THESIS

IDENTIFYING THE AREAS WHERE BUILDING INFORMATION MODELING SOFTWARE ADDS VALUE FOR GENERAL CONTRACTORS WORKING IN THE STATE OF COLORADO

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ABSTRACT

IDENTIFYING THE AREAS WHERE BUILDING INFORMATION MODELING SOFTWARE ADDS VALUE FOR GENERAL CONTRACTORS WORKING IN THE STATE OF COLORADO

The purpose of this research is to identify the areas where Building Information Modeling (BIM) software is currently adding value to General Contractors working in the state of Colorado. The scope of this study is limited to the top Local and National General Contractors in the state of Colorado generating over $100 million a year in revenue as reported by McGraw Hill 2009 Top Colorado Contractors. An exploratory study was completed using industry experts as well as academic research to identify areas where BIM adds value to general contractors. The findings indicate that the majority of the sample group is using BIM on their projects to a certain degree, with very little negative value in any category. There were slight differences when comparing the national and local contractors with regards to the area of added value through the use of BIM, but overall they were very consistent. A conclusion was drawn that while these firms are very interested in BIM and want to continue to grow it within their firms, there are still many areas where BIM has yet to be fully utilized to add value within both the national and local companies.

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Chapter – 1 Introduction

Technology today is increasing at a faster rate than ever before in history, yet the construction industry lags behind many other industries in adapting new technology, (Grillo, and Jardim-Goncalves 2010). Building Information Modeling (BIM) is one of the newest technological tools to make its way into construction offices and job trailers over the last few years. This research focuses on BIM software in the field of commercial construction, specifically general contractors, and the added value to the construction process for the companies that use it. The level of implementation of BIM varies among the sample group of General Contractors (GC's), and this alone will help to provide some insight when analyzing where companies are seeing value added to their projects through the use of BIM.

Statement of Problem

Mike Rush (personal communication, November 15, 2010), Colorado State University (CSU) Campus Architect noted, owners, including CSU, are requiring BIM on an increasing number of jobs as the technology becomes more widely used and owners become more educated in the benefits of BIM software on their construction projects. Many of the large national general contracting firms have been using BIM and exploring its potential for almost 10 years, (Becerick-Gerber, and Rice 2010). These national companies have found different levels of value through the implementation of BIM on their projects. Some companies have taken BIM to the level of creating paperless job sites. These paperless jobsites have 3D plans stored on a computer, accessed through touch screen monitors in the job trailer and hand held touch pads in the field by

superintendents and other field personnel. Other companies are just beginning the process of implementing BIM in their firm, and struggle with the concept of using it for anything besides clash detection, Webb Martin (personal interview, February 14, 2011). Identifying the value in BIM for both national and local GC's doing work within the state of Colorado is focus of this research.

Industry journals such as (McGraw Hill 2009) have annual publications that discuss the value of BIM in dedicated reports like *The Business Value of Building Information Modeling: Getting Building Information Modeling to the Bottom Line*. They note almost half of the construction industry does not use BIM software within the United States. However, the west coast has the highest concentration of companies using BIM (Zuppa 2009). Many of these construction journals sample the entire country, with no limitations on what type of a company receives these surveys, producing widely skewed results. Focusing this research on all Colorado GC's narrows down the study to a specific group of GC's within the construction industry.

Purpose Statement

Construction companies are taking a huge risk, investing both time and money into implementing BIM, especially in these unstable economic times. Risks must be met with rewards for companies to continue to grow throughout all types of business in our entire economy. These risks include investments in software, hardware and employee training. All of which according to (McCuen 2009) are costs that cannot be recouped from owners of projects and rarely can be integrated into increased fees. Academic journals and industry publications continue to hype the benefits of BIM software, for all

areas of construction. These segments of construction are most notably commercial, residential, education and health care, which make up over 73% of the demographics in construction where BIM is being implemented according research done by Becerik-Gerber, and Rice (2010). All of the Contractors in this study have done work throughout all of these areas making the significance of this study very high, yet only 84% of the GC's are currently using BIM regularly on their projects, compared to 100% of them using project management software, based on an earlier pilot study of the same sample group.

It is imperative to first understand where BIM is adding value for these contractors (Becerik-Gerber, and Rice 2010). Once identified, future research can provide a strategic plan of how to increase the use of BIM in the areas that rank lowest in value added. Not only is the value added important to understand, the potential value that BIM software can provide a company with is something that must also be analyzed when comparing how much value it is actually adding

Research Questions

Where are the areas that BIM software is currently adding value to Colorado General Contractors? If academic research and industry journals, combined with industry leaders on the national level are able to identify major areas of value for BIM software within their firm, how will these areas compare to the value a General Contractor working in Colorado gets from using BIM?

Theoretical Explanation

BIM is a process that has been working its way into the construction industry. Like project management and scheduling software programs of the past, there is a learning curve for companies, before the value added of that software can be recognized in the company. Throughout the course of the last 15 years, software has become a large part of every company's day to day operations, not just in the construction industry. Back in the mid 1990's Microsoft CEO, (Bill Gates 1995) noted that "today's Internet is not the information highway I imagine, although you can think of it as the beginning of the highway". Just 5 years later the birth of Online Project Management websites would become a trend in not only construction, but throughout all types of business. BIM is now that new software tool that web based collaboration sites were 10 years ago.

Chapter 2 - Review of Literature

Background of Construction Software

Understanding how software started to emerge in the construction industry as a tool that added value to a company, will help to understand BIM's future in the industry. During the late 1990's, project management software was beginning to evolve from project management software in other industries. (Liberator, Pollack-Johnson, and Smith 2001) studied scheduling software in construction that showed trends in construction management software usage. In 1985, 40% of all construction companies had used project management software. By 1996, 100% of all construction companies sampled had used construction management software. The graph in figure 2.1, represented in this study shows a consistent increase of approximately 4% every year from 1985 to 1996

where the construction market met the saturation point of having 100% of the companies having used construction management software.

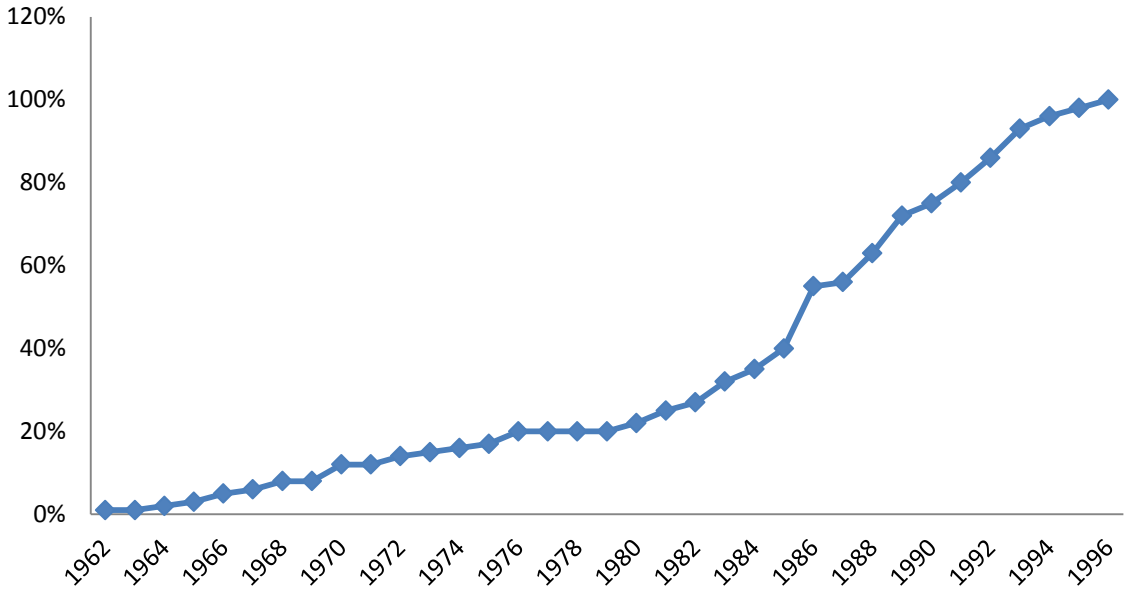


Figure 2.1 Year Construction Companies first used construction software

Project Management Software History

It is important to understand how the need for project management software evolved. A study by (Liberator, Pollack-Johnson, and Smith 2001) revealed the complexity of the project scored highest for reasons to use construction management software, yet the project complexity also scored highest for reasons not to use the software. Training/support was shown to be the lowest scoring for both reasons to use and not use construction management software. These challenges of project management software in the 1990's could be some of the exact challenges 20 years later companies implementing BIM are struggling with. At the time of this study in the late 1990's, owners were beginning to require the use of construction management software

on projects, and if the general contractor was not willing to use a particular software package, they would not be prequalified to submit a proposal on the project (Liberator, Pollack-Johnson, and Smith 2001). These owner trends are still being used in 2011 by sophisticated owners require certain types of BIM software as a prequalification requirement to bid a project, Mike Rush, (personal communication, November 15, 2010). Many of the projects with these software requirements back then and currently are government projects, ranging from federal, state and local governments who mandated the use of certain types of software packages.

Scheduling Software History

Some of the first types of project management software used in the industry during the 1990's were construction scheduling software programs. Primavera Suretrak became the industry standard at the time, and still to this day continues to lead the construction industry in scheduling software, (Basu 2007). Colin (1997) cited the use of complex schedules generated from scheduling software should be used as contract attachments, requiring the constant update of the schedule by the general contractor, to be one of the stipulations within the contract the general contract held with the owner. This puts the responsibility of developing a realistic schedule and maintaining it directly on the general contractor. (Khattab 1996) believes that a computer is the best way to create a construction schedule yet found Primavera at the time fell short because it's scheduling was based on unlimited resource availability.

Decades before, schedules were long, drawn out sheets of paper done by hand. They took weeks to develop, and required complex, in-depth understandings of how to

identify critical paths and potential areas of delay. With the advent of Primavera, these schedules could be built digitally with logic already written into the program. This allowed the builder of the schedule to have potential critical path delays identified and manipulated with ease. Primavera is not a project management software program though; it is strictly a tool for scheduling that helped push the technology side of construction management software programs.

