BUILDING INFORMATION MODELING AND ITS IMPACT ON DESIGN AND CONSTRUCTION FIRMS

By

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To my wife and family, for keeping me focused on the prize, and for giving me the opportunity to better myself. To them I will be forever grateful.

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BUILDING INFORMATION MODELING (BIM) AND ITS POTENTIAL IMPACT ON SMALL CONSTRUCTION FIRMS

By

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The Construction industry is a business focused around providing a product through the traditional construction process, which remains for the most part, independent of the design process. With the growing changes in technology, many areas of production and business (outside of construction) are being refined and redefined, leaving the construction industry behind. Process of construction is still basically the same as it was hundreds of years before, from a set of drawings, a building in erected. For the most part, these drawings are never without errors and omissions, causing many delays, multiple change order items, and late projects completion.

With the advent of Building Information Modeling (BIM) software, the Designer/Architect is given the opportunity to design the building, and the software develops the appropriate plans and sections needed for construction. This is good for the designers because the project is completed in 3-D and most, if not all conflicts can be resolved before construction begins. These are just the initial benefits that BIM can potentially help the design and construction industry.

Design/Build firms can be extremely efficient because they house both the designers (Architects and Engineers) and the Construction Management professionals; however they still operate with the same flawed system of designers generating construction drawings and the construction team erecting the building. More advancements can be made to increase productivity in construction, reduce requests for information, eliminate coordination problems, decrease construction time, and increase quality. The BIM Software is the gateway to solving these issues.

With dynamically linked on demand modeling, changes can be made by Designers in a remote location that would update digital construction drawings at the jobsite. Project managers on site can propose changes to the design team with no delay time. Means of construction can be displayed in 4-Dimensions for an increased understanding of construction sequencing by the contractor on site. Any and all questions can then be answered immediately and virtually from any location.

Understanding the potential that BIM software has to offer and implementing it into the construction industry can be the next great advance since the advent of power tools and equipment, however this innovation has many issues that need to be resolved before implementation of the software would be generally accepted. Once done, its full integration to improve productivity for the AEC industry will be significant. This change over will be market driven by the owners of projects and come at a large initial cost for all construction companies, large and small.

CHAPTER 1
INTRODUCTION

Construction is a labor intensive industry that has remained relatively unchanged for hundreds of years. Traditionally, a construction project, consisting of drawings and specifications, is delivered by architects and engineers to the owners/clients of the proposed project, with a warranty that the design is complete and free of any defects. Owners then put the project up for bid among a selected list of contractors; the lowest bid typically being awarded the job. Once the construction documents are in the possession of the general contractor and construction begins, the relationship between general contractors, architects and engineers also begins. This relationship tends to be typically limited and distant. Any changes or discrepancies that occur in the drawings are corrected, typically, by a long trail of paperwork, for a contractual period of time per each request for information (RFI). This can stifle productivity on the job site because of trades waiting for pertinent information, and it can decrease morale among crew members, which also decreases productivity.

Over the years, there have been many technological advances for architects, engineers and contractors. Architects and engineers are constantly updated with the most advanced computer programs to help in all aspects of their specific profession. Contractors have relied on large construction equipment to perform tasks, and computer programs to help in the estimating and scheduling process for construction, both of which are integral in determining whether on not a construction project will be profitable and if the construction company will continue to stay in business. There have been numerous advances in technology between the two sides of the industry, Architects/Engineers (A/E) and Contractors, but when information is exchanged between the two, it is continually done on paper in a 2-Dimensional (2D) representation.

This is an inherent problem between the A/E, and Contractors; the problem being that Architects take a 3-Dimensional (3D) image in their mind and, to the best of their ability, relate that information in 2D drawings on paper. Drawings are then realized in physical form by the general contractor, based on their ability to infer the design intent of the A/E. With the influx of technological advances in the construction industry, it stands to reason that the advancement having the largest, most influential impact would be one that changes the way in which the Architects and Engineers exchange information with the general contractors, sub-contractors, and suppliers.

1.1 Building Information Modeling

This technological advancement is being heavily promoted by Autodesk® with the program Revit®, which is used to develop Building Information Models. Building Information Modeling (BIM) software is a dynamically linked interface designed to take the place of redundant computer aided drafting (CAD) work. Idea being, architects are free to design, and the software generates the plans, sections, and elevations. Any changes to the documents change any other instance of it throughout the drawings, to improve coordination. Reduction in coordination issues will reduce RFIs, which will increase productivity. Knowledge of the program is essential for the general contractor on site to make suggestions to the architects and engineers who address unanticipated field conditions, this will reduce non-productive time on a jobsite and increase construction job efficiency and productivity.

1.2 Statement of Purpose

Purpose of this study is to research BIM and how it can be used successfully by both designers and builders. Since BIM is supposed to be the process that both sides of the construction industry can use for their specific needs, just how well can this BIM software meet their needs in conjunction with the specially tailored programs developed for designers and builders? Interviews were conducted to gage how BIM is being received by architects, engineers, and contractors; and how BIM can help construction companies improve their methods of construction and increase productivity. Intention being, to gain an understanding of BIM, to determine the shortcomings of the program and to become aware of the barriers to implementation that this program will offer in today's very technological world.

1.3 Objective of Study

Objective of this thesis is to study both the assets and limitations/complications with implementing a BIM program in the design/construction industry. With knowledge of the program and how it works; the benefits of how BIM can increase productivity in the construction industry can be projected. With this objective, interviews were conducted with local large (1) and small (2) construction companies, to determine the possibility of implementing BIM into their daily operations. Their perspectives will also be attained about using BIM on projects, it benefits to productivity and its disadvantages.

1.4 Scope and Limitations

Scope of this thesis involves doing research on what Building Information Modeling actually is, based on its core components. Research on BIM will make the benefits and limitations more readily understood. Research was also done on productivity improvements in the construction industry. Knowledge of practical concepts and initiatives used in the present construction industry are essential in knowing how the construction industry works, and more importantly, how BIM can influence the construction industry.

How BIM is being used in the AEC industry is revealing difficulties that have to be addressed. Limitations are encountered because historical data is not readily available due to the lack of recordkeeping. This software is still in its infancy, and although most experts consider BIM to be the future of the construction industry, the change over by architects and engineers is very slow. In the construction industry, BIM is more widely accepted because of the ways that it links with currently used scheduling and estimating software.

CHAPTER 2
LITERATURE REVIEW

With the rapid adoption of BIM in the construction industry, and its gradual implementation in the design industry, careful considerations have to be taken when making the change over from the traditional method of creating construction documents towards a BIM approach. There are plenty of positives, negatives, and unknowns that have to be considered when implementing BIM. This chapter will discuss research that was done about the background of BIM, its perceived positive and negative effects, and productivity improvements for the AEC industry.

2.1 Principles of Building Information Modeling

International Alliance for Interoperability (IAI) was formed in September 1995, and since its release, has published three major releases of the Industry Foundation Classes (IFC). This was the beginning of setting standards for object based data modeling. Standards that would define the interoperability of object based data modeling for the AEC industry. Idea being that multiple vendors would be able to access a building model to supply data to the architects and engineers in a 3D space. Interoperability is the dynamic exchange of information among all applications and platforms serving the entire building community throughout the life cycle of facilities (Keller 2004). Therefore, no matter what programs were being used across the broad spectrum of vendors, there would be a medium to transfer data to something that others in the industry could access, this medium being the 3D model.

Although these guidelines were set, they would need backing from major software companies in order to gain a foothold. Once Autodesk® decided to acquire Revit® (the same company that controls the most widely used computer drafting program, AutoCAD) the BIM era began to hit the main stream. With so large of a parent company, Revit® has become the staple in the industry for BIM.

BIM is a brand new design methodology and is defined by Autodesk (2004) as: "a building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction". BIM incorporates the use of 3D visualization techniques with real-time, data driven, object- based imaging as a tool by all facets of the industries (Holness 2006). This is a change from the current practice of; designs being manifested and put to paper with engineers then designing the structure and other supporting elements of the building. After completion of the design documents, a 3D model can be generated for the owner showing digital walkthroughs and to provide 3D renderings of spatial relationships. These tools are very useful to convey design intentions to owners and clients that who not able to visualize 3D space from 2D drawings. These can be very expensive and time consuming to produce.

BIM greatly increases the user's ability to control and manipulate data and information in an unprecedented way and in an interoperable format. Moving from paper-centric information to parametric, model-based information means that the digital design can be used for cost estimations, simulations, scheduling, energy analysis, structural design, GIS integration, fabrication, erection, and facilities management (Seaman 2006). All of which are relative to each other, and changes in one category will have impacts on the others that are automatically accounted for. Since all of the above information is dynamically linked, productivity from recalculation of simple and minor changes will be greatly increased because the computer program will be able to handle the changes and calculations internally.

> BIM application software has the capabilities of other modeling programs like sketch-up and 3D studio max, which architects traditionally use for generating walkthroughs and to convey spatial relationships. The difference being that this

> program will also be able model the HVAC, steel, structures, hot water pipes, cold water pipes, and communications. Not only will the program model this, but will correlate them with each other to find conflicts. Upon recognition of one, the program will mark it and send a flag for corrections to be made. Changes will then be made to make the program satisfied, but this could prove to be detrimental if the code does not allow the change. Careful consideration needs to be taken when implementing changes to accommodate the BIM software (Seaman 2006).

