Use of Building Information Modeling for the Design and Construction of Educational Facilities

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ABSTRACT

Building information modeling (BIM) is one of the most recent technologies introduced to the design and construction industry. Currently, some educational institutions are requiring a BIM component for new construction. The aim of this research was to investigate the current extent of BIM use on educational facilities projects. A survey inquiring about the current use of BIM, BIM benefits, perceived obstacles to using BIM, and the importance of particular BIM procedures was distributed to architecture, engineering and construction (AEC) professionals that have experience with educational facilities projects. The survey responses were analyzed using descriptive statistics. The survey results showed that the majority of the companies were using BIM. Many of the professionals who do not use BIM claimed to have no interest in using BIM. The largest proportion of the respondents perceived clients to be the driving force behind the use of BIM on educational facilities projects. Most respondents agreed that BIM was useful for increasing client engagement by providing clearer understanding of the projects through 3D visualizations. While most of the respondents believed that design-build was the best method to deliver educational facilities projects using BIM, the majority of the respondents still used the design-bid-build method. This research helped gain insight into the general opinions of BIM users across the different disciplines involved in designing and constructing educational facilities. These research findings can be used to assist AEC companies that are interested in implementing BIM on the educational facilities projects.

INTRODUCTION

As the "Information Technology" era has advanced, many industries have acted rather quickly to incorporate the new tools generated by these technologies. Building information modeling (BIM) is a crucial approach for the design and construction processes and has proven to be essential in the evolution of the AEC industry. As with any other technological advancement, the adoption of new tools takes time and dedication. The cautious nature of the design and construction industry has become a barrier impeding the professional field as a whole from progressing (Porwal et al. 2013).

BIM provides a broad range of users with a shared resource of knowledge and information that facilitates communication, problem-solving and the decision-making processes (McBride et al. 2011). BIM use cultivates and fosters new ways to enhance collaboration and information exchange between disciplines to increase efficiency, productivity, communication, performance and quality (Bynum et al. 2013). BIM provides easier management of asset portfolios and aids in the identification of strategic and planning needs (Wisconsin Department of Administration, Division of State Facilities 2009). The use of BIM results in shorter project delivery times, cost reductions and collaboration amongst all parties involved (Bryde et al. 2012). Azhar (2011) found that the implementation of BIM aids design and evolves the process into an interdisciplinary collaboration from the initial conception of the design to the construction and maintenance/operation of buildings.

BIM is currently experiencing fast adoption rates. It has been predicted that in 2013, 78% of AEC industry would be using BIM on projects or implementing BIM as a standard practice and that 84% of owners would be demanding a BIM component on 25% or more of all projects. This increase in BIM demand comes from both the private and the semi-public sectors (educational and health) of the construction market (Cefrio 2011). The recent adoption of BIM from a client perspective has also encouraged BIM adoption amongst design and construction companies. A McGraw Hill Construction (2012) survey confirmed that the industry-wide adoption of BIM increased from 28% in 2007 to 71% in 2012 (McGraw Hilll Construction 2012).

BIM is gaining significant support from government agencies as these organizations and clients are beginning to understand the valuable impacts of BIM use and are requiring BIM in the design and construction of new facilities (Barlish et al. 2012). For example, in 2007, the General Services Administration (GSA) implemented a BIM requirement on all new GSA projects (Arensman and Ozbek, 2012). Public entities noticed that the larger number of bidding proposals with BIM use showed a higher quality product because BIM guarantees a maximum value and optimizes the resources and opportunities of the project (Porwal et al. 2013). Government agencies try to optimize their spending by investing in BIM implementation and as a result they award projects to the firms that use BIM technology (Porwal et al. 2013).