Online Project Management Website History

By the turn of the century, there was an emergence of online construction management software programs that allowed owners to manage their architects, contractors, budgets and schedules through online collaborative web based programs, such as Pro Log Project Manager and Procore. The main advantages of web based project management programs are to provide a common area for project information to be stored allowing faster access to information by all participants, (O'Brian 2000). This enabled documenting of the project in real time without the delays of regular mail, fax machines, emails and other forms of communication which can cause information to get lost as well as duplicated many times. The information stored on the web based project management program is however restricted to certain parties that have been assigned certain security rights. For example, a subcontractor may be able to access the information on the site, and even go as far as to create a Request For Information (RFI). The subcontractor must then follow the correct channels of communications, requiring them to send the RFI to the project superintendent so it can be reviewed and sent to the project architect if the superintendent cannot answer the question from the subcontractor.

(O'Brian 2000) studied many project management website implementations. His findings revealed the biggest advantages of project websites were their increased communication. Conversely, he also found that the increased communications were their biggest hindrance. The same subcontractor, who has an RFI to ask the architect, must follow the proper channels, and submit the RFI to the project superintendent. The drawback was the project superintendent had a cell phone, fax, email, hand radio as well as the project website. Many of these other forms of communication were more familiar to the subcontractor so they would go with a more traditional form of communication and bypass the website creating gaps in information.

Another major impediment to project websites from (O'Brian's 2000) research was the sites were very generic. This was a result of the site being a place for storing project information that everyone could access. However, it was not the only means to manage the project from within the various companies using the site. The owners, architects, consultants, general and subcontractors had their own internal requirements for tracking a job from start to finish. While this research, (O'Brian 2000), is over 10 years old, the themes discussed still hold true today when looking at software packages. A project website was just another tool the construction industry used for project management software as it started to evolve.

By 2002 there was still an ongoing debate in the industry if companies, especially smaller ones should even spend the money for construction management software (Zind 2007). (Smith 2002) noted that software should only be purchased when the complexity of the project warrants the need for software to aid in the organization of the tasks required to complete the project. The focus on this article seemed to be more towards

scheduling type software, like what was discussed earlier in this paper. At that time, project management software was still beginning to grow into its own type of software, separate from that of the scheduling software that preceded it. While the larger companies at the time were beginning to use things like online project management websites such as Pro Log Project Manager, the smaller companies were still struggling with the concept of purchasing a robust scheduling program to manage their tasks (Smith 2002).

Smith (2002) also addresses whether a company really needs project management software or not. He says the best project management software cannot replace the human element required to manage a good project. A project requires a project manager that is able to lead, coordinate, organize and inspire other members of the team. A software package cannot replace the person that is in charge of these items, and all too often there is more emphasis placed on tools and technology rather than the requirements of the right project manager for the job. This view holds true when talking about 3D BIM models. Some of the most reliable and accurate models are generated with the input of a superintendent with 30 years of experience, not young designers and project engineers right out of school, Rick Kahn (personal communication, February 15, 2011).

History of BIM Software

Surge of BIM's Popularity

BIM as well as Project Management software continues to be the topic of much research and discussion with regards to how to better manage projects. According to a research paper presented in 2006 at the International Conference on Building Education

and Research, in Hong Kong, (Wall, Smith and Betts 2006), "All software packages should talk to each other, define a building project and automate the construction management business processes in an integrated way. A software interoperability solution (standard objects being interlinked) will result in lower expenditures for owners / users and opportunity for the industry to work together. This adds value to customers and most importantly will reduce life cycle costs." This is a not a new topic, as can be seen by the date of the 2006 conference, but it summarize a very key point that the industry as a whole is struggling with right now, software programs not communicating with other types of software.

BIM software has been surging in popularity year after year, and is becoming standard on many commercial construction projects in the United States. Many owners are requiring the use of BIM on past projects as prequalification for general contractors to bid on their project, (McGraw Hill 20010). A challenge with that requirement is BIM software must be able to communicate with the design team, general contractor, design consultants and subcontractors. There is no "industry standard" for BIM software, so this often requires double entry of information by the design team or general contractor, in an effort to build a complete model (Penn State 2010).

Early Challenges with BIM

This issue of software communicating with various types of software is still a major challenge today, but started as a hurdle with the web based project management software. When Setzer (2004) discussed how online project management collaboration tools are here to stay, he took his research a step further and investigated how this was

going to now affect the subcontracting community. Many of the subcontractors at the time in 2004, were still doing business the old fashion way with a pen and paper (Setzer 2004). Learning to use multiple types of new software was a major obstacle facing the industry.

Setzer (2004) focused on the standardization of document templates for items such as RFI's and change orders. He then addresses the larger issue, one which BIM struggles with today, and that is the standardization of file types such as word documents, pdf's, dwg files and so on. Many subcontractors continue to use various types of BIM software packages, and some do not communicate with others, rendering their model useless to a design team, resulting in the duplicate entry by the design team to incorporate that information into the model, Donnie Hirschfield (personal communication, November 17, 2010). It becomes increasingly difficult to share information as a result of multiple software programs and licenses required just to open a particular file, making collaboration difficult.

By 2007 online project management software programs were beginning to lose their momentum as the main tool for project management. After years of trying to get subcontractor participation in these online project management sites, Zind (2007) observed that general contractors found it increasingly difficult to manage a site with only partial buy-in of the subcontracting community, forcing many of these GC's to go back to using in house project management software and find another method of project collaboration. That new method was and still is BIM. Yet BIM continues to struggle with the same software constraints that hindered the project management software, file sharing, (Penn State 2010).

BIM is a process that has many different software programs and applications that can be considered "BIM Software". BIM originated from the MEP subcontractors constantly struggling with how to fit their equipment in ceiling areas that continued to get smaller and smaller, (Rosen, Knight, and Ross 2010). Productivity onsite decreased as they waited for design team responses to Requests for Information (RFI's) for where to run their equipment because the field conditions differed from the drawings. They began using a type of BIM software that specializes in strictly clash detection, which is identifying conflicts where structural, mechanical, electrical and architectural drawings do not match up, (Rosen, Knight, and Ross 2010). This software is called Navisworks, developed by Autodesk. A common example of a clash is, a piece of duct work or pipe, shown on the MEP Drawings at the same height as a steel beam on the structural drawings, causing a clash, where the duct or pipe would run right into the beam.

2004 was the first time BIM was used to design an entire building at the University of Trinidad, not just an MEP system, (Arnold 2010). This was one of the first documented examples of an entire building being built from 3D models vs. the traditional way of using 2D architectural drawings. Arnold (2010) talks about the use of ArchiCAD software used to build the 3D model of this university and how it helped reduce conflicts, saving the project team time during the design and purchase of the HVAC system.

Current Perception of BIM

The perception of BIM throughout the construction industry has been a highly contested topic for the last few years, and continues to evolve as BIM becomes more main stream on various types of projects. McGraw Hill (2008) cites 61% of the surveyed

contractors felt BIM had a positive impact on their company. Engineers were the lowest of the 4 groups surveyed citing only 39% felt BIM had a positive impact. Owners, however, had the highest percentage of negative impacts from the use BIM, at 10% while contractors only showed 4% negative impacts. The challenges of implementing BIM addressed in the article were costs and training. They were viewed as a moderate to lesser concerns when looking at the overall challenges a company faces. Regardless of their views on BIM, it is hard to argue with the vast amount of waste generated in the construction industry. Zuppa (2009) notes much of this non-value added work is related to the inoperability or inefficient information exchange as a result of the construction industries slow adoption of new technology.

Castro-Lacouture (2009) also surveyed Architects, Engineers and Contractors to get their perception of BIM software and how it worked. BIM currently is so new that many companies are not entirely sure who should own the BIM model. There are no governing guidelines identifying the General Contractor, the MEP Engineers or the Architect as the responsible parties for using this software to help the project along. Penn State (2010) cites that there is no clear defined person responsible for creating a BIM plan on a project. It only states that the earlier the plan can be initiated the greater success the project will have and in some cases the BIM project plan may need to be contracted through a third party. Contracting through a third party becomes even further complicated as a result of the different types of construction contracts. Penn State (2010) identifies Integrated Project Delivery (IPD) contracts as the ideal contract type for BIM projects, but recognizes this is not always possible, and therefore not a requirement.

IPD Contracts Role in BIM

(IPD) contracts require the owner, architect and contractor to all take ownership of the model. According to AIA (2007) IPD attempts to create the collaborative atmosphere required for the most comprehensive use of BIM by aligning the goals of all team members and incentivizing them to work closely together throughout all phases of the contract. However, in a study of 435 national construction companies, (Becerik-Gerber and Rice 2010) only 10.4% where using IPD contracts, while 32.7% where still using the traditional design-bid-build contract model with the use of BIM on a project. Whether the contract is IPD, Design Build or even traditional Design Bid Build, BIM has been proven in many studies to add value to a project, but the question remains: Are construction companies utilizing all of what BIM has to offer? This research addresses this topic.

Areas of Value for BIM

Planning

Penn State (2010) discusses four major uses for BIM, Planning, Design, Construction and Operations. In the past construction scheduling and planning was done through the use of a typical Ghant chart, which is a common bar chart from either a construction scheduling software program or Microsoft excel based program,(Khattab 1996). Linking construction schedules to BIM software for scheduling is referred to as 4D scheduling. The objective of 4D scheduling is to visualize the phasing and sequencing of construction, while communicating the scope of work to the parties

involved through the use of a 3D model. This allows the team to accurately visualize completed work in place at that particular point in time (Basu 2007). 4D scheduling allows project managers and superintendents to schedule subcontractor work throughout the life of the project, showing where other trades will be working, site restriction, access points, and possible equipment and material movement challenges that may occur at any given point in the model, rather than trying to anticipate them as work progresses (Basu 2007).