Documents a BIM can generate include, but are not limited to, drawings, lists, tables, and 3D renderings related to the project. Thereby contributing more to efficiency, and provide superior accuracy than traditional 2D CAD drawings (OCA 2006). Building models embedded with detailed information about a construction project are far beyond the capabilities of most design firms at present (which is why historical data is difficult to find and analyze, as it relates to productivity). These models are not just the electronic drafting tools that firms now think of as digital practice, nor are they three-dimensional renderings with separate construction documentation (Seaman 2006). These are object based digital models which the program itself constructs the appropriate plans, details, and sections from. Any change in one aspect of the drawings, will automatically be accounted for in the other drawings. The BIM process has the potential to remove the guesswork about how the most difficult parts of a building come together, which tend in most cases to be the corners. These models also transcend 3D and can be manifest in 4^{th} dimension (4D) and 5^{th} dimension (5D). Projects can digitally be built in the computer environment, showing any possible conflicts with the schedule; this is an incredible tool to relate information to the owners and show models for future production. If delays arise, they can be input into the model, and BIM will be able to determine any the necessary changes in the schedule. Four D (4D) models link components in 3D CAD models with activities from the design, procurement, and construction schedules. Resulting 4D models allow project stakeholders to view the planned construction of a facility over time on a computer screen and to review the planned or actual status of a project in the context of a 3D CAD model for any day, week, or month of the project (Fisher and Kunz 2004).

The 5D represents the money aspect of the program (Figure 2-1). Projects will have the materials for construction estimated, and work up a cost of material proposal. Changing materials for Bid Alternate purposes will be easy to see both the immediate cost impacts, but also a life cycle costing to the owner (AEdgar 2006). Moving to an integrated, parametric, and object-based system should lead to dramatic changes in design and construction as well as, possibly, compensation and risk allocation. Life cycle cost analysis can project to the owners, cost savings and operational costs over the lifetime of a building. This information can

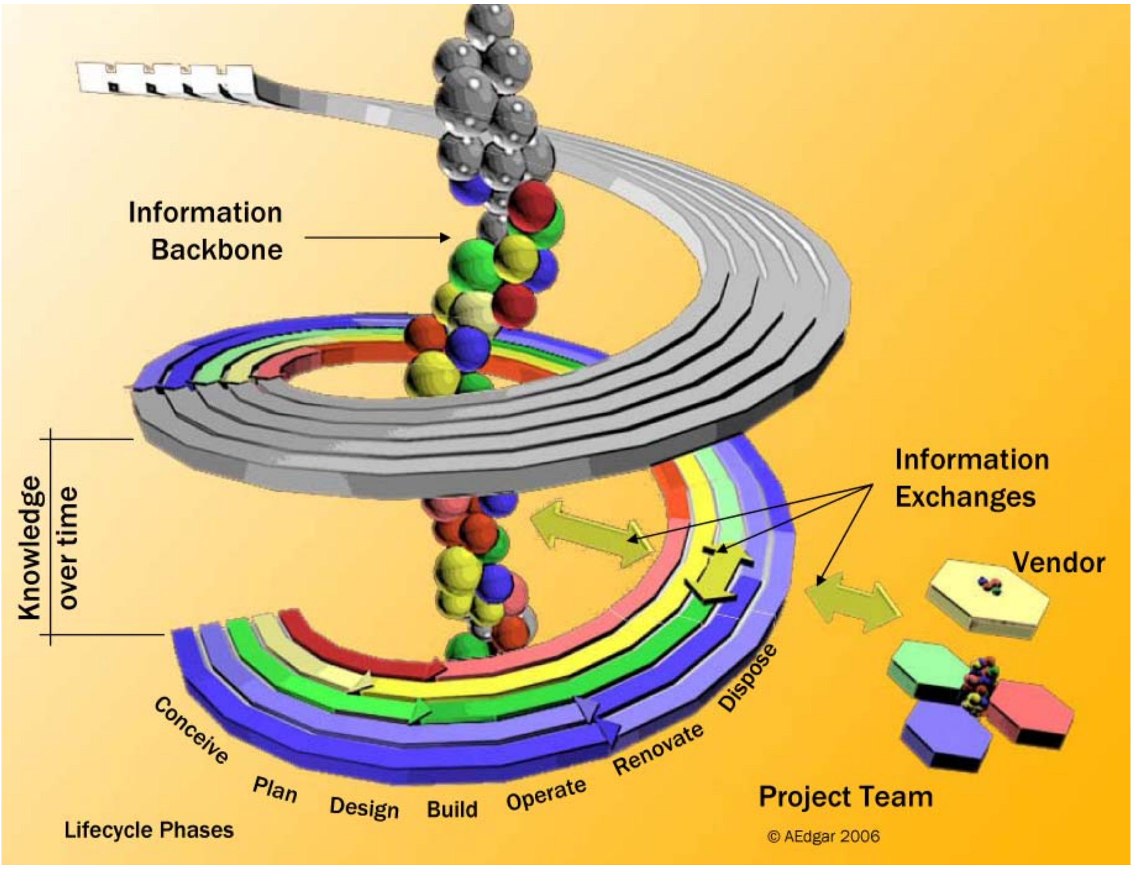

Figure 2-1. Relationship of a BIM to all facets of the AEC industry. Courtesy of NBIMS © AEdgar 2006.

prove to be very important in determining feasibility of a project. This information is also very important for determining whether a project meets Green Building specifications or LEED accreditation.

A BIM can be used with distributors for estimating cost of materials and the ability to control the cost of the building is very captivating to the owners. Material suppliers can insert their specific data and cost into the BIM with the appropriate cost factors, and from this information, a hard dollar cost and a solid estimate can be generated, which will be the actual cost of the building. Changes can then easily be made to any of the specified products, creating new estimates and building costs. When changes are made, they can then be assignable to the architect, engineers, or owners. This can then determine responsibilities for payment on change orders (Seaman 2006).

2.1.1 Increasing Value Through Shared Information

Results of this design methodology is not just a creation of the Architects design intentions and spatial relationships shown in 3D, a BIM is a repository for digital information and data generated by the design process and simulations; it is the design, fabrication information, erection instructions, specifications, materials palette, schedule, and project management logistics in one database (Schinnerer 2006). Data models will exist for the life of a building, can be used to manage the client's asset, and will exist as the "As-Built" documents for future additions, renovations, and upgrades.

Because the true benefit of a BIM is to the project owner, the push to use a BIM will most likely be a client-driven development. Many owners see the single point of responsibility in integrated practice as an attractive alternative to the "over-the-wall method" of design and construction in which an architect completes a design and hands it over to a contractor for construction (Elvin 2007). The value is in the significant building efficiencies and initial cost savings and extends to the operations and maintenance of the facility (Guidelines for Improving Practice 2007). Speed, accessibility, communality, and adaptability are achieved by the use of a common database, early information user input, knowledge representation and information technology, team collocation, and information exchange in small batches (Elvin 2007).

Based on expert studies, other benefits of BIM include reduced risks, improved productivity, streamlined production, maintenance of design intent, and facilitation of quality control through clear communication and sophisticated analytical tools (Guidelines for Improving Practice 2007). All of which will be realized from conception, thru construction, to the life cycle analysis of the building.

2.1.2 National Building Information Modeling Standards (NBIMS)

Once software had been established for the new design methodology and development of construction drawings, NBIMS set forth to develop standards to be followed by those using the software. With the adoption of CAD programs, a set of standards was never initiated, which is why construction drawings from different Architecture firm can be virtually similar, but have distinct differences in how they are shown, drawn, and notated. Early CAD programs were not interoperable with other programs specific to the AEC industry.

National Building Information Modeling Standards advocates that BIM is the future of the AEC industry and has been trying to develop a set of universal standards for the industry to follow. This is one of many components that will make using BIM a more productive asset for the AEC industry to use. Knitting together the broadest and deepest constituency ever assembled for the purpose of addressing the losses and limitations associated with errors and inefficiencies in the building supply chain is the goal (Davis 2006).

These standards are an integral part of making interoperability between all phases of a construction projects life from inception onward. Without this, using a BIM would essentially be pointless. Documents, that set standards for BIM, must overcome the impediments that have begun to be identified so the implementation of BIM, for the entire industry, to be successful.

2.1.3 Collaborative Working

The most beneficial aspect of using BIM technology with software like Revit® is the way it changes the design process. A BIM's goal is to recognize the potential benefits that collaborative working through all stages of design and construction can offer. This happens to be the hardest thing to implement in the design process being that there are complications for the interoperability of the design data. In all likelihood, multiple models will be produced in different disciplinary BIM applications and these will have to be combined into one composite model for visualization, clash detection, and other tasks (Figure 2-2). At the same time, the guide emphasizes that it is not necessary to create all the models to derive the benefits of using BIM on a project. Contractors can make many "partial uses" of BIM such as assisting with scoping during bidding and purchasing, reviewing portions of the project scope for analyses such as value engineering, coordinating construction sequencing (even if just for two trades), demonstrating project approaches during marketing presentations, and so on (Khemlani 2006).

Despite the great potential for collaborative working in the design stage of a project, this has not yet been fully exploited, due to the lack of applicable information exchange standards that can be widely adopted by the project team. While a great deal of attention has been focused on interoperability of design applications between design disciplines, there has been less focus on the specific information needs and exchange capabilities of the cost consultant (The IT Construction Forum 2006).

Cost consultants are integral to collaborative working in determining the costs of construction. This is something that BIM software is programmed to calculate automatically, from proper input in the digital model, this can save construction management firms time in the estimating process.

