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Current Status of Building Information Modeling (BIM) Adoptability in the U.S. Electrical Construction Industry

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Abstract
The electrical construction industry traditionally relies on 2D/3D drawings to layout, design, estimate, and install power and communication systems in building facilities. With the advent of Building Information Modeling (BIM), electrical contractors have begun to experience its potential benefits. However, the scale of BIM adoptability in the U.S. electrical construction industry and its impact on electrical design and construction are still unknown. Keeping these objectives in mind, this research study was carried out with the support of National Electrical Contractors Association (NECA), USA. A questionnaire survey targeted at NECA members was conducted to collect the necessary data. The results indicated that about 20% of the companies, who participated in this research study, are using BIM technology in their projects. Most of these companies are medium to large size in terms of annual revenues. These companies are mostly using BIM technology for clash detections, visualization of electrical design, space utilization, and partial trade coordination in commercial and healthcare projects. The majority of participants reported some-to-significant cost and time savings and quality improvements. The most common reasons for not using BIM were found to be lack of BIM knowledge and technological experience, software compatibility issues and high initial investment costs.

Keywords
Building Information Modeling (BIM), Virtual Design and Construction (VDC), Electrical construction, MEP coordination, Facilities Management (FM)

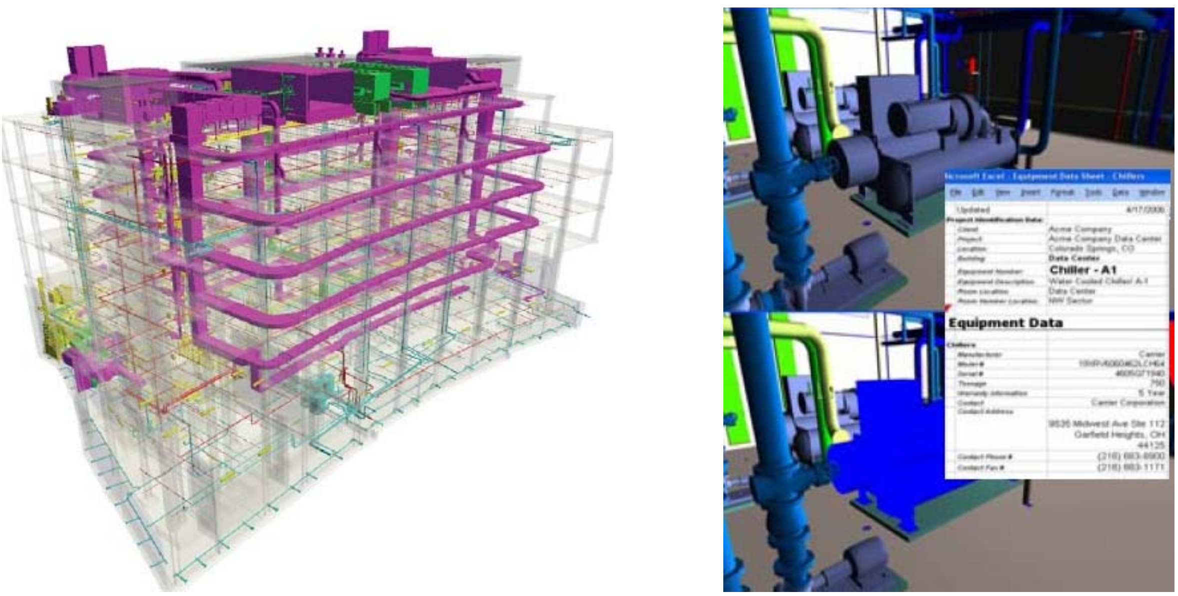
1. Introduction

One of the major challenges of constructing a building facility is the coordination of Mechanical, Electrical, and Plumbing (MEP) trades to install complex systems in a common and limited space. This multidisciplinary effort is time-consuming, expensive, requires knowledge of each system over the project life cycle and necessitates collaboration between the trades to discover and correct any conflicts (Korman *et al.*, 2003).

