# Understanding and Leveraging BIM Efforts for Electrical Contractors

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**Abstract –**
**The increased complexity of construction projects coupled with the increase in customer expectations has fueled electrical contractors' interest in innovation as a source of competitive advantage. Emerging technologies such as Augmented Reality and Digital Twins have recently gained momentum in the electrical construction industry. While these emerging technologies provide a novice approach to visualizing construction work, most of their use-cases are based on Building Information Modelling (BIM). Therefore, to unlock the full potential of emerging technologies, it is important to properly allocate and leverage BIM resources on a construction project. Therefore, this research aims to provide electrical contractors with a set of tools to understand and leverage their BIM resources before and during construction. To achieve the research objective, a survey was developed, and 23 complete responses were collected to identify factors that impact the actual percentage of electrical contractors' BIM Efforts. The survey results were augmented with follow-up structured interviews with subject matter experts having electrical and BIM experience. BIM practices collected from the interviews were grouped into three categories: people, process, and technology. The study aims to provide electrical contractors with a set of tools to leverage their BIM resources before and during construction. This study also highlights some of the ongoing challenges faced by electrical contractors when managing BIM changes during project execution.**

**Keywords –**
**Building Information Modeling; Electrical Contractors; BIM Effort Factors; Best Practices**

## 1 Introduction

Building Information Modeling (BIM) is a construction industry evolution that transformed the use of analog drawings into digital electronic BIM. It is defined by the National BIM Standard-United States (NBIMS) as "a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward" [1]. Autodesk defines BIM as "an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure" [2].

BIM can benefit all parties and stakeholders of any construction project, and subcontractors are no exception. BIM process can provide subcontractors with more control over their project, especially on cash-flows, service levels, resources, and change orders [3]. The 3D model-based BIM process helps MEP professionals in designing, detailing, and documenting building systems, all of which leads to improved accuracy, reduction in clashes, optimization of building system designs, improved collaboration and data sharing, and an increase in the transition from design to construction [4].

For mechanical and plumbing, BIM and 3D models did become the new norm; however, for electrical contractors, the use of BIM is still expanding [3]. Major reasons for this delay include the lack of standards, specifications, and software for rendering an intelligent electric design model in BIM [5], in addition to the size of electrical elements where modeling larger elements such as duct systems and air handlers are approachable options, while smaller elements such as electrical switches and outlets might prove more challenging [6]. This generated extensive industry effort to further promote BIM with electrical contractors, develop appropriate software and add-ons, identify industry practices, and provide BIM-friendly data beyond dimensions for elements like switch gears, pumps, and motors [4] [7].

[8] developed a survey targeting electrical contractors who are members of the National Electrical Contractors Association Construction (NECA) to study the state of practice of BIM adoption in 2009. Results showed that most companies using BIM are medium or large sized and they mostly use BIM on healthcare and commercial

projects. Electrical contractors preferred to model rigid components such as branch and feeder conduits and valued clash detection the most.

[9] conducted another research to study the state of practice of BIM with electrical contractors in 2014 through a survey distributed to members of the National Electrical Contractors Association (NECA), ELECTRI International, and Federated Electrical Contractors (FEC). This study showed an increase in the adoption of BIM in the electrical construction industry and an increase in BIM knowledge. Forty-one percent of study participants reported that MEP specialty trades lead the modelling coordination effort, 35% said general contractor, 14% mentioned electrical consultants. The study also suggested that it is safe to assume that the majority of staffing for BIM implementation is three or fewer.

BIM can result in major gains for electrical contractors. However, to create the 3D models, electrical contractors need to spend more time and resources on 3D modelling than traditional 2D drawings [3]. Different factors exist that affect the time and effort needed by electrical contractors to implement BIM and conduct 3D modelling. Such factors are not always internal, but they go beyond the company. This makes it impossible to isolate external factors and variables that affect the use of BIM for electrical contractors [10] [11]. Most recently, [6] investigated the impact of design and scope changes on the modelling performance of elerical contractors. Buidling on the existing work performed in the area of BIM modelling for electrical contfractors, this research, sponsored by the National Electrical Contractors Association, aims to provide electrical contractors with a set of tools to leverage their BIM resources before and during construction.