It has been shown, however that BIMs sometime miss-calculate the measurements of high level information. Currently, the wider uses of BIMs incorporate the capacity to generate measurements automatically from objects created by designers. This capability is being actively promoted although its application on live projects has been limited (The IT Construction Forum 2006). Forward thinking cost consultants can work collaboratively with design and construction firms that implement BIM into their projects, however they will continue to rely upon the quality

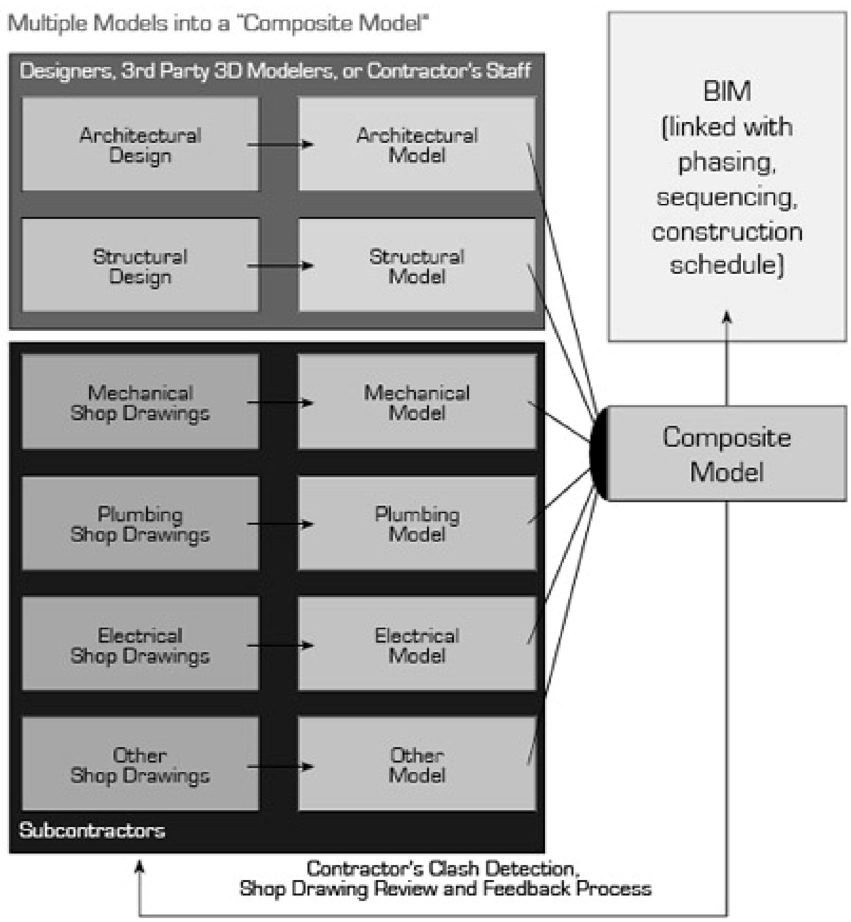

Figure 2-2. Combining multiple models into a composite model (Contractors Guide to BIM 2006)

and consistency of design information. Since a BIM is produced by a computer program, it has the same flaws that any other computer program has, it is limited by the ability of the user. Garbage in, garbage out, will be a mantra that will have to be acknowledged and constantly checked for. With the newest technologies and digital design, buildings are becoming more complex, the state of the art HVAC systems (Figure 2-3), and buildings are breaking the mold in a way that was never done before, and this is all attributed to computer design (Figure 2-4). Cost consultants are developing new ways of working in order to provide the best cost estimates possible given complicated designs.

Although BIM software is able to keep record of how much material is used, it is not able to determine how much labor and effort are required to construct these new and complicated designs, this is a specialty of cost consultants. They will become vital to construction estimators on very complex projects. Additionally, there will be no overnight conversion to collaborative

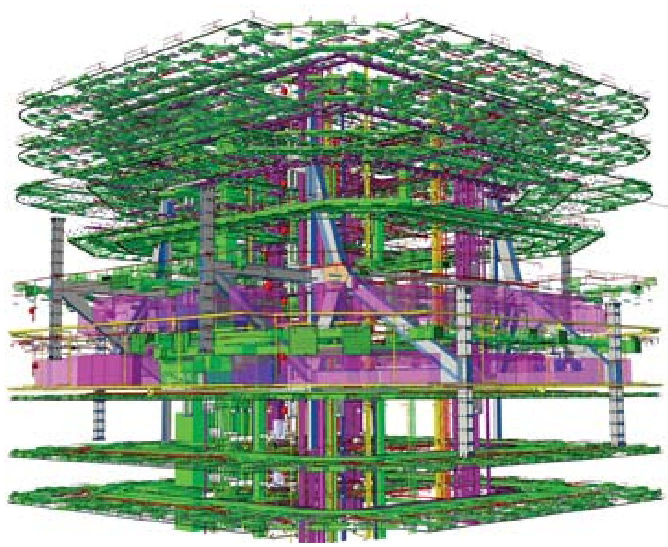

Figure 2-3. A section of the BIM model for One Island East tower in Hong Kong, Gehry Technologies' project with structural engineers, Arup. The drawing shows several floors of a mechanical zone halfway up the tower. HVAC systems are green; plumbing and electrical are purple and blue, respectively; and steel is gray. (The Architects Newspaper 2006)

Figure 2-4. Frank Gehry's Stata Center located at the Massachusetts Institute of Technology (MIT). The construction documents of this building are impossible to represent totally and accurately in 2D. The use of BIM was essential to the construction of this building. Image courtesy of © 2006 http://philip.greenspun.com/copyright/

working, but for those practices which have the opportunity and capability to respond positively, the eventual gains could be substantial (The IT Construction Forum 2006).

2.2 Productivity

Construction has remained unchanged for centuries, being a process where manual labor is used to place building components to erect structures. This present delivery system, in its current form, consists of:

- **Programming:** With the owner's input, an architect determines what the owners needs are and what supporting programmatic elements are essential for the building.
- **Schematic design:** Architects draw a conceptual spatial plan on paper. The owner then reviews the drawings and approves or suggests changes
- **Designed development:** Architect gets feedback from design professionals, i.e. the structural, mechanical and civil engineers.

- **Construction drawings:** Final developed drawings passed onto owner. Owner then approves the drawings to begin construction.

- **Bidding:** Contractors attain the construction drawings and estimates are prepared to submit back to the owners.

- **Construction:** After awarding the job to the contractor, construction begins.

Adrian (2004) writes that over the years there have been many technological advances in the construction process that have both increased the rate of construction, and supplemented the complexity of the construction processes. Largest impacts are from the advent of the mechanical crane, which enabled large heavy construction units to be moved quickly over vertical distances. This is widely responsible for the completion of complex designs for Gothic Cathedrals. With technological improvements to the crane, skyscrapers were able to be erected, something that was previously not attainable. Mechanical cranes have had a tremendous impact on productivity in the construction industry, but the construction process has remained unchanged.

Another great technological advance was with the advent of the cell phone. Lots of time was wasted, in comparison to today's standards, either waiting for clarifications on information or merely having to be off site to take calls. Productivity has dramatically improved, because cell phones receive and place calls, but also come with personal organizers and phonebooks. Now construction managers can make calls to Engineers and Architects while on the jobsite, being able to maintain supervision on construction workers. Suppliers can contact the job superintendent to confirm delivery appointments. This is perhaps the most recent technological advance to improve productivity in construction but what lies on the horizon is BIM.

Building Information Modeling has the potential to revolutionize the construction industry, although it is not without its potential drawbacks, and the benefits of BIM have yet to be documented since it is still relatively new to the construction industry. Productivity is the biggest selling point for the utilization of BIM in the AEC industry; therefore productivity has to be studied and forecasted since information for BIM on productivity is limited, specifically to the smaller construction firms that make up the majority of the construction industry.

2.2.1 Productivity in the Construction Industry

Productivity and quality in the construction industry have been on the decline over the years. In fact, construction productivity increases (see Table 2-1) are the lowest out of all listed individual industries according to the U.S. Department of Commerce (Construction Review 2002). Construction productivity increased was a dismal 0.80% in 2002. Reasons for this dismal amount of increased productivity is because of the high turnover rate in the construction industry, the duration on a project is typically only a year, so there is no chance for a learning curve to have an affect for each specific job, and the sub-contractor/general contractor relationships are continually changing. In one study, a Federal Price Commission concluded that an industry's ability to increase productivity is directly dependent on the degree to which it can set productivity standards (Adrian 2004). Implementation of BIM throughout the industry will help set productivity standards to follow.

The biggest factor that reduces productivity on a construction job is the amount of nonproductive time spent by laborers. Reasons for this can be attributed to a number of factors (see Table 2-2). This study will examine the possibilities of utilizing BIM to increase productivity in the following areas: industry related, labor related, and management related. This is particularly important for small size construction firms. As shown in Figure 2-5, the majority of construction firms that make up the construction industry are small companies, having less than 15 workers. These firms account for more than 10% of the gross national product annually and are most in need of some measures to improve productivity; unfortunately therein lays a problem. Small firms are hesitant to invest in research and development (R&D) or optimal

Table 2-1. Productivity increases for various industries (2002)

Industry	Productivity Increase (%)
Agriculture	3.64
Construction	0.80
Government	1.64
Manufacturing	2.60
Mining	3.17
Public Utilities	5.40
Transportation	4.60

Source: Construction Review, U.S. Department of Commerce, Washington D.C., 2002

computer programs to improve productivity. There are number of barriers that keep contractors from using the latest technology, including fears (legal/risk fears, fear of change, fear of the unknown, etc.), initial investment costs, the time to learn how to use the software, and perhaps

Table 2-2. Reasons for nonproductive time in the construction industry

Industry-related factors	Labor-related factors	Management-related factors
Uniqueness of many projects	High percentage of labor cost	Poor cost systems and control
Locations at which projects are built	Variability of labor productivity	Poor project planning
Adverse weather and climate seasonality	Supply-demand characteristics of industry	Poor planning for measuring and predicting productivity
Dependence on the economy	Little potential for labor learning	
Small size of firms	Risk of worker accidents	
Lack of R & D	Union work rules	
Restrictive building codes	Low worker motivation	
Government labor and environmental laws		

