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BUILDING INFORMATION MODELING: A REPORT FROM THE FIELD

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ABSTRACT

Since its inception in the early 2000s, Building Information Modeling (BIM) has evolved from an emerging innovation to an integral part of the construction industry. Though the benefits of BIM during the preconstruction and coordination phases have been thoroughly researched and documented, investigation into the present status of BIM implementation at the construction phase has remained primarily theoretical. This article aims to record the current state of field level BIM use by General Contractors in order to gain insight on how BIM is being implemented at the construction site today. The data used for analysis was collected via a nationwide survey distributed to several internationally known General Contractors. Through this research, the goal is not only to understand the ways through which field level employees are using BIM on their projects, but also to determine the underlying structures of the field implementation processes, the employees' comfort navigating the technology, the perception of BIM's reliability, and the impact of Lean Construction on project sites through use of the BIM. From this article's findings, it is the authors' hope that companies can leverage the information to stimulate training, revise inefficient BIM implementation structures, and further the integration of BIM and Lean at the field level.

KEYWORDS

Building Information Modelling, Collaboration, Continuous Improvement, Value

INTRODUCTION

Over the past 25 years, the use of BIM in the AEC industry has evolved from a technological novelty, to an integral part of the present day building and design process (van Nederveen and Tolman, 1992). During this same time period, research into the use and value of BIM in construction has steadily increased, providing insight into the implementation of the technology in a wide variety of building stages and conditions. This increase in research has helped to define the quantifiable benefits of BIM as well as

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theorize additional ways BIM may be used beyond design development and coordination. Though large strides have been made in understanding BIM's impact on the AEC field, current research into the present state of BIM usage at the operational level is lacking. Through this paper, the authors seek to understand both the current use of BIM and the current intersections of BIM and Lean at the field operational level on a national scale in order to help further industry understanding in those areas.

LITERATURE REVIEW

In the study "The Perceived Value of BIM", Becerik-Gerber and Rice (2010) found that less than half of AEC companies surveyed used BIM on their projects in any capacity. Of the companies taking advantage of the technology, benefits were noted in project profitability, decreased project costs, reduced project duration and increased quality and accuracy of construction documents. It was noted by survey participants, however, that "in order to effectively study the value of BIM and for significant returns on investment to be noticed, a time frame of 5 to 8 years is needed"

Since that time, academics and industry professionals have further explored the presence of BIM in construction. Sacks et al. (2010a) researched connections between BIM and Lean Construction, hypothesizing ways that BIM could further be used to affect change in the AEC realm. Dave et al. (2011) and Sacks et al. (2010b) piloted BIM programs (Visilean and KanBIM respectively) and both integrated Lean concepts within the BIM environment to support the management of construction operations. Bhatla and Leite (2012) suggested a framework to integrate BIM and the Last Planner System®,(LPS) which promotes the use of multiple Lean concepts to protect production tasks from uncertainty and stabilize the flow of tasks on site. On a similar note, Harris and Alves (2013) have discussed how BIM could be used on site to promote transparency, enhance communication between parties, and prevent wasteful activities. More recently, Lin and Golparvar-Fard (2016) have integrated 4D BIM with the capture of site images to manage construction activities in real time, and provided an unprecedented level of visualization of tasks indicated in multiple levels of the LPS.

Though these studies were ground-breaking in their investigation into BIM's relation to the construction process, little information was found which could serve to elucidate and quantify the degree to which BIM is being used on construction sites today and why its full potential has not yet been achieved. Practitioners and academics understand that BIM has yet to be fully used to manage field operations and synergistically promote Lean principles. As such, this study was performed in order to help bring clarity to the current status of field BIM implementation and indicate potential areas that need to be addressed if the industry is to achieve the numerous synergies identified by Sacks et al. (2010a).

METHODOLOGY

The survey questions and format were assembled over several iterations between October 2015 and December 2015. Following completion of the survey, it was recreated electronically for ease of testing and distribution, reviewed with industry professionals for content value, and distributed to a test group of individuals for confirmation of response timing and technical soundness. SurveyMonkey was used to create and distribute the survey.

Next, three internationally recognized general contractors were approached for inclusion in the study. All three companies were provided with identical surveys via separate, company specific survey links. An upper level management figure was presented with their company's specific survey link as well as verbiage describing the study. The link and verbiage were then disseminated to field employees via distribution email lists for response. Over the survey period of December 2015 to February 2016, a total of 149 survey responses were received.

