EVALUATION OF BUILDING INFORMATION MODELING APPLICATIONS FOR SMALL CONSTRUCTION COMPANIES

by

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Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN CIVIL ENGINEERING

THE UNIVERSITY OF TEXAS AT ARLINGTON

May 2011

ACKNOWLEDGEMENTS

I would like to show my gratitude to my thesis committee chairman, Dr. Mohammad Najafi, P.E., for guiding me throughout my graduate studies. Also, I would like to thank my thesis committee members Dr. Siamak Ardekani, P.E., and Dr. Laureano Hoyos, P.E., for taking the time out of their busy schedules to evaluate my thesis and provide constructive comments. I would like also to thank Mr. Raymond Gomez, President of Rayco Construction, for giving me the opportunity to learn about the construction management process first hand, and allowing me to implement the knowledge I acquired during my studies in my professional career.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of this thesis.

April 14, 2011

ABSTRACT

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FOR SMALL CONSTRUCTION COMPANIES

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The University of Texas at Arlington, 2011

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This thesis presents evaluation and recommendations to help small construction company's transition from traditional two dimensional plans to a Building Information Modeling (BIM) management process. Building information modeling covers information on geometry, spatial relationships, quantities and properties of building components to reduce operational conflicts and design changes during the construction phase of a project. Due to the cost of implementing BIM, the primary focus of the thesis is on the transitioning state of these two management areas in an effort to facilitate full integration of smaller contractors into BIM technologies at a future time.

Three case studies are used to assess and evaluate the effects of building information modeling on the schedule, material procurement, and information modeling aspects of a project. The intent of the case studies is to demonstrate a net positive result to apply modeling techniques to enhance a project's coordination, productivity, and procurement practices. The recommendations suggested in this thesis is a simpler and more manageable alternative smaller firms can consider in developing the skill set needed to implement a fully integrated BIM program using the tools and processes currently available to them.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure Page

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Statement of Problem

Traditionally, contractors have used an assembly of two-dimensional (2-D) documents consisting of plans, sections, elevations, and specifications among others as a guide in building individual projects. As projects become increasingly more complex, and owners demand quicker delivery and greater cost efficiency, contractors must incorporate new practices to effectively manage project constraints. This thesis is oriented towards aiding smaller to mid-sized construction businesses develop and implement a basic form of building information modeling (BIM) technique to manage projects. Small to mid-sized construction companies are defined as those companies with less than 19 employees (Sacks et al., 2008). Since BIM is a relative new concept within the construction industry, the costs and skill level associated with the implementation of BIM is not economically feasible for smaller construction companies. The development of supplemental models suggested by this thesis is a simpler and more manageable alternative to implementing a fully integrated BIM program by smaller firms.

This thesis uses three projects scheduled for completion in September 2010 as case studies. The case studies are used to assess and evaluate the effects of applying preliminary forms of building information modeling techniques to enhance the project's coordination and productivity by minimizing rework and delays due to unforeseen conditions.

The three projects evaluated in the case studies were selected with the intent of demonstrating the applicability of building information techniques in a wide range of project profiles. The projects selected for evaluation in the case studies included a small scale tenant/office space remodel, the construction of a new walking path, and a larger sized office remodel incorporating specialized construction aspects.

1.2 Importance of the Research Problem

In 2009 the U.S. Bureau of Economic Analysis reported that Construction accounted for approximately 4% of the 2008 US Gross Domestic Product with a revenue of $582 billion (U.S. Bureau of Economic Analysis, 2009). Research conducted by the Construction Industry Institute estimates that direct costs caused by rework in the construction industry average five percent of the total construction costs of a project (Hwang et al., 2009). This constitutes approximately $29 billion in 2008 alone.

Rework not only impacts the economy of a project, but also negatively affects the schedule and morale of all parties involved. The effects of rework on the project economy are due to the added costs associated with removal of the non-compliant work and the reinstating of the work to an acceptable level of quality. The effects of rework on time are identified as a delay in the project schedule and are illustrated by Figure 1 – Effects of Rework on Time.

Original Activity	Rework Duration			Continuation of Original Activity
	Standby	Rework	Gear Up	

Figure 1 – Effects of Rework on Time

Fayek et al. (2003) categorized the components of rework as the standby time during which the rework scope is identified, the time required to carry out the rework, and the time required to gear up to carry on with the original scope of the activity. The effects of rework on the psychology or morale of the project team can manifest itself in the form of doubt by the project owner in the capabilities of the contractor to perform the work, increased observation by the contractor in an attempt to avoid further rework and to try and make up any losses, and a potential decrease in the level of productivity by the workers to try and avoid future rework. These three elements associated with rework, loss of money, loss of time, and lowered morale, have a significant detrimental impact on the coordination and productivity of a project. It is reasonable to assume that by minimizing rework not only will the contractor benefit from a potential increase in the profit margin, but the owner will also benefit from faster project delivery. This thesis addresses these elements by enhancing project communication by incorporating basic forms of BIM techniques and thus another level of project communication to minimize or eliminate rework and delays, and enhance productivity.

1.3 Current State of the Research Problem

Research in project integration using Building Information Modeling (BIM) is actively conducted both within the industry and in institutions of higher learning. Pilot programs and research is currently being conducted by different organizations such as the National BIM Standard, FIATECH (Fully Integrated and Automated Technology), General Services Administration, US Army Corps of Engineers, and International Alliance for Interoperability among other organizations to attempt to establish standards and procedures in the implementation of BIM within the Architecture-Engineering-Construction (AEC) Industry (Eastman et al., 2008).

1.4 Applicability of the Research Problem

This thesis provides contractors another tool or management technique to aid them in coordinating and managing projects to minimize delays and enhance productivity. The research of this thesis is oriented toward aiding smaller to mid-sized construction businesses develop and implement a primitive form of building information modeling technique to manage projects. Since building information modeling is a relative new concept within the construction industry, the costs and skill level associated with the implementation of BIM is not economically feasible for smaller construction companies. The development of supplemental project information suggested by this thesis is a simpler and more manageable alternative to implementing a fully integrated BIM program by smaller firms.

The case studies will demonstrate a practical applicability to the implementation of preliminary BIM techniques by contractors in managing projects. The overall objective of the thesis, however, is to aid smaller contractors take the first steps towards implementing fully integrated building information modeling techniques.

This thesis deals with the onset of where project development and management is headed in the future: a fully integrated design-construction-operation process. The building industry has traditionally been a segmented/fragmented operation; nonetheless, with the growing complexity of projects it is becoming necessary for roles within a project team to coalesce. This thesis does not look at assessing the effects of a fully integrated building process proposed by BIM technology. The frame work associated with BIM processes has yet to be fully structured and accepted by the architecture-engineering-construction community. This thesis looks at raising awareness among builders and contractors in particular to the benefits of actively participating in the design segment of a project by supplementing constructability information in addition to the construction documents to enhance the management and productivity of a project. It does not warrant a substantial investment by the contractor in acquiring BIM enabled software or training. It proposes to begin the process of restructuring the traditional segmented mindset of the contractor by implementing development of simple complementary information transfer procedures.

1.5 Chapter Summary

The increasingly complex nature of projects, and demands by owners for quicker delivery and greater cost efficiency, has provided contractors with an opportunity to incorporate new practices to effectively manage project constraints. Building information modeling has become an attractive tool in achieving greater understanding of construction projects and minimizes the delays associated with unforeseen conditions. The frame work associated with BIM processes has yet to be fully structured and accepted by the architecture-engineering-construction community. This thesis proposes to begin the process of restructuring the traditional segmented mindset of the contractor by implementing development of simple complementary information transfer procedures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter one outlined the needs and aims of expending the time and efforts to investigate and evaluate the applicability of building information modeling in the construction industry. Chapter 2 focuses on establishing the current state of the architecture-engineering-construction industry and introducing the concept of building information modeling.

2.2 What is the Current AEC Model?

The architecture, engineering, and construction (AEC) industries have traditionally assimilated a fragmented approach when it comes to project procurement. Current project delivery processes are primarily dependent on paper-based modes of communication. Paper-based modes of communication have been common practice among the AEC industries for so long that incorporation of technology to supplement the current delivery process will not only require team members to learn a new skill set, but also the changing of an industry mindset.

The AEC industries have not completely ignored the incorporation of technology into the project delivery process; many of the activities associated with the delivery process are now performed and delivered faster via the use of software and web-based technologies. Estimating and scheduling activities for example can now be performed faster via the use of digitizers, digital drawings, and estimating and scheduling software. Information exchange between the contractor's field office (project site) and head office, architect/engineer office can now occur in real time via email and web-based programs. Arguably the cost implications associated with incorporating technology into the project delivery process among smaller sized firms could be the primary limiting factor. Due to the rapid advancements in technology, computer software and hardware costs become secondary to the costs of training staff to properly implement such technologies.

The dominant project delivery methods in the United States are currently Design-Bid-Build and Design-Build (Sanvido and Konchar, 1999). In the following subsections a brief introduction to the Design-Bid-Build and Design-Build delivery methods will be summarized as a basis from which to develop the transitional program proposed as an aid for small contractors to begin incorporating “BIM” concepts into their project delivery practices.

2.2.1 Design-Bid-Build Delivery Method

Traditionally, the Design-Bid-Build structure has been the common delivery method employed in the construction of new facilities. In 2002, a survey published by the Design-Build Institute of America estimated that approximately ninety percent of public buildings and about forty percent of private buildings where constructed using the Design-Bid-Build delivery method (Design-Build Institute of America, 2010). A general project organizational chart based on the Design-Bid-Build delivery method is illustrated in Figure 2.

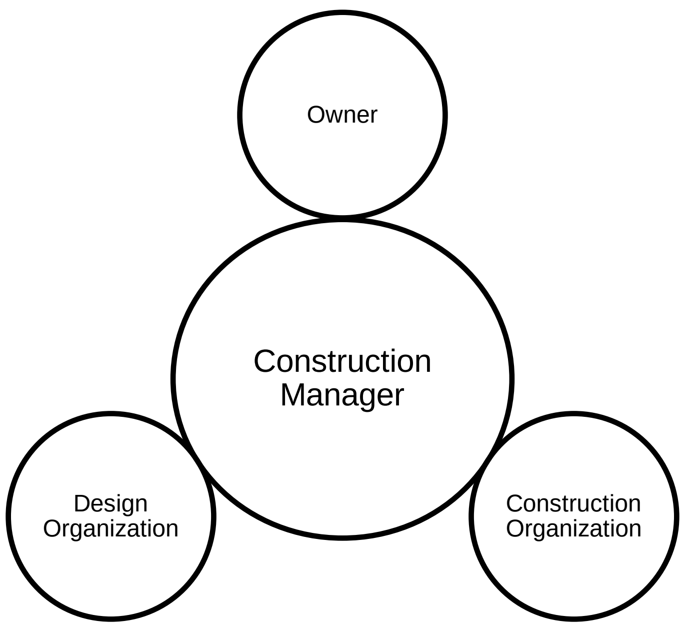


Figure 2 – Typical Design-Bid-Build Organizational Structure (Eastman et al., 2008)

A typical Design-Bid-Build (DBB) project process begins with an owner contracting a design firm to develop project documents based on a specific program. In a building (commercial/residential project), the architect generally takes the lead during the design phase to develop project documents, drawings and specifications into a construction document bid set to be issued for bid solicitations.

The next step in the DBB project process involves the solicitation of bids. Bid solicitation can be done via an open forum in which any contractor is able to submit an offer or via a private process in which only “pre-screened” contractors are invited to bid and participate. The owner and/or architect then make an award based on the best value to the owner; typically the lowest responsible and responsive bidder. The construction phase is then commenced during which the successful contractor must organize his or her team of subcontractors and suppliers and begin construction operations based on the project documents.