The electrical construction industry traditionally relies on 2D/3D drawings to layout, design, estimate, and install power and communication systems in building facilities. With the advent of Building Information Modeling (BIM), electrical contractors have begun to experience its potential benefits (Lane, 2006). In essence, BIM represents the process of development and use of a computer generated model to simulate the planning, design, construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility (Associated General Contractors of America, 2005).

The principal difference between BIM and 2D CAD is that the latter describes a building by independent 2D views such as plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 2D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns (CRC Construction Innovation, 2007).

A building information model carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of “smart objects”. For example, as shown in Figure 1, an air conditioning unit within a building information model would also contain data about its supplier, operation and maintenance procedures, flow rates and clearance requirements (Azhar *et al*., 2008).



(a) Building Information Model of Electrical Systems

(b) Equipment Data Extracted from a Building Information Model

Figure 1: A Building Information Model of Electrical Systems
(Courtesy: Holder Construction Company, Atlanta)

There are many important applications of BIM for the MEP trades such as the ability to detect clashes between building and MEP components before construction, provide material quantity estimates, generate shop drawings, check the model for code compliance, perform construction operations sequencing and assist in facilities management. Khanzode *et al.*, (2008) reported the use of BIM for MEP systems modeling for a $96.9 million healthcare project in California. The 250,000 square foot project allowed 4.5 feet of interstitial space between floors for the complex MEP systems. The project team reported significant savings in labor costs for all MEP subcontractors, along with a high level of prefabrication of system components, zero conflicts in MEP systems during construction of the facility, and only a single reported injury among MEP subcontractors. For the General Contractor, BIM benefits included 6 months savings on the schedule and almost $9 million in savings on the overall project cost.

Kieler (2008) published a case study depicting BIM use for electrical design and construction by an electrical contractor in various projects. The reported company, Wachter Electrical, which had revenue of $124.4 million in 2007, spent more than half a million dollars installing the BIM systems and hiring and training employees to use them. As a result, they were able to cut time in the field up to 60%. According to the company's president "The BIM system gives exact dimensions for materials. Through the room-in-a-box concept, the contractor prefabricates materials for delivery to the job site. This lets an electrician install a system in 15 minutes that might otherwise take an hour and a half".

Besides this case study there is not much information available about the extent of BIM adoptability in the U.S. electrical construction industry and its impact on electrical design and construction. Keeping this need in mind, the National Electrical Contractors Association (NECA) of USA initiated and funded this research project. The purpose of this project is to investigate the current status of BIM for electrical contractors and its possible benefits for the electrical construction industry. The necessary research data were collected via a questionnaire survey. In the following sections, the design of the questionnaire and survey results are briefly discussed.

2. Research Design

The data for this research were collected via a questionnaire survey targeted at member companies of the National Electrical Contractors Association (NECA), USA. NECA, composed of its 119 independently chartered chapters across the country, supports the electrical contracting industry through advocacy, research, continuing education, promoting effective labor agreements, hosting trade shows, and offering management training. More details about NECA can be found at http://www.necanet.org.

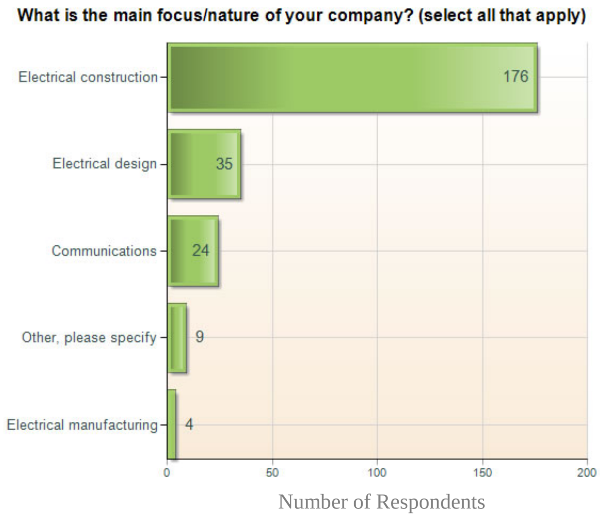
The questionnaire comprised of 24 questions was divided into four sections. The first section was designed to collect background information of the respondent and the organization. The second section was developed for only those companies who are currently using BIM to inquire about BIM scope and its most valuable features for the electrical construction industry. The third section contained questions about BIM benefits and implementation costs. The fourth section was focused on those respondents who are not using BIM to get a sense of factors that prevented its implementation.

