5D-BIM: A CASE STUDY OF AN IMPLEMENTATION STRATEGY IN THE CONSTRUCTION INDUSTY

Anoop Sattineni [a] and Jennifer A. Macdonald [b]

[a] Auburn University, Auburn, AL, USA
[b] University of Technology, Sydney, Australia
E-mail: anoop@auburn.edu, Jennifer.Macdonald@uts.edu.au

Abstract -

Several factors have contributed to the growth of BIM usage in the global construction industry, including availability of appropriate software and hardware tools, the opportunity to minimize errors, waste & cost and increasingly competitive markets [1][2]. An emerging approach in the construction industry is the use of 5D-BIM, by combining the traditional three dimensions of a BIM with the schedule as the fourth dimension and cost estimate as the fifth dimension [3]. This approach allows the contractors to better predict the cost of the project, the time-line of the project when these expenses are anticipated to occur, while simultaneously allowing the schedule to be optimized by considering the quantities of materials derived from the model and the productivity rate of construction crews. On the one hand 5D-BIM methods provide an excellent opportunity to connect processes in design, cost and construction methods; on the other hand they call for a significant shift in the way construction companies operate. It is unrealistic to commit extensive resources for a large construction company, towards a re-alignment of their internal processes, while continuing to be competitive and profitable. This paper considers how one construction company in the United States adopted the 5D-BIM methods, the challenges faced in implementing it within the company and the lessons learned in the process. A case-study method was used in an effort to understand the paradigm shift within the company in adopting 5D-BIM. Interviews with key personnel within the company were conducted and content analysis of the data was performed to describe the results. The results from this study show the intricacies of implementing a technology driven paradigm shift to a population of construction experts with a not-so erstwhile philosophy of success within the construction industry. The captains within the company communicated a great appreciation for the 5D-BIM concepts but were unwilling to delve into it whole-heartedly. Several reasons contributed to this attitude, including a reluctance to change by some, motivation to demonstrate immediate profitability and the lack of demand for such endeavours from the owner/designer community. However there were also personnel within the company that quickly adapted to the 5D way of thinking about construction and were keen to proceed with using the methodology on future projects. The advantages of using 5D-BIM and the problems encountered in implementing it are analysed in the results section of the paper.

Keywords -

Construction Management, 5D-BIM, Case Study, 5D-BIM Implementation

1 Introduction

There is much misconception regarding BIM and what it exactly entails. The term, Building Information Modelling (BIM) has been used as a label for the 3D geometric renditions created by modelling software such as Autodesk REVIT and ArchiCAD, among several others. In reality, the 3D geometry only represents a portion of what BIM really is and its full potential.

There are many definitions of BIM that have been developed through its evolution. The most descriptive of these definitions is from the buildingSMART Alliance through the National BIM Standard – United States. "A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shard knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward"

In the design and construction phase, BIM can begin be understood as a new process of delivering information and knowledge of a project to all the relevant parties. The information that is assimilated into a Building Information Model is provided by consultants, designers, manufacturers and engineers. This creates a new level of collaboration that the construction industry does not currently operate at. Thus, BIM is creating a new workflow from preconstruction

to post construction and beyond through a project's entire lifecycle.

There is general consensus in the academic and the AEC industry community that BIM is more than just a software tool. The true impact of BIM is the enabling of comprehensive, digitized and collaborative processes within the AEC industries. The American Institute of Architects (AIA) recognized this seismic shift in the process of designing and constructing facilities and has proposed a new delivery method, namely 'Integrated Project Delivery' (IPD) [4]. BIM is the cornerstone of realizing the benefits proposed in this new methodology for project delivery [5]. The use of BIM in the US construction industry and academic research regarding BIM has been on the rise and is predicted to continue to increase [6].

1.1 4D – BIM

The fourth dimension added to the traditional 3D-BIM model is 'time'. This allows the 3D parts or assemblies inherent to a BIM model to be combined with a construction schedule. The resulting 4D model is capable of creating virtual simulations of building the BIM model [7]. These simulations can be used to communicate the sequence of work to avoid rework in the construction industry as well identify, ahead of time any areas that may be congested due to too many trades being in one place at the same time. Congestion of various trades in one location within a construction site is considered a safety hazard.