It is during the construction phase that a majority of the problems associated with the Design-Bid-Build project process materialize. Errors and omissions by the design team are identified, unanticipated site conditions can cause changes to the design, and new requirements by the owner can arise. All changes deviating from the original design intent thus lead to monetary costs, time delays, and increased tension among the project team.

In the Design-Bid-Build delivery method each of the phases has its own project leads assigned the task of carrying the project through their respective phase; and for the most part, have traditionally operated independently of each other (see Figure 3). The final step in DBB project process is the operation and maintenance phase implemented by the building manager(s) for the life of the building.

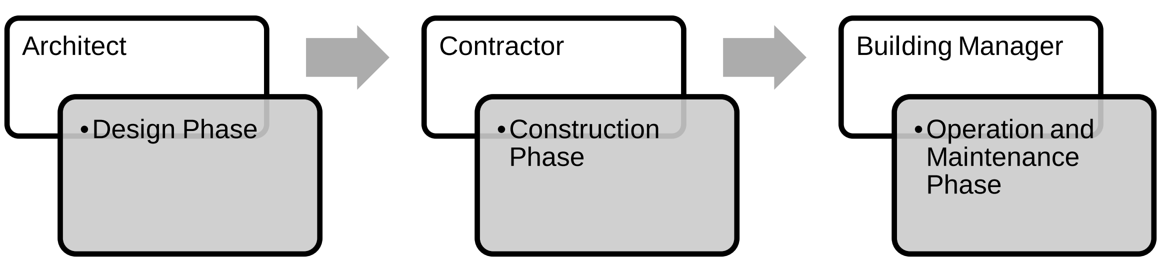


Figure 3 – Design-Bid-Build Delivery Method

2.2.1.1 Advantages of the Design-Bid-Build Delivery Method

The main benefit of the Design-Bid-Build project delivery method is an owner's ability to obtain competitive bids and thus in theory construct the project at the lowest possible cost. The economic benefit attributed to the DBB delivery method is only valid assuming changes in the project scope during the construction process is minimal. This assumption, however, is not accurate. Research conducted by the Construction Industry Institute estimates that direct costs caused by rework in the construction industry average five percent of the total construction costs of a project (Hwang et al., 2009).

2.2.1.2 Limitations of the Design-Bid-Build Delivery Method

There are a number of disadvantages associated with the Design-Bid-Build project delivery method largely attributed to errors and omissions in the design documents during the construction process. The design team develops documents based on known conditions and constraints which could potentially differ from the actual site conditions encountered by the contractor during the construction process. Moreover, because of potential liability issues architect may choose to incorporate fewer details in the construction documents or include verbiage indicating that the accuracy of the plans cannot be relied on solely and that the contractor is ultimately responsible for verification of dimensions and constructability of design. Discrepancies such as these can lead to disputes between the contractor and architect and can lead to added costs, and time delays for the project.

Another major limitation associated with the DBB project delivery method is its emphasis on project delivery fragmentation. The contractor typically has no input during the design phase and thus the contractor's knowledge of constructability, material availability, value engineering, and other such construction related information is lost and can only be incorporated into the project execution in a very limited way. Similarly, a project manager's experience and knowledge on what it takes to build a project is lost. The project manager is thus left to build the project reactively based on the architect's and engineer's decisions during the construction phase.

The underlying disadvantage of a Design-Bid Build project delivery method is thus the fragmentation of communication between all members of the project team. Valuable information privy to each member of the team is not proactively considered in developing the project and only incorporated into the project reactively as the project is carried on through each discrete phase.

2.2.2 Design-Build Delivery Method

Although the Design-Build contract method is considered to be one of the oldest project delivery approaches, it is now regarded as a new alternative delivery method. During ancient times, a master builder was charged with the task of both designing and building projects within an empire. Advances in science and technology during the 19^{th} century eventually led to the development of architecture and engineering as two independent professions and subsequently the fragmentation of the building process. The Design-Build Institute of America defines a Design-Build contract as follows:

> a method of project delivery in which one entity - the design-build team - works under a single contract with the project owner to provide design and construction services. One entity, one contract, one unified flow of work from initial concept through completion. (Design-Build Institute of America, 2010)

Data collected by the Design Build Institute of America indicates that the number of Design-Build type contracts has been experiencing continuous growth since 1985; (see Figure 4).

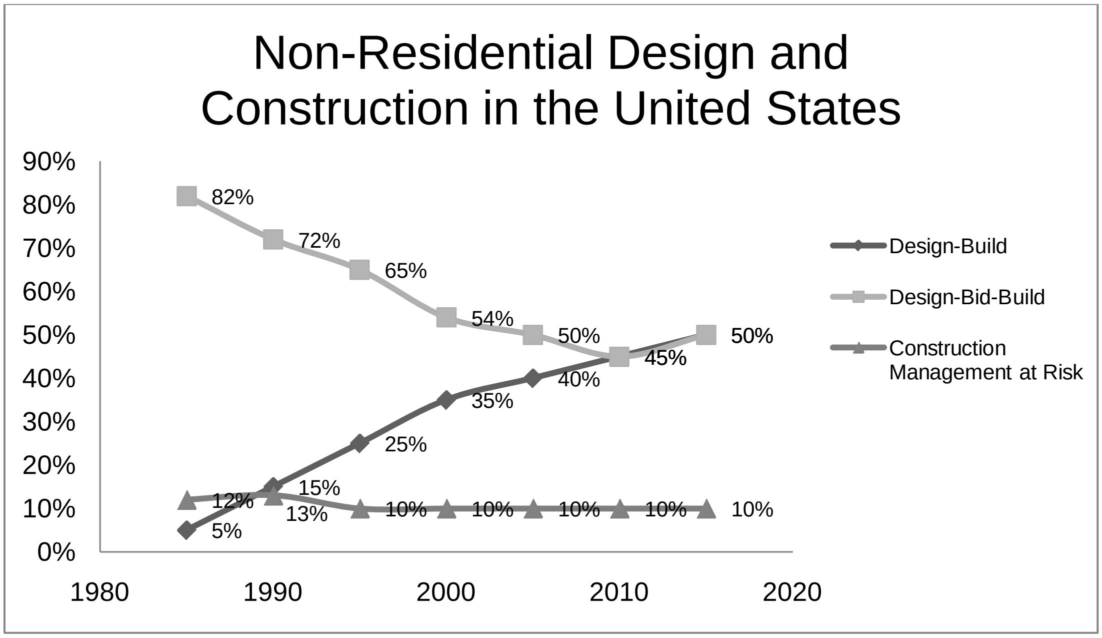


Figure 4 - Percentage of Contracts in the U.S. per Project Delivery Type
(Design-Build Institute of America, 2005)

A general project organizational chart based on the Design-Build delivery method is illustrated by Figure 5.

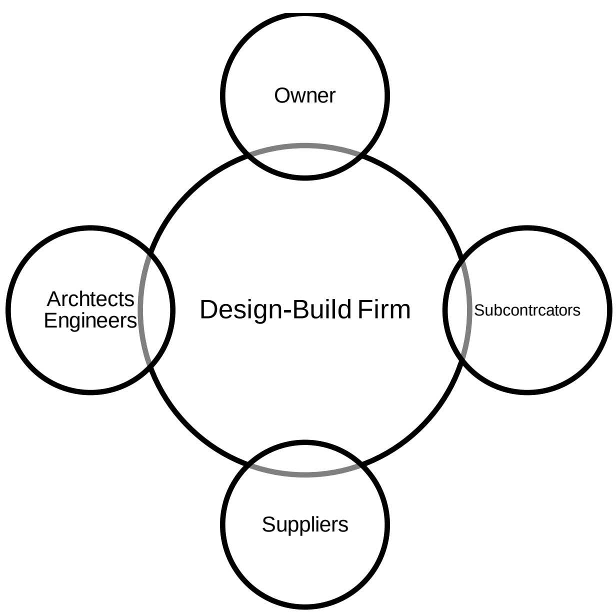


Figure 5- Typical Design-Build Organizational Structure

A typical Design-Build (DB) project process begins with an owner contracting a design-build team to develop a building program and design. The design-build team then typically submits the design, and estimated cost and time to the owner for approval. Upon approval by the owner, the design-build team can begin and complete construction.

2.2.2.1 Advantages of Design-Build Delivery Method

In a design-build contract the owner benefits from faster delivery because the designer and contractor are working together. The administrative burden of managing multiple separate contracts for the owner is decreased as well as accountability and risk in that one entity, the design-build team, is now accountable for cost, schedule and performance, as well as assuming the risk of any errors or omissions. The collaborative environment particular to a design-build contract also facilitates the incorporation of innovative technology and construction techniques such as Building Information Modeling and Leadership in Energy and Environmental Design (LEED) certification where communication among the project team is vital to the successful implementation.

2.2.2.2 Limitations of Design-Build Delivery Method

One of the draw backs of the Design-Build delivery method is loss of flexibility for the owner to make changes after the initial design is approved and a contract amount is established. Also, due to the nature of the Design-Build contract it is difficult for a project owner to obtain comparable competitive bids from different DB teams for a particular project. This is because each DB team would have his or her own interpretation of what the design should reflect; unlike in the DBB delivery method where all bids are based on interpretation of the same design.

2.3 Building Information Modeling

Regardless of the delivery method implemented in a project the underlying short coming in the AEC industry is project integration and data integrity. The AEC industry is taking steps towards addressing this issue and Building Information Modeling is being considered the applicable solution.

2.3.1 Where did the term BIM come from?

The exact inception of the acronym "BIM" to describe the evolution of computer-aided design (CAD) from a 2-dimensional platform to an object or parametric based design technology is debatable. Authorship of the phrase, however, is widely attributed to Jerry Laiserin. Jerry Laiserin is an industry analyst specializing in future technologies for the building enterprise and on collaborative technologies for project-based work (The Laiserin Letter, 2010). In the introduction to Building Information Modeling by Smith and Tardif (2009), the authors present the case that the term "BIM" first came into popular use as a result of its publication by Jerry Laiserin in his authorship of *LaiserinLetter No. 15*:

> In the December 16, 2002, issue of the LaiserinLetter™…. Citing a recent meeting of building industry strategists… Laiserin made a cogent argument for the term "building information modeling," or BIM, as the best term to describe "the next generation of design software.(Smith & Tardif, 2009)

Although the popularization of the term "BIM" is attributed to Laiserin; Laiserin considers himself as one of many contributors to the development of the term and notion of "Building Information Modeling." As cited in the foreword of the "BIM Handbook," Laiserin accounts that:

> The earliest documented example… found for the concept we know today as BIM was a working prototype "Building Description System" published in the… AIA Journal by Charles M. Eastman… in 1975. (Eastman et al., 2008).

According to Laiserin the first documented use of the phrase "Building Information Model" in the English language appeared in the paper Automation in Construction published by G.A. van Nederveen and F. Tolman in December 1992. Regardless of the origins of the acronym "BIM," building information modeling is popularly considered among the architecture, engineering, and construction (AEC) industries as the future of how we design, construct, and operate the built world.

2.3.2 What is BIM?

BIM is a modeling technology and associated set of processes to produce, communicate, and analyze building models (Eastman et al., 2008). Building models are compiled using intelligent digital representations of building components embedded with parametric data that describes how they behave; these components are also known as parametric objects. The building models developed are also consistent and coordinated such that the possibility of redundancy in data is eliminated.