The survey was composed of four major sections covering the respondent's personal demographics and BIM use. The first section asked general questions regarding the participant's location, role, construction experience, in addition to current project type and size. The second section asked respondents to detail their current use of BIM in the field via answers to multiple choice and fill in questions. The third section covered the respondent's access to tools and training for BIM. The last section asked the respondents questions regarding their opinion on the current value of BIM in field operations.

SURVEY RESULTS

This section discusses the results of the survey and puts them in context by comparing the results obtained from this study to previous studies when these are available for the same items analyzed in this study. The section starts with a discussion about the demographics and moves on to analyze BIM usage by different professionals with different roles and in projects with varied sizes, and the use of BIM-related tools.

RESPONDENT DEMOGRAPHICS

A total of 149 completed survey responses were received over the course of a two-month collection period. Of the three international general contracting firms approached to participate, the majority of the responses were received from one of the three GCs. Though it is possible that the lack of company diversity in the received responses impacted the representative nature of the data, the authors believe that the geographical spread of the data may limit the influence that localized corporate leadership choices could potentially have on the use of BIM in the field. The demographics of the survey can be summarized in the data presented below:

- 88% of respondents were located in Southern California, San Francisco, CA, Washington DC, Phoenix, AZ or Dallas, TX.
- The most frequent responders were Project Managers (48.3%); though Superintendents (22.1%), Project Engineers (19.5%), and BIM Coordinators (4.7%) were also represented.
- Approximately 1/3 of the respondents (37%) were still fairly early in their careers (0-10 years of industry experience). The remaining 2/3 of the respondents (63%) had been a part of the construction industry for 10 or more years.

- 16.1% of respondents were currently working on projects between 0-10MM, 62.4% on projects between 10-100MM, and 21.5% working on projects with values over 100MM.
- Most currently accepted delivery methods were represented in the sample, with 65.8% of the respondent's projects having a CM, GC, or DB delivery method

BIM USAGE IN FIELD OPERATIONS

When asked about individual usage of BIM, over 1/3 (37.6%) of the respondents reported that they did not personally use BIM on their current project. Of those that used BIM, the most common response (25.5%) was that BIM was used at least once per week. Comparing the proportion of people who used BIM between once a day and once per week, to those that did not use BIM at all, the amount of respondents were close in percentage (38.3% and 37.6%, respectively). As these responses are on either end of the BIM usage spectrum, this could indicate a dichotomy in the use of BIM on jobsites, with certain roles more frequently using BIM due to need or task delegation, while others of different roles may rarely open the model, if at all. This may also mirror a dichotomy in the application of Lean construction principles. The 37.6% of respondents not using BIM, will not have the opportunity to experience enhanced visualization and higher levels of transparency, at the field level, while those using BIM once or more per week will likely capitalize on these added benefits and enjoy better communication, shorter cycle times to identify and resolve problems, and fewer unnecessary steps to complete tasks. Though previous research did not cover the use of BIM at the field operations level in depth, a survey distributed and analysed in Becerik-Gerber et al (2010) report indicated a similar duality for their respondents with 38.9% of firms using BIM for 80-100% of their projects, and 30.0% using BIM for 0-20% of their projects.

Following the review of the individual uses of BIM, the effect of job role on personal BIM usage was explored. Figure 1 shows that BIM Coordinators used the BIM the most often of the job roles, with 85.7% of BIM coordinators using BIM daily. Superintendents, on the other hand, had the highest instances of BIM not being used, with 51.5% of superintendents not personally using BIM on their current projects. Project engineers showed a fairly even split between BIM being used daily (20.7%) and rarely (27.6%), while the majority of PMs appeared to be either not using BIM at all (38.9%) or using it once per week (27.8%).

