An Analysis of CAD Use In Wisconsin Architectural Offices

by

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A Research Paper

Submitted in Partial Fulfillment of the

Requirements for the

Master of Science Degree

in

Career and Technical Education

Approved: 2 Semester Credits

Research Advisor

The Graduate School

University of Wisconsin-Stout

August, 2008

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Title: ***An Analysis of CAD Use in Wisconsin Architectural Offices***

Graduate Degree/ Major: MS Career and Technical Education

Research Adviser: Howard Lee, Ph.D.

Month/Year: August, 2008

Number of Pages: 148

Style Manual Used: American Psychological Association, 5th edition

ABSTRACT

The architectural commercial design program at Wisconsin Indianhead Technical College in northwest Wisconsin is keeping abreast of how the architectural industry uses computer-aided design (CAD) software. Within the framework of the study entitled "An analysis of CAD use in Wisconsin architectural offices," surveys were sent to 87 architectural firms in Wisconsin. Fifty-two firms responded to the 17-question electronic survey. The results showed the following: Firms use multiple CAD programs for various design phases. For example, larger firms and firms located in large communities are more likely to use building information modeling (BIM). Around half of responding Wisconsin firms use both 2D CAD and BIM in their design process, while 39% use only 2D CAD. When CAD technicians are employed at an architectural office, CAD technicians do 92% the CAD work in the construction document phase and a little over half of CAD work in the design development and construction administration phases. In the construction document phase, CAD technicians use Revit 11% more than all other

employees and architects overwhelmingly use AutoCAD. BIM is being used most often for productivity, visualization, and to discover design options. Return on investment is both a major driver and a major limiter of BIM use. As a result of the survey, it is recommended that the architectural commercial design program requires a Revit course in the second semester and then requires students to apply Revit to their coursework in subsequent semesters, with an emphasis on creating working drawings. In the foreseeable future, an AutoCAD course should still be required the first semester of the program, and then incorporated into some of the drafting lab courses throughout the two-year curriculum.

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Acknowledgments

I would like to thank the following people who have assisted in the completion of this small oeuvre either directly or indirectly, willingly or at my behest.

To all the relatives, co-workers, and friends who have had to endure my prattle of thesis this and thesis that: no more!

To all the architects who responded to the survey, thank you for providing such lengthy and insightful answers and requesting copies of the results.

To the many librarians staffing the reference desk, my thanks to you for helping navigate through the maze of rules that lead to accurate citations and referencing.

To the people who understand statistics and surveying tools, please know, and I do not say this lightly, that there is no possible way I could have done this without you. Dr. Sally Dittloff, psychology instructor at WITC, reviewed the pilot survey results and assisted me with question revisions. Karla Meier, research technician at WITC, used her expertise to create a beautiful and easy to read electronic survey. And finally, I am in the debt of Susan Green, associate institutional research at UW Stout, for making the survey process, which initially terrified me, into something that I found to be incredibly interesting and enjoyable.

To Dr. Howard Lee, thank you for being available, thorough and encouraging. Nary had an email gone unanswered for more than a day. His proof-reading was essential and helped me become a better writer and researcher. His concise, yet polite,

encouragement definitely was the push to keep me on track through this incredibly long ordeal. Dr. Lee, you can now retire; I'm done!

And finally, I owe debt of gratitude to my wonderful family. Thanks, Mom, for willingly doing many early proof readings. Your nicely phrased writing critiques help me get through chapter two. Dad, a long time ago you said, "Finish your education before you're 30. After that, you just get tired." Well, for the record, you were right. I thank you by not making you sit through another pomp and circumstance. Tom, thank you for providing sustenance, beverage, and a listening ear to all my research woes. Emily, you are a trooper for putting up with a researching Mom on and off for the past few years. I promise to proof your thesis in return.

Table of Contents

List of Tables

Chapter 1: Introduction

Background of Study

There are three factors that relate to the use of computer-aided drafting (CAD) in architectural offices. These will be discussed in the following sections. The first factor is the development and current abilities of CAD. Second is the application of CAD in architecture. Third is CAD training provided at Wisconsin Indianhead Technical College's (WITC) architectural commercial design program.

Computer-aided drafting. Each generation of technology brings about changes that are both affected by and in turn affect the process in which they were designed to aid. Computer-aided drafting (CAD) is no different. Since the beginning of CAD's prominent use in the late 1980s/early 1990s, there has been a struggle with how to incorporate CAD into the existing structure of the architectural drafting process. In time, both CAD and the drafting process have changed in order to find a solution.

When CAD was introduced to architectural offices as a two-dimensional (2D) tool, it was implemented at the design development phase as architects, who were not trained in CAD, still created hand-drawn schematic drawings. With the introduction of three-dimensional (3D) CAD, CAD was still only incorporated into the last two phases of design. Post-construction model-based 3D presentation drawings were created separately from the object-based drawings, almost as an afterthought. Currently, both of these practices (2D and object-based 3D) appear to be the norm. However model-based 3D CAD is making waves in the architectural and construction industries. See Table 1, for a summary of programs currently being used.

Table 1

CAD Tools Currently Used for 2D Modeling Tasks

Program	Percent of Respondents
AutoCAD R14	48%
AutoCAD 2000	21%
MicroStation	9%
AutoCAD LT	9%
VectorWorks	7%
PowerCADD	5%
DataCAD	5%
MiniCAD	5%
All others (those under 3%)	20%

(Conlon, 2000)

Model-based CAD, now widely known as building information modeling (BIM), spurred changes in the drafting process; changes resembling the drafting process of the pre-CAD era. This type of CAD allowed drawings to begin during the schematic phase. These schematic phase model-based drawings are like electronic clay models except these electronic drawings can evolve into construction documents fluidly.

The impact of incorporating CAD at an earlier design phase is far flung. Presentation drawings are used by the architect to elicit client and public feedback, allowing changes to be made before construction begins. Drawings are also used by the client to obtain financial backing, to gain construction permission from planning

commissions and historic district boards, and to initiate marketing strategies (Hill, 1999; Hernandez, 2003).

With BIM, all elements of the drawing are connected. The elevations and sections are generated from the floor plans; and window schedules, door schedules, and room finish schedules are linked to their respective objects in the floor plan. For example, revisions made to an exterior door in the floor plan are reflected in the door schedule, sections, and elevations. This interconnectedness of drawing objects means that buildings can be drawn with greater accuracy (Conlon, 2000; Phair, 2002). This is especially true with BIM since the schematic massing is the basis for the rest of the drawing phases. Problems in design are ironed out early in the design process as the architect, engineer, and fabricator use the electronic model-based CAD, or BIM, drawings to communicate design concepts and resolve questions (Bennett, 2000). Once construction begins, this leads to fewer requests-for-information (RFIs) and fewer change orders. The result is a happy client whose project is on time and on budget (Post, 2003).

Many offices currently using 3D CAD, or BIM, are not using it to its fullest potential, see Tables 2 and 3. In fact, AutoCAD 14 was the most widely used 3D software in 1999, however only 13% of AutoCAD 14 users thought it was the most effective tool available. Popularity does not equal effectiveness (Conlon, 2000).

Table 2

CAD Tools Currently Used for 3D Modeling Tasks

Program	Percent of Respondents
AutoCAD R14	32%
Form Z	12%
AutoCAD 2000	10%
Design Workshop	9%
VectorWorks	6%
TriForma	4%
DataCAD	4%
All others (those under 3%)	20%

(Conlon, 2000)

Table 3

Percent of Each Program's Users Reporting That Their Firm's Use of 3D Modeling is "Most Effective"

Program	Percent of Respondents
ArchiCAD	30.3%
3D Studio Max	22.9%
Architectural Desktop	20.0%
MicroStation	15.4%
Design Workshop	14.8%
Form Z	13.9%
AutoCAD R14	13.0%
TriForma	10.0%
AccuRender	10.0%
DataCAD	6.7%
3D Studio Viz	5.4%
VectorWorks	5.3%
AutoCAD 2000	0.0%

(Conlon, 2000)

On the other hand some architects are pushing the horizons of model-based CAD, or BIM, by using the construction documents to fabricate building materials. The construction documents for the Bilbao Art Museum, and Soldier Field, both complex structures, also served as shop drawings. This allows the fabricator to fabricate a pre-approved building material via CNC machining and without paper documents. This process is virtually the only means of fabricating complex shapes required on complex

structures. Collaboration between the architect, engineer and manufacturer throughout the design process is imperative to the success of this type project (Post, 2003; Bennett, 2000; Day, 2004).

The future of CAD appears to be oriented around BIM. Collaboration will be made easier with increased access to and speed of the Internet. Universal adoption of CAD among architects, engineers, and fabricators would also speed up the design and construction phases (Bennett, 2000). The George Washington University (GWU) study forecast that by 2012, mass customization will be used in conjunction with computer integrated manufacturing (CIM). This will allow factories to fabricate unique parts per electronic specifications with little human interaction (Halal, Kull, & Leffman, 2000).

Architectural offices. Within the traditional framework, architectural offices are run by an architect who is either a partner or owner. The larger the firm, the more the owner deals with management and less with design. The older the owner, the less control he or she has on daily design and operations (Demkin, 2002).

Architectural offices rely on CAD to create various types of drawings for different project types and for different phases throughout the project. Project types include industrial, commercial, institutional, recreational, or residential. Each project goes through three phases: schematic, design development, and construction documentation (Jefferis & Smith, 2002). These phases take the project from the conceptual start of preliminary design to the finished construction. Each phase has an associated set of drawings that both become increasingly detailed and build on the previous phase. Typically, schematic design drawings are generated by the project architect through meetings with client. The design development drawings are initiated by a project

architect, or an advanced CAD technician, and developed through a series of meetings with engineers and consultants. CAD technicians continue to work on the construction documents with the project architect's feedback and revisions.