Parametric objects consist of geometric definitions and associated data and rules (Eastman et al., 2008). Parametric objects are non redundant when it comes to their shape; the plan and elevation views of these objects are always consistent. Parametric objects also support the objects inherent properties/attributes such that analysis on the object and object assembly can be performed. Parametric objects must also abide by associative rules such that the object automatically modify to or with associated objects.

2.3.3 Benefits of Implementing BIM in the Construction Industry

Although the application of BIM technology is relatively new to the construction industry three applicable benefits based on the current level of development of this technology include:

1. Construction Planning and Phasing – the linking of a construction schedule to 3-dimensional objects in a design to simulate the construction process and observe the status of a construction site at any given point in the schedule. This particular attribute can be beneficial to contractors as an aid in coordinating temporary construction elements, staging areas, and potential safety issues.
2. Pre-Construction Clash Detection – since in a building information model all aspects of the project are developed in a 3-dimensional environment from which 2-dimensional drawings are extracted discrepancies in drawings are eliminated. The routing of components for multiple systems can be adjusted to eliminate both hard and soft clashes proactively in the model's simulated environment as opposed to reactively in the field.
3. Quicker Response to Design Changes – the parametric nature of the building information model's components enables a contractor to obtain rapid information in reference to changes associated with the design. The associative properties of the model elements allow any changes made to the design to propagate throughout the model and the

revised information withdrawn from the model itself as opposed to the manual updates, checks, and data collection of traditional systems.

2.3.4 Challenges of Implementing BIM in the Construction Industry

The implementation of BIM practices highlights a number of benefits to all members of a project team; nonetheless, current practices within the AEC industry are not formatted to facilitate integration between the distinct project phases (design, construction, and facility management). Introduction of a collaborative based technology such as BIM therefore will warrant a shift from the predominantly segmented nature of the AEC industry towards a more integrated approach.

The challenges of implementing BIM in the construction industry include organization, economical, and legal issues.

Due to the predominantly segmented nature of the AEC industry, in implementing BIM practices contractors will have to take on a more collaborative role during the design phase and in facilitating transition into the operation and maintenance of the project. Moreover, making the transition from 2D based practices to a BIM based process will require investment in software, hardware, and staff training, as well as restructuring the firm's business such that the BIM process is tracked, modified as necessary, and implemented successfully. BIM practices involve implementation of a new ideology in terms of performing routine actions and not simply performing these routine actions in a new way.

Contractors also incur an economic cost associated with the implementation of BIM processes. The initial investment in implementing BIM practices includes the acquisition of BIM based software and the necessary hardware to properly operate it, as well as the necessary training to enable project team members to properly implement the technology. Another cost associated with BIM implementation is development of the building information model. If the design firm does not provide the contractor with a model, the contractor will have to incur the cost of developing. Furthermore, the model developed by the architect might not include the necessary information for the contractor to benefit from the model; as such a new model will have to be developed. These added costs incurred by the contractor in implementing building information modeling will consequently find their way into a contractor's overhead cost and into the project estimate. The added overhead cost can potentially be the difference between being awarded a contract and losing it.

2.3.4.1 Interoperability Issues

Implementation of building information technology is relatively new within the AEC industry and as such, the interoperability of BIM based software's has yet to be fully established. Consequently, the full potential of BIM in propagating an integrated approach and maintaining data integrity during project delivery is difficult to attain. Organizations such as the International Alliance for Interoperability, National Institute of Building Sciences, and FIATECH are actively researching into the area of interoperability within the AEC industry to attempt at establishing a:

> Standardized, machine-readable, and comprehensive building information model in a format that is useable and accessible to all players throughout the life cycle of the facility (National BIM Standard Project Committee, 2007).

The only current viable open international standard for interoperability is the Industry Foundation Classes developed by BuildingSMART International (Smith and Tardif, 2009). When complete interoperability is achieved within the AEC industry the full benefits of BIM will be possible. All team members then will be able to contribute and retract information from a single integrated repository of information, the BIM, as opposed to the current practice of a sequential degradation of information from one source to the other.

2.3.4.2 Legal and Liability Issues

The degradation of information as it passes from one source to the next is due to the liability issues that are associated with the transfer of information. In fostering an integrated approach to the AEC industry via BIM, members of a project team must be assured that their cooperation in maintaining data integrity and project integration will not assimilate additional liability beyond that warranted by their contract terms and compensation. In the case of a building information model, which team member is responsible for the development of the model and who will be responsible for the data integrity within the model are two questions which need to be clearly specified in contract agreements. This is to avoid confusion and remove biased leveraging of liability on any one of the parties involved.

The American Institute of Architects (AIA) has developed standard legal forms to indentify the terms of digital information exchange between parties in a contract. These standard legal terms include, AIA Contract Document E201 2007 “Digital Data Protocol,” as well as for parties that are not in privity, AIA Contract Document C106 – 2007 “Digital Licensing Agreement.” Both the Associated General Contractors of America (AGC) and the AIA have also developed contract documents specifically addressing building information models. These information models include ConsensusDOCS 301 BIM Addendum and AIA Document E202 – 2008 BIM Protocol Exhibit respectively, to structure the relatively new process of building information modeling and provide a framework for the new business relationships that are developed.

2.3.5 Inefficiencies of Traditional Approaches

Despite the exhaustive practice of traditional construction delivery methods the construction industry has not been able to fully capitalize on technological and organizational innovations. It can be surmised that the primary reasons the construction industry has been slow to implement beneficial change is due to the uniqueness of the product being delivered and segmented nature of the industry when it comes to its organization.

2.3.5.1 Productivity Inefficiencies

A 2007 study on Construction Industry Labor Productivity done by the Center for Integrated Facility Engineering (CIFE) at Stanford University documented that over a 40-year-long period of data evaluated from 1964 to 2004, the productivity of non-farm and non-construction industries has more than doubled whereas labor productivity within the construction industry has decreased by ten percent (Teicholz, 2007).

The reasons for the productivity inefficiencies are not completely understood but may possibly be attributed to organizational impediments within the construction industry. The increased efficiency in the manufacturing sector has benefited from automation, the use of information systems, improved supply chain management, and improved collaboration tools

(Eastman et al., 2008). A possible explanation for the success in implementing such tools within the manufacturing industry can be due to the fact that manufacturing industries tend to produce a limited number of products. Due to the redundant nature of its production of goods manufacturing industries can thus optimize the production process to maximize product delivery at lower costs.

Construction, on the other hand, is a unique industry in that distinctive products are generated via the collaborative efforts of independent firms contractually obligated to each other for limited periods of time. Each project within the construction industry is unique and distinctive therefore implementation of streamline technology such as automation is difficult. Collaborating members of a construction team can specialize and to some extent streamline a particular task; however, the assembly of each individual task tends to vary from project to project and thus limits how efficient the construction productivity can become.

2.3.5.2 Lack of Leadership

Another inefficiency of traditional construction practices is due to the lack of industry leadership. A large constituent of the construction industry, approximately 91.6%, is comprised of smaller firms consisting of less than 19 people, making it difficult for them to invest in new technology. Larger firms account for less than 0.5% of the total construction volume and are thus unable to establish industry leadership (Eastman et al., 2008). Due to the fragmented nature of the construction industry, in order to benefit from new processes and technologies, the industry as a whole will have to collaboratively induce adoption of new ideas.

Traditionally, adoption of innovative construction/business practices has been slow and primarily limited to larger firms able to offset the cost of implementing such innovative approaches. Implementation of innovative approaches; however, tend to necessitate reverting to more traditional practices to keep the participation pool for projects reasonably open and thus maintain cost effectiveness.

According to data published by the U.S. Bureau of Labor Statistics from 1974 to 1996, the real inflation-adjusted wages of construction workers have been declining over the years (Eastman et al., 2008). Consequently, the decline in union participation and increase influx of inexpensive immigrant workers has been detrimental to the development of labor-saving innovations. Thus, the traditional segmented approach to construction currently provides little economic incentive to implement innovative organizational approaches, at the same time the idea of project integration and information modeling seems becoming increasingly popular.

2.3.6 BIM's Return on Investment

An accurate evaluation of the return on investment (ROI) on the implementation of BIM related strategies and procedures are difficult to quantify. Tangible metrics such as productivity are easier to measure as opposed to the benefits associated with profits gained from increased project quality, repeat business, improved communication, and the interoperability of information. Within the construction industry, even productivity measures can be misleading due to the distinctive nature of each individual project. Unlike the controlled environment within a manufacturing industry, even in projects where the exact construction documents are used to assemble an array of building, each building's site conditions are different. Similarly, other factors such as weather, economic conditions, and labor conditions and morale can have a considerable effect on the production rates at each project location. Consequently, companies looking to implement BIM related strategies and procedures should not do so solely on the results of an analysis such as ROI, but do so more with the intent of promoting an integrated project delivery atmosphere to enhance a project's performance.

Despite the difficulty in measuring the ROI of BIM, research is available to "evaluate" the effectiveness of applying this technology. In evaluating a ROI for a new system, consideration must been given to the loss of productivity during the training and transitional stage of the system's implementation. Productivity gains, therefore, are not typically experienced until after users are familiarized and confident with the new system's capabilities. Figure 6 illustrates a graphical representation of the productivity loss and gain in implementing new software (Autodesk, Inc., 2007).

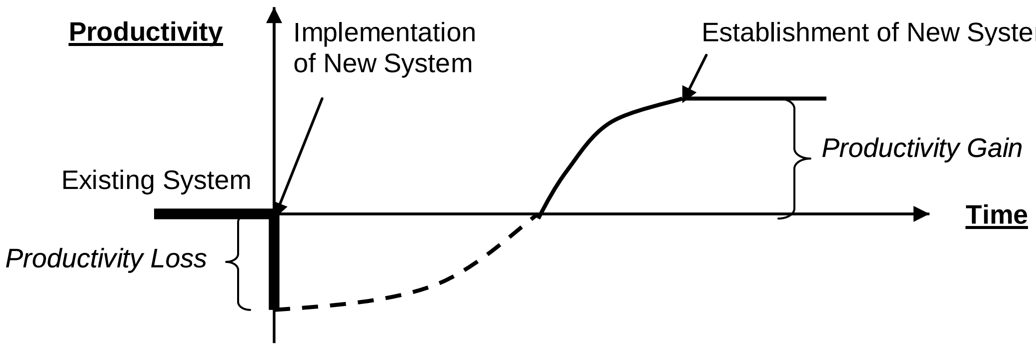


Figure 6 – The New Software Effect on Productivity (Autodesk, Inc., 2007)

2.3.6.1 Calculating ROI

Autodesk, the company who licenses REVIT as a BIM platform, proposes use of the following model (Figure 7) to measure the ROI:

$$ROI = \frac{\left(B - \left(\frac{B}{1+E}\right)\right) \times (12 - C)}{A + (B \times C \times D)}$$

Figure 7 – BIM ROI (Autodesk, Inc., 2007)

where:

- “A” is the cost of the hardware and software to implement BIM.
- “B” is the monthly labor costs associated with the individuals scheduled to implement the BIM platform in their tasks.
- “C” is the training time in months necessary for the users of the BIM platform to become familiarized and comfortable with the program.
- “D” is the percent productivity lost during training.
- “E” is the percent productivity gain after training.

Autodesk conducted an online survey of approximately one hundred users implementing Autodesk’s REVIT as their BIM platform to compile sample values for evaluation in Figure 7 and compute a representative ROI for BIM. The sample values tabulated by Autodesk are listed in Table 1.

Table 1 – BIM ROI Variables and Values

Variable	Value
A	$6,000
B	$4,200
C	3 months
D	50%
E	25%

Inputting the sample variables into the ROI model (Figure 7I) a Return on Investment of approximately 61% is obtained.

