

State of Adoption for Building Information Modeling (BIM) in the Southeastern United States

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Building Information Modeling (BIM) possesses the potential to change the paradigm within which the Architecture Engineering and Construction (AEC) industry operates. Holistic adoption of BIM can result in additional expenditure for the adopting unit. Thereby, necessitating an understanding of adoption by architectural firms, which are mostly small in size within the US. Thus, this study aimed to characterize the adoption of BIM by architectural firms for facilities constructed between the periods of 2000-2010 in the southeastern United States. The survey was sent to 2000 architectural firms in Georgia, North Carolina, South Carolina, Florida, Virginia, Maryland, and the District of Columbia. About 255 architectural firms responded to the survey and 42% of respondents indicated that they had adopted BIM. The study tested the hypothesis that certain functions of BIM were more frequently adopted than others and found visualization to be most adopted. The study also tested the hypothesis that certain characteristics of the adopting unit such as firm experience, firm size, previous experience with federal projects, and adoption of green buildings possessed relationship with BIM adoption. The study found that all characteristics possessed relationship with BIM adoption and the strongest relationship was exhibited by firms which had previously adopted green buildings.

Keywords: Adoption, BIM, Survey

Introduction

Multiple publications in the 1970's pointed towards the concept of Building Information Modeling (BIM) and the benefits that could be accrued with its adoption (Eastman et al., 1974; Eastman, 1976). Adoption has been defined in literature as "a decision to make full use of innovation as the best course of action available" (Roger, 2003), and in this case BIM would be the innovation for the potential adopters. The ability of BIM to compliment multiple aspects of the design and construction industry have been identified and highlighted by many researchers, since then (Arayici et al., 2012, Nederveen & Tolman, 1992; Siddiqui et al., 2009). Multiple researchers have indicated a multitude of opportunities/benefits to stakeholders, including architectural firms, with the holistic adoption of BIM (Azhar et al., 2008; Ku & Mills, 2010; Krygiel & Nies, 2008). In addition, researchers have also cited BIM to be a useful tool towards the design of green buildings (McGraw Hill, 2010; Siddiqui et al., 2009). Thus, BIM offers a multitude of benefits, not only in the design of conventional buildings, but also green buildings. For this study, the green buildings have been operationalized as "facilities that qualify to utilize and reduce the consumption of natural resources in an efficient manner." In the context of this study, buildings do not need to be certified by an existing rating tools such as Leadership in Energy and Environmental Design (LEED), the Nation Association of Home Builders (NAHB) green standard, or Green Globes in order to be considered green.

Even with these positive impacts, certain deficiencies within BIM still exist which acts as barriers for the adoption and they have identified by the researchers (McGraw-Hill, 2009; Ku & Taibet, 2011). In addition, holistic adoption of BIM (adoption as a product and process) results in additional direct and indirect cost for adopting unit, such as training of employees, cost of software and hardware upgrade, change in work process, cost of adoption on projects, and others (Arayici et al., 2011; Ku &Taibet, 2011). To conclude, BIM offers multiple advantages, but at the same time, entails certain cost (monetary, time, and effort) for the potential adopters, including architectural firms.

Thus, this study identifies the patterns for the adoption of BIM among the design firms in the southeastern United States. The need for such a study is highlighted by the fact that the majority of architectural firms in the United States are small (less than 10 employees) (AIA, 2009; AIA, 2012), and their ability to invest might be restrained in terms of required investment. Hence, it is important to understand the status for adoption of BIM among

architectural firms geographically located in the southeastern United States. Multiple studies have been conducted globally to analyze the adoption of BIM within the AEC industry and the next section discusses these studies.

