

**THE USE OF BUILDING INFORMATION MODELING IN THE ELECTRICAL
CONTRACTING INDUSTRY**

by

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EXECUTIVE SUMMARY

Due to declining productivity in the construction industry as the result of project change, the industry has been forced to rethink the way it completes work. In recent years, improved project delivery systems and new technology have both led to advancements in the industry. The industry has turned to Building Information Modeling (BIM) to maximize efficiency, maintain profits, and reduce the amount of project change. However, constructors have been reluctant to implement new information technology because they are skeptical about the benefits of the new technology in relationship to the cost to implement it.

Multiple reports conducted by other researchers showed an increasing use of BIM in construction along with growing demand for change to software and standards. Additionally, this research from 2009 showed that electrical contractors were modeling approximately 36 percent of their work. Electrical contractors estimated that two percent cost savings and three percent time savings could be attributed to the use of BIM. However, electrical contracting companies are still struggling to understand and implement the BIM process. The electrical contracting industry has not established many standards for information modeling, and very little quantitative research exists to demonstrate the effects of using BIM on a project. The goal for this research is to obtain solid data in order to make recommendations to the electrical contracting industry for improving its use of BIM.

This research project conducted an online survey to better understand electrical contractors' perception of BIM. Of the 800 companies invited to take the survey, seventy responded. Most of the geographical United States is represented by the survey, as seen by the typical company profile of respondents. Responding companies also perform a significant variety of work. For the most part, medium-to-large companies are represented. The data collected from the survey was then analyzed to identify correlations and trends. Lastly, interviews were conducted with professionals in both the construction and electrical contracting industry to gain better insight into survey responses and use of BIM

Overall, the use of BIM creates great value for the electrical contracting industry. Through the use of BIM, construction industry trades can better coordinate, increasing the value of BIM for electrical contractors during a project's early planning stages. Using BIM, better shop drawings are produced, leading to more accurate field release drawings. During construction, the use of BIM is often responsible for a reduction in field conflict and the greater productivity of electricians. Additionally, electrical contractors' using BIM reduces the cost of project closeout as seen through the reduction in the cost of rework, smaller punch lists, and a lower cost to produce as-built drawings. Both current BIM users and non-users predicted that their future use and investment in BIM will grow over the next two years and will continue to play a large role not only in electrical construction but also in the design and construction industry as a whole. Electrical contractors need to continue learning about the use of BIM in order to fully understand its impacts in the construction industry and to plan for implementing BIM within their company to improve profitability.

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CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

Over the last two decades, productivity in the construction industry has been studied closely. Starting in 1982, the Business Roundtable released a study that showed a negative production growth within the construction industry in the United States since the late 1940's. Through this study, more research has been completed on the issue in order to determine the factors related to the decline in productivity. These factors include change orders, rework, schedule compression, and working conditions (Hanna et al., 1999a). A different study released in 2000 showed that productivity is improving, however there is still more opportunities for growth by improving field management practices (Allmon et al., 2000).

Much of the improvement in productivity over the last twenty years has come through studying and improving the project delivery system. Design-build project delivery has shortened project's overall schedule and improved communication by combining the design and construction phases into one. Lean construction has improved the industry by focusing on refining construction tasks through built-in quality and new scheduling techniques. The implementation of new technology during design and construction has made an impact on improving productivity. Specific examples of new technology on the jobsite can be seen with the use of new tools and machinery. Technology improvements on the design side of construction are noticeable with the increasing use of information modeling and improved communication between the design team and the constructors (Zhai and Goodrum, 2009). That being said, constructors have been reluctant to implement new information technology because of skepticism of the benefits from the new

technology as related to the investment needed to purchase the software. Understanding the use of information technology and its effect on the construction industry is vital to improved productivity.

This study will investigate the current use of Building Information Modeling in the electrical contracting industry. Additionally, our research will try to establish a future direction for the use of Building Information Modeling in the electrical contracting industry. Controlling the factors that lead to poor productivity is vital for the future of electrical contractors and the industry as a whole. We believe that the use of Building Information Modeling will help to improve productivity issues in construction and likewise improve the construction industry.

1.2 PROBLEM STATEMENT

The relationship between change during construction and labor productivity is important to all construction firms. Change can come about in many different forms including the five main changes that were identified by Orczyk in 2002: acceleration, change in scope, delays, differing site conditions, and suspensions in work. Many studies have shown that if a change does occur during construction, productivity will not only be effected directly by the extra work that needs to be completed, but also indirectly by impacting unchanged work that is effected by the changed work (e.g., Hanna et al. 1999a). If contractors are not careful, this can mean disruptions and inefficient work that will lead to added cost. For the construction project, this could mean changes in schedule, the potential for cost disputes, and an overall negative impact on productivity (e.g., Ibbs et al. 2007).

Project teams need to reduce the amount of change that occurs during the life of a construction project in order to maximize efficiency and maintain profits. Using the lean construction principal of early planning, the master builder (or the contractor) takes part in the design process in order to catch issues upfront and decrease the amount of issues that would otherwise be found in the field (Abdelhamid et al. 2008). Through the use of Building Information Modeling, contractors can plan their work prior to starting and properly coordinate with other contractors on the project. Productivity improvements will then be seen on the project through comparisons to other projects.

Over the last three decades, an increase in construction productivity has been linked to an increase in the use of information technology (Zhai and Goodrum, 2009). More specifically, the use of Building Information Modeling in construction has led to the perceived notion by contractors that change during the project is being minimized and productivity levels are increasing (e.g., Zuppa et al. 2009). Statistical backup that shows improvement from BIM is hard to find. However, when surveyed or asked directly, contractors and designers will state that the productivity improvements from BIM exist. This is positive news for the construction industry that has been weakened by the poor economy over the last ten years.

The use of Building Information Modeling, specifically in the electrical contracting industry, has become a popular tool for controlling change and allows for better coordination during design and facility construction. A study performed in 2009 by the California Polytechnic State University and presented at the 2011 Architectural Engineering Institute (AEI) annual conference found that electrical contractors were modeling, on average, approximately 36% of

their work. Additionally, an approximate two percent cost savings and three percent time-savings were attributed to the use of Building Information Modeling. Electrical contractors are, however, still struggling to understand and implement the Building Information Modeling process. The industry does not have many standards for information modeling, and there is not much quantitative research showing the results of using Building Information Modeling on a project.

An increase in the understanding and use of Building Information Modeling in the electrical contracting industry will lead to a reduction in project change and an increase in productivity. Electrical contractors need to understand the use of BIM and its impacts in the construction industry while planning how to implement BIM within their company. With our findings we will provide electrical contractor insight into the current use of BIM, trends for the future use of BIM, and recommendations that will help improve the understanding and usefulness of BIM in the electrical construction industry.

1.3 RESEARCH OBJECTIVES

This thesis has three major objectives: quantify the current use and impact of BIM, approximate the future use of BIM, and offer the industry recommendations that will help improve the understanding and usefulness of BIM. The objectives of this research will be achieved through surveying and interviewing contractors in the electrical construction industry in order to determine possible trends and correlations.

After completion of this research, electrical contractors will be able to use this study to aid their company in planning for how to use BIM in order to stay competitive in the construction market.

Past research on the use of BIM has mostly concentrated on specific practices and tried to determine what software was popular (Simonian, 2009). We will reinvestigate the results and expand the research to determine the impact of BIM by looking at performance indicators and how BIM is adding value to a project. Ultimately, we hope to provide the electrical construction industry with information that will allow companies to make decisions that will help them increase efficiency and deliver better projects.

1.4 BACKGROUND

This section focuses on providing the reader with definitions and background concepts.

1.4.1 Definitions

Certain concepts used in this research can be interpreted differently throughout the construction industry. To eliminate any confusion and keep consistency, the following words have been defined for the readers:

- **Building Information Modeling** - the creation and use of computer models and collaborative work between companies to improve design and construction of facilities and other infrastructure.
- **Performance Indicators** - the measurement of a specific area of work to determine success or failure. This includes, but is not limited to, changes in the number of Requests For Information (RFIs), number of change orders, and project costs. As an example, if the use of Building Information Modeling led to a decrease in RFIs, the performance indicator would show that BIM was successful at reducing RFIs.

- **Return On Investment (ROI)** - a performance measure that individuals and organizations use to assess the productivity of an investment. The ROI is used prior to an investment to determine if the investment should be made. The ROI is also used following the investment to evaluate the decision that was made. The equation is as follows:

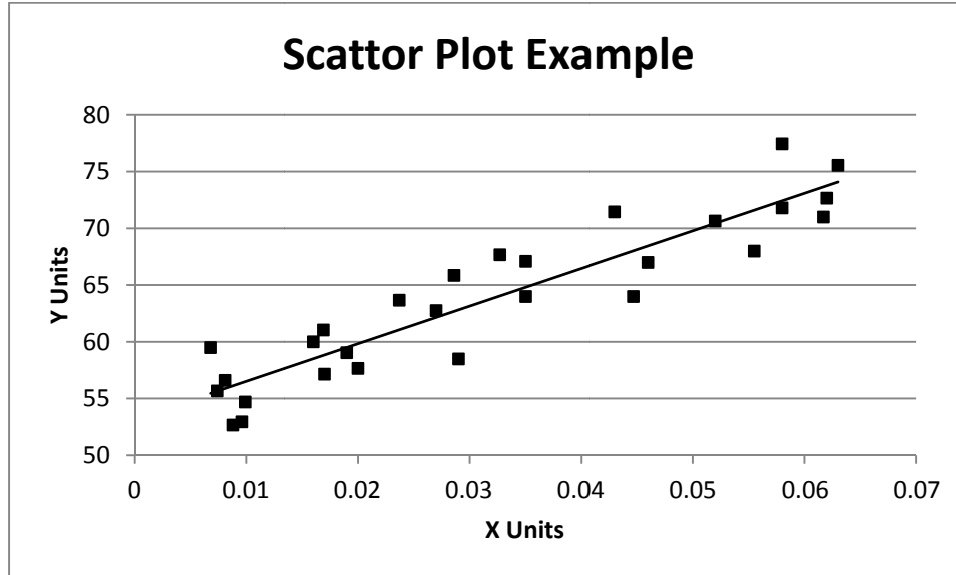
$$\text{Return On Investment} = \frac{\text{Gains from Investment} - \text{Cost of Investment}}{\text{Cost of Investment}}$$

1.4.2 Concepts Used in Research

Correlation Coefficient

Researchers typically collect data to determine the nature of a relationship between two quantities. Typically, after performing an experiment or surveying a group of individuals the researcher's main question is to determine how closely the two quantities are related to each other. The first task in finding a relationship is to plot ordered pairs of data on a scatterplot as shown in Figure 1.01. From this plot, a visual relationship between the data becomes more apparent. Furthermore, a least-squares line can be added to the plot that represents the regression of the data. Next, the researcher will want to measure the relationship between the least-squares line and the data to find the strength of the linear relationship. The summary statistic most often used to measure the closeness between two variables is the correlation coefficient.

Figure 1.01 – Example of a Scatterplot Constructed from Experimental Data



The correlation coefficient is defined as the numerical measure of strength for a linear relationship between two variables. Researchers carefully look for any correlations to ensure that confounding does not exist between that relationship. Confounding occurs when there is a third variable that is correlated with the two other variables of interest, resulting in a correlation between them.

The mathematical equation for the correlation coefficient is as follows:

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i^2 - n\bar{x}^2)} \sqrt{\sum_{i=1}^n (y_i^2 - n\bar{y}^2)}}$$

The correlation coefficient summary statistic will be used to evaluate the relationship between survey responses throughout this report. When a moderate to strong correlation is found, the relationship will be reviewed by sorting survey responses to investigate how respondents are grouped. These correlations will be presented in Chapters 4 and 5 of this report.

1.5 RESEARCH METHODOLOGY

The first step in this project was to complete a literary review. Specific information on the use of Building Information Modeling in the electrical contracting industry was sparse. Most of the literature review in this report will focus on the use of Building Information Modeling in the construction industry. The remainder of the literary review focuses on two studies that overview the use of BIM within the electrical contracting industry. Literature on the use of BIM in construction contained information on characteristics, adaption, usage, value, impact, infrastructure, and previous recommendations to companies and industry specific organizations.

1.5.1 Questionnaire

To obtain information from the electrical contracting industry on their use of Building Information Modeling, a survey was sent to electrical contractors across the United States. A previous survey written by McGraw-Hill in 2009 was used as a starting point. From there, a completely new survey was created. The University of Wisconsin-Madison Survey Center reviewed the survey and provided valuable input for improvement. The survey was then programmed into Qualtrics, a free surveying website provided by the University of Wisconsin-Madison. In total, the survey contained 24 questions, with some questions broken into categories that pertained to that particular question. Please see Appendix B to view the survey.

A “cover letter” email was written that included a link to the survey. The survey was sent to around 800 individuals that work in the electrical contracting industry and have headquarters or perform work within the United States. A few of the companies surveyed had offices in the United States but were headquartered in Canada or Mexico. The email addresses were obtained through databases of contractors from the National Electrical Contractors Association (NECA), Foundation for Electrical Construction, Inc. (ELECTRI International), and Federated Electrical Contractors (FEC). In total, seventy surveys were filled out in a one-month period. The data collected in the surveys acts as a sample population of medium-to-large electrical contractors that perform work in the United States. A more comprehensive review of this process will be presented in Chapter 3.

1.5.2 Analysis

After data collection, responses were placed in a Microsoft Excel file matrix with the questions on the horizontal axis and the respondent identification number on the vertical axis. The correlation equation in Excel was used on the previously-mentioned matrix to produce a new matrix that showed the correlation coefficient between all the questions. If a correlation coefficient was anywhere above 0.50, the data was investigated further. Using Qualtrics, data was sorted by keeping one factor constant and looking at other factors. In short, a certain response to a question in the survey was held constant to show how those respondents answered other questions. Appendix C presents the data used for the analysis. Using this information, trends and correlations were observed. Additionally, the data from this report was compared to the data of previous research to determine trends in the industry. The results of this analysis can be found in Chapters 4 and 5 of this report.

1.5.3 Recommendation Development

The last step of this project was to review the results of the data analysis and make recommendations to the industry. This was completed by reviewing the information with individuals in the electrical contracting and construction industry for further insight into BIM use and to then make recommendations to the industry. Using the information from the survey and the perspectives of those interviewed, comprehensive recommendations could be made. The ultimate goal of this research is to obtain solid data in order to make strong recommendations to the electrical contracting industry for improving the use of Building Information Modeling. Additionally, both findings and gaps in the research will be used to make recommendations for future research in both the electrical contracting industry and at the University of Wisconsin-Madison.

1.6 SCOPE OF RESEARCH

The scope of this research was limited to the perspectives and honesty of management and/or survey respondents within the electrical contracting industry. The Qualtrics survey asked questions about contractors' use of BIM. We did not look at specific projects nor the data associated with those projects. Instead we tried to get an understanding of the use and impact of BIM on a macro company level.

The collection of data was also limit to companies that are members of the National Electrical Contractors Association, Foundation for Electrical Construction, Inc., and Federated Electrical Contractors. Interviews with individuals did reach outside of the surveyed group.

1.7 SUMMARY AND REPORT ORGANIZATION

The construction industry is an ever-changing place, and if one is not careful, it is easy to fall behind on emerging technologies and practices. The impact of Building Information Modeling in construction is growing larger every day, and companies' decision-makers need to understand its use throughout the industry in order to stay competitive. This report, using the methodology previously described, will focus on three areas in the electrical contracting industry:

- (1) the current use of Building Information Modeling
- (2) the future use of Building Information Modeling
- (3) how to improve the use of Building Information Modeling

The report is intended for the use of electrical construction contractors and possibly other trades that work in construction to learn more about the use of Building Information Modeling. Chapter 2 reviews previous literature published on related topics. Chapter 3 consists of profiles of the respondents to the survey. Chapters 4 and 5 focuses on the correlations and trends in the data that was collected. The final chapter includes a summary of the project and recommendations for improving the use of Building Information Modeling and ideas for future research. The attached appendices will provide backup to the research that was performed.

CHAPTER 2 REVIEW OF EXISTING LITERATURE

2.1 INTRODUCTION

A thorough literary review was conducted in order to determine the history, present use, and predicted future plans for Building Information Modeling. This chapter will review the history of the design and construction industry to show how BIM developed. Next, BIM will be introduced and a general review of BIM's use in construction will be presented. The remainder of the chapter will review specific reports based from surveyed companies on the current and future use of Building Information Modeling in both the construction industry as a whole and then more specifically in the electrical contracting industry.

Information presented in the literary review will be compared to the information collected through surveys for this report. Comparisons can then be made to show the differences between the use of BIM in the electrical contracting industry as compared to the design and construction industry as a whole. Additionally, the change within the electrical contracting industry from previous reports to this report will be presented.

2.2 BUILDING INFORMATION MODELING BACKGROUND

The development of Building Information Modeling came from a long history of continuous improvement in the construction industry. The adoption of BIM has been slow but is starting to become a construction industry standard for both designers and builders. Many owners and construction managers now require companies to use BIM on construction projects. The

implementation of BIM by companies has been accompanied by many successes and failures. As will be discussed in this chapter and throughout the rest of this report, BIM has come a long way and improved the way companies and project teams deliver projects. However, many issues still need to be resolved, and BIM specific procedures still need to be created. This section of Chapter 2 will review the history of BIM and give a general overview of the successes and failures of the modeling process.

2.2.1 The History of Industrial Technology

The improved use of technology in construction can be seen throughout the history of the world. Over the past few millennia humans have created new tools in order to make construction of new structures easier. For example, during the Roman Empire, sophisticated wooden cranes were used to build large buildings (Becche et al., 2004). Today, tower cranes are typically seen on large construction projects. In 1835 the first mechanically-powered excavating machine, named the Dipper Shovel, was developed by American William Otis to assist construction crews with digging and truck-loading soil and other construction materials (Dipper shovel, 2012). Excavators and backhoes are now typically seen on construction project in today's world.

More recently, during the 1970's, Computer Aided Design (CAD) allowed designers to streamline their designs to improve replication of their design and the transfer of information (Cunz and Larson, 2006). With CAD, architects and engineers were able to replicate the drafting board on their computer and to improve the design process by producing ideas and designs electronically which cut down on the amount of time and effort needed to produce final design documents. Two-dimensional CAD eventually evolved into three-dimensional CAD. These

geometrical objects aided designers and builders with visualizing the final product, but did not contain relationships between objects in the design (Howell and Batcheler, 2005). For example, a steel beam would be connected to a steel column, but the model would not contain information on how these two objects were connected, i.e. weld type and/or bolting information.

In recent years, CAD has improved to include three-dimensional intelligent objects that recognize relationships between one another, or more specifically, Building Information Modeling. These objects have helped to communicate information more easily from the designer to the builder. Objects within a building model are embedded with information that shows connections, components, attributes, and other details that were not available in two-dimensional CAD programs. Examples of this include, but are not limited to, fire rating, hinge type, wall thickness, and anchor length. When all these intelligent objects are combined within the Building Information Model, a virtual structure is formed that the designers and builders can duplicate in the real world. Currently, the more popular Building Information Modeling software includes Autodesk Architectural Desktop, Autodesk REVIT, Bentley Systems, Graphisoft, and Nemeschek (Howell and Batcheler, 2005).

2.2.2 Building Information Modeling Successes

Building Information Modeling has transformed the way architects and engineers design a building and the way contractors construct a building. Using a BIM model, all information can be contained within a single design model, which includes plans, sections, elevations, schedules, details, and specifications. If an object is changed in the model, the associated communicator (ie. plan, specification, schedule) will change instantaneously. Using a single-source model allows

different design and construction disciplines to then detect problems before construction, including clashes between elements such as a concrete structure and a heat duct. Additionally, design teams can use the model to perform analysis on the building such as day lighting, energy use, and wind loads.

Using the Building Information Model, constructability issues can be more closely observed. Currently, contractors most often use 4-D (scheduling) and 5-D (cost-estimating) models to simulate construction of a building. The scheduling model helps with creating “Just in Time” deliveries if a project site is small. A cost-estimating model will help determine and track the cash flow throughout the project and aids in value engineering.

Building Information Modeling also adds value to a project for the owners and occupants. After construction is complete, the model can be turned over to the owner to be used for maintenance and operations. A final model contains information that can be used in the future for replacing fixtures, revealing the locations of systems (ducts, plumbing, electrical) behind finished walls, and remodeling or building an addition. The model can also be used with other software to create a living model of the structure that can display the current temperature of a room, an air handling unit that needs to be serviced, or a door that is currently ajar.

2.2.3 Building Information Modeling Limitations

As just discussed, Building Information Modeling has already demonstrated many promising successes in the construction industry. However, the limitations of BIM have also been

recognized by designers and builders in the construction industry. In order to continue BIM's implementation and improvement, these limitations must be addressed and overcome.