A SmartMarket Report published by McGraw Hill Construction in 2009 assessed the adoption of BIM across the construction industry and attempted to gauge the perceived value firms were receiving by implementing BIM. The research was conducted through an internet survey of 2,228 industry professionals between May 28 and July 2, 2009. The distribution of the industry professionals surveyed is depicted in Figure 8.

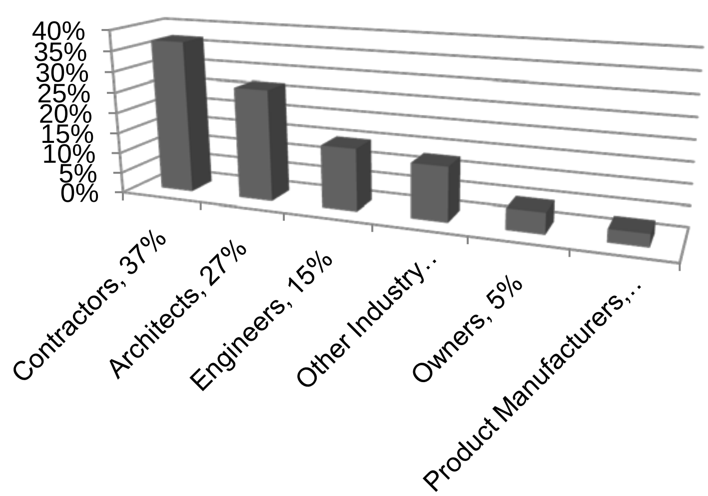


Figure 8 – Perceived Value of BIM (McGraw Hill Construction, 2009)

The survey conducted by McGraw Hill Construction evaluated the return on investment with respect to two conditions: a formally measured value and a perceived value. Approximately 72% of users who formally measure their ROI on BIM responded higher returns whereas approximately 53% of users who do not formally track ROI perceive they have garnered positive results (McGraw Hill Construtcion, 2009).

Among the surveyed professionals, approximately 71% of contractors report positive ROI, followed by owners at 70%, architects at 58%, and 46% of engineers experiencing positive ROI when using BIM (McGraw Hill Construtcion, 2009).

Contractors experience the most obvious benefits of BIM, primarily due to the ability of identifying systems clashes proactively in a digital platform during pre-construction activities as opposed to reactively out in the field once systems have begun to be routed in place. In 2009, the U.S. Bureau of Economic Analysis reported that construction made up approximately 4% of the 2008 US Gross Domestic Product (GDO) with a revenue of $582 billion (U.S. Bureau of Economic Analysis, 2009). As said earlier, research conducted by the Construction Industry Institute estimates that direct costs caused by rework in the construction industry average five percent of the total construction costs of a project (Hwang et al., 2009). This constitutes approximately $29 billion in 2008 alone. The magnitude of the cost savings in eliminating or reducing rework alone is substantial for contractors and a major motivator in adapting BIM practices into a contractor's business practice. The 2009 SmartMarket Report published by McGraw Hill Construction identifies that over 80% of contractors consider reduction of conflicts during construction as the element of highest value in implementing BIM (McGraw Hill Construtcion, 2009).

2.3.6.2 Direct Costs of Implementing BIM

The direct initial investment of implementing BIM by a contractor varies depending on the software platform selected as well as the salary of the users expected to implement the company's BIM program.

Table 2 tabulates the initial direct costs expected to be expended by a contractor prior to the accumulation of any measureable benefits. The BIM software evaluated is Revit Architecture by Autodesk, and the certified training is based on a 4-day introductory course offered by Avatech Solutions. The aim of BIM training is to integrate the segregated components of the project delivery system; as such a contractor at a minimum should familiarize key personnel with BIM practices. The evaluation of the direct initial investment considers the key office and field personnel, project manager and superintendent respectively, as well as an intermediary employee, the project engineer, as the suggested minimum personnel a small contractor should invest on in receiving training. The salary for the personnel is based on an industry average for each of the respective positions in the Dallas/Fort Worth area (PayScale, Inc., 2010).

Table 2 – Initial Investment of BIM ($)

Item	**Unit Cost**	**Unit**	**Qty**	**Subtotal**
Software	5,495.00	Per License Seat	1.00	5,495.00
Certified Training (Introductory 4-Day Course)	1,395.00	Per Attendee	3.00	4,185.00
Project Manager Salary (average $70,325.00)	270.48	Per Day	4.00	1,081.92
Labor Burden (approximately 12.07%)	32.65	Per Day	4.00	130.60
Project Engineer (average $55,731.00)	214.35	Per Day	4.00	857.40
Labor Burden (approximately 12.07%)	25.87	Per Day	4.00	103.48
Superintendent (average $70,051.00)	269.43	Per Day	4.00	1,077.72
Labor Burden (approximately 18.40%)	49.57	Per Day	4.00	198.28
TOTAL =				**13,129.40**

The data in Table 2 assumes the contactor has the necessary hardware required to properly run BIM software and only reflects the costs associated with familiarizing the office staff with the software. The time required for the users to become sufficiently confident and proficient with the program to warrant a substantial benefit in applying the technology is not considered. On average a typical software user takes approximately 3-months to become sufficiently proficient on software. Considering the project engineer as the team member designated as maintaining the data integrity of the BIM program implemented by a company; a small contractor will spend approximately $15,657 on training an inexperienced project engineer on BIM for a three-month period. The total direct expenditure absorbed by a small contractor during the startup of a BIM program for a three month period is approximately $28,786. The average annual salary of a BIM Manager is approximately $89,000 (PayScale, Inc., 2010), equivalent to approximately $31,000 during a three month period. The variance between employing an experience BIM manager and training existing staff is minimal, approximately 8% provided all assumptions implemented during the calculation hold true.

As for any other new process or program, BIM implementation will warrant an initial investment cost. Provided the economic standing of the contractor, implementation of BIM procedures should be incorporated into the business process in such a way as to minimize the financial and operational burden assumed by the company. Project integration, the core concept behind BIM, does not necessarily warrant the purchase and implementation of a software platform. Three dimensional modeling is only an element of BIM. Data integrity and project integration are more prominent in the hierarchy of BIM and require nothing more than a change in the segmented mentality of a contractor's business process.

2.4 Chapter Summary

Chapter two covered a brief overview of the current state of the AEC industry. The design-bid-build and design-build project delivery systems were defined as the predominant delivery systems in current use as well as discussing their respective benefits and shortcomings. Building information modeling was introduced and statistical data in terms of its initial investment, ROI, and benefits indicating both positive measured and perceived value to implementing BIM.

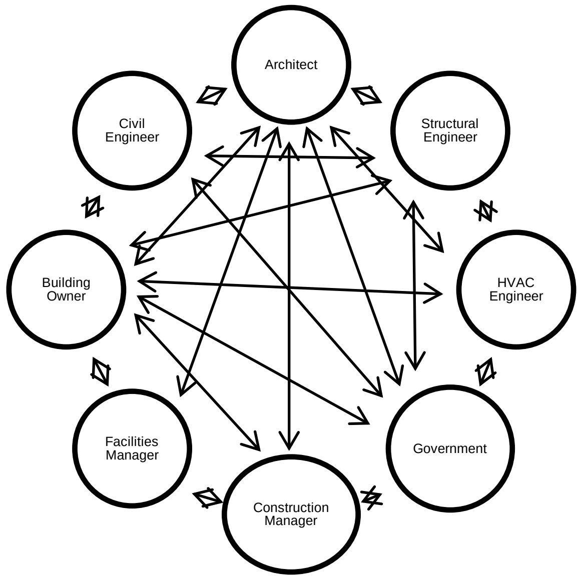
CHAPTER 3

METHODOLOGY

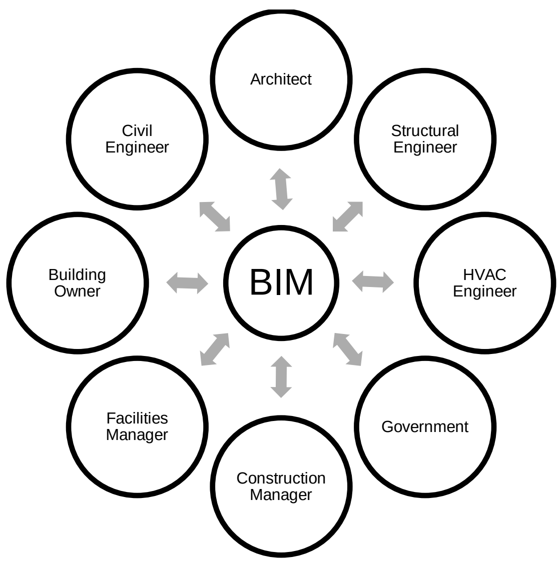
3.1 Introduction

Implementation of a Building Information Modeling program by a construction company requires a financial burden but more importantly a substantial cultural change. When it comes to BIM, it must be understood that it is more than software; BIM is an information management process. Business leaders have a tendency to evaluate incorporation of technology into their business model on the basis of acquisition cost rather than on its full implementation cost and full revenue generating potential (Smith and Tardif, 2009). In fact, business leaders must shift their view on managing technology from applying only to software licensing and training, to include the indirect costs associated with educating the organization on developing a new “business culture.” By focusing on how incorporation of technology will affect an entire organization and educating everyone involved a business can attain greater productivity. Limiting the application of technology to a single element of an organization will enhance productivity for that element of the company, but not the productivity of the business as a whole. In reference to BIM not only do companies have to educate and manage cultural change within their own organization but due to the segmented nature of the AEC industry must also address these issues at an industry wide level.

Figure 9 illustrates both the complex information exchange matrix (a) currently used in the AEC industry and (b) information depository system proposed by BIM.



(a)



(b)

Figure 9 - Information Exchange Matrices (a) Current AEC Information Echange (b) BIM Information Exchange

As can be observed from Figure 9, the complexity of the AEC environment makes it both difficult and cost intensive to implement a collaborative approach such as BIM. Larger construction companies are more likely to have the capital, both financial and personnel, to allocate towards the development of implementation strategies to incorporate BIM programs into their business practice. Furthermore, larger well established construction firms are more likely to foster an apparent sense of security in project owners and investors in regards to incorporating BIM to the project scope in comparison to smaller construction companies. This is not to say that smaller construction companies are unable to implement BIM programs successfully. Like in other aspects of business, each owner must develop a program suitable to their business' capability and implement it in accordance to their staff's potential to assimilate it into their workflow without substantial hindrance to the overall productivity of the company.

3.2 Techniques and Procedures Used

Within a construction context, building information modeling does not propose means and methods above and beyond what are current practices in the construction industry. Building information modeling, however, does propose a more efficient and reliable way of performing construction work. Current practice expects contractors to construct projects via the interpretation of two-dimensional and text based information (specifications). As BIM becomes increasing popular contractors will have to learn to adapt to the three-dimensional environment and information exchange at the core of building information modeling. The methodology used in this thesis is divided into two distinct outcomes. The first outcome will loosely outline recommendations applicable to contractors with the intent of raising awareness towards adopting BIM practices within their business. The second outcome will assess the effects of incorporating supplemental information, additional 2-D and 3-D models, to aid in managing a project. The incorporation of supplemental information will be divided as follows:

- Development of supplemental coordination and review documents including pre-construction clash-detection studies consisting of field reconnaissance and construction drawing overlays, and office developed construction layouts by the contractor providing managerial services.
    - Modeling attributes contributed: supplemental 2-dimensional plans, elevations, and sections provided to the field superintendent in addition to the project documents.

