Implementation of Building Information Modeling on K-12 Educational Facility Projects in Florida

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There has been a rapid adoption of building information modeling (BIM) within the architecture, engineering, and construction (AEC) industry. However, the extent of BIM implementation on K-12 educational facility projects has not yet been investigated. Thus, the objective of this research was to explore the existing utilization of BIM, benefits of BIM use, obstacles to BIM use, and future use of BIM on K-12 projects in Florida. In the spring of 2013, a survey was distributed to the various stakeholders involved in K-12 projects. Survey results showed that the majority of the companies used BIM on their K-12 projects. The construction companies were the dominant users of BIM. BIM was most frequently used for clash detection, building system coordination and project visualization. BIM was not widely used for building code checking and spatial program validation. The use of BIM resulted in improved project quality, more accurate cost estimates, and improved understanding of design intent. The lack of interoperability between BIM software, the limited number of BIM professionals, and the high cost of hardware upgrades were the major obstacles to BIM use. The majority of the respondents felt that BIM would be fully utilized on K-12 projects within five years.

Key Words: BIM, BIM implementation, BIM benefits, obstacles to BIM use, K-12 projects

Introduction

Building information modeling (BIM) is one of the most recent and promising technologies in the architecture, engineering, and construction (AEC) industry (Eastman et al., 2011). There has been a rapid increase of BIM adoption within the AEC industry since 2007 (McGraw-Hill Construction, 2012). In 2007, about one-third (28%) of the AEC companies used BIM while in 2012 almost three-fourths (71%) of the AEC industry used BIM. More than half (57%) of the BIM-users planned to deploy BIM on most of their projects by 2014. Nearly three-fourths of contractors and 70% of the architectural firms adopted BIM. Contractors also had the highest number of expert users. About one-third of non-BIM-users stated that they did not plan to use BIM. The most resistance to BIM use came from the non-using architects; 38% of them stated they did not plan to use BIM in the future. Almost half of the companies had used BIM for five years or more. Regarding the company size, the majority of the large to medium-to-large companies (90%) and almost half of the small companies had adopted BIM (McGraw-Hill Construction, 2012). A survey by Becerik-Gerber and Rice (2010) found that BIM was more appropriate for large projects. They also found that integrated project delivery (IPD) was the most effective method for delivering BIM-based projects. About 40% of the respondents used BIM on more than 80% of their projects. Autodesk BIM software (Revit, Navisworks) were used the most by the respondents; followed by Graphisoft Archicad and Bentley BIM solutions. The top three BIM applications used were visualization (3D modeling, rendering, walk-throughs), clash detection and building design. Becerik-Gerber and Rice (2010) indicated that the use of BIM for forensic analysis, LEED certification, facility management and code review was limited.

According to Eastman et al. (2011) the most commonly experienced benefits of the use of BIM were decreased project cost and decreased project duration. A survey conducted by Suermann and Issa (2009) showed that the majority of the respondents felt that BIM had high impact on quality control/rework, on-time completion and overall cost of the projects. The survey results indicated that almost half of the respondents did not think that BIM had an effect on safety. Similarly, Becerik-Gerber and Rice's study (2010) showed that the largest proportion of the respondents thought that the use of BIM resulted in increased overall project profitability, decreased project costs and decreased overall project duration. Their findings also showed that the costs of change orders, claims and disputes, and correcting errors and omissions accounted for less than 0.5% of the total project cost. Azhar (2011) found that use of BIM led to improved profitability, decreased project costs, improved time management and improved customer-client relationships. Giel and Issa (2013) conducted case studies that found that BIM is a worthwhile investment in terms of the returns produced and led to a decrease in the total number of requests for information (RFIs) and the number of change orders. Though an owner's decision to invest in BIM should be weighed against the scale and complexity of a project, their research suggests that savings may be realized regardless of the size of a construction project. As BIM requires collaboration of the stakeholders on a project, the use of BIM can result in greater efficiency and harmony among the stakeholders. According to McGraw-Hill Construction (2012), the major long-term benefits companies experienced due to the use of BIM were maintaining repeat business, decreased duration of projects, increased profits, decreased cost of construction and fewer claims and litigations while the short-term benefits included reduced document errors, marketing new business, and reduced rework.