## 2 Research Method

The methodology employed to achieve the research objective consists of five tasks. The first task consisted of synthesizing existing work on BIM. The review of literature allowed for the identification of key variables for allocating BIM efforts and a survey, acting as a foundation for the data collection efforts of this research, was designed to gather qualitative data from electrical contractors. The survey consisted of four phases: 1) contractor data, 2) project information, 3) parties' relationships, and 4) BIM. The first section included company-specific questions and the three remaining sections asked project-specific questions. Once the survey was developed, a pilot version was distributed to the Task Force supporting this research effort. Seven experts reviewed the survey and made a valuable contribution to the research effort. The survey was then polished and fine-tuned before mass distribution. The survey was transcribed into Qualtrics, a digital survey platform, and into an excel spreadsheet for ease of use. The Task Force supported the researchers in their data collection effort and distributed the survey to member companies of the National Electrical Contractors Association (NECA) and companies in their network soliciting their participation in the study. Once data was collected, statistical analysis was performed in the third task to identify factors that can impact electrical contractors' BIM effort.

The outcomes of the survey informed two questions on BIM best practices and BIM challenges which were further pursued in the fourth task with follow-up online meetings and interviews with industry practitioners and subject matter experts who have electrical and BIM experience. Structured interviews were conducted through NECA with nine electrical contractors and 14 subject matter experts having, on average, 20 years of electrical experience and 10 years of BIM experience. The interview data was then analyzed as the last task and recommendations on best practices and areas of improvement were formulated.

## 3 Survey Results and Analysis

A total of 23 complete responses were collected throughout the survey.

### 3.1 Characteristics of Electrical Contractors Surveyed

The annual electrical and low voltage systems *revenue* of the 23 electrical contractors who took the survey was uniformly distributed across the four revenue categories: 30% of respondents selected less than $50 million, 22% between $50 and $100 million, 26% between $100 and $250 million, and the remaining 22% of responses came from contractors with revenue over $250 million. This distribution expresses a general view of the use of BIM in the electrical construction industry. Compared to the 2014 study, the results of this survey indicate a balanced representation of companies of various sizes, highlighting the growth of BIM in the electrical construction industry.

Despite the equal distribution of companies in size, the *annual revenue of projects using BIM* varied within the industry. Of those who responded to the survey, 22% said that the annual revenue of projects using BIM within their company is less than $100 million, 13% selected between $10 and $25 million, 13% between $25 and $50 million, 30% between $50 and $100 million, 13% between $100 and $250 million, and 9% over $250 million. This unequal distribution shows that the frequency and types of projects on which BIM is used vary within the electrical construction industry.

At the portfolio level, the bulk of the 23 electrical contractors (61%) indicated that they develop all their BIM models *in-house* and very few electrical contractors (9%) *outsource* BIM. Respondents were asked about the breakdown of their BIM efforts between *detailing* and *coordination* across their project portfolio. On average, the majority of the 23 electrical contractors who participated in the survey reported that they spend more time on the BIM detailing efforts than the BIM coordination efforts.

Respondents were asked to report the number of full-time BIM modelers employed within their company. To get a better understanding of this variable, the number of full-time BIM modelers was plotted with respect to the size of the company Figure 1. The gray circles in Figure 1 represent individual responses and the green circles represent the average per category of size. Compared to the 2014 study [9] the data displayed in Figure 1 indicates that electrical contractors have been investing more in BIM as the number of BIM modelers has. The graph shows that larger companies hire more full-time BIM models with the average number of Full-time modelers ranging between 2 for small companies and 15 for larger companies according to the survey results. This observation was tested statistically using a correlation test and a positive correlation was detected between the two variables.

## 3.2 Characteristics of Collected Projects

Main features of the data collected from the three remaining survey sections are presented here where respondents were asked to provide information on one complete construction project. Data collected from 23 construction projects is described in the following sections. It is worth noting that respondents have selected an exemplary project to use for the survey. Thus, the results displayed in this paper represent data collected from good projects.

### 3.2.1 Relationships with Stakeholders

An example of the data collected here is presented for the relationship between electrical contractors and project owners. This section of the survey asked respondents to select a particular project for which they were asked if they had previously worked with the same owner before and 78% of respondents said yes. This 78% of the respondents were then asked to assess their past relationship with the owners using a five-point Liker scale of poor (1), fair (2), good (3), very good ($), and excellent (5). On average, these respondents reported that they had a very good relationship. Then all survey respondents were asked to evaluate their relationship with the owner of the project they have selected for the survey and on average, respondents said that they had a very good relationship with the owner.