Source: James J. Adrian, 2004

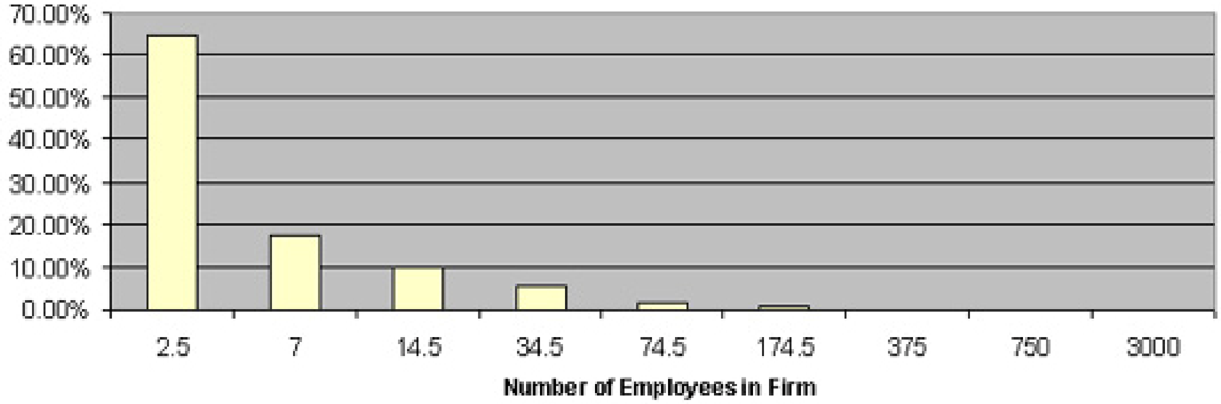

Figure 2-5. Distribution of construction company size by number of employees, 1996. (Dr. E. Douglas Lucas, 2008)

the lack of support from the senior leadership of the company, which may be the biggest barrier for many (Khemlani 2006). Building Information Modeling requires both research and development to implement into a construction companies process and a rather large investment. Software that can manipulate BIMs, like Revit®, cost about $6,000 per license. Cost of the software and training make it difficult for small construction companies to justify purchasing and implementing. This study will make a case for small construction firms to invest in a BIM program for their future survival in a changing industry. Estimates have also suggested that as much as 30% of project costs are wasted through poor management of the design-construction process (Brown and Beaton 1990). This is represented accurately in a study done by Adrian (2004) showing that roughly 50% of a construction laborers day is wasted either waiting for materials, or just not performing (Figure 2-6). Changes are an absolute necessity to increase productivity.

2.2.2 Input into Design

With the traditional relationship between the architect, owner, and contractor, the contractor has very little, if any, say about the design of a project. This gives the Architect the

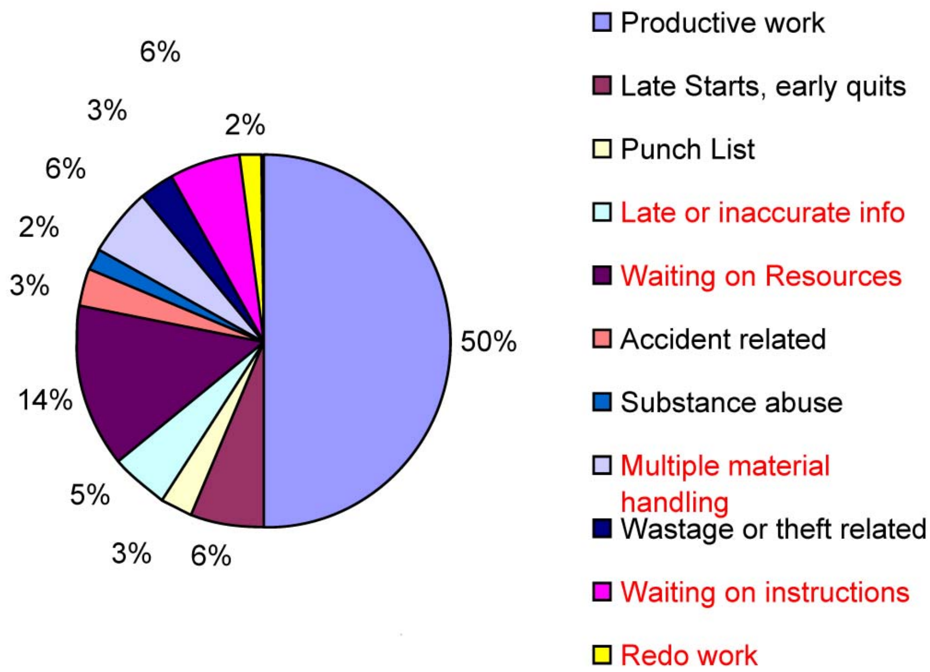

Figure 2-6. Analysis of productive and non productive time during a typical construction project (Adrian 2004)

complete freedom to design any type of building they wish, contingent upon approval by the owner. Next, the drawings are turned over to the owner for competitive bidding by various contractors. Since the relationship between the contractor and architect starts after the drawings are complete, there is little input that the contractor can offer to improve productivity during the construction process.

During the design phase of a project, the architect will prepare several levels of estimates on the size, quality, and cost of the building. This is based on their conception of the cost for building the project. Most architects base their costs on historical construction square foot costs of similar projects and neglect market trends and cost of materials. Small cost increases can have dramatic impacts of the final cost of a building. There is no doubt that if the estimates are grossly incorrect, both the quality of the project and the time it takes to complete it suffer (Adrian 2004).

Using a Construction Management (CM) firm early in the design process will result in more accurate preconstruction estimates that will keep the owner more informed for bankroll and cost purposes. Fully integrated BIM design process links the CM to the architect at the beginning of the design phase. Each of them will have input to the design of the building, and the end result will be a more cost effective building due to the increased productivity from this type of relationship. They enable the exploration and improvement of the project executing strategy, facilitate improvements in constructability with corresponding gains in on-site productivity, and make possible the rapid identification and resolution of time-space conflicts (Fisher and Kunz 2004). Although this system offers a more complex design process, it allows all participants to input the best possible scenario for a construction project (Figure 2-7).

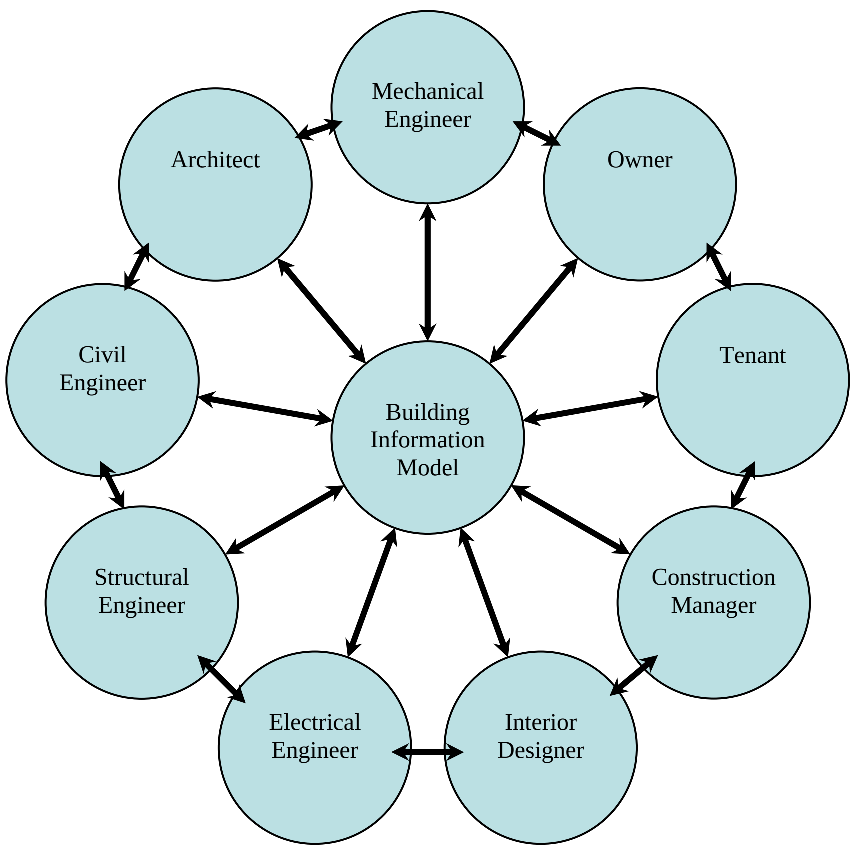

Figure 2-7. Reciprocal relationships between various parties involved in the design process and the BIM project

2.2.4 Ten Step Program for Improving Productivity

The ten step program for improving productivity in the construction industry as written by Adrian (2004) is as follows:

1. Making the project look like a firm rather than a job; developing a personnel management program.
2. Improved Communications
3. Planning a Productive Site Layout
4. Challenging the Work Process
5. Developing a scientific work standard versus an accounting based standards
6. Planning and Scheduling
7. Project Control and Productivity Improvement
8. Equipment Management to Enhance Productivity
9. Productivity Improvement through Safety
10. Productivity Through Attention to Quality

2.3 Advantages and Disadvantages of BIM

Parametric modeling as the design and construction database is a difficult one to examine from practice and insurance-coverage perspectives. Firms will have increasing challenges as they realize that they are moving from a physical model—and hard-copy plans and specifications—to the primary information generators for a digital database (Guidelines for Improving Practice 2007). Some problems with BIM will be related to liability. With the open access to the model from all aspects, (anyone involved in the construction project) how can engineers or architects be expected to sign a set of drawings, placing their liability on the line? This major issue could have potentially huge detrimental effects on productivity.

As A/E firms move from an analog system, where original construction documents are easy to identify and monitor, through our present “semi-integrated” system, to what could be called a “super-integrated” future, those firms will have to deal with new business rules and possibly unknown liability exposures. This happens because owners, CM, sub-contractors, and suppliers are supplying information to the BIM; and has all been done in a collaborative effort to streamline the design and construction process. Desired results are focused on a project that takes less time, is more economical, and less costly.