Adoption of Building Information Modeling

Multiple studies have been conducted to analyze the adoption of BIM with regard to the AEC industry. Ku &Taibet (2011) analyzed the adoption of BIM and the target population of the study was construction companies located in the mid-Atlantic region. The study found that construction companies currently used visualization and constructability as the major functions of BIM. The respondents planned to use the functions of estimating and cost control, in the near future. Luthra (2010) analyzed the adoption of BIM among architects within Indian context. However, at the same time, the context within which an architect operates within the US and India is different and the sample of respondents were only 25 architectural firms. The survey found that although the majority of the firms had heard about BIM, but they had not used it. Nearly 67% of the adopters had continued adoption after initial use with the focus on adopting functions associated with visualization. McGraw Hill (2009) conducted a survey to understand the adoption patterns for BIM among stakeholders within design and construction industry. Nearly 27% of the survey respondents were architectural firms and the survey found that architectural firms were using BIM the most. In addition, the study found that the architects were using it majorly for 3D modeling. Another study by McGraw Hill (2010) did investigate the adoption of BIM and sustainability. The study investigated implementation of both BIM and sustainability and had 494 respondents out of which 31% were architectural firms. The study found that BIM is used more for complicated projects including renovation. Additionally, the study found that the majority of A/E firms were using BIM for energy performance, and contractors used BIM for cost estimating. The studies aimed to measure the overall adoption in the industry and not specifically to the architectural firms.

Based on this review, certain questions still remain unanswered, dealing with the relationship between the adoption of BIM and the characteristics of the adopting unit (Adopting unit in this case were architectural firms adopting BIM). The characteristics of the adopting unit for this study have been identified as follows:

- Size and experience of the adopting unit.
- Adoption of green buildings by the adopting unit.
- Firm's experience with federal projects.

The architectural firms were chosen as the general population for the survey as they are involved from the early stages of the project feasibility to define a program (WBDG, 2012), and this is generally when adoption of BIM for a project is decided.

Apart from identifying the trends for the adoption of BIM among architectural firms, the study also tested the following hypotheses:

1. Hypothesis 1: Certain functions of BIM will be more frequently adopted than others, i.e., functions will not be uniformly adopted
2. Hypothesis 2: Adoption of BIM will be related to characteristics of adopting unit. The characteristics of the adopting tested were firm size, firm experience, adoption of green buildings by adopting unit and previous experience with federal projects

Across literature, researchers have pointed out that of the various functions generated by BIM such as visualization, construction documents, facility management, initial presentation, and others, certain functions are used more than others (Ku &Taibet, 2011; McGraw-Hill, 2009; McGraw-Hill, 2010). For example visualization has been pointed as the function that has been most commonly adopted by stakeholders (Ku &Taibet, 2011; McGraw-Hill, 2009). Thus this study identified if certain functions were adopted more than others. And if they did, which functions were adopted more and which were adopted less. The study also identified that the characteristics of adopting unit (architectural firms) was related to the adoption of BIM.

Multiple studies in the innovation literature have cited that characteristics of the adopting unit such as firm size influence the adoption of innovation (Askarany, 2006; Damanpour, 1992). Hence, as a part of characteristics of the adopting unit the relationship between firm size and BIM adoption was tested. In addition, multiple parallels have been observed across literature with regard to the process associated with adoption of BIM and green buildings such

as need for adopting interdisciplinary approach and active stakeholder participation from the very beginning of the project, need for a champion to support successful adoption of the innovation (BIM and green building), the ability to provide benefit(s) to the adopting unit and the environment (Azhar et al., 2011; Horman et al., 2006; Jernigan, 2007; Krygiel & Nies, 2008). Thus with these multiple parallels identified in literature between adoption of BIM and green buildings, this study also tested if any relationship could be observed between adoption of BIM and green buildings. Further, this study also identified if any relation could be observed between BIM adoption and the firm experience with operation in the industry. Last but not least, this study also tested if there is any relationship between the adoption of BIM and firms experience with federal projects. This is of key interest as government agencies such as GSA are utilizing the capabilities of BIM on projects.

The next section discusses the methodology accounted for the preparation of the survey, selection of the sample, data collection, and data analysis.

Methodology

Since the main aim of the study was to establish the patterns of BIM adoption among architectural firms, an online survey was deemed as an appropriate method. However, in order to conduct a survey, there were multiple steps which involved the selection of the sample, preparation of the survey, data collection, and data analysis. These tasks are discussed in the following subsections.