The same type of questions was asked to assess the relationships of electrical contractors with the Architect/Engineer (A/E), general contractor (GC), and other trade partners on the project.

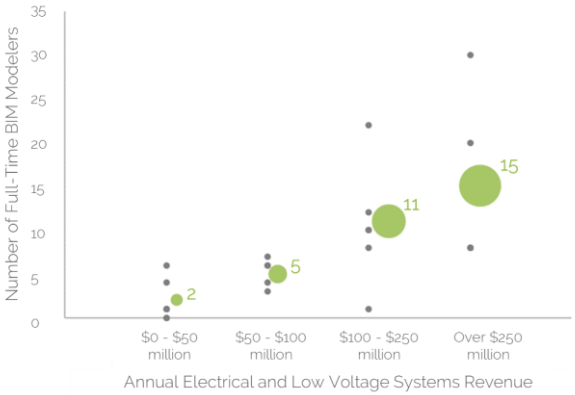


Figure 1. Number of full-time BIM modelers vs size of electrical contractors

### 3.2.2 Electrical Contractors' Perspective on Design

Respondents were asked about the design quality of the project they selected for the survey. Their perspective was measured on a five-point Liker scale of very poor (1), poor (2), average (3), good (4), and very good (5). The aggregated data indicated that the quality of the design is perceived as average by electrical contractors. It is important here to note that the projects respondents selected for the survey were exemplary projects.

Respondents were also provided with five design issues and were asked to indicate if they have experienced any on the project they selected for the survey. The results of this data show that 87% of the projects experienced design coordination, 83% additions, 74% deletions, 52% design errors and 43% reworks.

### 3.2.3 Electrical Contractors' Use of BIM

Respondents were asked to specify how BIM was used on the selected project Figure 2. The majority of respondents indicated that they have used BIM for 3D coordination and clash detection, MEP coordination, As-built drawing model, and drawings derived from the models.

### 3.2.4 Actual Percentage of Electrical Contractors' BIM Efforts

Respondents were asked to indicate the total actual project hours and the total actual hours spent on BIM. From these two variables, the *actual percentage of electrical contractors' BIM efforts* was calculated as follows: The actual percentage of electrical contractors' BIM efforts equals the actual hours spent on BIM divided by the total actual project hours (for electrical

contractors). The collected data shows that the percent effort of BIM ranges between 0.15% and 6.71% with an average of 2.94%. The actual percentage of electrical contractors' BIM Efforts is a key variable in this study and is used (as shown later) to identify the factors that can impact electrical contractors' BIM efforts.

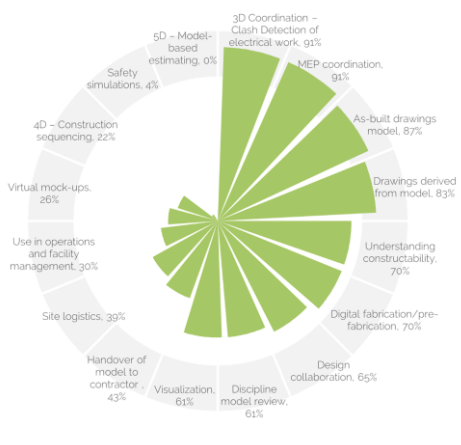


Figure 2. Electrical Contractors' use of BIM

#### 3.2.5 Distribution of BIM Resources on Construction Projects

Respondents were asked to specify the number of full-time and part-time BIM modelers used on the project used for the survey. Each set of a circle and cross corresponds to a project. Figure 3 shows that the data can be split into two groups. The first group highlighted here has an average project size of 12.8 million dollars, an average of two full-time BIM modelers and 1 part-time BIM modeler per project. The average percent BIM effort of this group is 2.83%. The second group highlighted to the left includes two projects with an average size of 190 million dollars, 13 Full-time BIM modelers on average and 4 part-time. The average percent of BIM effort for this group of large projects is 4.06%.

### 3.3 Statistical Analysis

The survey data was analyzed using three statistical tests: correlation test, Mann-Whitney-Wilcoxon (MWW) test (the non-parametric version of t-test), and Kruskal-Wallis test (the non-parametric version of ANOVA). All key findings are presented below, and significance for all three tests is reported at the 95% confidence level.