These findings seem to indicate the use of BIM and thereby the increase of potential positive BIM-Lean construction interactions, currently vary by project role. BIM Coordinators are required to use BIM on a daily basis to perform their work, while Superintendents and Project Managers, arguably two of the most important roles running a project, are not benefiting from the potential that BIM has when it comes to supporting production planning and control, simulation of activities during preconstruction meetings, and visualization to clear constraints and clarifications about systems. Moreover, this finding might also indicate that the responsibility for onsite BIM tasks do not fall on the entire team. This conclusion is further supported when reviewing survey responses regarding the inclusion of an onsite staff member who is tasked with BIM. Over half of the respondents (55.6%) indicated that there was a dedicated staff member for BIM tasks on their project. If so much of the responsibilities for using the BIM falls onto one single individual in so many projects, leveraging the synergies between BIM and Lean on site, is limited to how much this individual understand how BIM can lead to increased value delivered to clients (on site and the end users), better flow, and reduced waste.

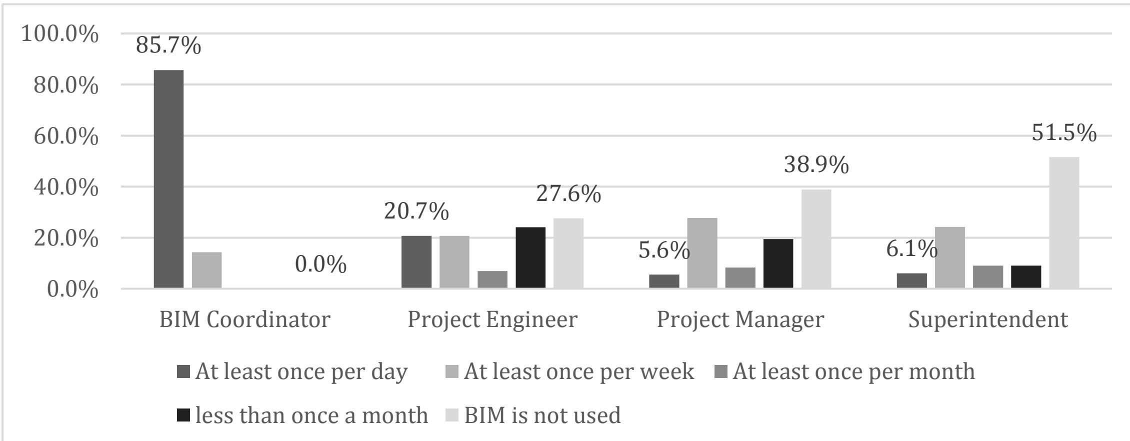

Figure 1: BIM Usage by Job Role

Respondents were next asked the ways through which BIM was used at their project site. The results of that question have been captured in Table 1.

Table 1: BIM Use by Task and Relative Location of Task Performance

	Percentage of BIM users who used BIM to assist with:	**Percentage of BIM tasks performed onsite**	**Percentage of BIM tasks performed remotely**	**Percentage of BIM tasks performed both onsite and remotely**
Clash Detection?	83.9%	34.6%	43.6%	21.8%
4D Scheduling?	10.8%	30.0%	40.0%	30.0%
Safety?	19.4%	72.2%	11.1%	16.7%
QA/QC?	28.0%	80.8%	3.8%	15.4%
Logistics Management?	20.4%	63.2%	21.1%	15.8%
Field Coordination?	61.3%	70.2%	12.3%	17.5%
Activity/Task Management?	16.1%	60.0%	13.3%	26.7%
Visualizing/Explaining Issues?	45.2%	64.3%	7.1%	28.6%
Commissioning?	3.2%	66.7%	33.3%	0.0%
Materials Management?	4.3%	50.0%	0.0%	50.0%
Closeout/Turnover?	17.2%	43.8%	25.0%	31.3%
Virtual Mock-ups?	17.2%	56.3%	25.0%	18.8%
Punch List?	16.1%	73.3%	13.3%	13.3%
Inspection Support?	4.3%	100.0%	0.0%	0.0%
Other BIM Field Use?	7.5%	57.1%	28.6%	14.3%