The education sector of the market is no exception to the recent BIM adoption trend. In the recent years, some universities and higher education institutions have requested a BIM component in all new construction projects. Beginning October 1, 2012, Indiana University (IU) issued a BIM requirement on all new construction projects with total project funding of $5 million or greater. As a result of this requirement, UI published BIM Guidelines & Standards for Architects, Engineers, and Contractors (UI 2012). The Pennsylvania State University (2011) also developed their own guides (BIM: Project Execution Planning Guide and the BIM: Planning Guide for Facility Owners). As research on the use of BIM progresses, professionals will gain insight into the use, implementation and benefits of using BIM and will begin to adopt this practice as a standard for the industry. Increased awareness of the extent of BIM use and emerging future trends will lead to more BIM support from the AEC community and drive the field to more lean practices and innovative approaches

(Arayici 2011). The aim of this research was to investigate the current (as of 2013) implementation of BIM on educational facilities projects in order to obtain an understanding of the AEC industry attitude towards BIM. The research objectives were to determine the current BIM use on educational facilities, the perceived need for use of BIM on future projects, the perceived benefits of BIM, and the perceived obstacles that impede BIM implementation.

RESEARCH METHODOLOGY

A literature review on BIM trends and BIM utilization was used to develop a survey instrument. The purpose of the survey was to obtain an understanding of the current BIM implementation on educational facilities. The survey targeted architects, engineers and contractors with experience in the design and construction of educational facilities. The survey participants were asked to answer questions on their current use of BIM, the perceived need for using BIM, the perceived benefits of using BIM and the obstacles that prevent the use of BIM. The survey was developed using SurveyMonkey. The link to the survey was emailed to the members of professional AEC societies in the USA, such as the American Institute for Architects (AIA), Associated Builders and Contractors (ABC), the Associated General Contractors of America (AGC), and the American Society of Civil Engineers (ASCE). One hundred responses to the survey were received.

Descriptive statistics was utilized to analyze the survey responses. A frequency count was used to determine the participant demographic characteristics, and the basic trends and general opinions of BIM users in the educational facilities market sector as a whole. The cross tabulation method was used to analyze the survey responses according to the respondent’s role (such as architects, structural engineers, contractors, civil engineers, and MEP engineers) in the design and construction of educational facilities projects in order to determine the trends by discipline. For certain analyses in this research the respondents that were categorized as structural engineers, civil engineers, or MEP engineers were grouped into the category titled “Engineers”.

RESULTS

Demographics. The five most common job roles that responded to the survey were architects (49%), structural engineers (15%), contractors (15%), civil engineers (7%), and MEP engineers (5%). The majority of the educational facilities projects (66 responses) were from the higher education sector of the industry; (e.g. universities). The public school (46 responses), private school (45 responses) and primary school (45 responses) sectors were selected roughly by the same number of the respondents. Regarding annual revenue, 22% of the respondents worked for companies that made over $1 million but less than $5 million. About half of the respondents worked for companies that had annual revenue of less than $10 million and the remaining respondents worked for companies that made $10 million or more. A couple of the respondents worked for companies that earned over $1 billion.

Company's Current Use of BIM on Educational Facilities. A majority of the respondents (78%) worked for companies that use BIM while the remaining 22% worked for companies that did not use BIM. When asked to describe the reason for their company's lack of direct involvement with BIM, 38% of the respondents answered that their company had no interest in using BIM. The majority of the respondents that answered that their company had no interest in using BIM where architects (83%) while the remaining 17% were contractors. Thirty-eight percent of the respondents stated they were interested in using BIM even though their company does not currently use BIM. Within the participating AEC companies, the majority of engineers (90%), architects (81%) and slightly more than half (57%) of contractors used BIM. The largest proportion of the respondents (23%) stated that their companies have been implementing BIM in their practice for the past five years. One-third of the companies have been implementing BIM for six or more years. Five percent of the companies have implemented BIM for 10 years while roughly the same percentage of the respondents claimed to have just recently begun to implement BIM in the past year. When referring to the different disciplines, MEP engineers had the longest average time (6.2 years) of BIM implementation. The architects have been implementing BIM for a little over four years while the structural engineers and contractors appear to have been implementing BIM use for about the same length of time (5.6 years and 5.5 years, respectively). Civil engineering was the discipline with the shortest period of BIM implementation with an average of 2.5 years.