The same survey (McGraw-Hill Construction, 2012) results indicated that the BIM-users thought that BIM benefits can be increased by improving software interoperability and functionality, defining more clearly BIM deliverables, more owners demanding BIM, reducing software cost, having more internal staff with the knowledge of BIM, hiring new staff with BIM skills as well as having more contracts that support use of BIM. Similarly, non-BIM-users felt that the following factors prevented their adoption of BIM: not enough demand from clients, expensive software, expensive hardware upgrades, insufficient BIM applicability, lack of time to evaluate BIM, and insufficient training. Azhar (2011) identified several BIM risks that needed to be addressed such as lack of determination of ownership of the BIM data, need for legal protection of the BIM data, assigning responsibilities for control of the data entry, and determining liability for the model inaccuracies. Azhar (2011) indicated that companies and/or vendors had to find a way of improving training of the potential and current BIM users.

Gu and London (2010) identified the following factors that were needed for successful adoption of BIM: collaboration across disciplines, standard processes and protocols, defined BIM model ownership, appropriate training, and presence of BIM manager. Won et al. (2013) indicated that critical success factors for BIM adoption included willingness to share information among project participants, effective collaboration among project participants and existence of organizational structure to support BIM adoption. According to the same study, the success factors were level of client satisfaction, number of BIM experts in the company and existence of abundant BIM libraries (Won et al., 2013). They also recommended that the companies needed to consider the following critical success factors when selecting appropriate BIM software: how well a BIM software supports services of interest, software interoperability, and expected return on investment.

Utilization of BIM can be beneficial for designing, constructing, and operating better quality K-12 educational facility projects. Even though there are research findings related to BIM adoption in the AEC industry in general, the literature review revealed that little research related to adoption and implementation of BIM specifically on K-12 projects has been conducted. In addition, conversations between the authors and the representatives of Florida Department of Education indicated that Florida Department of Education was interested in adopting and implementing BIM on K-12 projects and developing a guide for the BIM adoption and implementation. Therefore, the aim of this research was to explore the extent of BIM implementation on K-12 projects in Florida. The objectives of the research were to identify: 1) The existing (as of 2013) and future use of BIM on K-12 projects in Florida; 2) The perceived existing benefits and expected future benefits that can be achieved due to the use of BIM on K-12 projects; and 3) The perceived obstacles to the use of BIM on K-12 projects.

Methodology

In order to accomplish the research objectives, a survey questionnaire was developed and distributed to the various stakeholders (owners, designers, constructors, facility managers, and construction managers) that had been involved in K-12 projects. The survey consisted of 39 questions organized into five major parts: 1) Demographics, 2) Existing use of BIM on K-12 projects, 3) Perceived benefits of using BIM on K-12 projects, 4) Perceived obstacles to using BIM on K-12 projects, and 5) Perceived need for future use of BIM on K-12 projects and potential future benefits of BIM use. The survey was developed using an online survey tool, SurveyMonkey®. In the spring of 2013, a link to the survey was sent to the professionals that that have been involved in K-12 projects in Florida. The survey was distributed to: 1) The facilities and maintenance departments of public schools, 2) 78 architectural firms that were members of the American Institute of Architects (AIA) Florida chapter, and 3) 76 construction companies that were members of Associated Builders and Contractors (ABC) Florida chapters. Forty responses to the survey were received. Responses were received from nine architectural firms (yielding a response rate of 11.5%) and from 17 construction companies (yielding a response rate of 22.4%). In addition, six responses were received from owners, four from facilities and maintenance departments, and the remaining four from engineers. An invitation to participate in the survey was sent to the facilities and maintenance departments of public schools using an email list serve and, therefore, it was not possible to identify the exact number of invitations delivered, since some of the accounts might no longer have been active and some of the recipients might have forwarded the email to others. The survey data were analyzed using descriptive statistics.