Architectural drafters fill many roles. Drafters will start as junior drafters (CAD Tech II) and then move to roles as senior drafters (CAD TECH I), project managers, and CAD managers. The last two hold decision-making abilities within the office regarding selection and implementation of CAD software (Demkin, 2002; Jefferis & Smith, 2002). Architectural offices do not provide in-house training for CAD, unless they are switching software and are large enough to withstand the loss of income (Boyd & Fallon, 2003). Not all architectural firms are using the newest CAD releases (Conlon, 2000; Fullarton, 2002; Kutrieb, 2003). Upgrading to a new release or switching software is expensive for the company. The decision to do this has to be made wisely and with addressing fiscal concerns of lost time and training fees (R. Knapmiller, personal conversation, September 23, 2003). Therefore, an ideal newly hired drafter must be trained in the office appropriate software and must possibly be able to provide in-house technical support for software upgrades (Boyd & Fallon, 2003).

Wisconsin Indianhead Technical College. Wisconsin Indianhead Technical College (WITC), located in rural, northwest Wisconsin, is one of 16 statewide districts in the Wisconsin Technical College System (WTCS). Due to the district's large geographic area, there are four campuses. The architectural commercial design program is offered at the Rice Lake campus. It is one of 13 associate degree programs offered on the Rice Lake Campus (WITC, 2002).

Whereas there are four similar architectural programs offered at six of the WTCS districts, architectural commercial design is a unique program in the state (WTCS, 2004). Therefore curriculum decisions that affect the core classes are state-mandated. Instead they are based solely upon the WITC architectural commercial design department with the assistance of their advisory board.

The architectural commercial design program is a 65-credit program (WITC Catalog, 2008-2009). In the curriculum, 2D CAD instruction in the form of Architectural AutoCAD 614-135 occurs in the first semester. This is a pre-requisite to all other drafting courses. A second semester course, Introduction to Architectural Desktop 615-136[1], introduces 3D CAD in the form of AutoCAD Architecture and is prerequisite for two drafting courses. Both AutoCAD and AutoCAD Architecture are applied in the third semester course Commercial Drafting 614-105 and in the fourth semester course Architectural Drafting Studio 615-110. Offering an opportunity for the students to explore Architectural Desktop is important as it is widely used in the industry (Conlon, 2002). Finally, Case Studies in Architecture 614-116 is an elective offered fourth semester. It allows students the opportunity to explore model-based CAD or building information modeling (BIM) through the use of Revit.

Job placement is high for graduates of the architectural design program. Most graduates acquire jobs in northwest Wisconsin. Approximately 30% of graduates initially

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[1] The course was created when Architectural Desktop was the name of the software. Since then, Architectural Desktop software was renamed to AutoCAD Architecture. The course name has remained the same.

find jobs in architectural offices, typically larger metropolitan areas (Kutrieb, personal correspondence with graduates). It is likely that more graduates have the desire to initially work in architectural offices; however those offices often have work experience requirements, thus limiting students' opportunities. There are no studies to date that track graduates' specific place of employment, other than informal communication between instructor and graduate.

It is in the best interest of the architectural commercial design program to keep the instruction of technology current. Program and curriculum modifications are tools that allow a program to change in order to maintain instruction of current technologies. The implementation of program and curriculum modifications begins with the recommendation of the advisory board. The advisory board meets semi-annually and is comprised of people employed in architectural-related fields. Implementing a program or curriculum modification may take up to two years from the time it was recommended. Therefore, it is necessary to predict what the CAD usage trends are in architectural offices.

Statement of the Problem

CAD software is used at WITC in the architectural commercial design program. Providing instruction that applies industry used CAD software is essential for the effectiveness of the program. National research shows there is an industry-wide trend toward using model-based 3D CAD. WITC is located in a geographic location that lags behind national trends. No model-based 3D class is currently being taught in the program's core curriculum.

Purpose of Study

The purpose of this study is to identify CAD software usage and trends in Wisconsin architectural offices. This was done by studying the use of 2D CAD and BIM in all Wisconsin architectural offices affiliated with American Institute of Architects (AIA). An electronic survey was linked from an email sent to each firm. The results was used to provide the architectural commercial design program a timeline in which to guide future curriculum modifications.

Research Questions

This study sought answers to the following research questions in selected architectural firms:

1. What CAD software is being used?
2. How are the design phases affected by BIM?
3. To what level are they using BIM? For example, is it to increase production and efficiency or as a communication tool?
4. What are the drivers behind the implementation of BIM? For example, is it client-driven, production-driven?
5. How will BIM be used in 5, 10, 20 years?

Significance for Study

The analysis of CAD usage in Wisconsin architectural firms is significant for a number of reasons. Primarily, the study will give credence for the type of software included in the curriculum of the architectural commercial design program.

1. Architectural commercial design program. As a unique program with several other similar architectural programs in the state, it is important that the architectural commercial design program at Wisconsin Indianhead Technical College remain competitive with industry needs. One way of doing that is to use widely used industry CAD software. Keeping current and abreast of the industry needs potentially increases the marketability of the program, which in turn increases enrollment of the program. More students will likely graduate from the program, and these graduates will be able to find jobs easier.
2. Graduates of the architectural commercial design program. By providing architectural commercial design students with the most widely used CAD in the industry, they will be able to go after a wider range of jobs once they graduate. This leads to increased job opportunities. Once they have been hired, their ability to use CAD, manage CAD, and understand the trends of CAD allows them increased potential for advancement. In the end, this all leads to increased job security.
3. Employees of architectural commercial design graduates. Training drafters on new releases or types of CAD software is expensive for offices. By providing drafters from the architectural commercial design program who are trained in widely-used industry accepted software, the expense of retraining is lessened,

if not eliminated. Also, architectural commercial design graduates may have been trained in software that is ahead of the offices'. In that case, the employer can rely on the graduates' ability to lead the office into the future regarding CAD upgrades and software switches. In addition, the employers may even rely on the architectural commercial design graduates to provide informal in-house training for other CAD users in the office. This, again, lessens the amount of money the office needs to pay for retraining.

4. Instructors of the architectural commercial design program. Instructors also are affected by this study. Not only do instructors have a personal stake in providing students with the best possible training, but there is also the very tangible aspect of job security. The more competitive the program is, the more students are enrolled and graduate. Therefore, there is less likelihood of job termination.

Limitations of the Study

Limitations of the study include:

1. The study cites only the Wisconsin architectural offices that were listed through the American Institute of Architects web site. Some firms in Wisconsin may not be listed in that site.

2. Not all architectural commercial design students work at architectural offices. As this varies from year to year, in the past five years approximately 30% have begun their careers at architectural offices. It is important to note, however, that some architectural offices hire only experienced drafters and that some graduates have since become employed at architectural offices.
3. Some of the survey used to gather data from the architectural offices was created by the researcher. Even though every effort was made to reduce bias, there may be some unconscious motivation that has skewed the questions.
4. The study focuses on BIM. It is possible that another type of software will be developed in the future and become widely used. There are many individuals and companies developing software that may have application to CAD.
5. The study is generalizable only to other architectural programs within the Wisconsin Technical College System as it is focused on the small study of CAD use in Wisconsin architectural offices.

Definition of Terms

In order to understand this research paper, it is necessary to define terms commonly used with CAD and architectural offices. The following (in alphabetical order) are commonly used terms in this research paper and on a daily basis in architectural offices.

Building information modeling (BIM): a computer-aided drafting tool that uses a virtual 3D model created and stored in a single file with a database of retrievable (Mandel, 2004 May).

Computer-aided design or drafting (CAD): a term applied to systems to techniques for design and drafting that utilize integrated computer hardware and software systems to produce graphic images (Demkin, 2002).

Change order: an amendment to the construction contract signed by the owner, architect, and contractor that authorizes a change in the work, and adjustment in the contract sum or the contract time, or both (Demkin, 2002).

Construction documents: drawings and specifications that set forth in detail requirements for the construction of the project (Demkin, 2002).

Design development documents: drawings and other documents that fix and describe the size and character of the entire project as to architectural, structural, mechanical, and electrical systems; and such other elements as may be appropriate (Demkin, 2002).

Drawings: graphic and pictorial documents depicting the design, location, and dimensions of the elements of a project. Drawings generally include plans, elevations, sections, details, schedules, and diagrams (Demkin, 2002).

Object-oriented modeling: process of drawing 3D CAD in which the building information is created and defined as a collection of objects...rather than a series of lines and planes (Demkin, 2002).

Request for information (RFI): requests for clarification of the drawings during construction submitted by the contractor to the architect asking. They are usually submitted on an RFI form (Demkin, 2002).

Schematic design documents: drawings and other documents illustrating the scale and relationship of project components (Demkin, 2002).

used to assist in order to communicate the design: 2D renderings, virtual models, and walkthroughs (Jefferis & Smith, 2002).

The plan is further developed in the second phase: design development (DD). Engineers (such as mechanical, structural, and civil) and consultants (such as food service, security, fire protection, and historical restoration) now are included. They input their specialty's design concerns in order to iron out the function and massing of the design (Demkin, 2002). Many of the meetings are now held without the client as the discussions turn technical. It is during this phase, if not carefully monitored, that projects can develop costly design problems. Communication is very important. Tracking information, changes, and following through with the impacts of those changes are challenges any design firm faces. As the design becomes more developed, the floor plans become more detailed and elevations and sections are created. In some offices using 3D programs, the model becomes more developed with plans, elevations, and sections being created as byproducts.

The third phase, construction documents (CD), is the last design phase before construction begins. The intent of this phase is to refine the drawings based on the information gleaned during the multi-discipline meetings of the DD phase. The product of this phase is the CD set. Most of the work during this phase is created within each discipline's office. Multi-discipline meetings still occur, though with less frequency. Some call this the 'silo effect', so called because each discipline is creating information independently of other disciplines.

During the CD phase, the plans are refined, fully dimensioned, and fully noted. The sections and elevations are finalized. Since sections, elevations, and plans need to be

Shop drawings: drawings, diagrams, schedules and other data specially prepared for the work by the contractor or a subcontractor, sub-subcontractor, manufacturer, supplier, or distributor to illustrate some portion of the work (Demkin, 2002).