The survey asked a series of questions about the strategies that companies used to encourage BIM implementation. Thirty-nine percent of the respondents stated that their company requires BIM as a standard of the practice and a similar proportion (38%) of the responding companies provided training to encourage BIM use. Figure 1 shows that the majority of the respondents (54 %) believed that the best way for a company to acquire BIM expertise was through internal training. About one-third of the respondents thought that hiring new BIM-skilled professionals is the best way for a company to acquire BIM expertise.

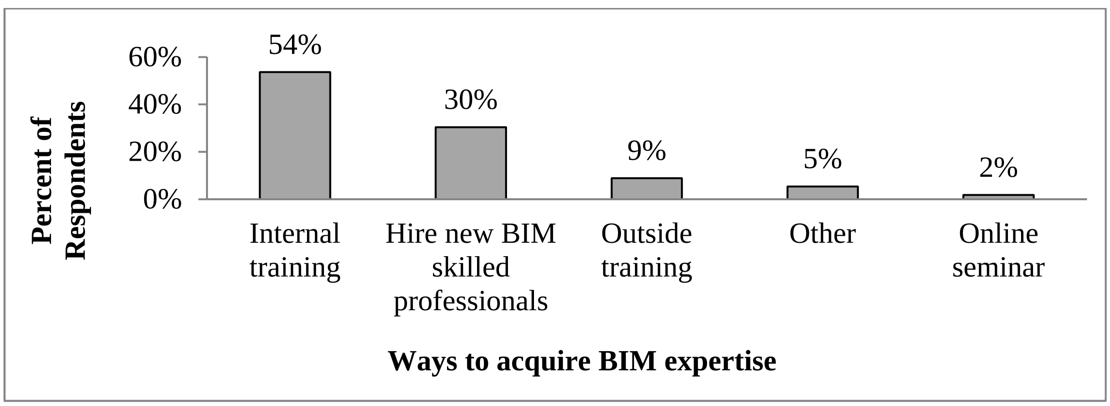

Figure 1. Best ways to acquire BIM expertise

Most of the respondents (34%) primarily share BIM information with architects when working on the design and construction of educational facilities. About one-third of the respondents claimed that engineers were the main discipline with which they primarily share BIM information during the design and construction phases. More respondents seem to share information with the owners than with contractors and subcontractors. Regarding the legal aspect of BIM implementation, the largest proportion of the respondents (38 responses) did not encounter any disputes with BIM implementation. Some of these disputes were evident based on the open-ended responses, which revealed that respondents encountered BIM disagreements related to not being adequately compensated for the BIM work. Other respondents stated that BIM disputes arose due to different levels of model accuracy and one respondent stated that contractors were not using BIM. The respondents perceived clients to be the main driver of BIM use on educational facilities projects. Twenty-six respondents thought that competition from other companies was a driving factor in their BIM implementation. When asked about project delivery methods, the traditional design-bid-build method was the primary approach (51% of the responding companies) used for the design and construction of educational facilities. The other most commonly used approaches were the design-build (12%), negotiated contract (11%), and the early contractor involvement (10%) methods. The least used project delivery methods were construction management and construction management at risk. However, one-third of the respondents agreed that design-build is the project delivery method that provides the best environment for using BIM on educational facilities projects while 17% of the respondents felt that integrated project delivery is the best delivery method (see Figure 2).