By reviewing Table 1, it can be determined that the majority of respondents used BIM for Clash Detection (83.9%), Field Coordination (61.3%), Visualizing Issues (45.2%), QA/QC (28.0%). For nearly all tasks reported, the data showed that the percentage of BIM tasks performed onsite was higher than those performed offsite or from dual locations. This is actually encouraging as those using BIM can take advantage of the "go and see for yourself" principle to match the model with site work as well as incorporate real time field knowledge into the models. The tasks performed mostly offsite were Clash Detection and 4D Scheduling. These findings seem logical as these two BIM tasks are incredibly time consuming and often require the assistance of a dedicated person. Often time these responsibilities are performed at a remote main office location by a support staff member separate from the onsite project team. When reviewing these BIM task results in conjunction with the BIM and Lean interactions identified by Sacks et al (2010), several areas of alignment were found between performed BIM tasks and positive LC interactions. Clash detection helped users to "reduce variability", "reduce cycle time" and "design the production system for flow and value" (Sacks et al, 2010). Field coordination and visualizing issues helped users "reduce variability", "reduce cycle time", and "use visual management" though increased communication and visualization (Sacks et al, 2010). Lastly, QA/QC BIM tasks allowed users to "reduce cycle time", "reduce variability", "verify and validate" and "go and see for yourself" (Oskouie et al, 2012).

Regarding the comfort level using BIM in the field, the most frequent response was that BIM users could open and navigate the model slowly, with issues (32.6%). It is interesting to note, however, that though approximately 2/5 of the respondents who used BIM were comfortable in the model, an additional 1/5 of users indicated that they did not know how to either open or pilot the BIM model. That's a full 19.6% of users who are currently unable to use BIM technology or benefit from Lean Construction capabilities inherent in the system.

INCORPORATION OF BIM TOOLS AND TRAINING AT THE FIELD LEVEL

When surveying the availability of BIM tools on the jobsite, it was found that the majority of respondents had access to a desktop/laptop computer (89.2%) and/or tablet (87.1%) hardware and BIM 360 (67.7%) software. When analyzing the respondent's available BIM tools in conjunction with the BIM tasks performed onsite, some connections can be made between the findings. The tasks with the highest percentages of performance onsite were inspection support (100%), QA/QC (80.8%), Punchlist (73.3%), and Safety (72.2%). The BIM 360 tool helped to provide a gateway to both the project team member's onsite BIM use and increased positive interactions with Lean Construction. Through BIM 360, teams were encouraged to "go and see for yourself" to complete safety checklists, were given an enhanced ability to "validate and verify" through QA/QC inspections, and "used visual management" to help trade contractors successfully complete work items with a visual punch list.

Regarding training on the use of BIM, 11.5% of respondents received a large amount of BIM training with the remaining 88.5% receiving either some or no training in the use of BIM. When taken in context with the responses to the users' comfort level using BIM (40% proficiency in navigating BIM), these numbers are understandable. Since BIM training appears to be lacking for the survey respondents, this absence of further training could explain the approximately 60% respondents who indicated issues opening and navigating the BIM. Additional survey questions confirmed that the majority of respondents (71.6%) believed that additional BIM training would be very beneficial to them in their current roles. A further 39.0% were neutral to additional training with only 2.4% believing that additional BIM training would be not at all beneficial. This mirrors many of the interview responses received. Nearly all interviewees indicated the need for additional training in order to support furthering the implementation efforts with BIM in the field. To capitalize on these trainings, inclusion of the benefits of Lean Construction in BIM operations should also be explored with the training attendees.

PERCEIVED VALUE OF BIM

Figure 2 shows the impact that job role has on the likelihood that survey respondents will find BIM to be a reliable source of information.