Hijazi, W., Alkass, S., and Zayed, T. (2009) studied the use of 3D BIM integrated with 4D Scheduling to help test the constructability of a job before construction begins. The benefit of building in 4D is the ability to test certain means and methods, identifying areas of conflict and further more planning material and equipment locations throughout the job as construction progresses. Teams are able to analyze existing conditions, review cost estimates, review site analysis, program planning, and phase planning to name a few. The design portion consists of code reviews, MEP analysis, LEED evaluation, structural analysis, as well as other engineering analysis. From a designer's point of view these areas are where the most value is being added to the project according to (Ernstrom 2006), differing from a contractor's point of view of the value added by BIM, which is in improved scheduling, estimating, shop drawings and coordination (Ernstrom 2006).

The design phase use of BIM can be further extended into a new area where designers are simulating building performance. This requires the integration of energy modeling within the BIM process and is being used today on many Green Building projects looking for various levels of LEED Certification. This use of BIM starts to cross the line between architectural design and mechanical design, much like the contractor

detailing the structural portion of the architectural drawings. (McGraw Hill 2010) notes that day lighting analysis has been one of the early benefits to this type of use with BIM, allowing for the reduction in lighting fixtures throughout the building during day time operations, thus reducing the overall energy costs to the owner, as well as reduced construction costs. However, this requires input from subcontractors early on in the design process. This early on input from design teams helps them market their product to project owners, showing that they have the owner's best interests in mind.

Marketing

There are many programs on the market currently such as Google Sketch-up that allow a designer or general contractor to build a 3D model of a building in a matter of hours, Greg Behmer (personal communications, February 23, 2011). This visualization of a building is a great tool for Marketing to owners. The majority of owners are not experienced at reading two dimensional construction drawings, Becerik-Gerber, and Rice (2010), so having the ability to show an owner their building in 3D can really help convince the owner into selecting that project team. The cost savings from clash detection, estimating, general conditions and RFI's are hard to quantify to an owner. Owners believe they contract for a 100% complete set of construction drawings, not understanding that there are errors or ambiguities in them, Mike Rush (personal communication, November 15, 2010). This is a large misconception for many owners in the industry.

3D models help owners better visualize what their end product will look like during the interview process, Greg Behmer (personal communications, February 23, 2011

The industry is in a transitional state where many companies, mostly smaller, are still trying to catch up on technology. Having the ability to showcase one company's grasp or perceived grasp on technology over another to win a contract, is one of the greatest areas of value to any general contractor. The award of a contract is the goal for any general contractor. That is why so many general contractors are now pushing for the use of BIM within their firms by implementing Corporate Strategies on how best to market and use BIM.

Corporate Strategy

With more and more companies making a commitment to implement BIM within their firms, Rick Kahn (personal interview, February 15, 2011) Corporate Strategy becomes a major area of value. CII (2010) states that change must come from the top down. BIM is something new and emerging, and many top level executives in construction companies have a tendency to resist change Rick Kahn (personal communication, February 15, 2011). Midlevel employees will see this resistance and be hesitant to bring new ideas and implement the industries newest tools. Many managers want to see how technology can impact the bottom line. The IBM "Go Green" commercials of the last few years have targeted upper management, showing entry level employees making sales pitches to the managers explaining how small changes in software applications and servers can reduce energy costs and consumables saving large amounts of money at the end of the year. This is considered "low hanging fruit" meaning simple changes that add great value to get company executives to support the cause (Post 2009). Post (2009) considers MEP Clash Detection MEP Clash Detection low hanging

fruit, which is a great way for mid-level employees to encourage Corporate Strategy that includes BIM.

Clash Detection

The reason for the reference to “low hanging fruit” is because most Mechanical, Electrical and Plumbing (MEP) subcontractors have been using it for upwards of 7-10 years now, (Rosen, Knight, and Roth 2010). Clash Detection is the coordination of these 3 trades in 3D to check for conflicts or “clash detections” between mechanical ductworks, plumbing or electrical fixtures with the structural elements of the building. This is what really developed BIM into the tool it is today, (Rosen, Knight, and Ross 2010). Costly overruns in time and resources on site by MEP trades drove the development of BIM to add value to the project. The costs not only affect the MEP trades, but get passed down to the general contractor, and off to the owner. They degrade the moral on the jobsite and often times strain the relationships between the owner-contractor, owner-architect, architect-contractor, and contractor-subcontractor. Considering many firms in Colorado receive 70%-80% of their business through repeat clients, Tim Carpenter, (personal communications, November 17, 2010), this area of BIM adds a great deal of value to a general contractor in an effort to maintain those relationships.

Clash Detection has evolved to beyond MEP trades identifying conflicts with the structure. Architects are now collaborating more seamlessly with MEP engineers through BIM models to develop more energy and cost efficient MEP Systems (Rosen, Knight, and Roth 2010). BIM models are being designed by the architect and sent to the MEP engineers to incorporate their scopes of work into the model. Engineers run load calculation on specific rooms through the entire model, collaborating with the architect

about how different R values on exterior walls and E values on windows will affect the sizing of MEP equipment. This collaboration extends into extends to the general contractor and owner who all benefit from the communication

Collaboration

Open communication between all parties involved is at the core of Collaboration, and is imperative for the success of a BIM project, (McCuen 2009). Teams must learn to change the way they have done business in the past, as evident by a case study where an electrical and mechanical subcontractor detailer ran into a conflict (Dossick 2010). The Electrical detailer wanted to make a change, with the help of the mechanical detailer yet the mechanical detailer was still bound by the contract language forcing him to go through the lengthy RFI process requesting that the design team provide direction rather than being able to work through the challenge together as a team. The example shows BIM must be used in a contract constraint that allows teams to work together rather than pushing responsibility on one particular entity over another. Without full cooperation from the designers, contractors and detailers, much of the value added in the design phase by BIM is lost through the old style contract structure. It does not allow for the people in the field to clearly communicate with the designers in the office. Having Field Operations provide input and collaborate with designers has been noted as one of the valuable parts in developing a BIM model for construction, Rick Kahn (personal communications, February 15, 2011)

Field Operations

Field Operations is one of, if not the last step in implementing BIM on a construction project, Greg Behmer (personal communications February 23, 2011). Many general contracting companies both national and local are in the process of implementing BIM at the operations level. The design phase use of BIM is without question the most commonly used one, but if a company is unable to take that 3D model and apply it to the Field Operations, much of that value is now lost, Burke Martin (personal communications January 4, 2011). Having superintendents educated in 3D software is one of the largest challenges companies are trying to overcome, (McGraw Hill 2009).

One national firm in the study has begun the daunting task of training all of their veteran superintendents in multiple types of BIM software. This allows the superintendent to carry items like I-pads with them on site. In the event of a conflict in the field, the superintendent has the ability to make minor adjustments to the model as a conflict arises in the field. This is done by collaborating with the responsible subcontractor of that trade, thus bypassing the lengthy RFI process in traditional construction contracts. As discuss earlier in the IPD style contracts, the contractor now has ownership of the model as does the designer and subcontractor, so the best possible solution can be arrived upon in a quicker manner. This adds more value to the owner by having input from the trades guaranteeing the best option has been selected.

The scheduling aspect is also very important, and without a field staff that is trained in how to use the BIM software, the BIM model becomes lost. The value is in the ability to sit down with various trades at one time. A superintendent can run the model for one, two, three, or six weeks in advance in an effort to help schedule

workloads for various trades. This ensures that there will be no overlap of work, while also making sure that adequate equipment and materials will be available in that location on the jobsite for the given time frame of work taking place. This visual representation is something everyone from subcontractors to project owners can visualize before the work is in place.

Shop Drawings

Before any work can be put in place however, subcontractors are required to submit what is called a Shop Drawing. These shop drawings are the installer's interpretation of the architect's drawings, of how the work will be manufactured and installed. During conventional construction from a 2D set of plans, a subcontractor is required to provide a set of Shop Drawings for review by the contractor, architect and engineer to ensure they meet the specifications and design intent of the architectural drawings of the project. The shop drawings are the manufacturers or the subcontractor's drawn version of information shown in the construction documents. The shop drawing normally shows more detail than the construction documents. Detailed BIM models have the ability to provide a detailed shop drawing incorporated into the model before construction is even priced in some cases. This allows the subcontractor to bid exact quantities, eliminating contingencies that may otherwise be included to cover the unforeseen costs in the final construction of the product.

MEP Clash detection is a form of shop drawing, yet without a detailed structural shop drawing; the risk remains that the MEP shop drawing model may not be 100% accurate. The current trend for the steel fabricator, millwork fabricator or even the structural concrete subcontractor is to contract with a third party they trust to detail a set

of shop drawings before building the structural steel, millwork cabinets, or pouring the concrete structure. Through the use of BIM, these detailed shop drawings are now done outside of the subcontractor's control. Should something be detailed incorrectly the subcontractor does not own the risk when something is incorrect, like they do with the traditional system.

Dossick (2010), discussed BIM from the standpoint of Mechanical Electrical and Plumbing (MEP) coordination. The MEP subcontractors and its coordination exercise between the design team, the consultants and the general contractor show the software itself does help with identifying conflicts, but the individual members of the team must be a part of the collaboration in order for BIM to work correctly. He highlights the MEP detailers and their work in BIM software vs. the work that is done by the General Contractor to change their models making it easier to build in the field, creating less waste and identifying conflicts before they happen. This leads to a need for a more detailed structural BIM model. The more accurate the structural model, the more value added to the rest of the subcontractors working on that model will have, ultimately resulting in fewer change orders, claims and disputes. This will reduce overall project costs, which were less than 0.5% of the total project costs in a study done by Becerik and Pollalis (2006).

Understanding all of these different aspects of BIM is just one piece of the puzzle. There must be people that are able to process this information and apply it to the construction site itself. Post (2008) addresses a major issue BIM is facing today, getting the education from the office to the field. This requires a re-education of the work force as well as a process change, and that is not something any company can accomplish

quickly. In the future, more technology savvy workers will migrate to the field, but that may take upwards of 10 – 15 years and in that time frame, re-educating the current field staff of these companies is a monumental undertaking.