The questionnaire was distributed via a web-based service Zoomerang™ (http://www.zoomerang.com). An e-mail list of over 2000 member companies was obtained from NECA. The questionnaire survey was launched on November 21, 2008. Reminders were sent on December 20, 2008 and January 15, 2009 to ensure maximum participation. The survey was closed on January 31, 2009. At that time, 384 individuals accessed the survey. There were 184 complete and 29 partial responses. It was decided by the research team to exclude partial responses to ensure maximum consistency in the reported results. The survey response rate is 48% (based on the number of persons who visited the survey website). This response rate could be considered as good enough to derive any reasonable conclusions. Seventy five percent (75%) of those respondents were Presidents and Vice Presidents of companies. On the basis of their positions, it can be inferred that the respondents had adequate knowledge of their companies' involvement in BIM technology.

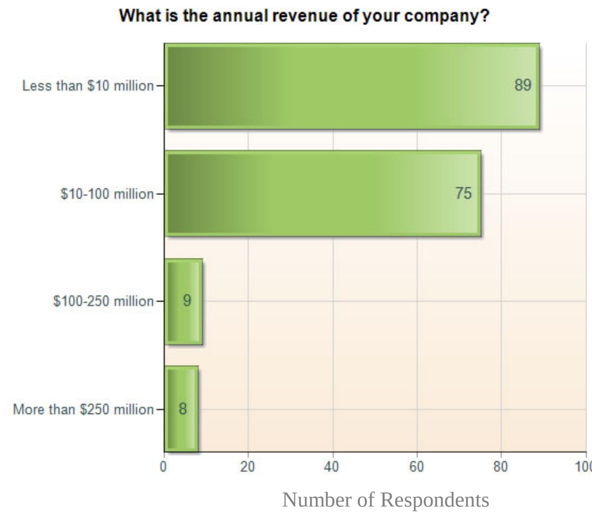
3. Research Results

3.1 Section 1: Respondents and their Organization Characteristics

As previously stated, 75% respondents were either company presidents or vice presidents. The remainders were senior managers, project managers and designers. Though the survey targeted companies of various types (main job function) and sizes (in terms of annual revenue), the majority of responding companies were small to medium size with major focus on electrical construction as shown in Figures 2a and 2b. These companies are located all over the USA while 9 have overseas offices as depicted in Figure 2c.