As mentioned previously, the design and construction industry is currently using many software programs to implement Building Information Modeling on a project. Every company has a design software package that they use internally, and the company normally has their own way of implementing BIM on a project. The lack of standardization in the industry and the availability of multiple software packages have hindered the calibration between companies when forming a single building model for a project. On many occasion BIM models will not converge into a single model. Additionally, the electronic file size of a building model can become so large that sharing or adding additional information can become cumbersome.

Early design decisions can also be very difficult to organize using Building Information Modeling. As discussed in Ian Howell and Bob Batcheler's paper titled *Building Information Modeling Two Years Later – Huge Potential, Some Success and Several Limitations*, design firms often try to present alternatives to the owner. Trying to represent all of the alternatives in one model is an extremely difficult task and usually requires multiple models. The separate design models need to be tracked closely because objects usually do not communicate between separate models. Additionally, "what if" scenarios become difficult to conduct because changes made to a model might not be kept in the final design.

The scheduling and delivery methods used on a project can also hinder the value of Building Information Modeling. If a project is fast-tracked, the time to add additional detail to a building

model and for coordination between designer and builders is extremely limited. Time constraints limit the usefulness of the building model. Also, fast-tracked projects limit the amount a building model can change as construction proceeds. The project delivery method can also dictate the success of using Building Information Modeling. The traditional design-bid-build delivery model nearly eliminates all interaction between designers and builders during the design process. Without this collaboration, the building model can often be missing important constructability, scheduling, and value engineering elements.

Another significant limitation to Building Information Modeling is the risk and liability associated with implementing the process on a project. Doctor Salman Azhar reviews two categories of risk connected with BIM in a journal article titled *Building Information Modeling: Trends, Benefits, Risks, and Challenges for the ACE Industry*. The first risk type pertains to ownership of the BIM model and the information contained within the model. Building owners often believe they own the model. However, the architects, engineers, and contractors are providing the majority of proprietary information to complete the model. The right to sell this information and responsibility for accuracy of information can cause problems following construction. The second risk, as described by Doctor Azhar, is determining who is liable for the data inserted into a model. On many projects, BIM specialists from different companies are responsible for creating a portion of the model. For example, the mechanical contractor models the heating, ventilation, and air conditioning systems. These designs are then brought together to create one large BIM model. If an inaccuracy is found in the model, the liable party can be difficult to determine; but if cost or schedule are impacted due to the inaccuracy, the responsible party must be discovered.

This risk can be mediated. In his concluding remarks, Doctor Salman Azhar emphasizes the importance of discussing these issues prior to beginning any planning or modeling starts. Additionally, contracts between parties should contain language detailing how risk is shared and who owns the various parts of a BIM model. This can be said for all of the limitations described in this section of the report. All parties need to communicate adequately in order to improve the BIM process. In section 2.3 and 2.4 of this report, BIM limitations will be investigated further and surveyed data will be presented from previous research.

2.2.4 Return on Investment

Previous research on the use of Building Information Modeling attempted to quantify the return on investment (ROI) of using BIM on projects, which was mainly observed through surveying and interviewing companies. Multiple reports, including a 2009 McGraw Hill SmartMarket Report on *The Business Value of BIM* showed that companies experience a positive return from using BIM. Additionally, these returns have been larger than companies originally expected, and the ROI tends to increase as a company becomes more experienced with BIM.

An observation from reading reports on BIM's return on investment is that there is a large variation on the return reported. In his report on Building Information Modeling, Doctor Azhar reviews ten projects and the ROI for using BIM on those projects. The smallest ROI, as a percentage, reported was 140% and the largest was 39,900%. The size of the ROI fluctuates depending on project-specific information and the way that BIM is being used. That being said, making conclusions or finding usefulness in the reported ROI is difficult due to the multitude of factors being looked at. Additionally, the return on investments were reported by companies and

not collected first-hand by the researcher. This could create discrepancies in the information used to calculate the ROI. For example, one company's response could use certain indirect costs to calculate their ROI that another company chose to exclude.

When looking at the return on investment from using BIM, the ROI must be viewed on a macro level instead of a micro level. Knowing that a company is obtaining a positive return from using BIM is far more important than the actual return that is reported. For this reason, the return on investment will not be tracked using the survey in this report. Future research on the ROI from using BIM is not recommended. This will again be mentioned in the conclusion of this report.

2.3 BUILDING INFORMATION MODELING IN THE CONSTRUCTION INDUSTRY

In December of 2008, McGraw Hill Construction released a SmartMarket Report titled *Building Information Modeling (BIM) – Transforming Design and Construction to Achieve Greater Industry Productivity*, the result of their research into the adoption, usage, value, and impact of BIM on users in the construction industry. The report also analyzed the anticipated use of BIM in 2009. Information was collected through surveys sent to architects, engineers, contractors, and owners involved in construction. The report showed BIM is increasingly used on construction projects and that many firms plan to continue implementing BIM on projects in the future. The research also showed that BIM needs to become more standardized for use in the design and construction industries and to improve the results of using BIM.

2.3.1 Adoption of BIM

The adoption of Building Information Modeling is steadily increasing in the construction market. In 2008, 35% of the users reported being heavy users while 38% reported lightly using BIM. Heavy users are defined within the McGraw Hill report as companies that use BIM on more than 60% of their project, and light users are defined as companies that use BIM on less than 16% of project. These numbers were expected to greatly change in 2009 when 45% of users reported planning to heavily use BIM and 18% planned to being light users. The total breakdown of use can be seen in Table 2.01. Within these numbers a greater number of contractors and engineers report being light users whereas architects and owners reported being heavy users.

Table 2.01 – Growth in the Use of BIM on Projects from 2008 to 2009 (McGraw Hill, 2008)

User Characteristic	2008	2009
Very Heavy Users (>60%)	35%	45%
Heavy Users (31-60%)	10%	17%
Medium Users (16-30%)	17%	20%
Light Users (1-15%)	38%	18%

The perception of BIM in the design and construction industry is also optimistic. Of the companies and organizations surveyed, 49% had a mostly positive view of BIM. Forty-four percent reported being neutral, and 7% were mostly negative. Contractors had the highest positive rating at 61%. Contractors are finding great value in the ability to find clashes in elements of the design and to improve the cost and schedule of the project when using BIM. On the other hand, engineers had the lowest positive rating 37% and a neutral rating at 54%. Engineers seem to see some value in BIM, but are hesitant to implement BIM because of the increased risk and cost. Many engineers are still using two-dimensional CAD to communicate their designs.

A strong correlation was found between the experience level of BIM users and the outcome from using BIM. For example, of the expert users, 82% reported mostly positive outcomes and 4% mostly negative outcomes. Conversely, of all the companies that considered themselves BIM beginners, 20% reported mostly positive outcomes and 15% mostly negative. These results show the importance of training within companies and organizations. As with any new technology, as employees begin to understand and become comfortable with software and tools, BIM results will improve.

Of all the challenges facing companies and organizations with the adoption of BIM (see Table 2.02), the three that stand out most are the availability of training for the new technology, buy-in from senior staff members, and the cost of the software. BIM is a relatively new practice and no standardization in the industry exists. For this reason, training is not readily available for new companies looking to implement BIM. Additionally, training new practices to senior employees is always difficult. Senior employees find changing practices from old to new challenging and time consuming, as seen thirty years ago when architects swapped drafting tables for Computer Aided Design programs. Lastly, with any new technology, implementation can be very expensive due to the necessary purchase of new software and tools. This includes, but is not limited to, computer programs such as Autodesk's Revit and tools such as total stations.

Table 2.02 – Challenges to BIM Adaption Within a Company (McGraw Hill, 2008)

Challenge	Users Reporting Most Challenging (8-10)	Users Reporting Least Challenging (1-4)	Mean Scale (1-10)
Adequate training	19%	35%	5.25
Cost of software	15%	44%	4.70
Cost of required hardware upgrades	13%	50%	4.46
Senior management/senior staff buy-in	17%	52%	4.37
Middle management/middle staff buy-in	11%	51%	4.27
No external incentives or directives moving us to use BIM	13%	61%	3.76
Risk of losing intellectual property and liability issues	9%	60%	3.72
Junior management/junior staff buy-in	12%	66%	3.61

2.3.2 Usage of BIM

Within a project team, there is normally a group member pushing for the use of Building Information Modeling. On 40% of projects that use BIM, the primary driver is often the architect. In its preliminary stages, most BIM projects start as a basic model depicting shape and massing. From that stage the architects detail the model. In other situations, Construction Managers/General Contractors (18%), owners (13%), or a combination of the team members (14%) are the drivers behind using BIM. In the instances where Construction Managers/General Contractors are the driver, they internally believe that they are the primary driver half of the time. This stems from the use of BIM to model the project regardless if the designer is using BIM or not. Additionally, owners often push to use BIM on a project but are not willing to pay the direct costs for using BIM.

A strong correlation exists between the industries that use Building Information Modeling and the frequency of modeled elements on a project. Architecture, structural systems, and mechanical systems are the most frequent modeled elements with each being completed 58%, 49%, and 38% of the time respectively. The least frequent modeled elements on a project include in-ground utilities, energy management systems, and transportation. Electrical elements fall in the middle with a frequency of 24%. This follows the general principal of BIM. Designers and builders want to collaborate so that clashes can be found. Typically, larger elements are more difficult to relocate and need more attention prior to being installed in the field. An improvement in designing building accessibility was also mentioned in the survey results. Contractors are using BIM to coordinate elements outside of the bricks and mortar. This includes scheduling, equipment locations, and sequencing. A total understanding of the project and its limitations is important to know prior to facing problems from possible limitations.

Each industry uses BIM in their own way to help support the work they are completing. Architects use BIM to visually display what the design will look like following the completion of construction. The most modeled element for architects is the building skin (83%), exterior openings (83%), exterior walls and skin (82%), and interior partitions (82%). Within the electrical contracting industry, light fixtures are the most frequent element modeled on a project, followed by the electrical panels. On the other hand, the least frequent elements modeled are the conduit and energy management systems, and these elements are easily coordinated in the field. As mentioned previously, larger elements tend to be modeled prior to construction so that issues can be resolved prior to construction and workers can be more productive.

As mentioned previously, Building Information Modeling can be used for more than designing elements within a project. BIM has also helped project teams with scheduling and cost-estimating. Contractors have the highest rate of response by using BIM in this manner. Of the contractors surveyed, 21% had a positive rating for scheduling using BIM as compared to architects at 10%, engineers at 6%, and owners at 0%. More project details are needed in order to create a project schedule, and contractors normally have a greater understanding of the smaller details compared to owners who understand more of the larger elements of the project. Project cost-estimating received positive reporting from 13% of owners and the same number from contractors. Much smaller positive responses were received from architects and engineers. Owners and contractors are far more interested in tracking the cost of a project than the designers. The report also recognized plenty of room for growth within the construction industry for using BIM to model project schedules and costs.

Companies and organizations that lack the capability to perform the task in-house, mainly the owners of construction projects, are outsourcing Building Information Modeling. Currently, 31% of owners reported a positive response when asked if they outsourced their BIM work. This is compared to 0% of architects and 1% of engineers. Contractors' positive response for outsourcing stands at 7%. The McGraw Hill report predicted a future increase in outsourcing based on survey results. Outsourcing will grow greatly in the coming years as modeling becomes an expectation on a construction project. Twenty nine percent of architects expected an increase in outsourcing BIM in 2009. Additionally, 60% of users who expect to increase outsourcing of BIM considered themselves to be beginners or intermediate users.

The McGraw Hill report also found a strong relationship between companies that use BIM on a large number of project and companies that are involved in green projects. Designers that used BIM to design a green building reported using BIM for space heating and cooling, energy savings, and light conditioned spaces. Interestingly enough, a greater percentage of contractors reported using BIM for green building more often than architects and engineers. An explanation for this was not given in the report. However, a possible correlation between the use of BIM and material tracking could exist.

2.3.3 Value of Using BIM

The value companies and organizations receive from using BIM can be difficult to track through a survey. The overall value is frequently only a perceived result and not actually backed by data. This does not mean the perceived results are inaccurate, but rather that the results are the observations of users without collecting data from the use of BIM. Companies in the McGraw Hill study cited many observations from using BIM, including easier coordination, improved productivity, improved communication, and improved quality control.

When companies attempt to track the value of BIM, the most common method is to track the return on investment (ROI). About half the users in the McGraw Hill report stated that they put moderate-to-high effort into tracking the return on investment from BIM. A wide range of return on investments has been found through multiple surveys and reports. The McGraw Hill survey reported the average perceived return on investment from using BIM to be between 11% and 30%. In Dr. Azhar's study, mentioned earlier in this chapter, ROI ranged from 140% to 39,900% with a mean of 1,633%. The average return on investment is hard to capture because of the many

different ways BIM can be used on a project. For example, if BIM is used during the early planning stages and a change is made to the project that eliminates a large portion of the budget, this return on investment will be extremely high compared to the cost savings found when using BIM for clash detection.

In order to gain a better understanding of BIM's the return on investment, companies track certain aspects of BIM. As can be seen in Table 2.03, companies believe that communication and coordination are the most important areas to track to find the return. A correlation was also found between a company's experience with BIM and a higher rate of tracking return on investment. The study found that 48% of companies that consider themselves BIM experts frequently track the return on investment, compared to 10% of beginners that track the return on investment as often.

Table 2.03 – Importance of Reasons for Measuring Return on Investment
(McGraw Hill, 2008)

Challenge	Users Reporting Most Important (8-10)	Users Reporting Least Important (1-4)	Mean Scale (1-10)
Improved project outcomes (fewer RFIs and coordination problems)	79%	3%	8.49
Better communication because of 3D visualization	79%	4%	8.31
Productivity improvement of personnel	62%	8%	7.78
Positive impact of winning projects	66%	7%	7.77
Life cycle value of the BIM	35%	25%	6.20
Disruption to implement new processes	30%	23%	6.19
Initial cost of staff training	29%	28%	5.97
Ongoing costs of software and training	26%	27%	5.81
Ability to secure plan approval and construction permits faster	33%	41%	5.46
Initial cost of software	24%	37%	5.39
Requirement for new hardware to keep up with software	22%	37%	5.38

2.3.4 Impact of BIM on Internal and External Processes

Building Information Modeling has changed the way teams communicate within their own organization and with other organizations working on the same project. The biggest change comes in the ability to visually communicate designs, ideas, and issues. In the past, this was mostly done using two-dimensional CAD drawings. BIM allows teams to communicate using three-dimensional objects either on a computer screen or a printed snapshot. BIM has also allowed designers and contractors to collaborate more on the design of a project by using the same model for the entire project, which has eliminated repetition of work and has decreased the need for shop drawings. Designers and builders can instead spend more time designing the project together prior to any work beginning. Table 2.04 provides a more detailed breakdown of process change seen within teams and the frequency of the change that has been reported.

Table 2.04 – Frequency of BIM Related Activities (McGraw Hill, 2008)

Challenge	Users Reporting Most Frequent (8-10)	Users Reporting Least Frequent (1-4)	Mean Scale (1-10)
Routinely using 3D visualization capability to communicate with all parties	47%	25%	6.52
Using BIM on the jobsite to guide construction activities	39%	31%	5.80
Increasing time spent on design	25%	29%	5.69
BIM reviews in collaboration environments with multiple parties	33%	40%	5.50
Meeting with key disciplines for clash detection analysis	31%	42%	5.26
Reducing time spent on contract documentation	25%	39%	5.05
Integrating schedule with BIM model	25%	45%	4.88
Reviewing models or deliverables generated from models as part of the review and approval process	23%	59%	4.33
Using the BIM model for site, infrastructure or facilities management and renovations	21%	59%	4.13
Hiring trade contractors early to participate in design assist role	16%	60%	3.97
Developing cost estimates from the BIM model	16%	61%	3.92
Eliminating shop for field drawings by having disciplines work within a shared model environment	16%	65%	3.64
Using BIM to facilitate regulatory approvals	16%	67%	3.37

Internal process change has been reported by roughly 70% of BIM users as shown in the McGraw Hill report. Architects reported the highest internal process change while owners reported the lowest process change. A strong correlation was found between the experience level of the BIM users and the impact on internal process change. Architects have a longer history of using BIM and have had the largest impact on internal process change. Similar results were found with external process change. Contractors reported the highest impact on external process change, with architects also reporting high change. Contractors are now able to detect clashes in the mechanical, electrical, and plumbing design prior to fabrication and installation. On many projects, representatives from each trade create a model to find clashes and work together to determine the best possible solution. Lastly, as was the case with internal process change, owners have reported the lowest external process change, which corresponds with the fact that owners have less experience with BIM.

New processes of collaboration come with new risks that teams need to resolve prior to any work beginning. Errors and accuracy issues within the model are a large concern for the owners of many projects. Mistakes can lead to extra costs, and teams must figure out who will be responsible for these costs. The experience levels of team members can also cause problems on teams. There is a perceived risk that the team member with the least amount of experience will slow the team's progress and create errors in the model. On any project, team members (internal and external) are expected to be responsible and take ownership of the decisions they make. This is especially true with Building Information Modeling. Anytime a person makes a change to a model, they become responsible for the change made. With most software packages, this is extremely difficult to track.

As discussed in the McGraw Hill SmartMarket Report, many liability and legal issues have arisen from the use of BIM. The design and construction industries are currently working to resolve these issues. One way they are doing so is by keeping separate models and not sharing information. This however reduces the ability for designers and builders to work together to deliver a project, and thus decreases the collaborative benefits of using BIM in the first place. Other ways to reduce risk is to discuss and agree upon the BIM process prior to starting the project. Although many changes have not yet been implemented, the American Institute of Architects (AIA) and Associated General Contractors of America (AGC) are currently working to standardize contract language in order to reduce the risk of using BIM on a project. Additionally, many teams sign off on completed models prior to construction. However, work still needs to be done in the construction industry to reduce legal and liability issues.

2.3.5 BIM Infrastructure

The benefits of using Building Information Modeling are sometimes overshadowed by software difficulties and the need for programming changes. Eighty-seven percent of respondents to the McGraw Hill survey reported that they believed improvements must be made to BIM software. Interoperability is the largest improvement as reported by the industry. Users want software packages and models to work better together so that the finished model is the highest quality. A different report published by McGraw Hill on interoperability stated that poor interoperability of software contributes to three percent of total project cost (Young, Jones & Bernstein, 2007). Table 2.05 shows many different BIM software packages and presents the industry's awareness of each software and how often each is used. As seen in the table, Autodesk's NavisWorks and

Revit are the most popular software packages. Autodesk BIM products are known for being user friendly and have gained in popularity over the last few years.

Table 2.05 – Popularity of BIM Software Packages (McGraw Hill, 2008)

Software Package	Aware (%)	Used (%)
Archicad	86%	34%
AutoCAD Civil 3D	89%	38%
Autodesk NavisWorks	89%	71%
Autodesk Revit	93%	67%
Bentley	83%	36%
Bentley Architecture (Triforma)	67%	17%
CS2	38%	9%
Digital Project	41%	5%
RAM	52%	31%
Tekla	35%	10%
Vectorworks	65%	10%
Vico	64%	30%

Building Information Modeling software is not just being used for designing mechanical, structural, and architectural systems. BIM is also used to analyze a building prior to construction. The popularity of analyst tools differs depending on the group within the industry. Architect's most popular analyst tool is the energy analysis function that can be performed on the finished model. After designing a building's enclosure architects can analyze the building to determine heat losses and gains, the building's weak thermo points, and where additional design might be needed. Table 2.06 shows the most popular BIM analysis tools in the construction industry. As noted in the table, quantity take off is the most popular tool and is mostly used by contractors to determine and track the cost of the project. The McGraw Hill report found that expert BIM users are twice as likely to use the quantity take off tool compared to all other users. BIM users have reported a need for continued content improvement in order to deliver better models. The top

needs include structural elements, mechanical equipment, and the building envelope/windows. Most users are looking for micro changes to specific content, not overhaul of the entire program.

Table 2.06 – Popularity of BIM Analysis Tools (McGraw Hill, 2008)

Analysis Tool	Percent of Use
Quantity Take Off	57%
Scheduling	45%
Estimating	44%
Energy Analysis	38%
Project Management	35%
Structural Analysis	32%
LEED or Other Green Analysis	32%
Storm Water Analysis	19%
Facility Management	18%
Vehicle Turning Analysis	15%
Other	15%

Establishing industry standards for BIM use and the availability of BIM training are needs recognized by current BIM users. Two-thirds of McGraw Hill respondents reported that they believe that professional industry organizations should create BIM standards. These standards would help to reduce duplication and improve interoperability. Training is another area of improvement sought by BIM users. Many recognize the competitive advantage of using BIM and desire to continually improve their skills. The method of training varies by group and skill level. A majority of expert users and 41% of contractors prefer using internal training. On the other hand, 40% of beginners and 30% of engineers prefer self-teaching training methods. Regardless of skill level and group, two-thirds of respondents reported the need for more training. The highest areas of training needs include basic skills, how to work collaboratively with outside firms, and sending and receiving models with outside sources.

