Organizational Transformation Strategies for Adopting Building Information Modeling in the Engineering-Construction Industry

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ABSTRACT: The architecture, engineering and construction (AEC) industry is beginning to utilize Building Information Modeling (BIM), benefiting from the resulting improved visualization and productivity, better coordination of construction drawings, building documents that contain embedded links to virtual information, faster delivery, and lower costs. However, construction firms often face challenges when reorganizing their company structure to take full advantage of these benefits. This paper proposes an organizational structure that will enable engineering-construction firms to successfully adopt and implement BIM for major construction projects. A case study research method is utilized based on in-depth interviews with four BIM directors and vice presidents charged with BIM adoption, implementation and education. Organizational transformation challenges and recommendations are discussed in detail for those considering implementing BIM in the engineering-construction industry. Topics such as organizational changes in the firm, costs and benefits of BIM implementation, strategies of BIM implementation (execution) plan, BIM education, risks and opportunities associated with BIM, BIM software, contract methods, human resource management and new hires, and the future implementation and direction of BIM are discussed in detail.

Keywords: Building Information Modeling (BIM), Organizational Structure, BIM Implementation

Introduction

Many construction practitioners and academicians tout information technology and Building Information Modeling (BIM) as essential tools for success [4,6,7,14,15,17,19] as construction projects become more complex and project stakeholders diversify into increasingly narrow areas of special expertise [13]. As a result, proactive stakeholders in the architecture, engineering, and construction (AEC) industry are adopting and implementing BIM in ever greater numbers to improve the design, construction, and operation & maintenance of buildings through a digital representation of that building's physical and functional characteristics [1,4,7,8,11,13,14,16,17,19,20]. In addition, introducing BIM from the earliest stages of the design and construction phase of the building life cycle can also decrease construction project costs, increase productivity and quality, and reduce project delivery times since BIM contains the precise geometry and relevant data needed to support all the design, procurement, fabrication, and construction activities required to realize the building [4,5,14]. During the operation and maintenance phase of the life cycle, BIM can provide comprehensive support for a wide range of facility and asset management functions, supporting collaboration and procurement relationships based on the sharing of intelligent building data with existing facility management and asset management systems [11]. Therefore, adoption and implementation of BIM in the construction project is becoming a critical success factor ensuring the delivery of the construction project and offering organizational benefits to all the project's stakeholders. However, to adopt and implement BIM effectively the construction stakeholders must take into account the organizational structure needed to support BIM, the number of subcontractors/partners who have prior experience with BIM projects, the need for continuous investment in BIM, the provision of BIM training programs, the number of BIM software experts in a company, etc. [26]. Won et al's study indicated that the organizational transformation necessary to support BIM was the single most important success factor for those seeking to adopt and implement BIM in construction. The purpose of this study is therefore to investigate organization transformation strategies for adopting and implementing BIM in the engineering and construction industry. In-depth case studies of four construction companies who have adopted and implemented BIM were conducted to investigate which transformation strategies were most successful and the problems encountered. For the purpose of this study, the definition of BIM is based on the definition of BIM provided by the American General Contractors (AGC), who define BIM as [1]:

> *"BIM is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a BIM, is a data-rich, objective-oriented, intelligent and parametric digital representation of the facility, from which views*

and data appropriate to various uses' need can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility."

First, BIM is introduced along with a discussion of its positive aspects and the limitations & cautions attached to its use in a construction project. Next, the study identifies the main goals and implementation areas related to BIM in a construction project and demonstrates how BIM can be prepared and executed for a project over the facility life cycle. Based upon a good understanding of how BIM operates throughout the life cycle of a typical construction project obtained through a thorough literature review and extensive interviews with BIM experts, four case studies involving professionals from four large construction firms were conducted for this study to identify their organizational transformation strategies for adopting and implementing BIM in a project. All four firms have a history of success in implementing BIM as an integral part of their practices and approaches to improving the process of delivering a project, and are very aware of how it can enhance their competitiveness and efficiency compared to their peers in the construction industry who do not utilize BIM.