#### 3.3.1 Impact of Company Profile on BIM Efforts

- There exists a positive correlation (0.48) between the *annual electrical and low voltage systems revenue* and the *percentage of in-house BIM models*. On average, larger electrical contractors tend to develop BIM models in-house.
- There exists a strong positive correlation (0.81) between the *annual electrical and low voltage systems revenue* and the *annual revenue of projects using BIM*. On average, larger electrical contractors tend to use BIM more than smaller electrical contractors.
- There exists a strong positive correlation (0.68) between the *annual electrical and low voltage systems revenue* and the number of *full-time BIM modelers*. On average, larger electrical contractors tend to fire more full-time BIM modelers
- There exists a strong positive correlation (0.84) between the *annual revenue of projects using BIM* and the number of *full-time BIM modelers*. On average, electrical contractors with a higher revenue generated from projects suing BIM tend to hire more full-time BIM modelers.
- The percentage of BIM models created *in-house* by electrical contractors is, on average, significantly higher than the percentage of *outsourced* models.
- Considering the portfolio of construction projects, the percent effort spent by electrical contractors on *detailing* is significantly higher than the percent spent on *coordination*.
- On average, there exists a strong positive correlation between the *annual electrical and low voltage systems revenue* (size) of electrical contractors and the *actual percentage of electrical contractors' BIM efforts*. Larger electrical contractors spend more time on BIM on their construction projects.

#### 3.3.2 Impact of Electrical Contractors' Relationships with Project Stakeholders on BIM Efforts

- There exists an inverse correlation (-0.39) between the *actual percentage of electrical contractors' BIM efforts* and their *past relationships with A/E*. The better the relationship with A/E on previous projects, the lower the percent BIM effort spent by electrical contractors on future projects with the same A/E.
- There exists an inverse correlation (-0.47) between the *actual percentage of electrical contractors' BIM efforts* and their *current relationship with A/E* on the project. The better the relationship with A/E on the ongoing project, the lower the percent BIM effort spent by electrical contractors.
  There exists an inverse correlation (-0.31) between the *actual percentage of electrical contractors' BIM efforts* and their *past relationships with GC*. The better the relationship with GC on previous projects, the lower the percent BIM effort spent by electrical contractors on future projects with the same GC.


Figure 3. Overview of the allocation of electrical contractors' BIM resources on construction projects

- There exists an inverse correlation (-0.42) between the *actual percentage of electrical contractors' BIM efforts* and their *current relationship with GC* on the project. The better the relationship with GC on the ongoing project, the lower the percent BIM effort spent by electrical contractors.
- There exists an inverse correlation (-0.42) between the *actual percentage of electrical contractors' BIM efforts* and their *current relationship with the other trade partners* on the project. The better the relationship with the trade partners on the ongoing project, the lower the percent BIM effort spent by electrical contractors.

### 3.3.3 Impact of Design on BIM Efforts

- There exists an inverse correlation (-0.42) between the *actual percentage of electrical contractors' BIM efforts* and the *quality of design*. The better the quality of design, the lower the percent of BIM effort spent by electrical contractors.
- The more *design issues* experienced on the project, the higher the percent of effort needed from electrical contractors to manage the BIM models.
- There is a significant relationship between the *actual percentage of electrical contractors' BIM efforts* and *design coordination issues* experienced on the project. Projects that experience design coordination issues result, on average, in a need for electrical contractors for a higher percent of BIM effort needed to manage the project.

### 3.3.4 Impact of BIM applications on BIM Efforts

- The more *BIM applications* used by electrical contractors on the project, the higher the percent of effort needed from electrical contractors to manage the BIM models.
- There is a significant relationship between the *actual percentage of electrical contractors' BIM efforts* and the following *BIM applications*.
    - MEP Coordination
    - Understanding Constructability
    - Digital Fabrication/Pre-fabrication
    - Design Collaboration
    - Visualization
    - Handover of Model to Contractor

Projects that use the above-listed BIM applications result, on average, in a need for electrical contractors for a higher percent of BIM effort needed to manage the project.

### 3.3.5 Impact of Updating BIM during Execution on BIM Efforts

There is a significant relationship between the *actual percentage of electrical contractors' BIM efforts* and the following reasons for electrical contractors to *update BIM models during execution*:

- Design Changes
- Incomplete information in the model by other trades
- Owner's request
- Incomplete information in the model by the electrical contractor

Projects that experience any of the above-listed reasons for updating BIM models result, on average, in a need for electrical contractors for a higher percent of BIM effort needed to manage their BIM effort.

