Application of Mechanical, Electrical, and Plumbing Contractor's BIM Practices to the Cal Poly San Luis Obispo Construction Management Program

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Mechanical, Electrical, and Plumbing (MEP) contractors play such a crucial role in the construction and design phase of building a project; their success or failure can drastically affect the project's overall success. MEP contractors' use of Building Information Modeling (BIM) in the construction industry has grown exponentially over the past decade. This paper will expand on the utilization and practices of BIM by MEP contractors. This information functions as a foundation for my research into current professional BIM trends as they relate to Cal Poly San Luis Obispo's (SLO) Construction Management (CM) curriculum. Cal Poly SLO's CM department has designed the current curriculum to thrive on the continual implementation of current industry practices. Understanding how MEP contractors are implementing BIM, in today's industry, helps the department prepare the next generation of Cal Poly CM students for success. This research will outline how MEP contractors use BIM in their construction processes and whether the implementation of BIM has affected MEP workflow. This research will be compared to how the CM department has designed the curriculum for the 'Specialty Contracting' (CM 411) course. Information will be compiled from surveys sent to MEP Contracting employee's (Senior Project Engineer or higher), students who have taken or are currently taking CM 411, and research of the course learning objectives defining the course. An important element of this research is to provide a better understanding of the gaps still existing between the Cal Poly CM department curriculum and the MEP contracting companies desired level of BIM fluency in their employees.

Key Words: BIM, implementation, MEP, mechanical electrical plumbing, Construction Management, Cal Poly

Introduction

Background Information

The ability to visualize an area in three dimensions has been recognized as an effective tool for enhancing one's understanding of the spatial relationship of complex systems within a building. In order to understand an architect's initial design, one must be able to visualize what is to be built in the given space. Architects, Engineers, and Contractors (AEC) that fail to communicate accurate information to one another will likely encounter clashes between the various building elements within the conceptual design. When dealing with

complex spatial relationships, such as building structures and systems, it becomes increasingly difficult to track and manage the coexistence of these systems (Love et al., 2011). Many tools have been developed in recent years to help the AEC industry get the job done quicker and more accurately. The most innovative and emerging tools are software categorized as Building Information Modeling (BIM), defined as "computer-generated models of a proposed building in virtual 3D space, using intelligent components, inserted at precise orientation, into precise locations in a space" (Crotty, 2012). The use of BIM in the construction industry is becoming standard practice and its frequency of use across all projects seems to increase as technology advances with time. The focus of my research is aimed at drawing a correlation between both MEP contractors and CM students' BIM practices by understanding how often they are utilizing and implementing BIM in both an academic and professional setting. Secondarily, this paper will explore MEP contractors' employment of BIM to determine if the use of BIM is as prolific in practice as it is in theory. If there is supporting evidence to suggest that MEP contractors are using BIM software increasingly on a majority of their projects, then this research will help to reinforce the idea that students studying Construction Management should experience a greater implementation of BIM in their coursework to remain relevant in the industry. This research is not intended to provide a comprehensive overview of the entire construction industry however; it will include contextual information to provide readers with a better understanding of the industry with respect to MEP contractors.

Problem Statement

The use of BIM has drastically changed the way Architects, Engineers and Contractors address and resolve problems in construction. The construction industry is a subject of continual innovation and progression with a key focus on improving quality, increasing productivity, developing greater efficacy and optimizing coordination. BIM has by far been the biggest proponent to addressing all of these standards (Korman, 2008). BIM's recognition within the industry has evolved over time and its use among subcontractors, tasked with the coordination of systems within complex spatial configurations, has led many other MEP and general contractors to exercise the use of BIM on larger projects (Korman, 2011). Subcontractors influence over a project's innovative nature has helped ignite the continual use of BIM in the industry. The success of any construction project hinges on the success of the smaller entities that collectively come together to create a finished project. In general, the cost of MEP work on any given commercial construction project ranges from 25-40% of the total construction cost (Blackburn, 2012). Students failing to recognize the importance of the 'smaller entities' (e.g. MEP contractors' role in design and construction) will be ill-prepared to join the professional world. However, the importance of a MEP contractor's role is influenced by many factors, such as the type of project delivery method used, the size and budget of the project, and the complexity of the MEP system. In the literature review, I will further investigate how the project delivery method, budget, and complexity of a project can affect an MEP contractor's willingness to use BIM on a project to improve efficiency in both design and construction. Challenges that stifle the implementation of BIM include: the rapidly evolving nature of BIM technology, the fact that BIM is resource intensive and difficult to train educators, and that it is not well received by those with weak technologically-oriented skills (Gordon et al., 2009). Understanding that the technology surrounding BIM is continually innovating, this research will investigate what software seems to be the most preferred by MEP contractors. Defining what BIM software is being utilized most by MEP contractors will help the Cal Poly CM department to draw a comparison to their BIM practice in their curriculum, to determine if change is necessary. The final result of this research will illustrate the BIM practice of MEP contractors and their opinions in regard to the implementation of BIM in Cal Poly CM curriculum, as it relates to courses teaching MEP systems.