The organization of this paper includes the presentation of the case study research method, followed by a discussion of the study's findings in terms of the resulting structural changes in their organization, the purpose of BIM implementation, its benefits and costs, BIM implementation methods, BIM education for their employees, the choice of appropriate BIM software, BIM in the field office, fee structure of a BIM related project, the integrated project delivery method, and the future direction of BIM in the construction industry. These findings will provide suggestions and guidelines for the many medium & small contractors and subcontractors who have not yet adopted and implemented BIM to help them successfully plan the organization transformation that will facilitate BIM adoption and implementation. The final section includes conclusions and discusses the managerial implications.

Literature Review

Benefits and Challenges of BIM

Scholars and construction practitioners have identified a number of benefits and challenges associated with BIM implementation in construction projects. These benefits and challenges are summarized in Table 1.

Table 1. Benefits and challenges of BIM Implementation

Benefits	**References**
• Improve decision-making process (better visualization and "what if "scenarios)	[25] [27] [12]
• Produce better design	[3,12]
• Reduce project time & costs	[12,16,27]
• Improve quality	[12,27]
• Improve the process and efficiency (better communication & collaboration)	[3,12,13,16]
• Improve safety	[18,23,24,30]
• Reduce claims or litigation (risks)	[3,12]
• Improve operations and maintenance	[12]

Challenges	**References**
• Lack of legal framework (Model ownership; legal contract)	[2,3,7]
• Additional resources/expenses (high economic investment-software)	[3,16,27]
• Lack of interoperability	[3,7,16]
• Attitude (Resistence to change)	[3,7,27]
• Lack of employee training	[3,7]
• Increased risk associated with changing work processes	[7]
• Liability insurance	[7]
• Current public policy procurement policy	[7]
• Organizational challenges among construction professionals	[13,26]
• Lack of comprehensive framework or implementation plan	[17]

Even though these benefits and challenges of BIM implementation have now been identified, little research has focused on the mechanisms that affect how BIM is implemented and spread within an individual organization and through the construction sector as a whole [22]. Dossick and Neff's study [13] found that in many instances organizational challenges were encountered that limited collaboration and BIM implementation. As a result, it is very important to study the organizational transformation needed to support BIM in a construction firm.

Research Method

Robson [21] states that a case study is an appropriate method for doing research on management and organization issues, which here consisted of describing the process of transformation involved in implementing BIM in an organization. The four construction organizations selected for this study had already implemented BIM in their construction projects and all now have a BIM expert group in their organizations. Yin [28] suggests the use of multiple case studies when they replicate each other in order to provide either similar results or contrasting results, in this case for the BIM implementation in each of the participating construction companies. Extensive interviews were

therefore conducted for this study with those responsible for BIM or Virtual Construction (VC) in each of the four construction firms.

The four construction companies in the case study (Table 2) were screened initially through a face-to-face interview, and then subsequent followed up via e-mail and telephone conversations. A case study research protocol based upon the research and conceptual discussions presented in the previously reviewed literature was created prior to data collection, which was conducted at their offices. Information-gathering techniques implemented during execution of the case study included obtaining historical and current data and documentation, as well as conducting structured interviews with a number of professional BIM personnel and other key informants.

Data generated through interviews with BIM experts were subjected to axial and selective coding analysis, in accordance with the guidelines provided by Yin [29]. The study utilized a case-oriented analysis that examined the interrelationships among variables within each case first, and then made comparisons across the cases looking for similarities, differences and patterns.