Chapter II: Literature Review

Introduction

This chapter includes several discussions to get an understanding of the subject matter. First is a discussion on the phases of the design process. Next is an integrated look at how computer-aided drafting (CAD) is used in architectural offices including a look at who is using CAD in the office and at what drives CAD purchasing decisions. Following that are discussions on building information modeling (BIM) and the shift toward BIM. The final section discusses the architectural commercial design program at Wisconsin Indianhead Technical College (WITC) with emphasis on curriculum decisions that are guided by industry CAD use.

Design Phases

The design process is broken down into five phases: schematic (or preliminary), design development, construction document, construction administration, and facility management (post-occupancy) (Jefferis & Smith, 2002). These phases create a common dialog within the architectural industry. The design of a project becomes more clarified during the first three phases. Construction happens in the fourth; and the building is owner-occupied in the last. CAD use permeates all five phases.

The first phase is the schematic design (SD) which follows the initial client-architect meeting. It is an exploration into massing, function, and budget. Basic plans are created that include overall dimensions and annotations per building function. Ultimately, the scope of the project is determined in this phase. Additional tools may be

close to finalized before detail can begin, it is during this phase in which construction details are started and finished.

The CD set includes both the complete set of drawings as well as the project specifications. The quality of a CD set is based on its ability to effectively communicate the design intent and to follow building codes (Jefferis & Smith, 2002). This quality is evidenced during the bid opening and throughout the construction administration phase. The bid opening shows how closely the contractor's bid compares to the architect's projected cost. Depending on how clearly information was communicated in the CD set the costs may be close, evidence of a good quality, well-communicated set, or far apart, evidence of a poor quality CD set. During the construction administration phase the contractor's questions of the project during construction are conveyed in RFIs and quantified in the costs of change orders. Both are explained in the next sections. Again, the more clearly the CD set has accurately communicated the design and construction, the fewer questions the contractor will have during the construction administration phase.

The fourth phase, construction administration (CA), deals with the architectural administration of a project's construction. The objective of the architectural office now switches from creating drawings to verifying drawings. Verification happens in two ways: shop drawings and requests for information (RFIs).

Shop drawings are created by a supplier, manufacturer, or fabricator of construction material such as doors, plumbing fixtures, or trusses. Manufacturers have design departments whose function is to create shop drawings. In order to do that, the CD set is reviewed in order to determine the scope of their product within the project. Then, drawings are created that show how that particular manufacturer's products will

work given the parameters stated in the CD set. For example, if the CD set shows a cantilevered floor structure using a pre-cast plank, the pre-cast manufacturer must determine the structural calculations for the cantilever and therefore the required depth of the plank. Shop drawings are created that reflect the calculations. The architect and contractor must then verify that the depth, for example, fits within the overall design. It could be that plank's depth impedes on other elements of the building like the HVAC requirements or the size of a window below, or the length of supporting columns. Reviews of the shop drawings are expected to be short: two to five days. Delays in shop drawing approvals can mean delays in delivery of the product.

Requests for information (RFIs) are questions the contractor has about the intent of the CD set. The contractor submits them to the architect via fax or email. The architect then analyzes the questions, finds a solution (often with the input of consultants, engineers, or the contractor), and communicates the solution in writing to the contractor in a timely fashion. Sometimes RFIs lead to revisions in the drawing and change orders (Jefferis & Smith, 2002). Most projects have revisions. A revised set of drawings occurs when enough small changes or corrections in the CD set deem making and delivering a new, revised CD set to the contractor during construction. Change orders occur when the revisions cost money. Depending on who is driving (or at fault for) the change, the architect, contractor, or client pays. Delays in responses could mean project delays. Again, better quality drawings lead to fewer RFIs, fewer revisions, and fewer change orders.

The last phase is facility management (FM). This phase deals with the building after the construction is complete. For the most part this means creating as-built

drawings: drawings that accurately reflect what was constructed. As will be seen in later discussion, this phase can deal with the life-cycle of the building.

Architectural CAD...or "Before Building Information Modeling"

Many types of CAD programs have been used in the design process prior to BIM. In fact these pre-BIM tools are still currently used in most firms. This section will briefly look at how both two-dimensional and three-dimensional CAD have been and are currently being used in the architectural design process. This discussion will help lay the foundation for understanding how and why BIM is having such an impact on the design process.

Two-dimensional computer-aided drafting.

> "The adoption of [2D] CAD is a perfect example of [simply automating the old way of working]—what we have done is to simply replace the pencil with a mouse, and computerize the production of the flat drawings that have been the basis of architectural documentation for centuries." (Bedrick, 2005)

Computer-aided drafting (CAD) has been used for architecture, engineering and manufacturing for decades. Replacing hand-drafting with two-dimensional (2D) CAD affected the industries for which it was used. This short section looks at 2D CAD, its benefits, and its limitations.

Computer-aided drafting began as a two-dimensional enhancement to replace the laborious nature of hand drafting. With it, floor plans, elevations, and construction details

were created from basic geometric objects (Henley, 2002). Drafting was computerized, but the process did not change, much like the shift from typewriters to word processors (Haapasalo, 2000).

Of course, CAD had many benefits which mainly revolved around its ability to increase productivity. CAD increased productivity during the revision process by using repeatable objects known as blocks. Taking a look at hand-drafting will help to explain this. In hand drafting, major plan revisions necessitated redrawing the design on a new sheet of vellum or Mylar. This took up a great deal of time and there was always a chance for information loss. The architectural industry is still battling the problem of information loss as will be explained in later sections. Also, with hand-drafting, repeatable objects were drawn anew at each location, on each sheet, for each project. With CAD, revisions allowed for merely modifying the existing drawing file, not starting from scratch. In addition, CAD allowed 'block libraries' to be used as repositories for frequently used symbols, objects, construction details, and even room layouts. Companies like Montgomery Ward's embraced architectural CAD to the extent of placing a press release in 1989 stating, "CAD makes everyone more productive, from the conceptual designers to the actual drawing producers" (CAD dominates, 1993, p. 69). For the most part, people saw CAD as a positive, forward-moving tool, however as new technologies presented themselves with new options, people began to jump ship.

Two-dimensional CAD did have limitations. CAD created a discontinuity in the design process that lead to poor quality drawings. First of all, not many architects were schooled in CAD therefore architects hand-drew initial designs only to have the designs recreated electronically by the CAD technicians. Architects viewed CAD as foreign

process, from which they felt very much detached (Barron, 2002). To exacerbate this even more, the focus shifted from the design to CAD; from the ends to the means. In the end, the quality of the designs began to decline (Haapasalo, 2000).

Many architects have attested to this poor quality. Frank Gehry went so far as to say:

> ...the process of automating the production of 2D documents actually expanded documentation. Drawings increased in numbers, the information became more fragmented and productivity went down, errors went up, change orders increased and so effectively, the technology had no impact on the industry in terms of productivity. (Day, 2004, n.p.)

James Cutler said "There's nothing more capable of making my employees stupid than AutoCAD, because they can draw something two-dimensionally and it looks right to them, but they're not seeing three-dimensionally" (Cheng, 2006). One could say, in effect, that the introduction of CAD drafting increased the amount of paper being used and decreased productivity.

The most outstanding feature in the utilization of 2D CAD is that while it had a major impact on the architectural industry the design process itself remained unchanged (Birx, 2005). This unsettled lack of change may have been the initial tremors of the major shift in the design process to come.

Three-dimensional computer-aided drafting. Today, almost all architectural firms implement some sort of CAD (Hernandez, 2003). Architectural CAD is maintaining a hold in 2D, but also strongly moving into model-based CAD and, ultimately, building information modeling (BIM). Three-dimensional CAD is popular mainly because it

allowed clients to visualize their projects prior to construction (Millard, 2006; Hernandez, 2003; Ellerin, 2003).

There are three ways of defining 3D CAD: isometric 3D CAD, one-directional parametric model-based CAD, and bi-directional parametric model-based CAD.

Isometric 3D CAD is used to model buildings, frequently to enable clients to more fully understand the project. Despite the fact that this is a CAD image, the isometric 3D CAD file has no more intelligence than a hand-drawn rendering as the 3D image does not link any information with the floor plan or building elevations.

One-directional parametric model-based CAD uses objects that contain data. That data can be used to create or generate other drawings such as sections, elevations, and schedules. It is "one-way" because the floor plan is originating point of the data: the point from which other drawings are created such as sections, elevations, and schedules. Changes made to the floor plan will be reflected in other drawings; however, changes cannot be made in reverse. A change in the schedule will not be reflected in the section, elevation or plans. An example of one-directional parametric model-based CAD is Architectural Desktop [name change is 2008 is AutoCAD Architecture]. It is a very popular CAD program, but most firms use it only for its model-based productivity and not the rich parametric features.

Bi-directional parametric model-based (PMB) CAD is similar to the previous example except that it is a true parametric. The focus in PMB is the model. The model can be viewed as a section, elevation, or plan. Objects in any view will modify or have effect on all the other views, but all views are a part of the model. For example, when a window is added to a floor plan, the window will show up on the elevations, sections and

schedules. Likewise, a change to the window in the section will affect the elevations, plans, and schedule. Even a modification to the window size in the schedule will affect change in the floor plans, sections, and elevations. Some examples of bi-directional parametric model-based CAD are Form-Z, ArchiCAD, TriForma, Revit, VectorWorks, and CATIA (Maxim, 2003).

Building Information Modeling

Building information modeling (BIM) is a concept that began to permeate certain architectural circles around 2004. It started from companies that were already using parametric model-based (PMB) CAD. Parametric model-based CAD was very effective for creating virtual models and was also an effective productivity tool. Beyond that, however, PMB CAD users started inputting data into these models. The models then started becoming database repositories. This was the beginning of Building Information Modeling (BIM). This section will define BIM and discuss how BIM is used.

Definition of BIM. The concept of BIM is new. As with any new concept, there are many definitions floating around dubbed by many industry-related organizations. In this case companies and organizations such as Autodesk, (2003); AIA, (n. d.); and Construction Users' Roundtable (CURT, 2006) are but a few who have thrown a definition into the hat. For this paper, Phair's succinct definition allows for a nice backdrop for the discussion to come: "...the holy grail of modeling is a single model that is created at the time of a building's inception, built up throughout the design and construction process, and eventually maintained and enhanced throughout the entire life of a facility" (2002). CURT alludes to the inclusion of BIM with the manufacturing

process in its definition (2006). American Institute of Architects (AIA) includes a nod to the creation of a database in its definition (n. d.).