Coordination between trades has become very important in the construction industry due the specialization involved in each trade. One of the advantages of using BIM in the construction industry is to optimize the space in the building where the services such as HVAC, water, waste and electrical systems are located. This can potentially reduce the amount of space needed for the various systems and hence reduce the overall height of the building, reducing the overall cost of the building. Under such circumstances, contractors installing these systems have to carefully coordinated so that each team has sufficient time and space to install their respective materials. By simulating the sequences of construction 4D-BIM can help optimize the process and allow for minimal rework and changes. 4D-BIM can also allow construction managers to optimize the movement of materials, equipment and people on a construction site ahead of time. This is depicted by the image in figure 1 created by HOAR Construction Company in Birmingham, Alabama. Hu [8], declares that the use of the fourth dimension is fundamentally changing the project planning, design and construction management strategies of companies.

Figure 1. Use of 4D BIM for optimizing construction site logistics at HOAR Construction Company

1.2 5D – BIM

The fifth dimension added to the 4D-BIM model is 'cost'. A 3D-BIM model has all the geometrical information needed to perform a take-off of material quantities. A 4D-BIM model has all the activities needed to complete the project. By attaching a cost database to the 4D-BIM model and by assigning actual costs to materials, equipment and personnel, a 5D-BIM model can be created to provide the construction team with a useful tool[9]. The implementation tools for implementing a 5D-BIM model have only been available for less than a decade.

The resulting 5D-BIM model can be used by construction professionals to give faster feedback about the cost of a project, allowing the designer to adjust the project design to fit the budget. The opposite scenario is often seen in the construction industry in that the project cost is estimated to be over what the owner can afford and consequently resulting in significant design changes and also perhaps losing the most attractive elements of the design. The 5D-BIM model can provide the owner and the design team with greater transparency in seeing the contractor's budget, building confidence within the various stakeholders of a project. Projects using 5D-BIM would also mean there would be a less of a need for a large contingency on behalf of the owner.

2 Methodology

HOAR Construction Company based in Birmingham, Alabama in the south eastern United States was chosen for the purpose of conducting this research. The 'Virtual Design and Construction' (VDC) team members were interviewed for the purpose of

conducting this research using a case study methodology.

A case itself can be defined as a single person, subject, group or organisation [10]. Case study research may involve the investigation of a single case or multiple cases and can be categorised as 'descriptive', 'explanatory' or 'exploratory' in nature. A descriptive case study is used to describe a phenomenon or a processes whereas an explanatory case study is usually theory driven and may be used to develop hypothesis in a large research project [11]. An exploratory case study is typically used to test hypothesis to come up with logical conclusions [12]. In this study a descriptive case study is presented in regards to the implementation of BIM at HOAR Construction Company.

Saunders et al. [13] draw distinctions between three types of interviews, namely 'Structured Interviews', 'Semi-Structured Interviews' and 'Unstructured Interviews'. Structured Interviews use a single set of pre-determined questions and the interviewer would read each question and record the answers for each of those questions. Structured interviews are used to collect quantifiable data and are referred as 'Quantitative Research Interviews' [13]. 'Unstructured Interviews', also referred to as 'In-Depth Interviews', on the other hand, are informal conversations where the interviewer does not have a pre-determined list of questions but instead is guided by a topic and asks questions allowing the interviewer to answer freely about events, behaviour and beliefs [13]. 'Semi-Structured Interviews' can be considered as occupying the middle ground between 'Structured Interviews' and 'Unstructured Interviews'. In this format, the interviewer is guided by a list of themes and questions, however the order of questions may be different and some questions may be eliminated altogether, while new questions may be required, depending on the context [13]. The interviewee in a semi-structured interview has more latitude to answer questions in an open manner, however the researcher may guide the whole processes in order to get responses to all questions fully and in a timely fashion. The use of interviews to collect data is an acceptable method in social research [14]. The VDC team members were interviewed for the purpose of conducting this research, in the semi-structured interview format.