Chapter 3 – Research Methods

Sample Size

This research originated with a pilot study on Project Management software. A preliminary study was conducted in late 2010 to only the Colorado based GC's, excluding national firms in Colorado. Through the responses from that survey, along with personal interviews within the sample group, it became apparent; there was a gap in knowledge between the large national commercial general contractors and Colorado based GC's when it came to the implementation of BIM and the value it adds to a company.

This study focuses on all commercial general contractors with offices in the state of Colorado. The same McGraw Hill revenue report was used to identify contractors completing over $100 Million a year in revenue within Colorado during 2009. The driving force behind the $100 million cutoff was research showed very few projects under $65 million during 2008 and 2009 used BIM in Colorado. A threshold of $100 million was established and many within the industry agreed. The highest earning contractor earned just over $406 million. With a threshold of $100 million, the 19th contractor completed just over $119 million that year, while the number 20 contractor did $92 million (McGraw Hill Mountain States 2009). Thus the study consisted of 19 participants.

While the sample size may seem small compared to a similar study conducted at a national level, the results would be very different. This research provides a good comparison at the state level for general contractors. Figure 3.1 below shows the revenue for 2009 of all the Colorado firms involved with the study. This group, while seemingly

small for a research study, makes up the largest group of general contractors in the United States. Very few cities can sustain multiple projects over $500 Million every year, yet many schools, hospitals, and commercial buildings fall into that range of $65 million to $200 million, which is the main type of work for these general contractors. Even though it's a Colorado based study, this is applicable to all midsized general contractors in the United States and even in other developing countries that have construction companies with the same level of competency as United States firms.

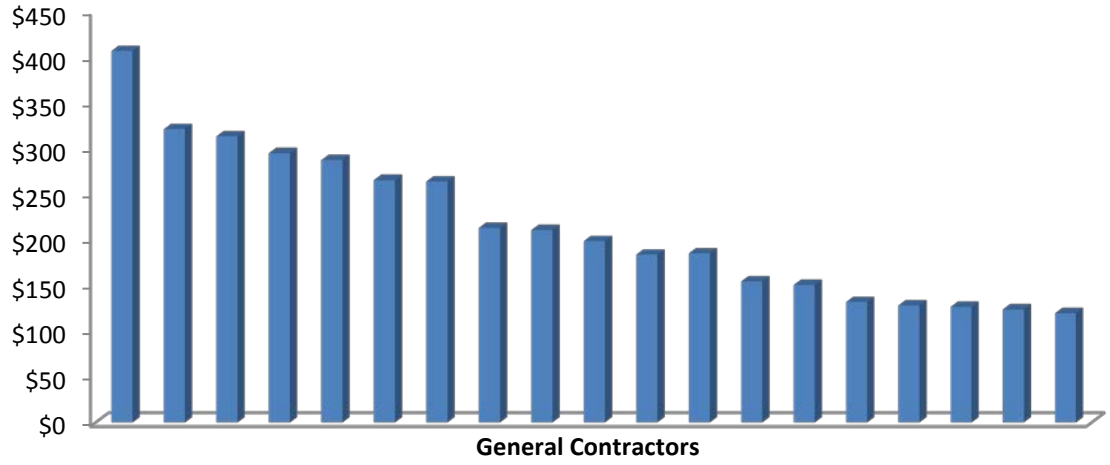


Figure 3.1 General Contractors 2009 Dollar Volume Per $Million of Revenue

The state of Colorado had 20 contractors overall in 2009 that generate over $100 Million in construction, however 1 of them was only 4% commercial construction, and this research is focused on commercial construction, so they were excluded. 10 companies were based in Colorado, and 9 companies were national firms that had offices in Colorado.

When analyzing how to best narrow this down a sample size, $100 million was set as a bottom line cut off. The cutoff of $100 million was designated because research showed that contractors generating $100 million a year in construction revenue will rarely have more than one project using BIM, and could therefore negatively impact the results of the survey Greg Behmer (personal communication February 23, 2011) Through a series of personal interviews of people inside the industry from chapter 2, as well as research from academic journals in chapter 2, it was determined that in the past few years, most projects under $65 million dollars were not using BIM. While a separate study could be conducted to identify where the cut off point for BIM providing value to a project, this was not the focus of this research.

Access and Permissions

Before sending out the survey, the Internal Review Board at Colorado State University was consulted for approval of a 20 question survey. A copy of this approval is attached in Appendix B. A survey was developed using a Likert scale of -2 to 2, with 0 being neutral, to sample whether these companies Strongly Agreed to Strongly Disagreed with the questions. The survey and its associated results were crafted in a way that every company would remain anonymous allowing for more realistic, truthful responses. Once permission was approved by the IRB the survey was sent out to the list of general contractors via email, and the results saved as a general file with no names associated with them.

Instruments and Reliability

The survey sent out to the 19 contractors is qualitative in nature, while the responses were analyzed in a quantitative manner using the Likert scale. By using this type of instrument, multiple questions were asked that related to the same area of focus, which will help to determine reliability of the responses by the sample group. The major areas of focus in this survey are Marketing, Planning, Clash Detection, Field Operations, Collaboration and Shop Drawings.

These groups were developed with the help of Rick Kahn (personal communication, February 15, 2011) and Kirk Alloway (personal communication, February 1, 2011), who work at two large successful national general contracting firms with offices in Colorado. Gregg Behmer (personal communication, February 23, 2011), Chris Evans (personal communication November, 16, 2010), and Tim Carpenter (personal communication, November 17, 2010) who are all champions of BIM in the smaller Colorado based general contracting firms that they work for, were also consulted. These personal interviews were conducted prior to sending out any surveys to get their opinions and viewpoints on this topic.

By using larger national commercial companies as well as local Colorado based companies, to help develop a survey for BIM, the survey is able to focus on the demands of the Colorado market, while still addressing the larger areas of BIM where it is being used on a national scale. In order for a response to be calculated, the company must first be at least Neutral about using BIM in the last 36 months. If they are neutral, which is 0 on the Likert Scale, or disagree, which is -1, to having used BIM on a project in the last 36 months; the validity of the responses skews the entire survey. Therefore the responses

of those companies will not be calculated into the results. Appendix A shows a copy of the 20 question survey. Of the 19 companies sampled all 19 responded to the survey, however, 3 of the 19 companies, either disagreed or were neutral regarding question 1 about the use of BIM in the last 36 months. As a result these 3 companies are excluded from the study because their answers would greatly skew the results. This study is about the use of BIM software and where it adds value, if the company is not using it, they cannot adequately respond to where it adds value there for taking away from the validity of the responses.

The only question besides question one that was not lumped into one of the seven categories shown on Figure 3.2, was question number thirteen, "Owners understand how using BIM on their projects will benefit the project". Originally designed as part of another category that was going to be labeled "Owner Understanding", it was left in because it was a direct and to the point questions, which help identify the views general contractors had of owners who are requiring the use BIM software on their projects.

One of the long standing ways to measure reliability of an instrument since the 1950's is Cronbach's Alpha. Cronbach's Alpha is a number that can range anywhere from zero to 1. Many professionals as a "rule of thumb" state that anything over 0.70 for Cronbach's Alpha is considered to be reliable. Table 3.1 shows that this survey has a Cronbach's Alpha of 0.841, making the survey questions themselves a reliable instrument.