Literature Review

BIM in the industry & amongst MEP Contractors

Before BIM, the coordination of MEP systems had always been seen as a major challenge for building contractors. In the past, the premier method of identifying and addressing clashes with MEP systems was done by overlaying shop drawings from multiple trades. This method was messy, inaccurate, and time-consuming (Korman, 2008). Technology like BIM has been able to streamline the process of MEP design to mitigate clashes and logistical issues. MEP contractors top used for BIM include coordination, prefabrication, and producing as-builts. However, MEP contractors also use BIM for creating system designs, jobsite layout, constructability analysis, estimating quantities, and modifying schedules. BIM's prowess lies in its ability to model the architectural, mechanical, electrical, plumbing, civil and structural elements within a single cohesive digital model, encouraging collaboration (McGraw-Hill 2008). The complexity of BIM, as a tool in construction, has created a working environment that facilitates the integration of the participating parties engaged in the building of a project, from design to inception (Love et al., 2011). The integration of all the entities involved on a project brings about greater efficiency and reduced error, and increased collaboration and communication between said parties (Love et., al 2011). However, given that the design of the Mechanical, Electrical, and Plumbing systems are done independently of one another the task of coordinating clashes becomes a bigger issue. In order to overcome the separation in design, the information has to be shared between the project participants through an integrated design process (Simonian, 2011). Projects, where MEP contractors don't collectively work together to create virtual models to avoid clashes and improve coordination, will end up yielding low productivity levels thus diminished profits (Kelly, 2016). It is becoming increasingly important that both the designer and builders be fluent in BIM to allow for uniform coordination of constructing all components, void of clashes.

Understanding that BIM is a continually developing technology makes it difficult to establish a set BIM software standard for which all MEP contractors can adhere to. Because technology is continually changing and BIM products are continually innovating, is it very difficult to say with certainty that MEP contractors will implement the use of one type of software always. Keep in mind, not all BIM software fulfills the same tasks. Software like "Bluebeam" or "Planswift" excel at performing quantity take-offs on PDF plans but currently are not capable of modeling. Similarly, "Navisworks", "BIM-360-Glue", and "Assemble" are pioneers in clash detection and performing quantity take-offs from 3D models but it requires the structure to be modeled prior to being uploaded. Determining what software for what task is difficult already because they all don't perform the same duties and once you add the evolutionary nature of technology into the mix it becomes even harder to say MEP contractors only use a finite amount and type of software. Construction, by nature, is variable and BIM's relationship to this industry is no different. Currently, most software lack compatibility with other similar software and are unable to share information. This may be due to a variety of reasons, whether it is due to competing company's desire to create separation so they may hold onto a larger share of the market, or maybe the technology has not reached the point that one software can recognize the raw data from another software and create a model based on that data. The important idea is that not all software 'play nice' with each other, and this inhibits contractors' ability to use BIM on projects to the fullest extent. Just as not all software is compatible with each other, not all construction projects facilitate an environment that is conducive to utilizing BIM. The endeavor to find a balance between a project that is welcoming to BIM while also utilizing programs that are used by all project participants interacting with the MEP contractors is a difficult task. This undertaking is further complicated by the relationships between all parties and their influential power over the direction of the project.

