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Flexibility of BIM towards Design Change

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Abstract. Change orders in construction industry have transformed this business into a complicated and laborious one. Even in BIM projects change orders are inevitable but they can be managed more efficiently. BIM tools are mature tools capable of producing Construction Documents with higher quality compared to 2D CAD software and are suitable for providing better information for downstream use. The aim of this paper is to reveal some of the limitations of BIM applications that are faced by BIM experts to identify the flexibility of these tools in applying changes. It is hypothesized that changes have been taken place in BIM projects. A questionnaire was designed and distributed among professionals and BIM experts. They were asked to reply to the questionnaire to evaluate the ease of applying changes and pinpoint the limitations of BIM tools. It was concluded that BIM Tools suffer from some shortcomings such as inability to produce design change comparative deviation report, unreliability of bidirectional links between external analysis software and BIM tools, not having a powerful user interface and lacking enough artificial intelligence to analyze and offer alternatives to design changes. It has been noticed that the current tools have the potential to improve in the future to aid experts in achieving a more efficient workflow.

Keywords: design changes, variations, BIM tools, BIM limitations, automated system.

1. Introduction

During many construction projects frequent changes often result in time delays, cost overruns, quality defects and other negative impacts. Many researchers investigated the resources and effects of project change and more significantly the causes behind the changes from different perspectives (1). Changes are mostly caused by clients, in favor of getting new ideas, cost reduction on projects or not having a proper conception to visualize the project in design stages until they observe it in reality.

To overcome the limitations of traditional 2D designs, building information modeling which is a novel technology and concept has solved many issues related to design changes. BIM supports new information workflows and integrates them more closely with existing simulation and analysis tools used by consultants (2). Since most processes in BIM are automated and the involvement of human resources is minimized, it is claimed that by using BIM, the efficiency of monitoring, controlling and updating in construction projects' life cycle is enhanced remarkably.

BIM merits are more than its shortcomings. However, In order to strengthen the functionality of BIM tools, their weaknesses must be identified first. This paper focuses on BIM tools and the level of their flexibility towards implementing changes during various phases of projects. The aim is to give recommendations and suggestions to improve the serviceability of such tools.

2. Literature Review

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Building Information Modeling (BIM) is an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project life cycle in the form of a data repository (3).

BIM as a comprehensive concept of process and tools which integrates all projects required data and information. As a management paradigm, it can be implemented through chains of building software such as Revit, Primavera, Naviswork, etc. by utilizing the managerial processes and concepts such as critical chain project management, critical path method and concurrent engineering at all stages of projects' life cycle.

The building information model (BIM) contains information needed in particular phases of a building's life-cycle (scheduling, analysis, cost evaluation, etc.). It is much more than a data container for the building model; it is an object oriented building design. Information structures of the design are presented as objects (walls, columns, windows, doors, etc.) with attributes and relationships between building elements (4). A major benefit of utilizing BIM in a project in the design and construction phase is obviously the ability to "model" and test the constructability of the design within the model prior to setting foot on the project site. In the past, this was accomplished utilizing a light table, with the construction documents overlaid.

It is clear that BIM benefits the project. However, we also need to assess the project's many challenges and collectively as a team determines how to address them in the rapidly changing technology. The followings are some of the challenges that menace the future of BIM.

- Project specific standards for collaborative file sharing / exchange
- Ownership of the model at various stages of the project
- Concerns that Model will change without all stakeholders input

The last one is very important since changes are inevitable in construction even in BIM projects. Changes are rampant in construction projects and from the preliminary studies of the design to the construction phase, architects and engineers face different dilemmas that call them to change the variables and find the best solution that fits the project's objectives such as cost, time and quality.

Design change is defined as "the changes resulting from a modification within or outside the original scope of work and require re-design and revision to the contract documents". Most of the changes happen during the construction phase and they are the roots of cost and time overruns disputes and relationship deterioration. Changes stem from different reasons. They may arise from the owner requesting for additions or deletions, differing site conditions and discrepancies in the drawings and specifications. Lee 2008, stated in his paper that between the traditional Design Bid Build system and Design and build delivery system, the latter one is less prone to change due to the better level of communication among parties and the involvement of the contractor from the incipient stages of design (5).