## 4 BIM Best Practices for Electrical Contractors

Electrical and BIM subject matter experts were asked during the interviews to share practices they have found to be successful in managing the BIM effort during project executions. The feedback collected from the 9

interviews was consolidated into three major themes: People, Process, and Technology (Figure 1). The following sections synthesize the best practices and lessons learned shared by the interviewees and provide electrical contractors with an overview of current BIM practices that can guide their implementation. The outlined practices also assist the electrical contractor in mitigating the impact of the project variables that have a significant impact on the percent effort spent managing BIM during execution.

## 4.1 People

The people-related practices that assist electrical contractors in managing their BIM effort during execution are summarized in this paper. The analysis of interview data showed that five best practices were collected at two levels: 1) internal to the electrical contractor and 2) at the interface between the electrical contractor and other project stakeholders. Practices are discussed in the subsequent sections.

### 4.1.1 Maintain Strong Relationships within the Electrical Team

Establishing and maintaining a solid working relationship between the project management team, BIM team, and field operations team is key to managing BIM efforts. Trust must be built between these three teams internally. The BIM modelers should be the link that connects the field to the office and need to communicate with the electrical team regularly (weekly conversations, daily huddles, etc.) to ensure alignment among the team members. Project managers also play a critical role in supporting the electrical team and enhacing its performance but establishing parameters for modelers to use consistently during the duration of the project, and thus, reducing errors, mistakes, and potential rework.

### 4.1.2 Hire the Right BIM Modelers

Developing and maintaining a good BIM model is not a simple task and the knowledge, attitude, and expertise of BIM modelers has a significant impact on the success of the construction projects. Interviewees noted that BIM modelers need to be able to get buy-in from the field operations team.They need to be detail-oriented with electrical background and field experience either directly or vicariously by working closely with the field workers. BIM modelers have to collaborate with the foreman and the people who are boots on the ground installing the electrical work. This collaboration brings invaluable knowledge and feedback for a modeler because it captures constructability knowledge and streamlines the as-built phase.

### 4.1.3 Empower Field Workers

Interviewees noted that electrical contractors need to empower field workers to be accountable. If workers see discrepancies between the model they are using in the field and actual conditions of other trades, they can send the electrical contractor an image of what is in the field along with an image of the model. The electrical contractor will then follow up with the GC.

### 4.1.4 Build Strong Relationship among Stakeholders

In addition to establishing and maintaining strong relationships internally, the relationship at the interface between electrical contractors and other project players is paramount. Having the right players who are updating models regularly is critical. Moreover, communication between project participants is essential especially when new changes are to be made in the model. Interviewees stated that receiving a notice of an upcoming change from the A/E, GC, or trade partner would help electrical contractors be prepared to fit the changes within their schedule and communicate the changes to the field.

### 4.1.5 Have the Right Entity Lead the BIM Coordination Effort

The project person/entity leading the multi-trade BIM coordination effort and setting the expectations plays a key role in the successful management of BIM. The leading entity should hold project team members accountable and leverage the available tools.

## 4.2 Process

People-related practices shared by the 14 interviewees are outlined in the next sections.

### 4.2.1 Start Right: Invest in Project Setup Standards

When embarking on a new construction project, the electrical contractor needs to start right. The following practices were consolidated from the interviews to assist electrical contractors in laying the right foundation to start the BIM process:

1. Ensure that control is set for the site and facility.

- Get the control points on site before any layout. Ensure control points are in a location that will not be disturbed throughout the construction of the project. This process is time consuming, but if done properly it can be very rewarding.
- All teams need to agree to the same three points of column line intersection point offsets.
- Make sure all layout teams check in on every level of the project and have the same coordinates on their machines. Documents these check-ins.
- Place the control points in the model.
- When control is set properly for the project, all subs will take control from the same points to start.

2. Use an object to verify the placement of the structural and architectural models in the Navis Model respective to the column lines and elevations. This should be done against a corner just on top of the floor. When all trades align, then you should be good to start modeling.

#### 4.2.2 Implement BIM Resolution Workflows

Electrical contractors are encouraged to implement a BIM issue resolution workflow where they document the issues, who is responsible to resolve them, and how they were resolved. This process is similar to maintaining an updated constraint logs for BIM issues encountered during project execution. To maximize the value of these practices, it should be applied to everyone on the project including the owner, A/E, GC, and trade partners.