Selection of sample and survey preparation

To achieve the goals for this study, a sample of 2,000 architectural firms located in Georgia, North Carolina, South Carolina, Florida, Virginia, Maryland, and the District of Columbia was selected. The selected firms were also registered with American Institute of Architects (AIA). After the selection of the general population for the survey, functions of BIM relevant to the architectural firms were also identified. In literature, 17 different functions were established that were used by construction firms (Ku &Taibet, 2011). Further, expanding on the works of Ku &Taibet (2011), a list of comparable functions relevant to architects were identified and further developed with an expert professional from the industry. In total, eighteen functions associated with BIM relevant to architectural firms were identified. Identified design-phase functions included:

1. Clash detection
2. Constructability
3. Construction drawings
4. Database information management
5. Design of complex structures
6. Estimation
7. Facility management
8. Initial presentation
9. Interior environmental analysis
10. LEED
11. Municipal code
12. Parametric design
13. Performance optimization
14. Site analysis
15. Restoration and renovation
16. Sustainable design
17. Value engineering
18. Visualization.

After identifying the functions of BIM, the method to conduct the survey was chosen. Of the many methods available, web-based survey methodology was utilized because of the ability to collect detailed information (Werner 2004). Upon the finalization of the survey method and sample, the survey tool was pilot-tested with architectural firms and the recommendations were incorporated. After incorporating the recommendations of the pilot-test respondents, the survey link was emailed with a cover letter to the sample. All cover letters were personalized, to

achieve a higher response rate. A reminder email was sent to the architectural firms which had not responded, after six weeks. This was done to improve the response rate. The literature indicates that the responses can increase up to 40% (Comer & Kelly, 1982; Murphy et al., 1990). Specifically in email surveys, Sheehan & Hoy (1997) observed that the follow-up email increased the response rate by 25%. For this study, the total number of responses increased by about 45% after the first reminder, which aligns with what has been observed in the literature. Four weeks after the first reminder the survey was closed.

Data collection and analysis

All the survey responses were downloaded from the website into a spreadsheet. Initial descriptive analysis was conducted to analyze the overall patterns observed in the survey and to test the hypothesis 1. Further, in order to test hypothesis 2, which aimed at establishing the relationship between the characteristics of the adopting unit and adoption of BIM, Chi Square Test of Independence was conducted. Upon completion of the Chi Square Test of Independence, it was ascertained if a relationship existed or not. Further, in order to test the strength of a relationship, Cramer's V test was conducted. Cramer's V measures the strength of relationship and the degree of association between the values of variables on a scale of 0 to 1.

Results

The survey was emailed to approximately 2,000 architectural firms, geographically spread across six states and the District of Columbia. However, nearly 15% of the architectural firms did not receive the survey due to reasons such as change of email address, firewall settings, retired from the practice, and others. Hence, for this study, the final sample size was considered at about 1700. Upon the completion of the survey, it was observed that the response rate for the survey was about 19%. However, upon closer inspection of the responses, it was found that 4% of the respondents had not completed the survey, in regards to the questions asked. Accordingly, the effective response rate lowered to about 15%.

Survey demographics

Figure 1, 2, and 3 represent the geographic location, firm size, and firm experience of respondents. As depicted in Figure 1, the survey received responses from respondents in all six states and the District of Columbia. The response from firms located in DC was lower in comparison to other states because of the lower number of firms operating in DC. In addition, as depicted in Figure 2, the maximum respondents of the survey were firms which had less than 10 employees, and large firms with 100 or more employees formed a small part of the respondents. As per surveys conducted by AIA (2009 & 2012), the majority of firms operating in the US have less than 10 respondents and firms with more than 100 employees formed 2% and 1% of the overall survey. Hence, close parallels to establish the generalizability of the study were observed between this survey and the national survey conducted by AIA in 2009 and 2012. Furthermore, as depicted in Figure 3, the study received responses from all the respondents, except from the firms that had less than one year of experience. The majority of responses were from firms which had between 11-25 and 26-50 years of experience.