Results

Demographics

Seventeen respondents (42%) were from construction companies, nine (22%) from architectural firms, six respondents (15%) were owners and four (10%) were facility managers. When asked about their role within the company, more than one-third of the respondents (14, 35%) stated they were project managers, eleven (28%) were vice-presidents, six (15%) were company presidents and four (10%) were directors. Regarding work experience, about one-third of the respondents (13, 33%) worked between 10 and 20 years and the same number of respondents (13, 33%) worked between 20 and 30 years. Four respondents (10%) worked in the AEC industry for more than 30 years. Regarding the number of employees in the company, nine companies (22%) had less than nine employees. The same number of companies (9, 22%) had 10 to 50 employees and 50 to 100 employees; thus, it can be concluded that the majority of companies were small to medium in size.

Use of BIM on K-12 Educational Facility Projects

The majority of the responding companies (30, 75%) had experience with BIM. All the respondents without BIM experience were, however, aware of the BIM approach. A large majority of the construction companies (16, 94%) used BIM on K-12 projects while almost half (4) of the responding architectural firms used BIM. More than half of the companies (23, 57%) had utilized BIM for more than two years, while four (10%) responding companies had used BIM for five years or longer. According to Won et al. (2013) the number of BIM professionals (that is, employees with working knowledge of BIM) within a company can be used as an indicator of successful BIM adoption as well. In the majority of the companies (24, 60%) up to one-third of all employees had working knowledge of BIM (see Figure 1). When asked about the number of K-12 projects on which BIM was used within the previous five years, more than half of the respondents (23, 57%) stated that they used BIM on up to one-third of their K-12 projects while almost one-fourth (9, 22 %) of the responding companies utilized BIM on more than half of their K-12 projects. Most respondents stated that they used the design-build delivery method for their BIM-based K-12 projects. In the majority of cases (23, 57%), the owner did not require use of BIM on K-12 projects.

The most commonly used BIM software packages were Autodesk Revit™ (28 responses) and Autodesk Navisworks™ (23 responses) while Grahisoft ArchiCAD (7 responses) and VICO constructor (2 responses) as well as Bentley Systems Architecture (1 response) were used to a lesser extent by the responding companies. The respondents were asked about the existing use of the specific BIM applications on K-12 projects (see Figure 2). The 16 BIM applications were identified based on the literature review and the respondents were asked to select all BIM applications that were used on their projects. BIM was most commonly used for clash detection (27 responses), coordination of building systems (24 responses), 3D modeling/design (23 responses) and project visualization (23 responses). The least utilized BIM applications were checking for compliance with building code (three responses) and spatial program validation (one response). No respondent stated that their company used BIM for digital fabrication.

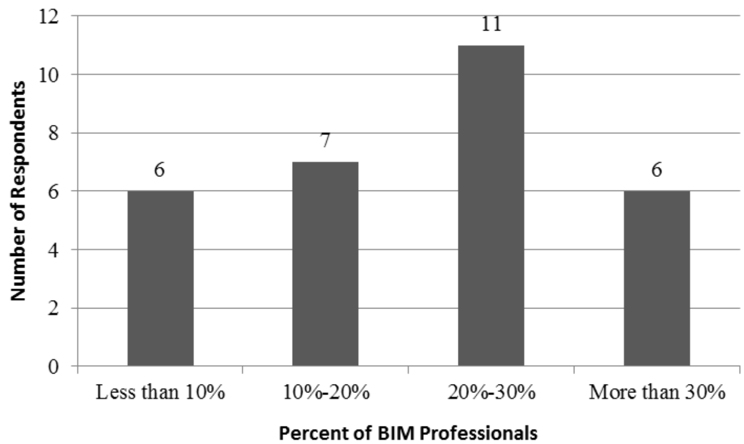

Figure 1: Employees with working knowledge of BIM within the company.