   - Objective: to aid the project superintendent and subcontractors coordinate construction activities and minimize any down time due to discrepancies between the site conditions and the project plans.
- Development of a 4-D schedule to aid in coordination of construction activities.
- Develop supplemental drawings to aid in the quantifying of materials (material surveys) to minimize waste.

Contractors, and project teams as a whole, currently spend a substantial amount of time "documenting their own actions as a bulwark against possible future legal action – a no-value task, as far as the project is concerned (Smith and Tardif, 2009)." As such, in order for contractors to advance their practice towards a more integrated approach they must reposition themselves away from an adversarial mentality.

3.3 Chapter Summary

Implementation of a Building Information Modeling program by a construction company requires a financial burden but more importantly a substantial cultural change. BIM should be viewed as more than software; BIM is an information management process. Building information modeling proposes a more efficient and reliable way of performing construction work. Current practice expects contractors to construct projects via the interpretation of two-dimensional and text based information (specifications). As BIM becomes increasing popular contractors will have to learn to adapt to the three-dimensional environment and information exchange at the core of building information modeling.

CHAPTER 4

CASE STUDIES

4.1 Introduction

Chapter four of this thesis will present and discuss the data collected and result obtained by implementing BIM techniques in combination with traditional construction management practices on three case studies. The data collected is used to develop a preliminary program on how to implement BIM practices, evaluate the benefits of developing an information depository, and evaluate the benefits of using preliminary modeling techniques in scheduling and estimating material quantities.

The prime contractor in all three case studies is a small business with little experience in building information modeling. The contractor is in the process of training its staff in managing information to begin incorporating building information modeling practices. No BIM enabled software was used in the modeling practices in each of the case studies. The intent of the exercises were to use existing tools and methods and apply them in a new way to familiarize the users with the type of information management scenarios they will encounter when the company does decide to fully implement BIM practices. The case studies are intended to provide examples on how companies with limited means can use the tools and procedures available to them to begin fostering the knowledge necessary to facilitate transition to BIM practices.

4.2 Case Study 1 – "Four Dimensional" Modeling

The first case study uses supplemental two-dimensional drawings to aid in the coordination efforts and streamlining the construction of a one-quarter mile walking track in Crowley, Texas. The supplemental two-dimensional drawings were also used to assemble a "four-dimensional" model to give the project owner a visual representation of the project progress. The City of Crowley, Texas solicited quotations by responsive bidders in the construction of a quarter-mile walking track to be constructed at the city's Bicentennial Park. The successful contractor was awarded the project with a completion time of seventy calendar days. Due to the relatively small size of the project and simplicity of the scope this gave the contractor a low-risk opportunity to implement “four-dimensional” modeling as a means of coordinating activities and conveying progress to the owner. To further mitigate risk, in assembling the project team, the contractor selected subcontractors with whom it had previously successfully completed projects of similar scope. The familiarity of the project team members amongst themselves provided the adequate environment conducive to the free flow of information exchange necessary to implement modeling practices.

4.2.1 Modeling Coordination and Progress

The contractor decided to add another dimension to its traditional scheduling practices by providing a visual representation of the project’s progress in conjunction with the project schedule. The assembly of drawings and schedule provided the project team with a pseudo 4-D model. Pseudo in the sense that the visual representation of the project schedule was limited to two-dimensional color coded drawings to be revised manually as opposed to the automated and three-dimensional nature of a true 4-D model. The intent of the exercise was to begin familiarizing the project team with the notion of thinking of the construction schedule and construction documents holistically as opposed to discrete elements of the project. Appendix A contains a copy of the “4-D model” developed in Microsoft Excel used on the project. The model is a simple Gantt chart with embedded hyperlinks at milestone events to 2-dimensional drawings highlighting the work in progress and completed to date

4.2.2 Case Study1 Outcomes

By fostering an environment of collaboration the project team was able to:

- Minimize site disturbance by establishing site access routes.
- Coordinate subcontractor work to eliminate interference.
- Streamline the construction schedule to complete the project early.

The project team’s commitment to modeling the project site enabled the contractor to minimize the extent of site disturbance. The city anticipated construction activities would result in the sodding of approximately 24,000 square feet. The project team, however, was able to model routes to access the walking path and reduce the city's estimate by approximately 43% resulting in a cost savings of roughly $4,100 in sod alone.

By modeling the project's progress and linking it to the construction schedule the project team was able to visually identify the extent of work needed to be performed at any given time and provide the field managers a visual gauge as to their productivity rates so that they could make adjustments as necessary. Similarly, the pictorial representation of the schedule enabled the field managers to coordinate site traffic and identify idle site areas and assign work to be performed at these areas if possible to streamline the project.

The construction savings for the project were calculated based on the savings experienced by the city as well as the contractor. The city's savings were based on the liquidated damages stipulated by the contract and were developed based on the management and lost facility revenue costs the city incurs on a daily basis during construction. The contractor's savings were based on the daily operating costs associated with managing the project. The project was completed sixteen days earlier than scheduled, which translates into an approximately 23% reduction in the schedule. The owner experienced a net savings of approximately $2,000 or approximately 23% of the management budget allocated to the project. The contractor experienced a net savings of approximately $8,500, approximately 9%, of its estimated management and overhead costs for the project.

Table 3 below tabulates the total time and cost savings obtained by modeling the project.

Table 3 - 4D Modeling Project Savings

Description	**Quantity**	**Units**	**Costs**
Allocated Construction Duration	70	Days	
Actual Construction Duration	54	Days	
Reduction in Schedule	16	Days	
City Savings ($127.00 per Calendar Day)			$2,032.00
Contractor Savings ($534.46 per Work Day)			$8,551.36
Estimated Sod Required	24,000	SF	
Actual Sod Used	13,673	SF	
Sod Savings	10,327	SF	$4,130.57
Total Cost Savings			**$14,713.93**

The cost savings presented in Table 3 reflect only those savings attributed to the prime contractor and owner resulting from streamlining the schedule. The cost savings do not reflect the costs associated with the additional time spent by the contractor in developing the supplemental coordination drawings to implement the “4-D” model. The cost savings by lower tier contractors are also not reflected in the total savings due to confidentiality concerns, nonetheless, it is reasonable to assume that the lower tier subs experienced similar savings.

The implementation of a “4-D” model to coordinate and streamline the project was successful, not only in resulting in cost savings, but also in providing the contracting team experience in managing and manipulating information to develop a building model. Although the model developed is not to par with existing BIM enable software, the underlying concept of information management remains the same providing the project team an opportunity to experience the issues and benefits of managing information by means of a model. Pending the contractor’s comfort in manipulating project information, future practices should focus on implementing the contractor’s knowledge of information management in the development of a true four-dimensional model on a BIM enabled software platform.

4.3 Case Study 2 – Modeling Material Procurement

The intent of the second case study is to relate another option in developing building information modeling techniques within a company via the analysis of previously completed projects. The second case study involves the modeling of the framing and drywall layouts for an interior remodel project for the Arlington Technology Incubator. The contractor developed the estimate and completed the project based on standard company practices. The simplicity of the project layout and manageable size, however, made it an ideal candidate for the contractor’s staff to implement BIM practices. The models were developed by the contractor post-construction as a means of comparison between the original estimate’s drywall and framing quantity take-off and the actual material procured to evaluate the benefit of expending time in modeling drywall and farming work in larger projects. The contractor modeled the track layout, metal stud layout, and drywall layout to try and minimize waste and the procurement of unnecessary materials.

4.3.1 Modeling Material Layouts

Since the contractor does not currently have BIM enabled software, scaled supplemental 2-dimensional drawings were developed using AutoCAD. Figures 10 and 11depict color coded models of the overall bottom and top track layout plans for the space. Figures 12 and 13 depict the metal studs and drywall layouts for the space. Table 4 displays the material quantities and costs associated with the model, original estimate and actual material procured.

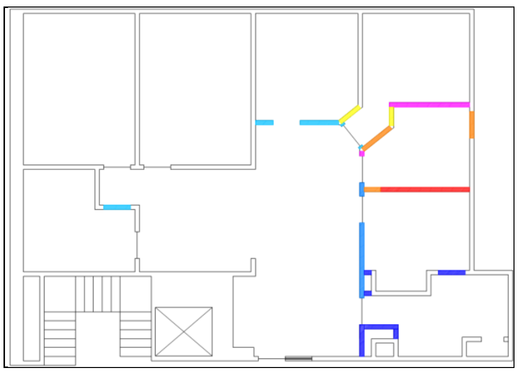


Figure 10 – Bottom Track Layout

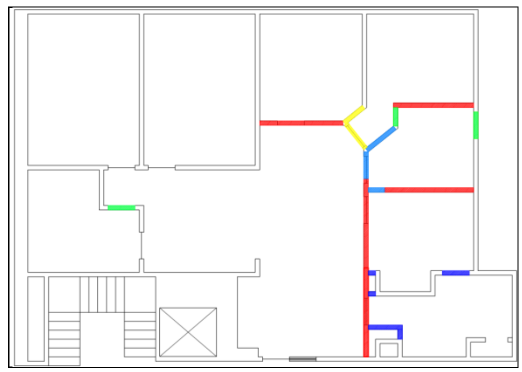


Figure 11 – Top Track Layout

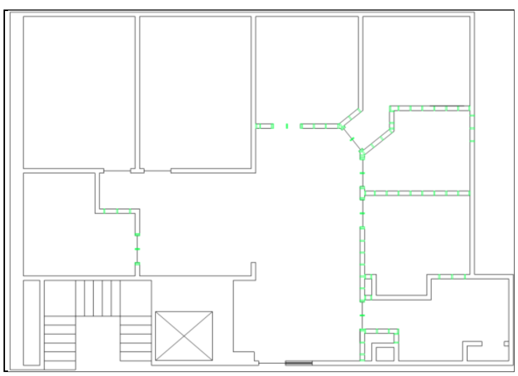


Figure 12 – Metal Stud Layout

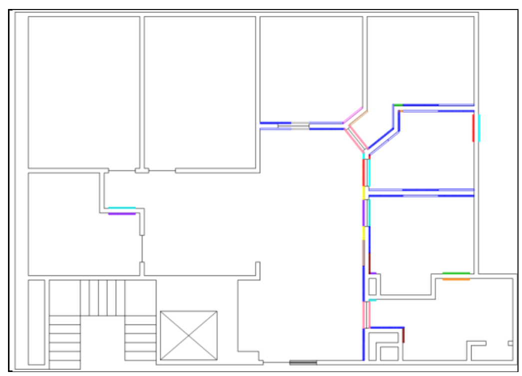


Figure 13 – Drywall Layout

Table 4 – Model, Original Estimate, and Actual Procured Material Costs

Material	Model Estimate		Original Estimate		Quantity Procured	
	Quantity	Cost	Quantity	Cost	Quantity	Cost
3 5/8” Metal Stud, 25Ga, 16’-0”	86 Ea	$313.90	100 Ea	$365.00	90 Ea	$328.50
3 5/8” Metal Track, 25Ga, 10’-0”	16 Ea	$56.64	20 Ea	$70.80	20 Ea	$70.80
5/8” Gypsum Board, 4’x10’	35 Ea	$272.65	50 Ea	$389.50	35 Ea	$272.65
Additional Time Spent Modeling	1.5 Hrs	$45.04				
Total		**$688.23**		**$825.30**		**$671.95**

4.3.2 Case Study 2 Outcomes

Analysis of the drywall and farming models indicated that by modeling the contractor is able to more accurately account for material quantities and thus reduce waste and the procurement of unnecessary materials. The models resulted in a net decrease of approximately 28% from the estimated material cost. Further analysis of the model estimate indicates that if material procurement packaging standards are applied to the quantities developed by the models the quantities identified by the model needed to be procured and the actual quantity of material procured are exactly the same. Procurement of metal studs and track are ordered in bundles of ten pieces not as individual pieces. The only cost difference between the quantity procured and the model estimate is therefore attributed to the additional time spent in modeling the material layouts. It is reasonable to conclude that using models to develop quantity take-offs can result in substantial cost savings and minimize the uncertainty of material quantities leading to more accurate cost estimates.