(2a) Nature of Company's Operations



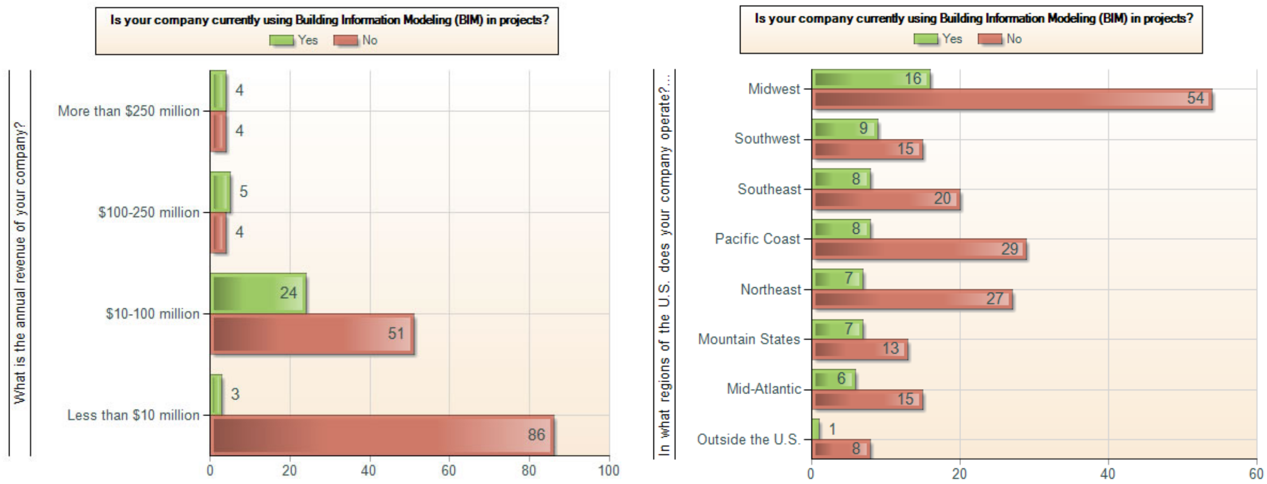
(2b) Annual Revenue of the Company

(2c) Geographical Location of the Responding Companies

Figure 2: Organizational Characteristics of Responding Companies

The survey results indicated that 36 out of 184 responding companies (20%) are using BIM technology in their projects. When this data was further analyzed with respect to company's size and location, the following information was obtained as shown in Figure 3.

- The majority of medium to large size companies are currently using BIM.
- These companies are somewhat uniformly distributed all over the USA. Though the majority (16 companies) is in the Midwest region but it cannot be considered as a representative result because the total number of respondent companies from this region are significantly high as compared to other regions.



(a) BIM Adoption vs. Company Size (b) BIM Adoption vs. Geographical Location

Figure 3: Current Status of BIM Adoption in the US Electrical Construction Industry

3.2 Section 2: BIM Scope and Applications for the Electrical Construction Industry

This section was developed for only those companies who are currently using BIM technology in their projects. The purpose was to inquire about BIM scope and its most valuable features for the electrical construction industry. As previously stated, 20% of the surveyed companies were BIM users. Of that group, 92% had used BIM technology in 10 or fewer projects. Most of these projects were healthcare and commercial buildings followed by industrial, education, government and manufacturing projects.

When asked about the most valued BIM features for the electrical construction industry, the following responses were obtained as shown in Table 1. These results indicate that clash detections, visualization of electrical design, space utilization, and partial trade coordination are the most popular features.

Table 1: Most Valued BIM Features for Electrical Construction

Feature	Number of responses	Percentage of responses
Clash detections	30	83%
Visualization of electrical design	28	78%
Space utilization	24	67%
Partial trade coordination	19	53%
Submittal/Shop drawings review	15	42%
Virtual mock-ups	14	39%
Shop fabrication process	13	36%
Walk-through and fly-through **features**	13	36%
Design validation	11	31%
Energy analysis/management	5	14%

Clash detection, which is selected by 83% of survey respondents as the most valued feature, allows the user to identify locations where two or more building/MEP components have been designed in the same virtual space. Clashes are especially prevalent in the electrical contractor’s scope of work because much of the electrical system is installed above the ceiling, along with mechanical systems, plumbing, and fire protection systems. Generally, the system with the largest components is scheduled first for installation. Often times, this leaves the electrical system last on the schedule and electrical contractors have to work around the work put in place. In addition, the building’s structure can interfere with MEP systems, as beams and trusses share the above ceiling space as well. The ability to detect clashes addresses a major obstacle in the process of delivering a facility on time and within budget. Without Building Information Modeling technology, or another tool with the same feature, the clashes would not be identified until a component had already been installed in the place where another item should go. In some cases, the first component would have to be removed and reinstalled, a process known as rework. Such process takes extra time and money and, if it happens often, can lead to low productivity.

Next question was developed to identify the electrical components which are typically modeled in a Building Information Model. The responses are shown in Table 2. It is found that most electrical contractors prefer to model all rigid components such as branch and feeder conduits, electrical rooms, cable trays and supports, equipment panels, lighting fixtures, underground conduits and junction boxes. Cables are the least modeled item because contractors can place them nearly anywhere in the walls or above ceiling spaces due to their flexibility.