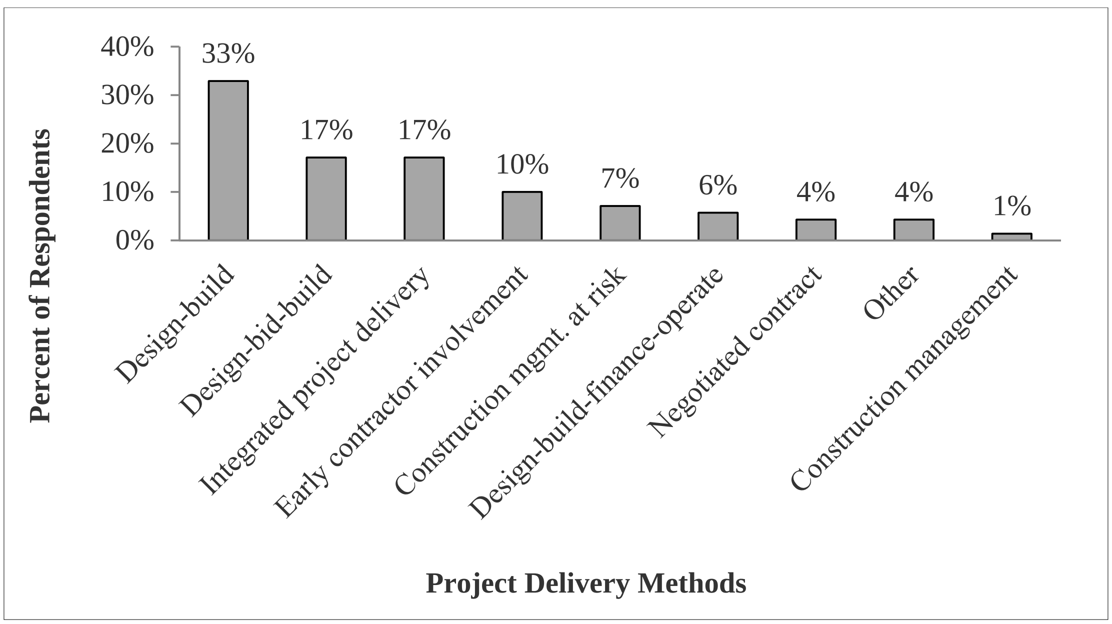

Figure 2. Best delivery methods for using BIM on educational facilities projects

Forty percent of the respondents stated that their company used some form of BIM software on 80% or more of the educational facilities projects completed. Slightly more than one-fourth of the respondents (27%) answered that their companies used BIM on less than 40% of their projects. The survey asked respondents to provide an estimate of the percent of educational facilities projects on which certain BIM applications were used. Figure 3 shows that the most used BIM applications on educational facilities projects were 3D visualizations (average percent of projects 69%), automation of documentation (average percent of projects 68%) and clash detection and collision assessment applications (average percent of projects 59%).

