Effectiveness of Building Information Modeling in Existing Structure Construction Compared to New Structure Construction

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Over the last decade Building Information Modeling has become a crucial aspect of the construction project for larger construction firms in the United States. BIM has many different facets and can be used to effectively manage construction projects in various ways. Modeling a structure in a virtual setting in preconstruction allows for adequate preparedness for the construction process and has been shown to be effective, on a broad scale, to reduce cost, compress schedules, and allow for a more fluid construction process overall. The goal of this paper is to look more closely at BIM and its effectiveness on existing structures as it compares to new structure construction. A qualitative analysis survey was conducted with a single construction company in San Francisco, California. The company is a commercial general contractor that completes work in both the existing and new construction areas. The company's unique experience with both types of construction processes and the use of BIM, made the company a good candidate for conducting a comparison on the challenges that are presented with utilizing BIM in existing construction. It was found that a lack of formal timeline structure for executing BIM on projects more greatly impacts successful timely completion of existing structure projects. Furthermore, the additional costs of laser scanning for existing structure projects create a greater barrier to entry in executing BIM.

Key Words: BIM, Existing Construction, New Construction, Effectiveness, Laser Scanning

Introduction

Building Information Modeling (BIM), has been a growing asset to the construction industry in the United States for the past decade. The adoption of BIM by Architecture, Engineering, and Construction (AEC) companies has moved from 28% in 2007 to 71% in 2012 (McGraw Hill 2014). BIM can be executed on many different levels and may play different roles for different types of construction companies. BIM can be made up of virtual models, scheduling and estimating software, as well as a synchronous combination of scheduling and estimating. In the design phase, BIM helps with modeling the building envelope, analyzing the mechanical systems, and creating a structural analysis of the difficult activities for the project (McGraw Hill 2014). The benefits that BIM provides are its technological superiority, interoperability capabilities, early building information capture, and improved cost control mechanisms which can reduce conflicts (Ghaffarianhosein 2017). The

efficiency and cost savings that have been achieved has made BIM a viable and necessary option for construction companies.

Clash detection is an aspect of the BIM coordination process that involves finding the discrepancies in the different building components of a structure. This is done by putting together all the different models from trade groups. These models are overlaid to find where work conflicts with other trades. Clash detection works as a reactive process, and decisions about how to coordinate cannot be completed until the models have been submitted (Poneware 2017). The main objective is to create a model free of clashes, identify and fix design issues, and improve design quality (Poneware 2017).

There can be various levels to the preconstruction process. Macroplanning involves design review, investigation into the project site, and sequencing for executing work elements (Waly 2003). This entails a broad overview for construction site logistics and processes. Microplanning involves the details necessary to provide crews with information on how to execute the work (Waly 2003). The microplanning level is most effective for the construction phase of the project where its basis is largely driven from what is laid out in the macroplanning level (Waly 2003). BIM takes place in the macrolevel of the preconstruction process. The purpose of BIM is to provide an understanding, for all parties involved, of where a project stands on a physical level and a planning level. This requires input from different parties involved on the project. From a modeling standpoint, this includes plumbers, electricians, and HVAC contractors. All these trades will have their own runs and routing for equipment that will need to be modeled. The ability for these contractors to coordinate and adjust their routing accordingly to not conflict with one another has proven to be effective in reducing conflicts in the field during the construction process. Furthermore, the inclusion of the Architectural Engineer for structural penetration locations is important for maintaining the structural integrity of a project. These models are presented in 3D to see and understand the project more easily. More advanced BIM processes allow for schedules to be integrated and can show a build out of the project over time for all different aspects of construction.

Existing construction consists of projects that attempt to refurbish, remodel, or structurally renovate a building that is already in existence. This type of construction presents its own unique challenges. These challenges include a comprehensive understanding of the built structure through accurate as-built drawings and surveying. From a constructability standpoint, the largest obstacles encountered are the many uncertainties involved in a project, such as climate change, services change, human behavior change, government policy change, all of which directly affect the selection of retrofit technologies (Ma 2012). Additionally, it is important for a greater understanding of unforeseen conditions, especially for structures that have been constantly developed over several years or decades with a lacking paper trail. The successful retrofit of an existing structure is largely dependent on building specific information such as geographic location, building type, size, age, occupancy schedule, operation and maintenance, energy sources, and utility rate structure (Ma 2012).

New construction projects are those that are to be built on a plot of land with no existing parameters. These projects present unforeseen conditions in the soil but also present greater freedom for design and changing design movement. Challenges that relate to the environment, geographical location, building type, and size apply to new structure projects as well.