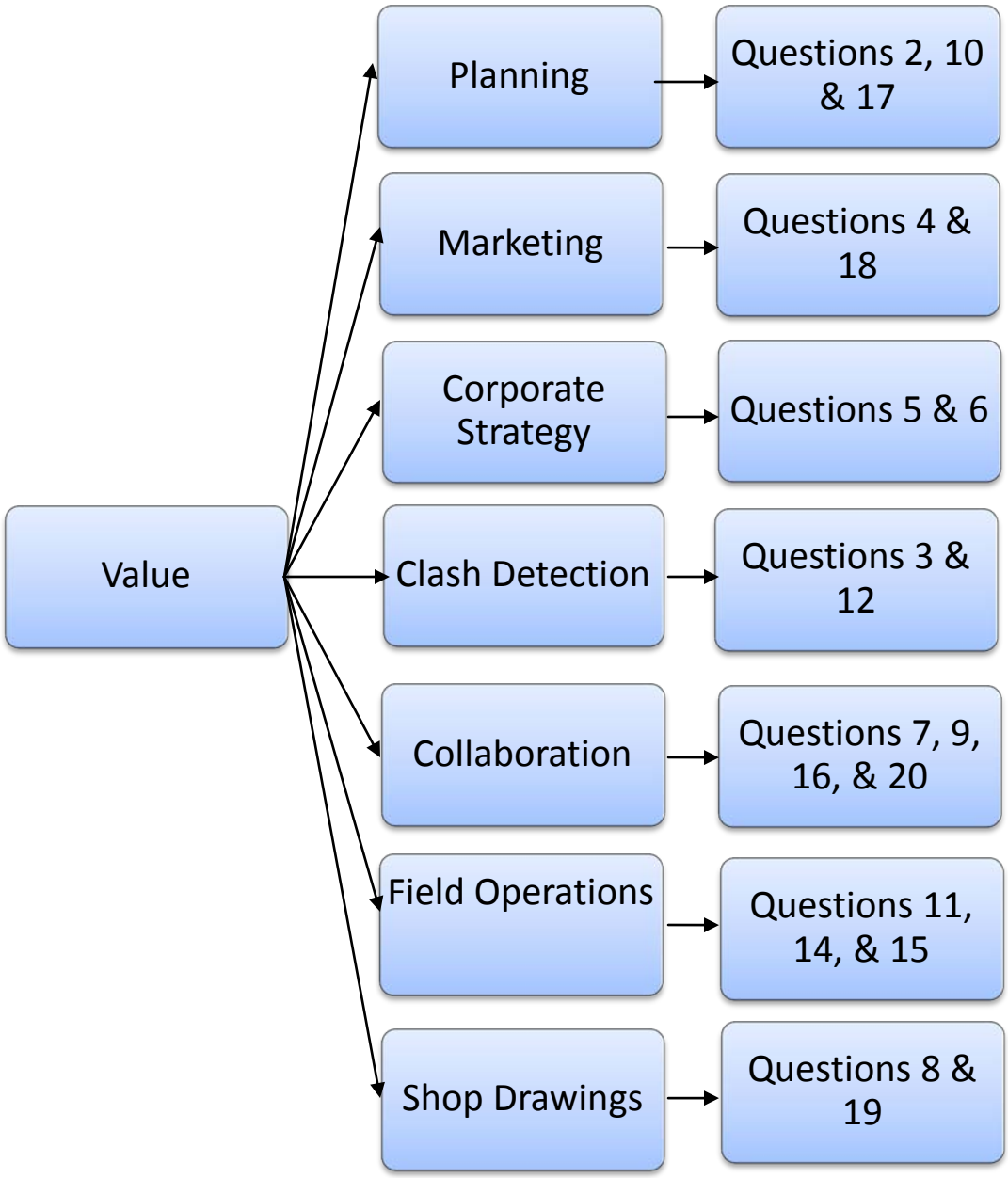
Table 3.1

Cronbach's Alpha for Research Study

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items

0.841	0.848	20

There are however some challenges to this study. A reliable instrument typically has four to five questions per category. This instrument has seven categories, yet many of them only have two to three questions. This is done intentionally in an effort to include as many areas of value as possible, while not overwhelming the participants in the study. Had the study only focused on three to four areas of value, it may have been possible to create a more reliable instrument or develop a longer questionnaire with more questions per category. However within the study, the questions had a high Cronbach's Alpha above 0.81, which further support the internal consistency of the study, suggesting that the questions themselves are correlated. It is important to note the data itself is reliable as a result of the high Cronbach's Alpha. Figure 3.2 shows the relationship of all questions to their areas of value.



Figure

3.2 Areas of Value and Related Questions

Procedures of Data Collection

The survey was sent out in a Microsoft Word Document via email to the people within the companies that are the champions of the BIM software within their firm. By having the person who oversees the implementation and use of BIM in their respective offices provides plenty of validity to the responses especially when combined with a 100% return rate of the survey. Once the results were in, all surveys were saved as PDF files with no names. They were sorted into two groups, national contractors and local contractors, printed, and randomly assigned numbers to keep them anonymous within their respective groups of national and local general contractors

Chapter 4 – Research Study

Analysis of Survey Results

The study focused on seven areas of value. An analysis of both the questions and the results must first be performed before the areas of value added can be identified. Table 4.1 shows a descriptive statistic of all areas. N= the number of respondents to the question, with the minimum and maximum response, the mean, and standard deviation.

Table 4.1

Descriptive Statistics of Areas of Value

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Planning	16	-.33	1.67	.4167	.59004
Clash_Detection	16	-1.00	2.00	.9063	.84101
Marketing	16	.00	2.00	1.0313	.61830
Corporate Strategy	16	-1.00	2.00	1.1250	1.05672
Collaboration	16	-1.00	1.25	-.0469	.72006
Shop Drawings	16	-.500	1.500	.56250	.727438
Field Operations	16	-1.00	1.67	.5000	.76012
Total All Questions	16	-.60	1.35	.5688	.48335

From this chart, Clash Detection, Marketing, and Corporate Strategy all had a maximum score of 2, which is the highest possible score. Clash Detection and Corporate Strategy, along with Collaboration and Field Operations also had the lowest scores of -1. Generally all of the questions had a very consistent standard deviation, with the exception of Corporate Strategy, which had the highest standard deviation of -1.053, meaning that overall the response rate was positive to this question, yet one company responded with a

-1 skewing the results. This is what also contributed to the higher standard deviation for corporate strategy. Figure 4.1 shows a graphical representation of the data, where it's easily identifiable that marketing is the only area within all the groups to not score below 0. This means no company felt BIM had a negative impact to any of the seven categories in this study.

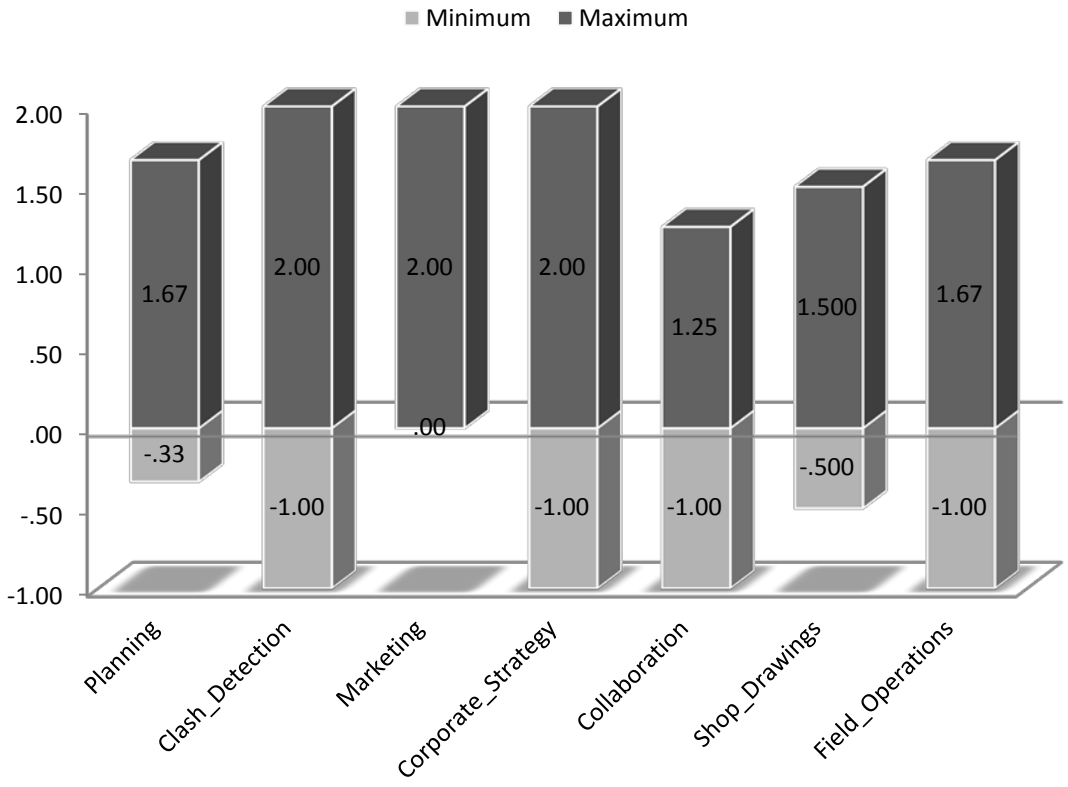


Figure 4.1Minimum and Maximum Response to the 7 Areas of Value

All the questions overall were consistent and show a similar response with regards to their mean, min and max response as shown in Figure 4.2. This representation identifies that the responses trended towards the higher numbers, but there were consistently responses which skewed the results by selecting a low response to the question. This once again shows the reliability of the study.

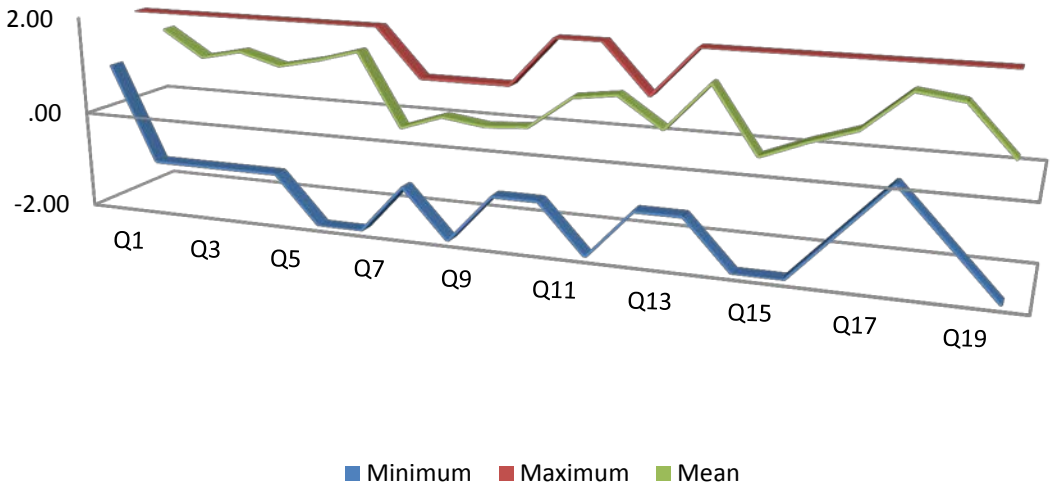


Figure 4.2 Mean, Min, & Max Response to Survey Questions Showing the Mean Trended Higher Rather Than Lower

Identifying Areas of Value Added

Planning

The first category was Planning, which included questions 2, 10 and 17. Question 2 dealt with using BIM software to help plan and coordinate material delivery, equipment needs and locations, both before and during construction. Question 10 dealt with managing the physical schedule through BIM software, and question 17 dealt with managing subcontractors during construction through BIM software. When analyzing the results using a reliability statistic, it became clear from Table 4.2 below, question 10 was not worded well.

Table 4.2

Scaled Means of Planning if Questions Deleted

Questions	Scale Mean if Item Deleted
Q2	.3750
Q10	1.3125
Q17	.8125

If question 10 were deleted the scaled mean would have been one of the highest for all categories, at 1.3. This can be attributed to the wording of the question, which created some confusion, by reading "Projects are scheduled through the BIM Model". This question has a very low overall mean of -.06, meaning most companies disagreed. The intent of the question is to ask if BIM models are linked to the construction schedule, not that the model is used to create a schedule. The responses to question 2 and 17 show there is value added by using BIM models to help manage both materials equipment onsite as well as subcontractors onsite, but as a result of a poorly worded question, the results don't adequately reflect how much value BIM is adding to the use of Planning for these companies.