2.3.6 Conclusion

The McGraw Hill Smart Market Report on Building Information Modeling provided this research report with great insight into adoption, usage, value, and impact of BIM on users in the construction industry. Additionally, the report exposed an increasing use of BIM on construction along with increasing demand for change to software and standards. This report will help compare industry BIM trends to specific electrical contracting trends. To measure trend changes over the last few years to the present, a BIM study on the electrical contracting industry will be compared to the data collected. Section 2.4 will cover this.

2.4 BUILDING INFORMATION MODELING IN THE ELECTRICAL CONSTRUCTION INDUSTRY

As mentioned in the McGraw Hill Smart Market Report, smaller components within a project are often not modeled to save time and resources. A lot of the electrical work throughout a building falls into the category of small components and does not get modeled. For this reason, the electrical contractors have been slow to implement Building Information Modeling.

Existing research on the use of Building Information Modeling in the electrical contracting industry is very limited. Two reports based on surveyed data were located; both were supported by The Foundation for Electrical Construction Inc. (ELECTRI International) and were published in May of 2009. ELECTRI International conducts research and provides training for the electrical contracting industry. The first source was a conference paper written by Salman Azhar and Seth Cochran from Auburn University titled *Current Status of Building Information Modeling (BIM) Adoptability in the U.S. Electrical Construction Industry*. The second was a

research report by Lonny Simonian, P.E., P.M.P. from the California Polytechnic State University titled *Building Information Modeling for Electrical Contractors: Current Practice and Recommendations* and was presented at the 2011 Architectural Engineering Institute conference in Oakland, CA. Both papers provide insight into the use of Building Information Modeling and recommend improvements to BIM practices within the electrical contracting industry.

2.4.1 Characteristics of Electrical Contractors

Both research projects surveyed contractors from the National Electrical Contractors Association (NECA), Inc., an organization that connects large and small union electrical contractors with each other to improve the industry. The annual profits for the electrical contractors surveyed ranged from less than \$10 million to more than \$250 million. The Azhar/Cochran report had a large response from smaller electrical contractor; therefore the report is a better representation of the entire industry. On the other hand, the Simonian report represents more medium to large companies.

The Simonian report provides a market sector breakdown that shows the areas of construction the respondents worked in. As seen in Table 2.07, 39 percent of the responding electrical contractors worked in the commercial industry. Only five percent of the respondents worked in residential or processing.

Table 2.07 – Company’s by Market Sector (Simonian, 2009)

Market Sector	Lowest Response (%)	Highest Response (%)	Average (%)
Residential	0%	100%	5%
Commercial	0%	90%	39%
Institutional	0%	80%	20%
Industrial	0%	100%	21%
Process	0%	55%	5%

As previously mentioned, Building Information Modeling is used on larger, more complicated projects. The Simonian report confirms this fact. Table 2.08 shows the percentage of projects on which electrical contractors use BIM, broken down by project type. Building Information Modeling is used on ninety percent of industrial, biotechnology, and semiconductor projects but is only used on 25 percent of educational projects (schools) and thirty percent of hotels. These smaller percentages correlate with the fact that less complicated electrical systems are used in these building, whereas complicated electrical systems are used in industrial and biotechnology buildings, hospitals, and on semiconductor projects.

Table 2.08 – BIM Projects by Project Type (Simonian, 2009)

Project Type	Percent of Use
Industrial	90%
Biotechnology	90%
Semiconductor	90%
Hospital	80%
Medical Office	50%
Commercial	50%
Institutional	40%
Hotel	30%
Education	25%

For electrical contractors, power and lighting are the most common systems that require modeling. These systems contain large components and multiple conduit runs that must be coordinated with other trades as well as the built structure. Smaller systems like security, fire alarm, and low voltage systems are often not modeled. The specific sizes of wiring and conduit within a system can be a factor determining whether components are modeled. The Simonian report found that 55 percent of six-inch conduit gets modeled compared to 25 percent of one-inch conduit. Electrical contractors try to be as efficient as possible with their time and modeling. Modeling large components while leaving out the small ones allows for the majority of the work to be coordinated prior to construction.

According to electrical contractors, clash detection is the most valuable Building Information Modeling feature. Prior to construction, electrical contractors, as well as mechanical, plumbing, and sometimes general contractors, model their work and combine models to determine where problems exist. This allows clashes to be resolved prior to construction and helps to avoid costly rework. Other valuable BIM features, according to electrical contractors, include the capability to visualize electrical design and utilize space. The least valuable BIM features are design validation and energy analysis/management. The low rating for these specific BIM tools is likely a result of the features geared more for designers than builders.

Specific Building Information Modeling software can be grouped into two categories. The first is design software allowing users to start with an empty space and build a model to include the walls, structure, and systems of a building. Often electrical contractors receive two-dimensional plans and use BIM design software to layout a building's electrical system. According to the

Simonian report, the most popular BIM design software package for electrical contractors is Autodesk Revit MEP. The second type of design software is typically used following initial design. The mechanical and plumbing contractors combine models with the electrical contractor using clash detection software. This software package combines all models into one and determines where problems exist, giving contractors the ability to coordinate their work. The most popular BIM clash detection software packages for electrical contractors are Autodesk Navisworks, Bentley, and Solidworks.

Many factors prevent electrical contractors from implementing Building Information Modeling. The largest factor, according to the Azhar/Cochran report, is that the companies do not know that BIM exists. This mostly pertains to smaller electrical contracting companies. Among medium to large electrical contracting companies, a lack of expertise, non-compatible software, and the overall expense limit the implementation of BIM. As noted in the report, these factors can be overcome. Twenty-five percent of respondents not currently using BIM had plans to start implementing BIM practices within their company.

2.4.3 Building Information Modeling Value and Costs

Electrical contractors have reported a large improvement in quality from implementing Building Information Modeling on projects. Quality improvement can be seen through the reduction of rework and prefabrication. BIM allows electrical contractors to fabricate large pieces of equipment offsite and place the final product in place with confidence. In the past, equipment was fabricated onsite and workers resolved problems while building components. With BIM, problems can be resolved prior to construction.

A major time savings from the use of BIM has also been reported by electrical contractors. According to the Simonian report, electrical contractors report an average overall project time savings of three percent. This number is perceived and not actually quantified. More upfront design and drafting work takes place prior to construction starting. However, once construction begins, time savings can be identified through less fabrication, installation, and rework time. Additionally, field crews spend less time coordinating work in the field since it was already completed through modeling the project.

The quality and time improvements resulting from BIM's use creates an overall cost savings for the electrical contractor and potentially the overall project. As was the case with time improvements, cost improvements are also hard to quantify. Cost improvements are usually an estimate based on the perception of the electrical contractor. As mentioned earlier in this chapter, cost improvements are based on a return on investment. Electrical contractors estimate the money spent up front on implementing BIM and then attempt to figure out how much money was saved by implementing it. This can range greatly, as was found in the Simonian study were reported cost savings from BIM ranged from zero percent to fifteen percent, with the average at two percent. In order to determine the actual cost benefit from using BIM, a more in-depth study would need to be performed using specific studies instead of a general survey.

2.4.4 Recommendations to the Electrical Contracting Industry

The previously mentioned research reports offered some suggestions and recommendations for use of BIM in both the electrical contracting industry and also the construction industry as a whole. The biggest recommendation to companies is that Building Information Modeling is more

than computer software; BIM is a process. Procedures must be created for using BIM internally, and companies must determine the steps to use BIM successfully during a project. Procedures must also be established for a company to best interact with other companies on a project. This includes, but is not limited to, determining who will be the BIM leader on a project, how information will be shared, and how clashes will be handled. The overall goal of BIM is for the project successful, and therefore all companies involved being profitable. Proper procedures in place for the use of Building Information Modeling will allow for this.

The electrical construction industry as a whole also needs to help facilitate improvements with Building Information Modeling. Industry groups, such as NECA and ELECTRI-International can provide companies with industry standards and training. Standards would allow companies to cut out waste and make the BIM process more efficient. Specific standards were not mentioned in any of the reports reviewed in this chapter, but each strongly encouraged the conversation. Industry groups could also provide training. As shown throughout this chapter, company employees do not come to appreciate BIM until they are comfortable with the software and the process. Industry groups could help companies transition from two-dimensional Computer Aided Design to Building Information Modeling and keep companies updated with potential BIM improvements.

2.4.5 Conclusion

The Azhar/Cochran report and the Simonian report provided this research report with some insight into use and value of BIM. The reports show that the overall use of BIM is limited and that the industry is struggling to adopt the new technology and process. Overall, the reports on

the use of BIM in electrical construction specifically were not as detailed as the McGraw Hill SmartMarket Report, and few correlations were found between the data presented. Performance indicators, associated risks, and planned future use were not well covered in the Azhar/Cochran or Simonian surveys, leaving room for more research to be conducted. A better understanding of Building Information Modeling's use in the electrical contracting industry will allow the industry to find a path forward for implementing BIM.

2.5 CONCLUSION

This literary review was completed in order to understand the history, present use, and predicted future plans for Building Information Modeling in the construction industry and, more specifically, the electrical contracting industry. The use of BIM in the construction industry is fairly well documented while the use of BIM in the electrical contracting industry is largely unknown to a certain extent. As previously mentioned, the goal of this research is to broaden the understanding of the use of BIM in the electrical contracting industry. Electrical contractors can then use this information to plan for future use of BIM.

The information obtained from this literary review will be used to create the survey sent to electrical contractors. Additionally, information presented in this literary review will be compared to data collected through surveys for this report. In Chapters 4 and 5, data will be compared to show the similarities and differences between the use of BIM in the electrical contracting industry and its use in the design and construction industry. Additionally, changes within the electrical contracting industry from previous reports to this report will be documented.

CHAPTER 3

BUILDING INFORMATION MODELING SURVEY

3.1 INTRODUCTION

Most construction contractors understand that there is a correlation between the use of Building Information Modeling and improved productivity during a project. The improvement is a result of better planning and improved project delivery. Examples of this include, but are not limited to, clash detection, quantity take-offs, and the shop drawing process. Additionally, improvements result from reducing the amount of change and delays that occur during construction. Change comes in the form of change orders, field conflicts, punch list items, etc. Delays can come from Requests For Information (RFIs), re-submittals, longer processing time, etc.

To better understand the perception electrical contractors have of Building Information Modeling, a survey was conducted. The data collected from the survey was then analyzed to identify correlations and trends. The survey for this research project was inspired by a previous survey distributed by McGraw Hill Construction to contractors in the mechanical contracting industry. Additionally, multiple advisors reviewed the survey for this research project to yield the best possible product. The survey had the following goals:

- To determine what modeling equipment and software electrical contractors are currently using;
- To gain insight into the resources electrical contractors use to implement Building Information Modeling on projects;
- To obtain data from electrical contractors on the current use and predicted future use of Building Information Modeling; and

- To identify outcomes from the use of Building Information Modeling through performance indicators.

This chapter reviews the methods used to develop and distribute the survey to the electrical contracting industry to obtain information on its use of Building Information Modeling. Additionally, a company profile will be presented to depict the characteristics of the companies that completed the survey that serve as the representative sample for the population.

3.2 METHODOLOGY

This research project was inspired by previous research conducted by McGraw Hill Construction in 2009 (McGraw Hill Construction, 2009). The McGraw Hill survey focused on the use of Building Information Modeling in the mechanical building systems industry. For a week at the end of May 2009, a web-based survey was distributed to engineers, architects, owners, contractors, manufacturers, and other industry representatives. In total, 2,228 professionals responded to the survey released by McGraw Hill. The survey created for this research project was original and specific to the electrical contracting industry. The survey included multiple questions that concentrated on the relationship between the use of Building Information Modeling and outcomes based on performance indicators. Additionally, survey questions were posed to obtain data on how often and what resources electrical contractors need to use Building Information Modeling.

The University of Wisconsin-Madison Survey Center reviewed a draft of the survey (Dykema, 2011) to improve questions, ensure the survey's effectiveness, and clarify questions for ease of those surveyed. For example, the first draft of the survey asked: "Currently, BIM isn't creating

value equality throughout the project lifecycle. For each phase of the project, please indicate the level of value being generated.” After the Survey Center’s review, this question read: “For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle.”

Additionally, values for the responses listed in the matrix tables were changed. The values listed in the first draft of the survey were “none,” “low,” “medium,” “high,” “very high,” and “don’t know.” The Survey Center considered these values weak and changed them to “none,” “a little,” “some,” “quite a bit,” and “a great deal.” According to the Survey Center, research has shown that those surveyed closely relate these values to a ranking system such as one, two, three, four, and five.

Following the collaboration with the Survey Center and additional reviews from professors in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison, the survey was generated online using Qualtrics. This web-based survey service is free to all students at the university. Qualtrics provides the survey with structure and efficiently reports the data collected from the survey. The survey consisted of 24 questions broken up into three sections: “Current Use,” “Future Use,” and “Company Background.” A replication of this survey can be found in Appendix B.

The survey was distributed to a wide variety of companies from the National Electrical Contractors Association (NECA), Foundation for Electrical Construction Inc. (ELECTRI International) council members, and Federated Electrical Contractors (FEC). In total, roughly

800 individuals received an email between January 31, 2011, and February 4, 2011. A copy of the cover letter sent in the email can be found in Appendix B. The survey was closed on March 15, 2011, with a total of seventy responses.

Following an analysis of the data collected, interviews were conducted with professionals in both the construction and electrical contracting industry to gain better insight into the responses and use of Building Information Modeling. Interviews were conducted with one architecture firm, one engineering firm, two general contractors, and four electrical contractors. The information gathered from these interviews will be mentioned throughout Chapters 4, 5, and 6. The firms are listed below and referenced in the bibliography Appendix A. Specific interview questions can be found in Appendix D.

- Affiliated Engineers, Inc. (Engineer – Madison, WI)
- The Boldt Company, Inc. (General Contractor - Appleton, WI);
- Faith Technologies, Inc. (Electrical Contractor - Menasha, WI);
- M. A. Mortenson Company, Inc. (General Contractor - Minneapolis, MN);
- Mona Electric Group, Inc. (Electrical Contractor - Clinton, MD);
- Pieper Electric, Inc. (Electrical Contractor - Milwaukee, WI);
- Westphal and Company, Inc. (Electrical Contractor - Madison, WI); and
- Zimmerman Architectural Studios, Inc. (Architect - Milwaukee, WI).

3.3 CHARACTERISTICS OF ELECTRICAL CONTRACTORS

When the survey closed, a total of seventy companies had responded to the survey, an 8.75% response rate and a true sample for the population. All responses provided usable data for this research project. Two sections of the compiled questionnaire responses showed occasional incompleteness. The first was the section asking companies to provide the area of the United States the company is headquartered. Three of the seventy respondents left the answer blank. This is reviewed in section 3.3.1 of this report. The other incomplete section was on revenue reported in 2010, which was optional. Three out of the seventy respondents chose to skip this question. This is reviewed in section 3.3.3 of this report.

The survey also asked respondents to list the number of projects on which their company had used BIM in 2010, as well as the total number of projects the company was involved with in 2010. The intention was to use these two numbers to determine the percentage of projects on which a company used BIM in 2010. Unfortunately, the data received from this question could not be used due to the inconsistency of the responses. Some respondents listed the number of large projects the company worked on in 2010, while others listed all of their projects which meant the total number of projects ranged from one to 1,000. For future research, the percentage of projects on which a company uses BIM should be asked in one question using percentage ranges for the response options.

3.3.1 Location of Respondents

Electrical construction contractors were asked two separate questions regarding the location of their operations. The first question asked the respondent to list the state in which their corporate headquarters is located. This question was optional to allow companies confidentiality if they

chose. The second question asked respondents to provide the areas of the United States in which their company is currently working. Five options were provided for this answer and respondents were allowed to select more than one area. The purpose of these questions was to determine if the sample of responses fairly represented the entire nation.

Figure 3.01 shows the state in which the corporate office of each respondent is located. The survey received responses from 21 states in the United States. Responses were also received from companies headquartered in Mexico, Canada, and Puerto Rico. Three of the respondents also left this question blank. Table 3.01 shows the areas in the United States where each electrical contracting company performs its work. Of the seventy companies that responded to the survey, 44 percent work in the Midwest, 43 percent in the West, 24 percent in the Northeast, 24 percent in the Southwest, and 23 percent in the Southeast. As seen from this data, the Midwest and Western United States are well-represented. The Southwest, Southeast, and Northeast were all slightly underrepresented.

Figure 3.01: Number of Electrical Contractors’ Corporate Headquarters from each State

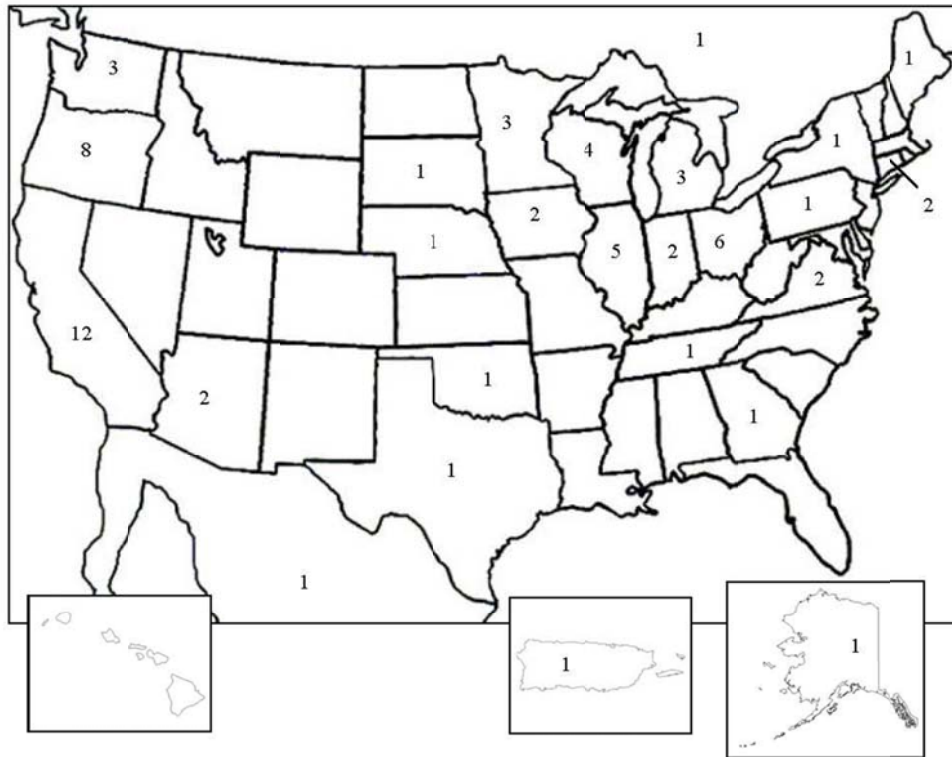


Table 3.01: Area of Work in the United States

#	Answer	Responses	Percentage
1	Midwest	31	44%
2	West	30	43%
3	Northeast	17	24%
3	Southwest	17	24%
5	Southeast	16	23%

3.3.2 Type of Electrical Construction Performed by the Respondents

Electrical construction contractors were asked a question about the type of construction in which their company typically works. Six options were provided as answers, and respondents could select more than one area. The last option was “other” and allowed respondents to specify the work they perform. The purpose of this question was to determine if the sample fairly

represented all areas of work and to determine if there is a correlation between the type of work performed and the use of Building Information Modeling.

Table 3.02 shows the type of construction in which each of the responding companies is involved. Commercial and industrial construction was tied with 63 of the seventy respondents, or 90 percent, stating their involvement in this type of construction. Additionally, of the companies responding to the survey, 84 percent perform work in institutional construction, 54 percent in remodeling and renovations, 26 percent in residential (including high rises), and 15 percent in the “other” category. Examples of “other” responses are listed below:

- Highway/street electrical (3);
- Medical (2);
- Utility (2);
- Airports/transportation centers;
- Communication wiring only
- Data centers;
- Energy efficiency;
- Gaming;
- Government;
- Line construction; and
- Water/wastewater.

Table 3.02: Type of Electrical Construction

#	Answer	Responses	Percentage
1	Commercial	63	90%
1	Industrial	63	90%
3	Institutional	59	84%
4	Remodeling and renovations	38	54%
5	Residential - including high rises	18	26%
6	Other	15	21%

Overall, the responses to this question are a good representation of the construction industry. A 2002 study by Joseph Sargent titled *Effects of Absenteeism and Turnover on Labor Productivity for Electrical Contractors* received similar responses to questions on the type of construction in which companies were involved. Additionally, the top three types of construction listed for this study are typically the types of projects that are candidates for use of Building Information Modeling. Commercial, industrial, and institutional construction projects are larger in scale and more complicated. Prior to our research project's survey's completion, a correlation was predicted between the overall use of BIM and the projects completed by companies. For example, a common idea exists that companies involved in complicated hospital, institutional, and industrial projects more frequently use BIM. This, however, was not found in the survey results. No correlation existed between the type of work performed by electrical subcontractors and any other data presented in this report.