Methodology

The project utilized a qualitative analysis approach of one commercial construction company. Plant Construction LP, located in San Francisco, California, is a commercial contractor that completes work for both existing and new structures. Due to the diversification of the company's work in both types of construction, Plant makes a good candidate to complete a comparative analysis as to the effectiveness of BIM in both types of construction. The approach involved a comprehensive survey to representatives of the company, which asked various questions that help compare the two types of construction and what issues may arise from both as it relates to BIM. Below is a list of the survey questions asked.

Preliminary Questions:

1. What type of service does Plant Construction LP provide? What type of construction work does this entail?
2. Who is Plant Construction LP's primary client base?
3. How large is Plant Construction LP in terms of employees and gross dollar value of work completed each year?
4. Does Plant Construction LP utilize Building Information Modeling as a means of completing its projects?

Focus Questions:

1. How much does Plant Construction LP utilize Building Information Modeling as a means of completing construction projects? Is there an in-house coordination team?
    a. How much does Plant spend on BIM coordination each year?
    b. In what areas of BIM are the funds being directed to?
2. What amount of the work that Plant Construction LP completes each year is conducted for existing structures? How much is conducted for new construction
    a. What amount of each type of work utilizes Building Information Modeling?
    b. How much is BIM coordination utilized for both types of construction?
        i. If there is a difference in the amount utilized for each type, why is this the case?
3. What specific tools of BIM does Plant utilize? i.e. (modeling, clash detection, Navisworks)
    a. Does the company prefer certain software and why?
    b. Does the company notice a pattern in software used for existing construction projects or new-out of ground construction?
4. How does the company treat the two different types of construction differently as it relates to BIM?
    a. Modeling?
    b. Coordination meetings?
5. Does the company notice a difference in the overall effectiveness in using BIM in each type of construction? ROI?
    a. What types of projects present the greatest amount of challenge in terms of BIM for the company?
    b. What are the specifics of the challenges that are presented?
6. What are the problems the company encounters when executing BIM for their existing structure projects?
    a. New out of ground projects?
    b. Is their repetition in the issues identified?

        i. If so, why is it a repeating issue?
        ii. What about BIM or lack thereof, restricts this from being resolved?
7. In terms of project duration time, does the time in either the design phase or execution phase alter the effectiveness of BIM coordination differently between new and existing construction projects?
    a. At what duration timelines does this become a problem?
8. Has the use of BIM reduced the number of items that needed to be resolved during punch-list?
    a. Is there a noticeable difference between new and existing construction?
9. Does the company receive pushback from subcontractors on the use of BIM?
    a. What type of projects does this occur on?
    b. What are their reasons for pushback?
10. What about BIM does not meet the needs of new and existing construction projects for the company?
11. Where does the company forecast their BIM department to go into the future?
    a. In terms of new and existing construction projects?
    b. What drives this change?

Results

Preliminary Questions

While a lot of the company's work is completed in the city of San Francisco, a sizeable amount of work is completed in the greater metropolitan area. The company has both public and private clients. These clients include developers, public K-12 schools, public/private universities, museums, hospitals, and hotels. Construction entails both new and existing structure projects. The company employs between 250 to 300 people with most of the employees being a part of the labor division. Last year the company completed a little over $400,000,000 in work.

Focus Questions

As it relates to modeling, Plant does not have its own in-house modeling team, rather a Mechanical, Electrical, Plumbing, Fire Sprinkler (MEPF) coordination team that manages the majority of their projects. The company subcontracts most of the work that would need to be modeled and requires its subcontractors to provide models and a process for coordination with the project team. The majority of the company's finances for BIM is for the MEPF coordination between the company, subcontractors, and architect. These coordination meetings allow for the subcontractors to adjust their models to eliminate conflicts and clashes between the work of the different subcontractors.

Existing structure projects make up around 85% of the company's work with the remaining 15% going to new construction projects. For the company's existing structure projects, 20% of them utilize BIM whereas almost 100% of the company's new structure projects utilize BIM. The discrepancy in the numbers is large between the two types of construction. There are a few conditions that attribute to this discrepancy. Some projects, particularly tenant improvement projects, do not merit the use of BIM because of the small size of the project. However, 60% of the company's existing structure projects are large projects. The other contributing factor is return on investment for the use of BIM.

For a lot of the existing structure projects, the return on investment for implementing BIM in the construction process is not feasible. This is more apparent with historical buildings, where a greater financial investment is needed for models. The current construction of these projects is more complex, and the time and money needed to invest in modeling is not feasible. The owner and architect play the largest role in the decision to use BIM for their projects.

The company uses various software for BIM including, BIM 360 Glue, Navisworks, Assemble, Revit, and AutoCAD. There are no preferences for which software should be used and all the software that are listed have no favorability or greater utilization to one type of construction project or another. However, for existing construction projects, laser scanning is heavily used as a precursor to the BIM process.