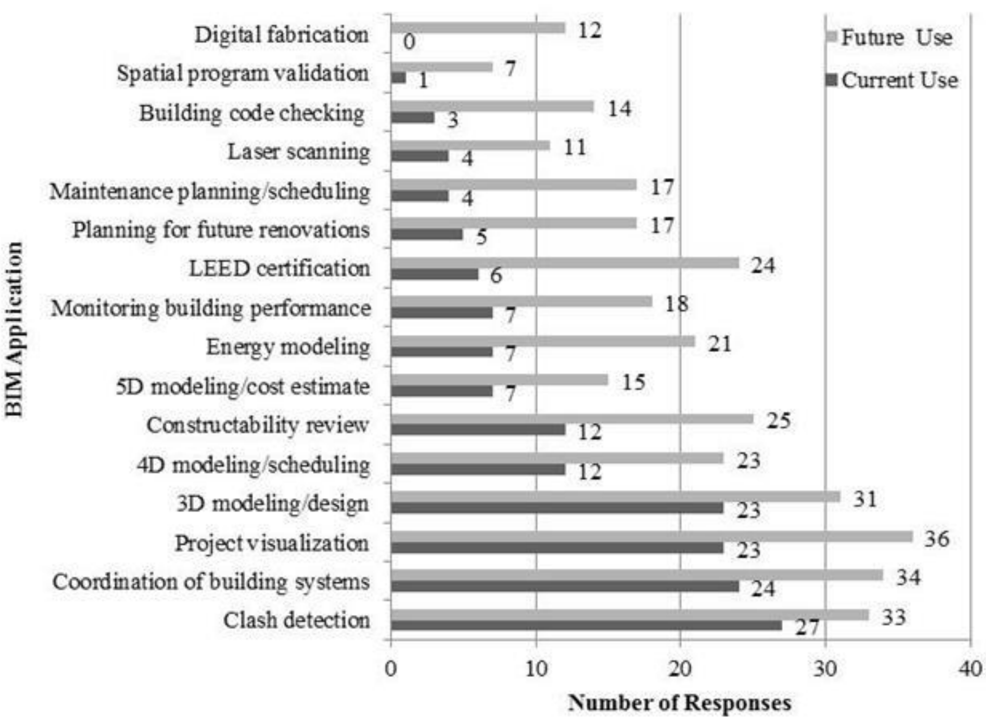

Figure 2: Extent of the existing use and expected future use of different BIM applications on K-12 projects.

When asked about the future use of BIM on K-12 projects, seven respondents (18%) stated they expected that BIM would be used on more than 80% of their K-12 projects, while 14 respondents (35%) perceived that 50-80% of their future K-12 project would be completed using BIM. The majority of the respondents (32, 80%) anticipated that BIM would be fully utilized on their K-12 projects within five years (i.e., by 2018). Similarly to the existing BIM use (see Figure 2), the respondents perceived that on the future K-12 projects BIM would be most commonly used for project visualization (36 responses), coordination of building systems (34 responses), clash detection (33 responses), and 3D modeling and design (31 responses). The least utilized BIM applications on the future K-12 project would be spatial program validation (7 responses) and laser scanning (11 responses). The reason for the anticipated lower use of laser scanning may be that the laser scanning is mostly used for renovation projects. According to the survey results BIM was more used for the new K-12 construction projects than for the renovation K-12 projects. In general, the respondents felt that the extent of use of all the BIM applications would increase in the future as compared to their existing use. The largest increase of use was anticipated for the BIM applications which are currently used the least such as digital fabrication, spatial program validation, building code checking, maintenance planning, and LEED certification.

Benefits of Using BIM on K-12 Projects

The respondents were asked to use a 5-point Likert scale (1-not beneficial at all, 2- slightly beneficial, 3-moderately beneficial, 4- very beneficial, and 5-extremly beneficial) to rate benefits their company experienced due to the use of BIM on K-12 projects. At the business level, BIM use was perceived to be moderately beneficial to achieving better quality of project (average rating score 2.8) and increased accuracy of cost estimates (average rating score 2.73). BIM use was slightly beneficial in increasing project profitability (average rating score 2.0) and decreasing project duration (average rating score 2.2) (see Figure 3).

Figure 3: Business benefits company experienced due to the use of BIM on K-12 projects.