Planning ranks so closely to Field Operations because the way in which the questions are phrased. The questions generally tie directly to site operations. Typically the superintendent is responsible for developing and managing the construction schedule. If the superintendent is not familiar with BIM, and how to use it, it is virtually impossible for that superintendent to take it to the 4D level and manage a schedule from there. This can be a great tool onsite for managing subcontractors, and has been proven by companies that are able to utilize 4D schedules with subcontractors to help avoid material staging conflicts, equipment needs, and even subcontractor staffing needs based on the powerful visualization characteristics a 4D BIM schedule has vs. a traditional Gantt chart type of schedule, Rick Kahn (personal communications, February 15, 2011)

Marketing

Planning is used primarily on the operations side of a company, but begins with the preconstruction. Preconstruction and marketing are directly tied to business development within these companies. For the Colorado based general contractors Marketing is tied for first place with Corporate Strategy for the most value added through the use of BIM ranking 1.125, yet for the national firms, Marketing scored third with a .94, behind Clash Detection and Corporate Strategy which are tied for first at 1.125. Overall Marketing scored second as you can see in figure 4.3 below, with a score 1.03.

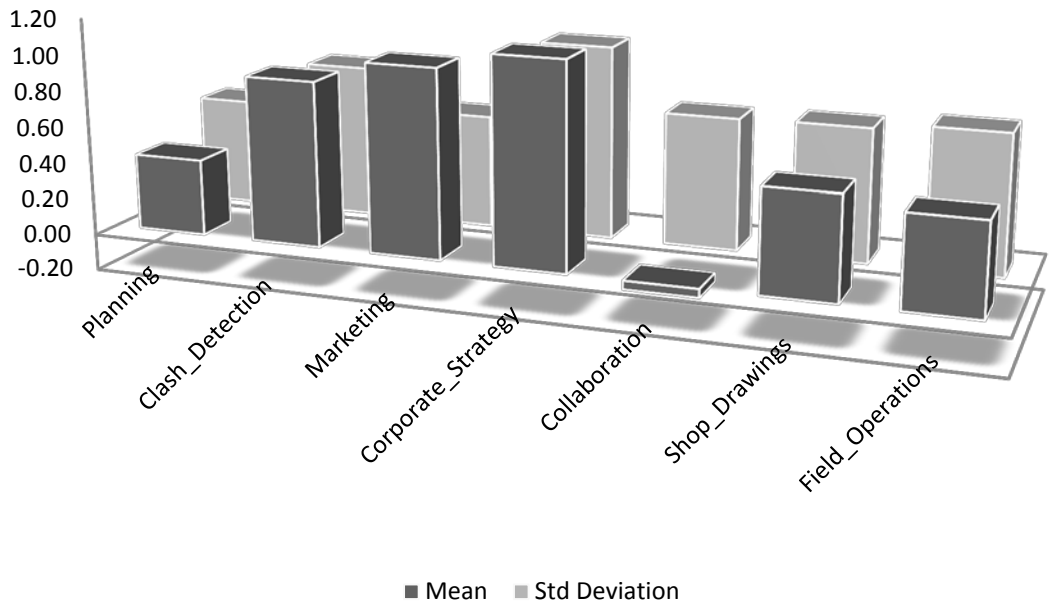


Figure 4.3 General Contractor Mean in Relation to the Standard Deviation

Combined with scoring second highest mean, Marketing also has the second lowest standard deviation at .62, which shows that as a group, all companies answered the questions related to Marketing consistently the same. This is significant because

Planning has the lowest standard deviation of any of the questions, yet Planning only ranked second to last as areas of value added. Marketing is clearly an area where BIM adds great value to a GC. The ability to show an owner what their finished product looks like before construction starts is a very powerful tool. It conveys the message that the GC fully understands the complexity of the project, and has a firm handle on how to build it. This provides the owner a level of comfort, which can help to alleviate the concerns of the risk associated with the start of any new construction project. Having the ability to calm an owner at the beginning, allows the GC to be short listed for the final selection of bidders on a project before the contract is awarded.

Corporate Strategy

As figure 4.3 above shows, Corporate Strategy not only placed first in the area of value added, with the highest mean of 1.13, it also had the highest standard deviation of any other category at 1.06. Having such a high standard deviation shows that not everyone agreed that this is an area of value added. This area contains only two questions, which is contributing to the widely skewed responses combined with only one company answering negatively while all the others answered positively to the question. Question 5, "Having a dedicated BIM department is integral to fully implementing BIM" scored just a 1.0 mean, with the highest standard deviation of any of the questions, with a 1.32, compared to the next highest standard deviation of 1.25 which is question 6, the other question related to Corporate Strategy, as well as question 18 which is tied to Marketing.

These results show great interest from a corporate level. It is imperative for the managers of these companies to support the use and implementation of BIM within the company structure. There have been many trends come and go in the construction industry, and it's always challenging to identify which ones are here to stay and which ones are truly a trend that will go away in short order. BIM has proven to add value to companies that can successfully implement it within their organization. The implementation cannot be a one man operation, past research (O'Brian 2000) has shown this must be a push from the top down and the results of the study show that companies do believe in BIM and want to make an effort to successfully implement it throughout their firms. This is supported by the research because it scored the highest out of all seven areas of value.

Clash Detection

Next in line after Marketing and Corporate Strategy, Clash Detection placed third in the area of value added to these companies. Like Corporate Strategy, Clash Detection also has a very high standard deviation in relation to its mean. The mean is .91, while the standard deviation is .84. This area too only had two questions, and as a result becomes difficult to interpret the results in great depth. The results however are somewhat surprising because most of the literature reviews from previous chapters talk about clash detection as the "low hanging fruit" when it comes to BIM adding value to a project. This data shows that it ranks third out of seven categories.

BIM is developed through Clash Detection, and that is the area originally adding the most value to companies, specifically MEP subcontractors. Over the years as it has developed, BIM began to add value in many other areas, which is the main focus of the

study. Part of the reason Clash Detection scored so low is a result of excluding the MEP portion from the study, however, it continues to grow with the development of steel and wood structures, cabinets and millwork, wall framing, flooring surfaces, counter surfaces, and even site layout of sidewalks and planted areas. These are all great areas where a 3D model can help eliminate conflicts of different material thicknesses and ensure all areas of the project line up at the correct elevation.

Collaboration

Literature stated, Collaboration is an integral part of BIM, and requires excellent communication amongst team members in order for a BIM model to truly be an effective model. Emerging contract structures like IPD focus on team collaboration allowing the design teams consultants to work directly with the subcontractors to help design and build a better project for the owner. By sharing in the risks and the rewards, everyone becomes accountable for mistakes, encouraging a team atmosphere (Grilo, and Jardim-Goncalves 2010). This particular method of project deliver lends itself very well to BIM because of its collaborative nature, yet is still new and emerging. That may be one of the reasons collaboration had the lowest mean of the study at -0.05. Collaboration is the only one of the seven categories to have a negative mean.

Collaboration is also the only category to have four questions, which should have made the responses that much more reliable. The wording of questions 7 and 20 were not clear however, and this led to some confusion amongst many of the respondents. The answers to these two questions are actually inverted from the survey because of the way the questions are framed. Furthermore, question 16, “Superintendents currently have a

large influence on the final design of the BIM models for construction" could also be categorized under field operations. When doing a statistical analysis of what the mean and Cronbach's Alpha would be, if question 16 is removed, Collaboration will have a mean of -.31, and a Cronbach's Alpha of 0.77, showing that the question itself negatively biased the alpha of the four questions for Collaboration as shown Figure 4.4.

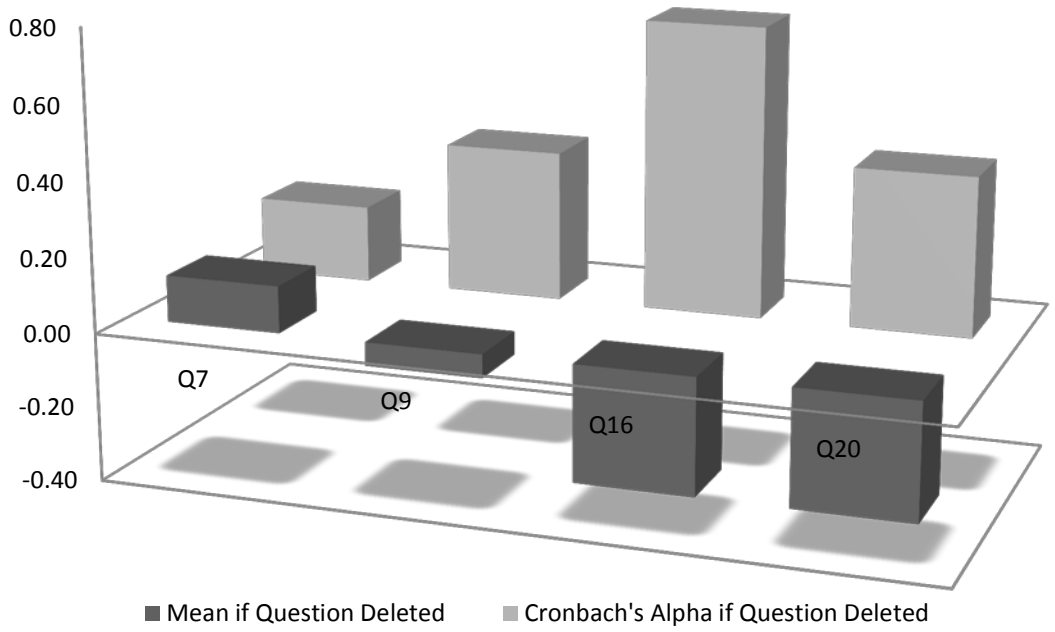


Figure 4.4 Collaboration Results of Mean & Cronbach's Alpha if a Question is Deleted

Field Operations

Field Operations and Planning are tied very closely together within a general contracting firm, not surprisingly; their value added from the use of BIM is also linked very tightly. Field Operations has a mean of 0.50 with a standard deviation of 0.76,

compared to Planning which has a mean of 0.42 and a standard deviation of 0.59. This places Field Operations in the lowest third of categories that add value to a company using BIM. Chapter 2 discusses this further in depth, but helps to support this finding by noting one of the largest challenges companies have, training seasoned superintendents to use new software. Just ten years ago companies struggled to train superintendents how to use email so they could respond to RFI's on web based project management programs, (O'Brian 2000). They now struggle installing BIM Software on superintendents computers and training them how to use this.