The construction industry: MEP & BIM

An MEP contractor's level of involvement towards the design of a project is greatly affected by the project delivery method utilized; the method dictates the subcontractor's role during the project from the design phase to finalizing construction. The informal definition of a 'project delivery method' is a system that is used by an owner or agency for organizing and financing design, construction, and operations for a structure by entering into a legal agreement with one or more entities (DBIA, 2015). Understanding the type of project delivery method utilized is important because, a subcontractor's role in a Design-Bid-Build (DBB) contract is very different then their role in an Integrated Project Delivery (IPD) or Design-Build (DB) contract. In a DBB situation the motivation to implement practices, like BIM, that would reduce clashes with MEP systems is limited because the financial burden these clashes inflict affects the MEP contractors more than its affects other project participant.

To better understand this concept, in a DBB situation the owner typically contracts with the designer first, then when the design is 100% complete the plans go out for bid in order to contract with a GC to build from the proposed design. However, in DB the contractor and designer work as a partnership and so the contractor is involved earlier when the design is roughly 20% complete (this number varies based on the type of project).

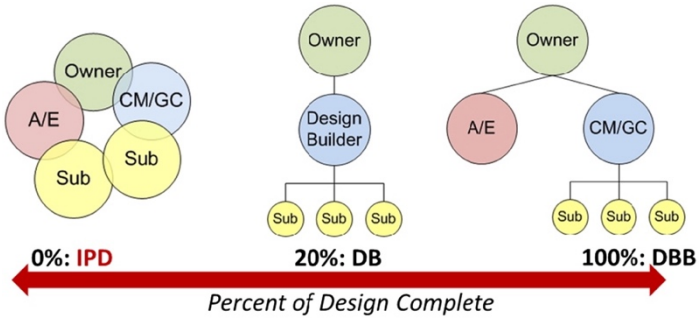

Figure 1: Differences between DB, DBB, and IPD (Asmar et al., 2013)

Similarly, IPD's percentage of design complete is 0% at the start of a project and begins when all contracting parties have signed the multi-party agreement. The multi-party contract ties all project members together financially for the design, construction and commissioning of a project. The key project members include many individuals, such as the owner, architect, contractor, engineer, subcontractors, suppliers, and consultants (Asmar et al., 2013). Once all key project participants have been located and signed the multi-party contract then the design and construction of the project can begin. This system is based on integration and collaboration between all project participants and thrives on value engineering and efficiency in design and construction.

When comparing an MEP contractor's ability to advocate for the implementation of a process, like BIM, to aid in design and reduce clashes and improve coordination, there is a big difference between a project that is DBB and a project that is utilizing IPD. The more a project has completed the design of its MEP systems by the architect or their MEP consultant, the less likely the MEP contractor will be utilizing BIM to its fullest extent. Those with more involvement, earlier on in the design of a project, have the ability to explore the implementation of BIM related processes that would benefit them, but that all depends on if they determine its benefit outweighs its burden. Key factors that influence an MEP contractor's decision to implement BIM are generally based on the size of the project and the complexity of its MEP systems. If the project is large in scale and highly complex, then these factors will motivate the MEP contractor to use BIM regardless of the project delivery method being used. The primary basis for deciding whether to use BIM is based on whether the program will save the contractor more money than it cost to implement, however, depending on the project delivery method BIM could be seen as a cost effective tool or

cumbersome practice. If it has been determined that it is financially feasible to implement BIM, then the next big step is deciding what software to utilize. Understanding what software is utilized most by MEP contractors is crucial not only for the AEC industry but also for universities educating students who seeking employment with a contractor. Having a clear idea as to what the trend is for practicing BIM is in the industry helps universities, teaching CM, gauge how heavily BIM related topics will be weighted in their curriculum.