In regard to project benefits, the respondents were asked to rate both the existing and anticipated future benefits of BIM use (see Figure 4). In its existing use, BIM was perceived to be very beneficial to achieving improved collective understanding of design intent (average rating score 3.63), moderately beneficial to decreasing the number of change orders and RFIs (average rating score 3.37), and slightly beneficial to lowering construction cost and speeding-up project delivery (average rating scores 2.03 and 2.17, respectively) (see Figure 4). Regarding the potential project benefits that can be achieved with BIM use in future, the respondents anticipated that the use of BIM would be very beneficial to achieving improved collective understanding of design intent (average rating score 3.78), and moderately beneficial to obtaining more accurate project documentation, decreasing the number of change orders and RFIs, and completing better designed and performing buildings (average rating scores 3.33, 3.25, 3.25, respectively). The respondents thought that in the future the use of BIM would be slightly beneficial to improving review and approval cycles; increasing individual participant productivity, and lowering construction costs (average rating scores 2.38, 2.35, 2.30, respectively). In general, the respondents felt that the project benefits due the use of BIM would increase in the future.

When asked to rate the project delivery methods, the respondents felt that the use of BIM was very beneficial on the projects delivered using design-build method (average rating score 3.50). The respondents were also asked to rate the benefits of the specific BIM applications (see Figure 5). They thought that BIM applications such as coordination of building systems, 3D modeling and design, clash detection and project visualization were very beneficial on K-12 projects (average rating scores 3.93, 3.83, 3.70 and 3.50, respectively). On the other hand, maintenance planning/scheduling, spatial program validation and building code checking received the lowest ratings and were perceived as slightly beneficial on the K-12 projects (average rating scores 1.77, 1.80 and 1.83, respectively).

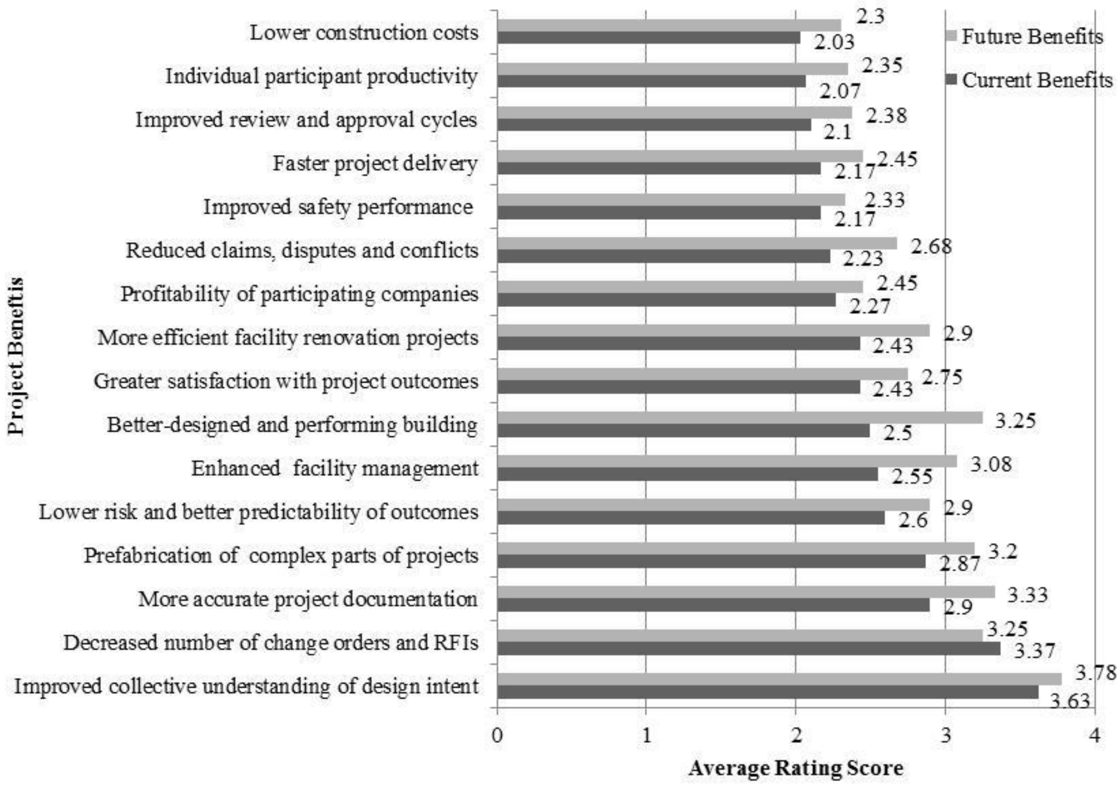

Figure 4: Comparison of existing project benefits and expected future project benefits company can experience due to the use of BIM on K-12 projects.