Interview questions relating to 5D-BIM implementation at HOAR construction were asked of BIM-team members. Questions focused on a historical perspective of BIM at HOAR construction, current use of BIM, their foray into implementing 5D-BIM, support and push from upper management within the company for implementing 5D-BIM, reaction from field personnel and senior field operations management team towards implementing 5D-BIM, surprises and challenges of implementing 5D-BIM and the future of 5D-BIM implementation at HOAR construction company were explored.

The data from the interviews was transcribed verbatim and analysed using qualitative data analysis. 'Content Analysis' and 'Thematic Analysis' are two common methods of analysing textual data. Content analysis is a qualitative method of analysing raw data as is thematic analysis, however thematic analysis only considers the qualitative nature of the data whereas content analysis generally results in quantifying the data by counting the frequency of the emergent themes and codes [15][6]. At the core of both content and thematic analysis, data is arranged into themes or codes by categorising raw text under meaningful labels or codes. While content analysis considers the frequency of the occurrence of codes to describe the data, thematic analysis interprets the data by analysing the meaning of the codes within that context [16]. The data collected in this research from the semi-structured interviews was analysed using the qualitative technique of thematic analysis by creating codes and labels. The findings of the interview data are grouped under appropriate themes and presented in the 'Results' section of this paper. The 'Conclusions' section presents the complicated nature of 5D-BIM implementation in the construction industry.

3 Findings

With over 300 construction professionals, HOAR Construction Company had an annual volume of construction of approximately $470 million USD in 2013. In 2013, HOAR was ranked 127 in the list of top 400 construction companies in the United State. In 2012 the company was ranked 107 in the same list and over the past decade has consistently stayed in the list of top 400 construction companies in the United States. These rankings are provided by the Engineering News Record (ENR) magazine. ENR is considered the premier trade magazine for the construction industry in the United States. HOAR as a company works in the civic & government, retail & mixed use, office & commercial, education, residential & hospitality, concrete & heavy-civil, industrial & manufacturing and healthcare sectors within the construction industry. Apart from being a construction company, HOAR also has a program management side of their business in which they advise owners about issues related to construction projects. Hoar construction has a dedicated staff of six people in their VDC team.

The VDC team was interviewed for the purpose of

conducting this research. The findings of the interview results are analysed using thematic analysis and presented under appropriate themes within this section.

3.1 BIM Adoption & 5D-BIM Exploration

BIM was first explored by one the current team members in 2006, using the Autodesk Revit software. The program was only used to consider a BIM model to count the number of various types of doors present in it. At this stage the adoption of BIM was also in the very early stages within the construction industry[17]. As the team started to receive more models from design teams and with the evolution of BIM software within the marketplace, the adoption of BIM increased at HOAR construction. The company also has a long history of working with the 'Walt Disney' group on its construction projects at Disney's various theme parks. Construction projects at these theme parks were described as futuristic and the owners encouraged and often required the use of latest technologies in design and construction of its various facilities. This also turned out to be a key factor in the evolution of BIM within HOAR Construction Company. The first 5D estimate was created on a Disney project in 2008. However, the use 5D models did not immediately involve other projects within the company. In fact a VDC group did not emerge within the company till 2011. A full team of six professionals are now in the VDC group. As of 2013, they have had five years of engagement with 5D models and three of those years were described as dedicated engagement with a full-fledged team. Apart from the cost of personnel for the VDC team, it was described that over the last three years approximately $0.5 million USD were spent on software & hardware costs related to BIM. These include the costs for training the personnel within the VDC group.

