BARRIERS TO BIM/4D IMPLEMENTATION IN QATAR

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Abstract. Gantt Charts have been used for decades as a tool for project planning and scheduling. However, they lack the desired output when it comes to schedule visualization. Building Information Modeling (BIM) has proven to be a very powerful design tool. BIM implementing firms are now investigating possibilities to expand the use of BIM to cover more aspects of projects. The first application of this would be construction planning and schedule development where design and construction come together for the first time. There is potentially much work needed to ensure appropriate people skills are in place to take advantage of BIM 4D capability. This paper's aim is to assess the level of awareness and experience of 4D planning and BIM in the Qatar construction industry as well as to identify possible challenges/barriers to widespread implementation. This assessment is achieved through a survey administered to industry professionals in Qatar. The survey identified and ranked 17 different barriers to BIM/4D implementation in Qatar.

1. Introduction

The Critical Path Method (CPM) in combination with conventional two-dimensional drawings have been the traditional tools used in the construction industry to analyze project design and plan for its construction. In the development process of producing schedules from a set of 2D drawings, construction planners require training as well as experience to interpret drawings and associate them with relevant construction activities precisely. Such a process is based on planners' ability to visualize drawings in the third dimension and interpret activity sequences in their mind. Complexities in current projects increase possibilities for even experienced planners to make mistakes in understanding designs, and that in turn leads to poor construction schedules. The next step would be to implement the planners' developed schedules for construction. Gantt charts have been the most commonly used method for visualization of CPM schedules for a considerable time. In addition, problems arise due to inadequate interpretation by technical and non-technical project stakeholders of the developed schedules and their ability to understand and visualize Gantt charts. Interpretation may differ from one person to another thus leading to conflicts and mistakes in execution of project schedules which leads to undesired performance and delays in projects. There is a lot of research that has investigated reasons for delay in different countries. The conducted studies identified ineffective planning and scheduling to be the most frequent cause of delay in developing countries (Al Sehaimi *et al.*, 2013). Shah *et al.* (2008) found from a survey that 29% of projects were delayed due to poor planning and scheduling.

Qatar has recently won the organization of the 2022 world cup. Consequently, massive development plans were announced in infrastructure, commercial, sports, as well as touristic sectors. The government of Qatar announced plans to spend 205 billion US dollars on various construction projects over the next five years (Reuters, 2014). With such enormous budgets and complex projects expected to meet the 2022 deadline, it is crucial that Qatar considers an improved and innovative planning and scheduling techniques to ensure the delivery of such complex projects in such a short time frame (GSDP, 2008).

2. Literature Review

The construction industry is often blamed for its inefficiency when compared to other industries; according to a study conducted by the National Institute of Building Science in the United States, government statistics shows that the non-farming manufacturing industries increased their productivity by almost double between 1964, and 2000, while construction industry productivity declined by 20% in the same period. The reason for this would be an increase in complexity of the construction as illustrated in Figure 1 and as debated by Kymmell (2008). In order to overcome such inefficiency, innovative and more creative approaches need to be implemented within the construction industry (Teicholz, 2004).