BIM use among Cal Poly CM Students

BIM has become a paradigm change for the construction industry due to its complete and accurate communication of construction related information from a model that can be converted to detailed drawings. As the construction industry shifts away from paper and towards advanced software, so to do the universities focused on educating students who will become the future builders of tomorrow. The implementation of BIM into the Cal Poly CM department came about over a decade ago when Professors Elbert O. Speidel, Lonny G. Simonian, and Thomas M. Korman began researching the application of BIM process in construction and then later relating that information to the curriculum. BIM had always been a part of the department but it wasn't until Prof. Speidel proposed there be a course specifically designed to teach students how to utilize BIM, this course was called "Emerging Trends - CM 421", and started off as a technical elective. It has since evolved into a required course called "Building Information Modeling – CM280" while, CM421 is still a tech-elective it is also known as the advanced version of CM280. In CM280 and CM421 student are exposed to dozens of different BIM related software. Weeks are broken up and focus on specific tasks like for example, modeling a parking garage in one week, then taking quantity take-off and preparing detailed shop drawings in the second week, and creating a schedule and linking milestones to building components to make a video that shows the evolution of the building from start to finish. Each week focuses on an important aspect of the construction process, however, to learn and become fluent in all of these different processes in 10 – 20 weeks is a tall order. The department has recognized this challenge and has begun implementing BIM in key course like: Commercial Construction, Heavy-Civil, and Residential. Though, it seems the department has a heightened focus on the larger sectors that GC's dominate while courses like "Specialty Contracting – CM411", which focuses on MEP contracting, is limited in its implementation of BIM. Given that MEP contractors are installing and designing systems that have some of the highest risk of clashing with other component, it would be reasonable to think courses teaching MEP contracting should include more BIM related processes. A significant constraint retarding use of the technology in the architecture, engineering, and construction industry, and more specifically in CM411, is the lack of personnel with BIM skills. Hypothetically, if a budget allowed for more professors with BIM related skills to teach MEP systems, from a software's standpoint, then the next step would be to determine if MEP contractors would recognize that as a significant benefit in new hires and if so then determining what software based on the task being used most regularly is crucial.

Methodology

Data for this project was compiled primarily through quantitative means. This research was structured around surveys sent to both MEP contractors and Cal Poly CM students. The goal of these surveys was to better understand the BIM related practices of students and MEP contractors. Although many factors effect both contractors and educational institutions reasons for implementing BIM, the objective was not to explore those reasons but to find a trend in their specific use of BIM. The style of questions, sent to both MEP contractors and students, was designed to be able to draw a comparison between industry and students studying CM at Cal Poly. It was meant to gauge both the MEP industry's implementation of BIM and how they view its use/value in the future, compared to how students view BIM or feel Cal Poly has treated the concept of BIM in their curriculum, as it relates to MEP. However, in order to draw a comparison, the

design of the questions for students and industry was not entirely homogenous, because of student's lack of experience. The questions sent out to students were more geared towards their exposure to BIM and opinion on Cal Poly's utilization of BIM in classes directly related to MEP contracting.

The goal of this survey was to determine the current BIM practices of MEP contractor and correlate them to the Cal Poly CM department. Companies with an open line of communication with Cal Poly were targeted to increase the number responses to opinionated responses regarding Cal Poly. The survey data was collected via an anonymous online survey, provided through www.surveymonkey.com, which analyzes the data using pattern coding techniques to find common trends in responses. Compilation of the data was focused on the use and value of BIM with fill-in-the-blank, 'yes/no', and multiple choice questions like, "what specific software do you use?" or "what tasks do you utilize BIM for?" or "Do you see fluency in BIM as an important trait to have in the future?". Participants who took the survey were chosen from the pool of MEP contractors who visit Cal Poly CM to host either an "Info Session" or "Meet and Greet" on regular occasions, where students have a chance to interact with employees from the company and potentially interview for an internship or full-time position. Because of the vested interest industry professionals have with Cal Poly students, I felt it necessary to highlight my research around these companies and included them in the conversation about how BIM should be practiced in the CM department, with respect to MEP contracting.