Table 2. Study samples

Company	Size	Interviewee
Company A	$4 billion	BIM Director
Company B	$4 billion	BIM VP
Company C	$4 billion	BIM Director
Company D	$4 billion	BIM VP

Research Findings

The research consisted of gathering information for four case studies that exemplify effective organizational practice and transformation associated with BIM to enable new adopters in the construction industry to achieve the potential benefits of BIM. The study first identified the areas of BIM implementation that improved the efficiency of the construction processes and brought value to the project in other ways. By analyzing the collected data from the four BIM experts (using a 1-5 Likert scale), the study identified the important areas of BIM-related tasks in the construction companies. The survey results indicated that construction companies actively used BIM as an important tool for spatial (MEP) coordination, visualization, communication, field management, marketing, and prefabrication (Table 3). However, the construction companies rarely used BIM for simulating operations, model based estimating or energy simulations. This indicates that all stakeholders seeking to maximize the benefits of BIM should develop strategies and technologies to make better use of BIM's capabilities in those areas. In addition, construction companies seeking to utilize BIM for the first time should begin by prioritizing the areas of BIM implementation that are most vital for their success.

Table 3. BIM implementation areas

BIM Implementation Areas	Mean
Spatial trade coordination (MEP coordination)	5
Visualization	4.75
Communication	4.5
Marketing	4.5
Prefabrication	4.5
Site logistics	4.25
BIM in field management	4.2
Constructability	4
Scheduling and sequence planning	3.75
Shop drawing & materials procurement	3.75
BIM as a tool for safety	3.5
Design review	3.25
Facility management	3.25
Laser scanning	3.25
Integrated project delivery system	3
Simulation of operation (dynamic animation)	3
Model based estimating	2.5
Energy simulation	2.25

All four contractors demonstrated similar benefits of BIM implementation and all four agreed that BIM could add value to a construction project by saving time and reducing costs. They also shared the view that BIM improved construction efficiency and quality; increased the use of prefabrication; decreased uncertainty; allowed them to develop more complete project documents, etc. In addition, BIM was thought to support a more collaborative environment among all stakeholders, promoting project success by reducing many of the common problems bedeviling construction projects such as poor cooperation, lack of trust, and ineffective communication, all of which result in adversarial relationships between construction stakeholders [9].

The participants were then asked how their construction company had modified their organizational structure to support BIM implementation (Table 4). Three of the four indicated that their company now has a BIM or VC department specifically to support BIM implementation an projects. These departments were also responsible for educating BIM experts, employees and subcontractors and for conducting research in how best to utilize BIM to maximize its value to the project and company. A vice president is in charge of this BIM department in these three companies and is supported by a number of BIM managers and coordinators with knowledge and skills related to BIM. The members of the BIM department generally consist of company

employees who have backgrounds in construction management, architectural engineering (mechanical engineering), architecture, and computer graphic and science. The diverse backgrounds of the BIM experts in the department appear to combine synergistically to enhance efforts to implement BIM in company projects. All the contractors except Company B have BIM experts in each regional office to provide BIM services; Company B provides a more centralized BIM service for their construction projects. However, the BIM departments at HQ all play a supportive role in BIM implementations in regional offices and projects. One of the major roles in all the BIM departments is to look for opportunities to improve BIM implementation by expanding into other areas such as BIM for estimating, and BIM for energy simulation, etc. Furthermore, the BIM departments also develops appropriate education or training modules to educate their BIM experts, project managers, superintendents, and subcontractors.

The BIM departments in each of the participating companies generally have two or three levels of competence for their BIM experts (Table 4). The first level, "BIM coordinator", coordinates BIM models provided by specialty contractors, while the second level, "BIM manager", confidently handles all different types of BIM implementation. One of the significant roles of a BIM department is to educate both company employees and subcontractors to maximize the benefits of BIM implementation. In addition, the companies use a range of instruction strategies, including BIM courses, training sessions, BIM conferences and forums, virtual BIM training programs, Blogs, and group study sessions. The education provided by the BIM departments takes the company through a series of transitions. The initial stage of the education process is to educate their BIM experts and employees who want to become BIM managers. The next stage is to deploy BIM to their project managers, superintendents, and engineers. Once these two stages have reached a sufficient level, the education effort focuses upon the company's subcontractors.