Uses for BIM. There are many other reasons for using BIM. This section will look at how BIM benefits the initial design, quality of drawings, the construction process, fabrication/procurement, and the building's lifecycle. Please note that BIM's integration into the design process has taken on a higher meaning in some circles who are dubbing this Integrated Practice. This discussion does not go into Integrated Practice, but instead focuses on BIM's applications only.

BIM benefits the design process. As proven in manufacturing industries, model-based CAD allows for quick turnarounds in the design process (Day, 2004; Beckert, 2000). In architecture, this fluidity in design enables many design scenarios to be thought through in a realistic, virtual way. Because information is embedded in the model, in the objects contained in the model, there is minimal loss of information between design phases (Bernstein, 2005). This means that technicians are more productive with CAD. By not re-entering data at the beginning of each phase or at the beginning of each design concept technicians ultimately spend less time designing projects (Birx, 2005).

BIM increases the quality of drawings. Creating a BIM project means, by virtue of its name, that information is being stored and controlled in the building model (Birx, 2005). One data-containing object is used repeatedly. For example a column in a floor plan may be seen in the elevations, sections, details, and schedules. Identical columns can be copied and placed at various places throughout the building. All will share the same data, the same retrievable information that will automatically be used in other drawings. Therefore, there is consistency between the objects which allows for fewer

errors (Bernstein, 2005). Fewer errors mean an increase in the overall quality of the drawings (Birx, 2005).

This is even true, perhaps especially true, with complex designs. The identical repeating column described above is a good example of a rectilinear design: a big box design, a Wal-Mart, a distribution center. However, not all designs are in want of such simplicity. Complex designs, though perhaps driven by the owners' desire to create a unique landmark, are also made possible through BIM. BMW Welt, Freedom Towers, and the San Francisco Federal Building are all examples of complex, sometimes organically shaped designs. Each, had they been done in 2D CAD, would have been cost prohibitive if in only the time it would have taken to design them.

Construction is improved with BIM. With the high quality drawings, the increased coordination, collaboration, and communication, the quality of construction increases as well. Whereas 2D CAD design was disconnected from actual construction, BIM helps to 'narrow the gap between design and construction.' BIM allows the initial design concepts (that were relayed to the client) to have some basis in reality through creating virtual models of the building (Lingerfelt, 2005). Since the objects used in a BIM designed are modeled and embedded with information fairly early on in the design process (not without help and collaboration from the contractors, sub-contractors, and engineers), there are far fewer questions in the form of RFIs in the construction administration phase (Post, 2003; AIA, 2005). This allows construction to be finished within a tighter time frame. It also helps to reduce the overall cost of construction as contingencies that typically cover unknown issues can be considerably lessened (Bordenaro, 2005).

Construction times are shortened also by an integrated process that combines design and fabrication. Collaboration like this necessitates bringing the fabricator into the design process earlier and designing with interoperable programs that can be used by both the architect and fabricator (Bennett, 2000). This omits, then, need to recreate shop drawings in the CA phase as objects drawn by the architectural team would merely need to be enhanced, not redrawn, by the fabricator (Post, 2003).

Finally, BIM data can be used throughout the lifecycle of the building after occupancy (Haapasalo, 2000; Bernstein, 2005). Embedded data can assist in doing a number of, some as of yet unknown, tasks. Some of the tasks are estimating, billing, maintenance, energy studies, code reviews, etc (Barron, 2002; Birx, 2005; Hernandez, 2003; Krouse, 2000)

The Shift toward BIM

There has been a lot of discussion about BIM since 2005. It appears to be the future of architectural design. Thom Mayne, in an address at the 2005 AIA Convention, stated,

> If you want to survive, you're going to have to change. If you don't change, you're going to perish. Simple as that. It's such a basic thing. You will not practice architecture if you're not up to speed with this. You will absolutely not practice architecture in ten years. I have no doubt about it, no question. (AIA, 2005)

To fully understand the shift toward BIM, this section addresses three topics. The first analyzes data regarding the shift toward BIM. The second looks at what is driving the shift. The last, addresses obstacles standing in the way of the shift toward BIM.

Data analysis regarding shift toward BIM usage. BIM usage has slowly, but steadily, been increasing since 2004. There have been several unscientific surveys done via on-line sites such as CADDmanager.com and augi.com. In 2004, an Autodesk Users Group International (augi.com) survey of 647 respondents showed that companies are using multiple platforms within Autodesk's programs. The survey did not look at non-Autodesk programs. The survey also showed that although 38% of those firms were using some form of BIM software, almost all companies were still using AutoCAD.

Table 4

Type of Autodesk Product Currently Used from May-August 2004

Program	Percent of Respondents
AutoCAD	92%
ADT	30%
Revit	8%

(CADDmanager.com, August 2004)

In February 2005, CADDManager.com, conducted a survey that analyzed usage of ADT and Revit. Twenty-eight people completed that month's online survey. The results show that 64% were using some form of BIM software. This is a 26% increase from the August 2004 AUGI survey done six months prior. Usage of Revit is virtually the same as the August 2004 AUGI survey at seven percent.

Table 5

Current use of either ADT or Revit

Program	Percent of Respondents
ADT	57%
Revit	7%

(CADDmanager.com, February 2005)

CADDmanager.com's October 2005 survey entitled "CAD or BIM?" analyzed the shift toward BIM. The survey analyzed the type of tools, 2D CAD or 3D BIM, being used in lieu of specific programs. Of the 122 respondents, 69% were using at lease some 3D with only 31% still using only 2D CAD.

Table 6

"CAD or BIM?"

Tools used	Percent of Respondents
2D only	31%
Mostly 2D and some 3D	30%
Some 2D and some 3D	11%
Some 2D and mostly 3D	19%
3D only	8%

(CADDmanager.com, October 2005)

In late 2005 to early 2006 another unscientific survey was done; this time by AIA and Association of General Contractors (AGC), see Table 7. This survey attracted a wider pool than previous surveys with 1,266 respondents. Overall, the survey found that 74% of all respondents are using 3D/BIM to some extent. This is roughly a seven percent increase since October 2005. Unfortunately, this number has been ill-used as it has been found in articles as 74% of architects are using BIM. What is important is how BIM is being used. This survey did ask that, and though the design phases are categorized differently than described in this paper, parallels can be made. Although the table only looks at those who are using BIM, it can be deducted that a little less than three quarters of responding firms are using BIM for the SD phase—the phase in which 3D modeling has always held a stronghold due to the need for clients to visualize their projects. However, a little over a quarter of responding firms are using BIM throughout the DD and CA phases, and only 9% are using BIM for FM. There is no data available to find out what percent of firms are using BIM throughout all phases. It is also not conclusive as to the level of BIM use within each phase. The survey descriptions states that 'intelligent modeling' is "generating project data such as cost/quantity information, in this instance, most are using it for determining quantities." Quantity takeoffs, though it is a form of retrieving data, does not fulfill BIM's potential. The category of construction is described "as a construction resource (conflict identification, shop drawings, etc.) and largely for conflict identification." This could mean BIM models created on an as-needed basis for conflict identification and not an all-encompassing use of BIM.

Table 7

How BIM is being used in Design Phases, from January 2006

Survey Phases	Comparative Thesis Phase	Percent using BIM
Visualization and Design	SD	98%
Intelligent Modeling	DD and CD	34%
Construction	CD and CA	34%
Post-Construction	FM	12%

(AIA/AGC, January 2006)

When looking at all of the surveys mentioned thus far, it is evident that BIM use has almost doubled from 2004 to 2006, see Table 8.

Table 8

Companies Using Some Form of BIM

Date of Survey	Months since last survey	Percent
May-August 2004	-	38%
February 2005	6	64%
October 2005	8	69%
December 2005 – January 2006	3	74%

(CADDmanager.com, August 2004; CADDmanager.com, February 2005; CADDmanager.com, October 2005; AIA/AGC, January 2006)

Drivers of change. The shift toward BIM is being driven by economics. Several studies in recent years have begun to quantify the amount of inefficiencies in the construction industry. In 2000, an article in The Economist stated that of the $600 billion spent on construction world-wide, $250 billion was based on inefficiencies (New Wiring, 2000). In 2002, an interoperability study found that $15.8 billion were spent on inefficiencies related to electronic data exchange (NIST, 2004; Sawyer, 2004). In 2004, a productivity study showed that of all the U.S. industries, only two decreased their productivity in the last 40 years. The construction industry was one of those (Khemlani, April 2004; Strong, 2006). It is important to remember that although there are several drivers behind this change; technology is not one of them. Instead, it is a catalyst that is allowing the BIM to be integrated into the design process.. The drivers are those who are affected by the inefficiencies in the construction industry. This section takes a look the three stakeholders who are ultimately the drivers behind the shift to BIM: owners, contractors, and architects. (Bernstein, 2005; AIA/AGC, 2006).

Owners are the biggest driver behind the shift to BIM. They are left paying for most of the inefficiencies listed above. (AIA/AGC, 2006; Gonchar personal conversation on July 21, 2006; Lingerfelt, 2005; Meyer personal conversation on July 18, 2006; Strogoff, 2006; Strong, 2006). This has been demonstrated most clearly by an organization called Construction Users Roundtable (CURT). CURT touts that is it "the owners' voice to the construction industry" (CURT, 2004). Owners rallied through CURT to draw attention to the fact that they were left footing the bills on costly construction scheduling overruns as a result of sloppy construction documentation. In 2004, CURT wrote the 1202 White Paper entitled "Collaboration, Integrated Information,

and the Project Lifecycle in Building Design, Construction and Operation." In it, they state that seventy percent of owners believe that the quality of construction documents is declining. Almost all owners believe that the power to improve CD quality lies at the feet of architects (Bernstein, 2005). The CURT 1202 paper set four recommendations: owner leadership, integrated project structure, open information sharing, and virtual building information models (CURT, 2004). To push this demand further, some government agencies are requiring new construction design to utilize BIM technology (Hunt, 2005). General Services Administration (GSA), United States Coast Guard (USCG), and Department of Defense (DOD) are requiring projects to incorporate BIM (Hunt, 2005). BIM is also being used for the design of the Freedom Towers (Hall, 2006; Hunt, 2005). Needless to say, CURT's white paper got the attention of industry giants like AIA.