Results

Data Interpretation – BIM: utilization frequency & construction related tasks

One of the first objectives of this research was to evaluate how often both MEP contractors and Cal Poly CM students were utilizing BIM on their projects/coursework, for what purpose, and what software they preferred/proficient with. Many people from both Industry and Cal Poly had varying backgrounds and levels of experience. So to mitigate unwanted responses, I negated information from students who were first year standing or had not had an internship. Similarly, I required all MEP industry participants to have at least two years of experience in the industry if they wished to take the survey. After I had performed my due diligence by withdrawing the opinions of those with limited experience, 8 industry professionals and 25 students who passed, I then gathered information and began to analyze. Taking this information, I created a list of software that were most frequently mentioned to be in use, via the courses taught in CM280 and by informal interviews with industry professionals. A list of these software, along with a text box to add additional software not mentioned, was included in both the survey sent to MEP contractors and Cal Poly CM students.

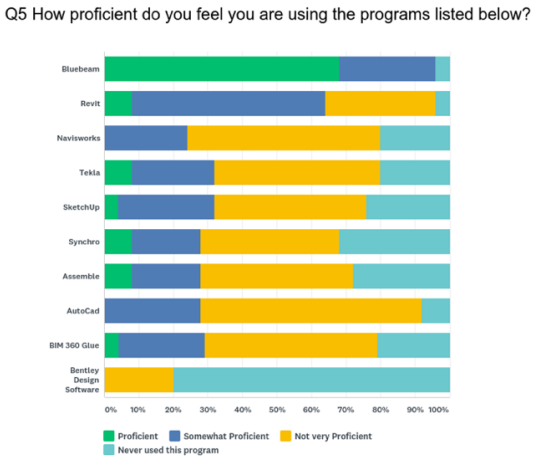

Figure 2: Student BIM software proficiency.

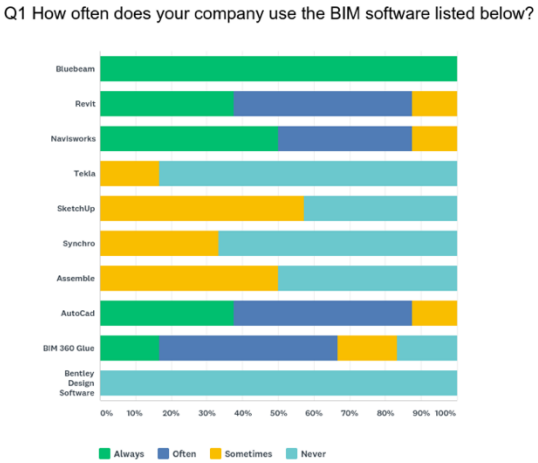

Figure 3: MEP Contractor BIM software use.

In figure 2, the question asked, “How proficient do you feel you are using the programs listed below?”. Similarly, in figure 3, the question asked was, “How often does your company use the BIM software listed below?”. The programs listed from top to bottom in both the Student and Industry survey were: Bluebeam, Revit, Navisworks, Tekla, Sketchup, Synchro, Assemble, AutoCad, BIM 360 Glue, and Bentley Design Software. To differentiate from least to most proficient software I include colors for the student survey; green = proficient, dark blue = somewhat proficient, yellow = not very proficient, light blue = never used this program. Likewise, to distinguish the frequency of use the software I include colors for the industry survey; green = always, dark blue = often, yellow = sometimes, light blue = never. Based on the data, I drew a correlation between how proficient students are and how often MEP contractors are utilizing with programs like Bluebeam. How this information benefits this research is based on the hypothesis that, students should be familiar with programs that the industry is using on a regular basis to be successful within the company. As you can see, students and MEP contractors both are exposed and feel comfortable with software like Bluebeam, Revit, and BIM 360 Glue. However, there seems to be a large discrepancy when looking at Navisworks or AutoCad. MEP contractors cited those as two programs they use ‘always’ but when looking at student responses they seem to lack proficiency with those programs.