The next question examined the potential costs of BIM implementation. All the interviewees confirmed that this requires additional investments in upgrading both software and hardware, and is also likely to involve hiring BIM experts. However, the initial investment can be offset by the benefits of BIM implementation. For example, Company B found that every $1 invested in BIM eventually brought the company $3 in financial benefits. Additional intangible benefits that could not be assigned a dollar value include improved communications; a more supportive and collaborative environment, and so on. All the interviewees stated that the decision to implement BIM for a particular project is based primarily on whether BIM can add value to that project or not, so a complex, large-scale project such as a hospital is most likely to be implemented using BIM.

The next question was related to the choice of BIM software. Ravit, Naviswork, and Google Sketchup were the most frequently named BIM software by the study participants, although Constructor B had just adopted BIM software provided by Bentley. All the interviewees commented that the low level of BIM knowledge in subcontractors and software compatibility are the major risk factors in BIM adoption because both can lead to inadequate models and poor construction. With regard to contracts among stakeholders, all the interviewees stated that they use a modified AIA/AGC standard contract for the building owner and a standard contract accompanied by a BIM execution plan for subcontractors. The BIM execution plan provides a structured procedure for creating and implementing BIM in a construction project [10]. Three of the participating companies have adopted the BIM executive planning guided developed by Penn State University and the other adopted its own execution plan with the support of the Building Science program at Auburn University.

The next section looked at how the contractors implement BIM at the field office. Field or virtual coordination meetings are the most important part of the process to bring value to the project by reducing the need to redo work, cutting the number of change orders, and generally improving efficiency. All four of the companies aim to have a weekly BIM coordination meeting at which all the stakeholders including a CM, an architect, specialty contractors, and engineers work together to address potential issues and problems as well as improve efficiency (Table 4). Several of the participants commented that one of the most important success factors for BIM implementation is to improve the collaboration with subcontractors. Thus, all contractors help their key subcontractors to improve their understanding of BIM and knowledge, as well as their software skills. This supports a collaborative environment in the construction project and represents a win-win situation for all the stakeholders.

The participants were then asked how the contractors prepare for future BIM implementations in their construction projects. All four companies had carried out a pilot project for the Integrated Project Delivery (IPD) system to prepare for implementing IPD in a real project and to assess the benefits of the new project delivery system. In addition, all had endeavored to develop a collaborative environment among all the stakeholders, especially the design team, in order to maximize the benefits of BIM. They had also studied how best to integrate BIM to facilitate estimating, facility management, and other areas that had not

previously been implemented. The final section of the study asked what types of new employees they would prefer to hire in the future. All indicated that BIM comes under the heading of "preferably needed skills", i.e. if a construction student has BIM skills and knowledge, this will give them an advantage when applying for a job at that company. These companies clearly expect that new construction graduates will have basic BIM knowledge, especially regarding areas of BIM implementation, and basic BIM software skills.

Conclusion

BIM is emerging in construction as an innovative way to virtually design and manage construction projects that will maximize benefits, including saving construction costs and time and improving the efficiency of construction processes and the quality of the project. Due to many potential benefits to be gained from implementing BIM, many leaders of construction companies have begun to adopt and implement BIM in a number of different areas. This study demonstrates how BIM can be successfully transferred into construction organizations through reviewing four companies that have actively implemented BIM in their construction projects. This study will be of particular interest to those construction companies currently considering adopting this new approach and implementing BIM in their construction process.

Table 4. BIM in the construction companies

Categories	Company A	Company B	Company C	Company D

Benefits of BIM adoption	• Save time and cost
	  ○ Lower labor costs
	  ○ Reduce reworking
	• Improve efficiency and quality
	• Increase prefabrication
	• Develop more complete project documents
	• Support a collaborative environment
		• Add the value to the project
		• Save time and cost
		• Save time and cost
		  ○ Lower labor costs
		  ○ Reduce reworking
		• Improve efficiency and quality
		• Increase prefabrication
		• Develop more complete project documents
		• Support a collaborative environment
			• Add value to the project and CM
			• Save time and cost
			  ○ Lower labor costs
			  ○ Reduce reworking
			• Improve efficiency and quality
			• Increase prefabrication
			• Develop more complete project documents
			• Support a collaborative environment
				• Save time and cost
				  ○ Lower labor costs
				  ○ Reduce reworking
				• Improve efficiency and quality
				• Increase prefabrication
				• Develop more complete project documents
				• Support a collaborative environment