Table 2: Electrical Components Most Commonly Modeled by BIM Technology

Component	Number of responses	Percentage of responses
Branch and feeder conduit	34	92%
Electrical rooms	33	89%
Cable trays and other supports	32	86%
Equipment panels	31	84%
Lighting fixtures	28	76%
Underground conduits	27	73%
Junction boxes	18	49%
Specialty lighting supports	17	46%
Hangers	17	46%
Outlets and switches	12	32%
Bundles of cable or wiring	8	22%

Last question inquired about the project life cycle phases in which the electrical contractors use Building Information Models (BIMs). As shown in Figure 4, most electrical contractors use BIMs in the preconstruction and construction phases. This response is fully consistent with their earlier response about the most valued BIM features (e.g. clash detections, visualization of electrical design, space utilization, etc.) which are typically used in these phases. It is also found that more than 50% of the respondents use BIMs in only preconstruction and construction phases while approximately 30% respondents use them in every phase of the project life cycle.

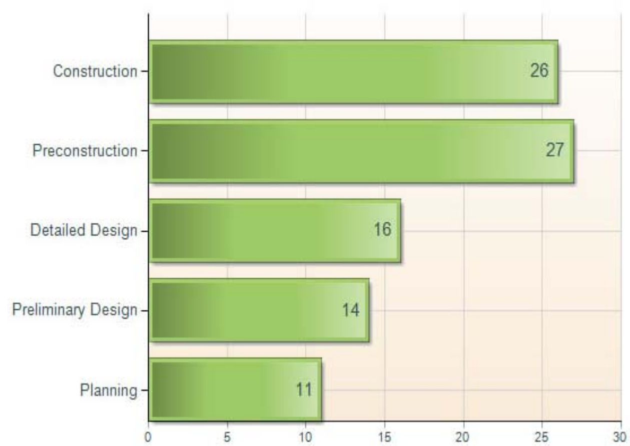


Figure 4: BIMs Use in Project Life Cycle

3.3 Section 3: BIM Benefits and Implementation Costs

This section contained questions about BIM benefits and implementation costs. As a whole, the majority of survey respondents indicated that the BIM technology is significantly helping to improve the process of delivering a facility. When asked about overall effects of BIM on the projects' performance, 70% of respondents reported 'some-to-significant' time and cost savings. Furthermore, 64% of the respondents indicated that BIM helps to improve the quality of work put in place, while 18% indicated that use of

BIM nearly eliminates rework. These statistics are illustrated in Figures 5a and 5b. It is important to note that these questions were subjective in nature and no exact data is available to translate 'some-to-significant' time/cost savings in to numbers.