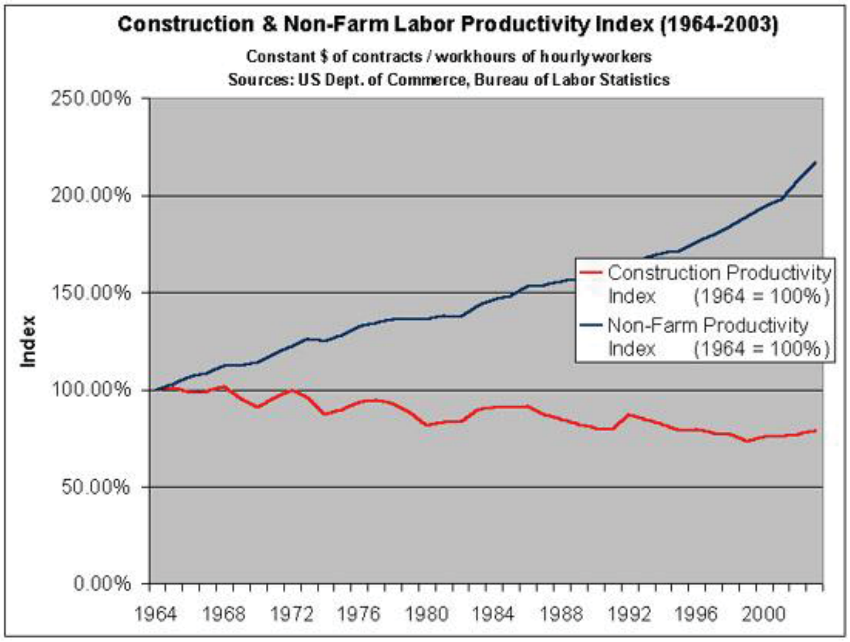

Figure 1: Labor productivity index for US construction industry and all non-farm industries from 1964 through 2003, National Institute of Building Science (NIBS) 2007

The construction industry has benefited from advances in information technology allowing much more complex designs to be produced and plans to be executed (Kassem *et al.*, 2012). Computer Aided Design (CAD) is a very good example of this. CAD is considered to be the greatest advancement in the construction industry in recent decades according to Long *et al*. (2009)

BIM emerged in the last few years as a revolutionary concept and is being looked upon as the future revolution of the Architectural, Engineering and Construction (AEC) industry (Kassem *et al.*, 2012). BIM is mainly a three-dimensional digital representation of a building and its essential features. It is composed of intelligent building elements which include data attributes and parametric rules for each object (Hergunsel, 2011). High quality 3D renderings of a building can be generated from Building Information Models providing a three-dimensional virtual representation of the building that serves as a great visualization tool.

4D models integrate 3D CAD models with project timelines. Previous experience from projects has shown that integrating schedule information with a visual model is a compelling communication and collaboration tool for technical and non-technical stakeholders (William, 1996). 4D models help in detecting defects in schedules in terms of inconsistencies and impossible activity sequences. This integration also helps anticipating potential time-space conflicts and accessibility problems, thus facilitating interface management, especially in complex projects. In addition, Griffis and Sturts (2003) reported that using 4D models resulted in an average of 5% savings in cost growth, 4% savings in schedule growth and 65% reduction in rework.

There has been little research conducted to identify barriers and benefits of BIM implementation, and there is no evidence for any study within the Middle East and specifically in Qatar. Kassem *et al.* (2012) developed a web-based questionnaire sent to 52 consultants and 46 contractors in the UK civil and building industry. The survey participants were 14 consultants and 17 contractors. The research concluded that the highest three barriers identified by both consultants and contractors were (1) lack of benefit for parties involved, (2) lack of experience within the workforce, and (3) lack of universal use within projects. However, the research was limited to the UK and did not include representation of clients, subcontractors, and other stakeholders associated with BIM implementation.

Von Both *et al.* (2012) did a market analysis for the potentials and barriers for implementing BIM in the German market. The analysis identified that BIM implementation in Germany is still at very early stages compared to the USA and Nordic European countries. The survey was addressed to all construction practitioners from various disciplines. The analysis showed that the BIM implementation within different target groups is considered low. 2D-Planning is still the favorite method for planners who tend to use it in more than 60% of their projects. The analysis also grouped the barriers under four main categories; technological issues, general issues, normative issues, and education. The analysis did not identify the factors impacting upon the implementation of BIM and did not have any ranking for such factors.