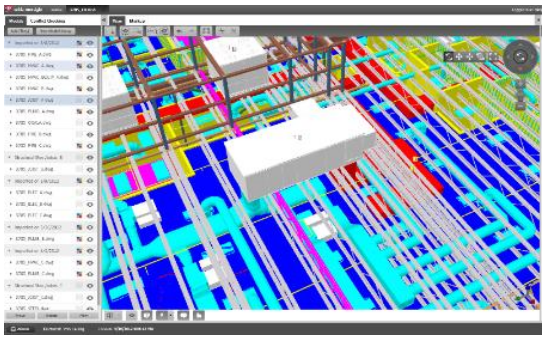

Figure 2. Use of 3D Clash Detection & 4D BIM co-ordination tools at HOAR Construction Company

Prior to the full-scale adoption of 5D-BIM the company used the 3D clash detection tools to identify conflicts in the design of various systems such as HVAC, electrical, fire-proofing etc., as shown in figure 2. The company also used 4D-BIM tools to virtually simulate the construction sequences to identify and resolve any problems in the planning phases of most large projects. These 3D clash detection and 4D-BIM sequencing processes are still in use within the company. The company is currently starting to use 5D-BIM on more projects and there is general optimism within the company about changing to these new processes. However 5D-BIM is currently not used on all projects as a limited number of staff knowledgeable enough in 5D-BIM is available to implement it on a company wide scale.

3.2 Internal Support for 5D-BIM Adoption

The use of 5D-BIM in the company was prompted by the senior management within the company. It was described that the vice-presidents were hearing about these concepts at various venues and industry gatherings and were keen to explore them within the company. The formation of the VDC group was a clear indication by the management to make real investments to incorporate BIM based processes within the company. The managers were particularly keen to see real-time cost data as design progresses, real-time quantities as design changes and real-time updates to project budgets. They actively recruited talented young people who could be trained in this area as well moved some individuals within the company in to the VDC department. In an effort to incorporate the cost estimating processes in to the 5D-BIM workflow, some estimators also joined the VDC team. The company started with some pilot projects where the cost estimation was performed using both 5D-BIM tools and conventional tools. These pilot projects were done to identify the processes that would need to change within the company to fully implement 5D-BIM. At this stage there was some push back from the managers and it was decided to slow down the adoption process. This was done as the original timeline for adoption would have meant radical changes and might have resulted in some unforeseen situations.

One example that was cited was that of the estimating database. The estimating database was created based on the 1995 'Master Format' of sixteen divisions, as specified by the Construction Specifications Institute (CSI) [18]. These sixteen divisions divide the materials and processes needed to build a facility with appropriate sections and sub sections, and allow all stakeholders involved to organize their data in a common format. However the software chosen for 5D-BIM, 'Vico', used 'Uniformat' which is

a format presented by the American Society for Testing and Materials (ASTM) [19]. 'Uniformat' is based on a system to enable construction project information to be classified from a life-cycle point of view. The two systems differ significantly from one another and adoption of 5D-BIM would have meant a new estimating database would have to be created. An estimating database is a key tool for any construction company to come up with an accurate cost estimate. The database is constantly updated with historical actual costs of construction and is often considered a confidential tool. It was decided by senior managers that it would be a risky move to switch databases as several projects were using the existing database, moreover they were not completely sure that all the information could be transferred in to the 'Uniformat' database. Overtime, however the VDC team was allowed to create a parallel 'Uniformat' database. The new database is currently being used for 5D-BIM projects whereas with the existing database is being used for projects that do not use 5D-BIM. It was described that the senior management within the company is starting to realize the benefits of using 5D-BIM and are again proponents of its growth within the company.

The reaction from the field personnel was described as mixed. The newer generation of field personnel were more open to using the new tools but there was some initial resistance from experienced field personnel. This resistance was described as an attitude of reluctance to change. However, over time it was described that everyone was on board with using 5D-BIM tools and adapt their processes

As previously described, the estimating database was a key issue and several similar issues had to be encountered with making the switch to 5D-BIM. Another key issue was the use of 'Location Based Schedules' also called as 'Flowline' methodology for scheduling. This was a departure from the traditional 'Critical Path Method' (CPM) for scheduling construction activities. Flowline methodology for scheduling represents a significant departure from the CPM method of scheduling and field personnel had to be trained to adopt the new method. However, it was found that several field personnel within the company liked the new method of scheduling and quickly adopted it. Some personnel even went to the extent of using the Flowline method of scheduling that were not using 5D-BIM.