The small size and simple layout of this project made the manual modeling and survey of the materials feasible. Moreover, the intent of the exercise was to raise awareness amongst the estimating team in the information and effort necessary to model and manipulate building information for estimating purposes. The application of material modeling to develop quantity take-offs or for estimating purposes in larger projects can become time consuming, therefore, the contractor should focus future exercise on using a BIM enabled software platform to automate material surveys.

4.4 Case Study 3 – Information Depository

The third case study involves the use of one of the AEC industries early efforts toward capturing and structuring building information: Construction Operations Building Information Exchange (COBIE). COBIE is a data specification for information transfer developed by the National Institute of Building Sciences. COBIE serves as an information depository from which project members can draw all data relevant to a project from a single source in lieu of the traditional multiple sources and media.

One of the common misconceptions behind building information modeling is that a three-dimensional model is the key to the concepts success. In reality the key behind building information modeling is proper information management. Kimon Onuma, FAIA, the principal of Onuma and Associates an architecture and technology firm and chief proponents of BIM, is credited in saying "any spreadsheet of building information, because it is a form of structured information, is a building information model."

The intent of the third case study is to educate the contractor's project team in that building information modeling is not simply a three-dimensional model but an information depository. Such is the case that building information modeling concepts were practiced without the development of a pictorial modeling element.

4.4.1 Information Organization and Management

The contractor used the COBIE template as part of the management strategy for an owner finish-out project. The contractor spent a substantial amount of time and efforts during the pre-construction portion of the project in compiling all available data from the contract documents into the COBIE template.

Figures 14 through 17 illustrate a series of screen shots of the COBIE Template which served as the information management depository used to integrate the project team.

ContactID	ContactRole	ExternalNameID	ExternalOfficeID	GivenName	FamilyName	OfficeName	OfficeDepartment	OfficeOrganizationCode	AddressStreet	AddressPostalBox	Address
1	34-21 27 00 Contract Administrator			Clint	Admin	Property Managers	Contracting	C.O.	999 Taylor St	N/A	Worth
2	34-11 21 21 Coordinator			Carol	Coordinate	Property Managers	Management	P.M.	999 Taylor St	N/A	Worth
3	34-41 11 00 Facility Manager			Frank	Manage	Building Managers Co.	Maintenance	F.M.	1111 E. Two Fig St.	N/A	Sans
4	34-25 21 00 Architect	M&I		Art	Architect	Inspectors and Managers Co	Architect	AIA	222 South Upper Broadway	N/A	Cross
5	34-11 21 21 Coordinator	M&I		Dan	Designer	Inspectors and Managers Co	Quality Control	Q.C.	222 South Upper Broadway	N/A	Cross
6	34-25 31 00 Engineer	M&I		Mark	Mechanic	Inspectors and Managers Co	Mechanical Engineer	P.E.	222 South Upper Broadway	N/A	Cross
7	34-25 31 00 Engineer	M&I		Eric	Electric	Inspectors and Managers Co	Electrical Engineer	P.E.	222 South Upper Broadway	N/A	Cross
8	34-25 31 00 Engineer	Re-Design		Sam	Structures	Inspectors and Managers Co	Structural Engineer	E.I.T	222 South Upper Broadway	N/A	Cross
9	34-35 14 00 Contractor	General Contractor		Owen	Owner	Building Contractors	Construction	CEO	3333 E. Randoll Rd, Suite 40	N/A	Frankf
10	34-35 14 00 Contractor	General Contractor		Peter	Project	Building Contractors	Construction	O.E.	3333 E. Randoll Rd, Suite 40	N/A	Frankf
11	34-35 14 00 Contractor	General Contractor		Sam	Super	Building Contractors	Construction	F.S.	3333 E. Randoll Rd, Suite 40	N/A	Frankf
12	34-35 17 00 Sub Contractor	Subcontractor		Eric	Erector	Structural Steel	Structural Steel Subcontractor	P.M.	444 Loop 303	N/A	Sans
13	34-35 17 00 Sub Contractor	Subcontractor		Charles	Cabinets	Custom Laminate Specialties	Millwork Subcontractor	CEO	410 Lillard Road	N/A	Frankf
14	34-35 17 00 Sub Contractor	Subcontractor		Robert	Roof	Roofing Company, Inc.	Roofing Subcontractor	P.M.	117 S. Hill Street	N/A	Sans
15	34-35 17 00 Sub Contractor	Subcontractor		Gary	Glass	Glass Company	Storefront Subcontractor	P.M.	343 North First Street	N/A	Gansb

Figure 14 – COBIE Contact Management

SpaceID	FloorID	SpaceFunction	SpaceReferenceID	ExternalSystemName	ExternalNameID	SpaceNumber	SpaceName	SpaceDescription	SpaceUsableHeight	SpaceUsableHeightUnits	ExteriorGrossArea	ExteriorGrossAreaUnit	InteriorGrossArea	InteriorGrossAreaUnit	PlannableGrossArea	PlannableGrossAreaUnit	RentableAreaUsableArea	RentableAreaUsableAreaUnits	InteriorPlannableArea	InteriorPlannableAreaUnits	CalculationMethod
1	1,First Floor	13-11 11 24 Information Counter	SpaceID			100	Check In	Reception	8'-6"	feet		AreaUnit	61.9	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
2	1,First Floor	13-15 11 34 17 Open Office Space	SpaceID			101	Squad Room	Offices	8'-10"	feet		AreaUnit	342.5	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
3	FloorIDPick	13-51 11 21 Break Room	SpaceID			102	Galley	Breakroom	8'-10"	feet		AreaUnit	108.9	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
4	FloorIDPick	13-41 11 14 11 Bathroom	SpaceID			103	Toilet	Toilet	9'-0"	feet		AreaUnit	55.8	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
5	FloorIDPick	13-71 00 00 Securing Spaces	SpaceID			104	Salley Port	Salley Port	9'-0"	feet		AreaUnit	43.1	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
6	FloorIDPick	13-11 21 41 Interview Room	SpaceID			105	Interview Room	Interview Room	9'-0"	feet		AreaUnit	36.6	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
7	FloorIDPick	13-11 21 41 Interview Room	SpaceID			105A	Interview Room Visitor	Interview Room	8'-6"	feet		AreaUnit	33.0	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
8	FloorIDPick	13-71 00 00 Securing Spaces	SpaceID			106	Salley Port	Salley Port	9'-0"	feet		AreaUnit	37.2	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
9	FloorIDPick	13-85 11 11 Corridor	SpaceID			107	Corridor	Corridor	9'-0"	feet		AreaUnit	62.4	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
10	FloorIDPick	13-15 21 11 24 Processing Room	SpaceID			108	Process	Processing Room	9'-0"	feet		AreaUnit	91.0	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
11	FloorIDPick	13-71 21 14 Holding Cell	SpaceID			109	Holding Cell	Holding Cell	9'-0"	feet		AreaUnit	146.9	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
12	FloorIDPick	13-71 21 14 Holding Cell	SpaceID			110	Holding Cell	Holding Cell	9'-0"	feet		AreaUnit	113.3	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
13	FloorIDPick	13-11 11 19 Computer Lab	SpaceID			111	Computer Room	Computer Room	8'-6"	feet		AreaUnit	191.1	squarefeet		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
14	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
15	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
16	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
17	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
18	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
19	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
20	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
21	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
22	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS
23	FloorIDPick	OmniClas Table 13	SpaceIDPick							LinearUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit		AreaUnit	ANSI/BOMA AS

Instructions / 01-Contact / 02-Facility / 03-Floor / 04-Space / 05-System / 06-Register / 07-Component / 08-Attribute / 09-Coordinate / 10-Schedule / 11-Document / 12-Tra

Figure 15 – COBIE Space Management

SystemID	FacilityID	SystemFunction	SystemReferenceID	ExternalSystemName	ExternalNameID	SystemName	SystemDescription	CreatedBy	CreatedDate	CreatedTime
1	1,O.C. Fisher Federal Building	21-41 71 11 31 00 Interior Partitions	SystemIDPick			Partitions		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
2	1,O.C. Fisher Federal Building	21-41 71 12 21 00 Interior Doors	SystemIDPick			Doors		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
3	1,O.C. Fisher Federal Building	21-41 71 15 00 00 Interior Finishes	SystemIDPick			Finishes		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
4	1,O.C. Fisher Federal Building	21-41 71 15 11 00 Floor Finish	SystemIDPick			Flooring		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
5	1,O.C. Fisher Federal Building	21-41 71 15 51 00 Ceiling Finish	SystemIDPick			Ceiling		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
6	1,O.C. Fisher Federal Building	21-51 11 11 00 00 Fire and Smoke Detection and Alarm	SystemIDPick			Fire Alarm		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
7	1,O.C. Fisher Federal Building	21-51 11 26 00 00 Security Monitoring and Surveillance	SystemIDPick			Security		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
8	1,O.C. Fisher Federal Building	21-51 31 00 00 00 Plumbing	SystemIDPick			Plumbing		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
9	1,O.C. Fisher Federal Building	21-51 31 11 14 00 Plumbing Fixtures	SystemIDPick			Plumbing Fixtures		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
10	1,O.C. Fisher Federal Building	21-51 51 00 00 00 Heating, Ventilating and Air Conditioning (HVAC)	SystemIDPick			HVAC		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
11	1,O.C. Fisher Federal Building	21-51 61 11 00 00 Integrated Automation Controls	SystemIDPick			Controls		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
12	1,O.C. Fisher Federal Building	21-51 71 00 00 00 Electrical	SystemIDPick			Electrical		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
13	1,O.C. Fisher Federal Building	21-51 71 15 11 00 Interior Lighting	SystemIDPick			Lighting Fixtures		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
14	1,O.C. Fisher Federal Building	21-61 11 21 71 00 Detention Equipment and Furnishings	SystemIDPick			Detention Equipment		5,Villafana,Agustin,Rayco Construction, Inc.	4-Nov-2010	15:30
15	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
16	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
17	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
18	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
19	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
20	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
21	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
22	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30
23	FacilityIDPick	OmniClass Table 21	SystemIDPick					ContactIDPick	4-Nov-2010	15:30

Instructions / 01-Contact / 02-Facility / 03-Floor / 04-Space / **05-System** / 06-Register / 07-Component / 08-Attribute / 09-Coordinate / 10-Schedule / 11-Document / 12-Tra