Stanley *et al*. (2014) undertook research to identify the benefits and barriers to BIM 5D implementation in the New Zealand market. A cross-sectional survey approach was adopted. The population was quantity surveyors, in private practice, or working for contractors. The outcome of the survey suggested that 5D BIM provide leverage over conventional forms of quantity surveying practices by increasing efficiency, visualization of construction details and early identification of risks. However, the following barriers were identified: lack of software interoperability, high initial setting-up cost, shortage of coding protocols for objects within the models, absence of coding standards for coding BIM software, and the lack of integrated models. Although the size of the sample of the survey was relatively small as described by the authors, the survey provides a 'snapshot' of current opinion on the benefits of, and barriers to, the implementation of 5D BIM in Auckland

Another survey was undertaken in the Middle East by Building Smart (2011). The aim of the survey was for better understanding of the market related to BIM and identifying capabilities and barriers to adoption. The survey respondents were consultants, contractors, owners, and suppliers. The survey showed that 54% were non-BIM users, and 21% were not familiar with BIM. The survey identified the highest three main obstacles to BIM adoption to be (1) availability of skilled staff, (2) cost of software, and (3) cost of implementation. The survey however did not specify which countries it included, which country the participants came from, nor did it cover the implementation of the 4D concept.

The literature review shows that studies on barriers to BIM/4D implementation are limited and need further investigation across different geographic locations.

3. Methodology

This section focuses on the methodology used in this study to explore barriers to BIM implementation in Qatar. The study constitutes an extensive literature review to identify barriers to BIM implementation in general, and is then supported by an online questionnaire. The questionnaire was validated in interviews with construction professionals before its distribution. The survey targeted construction professionals in Qatar and was sent to 203 practitioners out of which 54 responded; a response rate of 26.6%. This section will discuss the survey design and statistical tools employed to analyze the collected data.

3.1. SURVEY DESIGN

The survey contains two sections. The first section collected general information about participants' professional experience such as: type organization level within the supply chain, years of experience, level of seniority, scale of projects worked in, and discipline of engagement. In addition, participants were asked about their BIM knowledge and usage. Participants were also requested to rate the level of BIM existence in their current projects on a five-point Likert-scale ranging from (no presence, little presence, moderate presence, strong presence and extensive presence).

The objective of the second section was to measure the relative importance of the identified factors from literature acting as barriers to BIM implementation within the State of Qatar. The defined seventeen factors adapted from the literature, were presented to participants, as statements, and they were asked to rate their level of agreement on the importance of each on a seven-point Likert scale thus; (very strongly disagree, strongly disagree,

disagree, neither agree nor disagree, agree, strongly agree, and very strongly agree). Due to the unavailability of a database for BIM users in Qatar, it is very difficult to accurately estimate population size. Following the rule of thumb suggested by Olejnik (1984), the data collection approach was to obtain as many responses as possible

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3.2 DATA ANALYSIS

The data analysis tools used to test the reliability of the questionnaire, test the null hypothesis, and rank factors based on their relative importance were:

3.2.1. Reliability Test

Cronbach's alpha test is a tool to measure internal reliability of collected data. A high Cronbach's alpha implies that items measured have high consistency. Cronbach's alpha is calculated using equation 1:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k} \sigma_{u_j}^2}{\sigma_x^2}\right) \tag{1}$$

Where k is the number of questions in the survey; $\sigma_{u_j}^2$ is the variance of scores on each question; σ_x^2 is the total variance of overall scores.

3.2.2. Barrier's Ranking

Responses from the survey participants were used to rank the barriers according to their relative importance index (RII). These indices were used to rank factors based on participant's perception. The RII is calculated as using formula 2:

$$RII = \frac{\sum W x_i}{AN} \tag{2}$$

where W is the assigned weighting to each factor by participants and ranges from 0 to 6 where '0' is 'very strongly disagree' and '6' is 'very strongly agree'; x is the frequency of the i^{th} response; The highest possible weight for response that is 6 in this particular case; and N is the total number of respondents.

3.2.3. Hypothesis Testing

The independent t-test is a statistical inferential test for difference in means. The test examines if a significant difference between two groups exists. The null is rejected if the computed p-value is less than the significance threshold that is set at 0.05, in this study. In this study three null hypotheses were tested:

- H1: there is no significant difference on how different stakeholders perceive the barriers to BIM implementation;
- H2: there is no significant difference that stakeholders in various career levels have on the barriers to BIM implementation; and
- H3: there is no significant difference that stakeholders with different levels of experience have on the barriers to BIM implementation.