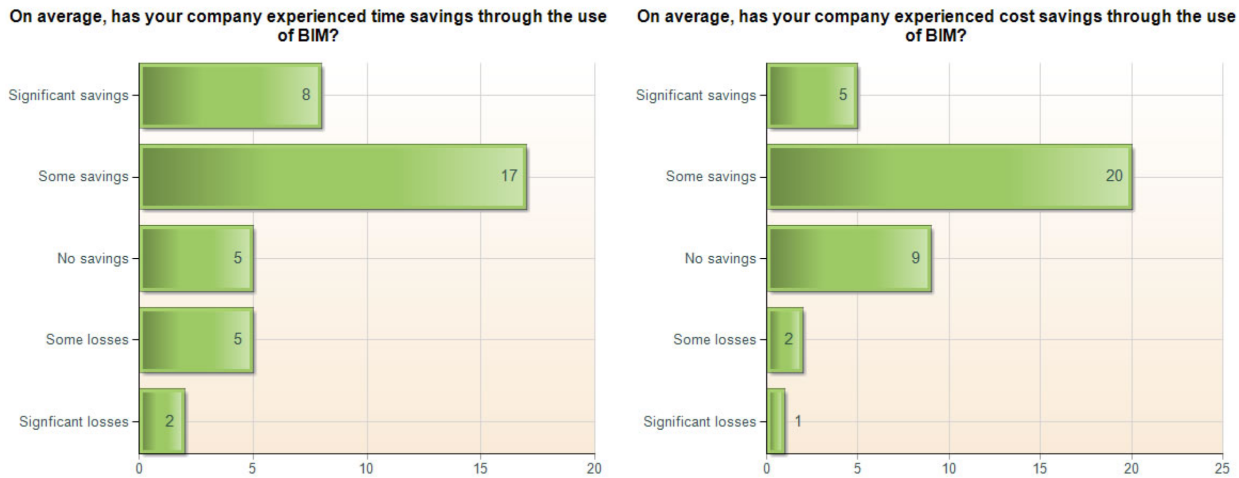


Figure 5a: Effect of BIM Process on Projects' Overall Cost and Schedule

The third section also inquired about BIM implementation costs. These costs include the software purchase costs along with any licensing fees, and costs required to train the employees. Some respondents mentioned that significant expenses were incurred in computer upgrades, as many BIM software require latest high speed computers. The survey received a wide range of responses to this question, from $2,000 to $50,000, with the average just under $13,000. These costs are subject to a number of unknown factors such as organization size and level of implementation. Given the fact that 70% of survey respondents experienced some cost savings, BIM has the potential to pay for itself over the years.

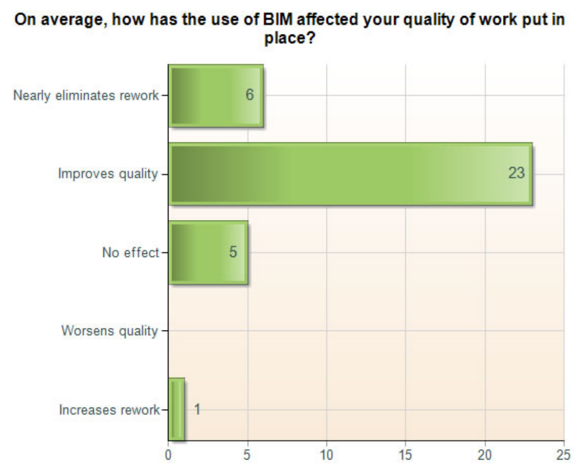


Figure 5b: Effect of BIM on Projects' Quality

3.4 Section 4: Factors Preventing BIM Implementation

The survey concludes by looking into the various reasons why 80% of the respondents are not currently using BIM. The collected data identifies the number one reason to be that the company does not know enough about BIM to make an informed decision regarding adoption, as selected by 65% of respondents. Other reasons, from highest to lowest response rate, are lack of technological experience, incompatibility with existing software, too expensive, and low expected return. Respondents were also encouraged to leave additional comments and explanations. One of the most notable and most common remark was that BIM is not required by the customer or design team. Finally, respondents were asked if their company has future plans to implement BIM. Twenty five (25%) of those companies who are not using BIM do have plans for future implementation. The barriers to BIM adoption are listed in Table 3.

Table 3: Barriers to BIM Adoption in the Electrical Construction Industry

Barrier	Number of responses	Percentage of responses
Do not know about BIM	94	64%
Lack of technological experience/expertise	35	24%
Existing software not compatible	18	13%
Too expensive	16	11%
Not required by customer or design team	12	8%
Low expected return	7	5%
No opportunity	3	2%
Not applicable to scope	2	1%
Too small (of a business)	1	0.7%
BIM is too new	1	0.7%
No use in local market	1	0.7%

4. Conclusions

Building Information Modeling is still an emerging technology in the electrical design and construction industry. About 20% of survey companies are currently using this technology, most of which are medium to large size in terms of their annual revenues. These companies are mostly using BIM technology for clash detections, visualization of electrical design, space utilization, and partial trade coordination in commercial and healthcare projects. The building information models are most commonly used in the preconstruction and construction phases and users reported positive savings in time and cost for the project, while improving the work put in place, thereby decreasing rework. For the 80% of companies that are not using Building Information Modeling, there is a variety of explanations. Most companies simply do not know enough about it. Other companies want to adopt it, but lack the technological experience required to manage and operate the system, and others will not consider adoption until it is required by the customers or designers. While BIM may not be an appropriate business venture for all electrical contractors, as it requires substantial investment and training, it certainly does provide many benefits to its users.

5. Acknowledgements

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