Figure 16 – COBIE System Management

ComponentID	SpaceID	RegisterID	ExternalSystemName	ExternalNameID	ComponentName	ComponentDescription	CreatedBy
1	1,100	7,Architectural Woodwork (Base, Chair Rail, & Crown Molding)			Base, Chair Rail, & Crown Molding	6" Red Oak Crown Molding, 7.5'x3/4" Red Oak Chair Rail, 6" Wood Base (AWI 1451, AWI 6421)	16,Villafana,Agustin,Rayco Constr
2	1,100	11,Polymer Resin Countertop (at Check-In 100)				High Pressure Laminate Black Plastic Shelf	16,Villafana,Agustin,Rayco Constr
3	1,100	21,All-Glass Entrances and Storefronts				Existing to Remain (Clear Anodize Finish)	16,Villafana,Agustin,Rayco Constr
4	1,100	23,Security/Transaction Window				(48"wx3'-11"h) Armotex Bullet Resistant Window w/ Stainless Steel Transaction Tray	16,Villafana,Agustin,Rayco Constr
5	1,100	27,Pivots				Rixson-Firemark - M19-626 and 195-626	16,Villafana,Agustin,Rayco Constr
6	1,100	29,Deadlock				Adams Rite, MS1850S-628	16,Villafana,Agustin,Rayco Constr
7	1,100	30,Cylinder				Sargent, 1042x13-0512-US26D	16,Villafana,Agustin,Rayco Constr
8	1,100	36,Push/Pull Bar				McKinney, OP810-US32D	16,Villafana,Agustin,Rayco Constr
9	1,100	37,Closer				Sargent, 351-O-EN	16,Villafana,Agustin,Rayco Constr
10	1,100	38,Floor Stop (at Aluminum Storefront)				McKinney, FS-16-US26D	16,Villafana,Agustin,Rayco Constr
11	1,100	42,Threshold				McKinney, MCK171A36-US26D	16,Villafana,Agustin,Rayco Constr
12	1,100	43,Perimeter Seal (at Aluminum Storefront)					16,Villafana,Agustin,Rayco Constr
13	1,100	56,Non-Loadbearing Metal Framing					16,Villafana,Agustin,Rayco Constr
14	1,100	57,Gypsum Board Assemblies					16,Villafana,Agustin,Rayco Constr
15	1,100	64,Suspended Acoustical Ceilings				2'x2' Grid Format by Armstrong Suspension System: Prelude XL 15/16" Exposed Tee Ceiling Tile: USG Sonatone Square Edge	16,Villafana,Agustin,Rayco Constr
16	1,100	67,Carpet				Joint Venture, JTV33 - Equity by Cambridge	16,Villafana,Agustin,Rayco Constr
						Sherwin-Williams Primer: Drywall Primer Interior Latex	

Instructions / 01-Contact / 02-Facility / 03-Floor / 04-Space / 05-System / 06-Register / **07-Component** / 08-Attribute / 09-Coordinate / 10-Schedule / 11-Document / 12-Tra

Figure 17 – COBIE Component Management

4.4.2 Case Study 3 Outcomes

Although the contractor assumed an initial cost in developing the COBIE template, the savings on time and efforts during the project close-out are believed to have offset this cost. By updating the COBIE template during construction, the contractor was able to use this template as the close-out documentation for the project, and offset the initial expenditure of developing the COBIE template. The contractor did not have quantifiable costs or savings data available attributed to implementing COBIE, however, in terms of the transfer of physical documents Table 5 displays the paper savings attributed to COBIE.

Table 5 – Traditional vs COBIE Close-Out Documents

Media	**Traditionally Submitted**	**COBIE**
As-Built Plans	5 Full Size Sets (34 sheets each)	
Project Specifications	2 Complete Sets (553 pages each)	
Operation and Maintenance Manual	2 Manuals (515 pages each)	
Compact Disk / Digital Data	-	2 Compact Disks (317.7 MB each)

It is important that company personnel not limit their understanding of building information modeling to the development of simple pictorial models but view it as a methodical process that uses information technology to compliment business process and thereby attain business goals (Alshawi, 2007). There are many different types of project and document management systems available in the market that can aid a contractor in developing the information management skills need to successfully implement building information modeling practices. Nonetheless, contractors must be conscious of interoperability and the need for these management systems to relaying information in a usable format to other team members. COBIE is a good candidate for a construction company to adopt in developing their information management skills given its industry accepted workflow mechanism for methodically compiling information into a structured format and in providing data interoperability. Not to mention the COBIE templates are developed using Microsoft Excel, a common software among businesses, and can be downloaded free of charge via the Whole Building Design Guide Website (East, 2010). As future exercises, the contractor should look at gradually implementing the structured information format of an information management standard such as COBIE in collaboration with three-dimensional models to manipulate a complete building information modeling environment during projects.

4.5 Chapter Summary

Three case studies identified the benefits of implementing BIM concepts without having to fully develop a digital model of a project. The first case study used supplemental two-dimensional drawings to aid in the coordination efforts and streamlining the construction of a one-quarter mile walking track in Crowley, Texas. The supplemental two-dimensional drawings were also used to assemble a “four-dimensional” model to give the project owner a visual representation of the project progress. The second case study involved the modeling of the framing and drywall layouts for an interior remodel project for the Arlington Technology Incubator. The models were developed by the contractor post-construction as a means of comparison between the original estimate’s drywall and framing quantity take-off and the actual material procured to evaluate the benefit of expending time in modeling drywall and farming work in larger projects. The third case study involved the use of one of the AEC industries early efforts towards capturing and structuring building information: Construction Operations Building Information Exchange (COBIE).

CHAPTER 5

DISCUSSION ON ADOPTING BIM PRACTICES

5.1 Introduction

Chapter 5 of this thesis defines and interprets the data gathered from literature reviews. The discussion includes the reasoning behind the selection of the respective recommendations included in the guide on adopting BIM practices.

5.2 Recommendation on Adopting BIM Practices

The main outcome proposed by this thesis, to outline recommendations on adopting BIM practices, is not quantifiable. A consensus is yet to be reached on the processes and roles of project team members when it comes to building information modeling. Consequently, the recommendations proposed by this thesis were determined through the review and evaluation of manuals, handbooks, and guidelines published by a variety of industry organizations and professionals. The recommendations proposed are presented with the intent of helping transition a contractor from current practices towards integrated project delivery practices proposed by BIM. The recommendations are not to be taken as a guide on implementing a BIM program within a company, but more so as suggestions with the intent of raising awareness on collaboration. The following items identify and discuss a number of issues and actions for consideration by contractors looking to begin incorporating building information modeling into their current business practices, with more information provided in the following sections.

1. Implementation of Building Information Modeling must have the support and leadership of senior management in order to be successful.
2. Management must perceive and accept the internal and external changes in business relationships needed to foster a successful BIM program, the integrated flow of information.
3. The entire company must be educated on the concept of BIM and support its adoption.

4. Management must establish a BIM program.
5. Management must select a BIM software platform which best aligns with its BIM program goals.

5.2.1 Managements Role in Adopting BIM Practices

The first two recommendations on adopting BIM practices are intended to bolster a well established foundation from which to develop the integrated project delivery atmosphere needed to successfully implement BIM. The decision to implement BIM processes into the company workflow must begin with the support of upper management. A company's operational structure is based on the decisions made by management as such any substantial change in operating procedures, such as those warranted by BIM, must be reviewed, accepted, and delegated by the company's senior officials. Substantial changes to a company's workflow structure can be costly and disruptive; consequently, companies tend to circumvent conditions which exert a substantial effect on the daily operating procedures of the company. Management must comprehend that the information management practices necessary to effectively model information will take time to implement and develop before they yield positive returns for the company. Management must also realize that:

> The most viable and flexible business strategy to BIM implementation is one that emphasizes the value of information exchange to support business processes (*modeling*) over the artifact that results from those processes (*the model*) (Smith and Tardif, 2009)

This is to say that management must not solely focus the company efforts on developing models, but rather on how to manipulate the information in modeling efforts to benefit the company's practices. Perhaps the most difficult attribute management must accept is the need to desegregate both internal and external relationships to foster the free flow of information. Managers must realize that the traditional roles of construction management personnel can no longer be limited to the bounds of their specific specialty and thus encourage team members to view projects holistically. Similarly, mangers must realign their view of external business relationships from professionally distant and often times adversarial to one of cooperation and mutually beneficial. Changes in external business relationship will perhaps be the more difficult of the two simply because of the liability and risk associated with the free flow of information from one organization to the other. Management, however, can mitigate some of these concerns by implementing integrated practices with businesses the company has previously completed projects with and has a good long standing relationship with to work out any issues. It should be noted that the parties involved in integrated information exchange practices be properly compensated for their added effort and assume a liability proportionate to their contribution to the project. A properly educated management, clear on the current state of their business process, the expectations of implementing BIM practices, and the effort need to achieve the desired expectations are essential to the implementation of a successful program.

5.2.2 The Company's Role on Adopting BIM Practices

Although the underlying concepts behind BIM are not new to the construction industry, BIM does present a new approach to addressing these concepts. Management must educate the entire company on the concept of BIM to foster an environment receptive to information exchange. Due to the segmented process of current construction practices, certain company personnel may view their knowledge of a specific area as job security and be hesitant when asked to share this knowledge. By educating the company as a whole any concerns or hesitation by company personnel in sharing information will be minimized or eliminated. Company personnel will realize that BIM is not an attempt to consolidate the company by eliminating jobs but instead an attempt to increase information flow to facilitate and improve their ability to perform their job more effectively. Both office and field personnel must realize that their knowledge about their respective activities can be beneficial to other positions within the company and the company as a whole must be taught to identify these relationships and be enabled to openly convey this information.

5.2.3 Developing a BIM Program

It is not feasible for a company to completely restructure its business process overnight as such implementation of BIM should be phased-in gradually. After educating the company about building information modeling management must develop a BIM program and assign a BIM program manager to carry it out. One of the first items the BIM program should address is determining a response on how to foster a culture of information exchange both amongst company employees and with outside business partners. When it comes to information systems, such as BIM, the systems alone:

> …cannot be used to improve internal performance nor can it create competitive advantage without a structured business culture first having been introduced. (Alshawi, 2007)

Management must also determine what aspects of BIM will be initially assimilated by the company and which will be explored at a later date. Some BIM practices, such as four-dimensional scheduling and coordination efforts, will be easier to incorporate into the company's existing practices than others. The BIM program should focus on developing familiar concepts first and slowly incorporate newer less familiar concepts. Managers should establish realistic goals and expectations for the company BIM program. This will give the BIM manager a guideline to follow in order to align the development of BIM practices to the company's service. A timeline should be established to measure the company's progress in implementing the BIM program whereby the BIM manager can evaluate the company goals and expectations of the BIM program and identify areas of success and areas in need of improvement as well as establish new goals. A company should consider practicing BIM concepts on previously completed projects or in parallel with current business practices until its personnel becomes sufficiently familiar with the concepts that they feel confident in using BIM as a standalone system.

5.2.4 Selecting a BIM Software Platform

In purchasing a BIM software platform, a company should research and identify the software that best aligns itself with its BIM program goals. The company should also consider the software's hardware requirements and whether its existing systems can properly operate the software package or if new systems will need to be purchased. An area that is obtaining increasing focus is the software's interoperability. In purchasing a BIM software platform, the company must consider the software's ability to transmit and process information from both in-house programs currently in use and with those programs used by business partners. BIM software with little to no interoperability will be of little service to a company and just add another layer of complexity to the implementation of their BIM program. As with other software, another thing to consider prior to purchasing BIM software is the software's dependability. A company should research if the software they are considering purchasing is developed by a reputable company with experience in BIM technologies, and the reliability of their product. Although important, the selection of the proper BIM software comes second to the development of the proper environment and program within a company in the successful implementation of BIM practices.

5.3 Chapter Summary

In implementing BIM into a company's workflow it is recommended that the company considers the owner's role in facilitating the transition from current practices into a BIM-enabled flow. The role of the company employees as a whole and its external partners must also be conditioned to foster the integrated information transfer proposed by BIM. The development of a BIM program can facilitate the implementation of BIM practices and gauge its progress providing metrics on which to improve performance. The proper software package must also be considered so that a company does not incur additional training and hardware costs above those necessary to implement BIM practices to the extent desired.