4. Results and Discussion

In order to achieve the research objective of identifying barriers to BIM/4D implementation, the factors identified from previous studies were piloted to professional practitioners in Qatar construction industry for feedback. Professionals were asked to comment and validate the relevancy of the factors identified. The feedback from the interviews confirmed the factors identified and that they are the most relevant to BIM implementation in Qatar. Following the interviews, the survey was published online and sent to construction professionals in Qatar.

The survey targeted professionals from the client side either public or government, contractors/subcontractors, as well as designers/consultants.
The distribution of the survey participants is as shown in figure 2.

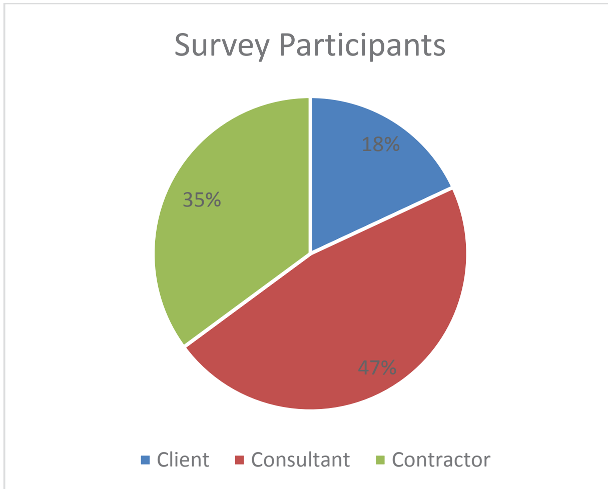

Figure 2: Survey Participants

The survey also measured the size of projects were BIM is being implemented in Qatar. The survey result showed that Mega projects with size greater than or equal 1 Billion US dollars are the highest in BIM implementation followed by large scale with size less than 1 Billion US dollars and greater than 100 Million US dollars. The results are illustrated in Figure 3.

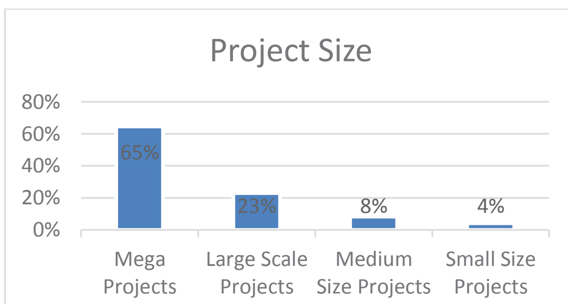

Figure 3: Project Size

The survey showed that client/owner identified the availability of skilled professionals as the highest ranked factor together with knowledge about BIM and accessibility to the BIM model by project team member. The findings are illustrated below in Table 1.

Table 1: Ranking of Barriers according to Clients/Owners

Description	Score	Rank

Availability of skilled professionals	0.854	1
Knowledge about BIM	0.854	1
Accessibility to the model by project team members	0.854	1
Availability of required training for users	0.833	4
ROI (Return on Investment) of using BIM not clearly defined	0.813	5
Disruption to current process / resistant to change	0.771	6
Availability of industry standards	0.750	7
Absence of contractual requirement for BIM implementation	0.688	8
Initial cost of Hardware / upgrades	0.688	8
Running cost of implementation of BIM / 4D	0.688	8
Interoperability between software's	0.667	11
Complexity of the BIM Model	0.667	11
High initial cost of software's	0.646	13
Lack of buy in from different stakeholders	0.646	13
Legal issues (i.e. ownership of the BIM model)	0.646	13
Availability of necessary software	0.583	16
Lack of usage BIM by competitors	0.583	16

The survey showed that Contractor/Sub-Contractors identified also the availability of skilled professionals as the highest ranked factor followed by absence of Contractual Requirement for BIM implementation and lack of usage BIM by competitors. The results reflect the importance of BIM being a requirement by the client as well as level of competition between contractors. The findings are illustrated below in Table 2.