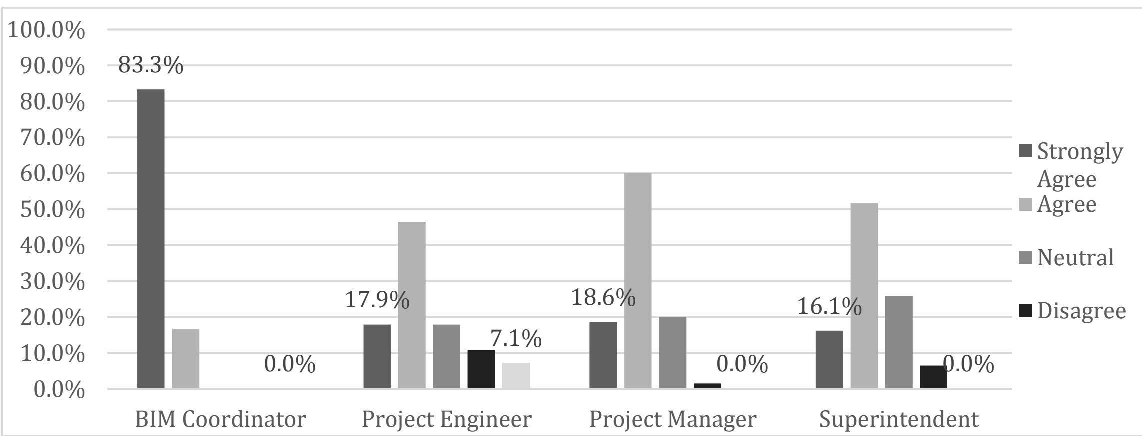

Figure 2: Perceived Reliability of BIM by Project Role

From Figure 2 it can be concluded that BIM Coordinators are the most likely to believe that the BIM is a reliable source of information, with 83.3% of BIM Coordinators strongly agreeing. This seems logical as BIM coordinators work in the BIM environment daily. Potentially skewing their perception, however, may be the fact that as BIM coordinators are mainly located outside of the project site, they may not recognize the issues with BIM that occur in the field, such as the model not keeping up to date with project changes or trade partners missing from the BIM coordination effort that have critical coordination scope.

Project Engineers (PE) are the least likely to find the BIM model as a reliable source of information, with 7.1% of Project Engineers strongly disagreeing. This result is particularly interesting because, per the personal BIM use results, PEs are the second most likely to spend the most amount of time in the BIM model. Due to their familiarity with the model as well as their responsibility for updating the plans/specs with construction document changes, PEs may not see the BIM as a reliable source of information because they are aware when the model is not up to date with the most current information. Instead of being updated by the trades as information is received, the BIM often time reaches the fully pre-construction coordinated phase then lays fallow until they are updated as as-builts for closeout. Superintendents follow project engineers in their likelihood to believe the BIM model is not reliable, with 6.5% of superintendents disagreeing that BIM is a reliable source of information. These findings are particularly troublesome to ramp up the use of BIM to support field operations because these are specific job roles that develop their tasks on site. This shows a great gap that needs to be bridged to promote the use of BIM to support field operations and promote the visual management of the project.

Figure 3 shows the impact that job role has on the likelihood that respondent found BIM to be valuable to field operations beyond use with clash detection. From this graph it can be determined that BIM Coordinators are the most likely to believe that BIM has value outside of clash detection with 100% responding "Yes", while Project Managers are least likely to believe that BIM has value outside of clash detection with 7.1% responding "No". These findings make sense when taking into account the findings from above regarding the different job roles understanding of the capabilities that BIM possesses beyond clash detection. Interestingly from these findings, though Project Engineers are more likely than other roles to believe that the information in the BIM is not reliable (Figure 2), they are the second most likely to believe that BIM is valuable outside of clash detection with 82.1% responding "Yes". This could indicate that though PEs are aware of the current shortcomings of BIM for use of the field, they may believe that with corrections to the BIM task structure, BIM could have further value/use at the jobsite level.

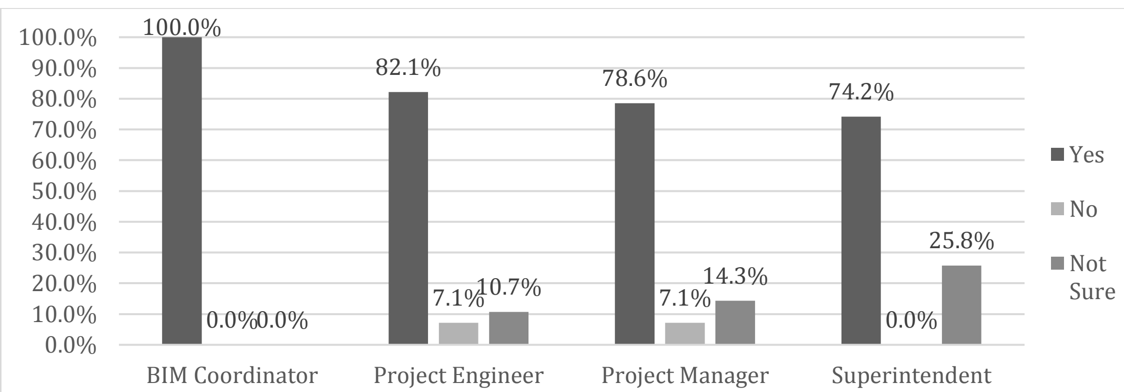

Figure 3: Perceived Value of BIM by Project Role

Similar to Figure 3, Figure 4 investigated the impact of time spent in BIM to the likelihood of finding the BIM valuable beyond clash detection. From the graph it was found that respondents who use BIM at least once per day were most likely to believe that BIM was valuable beyond clash detection, with 100% responding "Yes", and respondents who did not use BIM were most likely to either believe that BIM was not valuable beyond clash detection (7.8%) or not be sure of whether BIM held additional value (27.5%). Generally, it was seen that as the amount of time in the model increased, the perceived value of BIM beyond clash detection increased.