Contractors are often also victims of the industry's inefficiencies, and therefore are also key drivers for change. Many major construction conflicts are only first discovered during the construction phase of a project. As discussed before, conflicts lead to RFIs which can lead to change orders which then can lead to costly project delays. Fortunately for the contractor, many of these costs incurred by the contractor are typically paid by owner. However, no contractor goes into a project hoping that the owner will have to pay additional fees during construction. Cost overruns can tarnish a contractor's reputation and therefore are to be avoided whenever possible. BIM can help avoid these problems. Contractors use BIM to stage construction phases and assess potential construction conflicts. Subcontractors such as fabricators use BIM to analyze individual materials prior to fabrication and delivery.

Several contractors have begun to use BIM. Tompson-Tomasetti, structural engineers for Chicago's Soldier's Field, worked with Permasteelisa, a steel fabricator, to create an efficient schedule that allowed construction to occur at a break-neck speed. Construction on Soldier's Field was completed in only twenty months (Burns, 2005; Post, 2003). Mortenson Construction began using BIM on the Walt Disney Concert Hall when working with Gehry architects. Since then, they have found it useful for resolving conflicts and staging construction for almost all other projects (Khemlani, 2006).

More architects, with the help of the 2004 CURT report, are starting to realize that the shift to BIM is necessary. A very real factor is that architects need to use BIM to remain competitive on two fronts. The first is that other architectural firms are beginning to use BIM. The second is that owners, like the GSA, are requiring BIM (Duhnam personal correspondence, July 13, 2006; Rundell personal correspondence, July 13, 2006).

Obstacles to the shift toward BIM. Despite BIM's many strengths, some architects are still resistant to change. According to a 2005 survey, financial risk and interoperability issues are the major BIM obstacles.

Research shows that some architects believe that the risks of switching over to BIM outweigh the rewards. Change costs money. General obstacles are training and interoperability.

A survey done in December 2005 looked at architects' concerns regarding BIM see Table 9 (Bennett, 2000). At that time there were few if any formally BIM-trained employees. Cost drives most of the concerns. Sixty-one percent of concerns fall into the three cost-driven categories of initial cost, training, and cost to implement. The survey

also showed that a shift toward BIM means not only a change in software, but also training employees. In December, 2005, with no formally BIM-trained employees, training was the leading concern for architects shifting toward BIM (Baker, 2006; Birx, 2005). The cost of training includes the training and the loss of billable hours (Haapasalo, 2000). Even with training, employees will face a learning curve in which production will drop (Birx, 2005; Boyd & Fallon, 2003).

Table 9

Leading Concerns toward the BIM Shift from 2005

Concern	Percent
Cost	31%
Interoperability	25%
Training	17%
Cost to implement	13%
Risk outweighs reward	6%

(Baker, 2006)

Architects also feel that by using BIM they will be isolated from their design team. Through this survey, a quarter of architects believe that using BIM will prevent electronic collaboration with contractors and fabricators. The fear is that using BIM will isolate architects more from construction instead of drawing the two practices closer together (Baker, 2006; Bennett, 2000). Ironically, this excuse is one of the reasons BIM proponent use for pushing the adoption of BIM. Some architects using BIM currently have addressed this head-on by mandating that their design team (consultants, engineers,

and contractors) must all use BIM or be eliminated from the design team (Birx, from Wisconsin AIA fall conference, 2006).

Another factor is general resistance to change in the architectural industry (Barron, 2002; Cohen, 2005; Krouse, 2000). This resistance is fueled by fear of a complete digital movement. In Bennett's article, an engineer was quoted as saying, ' "You can make thousands of mistakes with a single keystroke. And it's harder to catch [them]. Unless you're doing some kind of independent check on the thing there's a danger you might not catch subtle ones" '(Bennett, 2000). As with any technology, the ability to solve problems, or to trouble-shoot, is a direct relation to the familiarity with the technology at hand. With BIM programs, the ability to problem solve will increase with more increased use.

Finally, BIM is somewhat limited by the available technology. Currently there are several programs that are capable of creating and storing information within a model. Most of these programs excel at creating an overall model, however there is a known disconnect within the industry once construction details are to be created. There are roughly two ways of creating details. The first is to put all the material connection information into the model, thereby creating a virtual building complete with all details. Though this seems to be the overriding and long-range goal of BIM, this takes time; and time is money. Most do not yet seem able to retrieve the upfront client payments that this would require. This leads to the second way to create details: separate from the model. This goes against the theory of BIM as a complete model of information. However when theory meets praxis, theory often yields.

There are at least two ways of creating details separate from the model. The first is to use the model as a background. In this case, a callout detail is placed on a section. The callout detail is nothing but a shell of a detail. Outlines and areas of materials are shown, but they are not shown with any detail. In order to create the desired level of detail one must access a material library, then choose and place the appropriate materials in the appropriate locations, "over" the background callout. The materials, and the subsequent corresponding annotation, only appear at the detail and not on the model. Another way of creating a detail, and frankly one that many firms are resorting to, is to create details in AutoCAD, completely separate from the model. Both of these methods resort to silos of information that BIM was intended to avoid.

In conclusion, BIM is being increasingly used in architectural design. Owners are the main drivers for BIM use, though contractors are also pushing for BIM. Technology will allow architects to implement BIM. Architects' discomfort with the existing design phases are a parallel catalyst for the shift toward BIM and will ultimately require a change in the design process. However there seems to be resistance to BIM.

WITC and BIM Training

Ultimately, this section concludes with questioning WITC's role as BIM trainer. However, to this end, several intermediary topics are addressed. The first looks at WITC as a whole: its background information, core trends, and core abilities. The second looks at the architectural commercial design program. Specifically, this topic includes program outcomes, preparatory job skill training for entry-level CAD technician jobs, and the curriculum of the program. The third looks at graduates of the program: where they are

employed and what their role is. This section concludes with a return look at the purpose of study by asking the questions relating to WITC's role as BIM trainer.

WITC. Wisconsin Indianhead Technical College is one of 16 technical college districts in Wisconsin and is located in the northwestern quadrant of the state. It is geographically the largest college in the state, encompassing 11 counties. It has four campuses located in Ashland, New Richmond, Rice Lake and Superior. The Rice Lake campus is home to 40 programs including the architectural commercial design program. Programs are one-year diploma, two-year diploma, or associate degree. There are also 34 certificates available at the Rice Lake campus (WITC, 2003-2004).

Every few years WITC identifies core trends and their implications. In 2004-2005, 20 core trends were identified. Four of those are applicable to this study. The core trends are the "awareness" that a trend is occurring and the subsequent implications describe how WITC fits into the trend through either action or reaction (WITC, 2002).

The first core trend is "flexible formats." This trend shows that because there are quicker demands on education to provide new opportunities via courses, programs, etc. that the overall system that allows those changes to take place must be allow for development of courses, programs within a shorter time frame. Typically, curriculum changes take at minimum 10 months to take effect. This trend states that there may need to be a more responsive way to affect change.

The second core trend is "respond quickly to changing trends." This seems to piggyback on the first trend; however the focus is more on education as a means to economic development. This trend acknowledges that industry is driving change within education as education is seen more and more as a return on investment.

The third core trend is "lifelong learning." Another tie in with industry, this trend looks at not only using WITC as a location of continuing education, but also looks at bringing in experts from industry into the classroom.

The last core trend applicable to BIM training and WITC is none other than "rapidly changing technology." This trend acknowledges that because technology is rapidly changes, WITC must be a provider of training. To that end, money will be spent on new technologies and training.

Architectural commercial design. The architectural commercial design program at Wisconsin Indianhead Technical College (WITC) provides training for drafters entering the architectural field. It is a unique program in the Wisconsin Technical College System. There are eight program outcomes for the architectural commercial design program. Program outcomes are core skills that students will have upon graduation. They are as follows,

- Draw and detail buildings.
- Apply construction knowledge to develop working drawings.
- Detail construction connections.
- Research product information.
- Utilize the Wisconsin Enrolled Commercial Building Code.
- Apply a working knowledge of heating, plumbing, electrical, and other mechanical systems within a building.
- Use computer-aided drafting and architectural-related software.
- Explain office practices, standards, and career options.

These program outcomes are incorporated into all of the courses in the architectural commercial design program. The outcomes are a result of a combined effort between the core instructors and the advisory board to keep the program current with industry trends.

The advisory board meets annually and is currently composed of 10 individuals who represent a wide variety of career options, geographic locations, and various levels within their careers. Currently, though not required, all advisory board members are alumni of the architectural commercial design program. The advisory board is the program's link to industry. It is through annual meetings and interspersed email that the program instructors are kept abreast of changes in the industry regarding technology, construction material use, etc. It is also through the advisory board that instructors receive feedback on what employers are looking for in entry-level CAD technicians.

The program is offered on WITC's Rice Lake campus in the northwestern Wisconsin. There are around 10 architectural firms in the northwest Wisconsin chapter of AIA. Most are smaller firms. Few others are larger firms with satellite offices in other cities and states. Rice Lake has an estimated population of 8,320 and is the largest city between Eau Claire and Superior, Wausau to New Richmond.

It is the intent of the architectural commercial design program to provide graduates with the skills necessary to succeed at an entry-level job. Such jobs may be

- CAD Technician
- Architectural Commercial Design Technician
- Civil Drafter
- Commercial Drafter

- Heating and Ventilating Drafter
- Plumbing Drafter
- Shop Drawing/Detail Drafter

Graduates find work at a variety of firms: architectural, engineering, construction manufacturing, design/build, lumberyards, etc.

From 2002 to 2007 there have been 62 graduates. Of those, 21% start their careers in architectural offices (see Table 10). Though it may not be the goal of all graduates to work in architectural offices, architectural offices are more likely to hire graduates with three to five years of experience. This allows for the assumption that the percentage of graduates working in architectural offices increases with the duration elapsed since graduation.