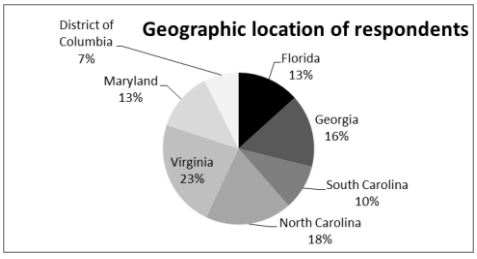

Figure 1: Geographic location of respondents (state in which main office is located)

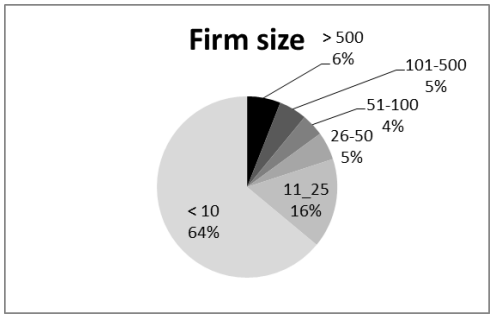

Figure 2: Firm size of respondents (number of employees)

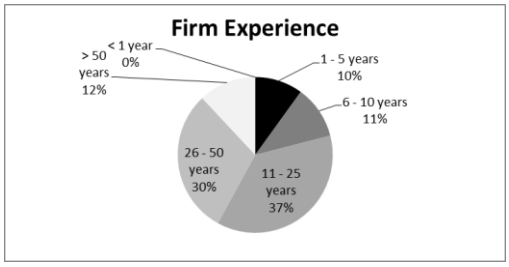

Figure 3: Experience of respondents (years)

The next section discusses the trends for the adoption of BIM as per the responses provided by the respondents of the survey.

Adoption trends for BIM

After this initial analysis, the responses were analyzed in terms of responses for green buildings. About 69% of the survey respondents indicated that they had designed Green building(s). In addition, 42% of the respondents were adopters of BIM and the rest of the 58% were non-adopters of BIM. Furthermore, 32% of the respondents had used BIM for the design of the green buildings. Of those respondents which adopted green BIM, about 83% respondents used for non-federal or non-state agencies owned green buildings.

Furthermore, Figure 4 depicts the functions that had been adopted on at least one project by the responding firms, based on the responses proved in the survey. Of the 18 functions identified earlier, visualization was the most commonly used, followed by initial presentation. Facility management and municipal code compliance were identified as the least commonly adopted functions of BIM by the respondents. Thereby supporting the hypothesis that certain functions of BIM were more frequently adopted than others.

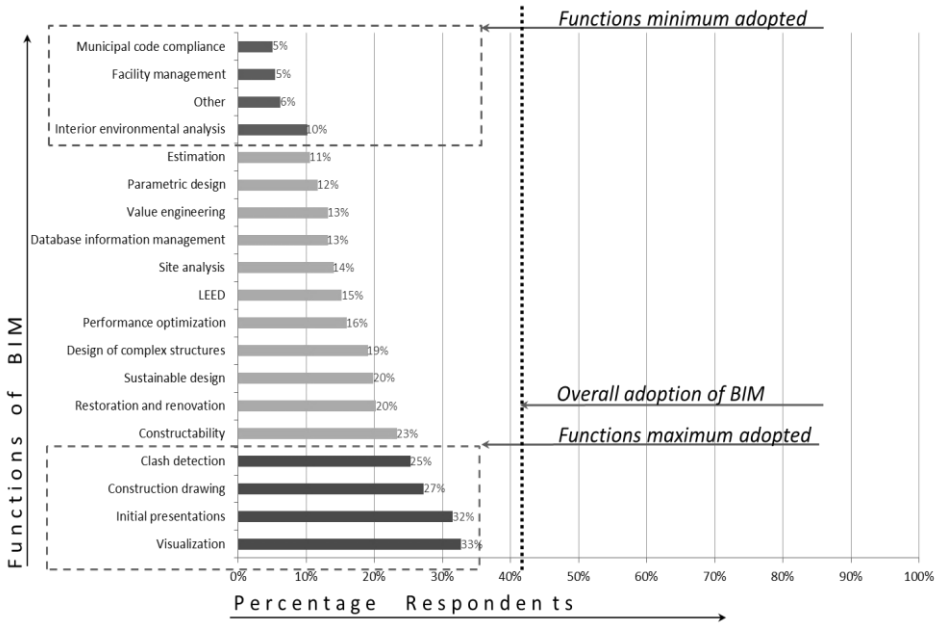

Figure 4: Adoption of functions of BIM by architectural firms

After completing the initial analysis the Chi Square Test of Independence and Cramer's V test was conducted, with p of 0.05, to test that the relation between BIM adoption and characteristics of adopting unit. The characteristics of adopting unit were:

- Firm size
- Firm experience
- Adoption of green buildings
- Firm's previous experience with federal projects

Table 1 depicts the type of relation between the each of the characteristic of the adopting unit and BIM adoption. The type of relationship was generated from the values obtained after completing the Chi Square test and the generation of Cramer's V Value.

Table 1

Testing relationship between characteristic of the adopting unit and BIM adoption

Sr. No.	Characteristic of adopting unit	Chi Square Test Value	Cramer's V Value	Existence of relationship	Strength of relationship
1	Firm size	55.01	0.48	Yes	Relatively strong
2	Firm experience	11.83	0.22	Yes	Moderate
3	Adoption of green buildings	229.50	0.94	Yes	Very strong
4	Firm's experience with federal projects	52.47	0.45	Yes	Relatively strong

As observed in the table adoption of BIM was related to characteristics of adopting unit and thereby supporting our second hypothesis. However it is seen that certain characteristics exhibit stronger relation than others. For example firm size of the adopting unit has a more significant relationship than firm experience (0.48 vs. 0.22) for the adoption of BIM. Hence, the firm size is a more important factor to consider than firm experience among architectural firms for the adoption for BIM. In regard to the relationship between BIM adoption and firm's experience with federal projects, the study found that relatively strong relationship existed. Finally, the study also

indicated that adoption of BIM was very strongly related to adoption of green buildings. This relationship was strongest of the all.
The next section discusses the conclusions that were generated out of this study and the set of future research areas which were identified upon the completion of this study.

Conclusions and future work

The study identified the state of adoption for BIM among architectural firms and also the patterns of adoption of BIM with respect to the adoption on Green Buildings. The study further identified the most and the least commonly adopted functions of BIM by the architectural firms, with visualization and initial presentation the functions that were adopted most by the architectural firms as of now. The identified that design firms used BIM least for municipal compliance and facility management. The reason for lower use in municipal compliance can be attributed to the fact that either municipalities do not require electronic submissions from design firm(s) or interoperability issues exist between the software used by the design firm(s) and the municipal office. In addition, from the results there is also an indication that the benefits of creating BIM model are not presently transferred by the designer to the owner. However, this is just an assumption based on the response received. A counter argument for the lower use of BIM model for facility management can be that the contractors at times act as model coordinators during design and construction and are responsible for updating the model upon completion of the project. Upon completion of the project, the model is submitted to the owner by the contractor. However, future investigations need to be conducted in both areas to identify:

- Firstly, are the municipal offices across the nation capable enough to handle such models so that these are not the barriers and can pave way for a global exchange of information?
- Secondly, are the benefits of creating a BIM model transferred to the owner on a general basis?

Furthermore, as per the responses to the survey, the study also found that not all functions of BIM have been adopted by the responding firms. It poses an important question: is BIM underutilized by the architectural firms, provided it is aimed for data integration and management apart from enhancing visualization? Are most adopters (architectural firms in this case) currently aiming for the lowest hanging fruit?

In addition it was also found that the characteristics of adopting were related with the adoption of BIM. For instance firm size of the adopting unit possessed a stronger relationship with the BIM adoption than the firm experience. The study also indicated that relatively strong relationship existed between BIM adoption and firms experience with federal projects. Last but not least, the study also indicated that a very strong relationship existed between adoption of BIM and green buildings. Adoption of BIM and green buildings shared the strongest relationship in comparison to the other relationships. This can be attributed to multiple similarities that have been identified in the literature with the adoption of the two, and so there exists a possibility that the adoption of the innovations (BIM and green building) complement each other. However this aspect of the two innovations (BIM and green building) needs to be further investigated.

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