The driving theory behind BIM is the elimination of change orders and RFIs that occur because of missing information in the construction documents since all the parties involved in creating the completed BIM will check for all possible conflicts and problems. Problems exist, not in the coordination of the BIM, but in the coordination of all parties involved with access to the BIM. Typically, design elements consist of (but are not limited to): surveying, architecture, civil engineering, electrical engineering, mechanical engineering, structural engineering, landscape architecture, fire/alarm engineering, communications, interior designs, owners, tenants, construction managers, commissioning, etc. These professionals will have input to the BIM before, up until, and after, construction begins. Once construction begins a secondary group of people are necessary, these are (but are not limited to): general trades, site/excavation, steel construction, mechanical construction, electrical construction, fire sprinkler construction, concrete construction, roofing, masonry, glazing, elevator controls, finishes, technology, and landscaping.

> This is a large group of people to get together and coordinate to use a BIM model for all construction information. Combine that with the fact that, the relationships between the involved parties are all connected to the model and they are also connected to each other. With such a complicated relationship, the biggest problem will be how to control who puts what into the system, and what kind of problems will that generate (Seaman 2006.

2.3.1 Proponents of BIM

Building Information Modeling software is unique and advanced in its ability provide architects, engineers, and construction managers the necessary interoperable program for all their needs. Proponents of BIM indicate that the only limitations to using BIM are the abilities of the users and list the following benefits of using BIM:

- Conflict Resolution - conflicts will be identified ahead of time so changes to the drawings can be made before construction begins.
- Adjusts costs as changes occur - determine changes in projects as time progresses. The costs for specific objects can be input into the BIM. Merely changing the objects will not only coordinate with the drawings, but will update the schedules and estimates.
- Speeds up Design/Construction process - BIM will speed up: programming, preliminary design development, preplanning for construction, but it still is beholden to the speed at which the architect produces drawings. Intelligent design takes time, and cannot be compressed. The program can speed up the development of construction drawings.
- Reduces Ultimate Cost - by compressing time for construction, generating specific costs for changes, and handling changes up front.
- Single Entry - Input only needs to happen once. When something is put into the plan view of a drawing, it will be shown in the door schedule, interior elevations, exterior elevations, and sections. Upon modification, when an object is changed, all instances of it in the BIM change as well, along with all accompanying notations. The same can be said of estimating. Changes in the estimate will trickle down throughout the BIM. It will even help you coordinate anything that changes from substitutions of objects, i.e. electrical demands on panels after changing lighting for the building.
- Alternates - Since substitutions are easy to interchange in a BIM, this will give owners the opportunity to request many more alternates to see how cost can be influenced.
- Design optimization - important for addressing LEED issues.
- Conflict Identification and Resolution - Is great for clarifying locations for running of the mechanical/electrical/communication/fire. The only limitation is that the contractor must run their system in the specified location, or other trades will face problems, especially in tight spaces.
- Constructability – Details can be developed to show how building components come together

- Construction Sequencing/Scheduling – the model will be sequenced and scheduled so you can see the approximate progress. Viewing the BIM in 4D will help keep the construction project schedule.

- Life Cycle Evaluations – Energy calculations can be run using solar heating to determine the cost of running the HVAC for a building. Useful for budgeting cost over time.

- Operational simulations – animate the model to show activity, how the building would be used i.e. a medical facility. Show how the patient would be moved from surgery or an industrial plant, see how the plant operates and make sure that you will have all the necessary clearances during operations. (Seaman 2006; Autodesk 2007; Sheldon 2007)

Interoperability is a huge component of BIM software. Manufacturing software will be able to access a BIM and derive all their applicable data. Idea being that this transfer of information will be seamless.

GSA use in Phase I – Government Service Administration (GSA) is requiring that BIM be used during Phase I of construction which means up to and including the schematic phase of the construction process. This is just the first step, and BIM will be adopted and moved forward in the construction process systematically. All GSA projects are encouraged to deploy mature 3D-4D-BIM technologies, spatial program validation and beyond. Contractual language has to be developed for this to take root. This is the same way in which LEED Accreditation came to the forefront in current government jobs. Typically, once government enacts something, the private industry will follow suit.

Green building is leading BIM to a certain extent because of its ability to do Cost analysis and Life cycle analysis over the lifetime of a building. Typically when doing the cost analysis now, it is an energy saving analysis (see Figures 2-8 and 2-9). In Green Buildings it is just applied to the Energy and recyclability side of it. A BIM allows the user to do cost analysis over the entire construction process as well. Most of what is being seen in Green building and LEED is a precursor for what is going to be seen from the implementation of BIM. United States Green

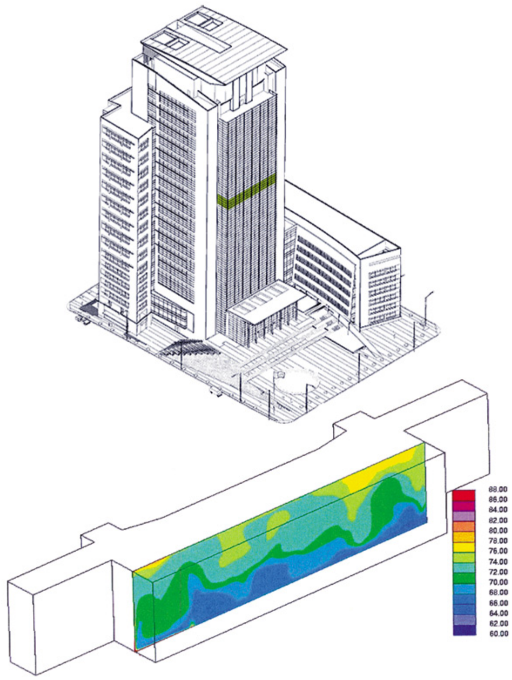

Figure 2-8. Computer modeling to analyze air temperature distribution to determine the benefits of displacement ventilation in the courtroom lobby, halfway up the tower, indicated with a green stripe on the drawing. (Google image 2007)

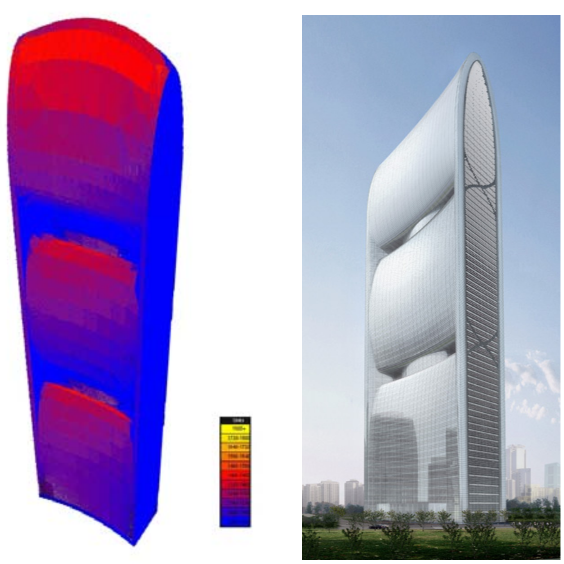

Figure 2-9. The Pearl River Tower includes integrated wind turbines and photovoltaic panels to offset its energy use. Inset is an Ecotect model showing the amount of solar radiation on the tower's various surfaces. (Fortmeyer 2008)

Building Council (USGBC) and Autodesk will explore opportunities to integrate Autodesk's technology with the USGBC's Leadership in Energy and Environmental Design (LEED) Green Building Rating System, to help the building industry more easily and rapidly meet goals for reduced carbon dioxide emissions (Cole 2006). Commissioning is a requirement in a LEED or green building. A BIM would allow the commissioning administrator to be involved from the beginning of the construction process to ensure that certain criteria are certified and a building will truly meet the specified commission rating.

2.3.2 Disadvantages of BIM

Below is a list of items that have to be considered before changing to a BIM methodology. The question being, whether or not the problems with implementing BIM are too big to overcome.

- Garbage in-Garbage out – when suppliers enter data into the model, will they be held responsible when things do not work, or will they blame the engineers for not checking over the drawings.

- No Standard BIM Contract Documents – if a set of standards is not developed, interoperability of BIM will not be efficient.

- Electronic Data Transfer – Engineers and architects are reluctant to providing digital data to suppliers and contractors because the data can be modified. A/E want to protect their data and work for liability and copyright purposes so pdf files are used. BIM gives access of the model to suppliers for doing takeoffs.

- Interoperability – How well will programs relate and talk to each other. BIM cannot interface with other programs (yet). When a different program takes a BIM and opens it with another program, who will check to make sure that all the engineered data is still correct from the transfer into another program. (Seaman 2006)

Will the Architect remain the representative of the owner in charge of overseeing the entire project, or will their role change, making the architect merely a supplier; the supplier of the design. International Building Code dictates that Architects are responsible and have to sign and seal documents, they will be the ones responsible for ADA and all code differences from state to state, country to country. Architects could possibly take over construction management duties since the software provides a lot of the specialized products that construction managers provide i.e. scheduling and estimating. From this reasoning, BIM should be a great asset for a design/build company, but currently this is not the case, as observed from my interview with a large design/build company that is utilizing BIM.

Who is going to have copyright of data when it is done, (processes cannot be copy written), will the architect be able to copyright drawings when the program actually makes changes to the drawings?

> In the current process, when changes need to be made to a set of drawings, the responsible party annotates the drawings with a revision date, and a revision number. Then the part of the drawing that is changed is marked with a cloud and the corresponding revision number, making it very easy for anyone who looks at the drawings to determine what has been changed. With BIM, revisions can still be made to the drawings, but instead of getting an accurate account of what has been changed, a whole new set of drawings is issued, and since the program has dynamic input, a change in one location is made throughout the drawings. These will not be marked with revision clouds, so finding changes on a set of drawings could be very difficult. Plus, who makes the change and why? This needs to be carefully considered when using BIM (Seaman 2006).