Table 10

Placement upon Graduation from 2002 - 2007

Type of company	Percent of Graduates
Manufacturing	23.2%
Architectural/Engineering	21.4%
Lumber Yards	14.3%
Corporate	12.5%
Transfer to 4-year College	7.1%
Design-build	3.6%
Other	16.1%
Non-related career	1.8%

(Kutrieb, personal conversations with graduates)

Though it may not be the goal of all graduates to work in architectural offices, architectural offices are more likely to hire graduates with three to five years of experience. This allows for the assumption that the percentage of graduates working in architectural offices increases with the duration elapsed since graduation.

Table 11

Placement upon Graduation From 2002 - 2007

Location of employment	Percent of Graduates
Within WITC district	41.1%
Within NW Wisconsin	26.8%
Elsewhere in Wisconsin	21.4%
Out-of-state	10.7%

(Kutrieb, personal conversations with graduates)

Most graduates stay in the northwestern part of Wisconsin. Very few move out of state. Some move to the Minneapolis-St. Paul metropolitan area. Others relocate to the southeastern corner around the Milwaukee and Madison metropolitan areas. Most however, remain in an area from La Crosse to Superior and from Eau Claire to Hudson.

Graduates typically have the opportunity to be promoted from CAD technician to project manager and even architect. Because of the vast knowledge required for promotion opportunities, the program relies on entry-level skills combined with acquired core abilities for student success. Two important skills with relation to this study are the ability to use industry accepted CAD program(s) and the necessity of students to be life-

long learners that enables the learner to have the ability to transfer knowledge from one program to another.

The 2007-2008 curriculum consists of 65 credits. Of those, 42 are considered core credits, with 26 lab or drafting credits. The inclusion of model-based CAD has been has been gradual, starting with elective courses and moving into core courses. Starting in 2002, an independent study course allowed students to explore areas including 3D presentation and model-based software. In 2004, four students explored ADT in this way; in 2005, it was five students.

In 2005, the core curriculum was modified to include a course in model-based CAD. This one-credit Introduction to Architectural Desktop course was included as a third semester core class. Because of this exposure to ADT, only two students chose to further explore ADT in the independent study class (since renamed to Case Studies in Architecture) while four students opted to explore Revit. Students had become interested in Revit after exposure to it at convention expos.

Currently in the architectural commercial design program, students use at least one form of CAD program in each semester of study. AutoCAD is learned in a first semester course and applied in the majority of all lab courses. Architectural Desktop (renamed to AutoCAD Architecture for the 2008 version) is now offered second semester and applied in a third and a fourth semester lab course. The independent study course, renamed to Case Studies in Architecture, which in 2007 only focused on Revit, is offered as an elective in the fourth semester. In 2007, all graduating students opted to take Case Studies in Architecture. In that course, students are expected to both learn and apply

their knowledge within the same semester, ultimately assembling a 6-sheet construction document.

It is the anticipation that students will be able to not only fit into a current CAD work environment, but that they will also be able to apply existing knowledge to future CAD programs. According to many articles and correspondence, Revit will be mainstreamed by 2010.

Chapter III: Methodology

Introduction

The purpose of this study was to evaluate CAD usage and trends among architectural offices in Wisconsin. National research shows there is an industry-wide trend toward using building information modeling (BIM) and model-based CAD (CADDmanager.com, August 2004; CADDmanager.com, February 2005; CADDmanager.com, October 2005; AIA/AGC, January 2006); however WITC is located in an area that traditionally lags behind national trends. As CAD software is used throughout the architectural commercial design program at WITC, keeping abreast of how the architectural industry is using CAD tools is essential for the effectiveness of the program. In this chapter the following topics will be addressed: selection of subjects, instrumentation, data collection and recording, and data processing and analysis.

Selection of subjects

The population for the study was created by referencing the American Institute of Architect (AIA) website, www.aia.org. There were 101 architectural firms listed in Wisconsin at the time of the search. Where there were multiple firms within the state, one location was chosen to receive the survey. This eliminated five firms.

The sample group was created by selecting one person from each architectural firm. It was initially intended that principal architects be selected to fill this role. Principals were chosen because they are the senior architects in a firm and who have ownership in a firm, make purchasing decisions, and have a stake in the future of CAD usage. All of which makes them likely to be fairly knowledgeable and aware of trends

regarding CAD use. In addition, using the principal was a good way to keep the sample group uniformly selected, eliminating personal decisions based on personal communication which could lead to biased decisions.

Some firms with websites listed email contact information for the principals. In this case, one principal was chosen at random to receive the survey. Approximately one third of firms did not have email contacts listed on their websites. In addition, 16 firms did not have a website. In each case, the firm was contact by telephone. During these conversations, it was discovered that the person most connected with a company's software decision-making is not always the principal architect. The job title of the ideal subject varied. There were different reasons for this at each firm. In some offices, the principal architect was not a CAD user and relies on others in the firm to use CAD and make CAD purchasing decisions. For other firms, company size was inadvertently a factor. At some smaller firms where CAD is used, the principal or CAD technician may be a good subject. For mid-sized firms, project managers or CAD managers might make a good subject. In large firms a good subject, is someone who is aware of the company's CAD use as a whole. In this case, perhaps a principal or CAD manager is a good subject. Overall, the ideal candidate was usually a CAD user and had a good understanding of current and future CAD use within the company use CAD during the various design phases. In a few cases, an office manager or secretary's email was used as that person would then direct the email to an available person when it was sent. Therefore, the most appropriate person's name and email were collected, regardless of job function.

After this allowance was made, the remaining companies were called to obtain a direct email address for an ideal participant within each company. By calling all of the

companies and obtaining a direct email for each participant, a higher rate of return was expected. As six were not able to be contacted by email, the survey was sent to 90 companies. Within the sample group, 84% of the emails were sent to a direct person, 16% were sent to a general email list for the company. Of the 90 emails, three were returned undeliverable. Therefore 87 surveys were delivered establishing the size of the sample group.

Instrumentation

The questions derived from the purpose of study are an attempt to pinpoint any shift in the current paradigm of CAD use for drafting in architectural offices in Wisconsin. The architectural commercial design program currently trains students to use various CAD programs: AutoCAD, AutoCAD Architecture, and Revit. By determining first what CAD programs are being used in architectural firms, and by whom, the architectural commercial design program can best align itself with the architectural industry.

In addition, the 2006 AIA/AGC survey findings reported that 75% of all firms were using BIM. Whereas, the survey was unscientific, the findings call to question how CAD or BIM is being used throughout the design phases and for what purpose. Another goal of the survey is to foresee future CAD and BIM use. By analyzing probable BIM use in relation to current CAD/BIM use, the curriculum of the architectural commercial design program can best prepare students for successful placement in the workplace.

The survey was created by the researcher as very few surveys pertaining to the research have been done to date, (CADDmanager.com, August 2004;

CADDmanager.com, February 2005; CADDmanager.com, October 2005; AIA/AGC, January 2006; Kunz, J., Gilligan, B, 2007). The survey was created with the specific intent of researching this topic. Some questions found in other surveys were used only in part, in order to be modified for the specific use of this survey.

The survey was done online and consisted of 17 questions. The survey's layout was designed to make the survey user-friendly and easy to read. To this end, a blue background with white lettering was used to ease eye strain. The survey was limited to 17 questions. Questions were grouped into three sections. Table formats all non-essay questions. The use of tables was mandatory for some questions as it provided a way for more data to be collected within a relatively small space. Tables were then used on all remaining questions to create a uniform appearance.

The type of questions used in the survey varies per section. The three sections were demographics, current CAD/BIM use, and future BIM use.

The demographics section had seven questions. Three of the questions were personal, asking the respondent about gender, age, and job title. Age and job title were also asked as these factors may affect their perception of future BIM use. The remaining four questions dealt with the respondent's company: location, size, and type of client. These were relevant to how a company is currently using software to create drawings, whether or not they are 2D CAD drawings or BIM drawings. Because of the nature of these questions, these were single answer multiple choice questions. An 'other' category was included where appropriate along with adequate space to write in an alternative answer. In addition, all of these questions were used to establish the survey's

generalization and to prove that one demographic either did or did not have a significant impact on the survey results.

The section on current CAD/BIM use had five questions. All of the questions in this section were multiple choice tables. Tables were implemented so that the question would allow the respondent to have answers for each of the five design phase. Listing the design phases consistently as row headers allowed respondents to answer similar questions quickly and easily. The first two questions in this section established whether or not the company uses 2D CAD, BIM, neither, or both for each phase. This was a simple yes/no question set in a table format. As this was a yes/no question, it was easy to understand, and set the stage for how they should answer the remaining questions in the section. For example, if a respondent answered no to 2D CAD use and BIM use for the construction administration phase, then in the remaining questions, no answers should be selected for the construction administration phase. The purpose of these two questions was to establish current software use within each phase and to draw comparisons to future BIM use. The next two questions determined what software is used and by whom is it used. As the lists were not definitive of all software and all job titles an 'other' category was included for these questions along with adequate space to write in an alternative answer. The goal of these two questions is to establish current software use. The aim of the final question in this section was to determine how BIM is being used in each design phase. To that end, this was the only multiple answer, multiple choice table in the survey. Categories for this question were loosely derived from the CIFE and AIA/AGC surveys. Abbreviated terms, such as "productivity tool" and "funding," were used to list the categories. A list of definitions for the terms was located directly below

the table. The definitions helped to clarify the categories allowing for more accurate data.

The section looking at the future of BIM had four questions. The first simply asked whether or not the respondent believes there will be a shift toward BIM. This was done using a basic yes/no question in a table format in order to address the five phases. The next two questions dealt with what the drivers and limiters will be in that shift. Responding to these questions is independent of the previous question as the respondent may believe that there are driving and limiting factors regardless of whether they feel there is a shift toward BIM. These two questions again were in table formats, using a single answer, multiple choice questions. "Other" was a category as not all options were listed. Room was left for an alternative answer to be offered. The last question in this section was an essay question asking the respondent how they see BIM used in five years. The goal of the last two questions was to establish the drivers and limiters of change. The purpose of all questions in this section was to establish future BIM use.