3.3.3 Size of Companies as Reported by the Respondents

The survey asked electrical construction contractors about their billings in 2010, and provided five answers to the question and respondents were allowed to select one answer. This question was optional to allow companies confidentiality if they so choose. The purpose of this question was to determine if the sample fairly represented all sizes of companies and to determine if there is a correlation between the annual billings and the use of Building Information Modeling.

Another test of company size is to determine the total number of projects a company was involved with in 2010. This information was also asked in the survey. Additionally, companies were asked to provide the number of projects on which the company used BIM in 2010. As previously mentioned, the number of projects on which companies used BIM in 2010 and the

total number of projects the company was involved with in 2010 had to be eliminated from this report. The responses received in the survey were inconsistent, and no useful information could be drawn from the data.

Table 3.03 shows the range of billings in 2010 as reported by the electrical contractors responding to the survey. The survey received responses from a good range of different-sized electrical contracting companies performing work in the United States. Three of the respondents left this question blank. Of the seventy companies responding to the survey, 44 percent listed between \$10 million and \$50 million worth of work, and 34 percent cited more than \$50 million worth of work in 2010. Seventeen percent of respondents had less than \$10 million in billings in 2010, and only one company reported having less than \$1 million in billings a somewhat poor representation of the electrical contracting industry since a majority of the firms that make up the industry are small companies. However, most of the work throughout the United States, in terms of total dollars spent, is completed by large firms.

Table 3.03: Electrical Contractor Billings in 2010

#	Answer	Responses	Percentage
1	Under \$1 million	1	1%
2	\$1 million to under \$5 million	6	9%
3	\$5 million to under \$10 million	5	7%
4	\$10 million to under \$50 million	31	44%
5	More than \$50 million	24	34%
6	Response Not Provided	3	4%
	TOTAL	70	100%

The responses to this question reveal that the survey for this research project represents medium-to-large electrical contractors in the industry. Unfortunately, this report will not accurately represent the use of Building Information Modeling throughout the entire electrical contracting industry. However, valuable data on the use of BIM used by medium and large electrical contractors will be presented in this report. Correlations between 2010 revenue and other survey questions were found through statistical analysis. These correlations will not be presented in this chapter but will be presented as further surveyed data is presented in Chapters 4 and 5.

3.4 CONCLUSION

Chapter 3 has provided a company profile for survey respondents that will be further analyzed in the remainder of this report. Most of the geographical United States is represented in the data. Additionally, a significant variety of work performed by electrical construction companies is represented. For the most part, medium-to-large companies are represented in the data for this project.

Chapter 4 of this report will focus on the current use of Building Information Modeling in the electrical contracting industry and will discuss correlations found between the data collected through the survey. Chapter 5 will focus on the future use of Building Information Modeling and will present trends that exist in the industry.

CHAPTER 4 CURRENT USE OF BUILDING INFORMATION MODELING

4.1 INTRODUCTION

The main purpose of the survey reviewed in Chapter 3 was to determine the use and impact of Building Information Modeling in the electrical contracting industry. As mentioned previously, most of the survey data collected from respondents is based on perceptions. This, however, does not change the accuracy of the data, but does not provide much quantitative data. Correlations will be made between all responses from the survey in order to find relationships between the data collected from the survey.

Chapter 4 will review responses to the survey—specifically on electrical contractors’ current use of BIM. This chapter is broken up into three large sections. The section on characteristics of current use reviews the involvement, investment, expertise, and experience of electrical contractors who use BIM. The project implementation section reviews how electrical contractors apply BIM to projects, specifically related to project size; leadership and staffing; software; and tools, cost, and risk. The outcome sections review the impact BIM has during specific project phases, within project activities, and how performance has improved through its use.

4.2 CHARACTERISTICS OF CURRENT USE

To gain an understanding of the use of Building Information Modeling in the electrical contracting industry, survey respondents were asked five separate questions. The characteristics of BIM use are reviewed through electrical contractor involvement, investment, expertise, and

experience. As seen in this section of Chapter 3, a majority of contractors are currently using BIM. However, as a whole, the electrical contracting industry lags behind other groups in the industry.

4.2.1 Involvement

Electrical contractors were asked two separate questions about their involvement with Building Information Modeling. The first question asked respondents to characterize their company's involvement with BIM. Respondents chose from four responses, ranging from not involved to using and creating BIM tools within the company. Setting this as the first question in the survey allowed for the separation of BIM user's data from non-users' data. If a respondent answered that their company was not involved with BIM projects, the respondent skipped questions about their current involvement and was directed to questions about the company's future with BIM. The second question asked electrical contractors how many years their company has been involved with BIM. Combined, these two questions depict electrical contractors' participation with BIM in the construction industry. Additionally, their responses can be compared to the responses of other questions to determine relationships between BIM involvement and improvement in performance indicators, such as a reduction in requests for information (RFIs).

As reviewed in Chapter 3, seventy electrical contractors responded to the survey. Table 4.01 presents the electrical contractors' level of involvement with Building Information Modeling. Thirty percent of the respondents reported not using BIM within their company, leading to the conclusion that seventy percent of the electrical contracting industry is using BIM information in some way. As seen in Table 4.01, seven percent of respondents are only creating BIM tools

within their company and not using programs available to the industry, such as Autodesk Revit. On the other hand, 26 percent of respondents are only using existing BIM tools and are not at the point of creating their own tools for internal use. Examples of these internal tools include, but are not limited to, cost data bases, internal BIM procedures, and modeling objects for use within a BIM program. Lastly, the largest group of respondents—37 percent—reported that they currently use existing tools as well as internally created BIM tools.

Table 4.01: Electrical Contractor’s Stated Level of Involvement with BIM

#	Answer	Responses	Percentage
1	We are creating BIM tools and using existing tools within our company	26	37%
2	We are not using BIM within our company	21	30%
3	We are using existing BIM tools but are not creating our own tools within our company	18	26%
4	We are creating BIM tools to use within our company	5	7%
	TOTAL	70	100%

As reviewed in Chapter 2, the Azhar/Cochran report found that in 2009 twenty percent of the medium-to-large electrical contracting companies used Building Information Modeling. The survey conducted for this research also represents medium-to-large electrical contractors as demonstrated in Chapter 3. From the data gathered and depicted in Table 4.01, the use of BIM within medium-to-large companies has increased two-and-a-half fold. This increase is likely the result of market demands. On many projects, owners, architects, and construction managers expect the mechanical, electrical, and plumbing contractors to coordinate their work using BIM. If an electrical contracting company decides not to respond to this challenge, they will likely lose the work. No correlation could be found between companies that use BIM and the company profiles present in Chapter 3.

Electrical contractors were also asked to provide the number of years their company has been using Building Information Modeling. Contractors chose from an incremental list that ranged from one year to more than five years. The data gathered from this question was intended to show when the majority of electrical contractors began using BIM. This data could then be compared to experience levels in other trades.

Table 4.02 displays electrical contractor's length of use of Building Information Modeling. Three-year involvement was the highest response, meaning that in 2008 BIM use in the electrical contracting industry greatly increased. The McGraw Hill report that reviewed in section three of Chapter 2 of this report expected a rapid increase of BIM use between 2008 and 2009. As mentioned previously, this is most likely a response to market demands. In recent years, the rate of BIM use has slowed, as expected since a majority of medium-to-large electrical contracting companies already use BIM.

Table 4.02: Electrical Contractor's Duration of BIM Involvement

#	Answer	Responses	Percentage
1	1 year	4	8%
2	2 years	8	16%
3	3 years	17	35%
4	4 years	7	14%
5	5 years	5	10%
6	More than 5 years	8	16%
	TOTAL	49	100%

No correlation could be determined between the duration of experience and any other data presented in this report. However, some correlation was identified within specific sets of data. All of the companies that reported involvement with BIM for five years or more also reported billings of \$10 million or more in 2010. Additionally, all of these respondents, except one,

reported using existing BIM tools as well as tools created internally. As seen in the total, the 21 respondents who did not report using BIM were not asked to answer this question. These respondents will remain excluded from the analysis of data for the remainder of this chapter.

Throughout the interviews conducted after the survey, many respondents commented on the relationship they see between their company's use of Building Information Modeling and the commitment of the company's leadership to BIM. Without a true commitment to BIM, a company may struggle to see BIM's full potential. The leadership team within a company must fully commit to using BIM and create steps for its implementation in order to make an impact on projects that can benefit from BIM's use. Additionally, many interviewees said they believe the electrical contracting industry is making large strides with its involvement in BIM. The mechanical contracting industry has long been ahead of the electrical contracting industry with its application of BIM. However, that gap is starting to close.

4.2.2 Investment

In the survey, electrical contractors were asked to rate their current level of Building Information Modeling investment in six specific categories:

- (1) Purchasing software,
- (2) Creating BIM procedures within the company,
- (3) Creating BIM libraries,
- (4) Creating BIM procedures with other companies,
- (5) Training staff with BIM, and

(6) Marketing BIM capability to potential customers.

Respondents were asked to rate their current investment on a scale from none to a great deal. Responses to this question reveal the current overall investment in BIM throughout the electrical contracting industry, and this section of the report analyzes the responses. This survey also asked respondents to estimate their predicted level of BIM investment in the next two years. Chapter 5 will review those responses and compare current investments to future investments.

As seen in Table 4.03, a percentage is matched to each rating (none to a great deal) adding up to 100 percent. Each rating factor was assigned a number: one to five. The mean scale represents the average of all the responses received for the category. These statistics are comparable to return on investment information presented in the literary review in Chapter 2. Electrical contractors are making investments in areas they believe will create the largest return for their company. Table 4.03 does not contain quantitative data on the investment value or the ROI. Instead, the table shows the areas of investment in which electrical contractors are concentrating.

With a mean scale rating of 3.55, the largest Building Information Modeling investment electrical contractors are currently making is in the area of marketing BIM capabilities to potential customers. During proposal and bidding interviews, many architects, engineers, and construction managers display their BIM skills by showing renderings or examples of complex building systems that were modeled and installed on other projects. Many times, this can be enough to win over a selection committee for a company to receive work. Electrical contractors are doing the same; during interviews, electrical contracting companies have the opportunity to display their BIM competencies, which, in turn, increases their chance of winning work.

Table 4.03: Electrical Contractor’s Current Level of Investment in BIM

#	Category	None	A Little	Some	Quite A Bit	A Great Deal	MEAN SCALE
1	Purchasing software	20%	8%	29%	33%	10%	3.04
2	Creating BIM procedures within the company	12%	18%	37%	20%	12%	3.02
3	Creating BIM libraries	16%	20%	27%	24%	12%	2.96
4	Creating BIM procedures with other companies	29%	24%	29%	16%	2%	2.39
5	Training staff with BIM	10%	20%	27%	27%	16%	3.18
6	Marketing BIM capability to potential customers	12%	12%	14%	31%	31%	3.55

Other large investments electrical contractors are making include purchasing BIM software, training staff, and producing internal libraries and BIM procedures. The respected mean scale ratings are 3.04, 3.18, 2.96, and 3.02. These four areas received a sixty percent or greater response of some investment or higher. Lastly, the lowest area of BIM investment by electrical contractors is in the area of creating BIM procedures in conjunction with other companies. As shown in Table 4.03, the mean scale rating is 2.39. A majority of respondents, or 53 percent, stated that they are investing “none” to “a little” in this area. The probable reason for this is that contractors want to make BIM investments internally before they concentrate on external investments. Additionally, based on the research presented in the review of literature in Chapter 2, the electrical contractor is rarely the team member leading the BIM coordination effort. Within a project, the architect, general contractor, construction manager, or even mechanical contractor often leads the BIM effort and creates procedures. In this area, electrical contracting industry groups have great potential to make improvements.

From survey data, a moderate correlation was discovered between electrical contractors' levels of BIM expertise and the level of investment respondents are currently making in marketing BIM capabilities to potential customers. This data will be further presented in Table 4.04. The correlation coefficient for this relationship is 0.682, demonstrating that as electrical contractors develop their knowledge and use of BIM, they feel more confident in their ability to showcase their talents to potential customers. Moderate correlations can also be found between the investment categories shown in Table 4.03. Respondents with a higher investment in a certain area typically have a higher investment in all other areas. On the other hand, contractors with a lower investment in a certain category usually have lower investments across all areas. Correlation coefficients for the responses to questions in this section ranged from 0.628 to 0.762.

For example, four of the five contractors investing a great deal into purchasing software are also investing a great deal in creating internal BIM procedures and libraries. Conversely, four of the five contracting companies not investing in staff training and creating libraries are also not investing in software and customer marketing. These trends show that as companies make investments in BIM, they make investments across the board to improve their use of BIM and will do so proportionally to their other BIM investments.

4.2.3 Expertise

To gain a grasp of an electrical contractor's expertise with BIM, respondents were asked to rate their level of proficiency with Building Information Modeling. The survey offered four levels ranging from "just started" to "advanced." As found in the McGraw Hill Construction SmarkMarket from 2008, a strong correlation appeared between a contractor's level of expertise

and their company outcomes from using BIM. Additionally, as shown in the Azhar/Cochran report, a lack of expertise or understanding of BIM can hinder electrical contractors from making further investments in BIM. This section of the report will show the survey respondents' levels of expertise and how those levels correlate with project outcomes when using BIM.

Responses to the survey demonstrate that a majority of electrical contractors, or 61 percent, believe their company to be at an "advanced level" of BIM use. Table 4.04 shows all responses to the question. The next highest response, at 24 percent, was "started but not efficient." Combining this data reveals that 85 percent of electrical contractors see themselves past the level of "just starting" with BIM but have not gotten to the point that they have maxed out their BIM potential. The responses shown in Table 4.04 are similar to the responses received through this report's interviews with individuals in the design and construction industry. Many companies consider themselves advanced in their understanding of BIM. However, they also understand that they have room for improvement.

Table 4.04: Electrical Contractor's Stated Level of Expertise with BIM

#	Answer	Responses	Percentage
1	Advanced	30	61%
2	Started but not efficient	12	24%
3	Expert	4	8%
4	Just started	3	7%
	TOTAL	49	100%

Responses to this question are based on the company's perceived level of expertise with Building Information Modeling. There is no industry standard for levels of expertise, nor should there be. When a company says that they are at an advanced level, they believe they have room to grow and knowledge to gain. No strong correlation could be found between the level of expertise and

the number of years a company has used BIM. For example, of the four respondents reporting an “expert” level of BIM knowledge, three companies had been using BIM for four or more years and one company had been using BIM for two years. No other correlations were found between the level of expertise and the data presented thus far in this report. Later in this chapter, correlations will be drawn between the level of expertise and outcomes from using BIM on a project.

4.2.4 Experience

The survey also questioned electrical contractor’s overall experience of using BIM. Respondents were given four response choices to rate their experience, ranging from “getting no meaningful value from BIM” to the company “maximizing their BIM capabilities.” Between the extremes were answers stating that electrical contractors had “just started using BIM” or had been “using BIM for a while,” and both selections recognized room for growth.

A majority of electrical contractors, or 78 percent, responded by saying that they are getting value from BIM but do not recognize room for growth. Another fourteen percent said they are just starting to use BIM but understand its potential. Only four out of 49 respondents said they had either maximized their BIM potential or were not getting any value out of BIM. Table 4.05 shows these results.

Table 4.05: Electrical Contractor's Stated Level of Experience with BIM Business Value

#	Answer	Responses	Percentage
1	We are getting value from BIM but believe there is more to learn	38	78%
2	We are just starting to understand how much value BIM can provide us	7	14%
3	We are getting no meaningful value from BIM	3	6%
4	We have maximized BIM potential within our company	1	2%
	TOTAL	49	100%

No correlation could be made with any of the data previously presented in this chapter. However, similar patterns can be determined from the respondent's perception of expertise and experience. Most electrical contractors believe that their companies have room for growth within BIM. Companies can learn more and take greater advantage of BIM's potential in order to increase value to their company. As shown in Section 2.2.2 of this report on BIM investment, electrical contractors have room to invest and grow within many aspects of BIM. The remainder of this chapter will name possible areas for BIM improvement during a project to improve outcomes.

4.3 PROJECT IMPLEMENTATION

This section of Chapter 4 reviews the implementation of Building Information Modeling by electrical contractors in the construction industry. Seven questions were asked to survey respondents to gain an understanding of how electrical contractors apply BIM to projects, specifically inquiring about project size, leadership and staffing, software and tools, cost, and risk. Responses depict that, generally, electrical contractor's implementation methods and BIM processes during construction are similar to other industry groups' implementation methods and BIM processes.

4.3.1 Project Size

The survey asked electrical contractors to select the typical project size, based on man-hours, on which they used Building Information Modeling. Respondents were provided with four response choices, with the largest being projects with “more than 100,000 man-hours” and the smallest being “less than 10,000 man-hours.” Larger projects that require more man-hours are typically more complicated and require greater coordination. Large hospitals, for example, have extremely complicated electrical systems that can require more than 100,000 man-hours to fabricate and install. These systems require a tremendous amount of coordination to be constructed properly and to avoid clashes with other systems. On the other hand, smaller residential buildings typically do not require any coordination. Responses to this question will help determine a benchmark for the size of projects that can benefit from the use BIM.

The most common response from electrical contractors about the typical size of projects using BIM was the “10,000 man-hours to 50,000 man-hours” range at 59 percent. The second largest at twenty percent was the “50,000 man-hours to 100,000 man-hours” range. The lowest two responses were “less than 10,000 man-hours” and “more than 100,000 man-hours,” each receiving ten percent. Table 4.06 displays the results including actual response totals.

Table 4.06: Typical Project Size for Electrical Contractor’s Using BIM

#	Answer	Responses	Percentage
1	Less than 10,000 man-hours	5	10%
2	10,000 to 50,000 man-hours	29	59%
3	50,000 to 100,000 man-hours	10	20%
4	More than 100,000 man-hours	5	10%
	TOTAL	49	100%

Only five percent of respondents stated that they typically use BIM on projects with less than 10,000 man-hours, which shows that contractors working on smaller projects typically do not use BIM to model electrical systems. Of the five respondents selecting “100,000 man-hours or more,” four had billings between \$10 million and \$50 million, and one had billings of more than \$50 million. Knowing this, a correlation between the typical project size for an electrical contracting company using BIM and the overall company size is expected. As companies become larger, they tend to take on larger projects. However, no correlation could be found. Of the companies that reported using BIM for projects under 10,000 man-hours, all had reported billings of more than \$10 million. No additional correlation could be found between the results reviewed in this section and any other responses received from the survey.

Many interview respondents noted that project size is not the only contributing factor in the decision to use Building Information Modeling on a project. Owners or construction managers often dictate the use of BIM on a project for electrical contractors. As stated by interviewees, a company considers many factors when making the decision whether or not to use BIM on a project. It considers project size, contractual obligations, the complexity of coordination, and the information provided by the design team, to name a few.

4.3.2 Leadership and Staffing

The survey asked respondents two questions to understand how project teams and companies manage the implementation of Building Information Modeling on projects. The first question asked a respondent to select which project team member typically leads the BIM electrical modeling coordination. Response options provided for the question included outside consultants,

project architects, general contractor, mechanical/electrical design consultants, and MEP specialty trades. The choice of “Other” was also listed to give respondents space to list a different project team member.

Mechanical, electrical, and plumbing (MEP) specialty trades received the highest response with 41 percent of respondents marking that this group leads the Building Information Modeling process on a typical project. The second largest response was for a project’s General Contractors with 35 percent. As seen in Table 4.07, a project’s architects, engineers, and consultants lead the modeling coordination on 22 percent of projects. Outside consultants, or team members that do not hold a direct contract with the project, were not chosen by any of the respondents. One respondent chose “Other,” naming the electrical contractor as the typical leader of BIM coordination. This response could also be grouped with the MEP specialty trades.

Table 4.07: Project Team Member that Typically Leads Electrical Modeling Process

#	Answer	Responses	Percentage
1	Outside Consultants	0	0%
2	Project Architects	4	8%
3	General Contractor	17	35%
4	Mechanical/Electrical Design Consultants	7	14%
5	MEP Specialty Trades	21	41%
6	Others (Please Specify)	1	2%
	TOTAL	49	100%

Responses to the question about who typically leads the electrical modeling process on a project demonstrate that team members directly involved in construction are always the ones leading the effort. Project contractors benefit the most from modeling mechanical, electrical, and plumbing

systems in a building. Modeling a building's systems allows for better coordination, with an end goal of eliminating clashes and rework. Contractors can then benefit financially from modeling the building. On the other hand, project design team members do not benefit much from modeling the systems for construction.

A relationship does exist between those who benefit from using Building Information Modeling and the team members leading the effort, one reason why mechanical contractors typically lead the effort. Their system is the largest of all the trades, and they want to make sure there is enough space for their system. For example, if a contractor has a large, complicated system to install and knows it could conflict with other building systems, they will want to lead a modeling effort in order to save money and prevent installation difficulties. Questions related to the correlation between project leadership versus benefits, however, were not directly asked of respondents and this relationship could more closely be considered in future research. No other strong, or even moderate, correlation could be found amongst the responses to the question of project leadership nor any of the other data presented in this report.