Polygonal modeling is what architects currently use to show the owner what spaces and buildings look like, this is a view of what exists, what is drawn on the paper. Parametric modeling creates the design from the input you use. If the user wanted to put in a specific window or door, product information could be retrieved from the manufacturer's database, inserted in the wall, and the program can generate details provided by the manufacturer's specifications. But who will be responsible for making sure that details are up to date, and who will be held accountable?

CHAPTER 3
METHODOLOGY

Objective of this thesis is to study the potential use of BIM in the AEC industry and how it can improve productivity for construction managers. A BIM is a design methodology that breaches the gap between the design intentions of architects and engineers, and the implementation of design by construction managers. It is a computer model that fulfills the needs of all parties involved in the AEC industry, offering CAD services, cost calculations, energy simulations, building code checking, life cycle analysis, and it is formatted to be interoperable with other programs that are specific to the AEC industry.

Productivity improvements for the construction industry were researched by reading various books and articles to understand the workings of a very labor intensive industry. History of BIM was researched to determine the purpose of the program and the limitations that it may have. The BIM program used for this study was Autodesk® Revit® because Autodesk® is the biggest software provider for the A/E industry. The author has over 10 years experience with AutoCAD® and 5 years of experience with construction documents. Using this experience, the author was able to test the performance of the program, helping to discover more limitations. Interviews with two small construction companies, one large design-build company, and one design firm were also conducted to gage BIM acceptance by well established companies.

3.1 Productivity

Knowledge about productivity was attained from reading “Construction Productivity: Measurement and Improvement” written by James J. Adrian (2004) along with other various journals/articles. Specifics that were especially considered in determining BIM’s impact on productivity were Adrian’s ten step program for improving productivity. Other various concepts for improving productivity were also considered during the research i.e. labor productivity for a typical day of construction, value engineering, the effect of information technologies on construction, and human factors.

3.2 Advantages and Disadvantages

Positive and negative effects of BIM and how it relates to the construction industry have to be considered when a construction company is deciding to implement BIM into their basic operations. It is easy to find out all the positive effects that BIM can have on the construction industry, but the negative effects have to be addressed as well. Drew Seaman, Esquire conducted a professional development seminar at a combined meeting of the A/E ProNet membership, the American Institute of Architects risk management committee, The National Society of Professional Engineers' insurance committee, representatives of the American Institute of Architects trust and representatives of The American Consulting Engineering Companies. This seminar provided an in-depth analysis of the issues that affect the deployment of BIM on the AEC industry. These are issues that need to be resolved and precedence that needs to be set for BIM to be successful in changing the construction industry.

3.3 Interviews

Interviews were conducted with small construction management companies (Company 1 and Company 2), a large design build company (Company 3), and a large and innovative design firm (Company 4). Representatives of construction Companies 1 and 2 interviewed about their current working operations and were informed about the BIM process. Questions were asked to evaluate their responses towards implementing such a system into their current operations. Representatives at Company 2 were interviewed about perceived benefits from utilizing BIM on some of their projects. Objective being: to attain knowledge from their first hand experience about how BIM is being accepted in the workplace and their perceived benefits or perceived drawbacks. Company 4 only utilized BIM for their operations because of the complexity of their designs. It is essential for them to use BIM because conventional drawings are not adequate to convey design intentions. These interviews along with the other studies conducted will provide good insight on both, how BIM is being received in the construction industry and what the barriers are for implementing BIM into small construction management firms.

Questions about issues related to productivity on the jobsite and issues about BIM in the marketplace that have been determined to be essential to this research are as follows:

- How much time is spent analyzing construction documents prior to the construction process?
- How long does it take to prepare a bid using a traditional set of construction documents?
- Approximately how many RFIs are submitted for a typical construction job?
- What is the average time spent waiting for a return on an RFI?
- How much time is spent conversing with the Architect/Engineers about the construction job?
- Are you currently using Building Information Modeling at your office?
- If not, do you foresee changing over to some kind of a BIM system at your construction company?
- If so, what problems have you encountered using the BIM process?
- Do you implement any productivity improvement practices with your construction crews and if so, what?

It should also be noted that using BIM may provide all of these benefits, but designing and development of the construction documents will be more costly than the traditional way of creating construction documents.

3.4 Process of BIM

This research also involved learning the process of BIM first hand from continued use, information seminars, and tutorials. Autodesk Revit® seems to be the program of choice for the A/E industry with their drafting program, AutoCAD® therefore; the program that was used for this experience was Autodesk's Revit®. The author's personal experience in architecture has given him ample experience with AutoCAD® and how construction documents are created. Revit® gives the user an interface that is not very similar to AutoCAD. This is one of the first drawbacks to changing from a drafting program to a BIM approach. Most of the A/E industry utilizes AutoCAD® in their operations. It is easier to learn BIM having no computer drafting experience at all than it is with 10+ years of computer drafting experience (Imaging Technologies, Autodesk Revit product representative 2007).

CHAPTER 4
INTERVIEW RESULTS

From the interview process, a good perspective of real world application was attained from construction Companies 1, 2, and 3. Company 1 and Company 2 were a small general contractor firm and a roofing sub-contractor, respectively. Company 3 was part of a large design/build firm. A conference was also held with a large design firm (Company 4) that uses BIM on their projects. Questions asked and answers provided are found in Appendix B. The interviews and meetings were conducted in December 2007.

4.1 Small Construction Companies

4.1.1 Construction Company 1

General Contractors (GC) typically will have between three to four weeks to compose a bid, and if awarded the contract, they have about two weeks to get finances and arrangements in order before construction begins. Representatives do most of their estimates using hand written notes. Although, thorough in reviewing the construction documents prior to bidding, (asking many questions for addendum prior to the bid date) little coordination errors go unnoticed, which become causes for change orders later on during construction. During the construction phase, typical wait times are between two to three weeks before receiving an answer to an RFI which, for the most part, does not impede progress on the job, but if something gets delayed because of an RFI, another change order gets added to the job. During the construction process, both formal and informal meetings are held with the Architects/Engineers to discuss progress on the job, change orders that have been requested, and possible conflicts and future progress on the job. This typically amounts to around three to four hours a week. From a small construction company's perspective, there is no real advantage in acquiring BIM. Up front costs, in both time and money, are more than can be justified.

From the interview, it is apparent that the amount of time used for all aspects of construction and the amount of change orders that get issued for a job are detrimental to productivity for Company 1.

4.1.1 Construction Company 2

This roofing sub-contractor has between two weeks and a month to compose a bid for construction. Their scope of work is very limited and specific. Jobs are typically performed with little coordination problems and few RFIs. They distribute the construction drawings to the steel fabricator or truss fabricator to obtain the necessary shop drawings. Since their time on the job is limited, they do not converse much with the architects and engineers until inspections are required. Any RFIs are typically issued from the shop drawings to the engineers for approval with the roofing sub-contractor acting as the middle man.

This roofing sub-contractor is opposed to the implementation of BIM for their construction operation. Although 3D models make it easier to visualize space, productivity advancements are not realized. This owner has been in the construction industry for more that 25 years. He is not prejudice against information technologies; but is unwilling to recognize the advantages of utilizing LEED practices in construction.

The author beliefs that implementing BIM into normal operations would give small or medium sized construction firms, a distinct advantage in the areas of: lost time and money and increasing productivity. Obstacle to implementation would be training in this area, but the current crop of building construction graduates will have a general knowledge of this program and its assets for a company, and will not be able to ignore the possible benefits. In addition, the new construction managers and job superintendents will be more computers savvy and will be able to learn this program with relative ease.

4.2 Company 3: Large Design / Build Firm

Data acquired from representatives at a large design build firm generated mixed feelings. One representative touted BIM as being the reason why construction on the new performing arts center in Miami, Florida was completed. Before a BIM was constructed, the steel fabricator had over 200 RFIs within the first three months because of the difficult angles and form of the building. Putting the drawings into BIM cleared up virtually all questions involved with the steel structure of the building.

This design/build firm has been implementing BIM on projects they are familiar and comfortable with, that have owners willing to try using a new delivery system, so projects are performing slower than their traditional method because of the learning curve. Most benefits of using BIM are attained when the design is too complicated to portray in 2D. Unfortunately, the pilot projects for BIM are very easy to attain through traditional means and this firm has an office full of extremely proficient users of AutoCAD®. It will take a while for the market to switch to a more BIM centric approach, and this will be enabled with its implementation during design and construction education in University curricula. Another representative has mixed reviews with the benefits that can be acquired. Since this company is a design/build firm, they fast track most of their projects, meaning that construction begins before construction documents are completed. A BIM is most beneficial in the 3D, 4D, and 5D realms when the building has been completely designed. Using BIM for fast track construction has not provided any significant advancement in productivity.

4.3 Company 4: Architectural Design Firm

A conference was held with a representative of a large design firm. This firm is one of the global innovators in BIM methodologies. During the conference, the benefits of a BIM were discussed against the added cost of utilization. Benefits this firm uses to promote using BIM included:

- A 40% elimination of unbudgeted changes (change orders)
- Cost estimate accuracy of 3%
- Less than 1% cost growth
- Bids within 2.5% of actual construction costs
- 60% less Requests For Information (RFIs)
- 80% reduction in time to generate a cost estimate
- Overall savings of 10% of contract sum through clash detection (coordination)
- 7% schedule cost reduction
- 10 to 20 times the return on investment though its life cycle analysis.

This provides convincing data for the implementation of BIM to owners. Inherent complexity of their projects make it essential to use BIM, because 2D drawings cannot accurately represent design intentions. Their projects have been very successful and they are one of the few firms that have historical data on the benefits of using BIM, however the problem is that results are subjective to interpretation by the design firm reporting them. It should also be noted that using a BIM will be a more expensive process than the traditional method of construction in up-front costs.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

A BIM is, in its most basic form, the move from analog to digital design and construction. It is a model-based, dynamically linked, technology with a database of project information for coordination that has a real time, dynamic aspect associated with it; and is poised to fundamentally change the way projects are built and how project stakeholders communicate with each other through the unlimited transfer of information between the project stakeholders, Architects, Engineers and all construction personnel.

