.29	4	Agree

The used construction planning method	The disability to provide uninterrupted usage of resources	69%	24	11%	4	14%	5	6%	2	0%		4.43	4	Agree
	The main concern is about activities and their relations	26%	9	60%	21	11%	4	3%	1	0%		4.09	4	Agree
	Disregarding the spatial and resources constraints	36%	13	46%	16	9%	3	9%	3	0%		4.11	4	Agree
	Disability to represent the spatial and temporal aspects of construction	20%	7	77%	27	3%	1	0%		0%		4.17	4	Agree
	Difficulty to evaluate the construction plan	43%	15	28%	10	23%	8	6%	2	0%		4.09	4	Agree
	Difficulty to communicate the schedule to the client and other stakeholders	11%	4	54%	19	26%	9	9%	3	0%	0	3.69	4	Agree
	Difficulty to communicate the schedule to the project team and foremen	37%	13	54%	19	6%	2	3%	1	0%		4.26	4	Agree
	Weakness to deal with repetitive projects	14%	5	46%	16	28%	10	11%	4	0%	0	3.63	4	Agree
The reliability of the construction documents	The reliability of bill of quantity BOQ documents	66%	23	28%	10	6%	2	0%	0	0%	0	4.6	5	Strongly agree
	The reliability of the construction drawings	23%	8	68%	24	6%	2	3%	1	0%	0	4.11	4	Agree
	The level of detail of the construction drawings	22%	8	46%	16	26%	9	6%	2	0%		3.86	4	Agree
	The coordination between the design disciplines	34%	12	40%	14	23%	8	3%	1	0%		4.06	4	Agree
	The availability of a 3-D model of the building	17%	6	46%	16	26%	9	9%	3	3%	1	3.66	4	Agree

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

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

The Proposed Integrated Solution

As in Table 4, there were an explicit agreement that

the traditional construction planning approach is faced by several challenges.

Based on the found facts in Table 4, suggestions were developed to produce an integrated solution in order to improve the traditional planning approach.

1. Moving toward the BIM- Based Scheduling

BIM (Building Information Modeling) is defined as a “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” (The National Building Information Modeling Standards, 2007).

Building information modeling has the capacity to comprise all construction documents, which facilitates construction managers' responsibilities, detects errors and avoids extra costs resulting from such errors.

Many studies have discussed the contribution of the

Virtual Reality (VR) in general and the BIM concept in particular for better visualizing 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, as well as cost estimation.

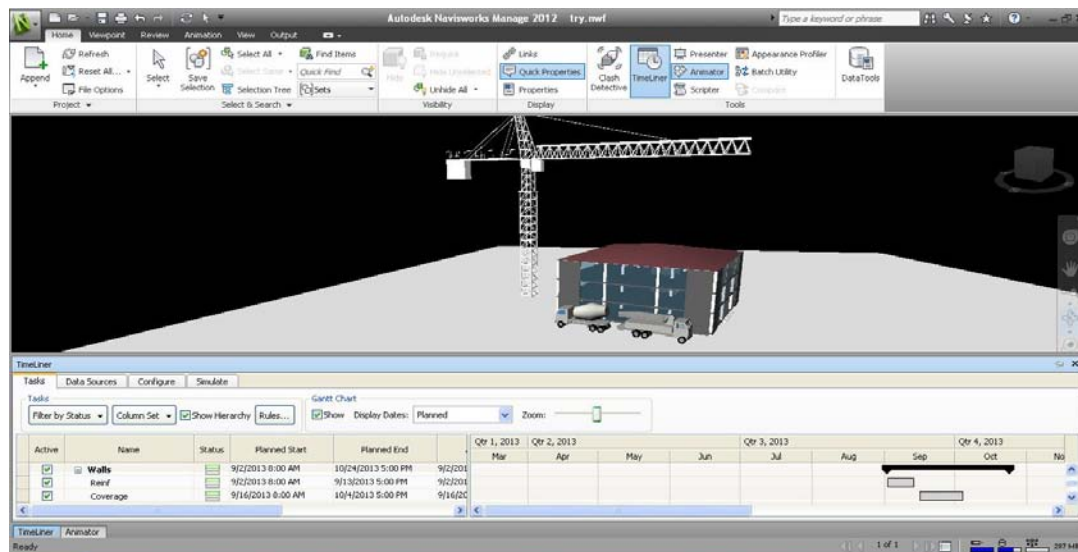


Figure (4): The 4-D model, autodesk navisworks

In CPM schedule, the listed activities are linked to each other with assigned duration and the longest path is defined as the 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 4-D modeling technique, as a construction planning technique, is the link between the objects in the 3-D model and the scheduled activities. Creating the 4-D model with specialized 4-D tools could enhance the production of the 4-D model and provide the planner with multiple options to build the 4-D model with particular specifications.

Building a 4-D Model

Building the 4-D model process depends on the

availability of the 3-D building information model and the purpose of building the 3-D model.

If the 3-D model has been created without taking in consideration the construction processes, some remodeling efforts will likely be required.

Assuming that the 3-D building information model was not being made, creating the 4-D model is developed through:

1. Building the 3-D model based on the 2-D drawings using the BIM software.
2. Establishing the 4-D model by linking the construction schedule to the 3-D model.