Many of the electrical contractors interviewed for this report stated that the process for selecting who leads a BIM effort could be improved. Electrical contractors have observed that many general contractors and construction managers still have not developed a full understanding of the process for implementing BIM on a project. The individual leading the BIM effort is often a BIM coordinator, not a project manager who would have a greater understanding of the project. Additionally, the project schedule is often not implemented into the BIM model to gain an understanding of sequencing. As noted by many interviewees, Building Information Modeling is

not just software that helps with coordination of trades. Rather, BIM facilitates a discussion on how the project will be built. Section 4.2.2 of this report showed that electrical contracting companies are not making investments to create BIM procedures with other companies. Industry groups must lead the charge to implement changes so that BIM coordination can run more smoothly on projects.

The second question asked respondents to select the number of Building Information Modeling staff members who typically work on a project to model electrical systems. Respondents could choose from four responses: “one staff member,” “two to three staff members,” “four to five staff members,” and “more than five staff members.” The objective of this question was to discover the reason for using a certain number of staff members on a project for BIM purposes. A correlation between the number of staff member and the project and/or the company size was expected.

As seen in Table 4.08, one modeling staff member per project is the most typical for electrical contractors on project. This is according to 23 of the 49 respondents. However, using two to three BIM staff members is not out of the ordinary. Forty-three percent of respondents stated that they typically use this many modeling staff members on a project. A few electrical contractors, ten percent, stated that they use four to five BIM staff members on projects, and none of the respondents stated that they use more than five modeling staff members.

Table 4.08: Typical Number of BIM Staff Members on a Project for Electrical Contractors

#	Answer	Responses	Percentage
1	1	23	47%
2	2 to 3	21	43%
3	4 to 5	5	10%
4	More than 5	0	0%
	Total	49	100%

As stated previously, a correlation between the project size and the number of electrical contractor staff members on a project for Building Information Modeling purposes was expected. As a project becomes larger and more complicated, more modeling needs to be completed to coordinate the installation of the system and to find potential clashes. To complete a larger modeling process, a larger staff is needed. Similarly to the project leadership question, the relationship between project size versus staff was not specifically asked so a quantitative correlation is not available.

Additionally, a possible correlation between the number of modeling staff members and company size was anticipated, but could not be found. Of the five respondents who reported using four to five modeling staff members on a project, two reported billings in 2010 of \$10 million to \$50 million, two reported 2010 billings of more than \$50 million, and one respondent chose not to respond to the question. Conversely, of the 23 respondents who answered that they use one staff member on a project, one reported 2010 billings of \$5 million to \$10 million, fourteen reported billings in 2010 of \$10 million to \$50 million, seven reported 2010 billings of more than \$50 million, and one respondent chose not to respond to the question. These larger companies may have a greater number of projects instead of larger-sized projects, meaning they might have multiple BIM staff members but all working on different projects. No other strong, or

even moderate, correlation could be found between the responses to this question and any other data presented in this report.

4.3.3 Software and Tools

Software programs and special tools help contractors implement Building Information Modeling on projects and deliver successful projects. To gain a better idea of the software the electrical contracting industry uses to accomplish BIM, survey respondents were asked to provide their most frequently used software packages. Seven popular software packages in the construction industry were listed as response options: Autodesk AutoCAD Electrical, Autodesk AutoCAD MEP, Autodesk Navisworks, Autodesk Revit MEP, Bentley MicroStation, Graphisoft ArchiCAD, and Graphisoft MEP Modeler. “Other” was also provided as an answer with space to allow respondents to list any other software they are using. Respondents were allowed to choose as many of answers as applied.

As seen in Table 4.09, Autodesk software products are by far the most popular among electrical contractors. More specifically, Autodesk Revit MEP is used by 67 percent of electrical contractors, AutoCAD MEP by 61 percent, and Autodesk Navisworks by 59 percent. This data is very similar to the information presented in Section 2.3.5 of this report. Bentley MicroStation was used by one electrical contractor, and Graphisoft products were not used by any of the respondents. Five respondents noted that they used other software than the ones listed including Autodesk AutoCAD 2009, Synchro, Quickpen Pipe Designer, Technical Sales International CAD Elec, and a custom product made for a specific company. One of the respondents did not know what product their company was using.

Table 4.09: Most Used BIM Software by Electrical Contractors

#	Answer	Responses	Percentage
1	Autodesk Revit MEP	33	67%
2	Autodesk AutoCAD MEP	30	61%
3	Autodesk Navisworks	29	59%
4	Autodesk AutoCAD Electrical	8	16%
5	Others (Please Specify)	5	10%
6	Bentley MicroStation	1	2%
7	Graphisoft ArchiCAD	0	0%
8	Graphisoft MEP Modeler	0	0%

Autodesk products have been the most popular design products in the construction industry since the switch from hand-drafting to Computer Aided Design in the 1980's. As two-dimensional drafting continues to change to three-dimensional drafting, many companies continued using products they knew and trusted. This is likely one of the reasons that Autodesk software is the most popular BIM product on the market. The ability to combine project models is also easier when the same software program is used on a project. If a company plans to purchase BIM software, they will likely not only consider its use internally, but will also assess how the software with mesh with the software other trades are using.

Of the six respondents who said they use non-Autodesk software (Bentley, and "Other"), five also use Autodesk software. This means that of the 49 respondents, 48 are using at least one Autodesk software package. This could potentially be 49 of 49 respondents, depending on the software package used by the respondent who stated they did not know what their company was currently using. As seen from the responses, Autodesk products are the most popular Building Information Modeling products in the electrical contracting industry. This is good news for coordination between contractors on a project. However, without more competition between software companies, advancement of BIM software could be limited. The electrical contracting

industry needs to closely monitor BIM software development in order to ensure their needs are being met and to demand software advancement.

After the Building Information Model is complete, contractors find ways to implement the information contained in the model into the physical project. This is done in a variety of ways, including, but not limited to, converting the model into two-dimensional plans, operating special equipment to fabricate parts, and employing total stations to mark layouts. In this report's survey, electrical contractors were asked to provide the tool they use to utilize a completed BIM model. Respondents were able to select "total stations," "GPS surveying," "other," and "we are not using additional tools." If "other" was chosen, space was provided for that respondent to provide the name of the tool their company uses.

Fifty-seven percent of responding electrical contractors are currently using tools to utilize completed BIM models on a construction site. Table 4.10 shows the most commonly used BIM tools as reported by survey respondents. The most popular tool is the total station as stated by 45 percent of respondents. GPS surveying is used by seven of the 49 respondents. Lastly, three contractors selected "other" and stated that they were using Trimble Positioning Devices to implement a completed BIM model. Trimble offers multiple devices for the construction industry that capture existing conditions, aid with layout, and increase accuracy (Trimble Navigation Limited, 2012). The Trimble 3-D Laser Scanner can be used in an existing structure to determine the location and layout of the structure, building systems, and architectural objects. The Trimble MEP and Trimble Field Link for MEP are devices used in conjunction with software packages and total stations in the field to show the locations and elevations of all

equipment and conduit during the installation process. No correlation could be found between the use of BIM tools and any other data presented in this report.

Table 4.10: Most Used BIM Tools by Electrical Contractors

#	Answer	Responses	Percentage
1	Total Stations	22	45%
2	We are not using additional tools	21	43%
3	GPS Surveying	7	14%
4	Trimble Positioning Device	3	6%

The use of Building Information Modeling tools in the field gives workers the ability to implement the modeled work without losing any three-dimensional information. On many projects, a BIM model is flattened into two-dimensional plans. The plans are then used to construct the building. When this happens, much of the information in the model is lost. With the use of BIM tools, the three-dimensional BIM model can be used directly in the field.

All of the individuals questioned during the interview process talked in-depth about their current and future plans to use BIM tools. If the information contained in a BIM model is not accurately relayed to field workers, the time and money spent on creating the model is wasted. For this reason, electrical contractors are currently making large investments to get this information to their field workers through the use of total stations for layout and computer kiosks set up throughout the jobsite. In the near future, as noted through interviews, many electrical contractors plan to make investments in tablets, which can be used to view the BIM model in the exact spot where the work is to be completed. One interviewee even mentioned the idea of using three-dimensional glasses to view the BIM model. Workers would be able to virtually walk through the BIM model while standing inside the structure of the model to be built. This is

currently only a vision. However, with further technological developments, this vision could become a reality. Many years ago the use of BIM was a characteristic that allowed electrical contracting companies to stand out from their competition. In the future, the use of BIM tools will define an electrical contractor.

4.3.4 Cost to Project

Building Information Modeling comes with an upfront cost that companies need to build into project costs. Ideally, electrical contractors want to know how much BIM will add to the cost of a project, allowing a company to generate more accurate estimates and make more competitive bids on projects. To gain an understanding of BIM project costs, electrical contractors were asked to provide the cost of BIM for a project as a percentage of overall electrical construction costs. Respondents were provided six options to choose from, starting with “less than one percent” and ending with “more than five percent.”

As mentioned in Chapter 2, the largest BIM cost to electrical contractors is the cost of initially implementing BIM within a company. These costs include software, hardware, and training. Once these costs are covered, there is still additional cost to implement BIM on a specific project. As shown in Table 4.11, BIM accounts for somewhere between one to two percent of the total electrical construction cost according to 41 percent of survey respondents. Twenty-seven percent of respondents replied that they spent less than one percent of the total electrical construction cost on BIM, and fourteen percent responded that their company spent two to four percent. The remaining eighteen percent stated that their BIM cost on a project was greater than three percent of the total electrical construction cost.

Table 4.11: BIM Cost as a Percentage of Total Electrical Construction Cost on a Project

#	Answer	Responses	Percentage
1	Less than 1.0%	13	27%
2	1.0% to 2.0%	20	41%
3	2.0% to 3.0%	7	14%
4	3.0% to 4.0%	4	8%
5	4.0% to 5.0%	2	4%
6	More than 5.0%	3	6%
	TOTAL	49	100%

Therefore, according to survey results, a majority of electrical contractors spend less than two percent of the total electrical construction cost for a particular project on Building Information Modeling. Typically, electrical contractors make a bid for a project based on a combination of square footage, linear footage, and quantity takeoffs. A correlation between the BIM cost on a project and the previously mentioned attributes, coupled with the complexity of the project, is expected but not tested directly in this study. Electrical contractors want to know the cost impact BIM will have on their project so that they can make accurate bid and therefore have a great interest in future study on this area, potentially conducted by universities, the electrical contracting industry, and/or individual contractors. No other correlations were found between the cost of BIM during a project and the data presented so far in this report. In Chapter 5 a correlation between the cost of BIM and future BIM planning will be presented.

4.3.5 Associated Risk

As is the case with other aspects of a construction project, the use of Building Information Modeling involves risk. If the risk is not managed properly, BIM could cost a project and contractors involved a large amount of money. Chapter 2 mentioned some of the risks linked to

using BIM, such as a model created for a construction project that does not mesh with other project models, creating errors to be fixed in the field. These fixes, or rework, typically cost a project time and money. To determine the risks associated with BIM use in the electrical contracting industry, survey respondents were asked to select risk factors associated with BIM use that they had encountered from past experience. Respondents could choose from “cost overrun,” “lack of BIM protocol,” and “other,” with space for providing the specific risk factor.

According to 71 percent of respondents, lack of BIM protocol is the largest risk factor, meaning that when internal and external protocol is lacking, BIM use has a greater chance for failure. All other survey responses pertaining to perceived BIM risk were chosen by less than twenty percent of the precinct. Table 4.12 shows all responses received. Cost overrun, which was provided as a standard response in the survey, was chosen by fourteen percent of the respondents. The only other notable response was lack of commitment and/or leadership by others. This response was written in by eight of the 49 electrical contractors currently using Building Information Modeling.

Table 4.12: Risks Associated with BIM

#	Answer	Responses	Percentage
1	Lack of BIM protocol	35	71%
2	Lack of commitment/leadership by others	8	16%
3	Cost overrun	7	14%
4	Lack of commitment internally	2	4%
5	Mistakes by BIM staff	1	2%
6	Poor software	1	2%
7	Unclear contracts relating to BIM	1	2%
8	None	3	6%

No correlation was found between respondents’ perceived risks from the use of Building Information Modeling and the data presented in this report. Surprisingly, respondents showed

that their companies were more interested in investing in marketing BIM capabilities and training staff members than creating internal and external BIM procedures to help mitigate risk. Of the 35 contractors who believed lack of BIM protocol to be a risk, the mean scale factors for creating internal and external procedures BIM procedures were smaller than the overall group as presented in Table 4.03. The two mean scale factors for the 35 respondents mentioned previously were 2.97 for creating internal BIM procedures and 2.34 for creating external BIM procedures. Contractors realize the risks associated with BIM but are not taking steps toward making improvements.

Throughout the interviews, many individuals discussed risks associated with using BIM. The largest risk that interview respondents had encountered or perceived was related to others outside of their company. When completing a BIM model, a contractor relies on others within the project team to provide and implement correct information into the model. Any mistakes can make a model incorrect and cause discrepancies in the field. To mitigate this risk, contractors need to create a protocol for dealing with these problems prior to beginning the modeling process on a project. For the most part, the risks mentioned in the interviews were similar to the risks shown in this report and the risks discussed by Doctor Salman Azhar as reviewed in Chapter 2.

4.4 OUTCOMES

To gain an understanding of the outcomes of using Building Information Modeling in the electrical contracting industry, survey respondents were asked three separate questions asking the respondent to rank separate categories listed within the questions. The outcome sections of this chapter review the impact BIM has made during specific project phases, within project activities,

and how performance has improved. The responses received to these questions, as reported in this section of the report, were mostly based on perception. This does not detract from the value of the data, but it should be recognized that these results are not based on quantitative data. As noted in this section of the report, many of the improvements electrical contractors notice as the result of using BIM are similar to improvements seen by mechanical and plumbing contractors in construction as stated in Chapter 2. As expected, construction improvements reported by electrical contractors differed from the improvements seen by architects and engineers.

4.4.1 Value Generated during Project Phases

Electrical contractors were asked to rate the level of value Building Information Modeling is generating during eleven specific project phases:

- (1) Feasibility,
- (2) Preliminary design,
- (3) Final design,
- (4) Construction documents,
- (5) Bidding,
- (6) Fabrication,
- (7) Construction,
- (8) Shop drawings,
- (9) Submittals,
- (10) Closeout, and
- (11) Operations and maintenance of the facility.

Respondents were asked to rate the level of value on a scale from “none” to “a great deal.” Responses to this question reveal the overall role BIM plays throughout a project for electrical contractors and gives a synopsis of the return on investment as seen in specific project phases. This section of the report analyzes survey responses. In some instances an electrical contractor might not typically be involved with the project, such as during the feasibility or operations phases. However, during many stages of a project the electrical contractors are extremely involved, such as during construction, shop drawings, submittals, etc.

Table 4.13 shows the value BIM generates for electrical contractors during project phases. Similar to Table 4.03, a percentage is shown for each rating (“none” to “a great deal”). Each rating factor was assigned a number: one to five. The mean scale represents the average of all the responses received for the category. Electrical contractors believe they are creating the largest BIM value during the construction phase of the project, or more specifically, when workers are using the BIM model to build the project. The mean scale for the value of BIM during construction is 4.10. This shows that the average electrical contractor gains quite a bit of value from the use of BIM during construction.

Table 4.13: Value BIM is Generating during Project Phases

#	Category	None	A Little	Some	Quite A Bit	A Great Deal	MEAN SCALE
1	Feasibility	29%	18%	22%	24%	6%	2.61
2	Preliminary design	10%	27%	20%	33%	10%	3.06
3	Final design	4%	8%	14%	57%	16%	3.73
4	Construction documents	8%	12%	14%	43%	22%	3.59
5	Bidding	41%	35%	12%	10%	2%	1.97
6	Fabrication	8%	10%	27%	33%	22%	3.51
7	Construction	2%	4%	14%	41%	39%	4.10
8	Shop drawings	12%	6%	27%	37%	18%	3.43
9	Submittals	24%	22%	31%	18%	4%	2.55
10	Closeout	14%	18%	20%	35%	12%	3.12
11	Operations and maintenance of the facility	29%	16%	27%	16%	12%	2.67

Two strong correlations were found in relationship to the perception respondents had on the value BIM generates during construction. The first correlation is the reduction of field conflicts. The correlation coefficient for this relationship is 0.807—this was the highest correlation found between responses within this research. The second correlation of value generated during construction from BIM was the improvement in coordination prior to construction. The correlation coefficient for this relationship is 0.764. The data for these two correlations is shown in Table 4.15, and the overall relationship will be discussed further in Section 4.4.3. However, it is notable that the relationship between electrical contractors using BIM correctly during the coordination process leads to promising results during construction as the result of a reduction in field issues.

Additionally, a moderate correlation was found between value added during construction from the use of Building Information Modeling and value added during the shop drawing process from the use of BIM. On most projects, following approval, shop drawings are used as the field release drawings used by workers to install the electrical system. That being said, an improvement in shop drawings leads to an improvement in the construction of a system. Similar correlations were found within the data in Table 4.14 and will be discussed further in Section 4.4.2.

The second largest value of BIM use to electrical contractors occurs during the final design phase of a project. Typically in this phase, the design team completes the overall design for the building. In some delivery models, electrical contractors play an active role in planning the overall design of a building. Electrical contractors can offer great insight into constructability and often suggest cost-saving measures. Building Information Modeling assists these contractors with creating a better final design, creating somewhere between “some” to “quite a bit” of value with the mean scale at 3.73.

Construction documents are created following the final design of a project. Construction workers use these documents to build the infrastructure of the building. As seen in Table 4.13, the creation of construction documents with the assistance of BIM creates the third largest value for electrical contractors during the overall project cycle. As was the case with the creation of the final design, the value lies between “some” to “quite a bit” of value, with the mean scale at 3.59. A moderate correlation was found between value being added from BIM during the final design

and construction document creation with a correlation coefficient of 0.633. The correlation was expected since the process and the value adding levels were similar

The last notable BIM value for electrical contractors throughout the project cycle is during fabrication. Thanks to BIM use, electrical contractors can fabricate most of their conduit and equipment off-site. The fabricated pieces are then delivered to a project site for installation. Completing fabrication off-site in a controlled environment saves time and money. Again, the value generated for electrical contractors is between “some” to “quite a bit” of value, with the mean scale at 3.51. A moderate correlation was found between the respondents who perceived value is added during the fabrication process and value added during shop drawing with a correlation coefficient of 0.603. Shop drawings are often used during fabrication. BIM enables electrical contractors to produce better drawings, which in turn allows contractors to fabricate more accurately and cost effectively. This same relationship will be discussed further in Section 4.4.3 and will reveal that better coordination has led to a reduction in field conflict and therefore a reduction in the cost of rework.

On the other hand, according to survey results, the lowest BIM value generated during the project cycle is during bidding. As noted in Table 4.13, 44 percent of electrical contractors are not using Building Information Modeling during the bidding phase. During the interviews, many contractors explained that a return on investment during the bidding phase does not exist. Contractors are careful not to spend money on completing a bid if they do not perceive that money spent will increase their chance of winning the bid. Building Information Modeling is currently only generating a little value for electrical contractors, with the mean scale at 1.97.

A correlation between value added during the bidding phase and the submittal process was discovered. The correlation coefficient is 0.606. The value rating for submittals is the second lowest at 2.55. During interviews conducted for this research, some respondents mentioned a disconnect when a model is handed over from designer to contractor. The submittal process could be greatly improved if all specifications were included directly in a model. This, however, is not a reality on many projects. Information is often missing or included in a separate specification booklet. When the electrical contractor submits on products being used during construction, they may not have a complete understanding of the designer's desires or expectations.

The other notable correlation is the relationship between the value added during the feasibility stage and the preliminary design stage from the use of BIM by electrical contractors. The correlation coefficient is 0.683. Electrical contractors are not usually involved in a project during these phases. For this reason, the add value rating was fairly similar for both phases.

4.4.2 Value Generated within Project Activities

Electrical contractors were asked to rate the level of value Building Information Modeling generates during twelve specific project activities:

- (1) Clash detection,
- (2) Cost estimation for project,
- (3) Energy/lighting analysis,

- (4) Facility space planning,
- (5) More efficient use of time,
- (6) Project turnover and closeout,
- (7) Quantity take-off,
- (8) Scheduling,
- (9) Shop drawing process,
- (10) Stakeholder engagement,
- (11) Submittal process, and
- (12) Visualization of facility design.

Respondents were asked to rate the level of value generated on a scale from “none” to “a great deal.” Responses to this question reveal the overall role BIM plays within a project for electrical contractors and provides another look at the return on investment as seen in specific project activities. The value ratings generated during project activities will be analyzed in this section of the report. As was the case with project phases, in some instances electrical contractors might not typically be involved with certain project activities, such as energy and lighting analysis. On the other hand, electrical contractors are normally very involved in the submittal and scheduling process.