Obstacles to Using BIM on K-12 Projects

The respondents were asked to use a 5-point Likert scale (1-not likely at all, 2-somewhat likely, 3- moderately likely, 4-very likely, and 5-extremely likely) to rate specific business and project related factors that could prevent the use of BIM on K-12 projects. Regarding the business related obstacles, cost of upgrading hardware and cost to hire BIM professionals were perceived to very likely prevent the use of BIM on K-12 projects (average rating scores 4.03 and 3.55, respectively). According to the respondents, the remaining business factors (such as inadequate training, cost of BIM software and low ROI) were moderately likely to prevent BIM use on K-12 projects (see Figure 6).

The respondents perceived the lack of interoperability of BIM software used by the team members, the lack of BIM-knowledgeable design professionals on the project and the limited BIM knowledge of clients as the major project-related obstacles that prevented BIM use on K-12 project (average rating scores 3.53, 3.18 and 3.15, respectively) (see Figure 7). The respondents also felt that the project complexity (average rating score 2.3) and size (average rating score 2.45) were somewhat likely to prevent BIM use on K-12 projects.

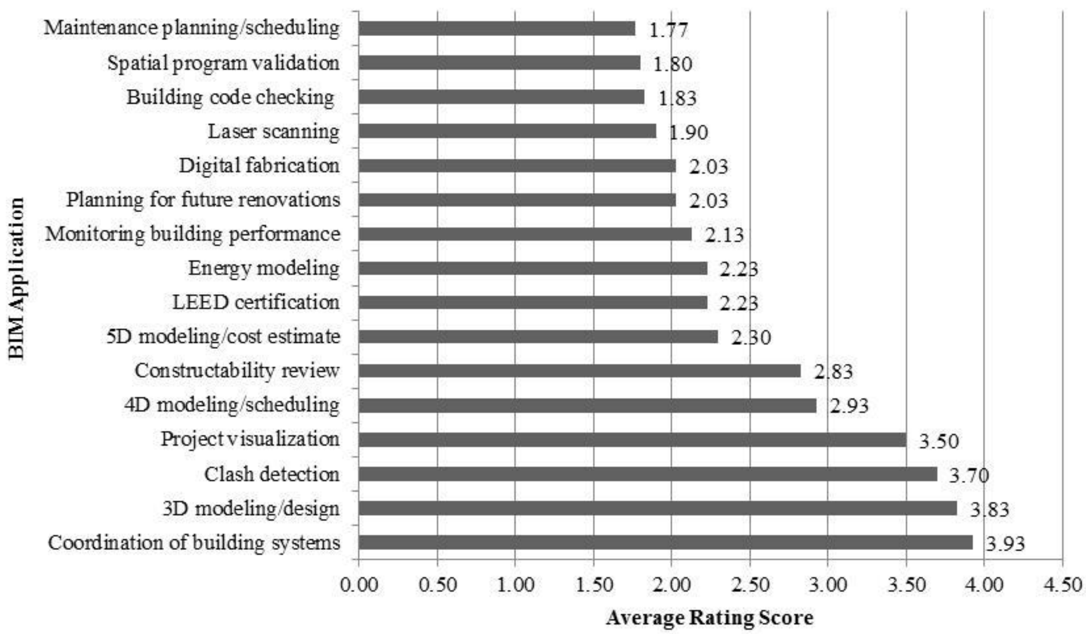

Figure 5: Benefits of using specific BIM applications on K-12 projects.