BIM is a powerful tool, but it is also a complex tool, that requires intensive training for anyone using it, and must be used regularly in order to retain the knowledge from the training. Field personal, superintendents in particular have generally come up through the trades "swinging a hammer". Most have been given very little training when it comes to technology (Becerik and Pollalis 2006). It becomes increasingly more difficult to train personnel that have very little exposure to technology on some of the industry's most complex technology available. As the presence of technology in construction increases, so does the demand for superintendents with experience in operating these complex programs. The shift in the required skill sets for superintendents will allow BIM to become a standard tool for a superintendent to use in the future. To expect this transition to happen in a matter of a few years is completely unrealistic. It is realistic to expect that some of the best seasoned superintendents will be able to learn this new technology and help add value to the field operations side of a company through the use of BIM over the next five years. As the younger generation of superintendents who

have grown up with technology work their way into the field, BIM's presence will continue to grow in the Field Operations category.

Shop Drawings

Shop Drawings is the last category in this study, and is ranked in the lower half of the areas that add value through the use of BIM. In part this is a result of how the questions are phrased. Question 8 asks, "Excluding MEP Subcontractors, you currently work with subcontractors that can develop detailed BIM models." This question, does not adequately address the topic of shop drawings because it excludes the MEP trades. The question is phrased such, that it challenged the general contractor to acknowledge if they are working with subs other than the MEP trades that are capable of using BIM. Had the MEP trades not been excluded from that question, there is much speculation that the results would be very different. However, MEP contractors are just handful of subcontractors on the job site, that a general contractor must work with, and there are trades out there other than MEP that are capable of building detailed shop drawings in 3D models. The response to this question shows that while those trades may exist, in the state of Colorado, there do not appear to be many of them.

The root of the question is based in the subcontracting community. It does not address how the general contractor is gaining value, but rather how the subcontractors are adding value to the general contractor. With a mean of 0.56, Shop Drawings adds just slightly more value than the Field Operations category to a general contractor in Colorado. This relationship is logical in the sense that the field operations team of a general contractor is the team that is going to interact most closely with the

subcontractor. If a subcontractor is providing 3D BIM models for shop drawing review before installation, it would only stand to reason that the field operations team would be familiar with these models and gain great value through them.

People are constantly looking for a way to save money on a construction job. Subcontractors that are using BIM to do their shop drawings before construction are gaining value from increased productivity on the job site, and reduce material waste. The challenge for many of these subcontractors is the upfront cost to build the model before construction. There is no question about it, the cost of a BIM shop drawings is increasingly more than a standard 2D shop drawing produced by a detailer. The key is to recognize the increased savings that can be had through on site productivity increases as a result of having a 100% clear cut design that goes in place seamlessly, and in many case allows for the product to be prefabricated offsite in large portions. By manufacturing items like ductwork for example, offsite, a subcontractor will have much greater control of the productivity of their workers, vs. fabricating on site. This is just one example of how BIM shop drawings can add value to both a GC and subcontractor.

Chapter 5 - Conclusion

Summary of Areas of Value for Both Sample Groups

The survey was issued to 19 participants, of which all 19 were responded back. From the 19, 16 have experience with BIM on past projects, and were entered into the analysis. The above analysis highlights the areas of value BIM has provided for this sample group. Corporate Strategy is the number one area, showing that all the companies involved in this research believe BIM to be an important tool that adds value. Marketing

is a close second, showing that using BIM is a great way to develop new clients and win new contracts. Clash Detection is ranked third, and the only one of the top three categories that applies directly to the day to day operations of a construction project.

The next step is to analyze the relationships these categories have to each other. Using both a Pearson and Spearman Correlation Test, relationships between the categories can be established. It is important to note that due to the small sample size in the study, both a Pearson and Spearman Correlation test were run. Both resulted parametric and no parametric correlations. The Spearman chart is used to check the findings of the Pearson chart. The results were confirmed by the Spearman and the findings of the Pearson chart represented below in Figure 5.1. They show the highest correlation is between Field Operations and Collaboration. As Collaborations begins to add value to a company, Field Operations will increase as well in relation to Collaboration.

Table 5.1

Pearson Correlation Chart

Variable	1	2	3	4	5	6	7
1. Planning	-	.577	.206	.303	.284	.116	.512
2. Clash Detection			.230	.445	.309	.501	*.669
3. Marketing				.070	.060	-.079	-.012
4. Corporate Strategy					.315	.293	.470
5. Collaboration				.		.515	.655

6. Shop Drawings	.462
7. Field Operations	-

*p<.005 **p<.001

Interestingly enough, Marketing, which ranked second overall for value added to a general contractor using BIM, has absolutely no correlation with any of the other six categories. This can be seen above in Table 5.1 by looking for a p value of 0.005 or less to show significance in correlation. Marketing ranges from 0.4-0.9, showing absolutely no correlation between any of the other categories.

Summary of Gap in Value Between Groups

This study originally included only the local Colorado based general contractors. Ten contractors fit in this category, and two of the ten contractors responded with -1 and -2 to question number 1 on the survey, asking if they had used BIM on projects in the last 36 months, narrowing the sample size down to eight contractors. In order to gain a better understanding of the value added by the use of BIM, the survey was then sent out to the reaming nine national general contractors in the state of Colorado. The goal of the research is to understand the areas where BIM is adding value to general contractors in the state of Colorado, however, since the information was gathered in such a way where the national companies were separate from the local companies, it seemed appropriate to briefly touch on the results found when comparing the two.

A comparison of the means for the seven areas of value in the research for the national contractors compared to the local contractors is shown in Table 5.2.

Table 5.2

National Contractors Compared to Local Contractors Mean Areas of Value for BIM

	National	N	Mean	Std. Deviation
Planning	Local Contractor	8	.1667	.56344
	National Contractor	8	.6667	.53452
Clash Detection	Local Contractor	8	.6875	.99777
	National Contractor	8	1.1250	.64087
Marketing	Local Contractor	8	1.1250	.74402
	National Contractor	8	.9375	.49552
Corporate Strategy	Local Contractor	8	1.1250	1.32961
	National Contractor	8	1.1250	.79057
Collaboration	Local Contractor	8	-.0938	.66732
	National Contractor	8	.0000	.81284
Shop Drawings	Local Contractor	8	.50000	.755929
	National Contractor	8	.62500	.744024
Field Operations	Local Contractor	8	.1667	.79682
	National Contractor	8	.8333	.59094

The results share many similarities, as well as minor differences between the two groups. The most notable similarity is the Corporate Strategy questions has exactly the same mean of 1.125, which is also one of the top two highest scores for both groups. The local companies however have the highest standard deviation of 1.33 for Corporate Strategy, which shows that not all companies felt this is their highest area, but overall the group selected it as an important area of value. The national firms on the other hand, are very consistent in the way they responded to the questions regarding Corporate Strategy, as their standard deviation is almost half of that of the local companies at 0.79. The

national companies scored Clash Detection as their second highest area of value, while local companies identified Marketing as their second highest area of value.

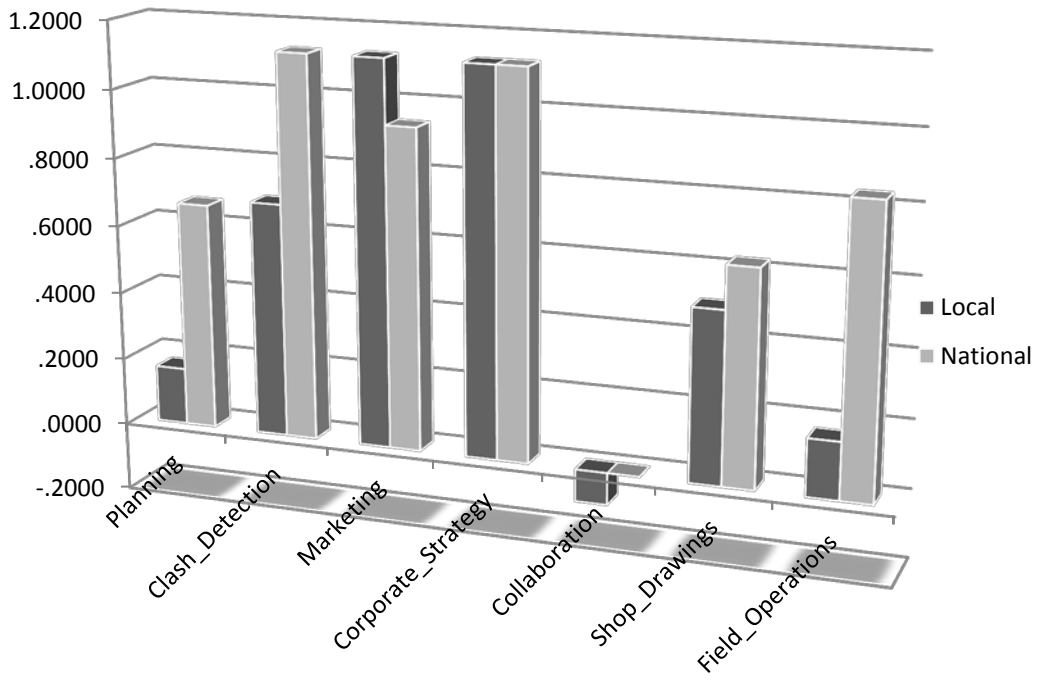


Figure 5.1National Firms Mean Response Compared to the Local Firms Response to the Seven Areas of Value

Clearly shown in Figure 5.1 above, Collaboration stands out as the only area that neither group of general contractors in the study has a negative mean. The local Colorado general contractors identify this as a -0.09, which is just slightly below neutral. For the national firms, Collaboration also ranks lowest on their list with a 0.00 mean combined with a 0.81 for a standard deviation, solidifying they are neutral with the questions regarding Collaboration. The consistency between the means for the local and

national general contractors helps to support the findings below regarding the areas of value added for BIM

The national firms also gain more value from Field Operations, Planning and Clash Detection. These are all areas that are tied together with the operations side of a company, as well as areas that literature has referenced for years as some of the main areas where BIM can add value to a company. The high initial investment to implement BIM into a general contracting firm has created a gap between the national firms with more capital and resources to invest in BIM than the local firms. It stands to reason that the national companies should be gaining more value added from the use of BIM than the local firms, as they've been using it for a longer period of time. As BIM becomes more widely used in the industry, the gap will quickly close. In 2011, BIM is just now taking its roots in all commercial contractors at the local level who are doing over $100 Million a year. Smaller local general contractors are beginning to adopt BIM as way to save their company money, while keeping up with the competition. This will continue to foster the value of BIM throughout the industry, as well as close the gap between national and local firms.