The project activity generating the largest value for electrical contractors through the use of Building Information Modeling is the clash detection process. The same findings were discussed in the literary review of this report in Chapter 2. Prior to work beginning in the field, contractors work to coordinate their systems in the building. The goal of this coordination is to find any and all clashes between the mechanical, electrical, and plumbing systems in the building. Completing

this prior to construction eliminates problems in the field that can slow work and cost money. As seen in Table 4.14, 88 percent of electrical contractors using BIM for clash detection believe BIM is creating “quite a bit” to “a great deal” of value. The mean scale for this is 4.31.

Table 4.14: Value BIM is Generating within Project Activities

#	Category	None	A Little	Some	Quite A Bit	A Great Deal	MEAN SCALE
1	Clash detection	2%	0%	10%	41%	47%	4.31
2	Cost estimation for project	27%	35%	33%	4%	2%	2.20
3	Energy/lighting analysis	39%	31%	22%	4%	4%	2.04
4	Facility space planning	31%	20%	14%	33%	2%	2.55
5	More efficient use of time	14%	14%	33%	31%	8%	3.04
6	Project turnover and closeout	20%	24%	18%	31%	6%	2.78
7	Quantity take-off	33%	33%	16%	18%	0%	2.20
8	Scheduling	20%	35%	22%	20%	2%	2.49
9	Shop drawing process	12%	18%	31%	29%	10%	3.06
10	Stakeholder engagement	27%	16%	18%	29%	10%	2.80
11	Submittal process	22%	31%	35%	10%	2%	2.39
12	Visualization of facility design	4%	8%	9%	18%	37%	3.86

Another value-generating activity resulting electrical contractors’ use of BIM is the creation of a model for the visualization of facility design. Using BIM, construction professionals create a three-dimensional model of the building. Previously professionals in the construction industry could only create a two-dimensional image of the facility in their mind based off CAD plans. Today, with the use of BIM, contractors can create a three-dimensional model for planning and communication purposes. As mentioned in Chapter 2, the ability to visualize a building prior to construction has made a large impact on the construction industry. As seen in Table 4.14, BIM has also had a similarly large impact in the electrical contracting industry. Survey respondents

stated that “quite a bit” of value is being created from BIM through visualizing a project prior to any work starting. The mean scale is 3.86.

The last two notable value-adding Building Information Modeling activities for electrical contractors are improvement in the shop drawing process and an overall improvement in time efficiency. These two activities were reported as adding “some” value with mean scale values of 3.06 and 3.04 respectively. A moderate correlation was found between these two BIM activities with a correlation coefficient of 0.646. Through the use of BIM during the submittal process, electrical contractors have created value by decreasing the time needed to complete submittals and improving the quality of the field release drawings for field workers. Additionally, through the use of Building Information Modeling, electrical contractors have improved the efficiency of installation. As reported many times throughout this report, early planning and clashes detected with BIM have reduced the number of issues found in the field.

Two other notable correlations relating to the previous paragraph:

- A moderate correlation between the shop drawing process (Table 4.14) and shop drawings (Table 4.13). The correlation was expected and has a coefficient of 0.688.
- A moderate correlation between the shop drawing process (Table 4.14) and scheduling (Table 4.14). The correlation coefficient is 0.650, and the reasoning behind this relationship is unknown.

According to electrical contractors, energy and lighting analysis is the lowest value-generating Building Information Modeling activity. As seen in Table 4.14, the mean scale value is 2.04. Many professionals in the construction industry do take advantage of energy and lighting

analysis as displayed in Chapter 2. However, these are mostly design professional. When asked to perform this type of analysis, electrical contractors use BIM software. However, they are not asked do so often. Seventy percent of respondents reported “none” to “a little” value generated from the use of BIM during energy and lighting analysis.

Two correlations were found in relationship to value-generated by electrical contractors from energy and lighting analysis through the use of BIM. The first is facility planning as listed in Table 4.14, with a correlation coefficient of 0.641. These two tasks are rarely performed by electrical contractors, and, for this reason, received answers from respondents supporting this data. The second is a correlation with bidding as listed in Table 4.13. As previously mentioned, the use of BIM during bidding is currently not generating value for electrical contractors. The two low value ratings created the correlation.

The other two notable low value-adding Building Information Modeling activities for electrical contractors are quantity take-offs and a project’s cost estimation. The mean scale value for both of these activities is 2.20. A moderate-to-high correlation was found between these two BIM activities with a correlation coefficient of 0.752. As mentioned in Section 4.4.1, contractors hesitate to spend large amounts of money on estimating a project for bidding proposes. Additionally, the design team rarely provides a BIM model to contractors prior to bidding. For these reasons, the BIM value rating is low. However, survey results that showed quantity takes-offs have a low value, which is surprising. BIM software providers often sell their software based on the fact that quantity take-offs can be completed faster. (Autodesk, Inc., 2012). After

discussions with professionals in the industry, it was determined that the low value could be tied to the fact that BIM models are often provided at very late stages in the design process.

Two other notable correlations relating to the previous paragraph:

- A moderate correlation between the quantity take-off activity (Table 4.14) and bidding phase (Table 4.13) with a correlation coefficient of 0.641. As was the case with value added from the use of BIM during energy and lighting analysis, two low value ratings created the correlation.
- A moderate correlation between the quantity take-off activity (Table 4.14) and project close-out (Table 4.14). The correlation coefficient is 0.619, and the reasoning behind this relationship is unknown.

Other notable correlations found through analyzing the data presented in section 4.4.2 include:

- A strong-to-moderate correlation between the project turnover and closeout activity (Table 4.14) and the project closeout phase (Table 4.13) with a correlation coefficient of 0.707. This correlation was expected.
- A strong-to-moderate correlation between the submittal activities (Table 4.14) and the submittal project phase (Table 4.13). The correlation coefficient is 0.760, and, again, this correlation was expected.
- A moderate correlation between the submittal activities (Table 4.14) and the project closeout phase (Table 4.13). The correlation coefficient is 0.673, and the reasoning behind this relationship is unknown.

4.4.3 Value Presented Through Performance Indicators

Electrical contractors were asked to rate the level of improvement generated from Building Information Modeling as seen in twelve specific performance indicators:

- (1) Reduction in RFI's,
- (2) Reduction in re-submittals,
- (3) Reduction in field conflicts,
- (4) Reduction in deficiency issues,
- (5) Reduction in punch list items,
- (6) Reduction in the cost of rework,
- (7) Reduction in the cost of as-built drawings,
- (8) Reduction in change orders,
- (9) Shorter processing time for change orders, and
- (10) Better coordination.

Respondents were asked to rate the level of improvement measured through these performance indicators on the same scales mentioned previously: “none” to “a great deal.” Responses to this question show areas of improvement from the implementation of BIM as seen by electrical contractors. The ratings of these specific improvement areas portray how BIM is impacting construction projects. Additionally, the areas where BIM is making little to no impact can also be seen.

According to electrical contractors, coordination improves the most from the use of Building Information Modeling. As depicted in Table 4.15, the mean scale value is 4.14. The use of BIM

by contractors has helped facilitate better communication between contractors before the start of construction. Prior to the use of BIM, much of the coordination of a project was done during the construction phase, which slowed down work. With today's technology, contractors are often contractually required to participate in BIM coordination prior to construction starting. The implementation of BIM along with the added collaboration has improved overall coordination and decreased problematic issues in the field. This has proven to be of great value to electrical contractors in the construction industry.

Table 4.15: Level of Improvement Generated from BIM as Seen in Performance Indicators

#	Category	None	A Little	Some	Quite A Bit	A Great Deal	MEAN SCALE
1	Reduction in RFI's	6%	18%	39%	33%	4%	3.10
2	Reduction in re-submittals	16%	33%	27%	24%	0%	2.59
3	Reduction in field conflicts	2%	0%	16%	51%	31%	4.08
4	Reduction in deficiency issues	4%	14%	37%	41%	4%	3.27
5	Reduction in punch list items	10%	22%	33%	33%	2%	2.98
6	Reduction in the cost of rework	4%	14%	22%	45%	14%	3.51
7	Reduction in the cost of as-built drawings	12%	16%	31%	33%	8%	3.08
8	Reduction in change orders	6%	24%	45%	22%	2%	2.90
9	Shorter processing time for change orders	31%	29%	27%	14%	0%	2.24
10	Better coordination	2%	4%	12%	41%	41%	4.14

As mentioned previously, implementing Building Information Modeling in electrical contracting has greatly improved the coordination of building systems within projects. In turn, improvement has reduced the number of field conflicts discovered by workers during construction. As is expected and shown in Table 4.15, the second highest level of improvement generated from implementing BIM, as seen in performance indicators, is the reduction of field conflicts. This item had a mean scale value of 4.08. During interviews, many contractors mentioned the

reduction of field conflicts due to BIM implementation. As stated by survey respondents, the use of Building Information Modeling in the early stages of a project allows the project team time to eliminate many conflicts between building systems that otherwise would have been discovered and dealt with in the field. Additionally, BIM implementation gives electrical contractors a larger voice during the coordination effort. Prior to BIM, electrical contractors were often the last trade to install their system. Today, thanks to BIM, electrical contractors are sometimes the first contractors to start installation. This gives electrical contractors more time to efficiently install their product.

As reviewed thus far in Section 4.4.3, BIM use in electrical contracting has led to better coordination, and thus a reduction in field conflicts. In addition to these benefits, the reduction of field conflicts has also led to a reduction in the cost of rework. As seen in Table 4.15, the third highest ranked improved performance indicator is the reduction in the cost of rework, with a mean scale value of 3.51. This category is where electrical contractors see direct value. If, at the end of a project an electrical contractor has improved coordination and reduced the number of field conflicts, they more than likely will have saved money by preventing a large amount of rework performed on a job. As discussed in Chapter 2, many electrical contractors previously reported an improvement in the cost of rework. This report confirms those finding and more clearly defines the progression to those cost savings.

Early implementation of Building Information Modeling on a project leads to improvements during construction and cost savings, which can be further proven with the following correlations:

- A moderate-to-strong correlation between better overall coordination (Table 4.15) and the value created during the construction phase (Table 4.13), with a correlation coefficient of 0.764.
- A moderate correlation between better overall coordination (Table 4.15) and the value produced from the clash detection activity (Table 4.14), with a correlation coefficient of 0.647.
- A moderate correlation between the reduction in the cost of rework (Table 4.15) and the value created during the construction phase (Table 4.13), with a correlation coefficient of 0.646.
- A moderate correlation between the reduction in the cost of rework (Table 4.15) and the value generated from more efficient use of time (Table 4.14). The correlation coefficient is 0.613.
- A moderate-to-strong correlation between the reduction in the cost of rework (Table 4.15) and the value caused by the reduction in field conflicts (Table 4.15). The correlation coefficient is 0.712.
- A strong correlation between the reduction in field conflicts (Table 4.15) and the value created during the construction phase (Table 4.13), with a correlation coefficient of 0.806.
- A moderate-to-strong correlation between the reduction in field conflicts (Table 4.15) and the value produced from the clash detection activity (Table 4.14), with a correlation coefficient of 0.712.
- A moderate-to-strong correlation between the reduction in field conflicts (Table 4.15) and better overall coordination (Table 4.15). The correlation coefficient is 0.752.

In contrast, electrical contractors believe the lowest improved performance indicator generated from Building Information Modeling is shorter processing time for change orders. Sixty percent of electrical contractors reported “none” to “a little” improvement in return time for change orders. The mean scale value is 2.24. As mentioned by multiple contractors during interviews, BIM does not play a large role in the change order process. Some contractors use BIM to gather cost information and proposals for change orders. However, the largest amount of time dedicated to a change orders relates to having others review costs and create contract revisions. A correlation was found with the facility space planning activity listed in Table 4.14 with a correlation coefficient of 0.604. This activity generates low value for electrical contractors, similar to the small improvement seen in shorter processing time for change orders as the result of BIM use. These low ratings created the correlation relationship.

The last notable performance indicator that was not largely impacted by BIM is the frequency of resubmittals. The mean scale factor for this performance indicator was 2.59. Many electrical contractors commented during interviews that BIM models provided by the design teams on projects do not contain information on the equipment and products to be used in construction. This means that electrical contractors are still relying on specification books to obtain information on products. If the design team is not clear about what is expected within the specification book, the electrical contractor might submit incorrect products for approval. For this reason, value created from the reduction in re-submittals through the use of BIM was not as high as other categories. In the future, electrical contractors should push design teams to provide more product information within the BIM model.

Other notable correlations found by analyzing the data presented in Section 4.4.2 include:

- A moderate correlation between the reduction in deficiency issues (Table 4.15) and the value created during the shop drawing phase (Table 4.13). The correlation coefficient is 0.626. This relationship is straight-forward—the use of BIM during the shop drawing process improves coordination prior to construction and decreases the amount of deficiency issues that arise in the field.
- A moderate correlation between the reduction in deficiency issues (Table 4.15) and the reduction in the cost of as-built drawings (Table 4.15). The correlation coefficient is 0.696. Decreasing the number of deficiency issues that arise in the field from the use of BIM results in fewer changes needed to be made within the field release drawings. Decreasing the number of changes to these drawings decreases the cost of the final as-built drawings.
- A moderate correlation between the reduction in punch list items (Table 4.15) and the reduction in change orders (Table 4.15). The correlation coefficient is 0.649. Change orders come about when plans are unclear or the design team wants to implement a change in design. On the other hand, punch list items are created when plans are unclear or the contractor did not correctly follow the plans. Through the use of BIM, communication between the contractor and the design team improves, allowing for a decrease in change orders and a smaller punch list.
- A moderate correlation between the reduction in the cost of as-built drawings (Table 4.15) and the value created during the closeout phase (Table 4.13). The correlation coefficient is 0.649. The value created during the closeout phase comes partially from fewer changes that need to be recorded within the as-built drawings. Reducing the time and cost of completing as-built drawings creates value during the closeout phase.
- Lastly, a moderate correlation between the reduction in the cost of as-built drawings (Table 4.15) and submittal activities (Table 4.14). The correlation coefficient is 0.613. The reason behind this relationship is difficult to determine and needs to be investigated further in future research.

4.5 SUMMARY

Chapter 4 of this report documents the electrical contracting industry's current use of Building Information Modeling through the use of the research survey and interviews conducted with professionals in the design and construction industry. As a result, readers should now have a sense of current use characteristics of BIM, project implementation of BIM, and BIM outcomes.

Electrical contractors are increasing the overall implementation of Building Information Modeling on projects. Many realize that their companies still have room for improvement and growth within BIM. In order to continue improving their use of BIM, electrical contractors are making investments in staff training and necessary software. Additionally, electrical contractors are marketing their BIM capabilities to potential clients as a way of winning work.

Electrical contractors continue to implement BIM on projects as a way to improve the coordination process with other trades. More often than not, implementing BIM on a project is required contractually. Owners, along with general contractors and construction managers, want electrical contractors to use BIM alongside the mechanical and plumbing trades. Autodesk products continue to be the most popular BIM software due to their compatibility with other software programs. Additionally, the use of and investment into BIM tools will play a significant role in the progression of BIM in the future of the electrical contracting industry. Electrical contractors, industry groups, and academia will need to concentrate time and effort into gaining a greater understating of BIM's cost to a project, as well as creating external procedures with other companies.

Through the use of Building Information Modeling better coordination between trades has created value for electrical contractors during a project's early planning stages. Additionally better shop drawings have been created through the use of BIM, which has led to more accurate field release drawings. Improvements found during construction can be seen through the reduction in field conflict and the greater productivity of electricians. Additionally, the use of BIM by electrical contractors has reduced the cost of project closeout as seen through the reduction in the cost of rework, smaller punch lists, and a lower cost to produce as-built drawings. Overall, the use of BIM has created great value for the electrical contracting industry.

Chapter 5 of this report will review the future use of BIM as predicted by electrical contractors. Survey results will continue to be presented in addition to correlations with other data and input from interviews conducted with design and construction professionals.

CHAPTER 5 FUTURE USE OF BUILDING INFORMATION MODELING

5.1 INTRODUCTION

The main purpose of the survey described in Chapter 3 was to determine the current and future use of Building Information Modeling in the electrical contracting industry. Chapter 4 reviewed the current use of BIM by electrical contractors. Chapter 5 will review the predicted future use of BIM as assessed by electrical contractors by reviewing survey results and summarizing interview responses. As mentioned in previous chapters, the survey data and interviews represent perceptions of these individuals. Lastly, correlations will be reviewed and presented throughout the chapter.

Chapter 5 will look at two specific areas of the future use of BIM. The first is the use of BIM by electrical contractors on projects. The second is the predicted future investment in BIM by companies. As mentioned in Chapter 2, previous research into the predicted future use of BIM in electrical contracting was not available. This chapter will fill in some of the missing information and give the industry an idea of where the represented whole is heading. This research was not concentrated on the future use of BIM, and additional research into future BIM planning and trends is recommended.

5.2 EXPECTED USE

To gain an understanding of the predicted future use of Building Information Modeling in the electrical contracting industry, survey respondents were asked to estimate the percentage of projects on which their company expects to implement BIM in the next two years. Respondents could choose from “less than 15%,” “15% to 30%,” “30% to 60%,” and “more than 60%.” This question was asked to all survey respondents and will be presented in two groups: current users and non-users. The original intent of this question was to compare current use of BIM to future use of BIM. As mentioned previously, the current use information was not presented in this report because of inconsistencies in the data. However, the future use data will still be reviewed to show the estimated future use of BIM in the electrical contracting industry, the comparison between current and non-users, and any correlations that may exist.

5.2.1 Current users

On the survey, current Building Information Modeling users responded to the question asking them to estimate the percentage of projects on which their company expects to implement BIM in the next two years with an even distribution of responses between less than fifteen percent all the way to sixty percent. As shown in Table 5.01, less than fifteen percent, fifteen percent to thirty percent, and thirty to sixty percent had responses of 29 percent, 24 percent, and 33 percent respectively. The lowest response to the future use of BIM by electrical contractors is by respondents expecting to use BIM on more than sixty percent of their projects.

Table 5.01: Predicted Future Use of BIM on Projects by Electrical Contractor's Currently Using BIM

#	Answer	Responses	Percentage
1	Less than 15%	14	29%
2	15% to 30%	12	24%
3	30% to 60%	16	33%
4	More than 60%	7	14%
	TOTAL	49	100%

Responses displayed in Table 5.01 show electrical contractors currently using Building Information Modeling plan to continue using BIM on many of their projects in the next two years. A strong-to-moderate correlation is found between the respondent's expertise level and percentage of BIM projects their company plans on executing. The correlation coefficient for this relationship is 0.690. This correlation shows that electrical contractors who are confident in their current use of BIM tend to have big plans for implementing BIM on future projects. A moderate correlation is also found between future implementation plans and current practices in training company staff in BIM and marketing BIM capabilities to potential clients. The correlation coefficients for these relationships are both 0.612. As seen from the data and correlations, electrical contractors currently making a strong investment in BIM typically have plans on using BIM more frequently on projects in the future.

During the interview process, all four of the electrical contracting respondents stated that they will continue to increase their use of BIM on projects. Many stated that this increase will be partially mandated by project owners, general contractors, and construction managers. Additionally, all of the electrical contractors stated that their planned increase in the use of Building Information Modeling related to the improvements seen from the use of BIM with layout, fabrication, and clash detection, to name a few.

5.2.2 Non-Users

Alternatively, responses by non-Building Information Modeling using electrical contractors to the same question told a different story. As depicted in Table 5.02, a majority of survey respondents, or 81 percent, intend on using BIM on less than fifteen percent of their projects in the next two year. The remaining respondents, or nineteen percent, planned to use BIM on fifteen to thirty percent of their projects in two years. Of all the non-Building Information Modeling electrical contractor users, none expected on using BIM on more than thirty percent of their projects in two years.

Table 5.02: Predicted Future Use of BIM on Projects by Electrical Contractor's Currently Not Using BIM

#	Answer	Responses	Percentage
1	Less than 15%	17	81%
2	15% to 30%	4	19%
3	30% to 60%	0	0%
4	More than 60%	0	0%
	TOTAL	21	100%

These responses reveal that electrical contractors who are not currently using Building Information Modeling do not have big plans for implementing BIM on future projects. As stated previously, many individuals mentioned that owners, general contractors, or construction managers dictate BIM implementation on projects. Some companies would not use BIM unless they were required to use BIM on a project. The electrical contractors who are not currently using BIM and do not have plans to change their use in the future most likely work in markets and with teams that are not mandating BIM's use. Without this enforcement and if a company does not see return on the investment potential electrical contractors not currently using BIM do not desire to make the investment. As shown in this section, current non-BIM using electrical

contractors are likely conservative contractors who are not adept to change. No strong, or even moderate, correlation could be found between the data presented in Table 5.02 and any other data presented in this report.