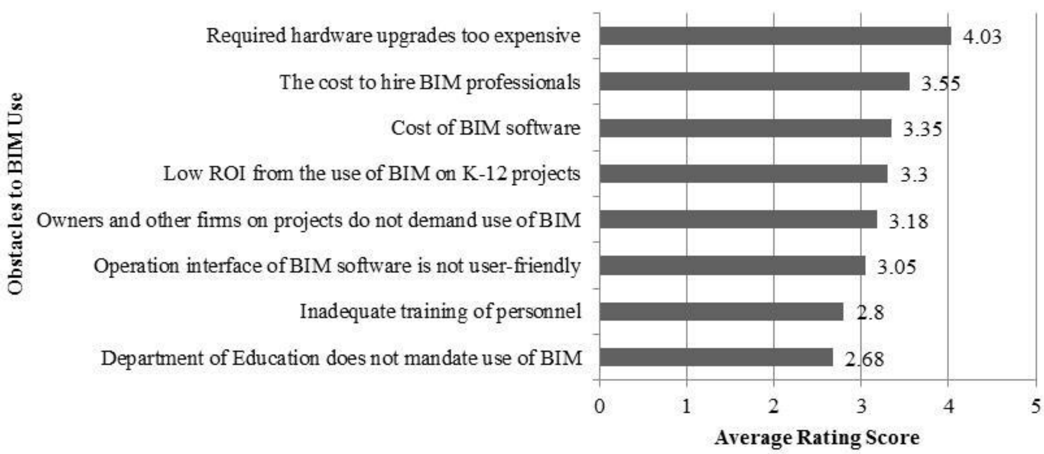

Figure 6: Business factors that prevented the use of BIM on K-12 projects.

Conclusions

A survey that explored the extent of BIM implementation on K-12 educational facility projects was distributed to various stakeholders (owners, designers, constructors, facility managers, construction managers) involved in K-12 projects in Florida. The survey investigated the existing use of BIM, the existing benefits of BIM use, the obstacles to BIM implementation, the anticipated future use and future benefits of BIM on K-12 projects. The survey findings showed that the majority of the responding companies used BIM on the K-12 projects. The most commonly used software was the Autodesk BIM suite (Revit, Navisworks). The most frequently used BIM applications were clash detection, coordination of building systems, 3D modeling and project visualization while checking for code compliance and spatial program validation were the least utilized BIM applications. As expected, BIM was most commonly used on design-build projects due to the requirement for collaboration among the parties. The survey showed that the cost of upgrading hardware, the lack of BIM software interoperability, the cost to hire BIM

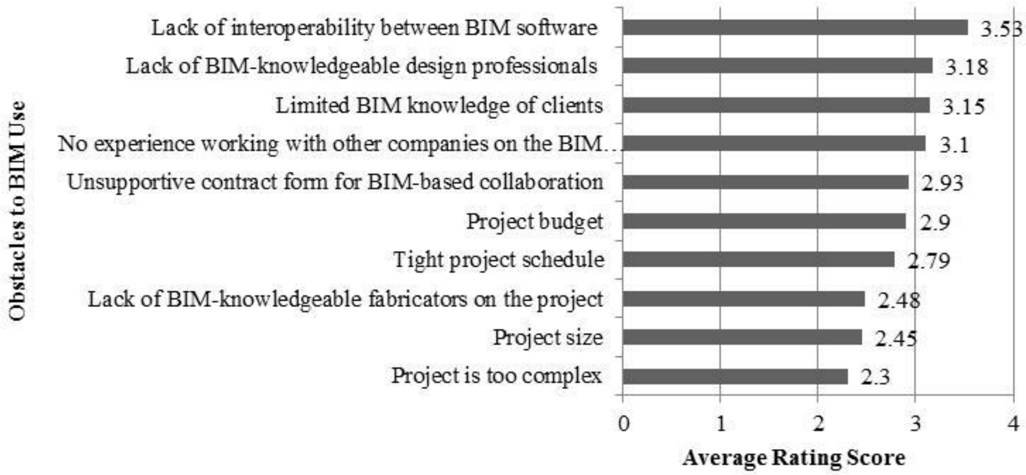

Figure 7: Project factors that prevented the use of BIM on K-12 projects.

professionals, the lack of BIM-knowledgeable design professionals on the project and the limited BIM knowledge of clients were the obstacles that prevented the use of BIM on K-12 projects. Project size and complexity were not perceived as obstacles to BIM implementation by the responding companies. Regarding the future use of BIM on K-12 projects, the respondents perceived increased use of all BIM applications. The majority of the respondents felt that BIM would be fully utilized on their K-12 projects by 2018. They perceived that the future use of BIM would bring benefits such as achieving improved collective understanding of design, obtaining more accurate project documentation, decreasing the number of change orders and RFIs, and completing better designed and performing buildings.

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