For both types of construction, the architect is providing models for the owner and general contractor. For existing construction, the general contractor focuses on checking the accuracy of the model of what needs to be demoed and constructed by verifying with the existing elements of the building. Additionally, the company needs to complete its own laser scanning and survey work to verify the models. Coordination meetings for both types of construction are treated similarly. The experience is that subcontractors have a greater feel for what is happening in an existing structure project because they have an existing building to look at and analyze. A caveat to this process is that there is a greater amount of constraints found in the existing structure coordination meetings. Subcontractors on these projects face greater challenges as it relates to placing their equipment or lines because they are confined to a space with less flexibility for moving equipment and utilities. As a result, the coordination process is more involved for existing construction.

The use of BIM for new construction projects has shown to be highly effective and has increased the efficiency in the construction of these projects. Here the return on investment is remarkably high and this plays a large role in why BIM is used for almost 100% of new structure projects. Return on investment (ROI) is an important part of determining whether to utilize BIM. ROI is how much profit can be generated from an initial investment. How quickly this is obtained is an important factor for the implementation of BIM. For existing structures, ROI is largely dependent on what is known about the structure. With these types of projects, the potential for unforeseen conditions is greater than that of new construction projects. Furthermore, the company finds it more difficult to obtain accurate information for the existing structures. Reasons for this are inaccurate as-built drawings, or as-built drawings that have not been updated through multiple renovations of the structure. To make up for these shortcomings, laser scanning is a tool that has been used to give a more accurate picture of the existing structure. However, given the circumstances, laser scanning is extremely expensive. The company says that laser scanners can cost anywhere from $60,000-$70,000. Total stations for surveying can be expensive as well. Moreover, a large amount of training is needed to work these machines and is costly. The company subcontracts their laser scanning work.

Regarding BIM, the largest problem the company faces applies to both types of projects. The BIM process is often not started soon enough. These projects take a fair amount of time to coordinate and after this coordination process takes place, the subcontractors must come up with their shop drawings. The total process for 3D coordination and a final product onsite is often underestimated for both types of construction projects. Additionally, variation for completion time is high due to different subcontractor development resources for their detailing of the projects. In other words, some subcontractors have an easier time developing models and designs than others. This results in projects running up against the project schedule with coordination and shop drawings needing approval before

moving forward. The causation is largely a lack of understanding for how long the BIM process will take. There is no published standard timeline for how long the BIM process should take for any given project. A standard unit of measure, similar to RS Means for budgeting and estimating a job, could benefit the company in the scheduling this coordination. Moreover, existing structure projects present even more unforeseen conditions making it even more difficult to produce an accurate timeline for the coordination process.

The scheduled construction timeline does not make a difference between the types of construction in terms of the effectiveness of BIM for the projects. However, in general the company finds that more time and money is needed for BIM coordination of existing structure projects. The complication and constraints that unforeseen conditions present for existing project are a driving factor as mentioned earlier.

In terms of punch-list, the company has not recognized any pattern between the number of unresolved punch-list items or recurring issues with punch-list items with the implementation of BIM in their projects. This applies between the two types of construction as well.

In the past, the company used to receive pushback from subcontractors when requiring the use of BIM on their projects. In the earlier usage of BIM on projects, this would be an added expense for subcontractors that was more difficult for them to quantify. The industry has adapted, and this pushback is not as common. If there is pushback for the usage of BIM it is because subcontractors express that the project size may not warrant its usage. This pushback also happens on projects where there may be more space for installation and coordination appears to be less difficult.

Areas where BIM does not meet the needs of the company for both types of construction are in the translation of the models to the 2D drawings. It would be easier for people in the field to look at the 3D models and be able to find a corresponding detail on the model. The concern is that many of the models represent a vision with no relation back to the 2D details. They acknowledge that this can be done with software such as Revit, but that it is not user friendly to the field staff.

The company has two employees that focus on BIM modeling and coordination. These employees are also part of a larger role in the estimating department. The company has been focusing on training their project managers in the BIM coordination process, specifically running clash detection meetings. Financially, it has not shown to be feasible to have an in-house BIM modeler. However, as the company grows the company is thinking about the addition of a couple of employees to work solely on BIM modeling and BIM coordination.

Analysis of Results

Company Overview

The company completes a large dollar value of work each year almost amounting to half a billion dollars this past year. Additionally, the company is diversified in its project profile, completing work in the public and private sector. Their work consists of both existing and new structure construction with a greater emphasis on tenant improvement work. The company shows a large commitment to BIM in their projects, embracing BIM coordination to almost 100% of their new structure construction projects.