5.2.3 Comparisons

A large contrast exists between companies that are currently using BIM and companies that are currently not using BIM with regards to the future planned use of Building Information Modeling. As seen in Tables 5.01 and 5.02, and as discussed in the previous sections, 81 percent of current non-BIM users plan on using BIM on fifteen percent or less of their projects in the next two years compared to 71 percent of current BIM users planning to use BIM on fifteen percent or more of their projects in the next two years. Contractors currently using BIM have big plans to continue their use of BIM as compared to contractors currently not using it. These contractors have hesitations about implementing BIM because they know there are costs and risks associated with BIM. Additionally, implementation of BIM within a company can be a huge undertaking without proper leadership and direction. This will be discussed further in Chapter 6.

5.3 INVESTMENT

As a follow-up to a similar question reviewed in Chapter 4, electrical subcontractors were asked to rate their estimated future level of Building Information Modeling investment in six specific categories:

- (1) Purchasing software,
- (2) Creating BIM procedures within the company,
- (3) Creating BIM libraries,
- (4) Creating BIM procedures with other companies,
- (5) Training staff with BIM, and
- (6) Marketing BIM capability to potential customers.

Respondents were asked to rate their future investment on a scale from “none” to “a great deal.” As was the case in the previous section, this question was asked to all survey respondents and will be presented in two groups: current users and non-users. The responses to this question reveal future BIM investment throughout the electrical contracting industry and help gage the future use of BIM. A comparison will be made between current and future BIM investments. Additionally, this section will investigate the comparison between current and non-users and present any correlations that may exist between future investment and other data.

5.3.1 Current users

In the next two years, the largest investment area for electrical contractors currently using Building Information Modeling is marketing BIM capabilities to potential customers. The means scale factor is 4.00. As shown in Table 5.03, 74 percent of respondents stated that they planned

on investing “quite a bit” to “a great deal” in this area. The second largest area of investment is in training staff members with a mean scale factor of 3.43. More moderate investments are planned for creating BIM procedures and libraries within the company. Lastly, the lowest areas of investment in the next two years are in creating BIM procedures with other companies and purchasing BIM software. The mean scale factors are 2.78 and 2.98 respectively.

Table 5.03: Predicted Future Investment in BIM by Electrical Contractor’s Currently Using BIM

#	Category	None	A Little	Some	Quite A Bit	A Great Deal	MEAN SCALE
1	Purchasing software	8%	18%	45%	25%	4%	2.98
2	Creating BIM procedures within the company	4%	18%	37%	29%	12%	3.27
3	Creating BIM libraries	10%	12%	35%	29%	14%	3.24
4	Creating BIM procedures with other companies	10%	33%	35%	14%	8%	2.78
5	Training staff with BIM	6%	12%	29%	39%	14%	3.43
6	Marketing BIM capabilities to potential customers	2%	10%	14%	33%	41%	4.00

This data shows that electrical contractors currently using Building Information Modeling are interested more in marketing their abilities and continuing to train their staff as opposed to purchasing new software and creating BIM procedures with other companies. All six of the areas of future investment shown in Table 5.03 correlated as a whole—meaning that companies who plan for a large future investment in one area likely plan a large future investment in another area. The overall correlation is slight-to-moderate with values ranging from 0.439 to 0.774. The mean correlation coefficient for all of the data presented in Table 5.03 data is 0.577. Additionally, an overall slight-to-moderate correlation was found between the future investment of BIM and the predicted future use of BIM on projects by electrical contractors, depicted in

Table 5.01 and Table 5.03. The correlation coefficients range from 0.340 to 0.773 with a mean of 0.559.

A moderate correlation exists between the cost of BIM on a project and electrical contractors' desire to develop BIM procedures with other companies. Of the thirteen companies who spent less than one percent of project costs on BIM, three stated that in the next two years they would have "some" focus on creating BIM procedures with other companies, six stated they would have "a little" focus, and four stated they would have no focus. On the other hand, of the nine companies that spent more than three percent of project costs on BIM, four stated that in the next two years they would have "a great deal" of focus on creating BIM procedures with other companies, two stated they would have "quite a bit" of focus, and three stated they would have "some" focus. The correlation coefficient between these relationships is 0.611. This correlation shows that, in general, companies that have increased funding for BIM coordination are also planning for the future and recognize the need to create better procedures. However, the correlation is only moderate, so there is some flexibility with this relationship. Some companies may have better control of their BIM costs and may still plan on creating better BIM procedures in the future.

Two significant correlations were discovered relating to the planned use of marketing BIM capabilities to potential clients in the next two years. The first is the correlation between the level of expertise and the future marketing of BIM. Through statistical analysis, data showed that a company with a high expertise level will likely have greater plans for future investment in marketing BIM capabilities. Of the four companies that stated their level of expertise is

advanced, all four plan on investing a great deal into marketing in the next two years. Alternatively, of the three companies just starting to use BIM, all three only plan on investing a little into marketing in the next two years. This data shows that as electrical contractors become confident in their use of BIM, they will be more confident displaying their ability to clients. The correlation coefficient for this relationship is 0.736.

The second correlation is between the future marketing of Building Information Modeling and the current value generated from the use of BIM during fabrication and shop drawings. Similar to the correlation between future marketing and expertise, if an electrical contractor generates significant value during shop drawings and fabrication they will likely have an interest in marketing their BIM capabilities in the future. Of the twenty contractors who stated they planned on investing a great deal into future marketing of BIM capabilities, seventeen were generating “quite a bit” to “a great deal” of value through the use of BIM during shop drawings and fabrication phases. The correlation coefficient for these relationships is 0.614 and 0.615 respectively. These relationships show that electrical contractors desire to market their use of BIM on projects and the successes they have had using BIM in the past. They try to win future work by showing owners a significant cost savings through their use of BIM during fabrication and shop drawings.

As stated previously in Chapter 4, many of the interview respondents noted that they planned to invest in Building Information Modeling tools that would aid in relaying information from the modeling team to the workers in the field through an investment in total stations, kiosks, and tablets. Additionally, many interview respondents recognized the need for creating procedures

with other companies. As shown in Table 5.03 and mentioned previously, this remains the lowest priority for future investment amongst electrical contractors. Lastly, a few of the design and construction firms outside of the electrical contracting industry recognized the need for electrical contractors to develop internal BIM libraries and to work to improve fabrication methods through investments in BIM. To stay competitive in the electrical contracting industry, companies will need to continue investing in Building Information Modeling and working towards maximizing their potential with BIM.

5.3.2 Non-Users

Responses to the same question by electrical contractors not currently using Building Information Modeling showed similar patterns to the information presented in section 5.2 of this report. As seen in Table 5.04, electrical contractors not currently using BIM do not have big plans to invest in BIM in the next two years as compared to electrical contractors who are currently using BIM. Purchasing BIM software is the largest investment current non-BIM users plan on making in the next two years. The mean scale rating is 2.29 out of 5. Ninety percent of the respondents stated that they plan on investing “a little” to “some” in purchasing BIM software. The next two largest investments by non-BIM users is training staff with BIM (2.05 mean scale rating) and creating BIM procedures within the company (2.00 mean scale rating).

Table 5.04: Predicted Future Investment in BIM by Electrical Contractor's Currently Not Using BIM

#	Category	None	A Little	Some	Quite A Bit	A Great Deal	MEAN SCALE
1	Purchasing software	10%	52%	38%	0%	0%	2.29
2	Creating BIM procedures within the company	24%	52%	24%	0%	0%	2.00
3	Creating BIM libraries	43%	38%	19%	0%	0%	1.76
4	Creating BIM procedures with other companies	62%	19%	19%	0%	0%	1.57
5	Training staff with BIM	24%	52%	19%	5%	0%	2.05
6	Marketing BIM capabilities to potential customers	48%	38%	14%	0%	0%	1.67

The lowest area of investment planned for the next two years by electrical contractors who are currently not using BIM is creating BIM procedures with other companies. The mean scale rating is 1.57. A majority of respondents, or 62 percent, stated that they did not plan on investing any resources into creating BIM procedures with other companies. The other two low areas of investment are marketing BIM capabilities to potential customers and creating BIM libraries. The mean scale ratings are 1.67 and 1.76 respectively.

The three highest areas of investment by electrical contractors currently not using Building Information Modeling, as shown in Table 5.04, are the areas on which electrical contractors need to concentrate when their company first starts using BIM, including software purchases, staff training, and the creation of internal BIM procedures. Alternatively, the three lowest areas of future investment, as shown in Table 5.04, can be postponed until the company is further established with BIM. These are also areas that electrical contracting industry groups can

concentrate to help improve the industry, which will be further discussed in Chapter 6 of this report.

Similar to what was discussed with current BIM users, all six of the areas of future investment shown in Table 5.04 mostly correlated as a whole. Companies that are not using BIM and do not have plans for a large future investment in one area will likely not have plans for future investment in another area. The overall correlation is moderate, with values ranging from 0.426 to 0.828. The mean correlation coefficient for all of the data presented in Table 5.04 data is 0.639.

5.3.3 Comparisons

Similar to what was discussed in Section 5.3.3 of this report, another large contrast exists between companies currently using BIM and companies not currently using BIM when looking at how these companies are planning for future investment in Building Information Modeling. As shown in Tables 5.03 and 5.04 and discussed in the previous sections, companies currently using BIM tend to have larger plans for BIM investment in the next two years as compared to companies not currently using BIM. This fact is true for all six categories measured. Differences are noticeable between users and non-users when looking at the levels of investment within each category. For example, current BIM users are most interested in what markets their capabilities to potential clients in the next two years, whereas non-BIM users are more interested in purchasing software. The one area that both groups plan on having a comparatively high investment in is training staff in BIM. During the interviews, many individuals mentioned a

continual need for training in order to stay up-to-date on software changes and the evolving industry.

Similarities and differences are also noticeable between Building Information Modeling users' current investments and future investment plan. Comparing Table 5.03 to Table 4.03 shows that all areas of investment rose except for software purchasing. Electrical contractors currently using BIM plan to continue and even increase their investment in BIM, suggesting the confidence current BIM users have in the modeling process and the impact BIM has had and will continue to have on construction. As previously mentioned, the only area not showing an increase in future investment was software purchasing. Overall, the level of investment stayed at the same level. Electrical contracting companies do not plan on making any significant changes in this area due to the high cost of purchasing new BIM software.

A general correlation exists between level of investment electrical contractors are currently making compared to their planned level of investment in the next two years. Electrical contractors with a high level of current investment tend to have a higher planned level of investment for the future. For example, of the fifteen electrical contractors currently investing "a great deal" in marketing BIM capabilities to clients, thirteen plan on having the same level of investment in two years and the other two respondents will invest "quite a bit" in this category. Additionally, the current level of investment within a specific category is typically similar to the future level of investment within a different category. For example, of the five contractors not currently investing in training staff in BIM, four do not plan to create libraries and one plan to invest "a little" into creating libraries in the next two years. The overall correlation is moderate

with values ranging from 0.416 to 0.782. The mean correlation coefficient for the comparison of Table 4.03 to Table 5.03 is 0.602.

5.4 SUMMARY

Future growth of Building Information Model in electrical construction was predicted in the literary review presented in Chapter 2. From the research presented in Chapter 5, readers can see that the use and investment in BIM by current users and non-users will grow over the next two years. Building Information Modeling will continue to play a large role not only in electrical construction but also in the design and construction industry as a whole.

The report finds that the future use and implementation of Building Information Modeling will continue to rise in the electrical contracting industry. As shown in Chapter 4, companies are looking to improve early coordination in order to decrease field conflicts and reduce the cost of rework through the use of BIM.

In the next two years, current BIM users will still investment in marketing their BIM capabilities and training their staff in BIM. However, some investments will shift to a focus on creating internal procedures and libraries. On the other hand, non-users plan for start-up investments, which include purchasing BIM software and investing in training. Investments in BIM tools, fabrication, and the creation of BIM procedures should be the main focus for the electrical contracting industry to help companies stay competitive in the industry.

A noticeable difference between use and investment of users and non-users was found. Users typically use BIM on more projects and invest in resources to improve its use within their company. Regardless of a company's current use, they will need strong commitment and leadership to make a good effort at implementing Building Information Modeling.

As mentioned earlier, previous research into the future use of Building Information Modeling was not available. This report begins to address some of that information; however, additional research into future BIM planning and trends is needed. Chapter 6 summarizes the information contained throughout this report and proposes paths forward for continued BIM improvements and research.

CHAPTER 6 SUMMARY AND CONCLUSION

6.1 INTRODUCTION

Over the last three decades, the construction industry has tracked project change and its relationship to productivity. In order to decrease project change and increase productivity, the construction industry implemented lean construction techniques and new technology. Through the use of early planning, built-in quality, and a focus on reducing changes throughout a project, lean construction has reduced project change and improved the construction process. Additionally, the use of new technology, including Building Information Modeling, in construction has led to the perceived notion by contractors that change during a project is minimized and productivity levels are increased.

The electrical contracting industry lags behind in understanding and implementing BIM. An increase in the understanding and use of Building Information Modeling in the electrical contracting industry will lead to further reductions in project change as well as an increase in productivity. Electrical contractors need to understand the use of BIM and its impacts in the construction industry in order to plan on BIM implementation within their company. We give electrical contractors insight into the current use and trends for the future use of BIM as the result of this research. We will now suggest recommendations for improving the understanding and usefulness of BIM in the electrical construction industry.

6.2 SUMMARY OF RESEARCH

Chapter 1 presents background on the purpose of this research in showing the relationship between construction productivity, information technology, and the use of Building Information Modeling. It also includes a breakdown of the problem statement, research objectives, definitions and concepts used throughout this report, research methodology, and scope of the research.

Chapter 2 provides a thorough literary review to determine the history, present use, and predicted future plans for Building Information Modeling in both the construction industry as a whole and more specifically in the electrical contracting industry. Information on BIM's adoption, usage, value, and impact was reviewed throughout the chapter.

Chapter 3 includes the methodology used in creating the survey and interviewing individuals in order to collect information on the current and future use of BIM in the electrical contracting industry. Additionally, data characteristics were presented, which depicted the location, construction type, and company size of the survey respondents. A total of 70 companies responded to the survey, and eight individuals were interviewed

Chapter 4 contains information on electrical contractors' current use of Building Information Modeling. Of the 70 survey respondents, 49 were currently using BIM, and these companies represent all medium to large companies in the electrical contracting industry. Current-use characteristics of BIM are presented through involvement, investment, expertise, and experience. Project implementation of BIM was reviewed through the ways electrical contractors apply BIM to projects by specifically looking at project size, leadership and staffing, software and tools,

cost, and risk. BIM outcomes show the impact BIM is making during specific project phases, within project activities, and how performance has improved. Correlations were presented between data and backup was provided from interviews and the literature review presented in Chapter 2.

Chapter 5 provided a look at two specific areas in the future use of Building Information Modeling by electrical contractors. The first is the use of BIM by electrical contractors on projects, and the second is the predicted future investment in BIM by companies. Each category was broken up into current users and current non-users. Again, correlations were presented between data and backed up through interviews with contractors and the literature review presented in Chapter 2.

6.3 RESEARCH CONCLUSIONS

The following are conclusions drawn from the study of the current and future use of Building Information Modeling in electrical construction:

- (1) Roughly two-thirds of medium-to-large electrical contracting companies currently use Building Information Modeling, a significant increase from previous research conducted on the use of BIM in electrical contracting. Of the companies using BIM, many are using existing tools and some are creating their own tools internally.
- (2) Between 2008 and 2009 a significant increase in the use of BIM can be seen in the electrical contracting industry. This increase was a reaction to market and owner demands for the use of BIM on projects.

- (3) Electrical contractors are making significant investments in marketing their BIM capabilities to potential customers as well as in training staff on the use of BIM. Investments in creating BIM procedures are currently a low priority. Companies desire to invest more on BIM internally than externally.
- (4) A majority of electrical contractors consider themselves at an advanced level of expertise. Additionally, a majority of companies receive value from BIM but believe they have more to learn. Most electrical contractors realize they have room to invest and grow within many aspects of BIM.
- (5) The typical lowest project size electrical contractors use Building Information Modeling on is in the range of 10,000 to 50,000 man-hours. That being said, owners or construction managers normally dictate the use of BIM on a project for electrical contractors, not the project size.
- (6) Most electrical contractors state that the General Contractor or a Mechanical, Electrical or Plumbing trade leads the BIM effort during construction. Additionally, many companies recognize the need for an improved BIM process during construction. The leader of the BIM coordination needs to have a full understanding of the project, including schedule, sequencing, and maintenance, in order to properly manage project coordination.
- (7) On a typical project, electrical contractors use one to three BIM staff members for the modeling process. Many interview respondents notice a relationship between project size and the BIM staffing needed.
- (8) AutoCAD continues to be the leader within the electrical contracting industry in providing BIM software.
- (9) The use of tools to relay information from the BIM model to the project site is currently an important topic within the industry. Communication currently takes place through the use of total stations and kiosks located on the project site. In the future, the use of tablets and other tools will be what defines an electrical contracting company.
- (10) The majority of electrical contractors spend less than two percent of the total electrical construction cost on Building Information Modeling for a particular project. This percentage can fluctuate depending on how far long a company is with implementing BIM.

- (11) The largest risk associated with the use of BIM continues to be the unpredictability of others on a project team. This risk can normally be mitigated with the implementation of protocol prior to the start of modeling. However, this implementation is still not being performed very well and the risk remains.
- (12) The largest value generated from the use of BIM during project phases for electrical contractors is seen during construction, completing final design, creation of construction documents, fabrication, and shop drawings. The smallest value generated is during bidding.
- (13) The largest value-generating activity from the use of BIM for electrical contractors is seen from clash detection, visualization of the facility design, improvement in shop drawings, and more efficient use of time. The smallest value generated is from light and energy analysis, cost estimation, and quantity take-offs.
- (14) The largest improvement seen through performance indicators from the use of BIM for electrical contractors is seen through improved coordination, a reduction in field conflicts, and a reduction in the cost or rework. The smallest improvements are reductions in processing time for change orders and reductions in re-submittals.
- (15) A relationship that starts with early use of Building Information Modeling and ends with cost savings was found. Through early planning and better coordination between trades, electrical contractors have created better shop drawings leading to more accurate field release drawings. This in turn leads to improved construction with a reduction in field conflicts and greater productivity of electricians. All of this helps companies reduce the cost of project closeout by minimizing the cost of rework, creating smaller punch lists, and a lowering the cost to produce as-built drawings.
- (16) Current BIM users and non-users expect an increase in the use of Building Information Modeling in the next two years.
- (17) Electrical contractors currently using BIM plan to continue investing in marketing their BIM capabilities to potential customers and training staff in the next two years. On the other hand, non-users who will start using BIM in the next two years plan on investing in software, training staff, and creating internal BIM procedures.

6.4 SUMMARY OF COMMENTS BY ELECTRICAL CONSTRUCTION INDUSTRY PROFESSIONALS

This section summarizes the comments made by interview respondents during the interview process that took place for the completion of this report. These comments were used in Chapters 4 and 5 as a way to provide further insight into the survey data presented. Additionally, the comments collected from the interviews will be used as the basis for making researcher's recommendation. The following is a list of direct comments made by professionals in the design and construction industry:

- The electrical contracting industry's use of Building Information Modeling is quickly advancing.
- The use of BIM works best when there is a construction manager involved with the project.
- The construction industry needs to determine when a BIM model will be transferred from design to construction. There is definitely a handoff point. However, this has yet to be defined.
- From a design standpoint, AutoCAD needs to provide better analysis tools within their BIM software packages.
- Electrical contractors need to concentrate on the following:
 - Developing better internal libraries.
 - Identifying levels of modeling
 - Further work on joined modeling efforts with other trades
- Our use of Building Information Modeling has been fully dictated by our contracts with owners. If we were not contractually obligated to use BIM, we wouldn't be.
- The biggest risk associated with BIM is conveying information accurately. Our BIM drafters do not have construction experience or knowledge and are having a difficult time showing details correctly. It seems that drafting is becoming a specialty—not just anyone can do it today.

- The learning curve with BIM is huge.
- The use of BIM in electrical contracting is behind as compared to mechanical contractors. They have been using it for years because of the fabrication value they get from BIM.
- When looking at the entire project, cost saving is sometimes not seen because the cost shifts from construction to planning/preconstruction.
- A cost savings can be seen at the end of the project because record documents are created throughout the project, not just at the end.
- There is a great need for BIM software to be tied to estimating software.
- The electrical contractors need to trust the software and continue to learn about BIM.
- An understanding of how owners are using BIM does not exist. Many owners do not even know how they will use the BIM model following construction.
- People must understand that BIM is evolutionary, revolutionary.
- General contractors and construction managers need to better understand BIM and take the lead on projects. Many do not fully understand the process. Additionally, they do not have the correct people on the BIM team—we would rather see a project manager who understands the project leading the modeling process instead of a BIM coordinator.
- There is no way to calculate the return on investment or productivity savings from the use of BIM.
- There is no benefit using BIM for one's self. It is need for coordination.
- The following are needed in order for an electrical contractor to be successful with BIM:
 - Leadership—BIM is not an experiment,
 - Continuous training,
 - Commitment to provide the resources needed,
 - Good hardware and software,
 - A dedicated effort.
- The use of BIM for scheduling is the next step the construction industry needs to make.