CHAPTER 6

CONCLUSION

Building Information Modeling (BIM) is a new concept, in its early stages of development within the Architecture-Engineering-Construction (AEC) industry. Nonetheless, the AEC industry appears poised on the idea that BIM is the future of project delivery methods and actively engaged in promoting its widespread use. It is much like the once innovative concept of “green building” and “high-performance facilities” promulgated the popularity of energy efficiency and environmentally responsible design and construction practices. The concepts of green and sustainability have become common place when it comes to the AEC industry. The innovative status of BIM is now experiencing the same celebrity and many companies are expending a substantial amount of effort in trying to be associated with “BIM” for fear of being left behind. Smaller contractors or contractors with limited means must take care not to be pressured into adopting BIM practices before having established the proper frame work to successfully foster a BIM program.

A consensus has yet to be reached on the organizational and information structure of BIM, and as such, contractors should not be bothered with the idea of being left behind until it is achieved. This is not to say that the status quo of current AEC business practices will remain unchanged. The growing complexity of designs and systems warrant a restructuring of how building information is managed and transmitted and it is aimed towards an integrated project delivery.

Now is the ideal time for contractors to begin familiarizing themselves with the concepts behind building information modeling, information management, and integrated project delivery.

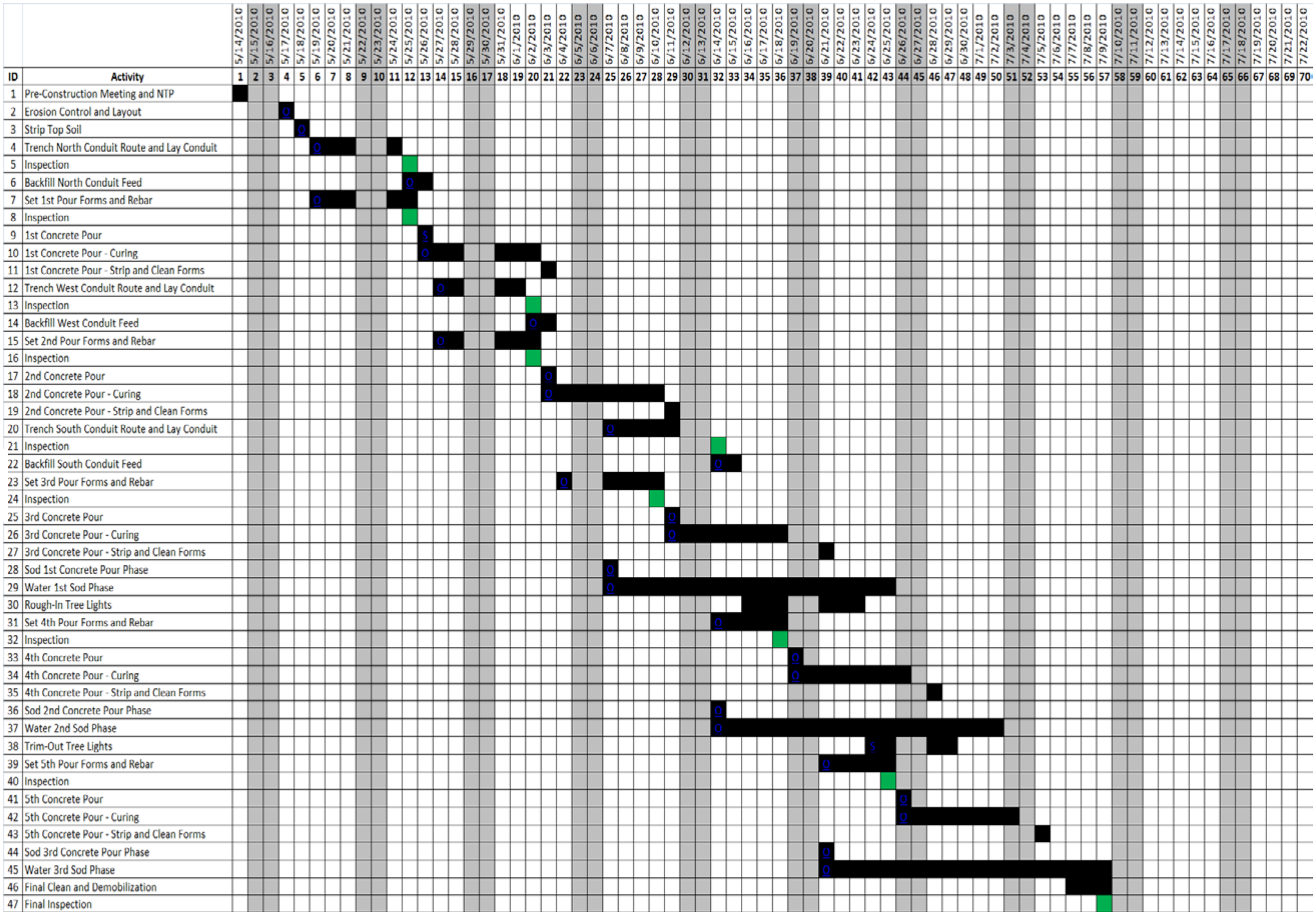
As this thesis intended to demonstrate, the application of BIM concepts does not warrant a substantial expenditure in BIM enable software. A company can use its existing tools and procedures applied in a new way to begin familiarizing itself with the basic concepts behind the new trends in project delivery. Perhaps most importantly is educating all company personnel on the basics of BIM and fostering an environment that promotes the free flow of information. The recommendations presented in this thesis as well as the examples of how to begin incorporating BIM concepts into a company's standard processes are intended to help begin fostering a BIM enabled culture. By slowly assimilating BIM concepts a company can prepare itself to facilitate its transition to fully integrated BIM practices when these practices stop being an innovation and start being the norm.

6.1 Recommendations for Future Research

Building Information Modeling is a relatively new concept within the AEC framework therefore it is still in a relatively developmental stage in reference to its applicability to the industry as a whole. Future BIM researchers should consider the development of suitable metrics applicable to the analysis of BIM in the construction industry, accounting for the dynamic and varied nature of construction projects. Future investigations should be conducted in the area of interoperability standards and development of guidelines to minimize information degradation during its transfer. Ultimately, the information developed in models has to be conveyed to the actual workers performing the tasks and activities being modeled; therefore, research into the implementation of model based information communication as applicable to field operations is important to the acceptability of BIM over traditional 2-D drawings by the construction workers.

APPENDIX A

CROWLEY, TX. BICENTENNIAL PARK WALKING PATH “4-D” MODEL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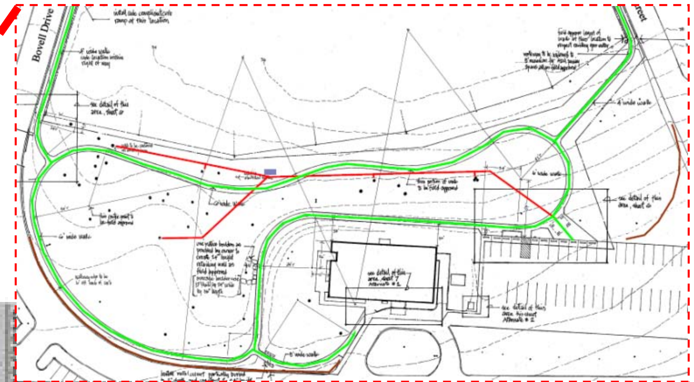
ID
Activity
1 Pre-Construction Meeting and NTP
2 Erosion Control and Layout
3 Strip Top Soil
4 Trench North Conduit Route and Lay Conduit
5 Inspection
6 Backfill North Conduit Feed
7 Set 1st Pour Forms and Rebar
8 Inspection
9 1st Concrete Pour
10 1st Concrete Pour - Curing
11 1st Concrete Pour - Strip and Clean Forms
12 Trench West Conduit Route and Lay Conduit
13 Inspection
14 Backfill West Conduit Feed
15 Set 2nd Pour Forms and Rebar
16 Inspection
17 2nd Concrete Pour
18 2nd Concrete Pour - Curing
19 2nd Concrete Pour - Strip and Clean Forms
20 Trench South Conduit Route and Lay Conduit
21 Inspection
22 Backfill South Conduit Feed
23 Set 3rd Pour Forms and Rebar
24 Inspection
25 3rd Concrete Pour
26 3rd Concrete Pour - Curing
27 3rd Concrete Pour - Strip and Clean Forms
28 Sod 1st Concrete Pour Phase
29 Water 1st Sod Phase
30 Rough-In Tree Lights
31 Set 4th Pour Forms and Rebar
32 Inspection
33 4th Concrete Pour
34 4th Concrete Pour - Curing
35 4th Concrete Pour - Strip and Clean Forms
36 Sod 2nd Concrete Pour Phase
37 Water 2nd Sod Phase
38 Trim-Out Tree Lights
39 Set 5th Pour Forms and Rebar
40 Inspection
41 5th Concrete Pour
42 5th Concrete Pour - Curing
43 5th Concrete Pour - Strip and Clean Forms
44 Sod 3rd Concrete Pour Phase
45 Water 3rd Sod Phase
46 Final Clean and Demobilization
47 Final Inspection



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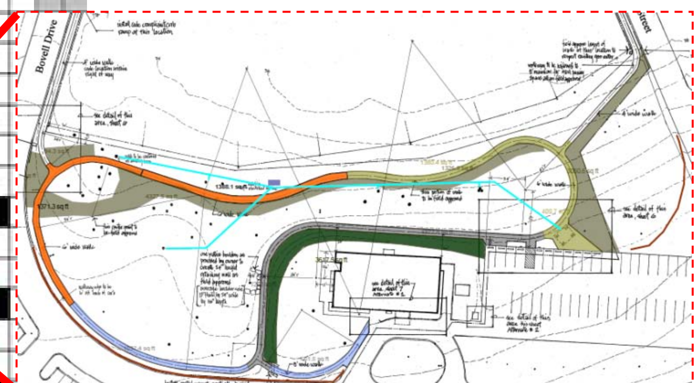
ID	Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Pre-Construction Meeting and NTP																								
2	Erosion Control and Layout																								
3	Strip Top Soil																								
4	Trench North Conduit Route and Lay Conduit																								
5	Inspection																								
6	Backfill North Conduit Feed																								
7	Set 1st Pour Forms and Rebar																								
8	Inspection																								
9	1st Concrete Pour																								
10	1st Concrete Pour - Curing																								
11	1st Concrete Pour - Strip and Clean Forms																								
12	Trench West Conduit Route and Lay Conduit																								
13	Inspection																								
14	Backfill West Conduit Feed																								
15	Set 2nd Pour Forms and Rebar																								
16	Inspection																								
17	2nd Concrete Pour																								
18	2nd Concrete Pour - Curing																								
19	2nd Concrete Pour - Strip and Clean Forms																								
20	Trench South Conduit Route and Lay Conduit																								
21	Inspection																								
22	Backfill South Conduit Feed																								
23	Set 3rd Pour Forms and Rebar																								
24	Inspection																								



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BIOGRAPHICAL INFORMATION

Agustin Villafana, raised in Dallas, Texas, graduated in 2002 from Skyline Career Development Center High School. He graduated Summa Cum Laude from the University of Texas at Arlington with a Bachelor of Science in Civil and Environmental Engineering. He started working for Rayco Construction, Inc. a minority owned general contracting company based in Arlington, Texas in a quality control/quality assurance role in 2006. Since then he has participated in job estimating, job costing and procurement, scheduling, and coordination; and is currently working as a project manager. Agustin is a register Engineer-In-Training, EIT, and Leadership in Energy and Environmental Design Accredited Professional, LEED AP.

After he graduates in May 2011, Agustin plans to pursue his post-graduate education as a doctorial candidate at the University of Texas at Arlington. Agustin's career goal is to become a professor.