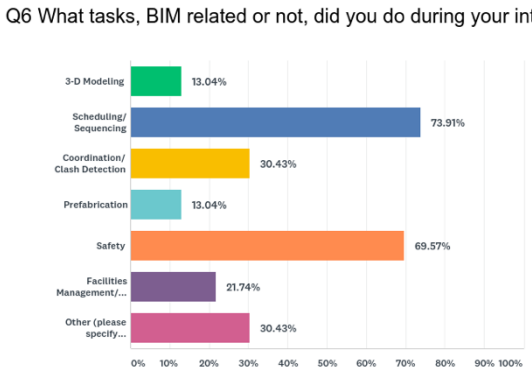

Figure 4: Student: Construction task experience

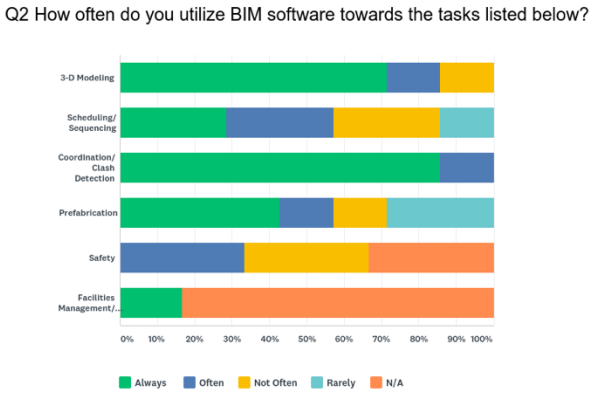

Figure 5: Industry: BIM task utilization

In figure 4, students were asked, “What tasks, BIM related or not, did you do during your internship?”. Similarly, in figure 5, the question to Industry was, “How often do you utilize BIM software towards the tasks listed below?”. The construction related tasks listed from top to bottom in both the Student and Industry survey were: 3-D modeling, Scheduling/Sequencing, Coordination/Clash detection, Prefabrication, Safety, and Facilities management. Similar to figure 3, colors were used to denote the frequency of BIM use towards the stated task; green = always, dark blue = often, yellow = sometimes, light blue = never, orange = n/a. By looking at this data there is clear discrepancy between industry and students but both questionnaires aren’t identical so a direct correlation cannot be drawn. The question to students was focused on understanding what construction related tasks they had experience with, as all the tasks stated could benefit for using BIM. The question to industry was about the same tasks but focused on whether they were implementing BIM towards completing the said tasks. Information from the student survey indicates that most entry level employees working for a contractor will be dealing with scheduling, safety, estimating (stated in ‘Other’), and coordination/clash detection. Looking at industry it’s clear that MEP contractors are utilizing BIM for 3-D modeling and coordination/clash detection primarily. This information indicates that students who wish to work for or alongside an MEP contractor as an entry level Project Engineer should at the bare minimum be learning how to use BIM for scheduling and coordination/clash detection, as those to task scored high on both sides. However, just going solely based on this data may lead students down the wrong path. Understanding if fluency in BIM = success is the key to whether or not this information is accurate and true.

Data Interpretation – BIM's use value

Determining what projects would benefit from the implementation of BIM is not a simple process. The quickest path to an answers lies in a seemingly simple metric of whether the cost to implement is less than the cost saving from implementation. However, there are many variables that effect whether implementation of BIM is feasible like, the size of the project and its complexity, the project delivery method utilized, if a design and program is already in place or not, and the cost of the software itself. Based on the best case scenario that included an implementation of BIM, Industry was asked, "What software's should students be learning before working with or for a Specialty Contractor?" with the following software from top to bottom: Bluebeam, Revit, Navisworks, Tekla, Sketchup, Synchro, Assemble, AutoCad, BIM 360 Glue, and Other (OST & Quickbid). Comparing their response to what students indicated to be the software they used primarily during their internships, it seems that Bluebeam and Revit shared common ground. Students in figure 2 stated that they felt most proficient in using Bluebeam which could be a product of their time using the program during their internship. Overall, if students hoping to work for an MEP contractor want to focus on a software then they should refer look into learning Bluebeam, Navisworks, Revit, and AutoCad.