Table 2: Ranking of Barriers according Contractor/Sub-Contractor

Description	Score	Rank
Availability of skilled professionals	0.688	1
Absence of contractual requirement for BIM implementation	0.677	2
Disruption to current Process / resistant to Change	0.656	3
Lack of usage BIM by competitors	0.656	3
Availability of industry standards	0.625	5
ROI (Return on Investment) of using BIM not clearly defined	0.604	6
Knowledge about BIM	0.604	6
High initial cost of software's	0.594	8
Complexity of the BIM Model	0.594	8
Lack of buy in from different stakeholders	0.583	10

Availability of required training for users	0.563	11
Accessibility to the model by project team members	0.563	11
Initial cost of hardware / upgrades	0.552	13
Legal Issues (i.e. ownership of the BIM model)	0.552	13
Running cost of implementation of BIM / 4D	0.542	15
Interoperability between software's	0.542	15
Availability of necessary software	0.500	17

The survey finally showed that Consultants/Designers identified the knowledge about BIM as the highest ranked factor followed by absence of Contractual Requirement for BIM implementation and disruption to Current Process / Resistant to Change. The results reflect the importance of BIM being a requirement by clients and enforcing its implementation in the projects. The findings are illustrated in Table 3.

The overall ranking showed that availability of skilled professionals, followed by knowledge about BIM, and disruption to the current process/resistant to change are the barriers with the highest impact to BIM implementation, the results are illustrated in Table 4.

Table 3: Ranking of Barriers according to Consultants/Designers

Description	Score	Rank
Knowledge about BIM	0.714	1
Absence of Contractual Requirement for BIM implementation	0.698	2
Disruption to Current Process / Resistant to Change	0.698	2
Availability of Skilled Professionals	0.683	4
Availability of Industry Standards	0.643	5
ROI (Return on Investment) of using BIM not clearly defined	0.643	5
Interoperability between Software's	0.643	5
Lack of Buy in from different Stakeholders	0.635	8
Availability of required Training for users	0.619	9
High Initial Cost of Software's	0.595	10
Initial Cost of Hardware / Upgrades	0.563	11
Complexity of the BIM Model	0.563	11
Accessibility to the Model by project team members	0.563	11
Lack of usage BIM by competitors	0.548	14
Legal Issues (i.e. Ownership of the BIM Model)	0.548	14
Running cost of Implementation of BIM / 4D	0.524	16

Availability of Necessary Software	0.429	17

Overall relative importance to barriers is 62.20%, which is calculated as the mean of RII for all barriers. The overall relative importance is considered as a high percentage that implies considerable barriers within Qatar construction market to widely implement BIM.

Cronbach's Alpha is 0.85 is greater than the 0.7 benchmark which means good level of internal consistency and reliability of the collected data.

The probability results from t-test as reported in table 5, suggests that a significant difference between owners and contractors in their ranking of the barriers.

Table 4: Overall Ranking of Barriers

Description	Score	Rank
Availability of Skilled Professionals	0.715	1
Knowledge about BIM	0.700	2
Disruption to Current Process / Resistant to Change	0.696	3
Absence of Contractual Requirement for BIM implementation	0.689	4
ROI (Return on Investment) of using BIM not clearly defined	0.659	5
Availability of Industry Standards	0.656	6
Availability of required Training for users	0.637	7
Lack of Buy-in from different Stakeholders	0.619	8
Accessibility to the Model by project team members	0.615	9
Interoperability between Software's	0.611	10
High Initial Cost of Software's	0.604	11
Lack of usage BIM by competitors	0.593	12
Complexity of the BIM Model	0.593	12
Initial Cost of Hardware / Upgrades	0.581	14
Legal Issues (i.e. Ownership of the BIM Model)	0.567	15
Running cost of Implementation of BIM / 4D	0.559	16
Availability of Necessary Software	0.481	17