Identifiable Issues

Tenant improvement projects are more difficult than new structure projects in part to there being more constraints on the project parameters. The project already has a definable dimension to work in and the opportunity for flexibility is more constrained. BIM is useful for both types of projects and plays a large role in coordinating the location for all of the trade work on a project. The company finds that it allocates more of its BIM resources and coordination time to existing structure projects because of the constraints found with these projects. This is the case even though the company uses BIM more often on new structure projects. Existing structure projects present clashes more often between the trades, and multiple rounds of clash detection are needed to be held to resolve these issues. Moreover, the accuracy of the models based around the existing structure, need to be more precise than that of a new construction project. If mistakes are made on the structural side of the model, features of the building cannot simply be redesigned or moved. With renovation type projects, the structure largely keeps its original integrity. This means that instead of being able to make small adjustments to the location of different trade items, entire models will need to be modified. When the structural model needs to be adjusted every trade will need to rerun its clashes causing for additional work. For new construction, models can be generated around the architect's and structural engineer's plans. That is hardly ever the case with existing structure projects. There are often many inconsistencies between the as-built drawings and the structure itself. This has led to the utilization of laser scanners.

Laser scanners and surveying equipment is the most prominent way that an existing structure is evaluated for use in BIM modeling. The company noted the financial challenges that are associated with the use of this equipment and the additional training required to run it. For the company, the barrier to entry on buying this equipment is still too high. For smaller projects, renting this equipment for modeling may not see a high enough return on investment. In either case, a financial risk is taken in this situation. On one side, in renting this equipment the company spends quite a bit more money for accurate modeling. Doing so brings up the potential bid price. On another side, not making the investment leaves the doors open for many more unforeseen conditions. The company is thrust into a position of making a larger financial risk decision. As mentioned earlier, the size of the job for these types of projects largely determines whether BIM is ultimately implemented on the project. The company expressed how it is inevitably up to the owner and architect to decide on the use of BIM on a project. Furthermore, subcontractors sometimes voice their concerns to the usage of BIM as well. Higher costs in terms of laser scanning and surveying create a greater barrier to entry on its usage for these types of projects. These costs are often associated to the duration of the coordination process which has been difficult to track.

The largest problem the company faces with BIM is in determining how long to schedule the BIM coordination process. Overall, there is no standard method for determining how much times is needed for BIM to be executed on construction projects. This applies to both new and existing structure projects but may be more consequential for existing structure projects due to more unforeseen conditions. In many cases, the scheduling duration is underestimated, and this holds up the sign-off of drawings for the subcontractors. Without this knowledge, the contractor has to use its best judgement on how long the coordination process may take. Using past-experience is only one of a few ways that a reasonable estimate can be provided. Moreover, there is no way of knowing the number of clashes that will be discovered and how long it will take to resolve them. Depending on the complexity of a project, the adjustment of models will fix some clashes, but will ultimately produce new ones as a result. Lastly, the greater number of unknowns that an existing structure project presents in

comparison to a new project, exploits more greatly the financial risk a contractor takes in implementing BIM.

Conclusion

The results of the company analysis do not find flaws in BIM software but rather shortcomings in having tools to properly address time allocation for executing the BIM process. What existing structure and new structure projects have in common is the scheduling aspect. Where the types of construction differ is in how apparent poor estimation of scheduling affects one type of construction versus the other. Being that existing structures have more variables than new structures in terms of unpredictability with unforeseen conditions and poor as-built drawings, the time allocation needed for BIM coordination is more difficult to project. This variability plays a large role in why the company finds that executing BIM on existing structure projects is more cumbersome than with new structure projects. Moreover, this conclusion does not find that this problem is mutually exclusive to existing structure projects, but that these types of projects appear to be more impacted. In general, for all types of construction projects, this may be cause for the creation of a BIM timetable guideline. A guideline for when to start the BIM process, given a projects criterion, may better enable contractors to execute the BIM process more effectively in a timely fashion.

Secondly, as it relates to existing structure projects, the BIM process may be more expensive in comparison to new structure projects. Aspects such as laser scanning are very costly to companies and disincentivize companies to execute the BIM process. Lowering the barrier to entry from a cost standpoint may help companies in tackling more existing structure projects with BIM. More research is required to accurately determine the cost relationship in terms of equipment needed for both construction types.

Overall, the lack of effectiveness of BIM for existing structure projects compared to new structure projects is in how BIM coordination is predicted for both construction types. The additional variables that existing structure projects pose, along with an increased cost in equipment needed, make the distinction between the effectiveness of the two project types. A method for understanding how to accurately schedule the BIM process may cause for decreased timeliness for both types of construction projects.

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