Overall the VDC team had to deal with waning enthusiasm from various quarters within the company but were able to successfully convince senior managers and several field personnel to adopt the new methods.

3.3 Challenges to Implementing 5D-BIM

The VDC team expressed several technical and human challenges that had to be overcome to implement 5D-BIM. There currently is no single software available in the market that can perform all functions that BIM is capable of enabling. Therefore while incorporating 5D-BIM the team also had to assist in several projects that were using for 3D clash detection and 4D simulation purposes. 5D-BIM projects generally cost more and take longer to prepare in the initial implementations as more time is spent by key personnel within the company, as compared to traditional projects. Due to the higher costs incurred, it was also more challenging to convey the value of adopting 5D-BIM to senior managers within the company. The VDC team had to overcome the attitudes of people of towards change in general when incorporating 5D-BIM within the company.

The 5D software itself was described as robust but complicated and cumbersome to use. The software programs that enable 5D-BIM require a high level of technological expertise as well as expertise with construction processes. They described an occasion when an experienced team member unintentionally over-wrote the estimating database with no recourse to restoring the previous working version. On that occasion the team was forced to switch to the newer version of the database in a very short time period, while several active projects depended on the database.

There are also some gaps within the industry to implementing a successful 5D-BIM environment within the company. The 'Level of Detail' (LOD) used in the creation of a model by the design team may not be sufficient to extract accurate quantities for cost estimation purposes. The models may have errors in them with elements not touching or duplicate elements and models need to be checked to ensure that estimates can be accurately extracted. Initially in some cases designers were not willing to share models with the construction team.

A majority of the work on construction projects within the company was outsourced to subcontractors. Therefore the scheduling of construction activities depended on knowing the productivity rates for subcontractor crews. Some subcontractors were unwilling to share this information with the construction team. Furthermore there were no guarantees that subcontractors would send the necessary numbers of crew members to the site on a given day as the subcontractors themselves are often trying to meet obligations on multiple projects. This meant that updating the schedule and coordinating with various trades was complicated. However, it must be noted that

this practice continues in the industry regardless of whether it is a 5D-BIM project or otherwise.

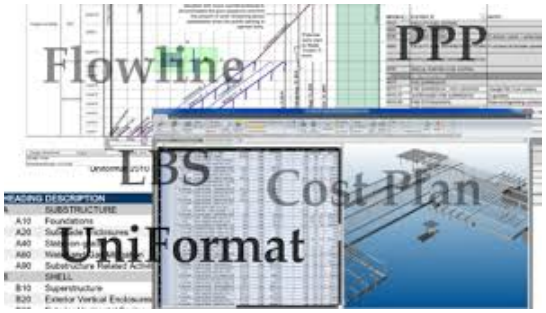

Figure 3. Use of 5D BIM tools at HOAR Construction Company

3.4 Future of Implementing 5D-BIM

The VDC team expressed that the company was starting to reap the benefits of implementing 5D-BIM as they never before had so much data about their own internal processes. An evaluation of process had to take place so that 5D-BIM could be implemented and processes were streamlined to better fit the new workflow. One of the team members expressed that "It is possible to teach an old dog some new tricks and our estimators now have a higher opinion to the whole 5D-BIM concept". The team expressed hope that the software would get easier over time. It was also remarked that 5D-BIM, like other software tools has to be web-enabled to ensure that field personnel are able to extract maximum benefit from it. The VDC team mentioned that they are able to provide much faster feedback to their design counterparts for cost planning purposes. The team is currently exploring the possibility of a tie-in between their 5D-BIM and their web-based project management software. The team has matured its processes to now account for 'change orders' that occur downstream in a project in the 5D-BIM environment. There is definite 'no turning back now' mood within the company about implementing 5D-BIM. The team itself could be re-aligned so that instead of working on several projects in a given year, each team member would get more immersed in one project and see it through key execution stages and consequently have no more than two or three projects in a year. As mentioned earlier not all projects within the company use 5D-BIM but it is hoped that more construction professionals within the company would be trained in it and would be using it on future projects.