#### 4.2.3 Develop Standard Operating Procedures

Developing standardized processes plays a major role in enabling continuous improvement and sharing knowledge. Among the process-related practices discussed is the development and use of BIM Standard Operating Procedures (SOP). Interviewees highlighted the need to standardize processes internally especially as the team grows, streamline documents into a centralized reference, and set up modeling templates for the project (use the same families and annotations for example).

#### 4.2.4 Establish Modeling Guidelines

Establishing modeling guidelines and rules at the front end of the project for all participants who need to develop, use, access, or update the BIM models is important to build standardization, transparency, traceability, and accountability into the project. Some suggested modeling practices shared by the interviewees included:

- Hold an internal kick-off at the beginning of every project to establish the modeling guideline for the project.
- Provide NWC files that include model parameters to field workers to give them all the information they need to do the installation.
- Isolate modelers from working on top of each other.

#### 4.2.5 Manage Data

To create a reliable BIM dataset, it was recommended that electrical contractors keep a rework log to track BIM time that is out the expectancy of the electrical contractor (time that wouldn't have been budgeted to begin with).

#### 4.2.6 Provide Training

Interviewees encouraged electrical contractors to provide training videos to ensure the cohesion of the BIM team.

#### 4.2.7 Keep Yourself In Check

Interviewees emphasized that trades need to run clash detection between themselves and other trades and resolve any clashes prior to uploading the models and before the coordination meeting. Coordination meetings are to handle difficult challenges that need the team to solve them.

### 4.3 Leverage the Use of Technology

The technology-related practices fall into two major categories: leverage cloud-based technology and utilize new technologies.

Regarding cloud-based technology, interviewees shared the following practices:

- Cloud-based software such as BIM360 and Procore enable models to be centrally located, enhance documentation sharing, and allow access to the most current information instantly.
- Leverage cloud-based workflows for more streamlined processes and allows multi-regional teams to work together.
- Use cloud-models internally.
- Interviewees also noted the the benefits of using new technology to help manage an up-to-date and accurate model such as productivity applications and 360 photographs/video and laser scanners to help confirm the install

## 5 BIM Challenges for Electrical Contractors

Interviewees also shared the following major challenges faced by electrical contractors when managing BIM changes during project execution:

- Trades using a different technology (i.e., 2D vs 3D) and different file formats being shared.
- How frequently do trades update their models (i.e., every few hours or every week for instance).
- Base model does not get updated after contract execution.
- Agreement of model ownership.
- Lack of accuracy of the trades.
- Sign-off dates can be aggressive.
- BIM coordination process begins on an incomplete design.
- Design changes need to cascade to the prefab team and the field before installation.
- Receiving feedback from the foremen is as good as the information provided to them.
- Scope creep.
- What is contractually required by the GC and what is required or requested by the electrical operation team needs to be clearly defined.

- The actual set-up of the model.
- Time commitment and investment into developing the BIM model before execution.

## 6 Conclusions

This research aimed to help electrical contractors understand the factors that impact the level of effort needed to develop BIM models and to provide the electrical contracting community with best practices to efficiently manage and update BIM models during execution. Following a literature review, a holistic survey was developed and a total of 23 completed responses were collected. The statical analysis of the collected data showed that the following project variables have a significant impact on the actual percentage of electrical contractors' BIM efforts: past and current relationships with project A/E and GC, current relationships with project trade partners, design quality, design coordination, MEP coordination, and the use of BIM for visualization, design collaboration, digital fabrication and prefab, handover of the model to the contractor, and understanding constructability. Follow-up interviews were conducted to collect further details from electrical contractors on their uses and perceptions of using and managing BIM during construction. Shared BIM practices were grouped into people, process, and technology practices. Ongoing BIM challenges were also shared by the interviewees, highlighting areas in need of improvement.

It is important to recognize that BIM practices vary across electrical contractors and given the uniqueness of every company, future work could focus on studying a company's BIM database to develop accurate models to help the company better estimate its BIM efforts. Addiotnally, while data was collected for the Level of Development (LOD) of BIM, the responses collected for each level did not enable the analysis of this variable. A trend was however detected showing that projects with LOD greater than 350 result in greater efforts. Future research can analyze the LOD for major electrical assets and their impact on the overall electrical BIM efforts.

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