Organizational structure	• BIM support group at HQ • Senior vice president • 6 BIM experts at HQ • BIM experts (1-3) in each regional office • BIM HQ: supporting role for the regional offices or project • Training for BIM experts, project managers and subcontractors • Research into areas of BIM implementation, sustainability and BIM, BIM and lean construction, the development and improvement of BIM implementation plan	• BIM department at HQ • Vice president • 22 BIM experts (2 BIM managers, 8 BIM engineers, 9 BIM experts in the field) • Deployment of BIM expert from the BIM department to the project • Training for BIM experts, project managers and subcontractors • Research into areas of BIM implementation, sustainability and BIM, BIM and lean construction, the development and improvement of BIM implementation plan • Three levels (BIM coordinator, BIM modeler, BIM manager)	• No BIM department at HQ • Decentralized BIM approach based on the regional office • BIM experts (1-3) in each regional office • BIM committee meeting in the company (research and education) • Research into areas of BIM implementation, sustainability and BIM, BIM and lean construction, the development and improvement of BIM implementation plan • Two level (BIM manager / BIM coordinator)	• BIM support group at HQ • Vice president • 6 BIM experts at HQ • Support BIM experts in the regional office • Training for BIM experts, project managers and subcontractors • Research into areas of BIM implementation, sustainability and BIM, BIM and lean construction, the development and improvement of BIM implementation plan • BIM experts (1-3) in each regional office • Two level (BIM manager / BIM coordinator)
BIM experts' education background	• CM, architectural engineering, architecture or architecture+CM	• CM, architectural engineering, architecture or architecture+CM, computer science or graphic	• Architecture, construction management, engineering	• Architecture, construction management, architectural engineering
BIM education	• BIM courses (Content and use of hardware&software) • BIM forums and conferences (Auto Desk University) • Blog (share BIM knowledge and problem solving) • Internal BIM study group	• BIM courses (Content and use of hardware and software; 4 levels including intro, hand on, apply, and avance) • BIM forums and conferences • Virtual BIM training • Blog (share BIM knowledge and problem solving) • Internal BIM study group	• BIM forums and conferences (Autodesk University) • Internal BIM study group	• Virtual training • BIM courses (Content and use of hardware) • BIM forums • Blog (share BIM knowledge and problem solving)
BIM implementation cost	• Global agreement with Autodesk • BIM engineer, software & hardware costs	• BIM expert, software & hardware costs	• BIM expert, software & hardware costs	• BIM expert, software & hardware costs (0.75%-11/2%)
Project Type of BIM Implementation	• Healthcare, government, institutional projects	Healthcare, government, commercial office, institutional projects (BIM brings the value to the project)	• Healthcare, government, commercial office, institutional projects	• Healthcare, government, institutional, commercial office projects (BIM brings the value to the project)
BIM software	• Revit, Navisworks, Google Sketchup	• Revit, Navisworks, Google Sketchup,	• Revit, Navisworks, Google Sketchup	• Revit, Navisworks, Google Sketchup