A BIM is designed to be the mediating program between the specific programs used by architects, engineers, contractors and suppliers/venders. It moves towards a completely universal and interoperable program working with computer based models in 3D, 4D and 5D. From the 3D model, plans and sections can be developed (Figure 5-1). The 3D capabilities of the program will visually solve any questions about material and spatial relationships. This makes conflict resolution easier to detect as well. Engineers can design their respective systems (i.e. plumbing, HVAC and fire sprinkler) and coordinate with each other. Once the model is composed,

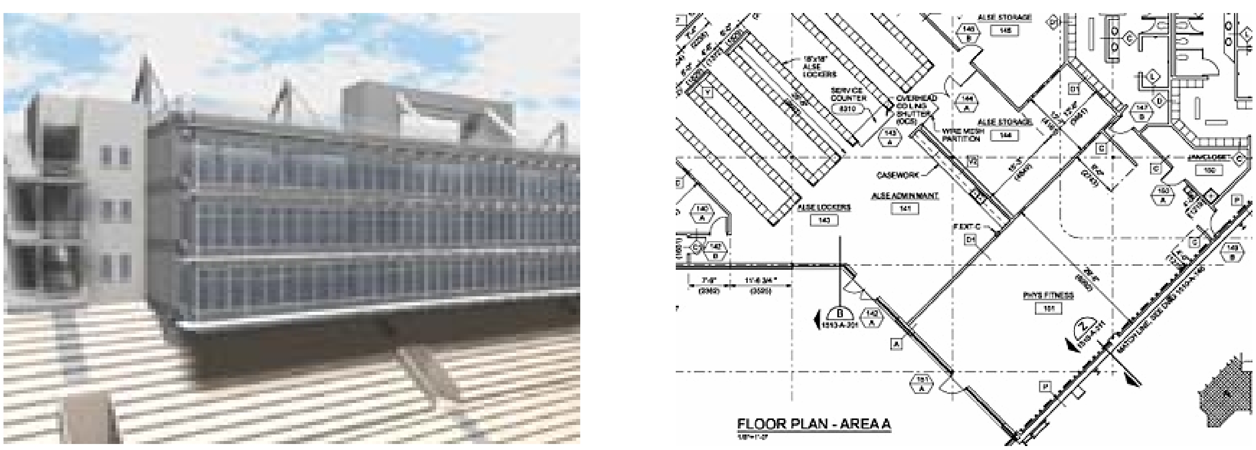

Figure 5-1. A 3D polygon model and 2D lines and text compose a set of integrated construction documents. Images courtesy FacilityGenetics, LLC and Ghafari Associates (NIBS 2006).

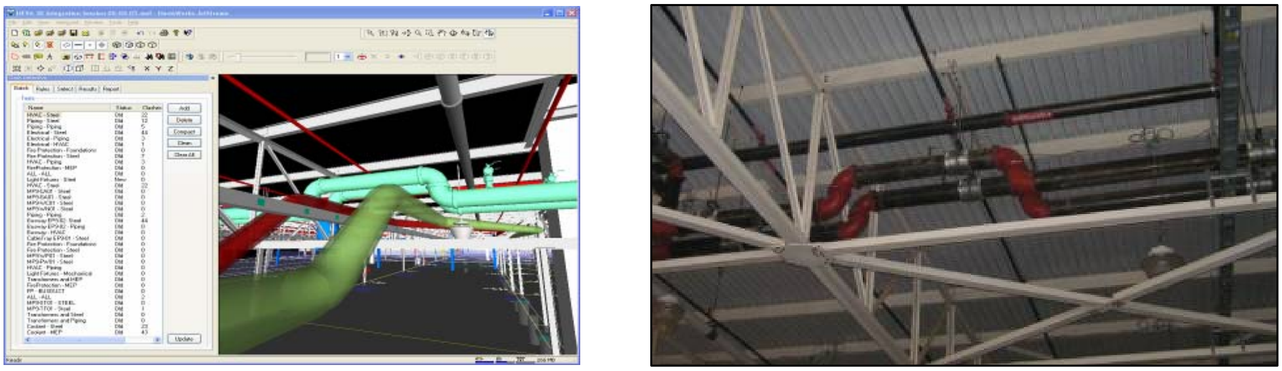

Figure 5-2. Virtual construction documents and installation photograph. Images courtesy FacilityGenetics, LLC and Ghafari Associates (NIBS 2006).

installers can follow the BIM to prevent any conflicts in future construction (Figure 5-2). Models can then be created in 4D so contractors can both visualize construction before it actually takes place, and predict the best locations for construction equipment and lay down areas. Progress can also be monitored to ensure that productivity levels are being maintained (Figure 5-3). With 50% of a typical construction day being non-productive, BIM applications can be used to gain a 33% increase by addressing: late or inaccurate info, waiting on resources, multiple material handling, waiting on instructions and rework. This will have a dramatic increase in productivity for the construction industry, making it more compatible with productivity increases in other industries like agriculture, manufacturing, transportation, etc.

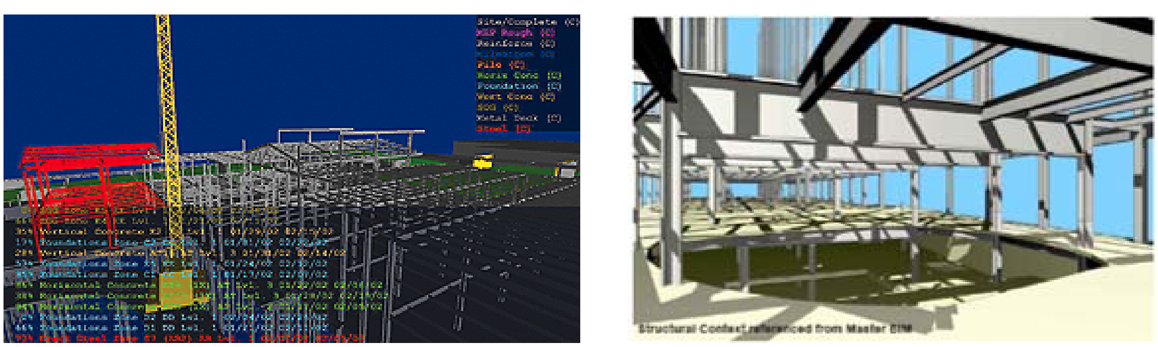

Figure 5-3. Installation process and equipment requirement. Accurate steel sizes, members, weight and cost. Images courtesy Kling (NIBS 2006).

Negative aspects of BIM have to be addressed for the technology to be successfully integrated into the AEC industry. There are a lot of specific requirements with structure, inspections, etc. that relate to the International Building Code. A BIM has to be capable of recognizing project locations to meet regional building codes, especially for overseas projects. All the input from users accessing the drawings may become problematic. Sealing of drawings may prove to be difficult if 30 different people have input to the drawings, how will professionals be able to verify that they witnessed what work had been done on the BIM model. This also applies to the actual program, BIM is supposed to make changes for the user as well when structures are changed, columns are inserted or removed. How will the engineers be able to identify all the changes that the program itself can make to the model and would they be willing to sign and seal the drawings not knowing what changes may have taken place from their original intent or design.

Who will be held accountable for Coordination? Architects and engineers are the professionals responsible for coordination. Since this new program is supposed to manage coordination for you, who will be at fault and who will make the changes when things conflict. Plus, the engineers and architects are going to have to learn a new program that is more expensive, and their fees are not going to increase. This could cause some hesitation for the AEC industry to change.

Future of BIM in the construction industry will be just as important as traditional computer aided drafting (CAD) programs. It will require many years of gathering data and compiling a databases, both from the Architecture/ Engineering side with traditional construction details, and the construction side from gathering actual productivity data. Once a solid database has been formed, productivity will begin to improve, and through continuing education, more opportunities for improvement will begin to reveal themselves. Perhaps the most important issue to remember is the program can only be as helpful and the information that is input to it. The old adage "garbage in, garbage out" could have a significant impact on productivity using this program.

5.1 Increasing Productivity with BIM Using Adrian's Model

Adrian's 10 step model can be used to increase productivity in the construction industry. Results of this study suggest that using Adrian's model BIM can be used to improve productivity.

5.1.1 Making the Project Look Like a Firm Rather Than a Job: Developing a Personnel Management Program

This helps to encourage construction workers to take pride in their work, and sets precedence for performance and appearance. Use of BIM during the planning phase can predict the best location for lay down of materials through the animated construction process. This can be relayed to all trades doing work long before they even get to the site. Having this knowledge gets the job started immediately and without delay.

5.1.2 Improved Communications

Poor communication at a jobsite leads to low productivity, and redo work. A BIM will be able to increase communications between the Architect/Engineers and the jobsite superintendent. There needs to be knowledge of BIM on both sides so communications is through the program. A BIM can also be used to document a job and to keep all involved parties free from problems, delays, and increases progress and achievements.

5.1.3 Planning a Productive Site Layout

Building information modeling can be used to determine proper locations for the construction lay down of materials and the delivery times of materials because of the dynamic scheduling ability that BIM has to offer. Coordination becomes easier, and as-built drawings become more accurate. Construction site layout entails things such as trailer locations, materials, equipment, and storage areas, signs and lavatory locations, break areas, etc. Proper jobsite layout can stem equipment theft. All of these things are critical for increases in productivity.

5.1.4 Challenging the Work Process

Questions like "why are we doing it the same way, where is the best place to do it, when is the best time to do it, etc." need to be asked to find ways of improving the construction process. Object being, to improve the work process, which will increase jobsite productivity. BIM methodology is a new and inventive way to construct a building, and shall not be dismissed because it is difficult.