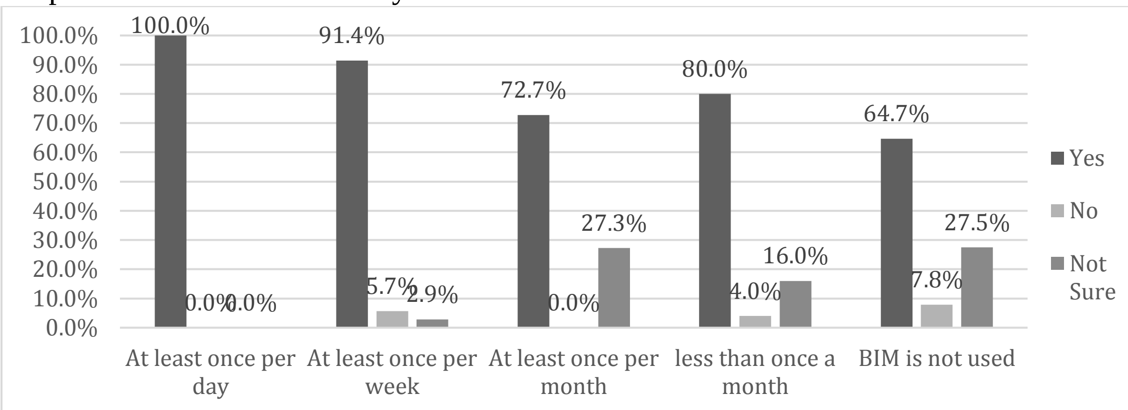

Figure 4: Perceived Reliability of BIM by BIM Usage

Looking at the findings on users' perception of the reliability and value of BIM, it can be inferred that a positive change in the perceptions of BIM could potentially lead to an increase in the use of or willingness to explore BIM. Given the interconnectedness of BIM and Lean, this potential increase in BIM would likely allow for increased instances of Lean Construction interactions.

CONCLUSIONS

From analysis of the survey results it was found that the use of BIM in the field is still not where it should be in order to reap the potential benefits of construction stage BIM usage, and consequently those related to BIM-Lean synergies. Potential interactions between BIM and Lean that can be leveraged at the field level have yet to materialize given that the use of BIM and its related tools, as well as the confidence practitioners have on these tools have to improve. Despite all of BIM's documented benefits, including but not limited to increased levels of visualization and collaboration, field personnel will not fully embrace the technology unless they perceive it as reliable. Data revealed that BIM coordinators are the ones who trust BIM the most, perhaps because they are the ones creating and manipulating the models. Further investigation of why reliability levels vary across job roles is needed. BIM coordinators appear to have a strong role if the synergies between BIM and Lean are to materialize. Findings indicated that over half of the respondents reported that their projects have a dedicated person to work with the BIM. This individual might be the gatekeeper who will be able to unlock enormous benefits indicated by Sacks et al. (2010a) regarding improving flow, increasing/generating value, developing partners and solving problems. Moreover, the low levels of use and confidence displayed by Project Engineers (PEs) also point to an important job function that might have been underutilized as far as BIM use goes. While BIM Coordinators are BIM savvy and might or might not be on site, PEs need to be on site and would greatly benefit from BIM to perform their daily tasks and support leaner field operations.

The results also showed that use of and reactions to the BIM may be influenced by several factors including job role, project size, time spent in the model, and available

BIM tools. Most participants were aware that they were not using BIM to the max of its capabilities and indicated that additional training would likely help close this gap in technology familiarity. Through targeted training of project team members, it is likely that implementation of BIM at the jobsite level would increase. Project Managers, Superintendents, and Project Engineers all displayed different levels of comfort and confidence in the model. It is suggested that training programs be designed to show specific benefits BIM can bring to each of these roles in a project in addition to the overarching capabilities and benefits it can bring to the project as a whole.

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