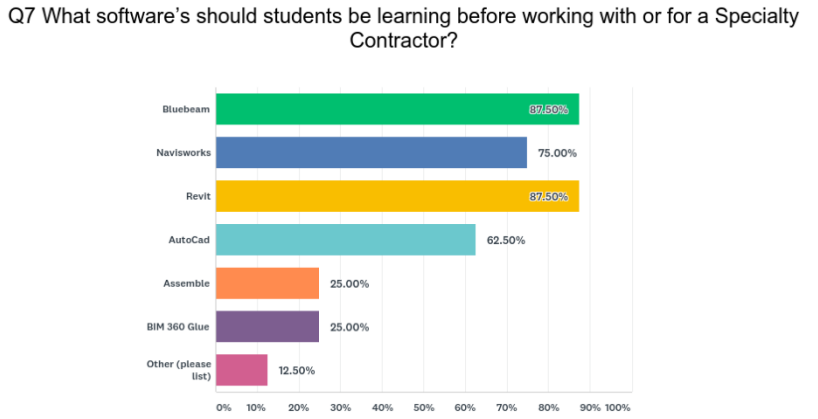

Figure 6: Industry: Software preference

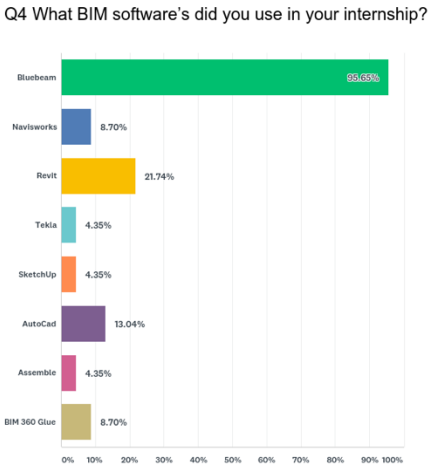

Figure 7: Student: Internship BIM experience

In a perfect world, where BIM is utilized on all project, the information provided above provides a guideline to what software is favored most by MEP contractors. However, not all projects utilize BIM to the fullest extent. This idea of a lack of BIM on all projects is reinforced by the information in both figure 8 and figure 9. In figure 8, Industry was asked, "Do you believe BIM will be utilized on ALL of your company's projects in the next 5-10yrs?". In figure 9, Industry was asked, "Do you believe students need to be proficient in BIM to be successful in the MEP contracting industry?". Surprisingly, the split for both figure 8 & 9 was 50/50. For figure 8, half indicated, 'yes', BIM should be utilized on all project in the future and the other half saying 'no'. Included with the question in figure 8 & 9 was a supplemental free response to allow participants to reinforce the response they provided.

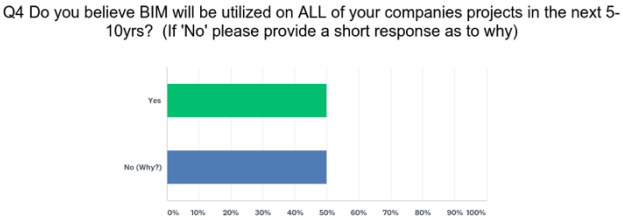

Figure 8: Industry Opinion: BIM utilization on all projects in 5-10yrs

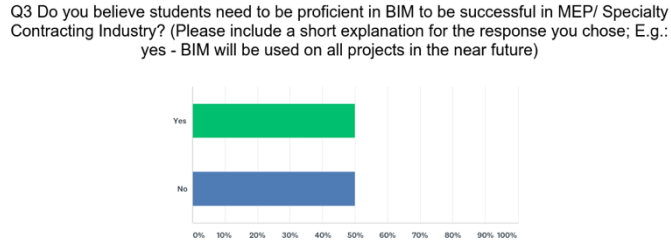

Figure 9: Industry Opinion: BIM proficiency = Successful w MEP contractor

An individual who answered the free response in figure 8 stated, “On some smaller projects like existing office renovations/remodels or facility upgrades BIM is rarely required. On these projects it is often easier and more cost effective to work everything out in the field and it would not yield a ROI by utilizing BIM”. This response reinforces the idea that before any process can be implemented it must first be recognized as a benefit to the project and provide a return on investment. Likewise, individuals who likely answered ‘no’ on the free response in figure 9 stated, “More focus on constructability in each trade versus being software proficient. It is far easier bringing someone up to speed on a technical basis that knows the constructability portion of a trade versus taking someone who has the technical skills and train them to understand constructability.” This response supports the claim that students don’t need to be proficient in BIM if they wish to be successful working with an MEP contractors. However, others who answered ‘yes’ stated, “BIM used to be a technology that gave contractors a competitive edge but is quickly becoming a necessity to stay competitive in delivery of quality in a given project.” As technology advances, things that were once seen as the latest and greatest are quickly becoming the norm. Both responses given were extremely valuable, they highlight the fact that more focus should be put on what the end goal is when deciding to learn or implement BIM, from a student or industry perspective.