The associated p-value reported at 0.042 which is less than the significance level of 0.05. Moreover, the probability of t-test between consultant and owners is reported at 0.068, which is higher than 0.05, but it is close to it. Further analysis is carried out to identify the barriers with difference opinions. There were three common barriers between the two pairs those are: availability of required training for users, ROI of using BIM not clearly defined, and accessibility to the model by project team members. In addition, one barrier with a significant difference for each of the two pairs is identified. In the owners/consultants this barrier is availability of skilled professionals and for owners/contractors group the barriers is knowledge about BIM. As suggested by results the null hypothesis H1 is rejected.

The probability value resulted from t-test for difference in means between different groups of experience, showed a result of 0.365, which is higher than the significance level of 0.05, therefore, the null hypothesis H2 cannot be rejected.

For the set significance $p \leqslant 0.05$, for the ‘high experienced group‘ n of 30 with a mean of 63.67 and ‘less experience groups’ n of 15 with mean of 63.00,the t-test for different experience bands reported a result of 0.878 and therefore the null hypothesis cannot be rejected (H3).

Table 5: Probability values of t-test

Description	Owners-Consultant	Owners - Contractors	Consultants - Contractors
Absence of Contractual Requirement for BIM implementation	0.936	0.939	0.824
Availability of Industry Standards	0.278	0.252	0.846
Availability of Skilled Professionals	0.030*	0.069	0.949
Availability of Necessary Software	0.253	0.529	0.468
High Initial Cost of Software's	0.591	0.583	0.985
Initial Cost of Hardware / Upgrades	0.198	0.164	0.886
Running cost of Implementation of BIM / 4D	0.066	0.116	0.845
Availability of required Training for users	0.008*	0.007*	0.572
Disruption to Current Process / Resistant to Change	0.479	0.295	0.624
Lack of Buy-in from different Stakeholders	0.919	0.554	0.538
ROI (Return on Investment) of using BIM not clearly defined	0.041*	0.019*	0.670
Lack of usage BIM by competitors	0.758	0.532	0.163
Interoperability between Software's	0.832	0.273	0.204
Knowledge about BIM	0.054	0.006*	0.187
Legal Issues (i.e. Ownership of the BIM Model)	0.380	0.415	0.959
Complexity of the BIM Model	0.319	0.511	0.735
Accessibility to the Model by project team members	0.003*	0.008*	0.992
Overall	0.068	0.042*	0.810

5. Conclusion

This research aimed to identify the barriers to the implementation of BIM/4D in Qatar. The research used a survey questionnaire that was published online to professionals in construction industry in Qatar. Questionnaire participants were different stakeholders in the construction industry covering the client, contractors, as well as consultants. The questionnaire ranked 17 different factors identified earlier from the literature review as the barriers to BIM implementation. Further statistical tests were applied to the survey data to ensure its reliability and to test the correlation among different groups. The reliability test demonstrated a good level of reliability that gives confidence in survey data.
The survey identified and ranked the following to be the highest impact to the BIM/4D implementation in Qatar:

- Availability of Skilled Professionals
- Knowledge about BIM
- Disruption to Current Process / Resistant to Change
- Absence of Contractual Requirement for BIM implementation
- ROI (Return on Investment) of using BIM not clearly defined

The survey clearly reflected that lack of qualified resources is and the knowledge of BIM are main barriers to implementation of BIM in Qatar. Moreover, the analysis shows a significant difference in how different construction stakeholders perceive the barriers to BIM implementation.
The recommendations for further researches would be to increase the sample size to confirm the research findings. Also it would be beneficial to conduct surveys to cover the GCC region as a whole since the nature of GCC countries is always the same. In addition, an in-depth study to understand the differences of views between construction parties is a potential research area that will assist in identifying root causes. Finally, more studies should focus on removing these barriers to exploit the benefits of using BIM.

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