- The use of total stations with the BIM model is making a large impact on construction.
- We have been coordinating building systems using two-dimensional CAD for many years, so the switch to three-dimensional modeling was relatively easy.
- Sometimes BIM models contain too much information and can hurt the modeling process.
- Our drafters are becoming faster using three-dimensional modeling than they were with two-dimensional CAD.
- BIM libraries are not always available from manufactures or suppliers. If these were offered, our company would be willing to pay slightly higher prices for this equipment due to the convenience found during modeling.

6.5 RECOMMENDATIONS TO ELECTRICAL CONSTRUCTION INDUSTRY

PROFESSIONALS

This research has concluded that the use of Building Information Modeling in the electrical construction industry has helped to improve productivity and profitability. However, electrical contractors and the electrical contracting industry as a whole are still struggling to implement BIM. The use of BIM in construction is still relatively new, so fully understanding the concept can be difficult. Many companies faced with implementing BIM choose not to make the commitment because of their lack of understanding. From information provided in the surveys and comments collected during the interviews, the following suggestions are recommended for improving the use of Building Information Modeling within the electrical contracting industry.

6.5.1 Implementing BIM in a Company

When a company first decides to implement Building Information Modeling, the task can seem daunting. The company must first understand that they will have start-ups costs. This includes, but is not limited to, purchasing software, improving hardware to handle the software and file sizes, and hiring full-time BIM staff members. Next, internal procedures and policies relating to BIM use needs to be implemented. These procedures and policies create a consistent practice throughout the company and minimize the risk from using BIM. Lastly, the company needs to find an effective way to communicate information between the staff who create the model and the field personnel who fabricate or build the electrical system.

Companies who have utilized BIM in the past will also want to continue focusing on how they use BIM within their company. A company must provide continuous training for their BIM staff members so they stay updated on software changes. Additionally, companies may want to consider training their field personnel in navigating a BIM model. Lean construction principals focus on workers in the field. If these workers can access and understand the model, less information will be lost in translation. Investments in new software, hardware, and field tools are also important. To stay competitive in the industry, a company must understand technological changes. Lastly, electrical contractors must continue reviewing and updating their policies and procedures relating to BIM. With experience, a company can grasp the risks associated with BIM and implement procedures and policies to minimize this risk.

The most important part of implementing Building Information Modeling within an electrical contracting company is leadership and commitment. BIM cannot be taken for a test drive. If a

company is to use BIM, they need to be truly committed to the practice and must have leadership within the company to take on the challenge. Additionally, the company must work to fully understand BIM and continue to grow within the concept of information modeling and collaboration with a lean approach.

6.5.2 Implementing BIM on a Project

Creating a BIM model occurs in two phases on a project: the first during the design and the second during construction. At some point the design team transfers the model to the contractors. As a whole, early on the owner, the design team, and possibly construction manager, needs to discuss when the transfer will happen and how early the specialty trades should be involved. Additionally, an agreement should be made on how complete the model will be and what is expected of the specialty trades.

Implementing BIM on a project during construction can be difficult due to the number of members involved. Prior to the beginning of the modeling process, the team must work together to understand why BIM is needed on that particular project. All members involved in the process must have an understanding of the owner's needs when the completed model is turned over to the ownership team following construction. Within the project team, system complexity or contractual requirements might be driving the use of BIM. Additionally, an understanding of each company's needs must be known. A company may use BIM for fabrication purposes, better layout, and/or to visualize their system for improved productivity.

Creating procedures for the project team is also important. All contractors must agree on expectations and how the model will be completed. Additionally, all contractors must be held accountable to these procedures. The following are examples of procedures for use within a project team:

- Determining the team leader,
- Determining how information will be shared,
- Stating the level of detail expected,
- Setting deadlines and standard meeting times,
- Creating procedures for dealing with clashes,
- Choosing standard software, and
- Defining constraints.

6.5.3 Help from the Industry

There are many ways electrical contracting industry groups could help improve the implementation and use of Building Information Modeling within electrical contracting. The first is guidance on how to implement BIM within a company for the first time. As seen from this research, many companies struggle with implementing BIM, mainly due to the fact that implementation can seem daunting, and many companies are unwilling to be fully committed to implementation. Industry groups, such as the National Electrical Contractors Association (NECA), Foundation for Electrical Construction Inc. (ELECTRI International) council members, and Federated Electrical Contractors (FEC), need to provide more guidance for electrical contractors just starting to use BIM, possibly in the form of training, providing common internal procedures, and/or documenting good practices.

The second way electrical contracting industry groups can improve the industry is by creating dialog with other industry and ownership groups about areas on which companies are not concentrating. As discussed within this report, companies are not currently making large investments in external BIM procedures and are not looking to significantly increase their investment in this area in the next two years. Creating external procedures with other industry groups and understanding owner's needs is crucial. Electrical contracting industry groups can facilitate this conversation. There are also other areas that industry groups can help improve, including, but is not limited to, customizing BIM software for electrical contractors, improving fabrication from BIM models, and developing BIM libraries with the assistance of manufactures and suppliers. Additionally, the creation of industry and owner expected BIM procedures would help with the advancement of software development. As shown, Autodesk has control of BIM software development throughout construction. Providing industry standards to Autodesk would help with the development of BIM software and advance the construction industry.

6.5.4 BIM is Not Just a Software

Lastly, individuals, electrical contracting companies, and the electrical contracting industry as a whole must realize that Building Information Modeling is more than just software. As stated in Chapter 1, BIM refers to the creation and use of computer models and collaborative work between companies to improve design and construction of facilities and other infrastructure. Collaboration is the key ingredient to BIM. As revealed through the interviews in this report, most companies realize this but are still working to understand and maximize BIMs potential for collaboration. All parties involved with Building Information Modeling must continue to discuss collaborative efforts both internally and externally. Owners, architects, and construction

managers often dictate collaborative efforts. Electrical contractors must continue to push early involvement and flexibility in the process. Additionally, electrical contractors must have a voice within a project team during the coordination effort so all trades can be on an equal playing level.

6.6 RECOMMENDATIONS FOR FUTURE RESEARCH

This research provides a report revealing the comprehensive use of Building Information Modeling in electrical contracting. The study provided a general overview of electrical contractor's current and future use of BIM. Future research should be conducted where this report may be inconclusive. The following are recommendations for future research either by industry groups or academia:

- **Return On Investment:** As mentioned earlier in this research, no good method for calculating the return on investment from the use of Building Information Modeling currently exists. Many previous researchers and companies have attempted to calculate the value of using BIM, but no consistent results were obtained. Nearly all companies understand that there is a return from using BIM and do not need specific data to show this. Due to the complexity of these factors and the fact that BIM is often required contractually, future research on the use of BIM is not recommended.
- **Cost:** As stated in Chapter 4, electrical contractors are interested in knowing the cost of BIM use for bidding purposes. With two-dimensional CAD, electrical contractors are able to calculate the cost of drafting per linear foot of conduit or per piece of equipment. Today, with the use of BIM, that data is not applicable. Some of the electrical contractors interviewed noted that they are starting to track these cost internally. However, they are interested in knowing the cost of creating a BIM model in the electrical contracting industry.
- **Future Use:** The research contained in this report focuses on the current use of Building Information Modeling. The limited information on the future use of BIM is presented using survey data and interviews. To gain further insight on the future use of BIM in the electrical contracting industry, further research is recommend to help shape and guide the industry as more technology is implemented to improve productivity and profitability.

- **Scope:** The research contained in this report was limited to the electrical contracting industry. To gain an understanding of the use of Building Information Modeling in other trades, research must be expanded to include mechanical, plumbing, fire protection, low voltage electrical, general contractors, and other specialty trades. Additionally, the scope of this research was extremely broad. Individual topics could be explored more closely to gain a better understanding of BIM.
- **Procedures:** A list of best practices pertaining to the use and implementation of Building Information Modeling would be helpful for the electrical contracting industry and probably all of the construction industry. As is the case with all construction, when a contractor has more experience with a topic, they know how to react to a situation. If a best practice list existed for contractors new to BIM, the learning curve would be less steep. Additionally, as mentioned in the recommendations to the industry section, further development of standards is need in order to force further software development.
- **End Users:** In the eyes of many contractors, Building Information Modeling is used for internal construction purposes: coordination between trades, visualizing design, fabrication, scheduling, etc. The use of the model following construction is low on the priority list. Future research should work to understand how owners use the final model and what information they want to see in the model. This understanding will help future owners decide how to use their model and will help contractors in forming the model.

6.7 CONCLUSION

The ultimate goal for this research was to obtain solid data to make recommendations to the electrical contracting industry for improving its use of Building Information Modeling. This research thesis had three major objectives: quantify the current use and impact of BIM, approximate the future use of BIM, and offer the industry recommendations to help improve the understanding and usefulness of BIM. These intentions were achieved through surveying and interviewing contractors in the electrical construction industry in order to determine possible trends and correlations. The findings presented in this report are intended for the use of electrical construction contractors and possibly other trades working in construction to learn more about Building Information Modeling's use and implementation in construction.

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APPENDIX B
COVER EMAIL AND SURVEY QUESTIONNAIRE

This section contains the cover email sent out to the electrical contracting companies throughout the United States. The email details the purpose of the survey and gives directions for responding to the survey. Additionally, this section includes the survey available through the link provide in the email and administrated through Qualtrics.

SUBJECT: Electrical Contracting Research at UW-Madison

Greetings,

My name is Michael Yeutter, and I am a graduate student working with Dr. Awad Hanna in the Civil and Environmental Engineering Department at the University of Wisconsin-Madison. We are conducting research on the use of Building Information Modeling (BIM) in the electrical contracting industry. The goal of the research is to determine the current use of BIM in the industry, the results from using BIM on projects, and to get an idea of the future use of BIM.

Listed below, you will find a link to a survey on the subject matter. The survey is very short and should only take 10 minutes to complete. All responses will be strictly confidential. For the purpose of this survey, BIM refers to the creation and use of computer models and collaborative work between companies to improve electrical design and construction.

Link to survey: https://uwmadison.qualtrics.com/SE/?SID=SV_7WN1dn9bPA2UMcc

(If this link does not work, please copy it into your internet browser)

The results of the survey will be summarized in a report and possibly published within the construction industry. All survey participants will receive a copy of the report. Through our research, we wish to get a better understanding of Building Information Modeling trends in the electrical contracting industry. With this information, electrical contractors will be better prepared for changing design and construction practices.

If you have any questions or concerns, please feel free to contact Michael by email at <yeutter@wisc.edu>.

Thank you for your time and consideration with this research.

Dr. Awad Hanna, P.E

Professor and Chair

Construction Engineering and Management Program

Department of Civil and Environmental Engineering

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Michael R. Yeutter

Graduate Student

Construction Engineering and Management Program

Department of Civil and Environmental Engineering

University of Wisconsin-Madison



The Use of Building Information Modeling in the Electrical Contracting Industry

Current BIM Use

1) How would you characterize your company's level of involvement in BIM?

- We are not using BIM within our company
- We are creating BIM tools to use within our company
- We are using existing BIM tools but are not creating our own tools within our company
- We are creating BIM tools and using existing tools within our company

**If answer to question 1 is "We are not using BIM within our company," please skip to question 18.

2) Which statement best characterizes your company's experience of BIM's business value?

- We are getting no meaningful value from BIM
- We are just starting to understand how much value BIM can provide us
- We are getting value from BIM but believe there is more to learn
- We have maximized BIM potential within our company

3) What is your company's level of expertise with BIM?

- Just started
- Started but not efficient
- Advanced
- Expert

4) On how many projects did your company use BIM in 2010?

5) What is the total number of projects your company was involved with in 2010?

6) How many years has your company been using BIM?

- 1 year
- 2 years
- 3 years
- 4 years
- 5 years
- More than 5 years

7) From your experience, which project team member leads BIM electrical coordination in the modeling (vs. the managing) process?

- Outside Consultants
- Project Architects
- General Contractor
- Mechanical/Electrical Design Consultants
- MEP Specialty Trades
- Others (Please Specify)

8) Please select the BIM software your company is currently using:

- Autodesk AutoCAD Electrical
- Autodesk AutoCAD MEP
- Autodesk Navisworks
- Autodesk Revit MEP
- Bentley MicroStation
- Graphisoft ArchiCAD
- Graphisoft MEP Modeler
- Others (Please Specify)

9) Of the total electrical cost for a project, what is the average percentage that is used for BIM?

- Less than 1.0%
- 1.0% to 2.0%
- 2.0% to 3.0%
- 3.0% to 4.0%
- 4.0% to 5.0%
- More than 5.0%

10) What is the typical size of the projects in which your company is using BIM?

- Less than 10,000 man-hours
- 10,000 to 50,000 man-hours
- 50,000 to 100,000 man-hours
- More than 100,000 man-hours

11) From your experience, what are the risks associated with BIM?

- Cost overrun
- Lack of BIM protocol
- Other (Please Specify)

12) How many BIM staff members are typically on a project?

- 1
- 2 to 3
- 4 to 5
- More than 5

13) Is your company using tool(s) that utilize a completed BIM model?

- Total Stations
- GPS Surveying
- Other (Please Specify)
- We are not using additional tools

14) For each of the following categories, to what extent is your company **currently** investing in BIM?

	None	A Little	Some	Quite A Bit	A Great Deal
Purchasing software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating BIM procedures within the company	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating BIM libraries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating BIM procedures with other companies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training staff with BIM	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marketing BIM capability to potential customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle.

	None	A Little	Some	Quite A Bit	A Great Deal
Feasibility	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Preliminary Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Final Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Construction Documents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Bidding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fabrication	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shop Drawings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Submittals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Closeout	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Operations and Maintenance of the facility	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle.

	None	A Little	Some	Quite A Bit	A Great Deal
Clash detection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost estimation for project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Energy/lighting analysis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Facility space planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
More efficient use of time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project turnover and closeout	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quantity take-off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shop drawing process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stakeholder engagement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Submittal process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Visualization of facility design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle.

	None	A Little	Some	Quite A Bit	A Great Deal
Reduction in RFI's	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in re-submittals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in field conflicts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in deficiency issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in punch list items	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in the cost of rework	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in the cost of as-built drawings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction in change orders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shorter processing time for change orders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Better coordination	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Future BIM Use

18) In the next 2 years, what percentage of your company's projects do you expect will be using BIM?

- Less than 15%
- 15% to 30%
- 30% to 60%
- More than 60%

19) In the next 2 years, please indicate the level of investments you plan to focus on each of the following:

	None	A Little	Some	Quite A Bit	A Great Deal
Purchasing software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating BIM procedures within the company	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating BIM libraries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating BIM procedures with other companies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training staff with BIM	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marketing BIM capability to potential customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Company Background

20) How much were your company's billings in 2010?

- Under \$1 million
- \$1 million to under \$5 million
- \$5 million to under \$10 million
- \$10 million to under \$50 million
- More than \$50 million

21) What type(s) of projects is your company involved in?

- Industrial
- Institutional
- Commercial
- Residential - including high rises
- Remodeling and renovations
- Other (Please specify)

22) What is the state that your corporate office is located in?

23) What area(s) of the United States is your company operating in?

- Northeast
- Southeast
- Midwest
- Southwest
- West

24) Please provide an email address so we can provide your company with the final report:

We thank you for your time spent taking this survey.
Your response has been recorded.

APPENDIX C SURVEY DATA

This section contains data collected from a survey distributed to electrical contracting companies. Information collected from the survey was analyzed and presented throughout this report. Correlation coefficients between data were found using the correlation function within Microsoft Excel. The questions listed below correspond with numbers that appear on the x-axis of the table on the last page of Appendix C. Respondents are listed on the y-axis and are assigned numbers chronologically. The numbers which appear in the table correspond to the provided answers within the survey questions as shown in Appendix B.

- 1) How would you characterize your company's level of involvement in BIM?
- 2) Which statement best characterizes your company's experience of BIM's business value?
- 3) What is your company's level of expertise with BIM?
- 4) On how many projects did your company use BIM in 2010?
- 5) What is the total number of projects your company was involved with in 2010?
- 6) How many years has your company been using BIM?
- 7) From your experience, which project team member leads BIM electrical coordination in the modeling (vs. the managing) process?
- 8) Of the total electrical cost for a project, what is the average percentage that is used for BIM?
- 9) What is the typical size of the projects in which your company is using BIM?
- 10) How many BIM staff members are typically on a project?

- 11) For each of the following categories, to what extent is your company currently investing in BIM? (Purchasing software)
- 12) For each of the following categories, to what extent is your company currently investing in BIM? (Creating BIM procedures within the company)
- 13) For each of the following categories, to what extent is your company currently investing in BIM? (Creating BIM libraries)
- 14) For each of the following categories, to what extent is your company currently investing in BIM? (Creating BIM procedures with other companies)
- 15) For each of the following categories, to what extent is your company currently investing in BIM? (Training staff with BIM)
- 16) For each of the following categories, to what extent is your company currently investing in BIM? (Marketing BIM capability to potential customers)
- 17) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Feasibility)
- 18) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Preliminary Design)
- 19) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Final Design)
- 20) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Construction Documents)
- 21) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Bidding)
- 22) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Fabrication)
- 23) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Construction)

- 24) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Shop Drawings)
- 25) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Submittals)
- 26) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Closeout)
- 27) For each of the following project phases, please indicate the level of value BIM is generating throughout the project lifecycle. (Operations and Maintenance of the facility)
- 28) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Clash detection)
- 29) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Cost estimation for project)
- 30) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Energy/lighting analysis)
- 31) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Facility space planning)
- 32) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (More efficient use of time)
- 33) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Project turnover and closeout)
- 34) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Quantity take-off)
- 35) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Scheduling)
- 36) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Shop drawing process)

- 37) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Stakeholder engagement)
- 38) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Submittal process)
- 39) For each of the following project activities, please indicate the level of value BIM is generating throughout the project lifecycle (Visualization of facility design)
- 40) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in RFI's)
- 41) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in re-submittals)
- 42) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in field conflicts)
- 43) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in deficiency issues)
- 44) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in punch list items)
- 45) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in the cost of rework)
- 46) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in the cost of as-built drawings)
- 47) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Reduction in change orders)

- 48) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Shorter processing time for change orders)
- 49) For each of the following performance indicators, please indicate the level of improvement from the use of BIM throughout the project lifecycle (Better coordination)
- 50) In the next 2 years, what percentage of your company's projects do you expect will be using BIM?
- 51) In the next 2 years, please indicate the level of investments you plan to focus on each of the following. (Purchasing software)
- 52) In the next 2 years, please indicate the level of investments you plan to focus on each of the following. (Creating BIM procedures within the company)
- 53) In the next 2 years, please indicate the level of investments you plan to focus on each of the following. (Creating BIM libraries)
- 54) In the next 2 years, please indicate the level of investments you plan to focus on each of the following. (Creating BIM procedures with other companies)
- 55) In the next 2 years, please indicate the level of investments you plan to focus on each of the following. (Training staff with BIM)
- 56) In the next 2 years, please indicate the level of investments you plan to focus on each of the following. (Marketing BIM capability to potential customers)
- 57) How much were your company's billings in 2010?

APPENDIX D INTERVIEW QUESTIONS

This section contains questions used during the interview process. This information was analyzed and presented throughout this report as a way to provide further backup and fill in missing information.

- 1) Please characterize your company's level of involvement in BIM.
 - a. How would you characterize the construction industry's level of involvement in BIM?
 - b. How would you characterize the electrical contracting industry's level of involvement in BIM?
- 2) How many years has your company been using BIM?
- 3) What is your company's level of expertise with BIM?
- 4) How would you best characterize your company's your company's experience of BIM's business value?
- 5) From your experience, which project team member leads BIM electrical coordination in the modeling process (vs. the managing process)?
- 6) What BIM software is your company currently using?
- 7) Of the total contract cost for a project, what is the average percentage that is used for BIM?
- 8) What is the typical size of the projects in which your company is using BIM?
- 9) From your experience, what are the risks associated with BIM? Please comment.
- 10) How many BIM staff members are typically on a project? Please comment.
- 11) Is your company using tool(s) that utilize a completed BIM model?

- 12) To what extent is your company currently investing in BIM?
- 13) Please speak to the level of value BIM is generating throughout the project lifecycle:
- a. During project phases (i.e. Preliminary design, construction documents, shop drawings, etc.)?
 - b. Project activities (i.e. clash detection, energy analysis, scheduling, etc.)?
- 14) Please speak about the level of improvement seen during the project from using BIM. What areas specifically?
- a. What improvement have you seen in the electrical contracting industry?
- 15) In the next two years, does your company plan on increasing its use of BIM?
- 16) In the next two years, what areas of investment with BIM does your company plan on focusing (i.e. software, procedures, training, etc.)?
- a. What areas should the electrical contracting industry focus on?
- 17) How can the electrical contracting industry improve its use of BIM?
- 18) Any other comments?