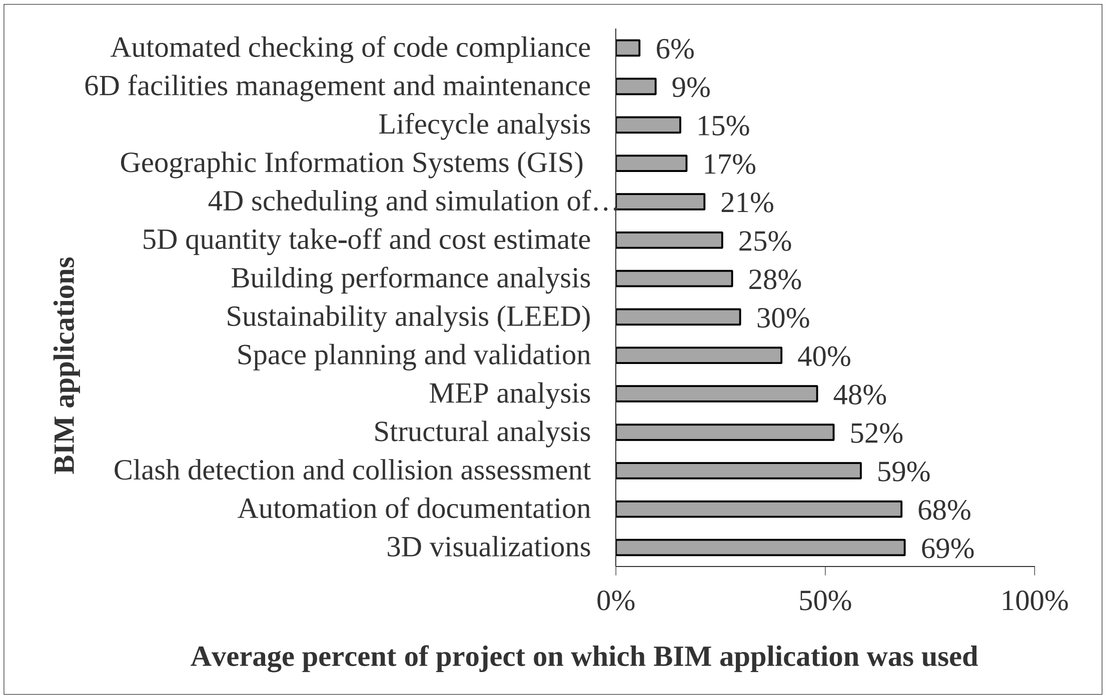

Figure 3. BIM applications for the design/construction of educational facilities

Perceived Need for BIM Use on Future Projects. The largest proportion of the respondents (40%) stated that the use of BIM on educational facilities projects today is very important while 9% percent of the respondents felt that BIM use is not important. Sixty-four percent of the respondents thought that in five years (i.e., by 2018) the use of BIM on educational facilities projects will be very important. A comparison of these results shows that about an additional one-fourth of the respondents thought that BIM use will be very important within five years as compared to their perception of the current importance of BIM use.

Perceived Benefits of BIM Implementation. Respondents were asked to rate their level of agreement with various benefits of BIM using a five-point Likert scale (5 meaning the respondents strongly agree with the specific benefits, 1 meaning the respondents strongly disagree with the BIM benefit). The respondents agreed that the use of BIM for the design and construction of educational facilities increases client engagement and provides clearer understanding of the design (average rating of 4.15), serves as a new marketing tool for firms (average rating of 4.07), and improves collaboration and communication amongst disciplines (average rating of 3.84). The respondents also agreed that lowering risk and better predicting outcomes due to discovery of errors, omissions and conflicts prior to construction (average rating of

3.76), and automation of documentation (average rating of 3.82) were beneficial for the design and construction of educational facilities. Respondents neither agreed nor disagreed that construction safety (average rating of 2.85) and consideration for sustainable approaches (average rating of 3.16) were beneficial.

Perceived Obstacles to BIM Implementation. The respondents were asked to rate the perceived likelihood of various obstacles impeding BIM implementation using a five-point Likert scale (5 representing an obstacle that is extremely likely to prevent BIM implementation, 1 representing an obstacle that is not likely at all to prevent BIM implementation). The contractors thought that the cost of new hardware and software (average rating score of 3.92), and the cost of hiring new staff (average score of 3.85) were very likely to prevent BIM implementation. The architects felt that the lack of expertise (average score of 3.33) and the disruption in workflow caused by the implementation of new BIM processes (average score of 3.21) were moderately likely to prevent BIM implementation. The engineers thought that the lack of expertise (average score of 3.41) and unclear responsibilities and BIM deliverables (average score of 3.38) were moderately likely to impede BIM implementation.

CONCLUSION

The results of the survey imply that the AEC industry seems to favor the use of BIM in the design and construction of educational facilities. Generally, most firms seemed to have started implementing BIM five years preceding their response to the survey. Internal training was perceived by respondents as a good way of both acquiring BIM expertise within a company and of encouraging BIM use. The survey findings showed that architecture and engineering are the two disciplines that communicate the most through BIM on educational facilities projects. The traditional design-bid-build project delivery method was most commonly used by the respondents. However, most respondents believed that design-build and integrated project delivery were the project delivery approaches that best suit the use of BIM on educational facilities projects. This suggests that BIM promotes cooperation between disciplines because both integrated project delivery and design-build are associated with high integration and collaboration between disciplines. Overall, BIM users seem to benefit from increased client engagement, using BIM as a marketing tool and the improved collaboration and communication amongst different disciplines. For contractors, the main obstacle impeding BIM use was the cost of new hardware and software; while for architects and engineers the biggest perceived obstacle was the lack of expertise. The survey results suggest various generalizations about the current trends of BIM use on educational facilities. It can be concluded that the majority of the disciplines involved in the design and construction of schools, whether higher education or K-12 projects, are using BIM in one way or another. In addition, the survey results indicated that the industry's awareness of BIM is increasing and that the industry will continue to adopt BIM. The respondents recognized that the value of BIM will increase within the subsequent five years (by 2018) and that BIM use on educational facilities will be more important as time passes by.

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