A. Creating the 3-D Model

The 3-D model was created based on the 2-D drawings by using the BIM software Revit

Architectural. The adopted method of transforming the 2-D drawings into a 3-D BIM model consisted of several stages as follows:

- 1) Setting up the project environment.
 - a) Developing a custom template.
 - b) Setting the project information, parameters, units and precision display.
 - c) Organizing the project browser.
 - d) Transferring standards into the project.
- 2) Modeling the project.
 - a) Importing plan layouts.
 - b) Building the 3-D model by using Revit built-in elements and customized elements.
- 3) Modifying the model.
- 4) Exporting the 3-D Model to Naviswork.nwc File.
- 5) Static Clashes Detection.

B. Presenting the 4-D Model

- 1) Developing and Linking the Time Schedule.
- 2) Creating the Task Types.
- 3) Creating the Selection Set Structure.
- 4) Creating 'Selection Sets' with Respective Geometry for 'Tasks'.
- 5) Linking 'Selection Sets' with 'Tasks'.
- 6) Creating 'Viewpoints' that Show the Construction Sequences and Setting the Simulation Settings.

4-D Building Information Modeling Benefits

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

I. Visualizing the Construction Process

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

single source. This visualization tool assists the construction manager in selecting the appropriate construction method, helps the planner to define the right consequence of the construction activities and provides the consultant with a powerful tool to evaluate the construction plan provided by the contractor.

II. Communicating of the Construction Plan

As mentioned previously, the construction project is divided into various disciplines, parties and stakeholders. Simulation production options allow project participants to view the planned construction, compare construction alternatives and review the actual status of the project (Jongeling et al., 2006). The outputs of the 4-D modeling process do not require a specific knowledge in the construction planning field to be understated which could assist in communicating the construction plan to the workers within the construction site. As a result, the 4-D model could reduce the time for communicating the schedule to the sub-contractors and enhance their feedback (Norberg and Olofsson, 2008).

III. Solving and Detecting Spatial Conflicts and Detecting Clashes

Using the BIM 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 is performed based on the 2-D 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 the light table (Eastman et al., 2011). On the other hand, utilizing the 4-D modeling technique gives support in detecting clashes resulting from the movement of the construction equipment within the construction site and assessing the temporal constrains of the construction resources.

IV. Improving Constructability

Implementing the constructability 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 they take place in reality. 4-D modeling based on BIM technology provides a helpful tool to figure out what will go wrong and go right before commencing the execution (Hijazi et al., 2009).

Aranda-Mena et al. (2008) found that BIM could improve the constructability of the design in compliance with its functionality.

V. Providing an Uninterrupted Usage of Resources

To increase the productivity in the construction site, it is important to ensure a continuous flow of the allocated resources. BIM-based scheduling facilitates preparing a suitable site layout to ease the movement of workers and other facilities.

Also, BIM-based scheduling supports the “What if scenarios” which is helpful in selecting the most appropriate construction method that ensures uninterrupted usage of resources.

VI. Creating a Consequential Data Base

Parametric modeling, adopted by the BIM software, allows creating standards for most of the construction objects like cost, installing duration, manufacture, resources needed... etc.

BIM assists in developing a reliable database for most of the construction elements which could be updated and used continuously.

Such standards could reduce human errors and provide a single source of data that could be used by the planner within the construction planning process.

VII. Creating Reliable Construction Documents

The complete building information model provides coordinated construction drawings and accurate quantities for most of the building elements including their counts and volumes. The specification and the pricing data could be linked to the building information model.

By linking the specification and pricing data to the building elements and developing an adequate bill of quantity, planners can produce a more credible estimation for the activity durations and required resources.

2. Adopting New Project Delivery Methods

Beside the traditional Design-Bid-Build delivery method, there is an emergence of some alternative methods in the construction industry field. The Integrated Project Delivery (IPD) method is used in construction projects to improve team efficiency and communication between the construction project core stakeholders including the owners, the design team and the contractors (The American Institute of Architects (AIA) and AIA California Council, 2007). The American Institute of Architects (AIA) defines IPD as “A project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and maximize efficiency through all phases of design, fabrication and construction” (The American Institute of Architects (AIA) and AIA California Council, 2007).

The selection of the project team in the integrated project delivery approach is a qualification-based selection which enhances the success chances of this approach (An owner’s guide to project delivery methods, 2012).

IPD provides a collaborative process that spans the design and construction, allows for early contribution of subcontractors and manufacturers in the master schedule which enhances the estimation of the construction activities durations and resources and eases the utilization of technological capabilities and supports.

RESULTS AND RECOMMENDATIONS

The results of the survey show that the traditional

planning approach including the planning techniques and processes faces several challenges which affect the efficiency of the construction plan.

The reliability of the construction documents has the most effective impacts on the construction plan, as it is considered the corner stone in the planning process. For example, the BOQ documents are used basically to estimate the construction activities durations and resources.

Also, the used planning technique has no less important impact on the construction plan. The CPM schedule does not provide enough information pertaining the spatial context and complexities of the project components. Different project members may develop inconsistent interpretations of the schedule when viewing the CPM schedule and 2-D drawings. This in turn makes effective communication among project participants difficult.

4-D modelling offers better visualization of the construction process and better communication among the project team assisting the client and the contractor in developing a better understanding of the project scope.

In summary, there are great advantages of adopting the 4-D modelling, based on BIM concept, which are not available in the traditional planning methods being used.

In order to seek the maximum benefits from applying the BIM in construction projects, it is necessary to adopt a new project delivery method, Integrated Project Delivery (IPD), in order to achieve more organization and govern the project team relationships.

When IPD and BIM are used in conjunction, the expectations for the project to be completed successfully are considerably increased.

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