		Bentley systems,		
BIM risks	• Lack of BIM knowledge for subcontractors • Collaboration among all stakeholders • Software compatibility	• Lack of BIM knowledge for subcontractors • Collaboration among all stakeholders • Software compatibility	• Lack of BIM knowledge for subcontractors • Collaboration among all stakeholders • Software compatibility	• Poor QC-Inadequate model-poor construction • Level of BIM knowledge for subcontractors
BIM contract method	• AIA/AGC contract (Adjusted by the contractor) or general BIM requirement based upon the BIM execution plan	• AIA/AGC contract (Adjusted by the contractor) or general BIM requirement based upon the BIM execution plan	• AIA/AGC contract (Adjusted by the contractor) or general BIM requirement based upon the BIM execution plan	• AIA/AGC contract (Adjusted by the contractor) • Owner-GMP, IPD, lump sum • Subs-GMP, design assist lump sum
BIM fee structure	• General cost in the quote (BID) • Owner responsible for costs	• General cost in the quote (BID) • Owner responsible for costs	• General cost in the quote (BID) • Owner responsible for costs	• General cost in the quote (BID) • Owner responsible for costs
BIM implementation plan	• Use a modified BIM execution planning guide (Penn State)	• Use a modified BIM execution planning guide (Penn State)	• Use a modified BIM execution planning guide (Auburn Uni)	• Use a modified BIM execution planning guide (Penn State)
BIM at the construction phase	• Field office (project engineer with the support of BIM expert in the regional office) o Guide use of BIM o Coordination meeting • BIM coordinate meeting o Weekly coordination meeting • Design +construction+all trades (plumbing/piping, HVAC/duct work, fire protection, structure, electrical/telecom, site utilities, etc.)	• Field office (project modeler with the support of BIM expert in the HQ) o Guide use of BIM o Coordination meeting • BIM coordinate meeting o Weekly coordination meeting o Design +construction+all trades (plumbing/piping, HVAC/duct work, fire protection, structure, electrical/telecom, site utilities, etc.)	• Field office (project engineer with the support of BIM expert in the regional office) o Guide use of BIM o Coordination meeting • BIM coordinate meeting o Weekly coordination meeting • Design +construction+all trades (plumbing/piping, HVAC/duct work, fire protection, structure, electrical/telecom, site utilities, etc.)	• Field office (BIM expert) o Guide use of BIM o Coordination meeting • BIM coordinate meeting o Weekly coordination meeting o Design +construction+all trades (plumbing/piping, HVAC/duct work, fire protection, structure, electrical/telecom, site utilities, etc.)
Subcontractor relationship	• Strong involvement (win-win or partnership) • Requirement of a BIM expert in subs • Constant model or information sharing • CM manages the model & information • Education for subs • Improve the relationship	• Strong involvement (win-win or partnership) • Requirement of a BIM expert in subs • Constant model or information sharing • CM manages the model & information • Education for subs • Improve the relationship	• Strong involvement (win-win or partnership) • Requirement of a BIM expert in subs • Constant model or information sharing • CM manages the model & information • Education for subs • Improve the relationship	• Strong involvement (win-win) • Requirement of a BIM expert in subs • Constant model or information sharing • CM manages the model & information • Education for subs • Improve the relationship
Future direction of BIM	• Pilot project of the IPD • Change the project delivery system • Collaborative environment with a design team • Potential opportunities in BIM (estimating, facility management, etc.)	• Pilot project of the IPD (No contractual relationship) • Change the project delivery system • Collaborative environment with a design team Potential opportunities in BIM (estimating, facility management, etc.)	• Pilot project of the IPD or innovative project delivery • Potential opportunities in BIM (estimating, scheduling, facility management, etc.)	• Pilot project of the IPD or innovative project delivery • Potential opportunities in BIM (estimating, scheduling, facility management, etc.)
New employees	• Basic and general knowledge of BIM • Areas of BIM implementation (visualization, MEP coordination, site logistic, etc.) • Software skills and knowledge • BIM sustainability integration and lean construction concept • Recommended skills set for a job search	• Basic and general knowledge of BIM • Areas of BIM implementation (visualization, MEP coordination, site logistic, etc.) • Software skills and knowledge • BIM sustainability integration and lean construction concepts • Recommended skills set for a job search	• Basic and general knowledge of BIM • Areas of BIM implementation (visualization, MEP coordination, site logistic, etc.) • Software skills and knowledge • BIM sustainability integration and lean construction concept • Recommended skills set for a job search	• Basic and general knowledge of BIM • Areas of BIM implementation (visualization, MEP coordination, site logistic, etc.) • Software skills and knowledge • BIM sustainability integration and lean construction concept • Recommended skills set for a job search

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