Just because the national companies have a leg up on the local GC's does not indicate that they are using BIM to its fullest potential by any means. As state earlier, the national firms rank Collaboration at 0.000, which indicates they are gaining no value from BIM software when it comes to collaboration. This is an area, which has been discussed extensively in research as one of the great values of BIM. It allows teams of designers and engineers to work directly with the contractors and subcontractors that install the work on a daily basis. This open form of communication benefits everyone

involved. Designers can develop stronger, more efficient systems based on feedback from subcontractors who work with these products on a regular basis. Even owners, such as facility managers, can collaborate with engineers to provide feedback on systems previously installed in their facilities. This is very important for clients like school districts and health care providers who have multiple buildings, and many times have new construction projects every few years. By using BIM to collaborate, the value added is passed on to the entire team, not just the GC. Figure 5.2 below shows just how underutilized BIM is for the entire sample group, showing the full potential and where the value is actually added.

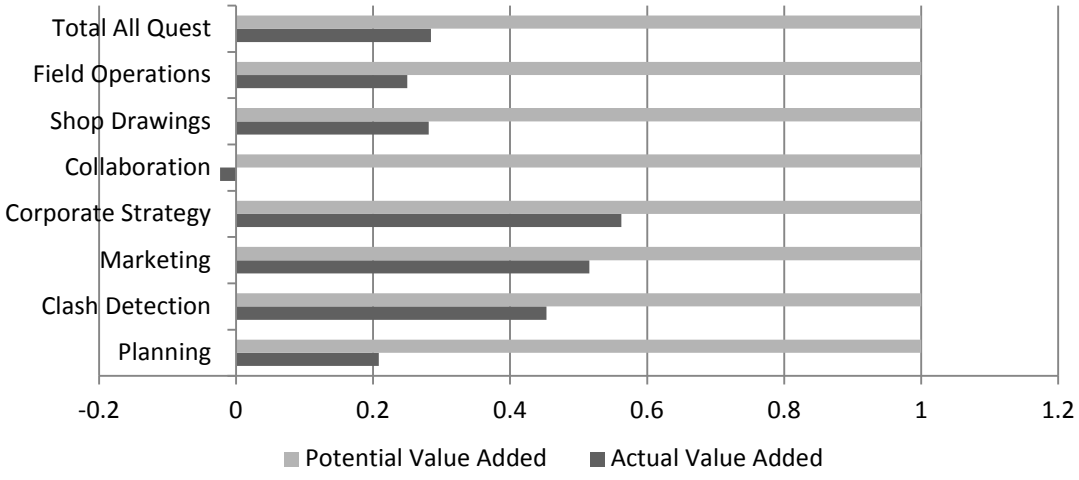


Figure 5.2 Potential Value Added from the use of BIM Compared to the Actual Value Added through the use of BIM

Comparison to Previous Research

Historically research on BIM has been focused on the construction industry in the United States, not pinpointed at a particular state. Breaking down the sample groups to a state level where national and local companies can be prepared is a great way to focus on how the industry as a whole functions. McGraw Hill has issued their Smart Market Report on BIM for over 3 years. These reports take a look at industry on a national level, and analyze case studies such as the Department of Energy (DOE) 45,000 sqft high explosives facility in Texas built by CH2M Hill (McGraw-Hill 2009). This is a very unique project that had a budget of over $100 Million, and an estimated cost savings of $10 Million through the use of BIM. Comparatively speaking this represents a small project for much of the research regarding BIM software and its applications.

Areas of Future Research

The focus on the state level contractors is a newer concept in BIM research because until recently, it was cost prohibitive for smaller state based general contractors to afford the software, let alone work with designers, consultants and subcontractors who had access or even knowledge of BIM. It is hard to decipher the true understanding when focusing on such large diverse groups. There are literally hundreds of thousands of all those groups across just the United States, and sampling just a few hundred does not provide an accurate portrayal of what is going on in the industry, let alone in a particular region of the country.

This research could be duplicated each year for the next 5 years and the results would change every year. This is a base line of where the industry stands in 2011 when

looking at how BIM can add value for Colorado general contractors. A study like this of only national contractors could be performed to help create a benchmark of where the industry leaders are at this point in time. A good comparison would be to study both every year, and find out how large the gap is between the midsized state level general contractors and the national general contractor. This would provide insightful information as to how large that gap of knowledge between the two really is, and would also show how quickly that gap is closing or widening over time.

Technology is advancing at a rate faster than any other time in our history, and the longer companies hold out before embracing the new technological advances, the farther and faster they fall behind. The learning curve for new technology over the last 10 years has become increasingly steeper, Mostafa Khattab (personal communication February 10, 2011). This will cause some companies to eventually fall far enough behind that they will no longer be able to keep, and eventually close their doors due to lack of business. Studying how quickly this technology is adapted into firms would be another great area of research over the next ten years to see how companies are able to adapt with the constant change. There is always a desire for a company to benchmark themselves against the competition

People by nature want to benchmark themselves against others. Currently there is a lot of buzz going around with regards to BIM, its use and where it's adding value to a company. With such strong marketing departments in many of the construction company's across the United States, BIM's value sometimes gets over inflated to make a company appear that it has a better understanding and grasp on how to use BIM. Being able to identify where contractors involved in this study are using BIM, will help the

industry as a whole have a better understanding of where a company's knowledge of BIM is really at.

Design firms such as SHP are currently testing new forms of energy modeling software that can track energy usage before a building is even built, John Phillips (personal communication March 14, 2011). This is being used to help create designs that use less energy. There is also a large push in the design field to use the BIM model from construction as a tool for Operations and Maintenance of the building once it's constructed. It will allow the facilities manager to identify when to change filters on equipment, where to buy replacement parts, and when to perform scheduled maintenance on items to help ensure they last longer. These are great advances, as are the 4D Scheduling, and the 5D Costing models that firms are buzzing about, but in order for these things to happen, the industry must first get a handle on how the 3D model works, before adding all of these other layers of complexity to an already complex BIM model.

The last area of future research could be a study of construction superintendents. This research has shown the least value added to these companies is in the areas of planning, field operations and collaboration, all of which are tied to the superintendents. As the current group of construction superintendents continues to age and retire, a new emerging group that has been raised in the technological era will begin to emerge. This will help shift the balance of what areas of construction BIM truly is adding value to a general contractor.

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Zind, T. (2007). Web Begins to Snare Project Management Challenges. *Electrical Construction & Maintenance*(February): (3), 14-17Appendices (e.g., Instruments, key questions)

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APPENDIX A

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. In the past 36 months, most of the jobs you worked on used some type of BIM.	❍	❍	❍	❍	❍
2. Materials & equipment staging is part of our BIM models.	❍	❍	❍	❍	❍
3. MEP clash detection is used on all BIM models.	❍	❍	❍	❍	❍
4. When interviewing for a potential job, you have developed a BIM model for that job to help showcase your use of BIM to the owner.	❍	❍	❍	❍	❍
5. Having a dedicated BIM department is integral to fully implementing BIM.	❍	❍	❍	❍	❍
6. You are currently proficient in multiple types of BIM software.	❍	❍	❍	❍	❍
7. Design teams are responsible for developing detailed BIM models for construction use.	❍	❍	❍	❍	❍
8. Excluding MEP Subcontractors, you currently work with subcontractors that can develop BIM models.	❍	❍	❍	❍	❍
9. A design firm's use of BIM plays a role in whether you choose to work with that firm.	❍	❍	❍	❍	❍
10. Projects are scheduled through the BIM model.	❍	❍	❍	❍	❍
11. Project Superintendants are familiar with use of the BIM model.	❍	❍	❍	❍	❍
12. MEP subcontractors are responsible for designing their scopes of work before construction begins.	❍	❍	❍	❍	❍
13. Owners understand how using BIM on their project will benefit the project.	❍	❍	❍	❍	❍
14. BIM models for construction are designed within your company.	❍	❍	❍	❍	❍
15. BIM software is currently installed on all field personnel computers.	❍	❍	❍	❍	❍
16. Superintendents currently have a large influence on the final design of the BIM models for construction.	❍	❍	❍	❍	❍
17. Once construction starts, the BIM model is used on a regular basis to plan subcontractor work onsite.	❍	❍	❍	❍	❍
18. Past BIM projects are great marketing tools you can use to show owners the benefits of BIM.	❍	❍	❍	❍	❍
19. Detailed BIM models of the building structure are currently being developed before construction starts	❍	❍	❍	❍	❍
20. As a GC's we are responsible for coordinating design team and subcontractor models, not developing our own.	❍	❍	❍	❍	❍

APPENDIX B

Colorado State University

Research Integrity & Compliance Review Office
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

DATE: February 28, 2011

TO: Farook Hamzeh, Construction Management
Wally Sheata, Construction Management

FROM: Janell Barker, IRB Administrator
Research Integrity & Compliance Review Office

TITLE: Where is the Value of BIM Software for a Midsized General Contractor?

IRB ID: 024-12H **Review Date:** February 28, 2011

The Institutional Review Board (IRB) Administrator has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b)(2): Research involving the use of educational tests,….survey procedures, interview procedures or observation of public behavior, unless: a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects. The IRB determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as proposed in the Exempt application**, including obtaining and documenting (signed) informed consent if stated in your application or if required by the IRB.
- **Any modification of this research should be submitted to the IRB through an email to the IRB Administrator, prior to implementing any changes**, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.
- **Please notify the IRB if any problems or complaints of the research occur.**

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB may make the determination of exemption**, even if you conduct a similar study in the future.