A final essay question, independent of the three sections, asked the respondent to add any additional comments. The purpose of this was to allow the respondent to address any information that may have either been missing, difficult to explain elsewhere. More importantly, however, it gave the respondents a platform to espouse their thoughts and views on the current and future of creating drawings in architectural firms.

A 2X2 matrix format was employed to compare survey questions with the research questions. Research questions were placed on the y-axis. Survey questions were listed on the x-axis. All survey questions were found to employ at least one of the

research questions. Most of the research questions were used multiple times. Two of the survey questions are used to test the survey's generalization.

Table 12

2x2 Matrix of Research Questions to Survey Questions

Survey Questions	Research Questions				
	1	2	3	4	5
1					
2					X
3					
4				X	
5	X				
6	X				
7	X				
8	X	X			X
9	X	X			X
10	X				
11	X				
12		X	X		
13					X
14					X
15				X	X
16				X	X
17					

Data Collection and Recording

An online survey was created that could be accessed from a link on an email. There are advantages and disadvantages to doing this. The advantages are that an online survey is inexpensive and can be completed at the convenience of the respondent. Confidentiality is easy to maintain as the researcher cannot identify a respondent with a set of responses. Anonymity is virtually apparent to researcher and can only be overridden by extensive work. One disadvantage is that the email could possibly be overlooked as junk mail or spam. However, as all the companies were called for their contact information, this was less likely to be a factor. In fact, as all companies were contacted, perhaps this increased the response rate. In the end, the advantages of doing an electronic, emailed survey greatly outweighed the disadvantages.

The survey was created by WITC's research technician, Karla Meier. To do this, requests for approval were submitted and granted from both the researcher's supervisor and WITC's Office of Research and Planning. The survey was placed electronically using Survey Tracker software.

After the survey was developed, it was shared with research advisor, Dr. Howard Lee. A pilot study was conducted to ensure that the questions were clearly stated and that the outcomes were statistically definable. This was done in November 2007 through an email that contained a link to the survey. The pilot group consisted of members of the WITC architectural commercial design advisory board. There was no duplicity between the pilot and the study groups. The study was kept open for two weeks. Eight responses were received. Other than the study results no additional feedback was received from this group. Karla Meier created the code book and the frequencies table. This information

was shared both with Dr. Howard Lee, Dr. Sally Dittloff, instructor at WITC, and Susan Green, associate institutional research, at UW Stout.

Based on these reviews several changes were made to the survey. The intent of all questions was maintained. Wording was modified in several questions to create clarification, enhance respondent understanding, and to increase response rate. Within the demographics section new questions were added that addressed gender, age, firm size, location, and client. For the most part, these were added to establish the generalization of the survey. In a few instances, "other" was added as an option with room to offer an alternative answer.

Additional changes were made in the section on current CAD/BIM use. The piloted question on whether or not they use BIM or CAD was expanded into two separate questions. The new questions provided a good indicator of who uses 2D CAD, BIM, both, or neither for each of the five phases. The other change in this section was to the multiple answer, multiple choice table regarding how BIM is used. The x and y-axis of this table were flipped so the phases were the row headings instead of the column headings. This was important to do in order to increase the response rate and maintain a user-friendly survey, as the adjacent three questions have the phases listed as row headings. One problem did arise after changing the table format. As there were more column headings than before, the table stretched off the screen. This varied according to the computer screen used. Therefore some respondents may have had to scroll to see the full table. However, in the end, this was not seen as a limitation as the options on the right were not found to be selected significantly less than the options on the left. In addition, the definitions for this table were moved from the end of the survey to directly

follow the table. This allowed the respondent to quickly verify the option selected and therefore allowed for more accurate responses.

There was only one modification to the section on future BIM use. A new question was that addressed what is limiting future BIM use. This question was placed directly after a similar question regarding what is driving future BIM use. The new question was single answer, multiple choice with similar options as the preceding question.

The IRB request was submitted and found to be exempt as the survey focused on data collection from architectural firms and not personal questions. All of the respondents were adults.

On May 9, 2008, the survey was sent electronically to 90 architectural firms in Wisconsin as a hyperlink from an email letter. The final survey can be found in Appendix A. The introductory email letter (Appendix B) was developed that invited the sample group to take part in the study. The subject heading read, "Thesis Survey – CAD Use in Wisconsin Architectural Firms." It introduced the researcher and the purpose of study. It included the link to the survey and explained the number of question, approximate time to complete, and date the survey would close. In addition, the selection of the sample group was explained with the hopes of emphasizing the importance of each and every person's response. The IRB exemption was noted along with a statement of confidentiality. The researcher's phone number was given if there were questions or need to clarify questions. The electronic signature included the researcher's WITC job title, address, and phone information.

Three emails were returned undeliverable. Upon doing further research, the emails for those three were correct. The firms had all been contacted in November 2007. The surveys were sent in May 2008. It is possible that in that six month time span that those three firms changed email providers, merged with another company, or disbanded. This leaves 87 people in the sample group.

The survey was open electronically for 10 calendar days. A reminder email (Appendix C) was sent five days before the survey closed. The subject heading was, "Thesis Survey – CAD Use in Wisconsin Architectural Firms – final reminder." The purpose of the reminder was to encourage those who had not yet completed the survey to do so. At the end of 10 days, only 32 responses were received, with a response rate of 36.8%.

After reviewing the response rate with Dr. Howard Lee, it was decided to keep the survey open for another week. Therefore, another email was sent (Appendix D), and the survey was kept open for an additional eight days. The subject heading this time was, "Thesis Survey – final plea." This was a decidedly more informal, more desperate letter. It implored the reader to take the survey as the future of the architectural community in Wisconsin depended on their response. In the letter, 10 more responses were requested. Instead 20 responses were received, for a total of 52 responses or a response rate of 59.8%.

A thank you email (Appendix E) was sent at the close of the survey thanking everyone for their participation. This email also offered the recipients electronic access to the survey upon its completion. To date, 13 have requested the results.

Data was collected electronically using SPSS software. Data was then converted into frequency tables using SPSS as well as into raw data using an Excel spreadsheet. The researcher reviewed the spreadsheet. The original spreadsheet was left unaltered. An additional spreadsheet was created to reflect the recoding that was necessary based on comments provided by the respondent. All modified cells were highlighted in gray to reflect the override. Explanations for all modifications were listed in a separate document.

A research question analysis document was created and was used to cross-reference exactly how research questions could be derived from the survey questions. That document was shared with Susan Greene and served as the basis for the final analysis.

Data processing and analysis

All appropriate descriptive statistics were run on the data to address the research questions.

Limitations of the methodology

1. From the 87 architectural firms who received the email, only 52 responded of a desired 70 responses, leaving a response rate of 60%.
2. Not all architectural commercial design students work at architectural offices. As this varies from year to year, in the past five years approximately 21% have begun their careers at architectural offices. It is important to note,

however, that some architectural offices hire only experienced drafters and that some graduates have since become employed at architectural offices.

3. The survey used to gather data from the architectural offices was created by the researcher. Even though every effort was made to reduce bias, there may be some unconscious motivation that has skewed the questions.
4. The study focuses on BIM. It is possible that another type of software will be developed in the future and become widely used. There are many individuals and companies developing software that may have application to CAD.
5. The study is generalizable only to other architectural programs within the Wisconsin Technical College System as it is focused on the small study of CAD use in Wisconsin architectural offices.
6. The survey was sent in May. As May is a busy time for architects, this may have a negative effect on response rates.

Chapter IV: Results

Introduction

The purpose of this study was to evaluate CAD usage and trends among architectural offices in Wisconsin. As CAD software is used throughout the architectural commercial design program at WITC, keeping abreast of how the architectural industry is using CAD tools is essential for the effectiveness of the program. Two basic topics will be addressed in this chapter: analyses of survey data and analysis of research questions.

Analysis of Survey Data

Ninety surveys were sent electronically. Two were undeliverable. One email was delayed, and then found to be undeliverable. Therefore the following data is based on 87 successfully sent emails. Of those, 52 responded to the survey making a 60% response rate. The following is an analysis of the 17 survey questions. In addition, one respondent chose to not answer most of the questions. Because of this, the total for some questions will be only 51 and a valid percent will be used to accurately reflect the missing response.

Gender (Q1). The first question identified the respondent's gender. Most of the respondents were male at 44 respondents, representing 84.6% of the respondents. Seven, or 13.5%, were female.

Table 13

Please Select Your Gender

Gender	N	Percent
Female	7	13.5%
Male	44	84.6%
Missing	1	1.9%
Total	52	100%

Age (Q2). The next question asked the respondent's age. Ages in the survey were grouped by decades. Over 60% of the respondents were between 40 and 59 years old as each group (40-49 and 50-59) received 16 responses or 30.8% of the sample. The next largest group was the 30-39 year olds with 11 respondents or 21.2% of the sample. The two age groups with the fewest respondents were 60 and over with 5 respondents or 9.6% of the sample, and 20-29 with only 3 respondents or 5.7% of the sample.

Table 14

Please Select Your Age

Age	N	Percent
20-29	3	5.7%
30-39	11	21.2%
40-49	16	30.8%
50-59	16	30.8%
60 and over	5	9.6%
Missing	1	1.9%
Total	52	100%

Which Category Best Describes Your Organization (Q3). The answers to this question were surprising considering the sample group. The sample group was derived from a search on the American Institute of Architect's website (www.aia.org). All of the 90 firms found by using "Wisconsin" as the limiter were selected as a sample group. Of these 90 firms, 56 or 62.2% of the companies have "architect" in the company name of the sample. The remaining 34 firms, or 37.8%, do not have "architect" as a part of the company name.