Keane *ET all* categorized the reasons of change into four groups:

- Changes due to the owner's decisions to change the scope of the work owing to financial problems and wrong conception of final work.
- Consultant related variations due to errors and discrepancies between the drawings and the site.
- Contractor's inefficiency in planning for plants and long lead materials and financial difficulties.
- Changes due to unforeseen problems.

However, the most claimed reasons for the occurrence of changes are detail inadequacies, misinterpretations and incompetency in preparing the set of detailed drawings (6).

With the advent of new technologies and systems such as BIM and its tools, this matter has been somehow alleviated but this behooves us to study the implications and appraising the strengths and weaknesses of such tools toward design changes.

3. Research Methodology

To achieve the objective of this paper, firstly the current states of BIM and design changes were investigated from literature review; secondly, the questionnaire was set up to obtain professional opinions on the level of satisfaction on the existing BIM tools for applying design changes. In this phase, the

questionnaire was designed through Google's document form and sent to 170 BIM experts. As shown in figure 1, 54 results were submitted online successfully. Finally, the responses were analyzed, shortcomings were revealed and some recommendations were made.

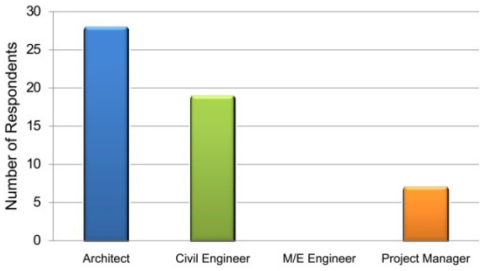

Fig. 1: Distribution profile of survey respondents

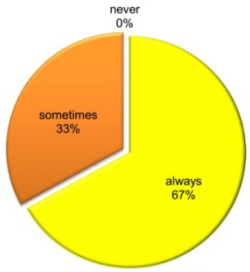

Fig. 2: Frequency of change occurrence in BIM projects

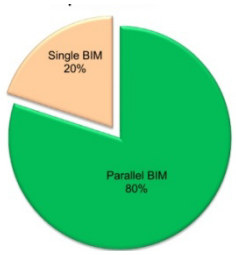

Fig. 3: Compatibility of BIM with regard to change implementation

4. Analysis and Discussion

As it was expected, most of the respondents contented that change happens even in BIM projects. Figure 2 shows the level of frequency of change occurrence in BIM projects.

The respondents were asked to choose the best type of digital information transfer standard which is more compatible with regard to implementing design changes. As depicted in figure 3, 80% of respondents chose parallel BIM in which a separate model is created by a contractor, based on the information of consultant engineers. This leads to miss the opportunity of working together with a project team. On the other hand, the rest chose single (composite) BIM where an advanced understanding of BIM software programs and relationship among team members is required. This fact indicates an insufficient technical and conceptual knowledge of BIM which is vital to be given more consideration in the future.

According to the results in table 1, it can be seen that totally more than 55 % of the respondents are discontented with respect to the ability of current BIM tools in producing comparative deviation reports.

Deviation report in this context means, illustrating the differences and employed changes in contrast with the original design. Apparently, available BIM tools are not developed enough to be able to archive the history of applied changes in the model.

Furthermore, Most of the structural engineers are disappointed with the reliability of bidirectional links between structural analysis software and BIM tools available in the market. Unfortunately, the various structural analysis companies that Autodesk has partnered with, are responsible for creating such a link to their respective programs but each of them has shown a different level of commitment to this effort (7).

Only 7% of respondents agreed that BIM tools are appropriate to comment and mark up on RFIs in specifically 3D environment. The rest unanimously agreed that once dealing with RFIs and in field document management, it is important to have as many resources available as possible. At the current date, the ability to create a document in design reviewers that contain both the 3D model and the 2D sheet files doesn't exist (8).