Becoming aware to the idea that not all projects should be required to have a detailed BIM model to be successful opens the door to accepting a lower expectation towards BIM fluency. In figure 10, industry was asked, “Do you believe Cal Poly’s CM graduates have been taught a sufficient amount (time & variety) of BIM software?”. The majority response for this question was yes, meaning a majority of MEP contractors believe Cal Poly students have been taught a sufficient amount (time and variety) of BIM. This information is not 100% reliable, as only 8 people are included in the response, from industry with more than 2yrs of experience. As a whole though, the information gathered in these surveys shows that Cal Poly’s curriculum is exposing students to a good amount of BIM as to become successful working for a contractor.

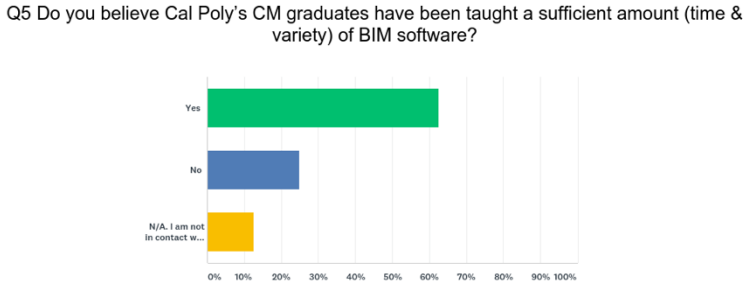

Figure 10: Industry Opinion: Cal Poly Students know enough BIM

Conclusion

The impact BIM technology has had on the construction industry has encouraged greater multi-disciplinary collaboration and provided tremendous advantages in MEP processes. (Korman, 2008). If a problem occurs during construction due to a lack of BIM, such as a clash between structural components and MEP system, the problem often has to be address onsite with the consultation of an engineer and MEP contractor, which is not cost efficient (Guo, 2014). For this reason, most MEP contractors have transitioned from overlaying paper shop drawings to adopting BIM to avoid encountering clashes and coordination issues during construction. The use of BIM on projects around the world initially escalated from 30%-70%, between 2007 and 2012 (McGraw-Hill Construction, 2012), and continues to increase every year. The majority of MEP contractors that participated in the industry survey all had indicated they were using BIM on over 60% of their projects. Of the students who participated in the student survey over 90% that had internship experience indicated that they had been exposed to BIM software. BIM is becoming a standard in the construction industry but not all projects are created equal, some are better suited for the greater implementation of BIM while others are smaller or would not yield a return on investment by utilizing BIM.

Initially, it was assumed the BIM practice of MEP contractors was straight forward, and sometimes it is but generally it is not. It was far more complex than previously anticipated due to the many variables that effect

whether implementation of BIM is feasible like, the size of the project and its complexity, the project delivery method utilized, if a design and program is already in place or not, and the cost of the software itself. Because of this, there is no clean cut “yes/no” answer to if BIM should be implement in practice without first taking a deeper look at all that factors that surround each individual project. Additionally, if the goal is to be a successful project engineer, project manager, or project executive then it seems that being completely fluent in BIM is not required. This information will prove helpful in mitigating those considering trying to swap out courses that teach the constructability of a trade for courses that teach the technical knowledge required to operate a BIM program. From the analysis it is clear that Cal Poly CM pre-graduates are being taught a wide variety of BIM software and continue to into their internships. However, there is evidence that suggest that there are some programs that are being favored more than they should, and other programs that post-graduates will be exposed to are not being taught enough. All in all, based on the findings in this research, MEP contractors and the Cal Poly CM curriculum are on par with each other, with the exception that more focus on programs like, Navisworks, AutoCad, and Revit, should be applied.

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