4 Conclusions

Implementing 5D-BIM in a large construction company has several challenges associated with it. There exist technological challenges that have to be overcome to implement 5D-BIM. These projects generally require an experienced construction professional who also has a high level of talent on the technology side. There are significant hardware, software and training costs associated with adopting 5D-BIM processes. It is also challenging to overcome the human reluctance towards change on part of some personnel within a company. Training existing personnel who have a wealth of industry knowledge to adopt new methodologies for estimating and scheduling can be challenging. This issue is further complicated by construction companies having to remain profitable while exploring these new technology enabled processes. The process of implementing 5D-BIM involves a close inspection of internal processes with a company and can be beneficial to streamline them. Increasingly designers are sharing valuable information with the construction team by means of BIM models. 5D-BIM represents a clear departure from the existing methods of planning construction projects and can potentially be a transformative experience for a construction company.

References

[1] S. Azhar, M. Hein, and B. Sketo, "Building information modeling (BIM): Benefits, risks and challenges," presented at the Proceedings of the 44th ASC National Conference, Auburn, AL, 2008.

[2] N. Gu and K. London, "Understanding and facilitating BIM adoption in the AEC industry," *Autom. Constr.*, vol. 19, no. 8, pp. 988–999, Dec. 2010.

[3] H. Kim, C. Benghi, N. Dawood, D. Jung, J. Kim, and Y. Baek, "Developing 5D System Connecting Cost, Schedule and 3D Model," *IABSE Symp. Rep.*, vol. 97, no. 24, pp. 32–38, Jan. 2010.

[4] D. Kent and B. Becerik-Gerber, "Understanding Construction Industry Experience and Attitudes toward Integrated Project Delivery," *J. Constr. Eng. Manag.*, vol. 136, no. 8, pp. 815–825, 2010.

[5] P. Larson, "Constructech magazine | Defining the 5D of BIM." [Online]. Available: http://constructech.com/news/articles/article.aspx?article_id=9229. [Accessed: 22-Feb-2014].

[6] B. Becerik-Gerber and K. Kensek, "Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends," *J. Prof. Issues Eng. Educ. Pract.*, vol. 136, no. 3, pp. 139–147, 2010.

[7] M. Muzvimwe, "5D BIM Explained," 2011. [Online]. Available: http://www.fgould.com/uk-

europe/articles/5d-bim-explained/. [Accessed: 22-Feb-2014].
[8] W. Hu, "Integration of Radio-Frequency Identification and 4D CAD in Construction Management," *Tsinghua Sci. Technol.*, vol. 13, Supplement 1, pp. 151–157, Oct. 2008.
[9] Vico, "5D BIM | Model-Based Estimating | Construction Estimating Software." [Online]. Available: http://www.vicosoftware.com/what-is-5D-BIM/tabid/88207/Default.aspx. [Accessed: 22-Feb-2014].
[10] J. Corbin and A. Strauss, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. SAGE, 2008.
[11] R. F. Fellows and A. M. M. Liu, *Research Methods for Construction*. John Wiley & Sons, 2009.
[12] R. K. Yin, *Case Study Research: Design and Methods*. SAGE, 2009.
[13] M. Saunders, P. Lewis, and A. Thornhill, *Research Methods for Business Students*, 5th Edition. Pearson Education, 2009.
[14] M. Denscombe, *The Good Research Guide*. McGraw-Hill International, 2007.
[15] M. Vaismoradi, H. Turunen, and T. Bondas, "Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study," *Nurs. Health Sci.*, vol. 15, no. 3, pp. 398–405, 2013.
[16] D. F. Marks and L. Yardley, *Research Methods for Clinical and Health Psychology*. SAGE, 2004.
[17] McGraw Hill, "Business Value of BIM," 2012.
[18] CSI, "The Construction Specifications Institute." [Online]. Available: http://www.csinet.org/. [Accessed: 22-Feb-2014].
[19] ASTM, "ASTM International - Standards Worldwide." [Online]. Available: http://www.astm.org/. [Accessed: 22-Feb-2014].