Based on the received data from respondents, more than half of respondents were satisfied with the BIM tools in terms of comfort-ability for applying changes concerning deleting, adding, dividing and merging existing elements. In addition, 22% of them had a neutral idea and approximately a quarter of them felt dissatisfied about the level of simplicity of BIM tools in respect to changes implications.

It is obvious from table1 results that BIM tools have not provided a user friendly interface standard for their users. Roughly, half of the respondents were disagreed upon the "user friendly interface" motto of current BIM products especially when it comes to applying design changes via an automated system of BIM tools. Clash detection is one of the most important advantages of BIM tools that can reduce the design errors prior to the construction phase. However, as more than half of the respondents pointed out, the detection of the origins of clashes still is an issue that needs more contemplation.

Variable	○ SD	○ D	○ N	○ A	○ SA
BIM is flexible to reload updated links and changes easily.	0%	9%	21%	39%	31%
BIM is capable of making a comparative deviation report from change implementation In order to have a comprehensive imagination of applied design changes.	19%	37%	15%	19%	11%
During the structural and MEP design changes process, BIM tools and analysis software are compatible and flexible enough to implement changes order smoothly.	20%	35%	30%	15%	0%
In dealing with RFIs for applying changes, it is easy to comment and markup documents, drawings and specifications within BIM tools.	28%	33%	19%	13%	7%
It is easy to apply changes involved; adding a new element to the model, deleting an existing element and merging or dividing existing elements.	7%	19%	22%	35%	17%
BIM software have "user friendly interface" to organize and store data regarding design changes.	15%	33%	30%	13%	9%
There is a proper process in place of updating the designed model to incorporate the change made during construction.	13%	48%	19%	18%	2%
Once clashes detected, there is a specific method to identify the origin of clashes.	20%	37%	19%	15%	9%
BIM has all required information and automated system in compliance with applying change order during construction lifecycle.	22%	41%	13%	17%	7%
Changes implementation is easy enough through BIM automated system that no additional design changes fee is required.	9%	43%	17%	24%	7%
As cost estimation can be done through BIM, so it can compute all the cost variance caused by changes automatically.	17%	28%	35%	13%	7%

Table. 1: The ability of BIM tools for applying changes

On one hand, the use of BIM significantly reduces the time required to generate shop drawings and material takeoffs for procurement (2). This can be inferred from table 2 where the aggregate of 40% confessed that BIM tools are effective in adopting change throughout the model. On the other hand, respondents believe that BIM reacts weakly to assess the impacts of design and suffers from lack of artificial intelligence in order to analyze change alternatives.

	Excellent	Good	Fair	Poor	Very Poor
How efficiently does BIM adopt changes in the project automatically?	20%	20%	41%	17%	2%
How does BIM assess change effects prior to implementing in the project?	0%	9%	21%	39%	31%
How capable is BIM of analyzing change alternatives by means of artificial intelligence?	0%	0%	0%	83%	17%

Table. 2: the quality of BIM functions

5. Conclusion

Construction industry is a change prone one. Changes happen in different phases from the design to construction. However, the most common reason of change can be classified as inadequacy of details, errors in design, misinterpretations and incompetency in preparing the set of detailed drawings. Building Information Modeling is a new technology that assists building experts to model and test the constructability of the design within the model prior to setting foot on the project site. Flexibility of BIM tools towards design changes was studied in this paper to evaluate and disclose their drawbacks. Apart from this fact that BIM is efficient in adopting and propagating changes in the model, editing objects and reloading updated links, it suffers from some shortcomings such as inability to produce design change comparative deviation report, unreliability of bidirectional links between external analysis software and BIM tools, not having a powerful user interface and lacking enough artificial intelligence to analyze and offer alternatives to design changes.

Investigation for better integrated representation of sensed information and as-designed information, developing finer geometric reasoning mechanism and spatial query approach for better deviation interpretation and probing approaches for automatically generating other forms of change orders based on an

object-oriented model, are some of the recommendations to enhance the functionality and flexibility of BIM tools towards design change. BIM is not the end-all solution to technological development in the design and construction industries. If BIM is to succeed, it must continue to be a conduit of change by transforming the way we practice design and construction.

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