5.1.5 Developing a Scientific Work Standard Versus an Accounting Based Standards

Utilization of BIM will, hopefully, introduce a new, more standard way to develop drawings from multiple/different design firms. This new standard will increase the knowledge of persons preparing bids and reading drawings because of the similar/typical styles to compose a set of drawings, promoting a more cohesive work environment.

5.1.6 Planning and Scheduling

This was discussed earlier because of the 4D and 5D opportunities that BIM offers as part of its database. Ability to render time lapse studies into a project will help in predicting better more efficient ways to utilize time and improve scheduling.

5.1.7 Project Control and Productivity Improvement

One need's to know what problems are if they are to correct them and improve productivity. Information needs to be recorded regularly to determine the productivity of the current crew on a jobsite. This information could be cataloged and studies will determine what needs to be done to find increases in worker productivity. This will also set a precedence on which BIM projects can be judged, and compared to previous projects that used the traditional construction method.

5.1.8 Equipment Management to Enhance Productivity

This is not relevant to BIM, it relates to the issues of renting rather than owning equipment and worrying about maintenance. It is focused on using new and not outdated equipment to improve productivity on a jobsite.

5.1.9 Productivity Improvement through Safety

It is clear that a safe jobsite is a more productive jobsite, helping to increase worker moral and keep workers motivated (knowing that their employer is concerned about their safety). A BIM can give early clues about potential hazards that may occur on the jobsite.

5.1.10 Productivity through Attention to Quality

Quality products are a necessity to improve productivity; it gives the workers something to take pride in. With BIM, buildings will be able to be estimated and bid more accurately. Cutbacks will not be necessary to bring a project back within budget. Through the use of conflict resolution, more attention can be set on construction detailing.

5.2 Conclusion

True benefits of BIM will be realized when architects, engineers, and contractors use the software seamlessly between each other. Although this is a great program for the industry, it is not the “end all” program. It is a program that has to be used in conjunction with the already used programs of the various trades, i.e. the details that it generates are not suitable for construction, and a separate CAD program is necessary for detailing construction elements correctly (Figure 5-4).

5.3 Recommendations

For future analysis of BIM and productivity in the construction industry, a set of design and interoperability standards has to be adopted, and a shift from CAD to BIM needs to happen.

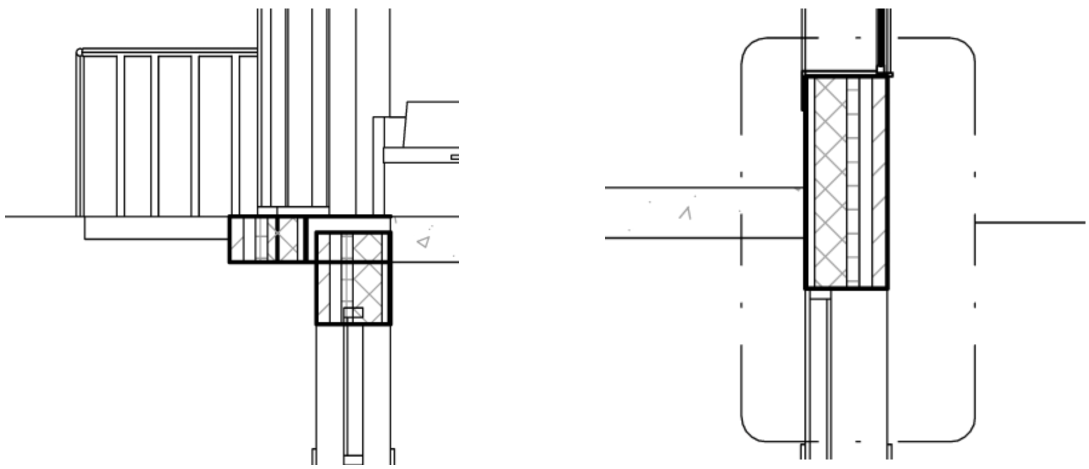

Figure 5-4. Section details from Revit Tutorial (Revit 2008).

Once this takes place, historical data will become more readily available, and surveys can be conducted to compare the traditional method of construction against the BIM methodology. This kind of information will be essential in figuring out the future of the industry, instead of just relying on projections.

Future research needs to be done on interoperability with the various programs that are essential to the AEC industry to see how well BIM can be integrated into daily use. Surveys should be conducted to determine how well BIM is improving productivity, and how productivity levels compare against other U.S. industries. This will become more readily available once more historical data is gathered from construction and design firms that have implemented the program.

APPENDIX A
LIST OF TERMINOLOGY AND ABBREVIATIONS

- 2D. A drawing that exists in only the X and Y planes
- 3D. A drawing that exists in the X, Y, and Z planes
- 4D. A BIM that can also be shown in a time stamp sequence, to show progress
- 5D. A BIM that can forecast cost analysis over the lifespan of the building
- A/E. Architects and Engineers
- AEC. Architecture / Engineering / Construction
- AIA. American Institute of Architects
- BIM. Building Information Modeling
- CAD. Computer Aided Drafting
- CM. Construction Management Firm
- IAI. The International Alliance for Interoperability
- IFC. Industry Foundation Classes
- INFORMATION. The Information / data that is obtained from the building.
- LEED Leadership in Energy in Environmental Design
- LIFECYCLE. Describes all the phases of the building process: design, construction documents, procurement, construction, maintenance, additions, and demolition.
- MODELING. The model that houses, maintains, and controls the flow of information needed to manage the building
- NBIMS. National Building Information Model Standards
- NIST. National Institute of Standards and Technology
- R&D. Research and Development
- RFI. Request for Information

APPENDIX B
INTERVIEW QUESTIONS AND ANSWERS

1. Company 1 (small general contractor)
2. Company 2 (small roofing contractor)
3. Company 3 (large design/build firm)

- **How much time is spent analyzing construction documents prior to the construction process?**
    1. Typically have three weeks to a month to prepare bids for a project.
    2. Between two weeks and a month.
    3. Since most jobs are fast-track, we start building as soon as we get the drawings.
- **How long does it take to prepare a bid using a traditional set of construction documents?**
    1. It takes the entire time we have the construction documents for review. Typically we get our sub contractors bids the day before the base bid is due.
    2. Typically between one or two weeks
    3. -
- **Approximately how many RFIs are submitted for a typical construction job?**
    1. This is dependent upon the architect and the owner, they range from 0 to 35, depending on the complexity of the job.
    2. Typically roofing jobs do not have many RFIs, but when substituting materials or adding a roof penetration, there can be as high as 10
    3. Projects that are fast-track typically have a lot of RFIs numbering into the hundreds on a single project
- **What is the average time spent waiting for a return on an RFI?**
    1. the average time is around two weeks to three weeks
    2. two weeks
    3. It depends on how difficult the question is, but typically they are answered within a week, and sometimes the same day.
- **How much time is spent conversing with the Architect/Engineers about the construction job?**
    1. Before the construction begins, very little – during construction, regular monthly progress meetings are held, and correspondence continually occurs
    2. not much at all, both before and during construction
    3. There is an open dialogue between the architects/engineers and contractors throughout the entire project.
- **Are you currently using Building Information Modeling at your office?**
    1. No
    2. No
    3. Yes, we are implementing BIM on projects that lack complexity, but use 3d design regularly in the construction process.
- **If not, do you foresee changing over to some kind of a BIM system at your construction company?**
    1. No, it would be to large an investment and change for our company
    2. No
    3. -

- **If so, what problems have you encountered using the BIM process?**
    1. -
    2. -
    3. BIM is a great concept, problems occur because fast-track jobs are started with 50% completion of construction drawings. The problem with BIM is that the drawings have to be complete to gain any benefit from estimating the job and developing the drawings.
- **Do you implement any productivity improvement practices with your construction crews and if so, what?**
    1. No
    2. No
    3. –

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4. Company 4 (Design Firm)

- **What BIM software do you use?**
    a. Digital Project®

- **When did you start utilized BIM in the design process at Ghery Technologies?**
    a. I was a co-founder of Ghery Technologies with Frank Gehry and Jim Glymph. Ghery Technologies was established in 2002.

- **How would you compare Digital Project with Autodesks Revit®?**
    a. They similar in scope and are used to create BIMs, but Digital Project is a more complicated and advanced system.

- **What are the benefits of using BIM that Ghery Technologies has observed?**
    a. The benefits that we have been experiencing with BIM are:
        - A 40% elimination of unbudgeted changes (change orders)
        - Cost estimate accuracy of 3%
        - Less than 1% cost growth
        - Bids within 2.5% of actual construction costs
        - 60% less Requests For Information (RFIs)
        - 80% reduction in time to generate a cost estimate
        - Overall savings of 10% of contract sum through clash detection (coordination)
        - 7% schedule cost reduction
        - 10 to 20 times the return on investment though its life cycle analysis

- **How many projects have you used BIM on?**
    a. There have been 32 major projects accomplished using BIM

- **How long before you expect the majority of AEC to convert over to a BIM system?**
    a. It will probably take around seven years

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BIOGRAPHICAL SKETCH

Joseph C. Kuehmeier earned his master's (MSBC) degree from the M.E. Rinker, Sr. School of Building Construction at the University of Florida. During his studies he worked as an associate architect for CRG Architects / Palatka Inc. where he dealt with all phases of the design and construction process. Prior to earning his MSBC he earned a bachelor of design in architecture from the University of Florida, graduating cum laude, and earned a Master of Architecture (MArch) from the University of Florida. He is currently working on achieving his architectural license in conjunction with his contractor's license.

Joseph's research interest are related to how the design and construction processes can communicate together seamlessly using a common digital language. He has five years' experience in the design industry and looks forward to future endeavors in the design/build environment.