Table 15

Companies with "Architect" in the Company Name

"Architect" in Company Name	N	Percent
Yes	56	62.2%
No	34	37.8%
Total	90	100%

This is significant because of the results of the question, "Which category best describes your organization?" does not reflect the same result. The survey question listed six choices. The two most selected, "Contractor or Construction Management" and "Environmental Services" had 16 responses each, or 30.8% of the sample. The next most frequent choice was "Civil Engineering" with 11, or 21.2% of the sample. "Governmental Agency" was chosen by five of the respondents, or 9.6% of the sample. Surprisingly last, "Architectural" was selected by only three of the respondents or 5.7% of the sample.

Table 16

Which Category Best Describes Your Organization?

Organization Types	N	Percent
Architectural	3	5.7%
Civil Engineering	11	21.2%
Contractor or Construction Manager	16	30.8%
Environmental Services	16	30.8%
Governmental Agency	5	9.6%
Missing	1	1.9%
Total	51	100%

There are several possible reasons for this dichotomy. It is possible that even though 62.2% of the firms had "architect" in the name, only three of those firms responded. However that would mean that there was not only a 100% response rate from the companies that had "architect" in the name, but also that an additional 18 firms with "architect" in their name responded incorrectly. This is not probable. It could be that the firms don't see themselves as architectural even though they have "architect" in the company name. This may be because respondents answered based on income generated from various clients and chose the most lucrative type of client to describe their organization. Regardless, the next time the survey is administered the question should be rewritten to more clearly reflect the intent on finding out the primary function of the company.

Job Title (Q4). There were five job titles from which to choose. "Principal Architect" was the most selected, as 30 of the respondents, or 57.8% chose "Principal Architect" as their title. Five, or 9.6%, chose "Registered Architect." Five also chose "CAD Manager" as their job title. "Project Manager" and "CAD Technician, Drafter, etc." were each chosen by 4 of the respondents, or 7.7% of the sample. Two respondents, or 3.8% of the sample, chose "Architectural Intern" as their job title. Only one respondent, or 1.9% of the sample, chose "Business Manager." Having the majority of respondents as "Principal Architect" met the survey's goals nicely, based on the decision of how to create the sample group. As there was on missing response, all data is shown as valid percentages.

Table 17

What Best Describes Your Title?

Job Title	N	Percent
Principal Architect	30	57.8%
Registered Architect	5	9.6%
Architectural Intern	2	3.8%
Project Manager	4	7.7%
CAD Technician, Drafter, etc.	4	7.7%
CAD Manager	5	9.6%
Business Manager	1	1.9%
Missing	1	1.9%
Total	52	100%

Office Size (Q5). There were five options to choose from for this question. In addition, for companies with more than one office, the question asked for the number of employees at all locations. Almost three-quarters of the respondents were from firms who employed less than 25 people. Twenty-five respondents, or 49% of the sample, worked in very small firms that employ between one and 10 people. Thirteen respondents, or 25.5% of the sample, work in firms that employ between 11 and 25 people. Six respondents, or 11.8% of the sample, work in firms that employee between 26 and 50 people. Five of the respondents, or 9.8%, work at very large firms employing over 100 employees. Only two respondents, or 3.9% of the sample, work at companies

with 51 to 100 employees. As there was on missing response, all data is shown as valid percentages.

Table 18

How Many People Are Employed at Your Company?

Number of Employees	N	Valid Percent
1-10	25	49.0%
11-20	13	25.5%
26-50	6	11.8%
51-100	2	3.9%
101 ad over	5	9.8%
Total	51	100%

Community Size (Q6). There were five options for the population of the community in which the office is located. Over half of the respondents were from very large cities. Only one respondent was from a very small community. "Over 200,000" was selected by 27 people, or 52.9% of the sample. Next, communities with populations 10,000 to 50,000 had 11 respondents or 21.6% of the sample. There were six respondents each for "50,000 – 100,000" and "100,000 – 200,000" with 11.8% of the sample each. Only one respondent chose "Less than 10,000" for population size for 2.0% of the sample group. As there was on missing response, all data is shown as valid percentages.

Table 19

What Is the Population of the Community Where Your Company Is Located?

Population Size	N	Valid Percent
Less than 10,000	1	2.0%
10,000-50,000	11	21.5%
50,000-100,000	6	11.8%
100,000-200,000	6	11.8%
Over 200,000	27	52.9%
Total	51	100%

Residential or Commercial (Q7). This question asked whether the company's primary clients were residential or commercial. The architectural commercial design program decidedly focuses on commercial design. "Commercial" was chosen by 41 people, or 82% of the sample. Only 9 chose "Residential" for 18% of the sample. Two respondents did not answer, therefore all data is shown as valid percentages.

Table 20

Does Your Company Focus Mainly on Residential or Commercial?

Company's focus	N	Valid Percent
Residential	9	18%
Commercial	41	82%
Total	50	100%

Current 2D CAD and BIM Use per Design Phase (Q8 + Q9). The following two questions asked the respondent if the firm used 2D CAD and BIM for each of the design phases. It must be noted that if a respondent answered "no" to both Question 8 (using 2D CAD) and Question 9 (using BIM), that their response was re-coded as "not applicable" to reflect that the company does not use any form of CAD for those phases. Because of this, the data for the next two questions will be shown in valid percents to include only those companies who use some sort of CAD for a particular phase.

Current 2D CAD Use per Design Phase (Q8). This question was a yes/no table that asked respondents if they used 2D CAD in the five design phases. Of the firms who use CAD, there was no significant difference in how CAD was used in the different phases. On average, 90% of the firms use 2D CAD in all phases. In the schematic design phase, 42 firms use 2D CAD or 89.4% of the sample. 2D CAD use was slightly higher in the design development and construction document phases with 46 firms, or 90.2%. In the construction administration phase 41 firms use 2D CAD, or 89.1%. Only 19 firms used some sort of CAD in the facility management phase. Of the 19 firms, 17 or 32.7% use 2D CAD for facility management. These strong percentages show that 2D CAD is very prevalent if a company is using CAD in any phase.

Table 21

Does Your Company Use 2D CAD Software for the Following Design Phases?

Design Phase	Yes (%)	No (%)	Total
Schematic Design	42 (89.4%)	5 (10.6%)	47 (100%)
Design Development	46 (90.2%)	5 (9.8%)	51 (100%)
Construction Document	46 (90.2%)	5 (9.8%)	51 (100%)
Construction Administration	41 (89.1%)	5 (10.9%)	46 (100%)
Facility Management	17 (89.5%)	2 (10.5%)	19 (100%)
Total	192	22	214

Current BIM Use per Design Phase (Q9). This question was a yes/no table that asked respondents if they used building information modeling (BIM) in the five design phases. Of the companies that use CAD in the various phases, BIM is used most prevalently in the schematic design phase, with 63.8%. BIM is used in the design development and construction document phases fairly equally, with 56.9% and 54.9% respectively. BIM is used by less than half of the respondents for the construction administration and facility management phases. Therefore, BIM use decreases through the phases. In the schematic phase, 30 companies use BIM, or 63.8% of the sample. In the design development phase, 29 companies use BIM, or 56.9% of the sample. In the construction document phase, 28 companies use BIM, or 54.9% of the sample. In the construction administration phase only 19 firms use BIM, or 41.3% of the sample. In the

facility management phase, the number of firms using BIM drops to only eight. However, as there are fewer firms using CAD for facility management, this is still 42.1% of the sample.

Table 22

Does Your Company Use BIM Software for the Following Design Phases?

Design Phase	Yes (%)	No (%)	Total
Schematic Design	30 (63.8%)	17 (36.2%)	47 (100%)
Design Development	29 (56.9%)	22 (43.1%)	51 (100%)
Construction Document	28 (54.9%)	23 (45.1%)	51 (100%)
Construction Administration	19 (41.3%)	27 (58.7%)	46 (100%)
Facility Management	8 (42.1%)	11 (57.9%)	19 (100%)
Total	114	100	214

Type of CAD Software per Design Phase (Q10). This question was a single answer, multiple-choice table that allowed respondents to select the software/program that their company uses most frequently during each of the design phases. It must be noted that this data was re-coded similar to the previous two questions. If a company did not use 2D CAD or BIM for a particular phase, then it was assumed that the company does not use CAD for that phase. For those companies and those phases, data was re-

coded to "not applicable." Therefore the following data is shown in variable percentages limiting the data to describe only firms who use CAD in a particular phase.

Table 23

What is the Most Frequently Used Software/Program for the following Design Phases?

Program	Design Phases, in Frequencies					
	SD	DD	CD	CA	FM	Total
AutoCAD	12 (18%)	15 (23%)	17 (26%)	15(23%)	7 (10%)	66 (32%)
AutoCAD Architecture	7 (13%)	13 (24%)	14 (26%)	13 (24%)	7 (13%)	54 (26%)
Revit	10 (22%)	14 (31%)	11 (24%)	8 (18%)	2 (5%)	45 (22%)
SketchUp	11 (92%)	1 (8%)	0 (0%)	0 (0%)	0 (0%)	12 (6%)
ArchiCAD	2 (22%)	2 (22%)	2 (22%)	2 (22%)	1 (12%)	9 (4%)
Microstation	1 (20%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)	5 (2%)
VectorWorks	1 (25%)	1 (25%)	1 (25%)	1 (25%)	0 (0%)	4 (2%)
Other	3 (23%)	3 (23%)	3 (23%)	3 (23%)	1 (8%)	13 (6%)
Total	47	50	49	43	19	208 (100%)

Forty-seven out of the 52 respondents use CAD software in the schematic design phase. Of those 47, the three most frequently used programs were AutoCAD, Sketch Up, Revit, and. AutoCAD was used by 12 firms, or 25.5% of the sample. SketchUp was used by 11 firms, or 23.4% of the sample. Revit was used by 10 firms, or 21.3% of the sample. Less frequently used is Architectural Desktop (current name is AutoCAD Architecture) which was used by seven firms, or 14.9% of the sample. The three

programs that were least used were ArchiCAD used by two firms, and Microstation and VectorWorks, each used by only one firm.

Table 24

What is the Most Frequently Used Software/Program for the Schematic Design Phase?

Schematic Design	N	Valid Percent
AutoCAD	12	25.5%
ADT (or AutoCAD Architecture)	7	14.9%
Revit	10	21.3%
Sketch Up	11	23.4%
ArchiCAD	2	4.3%
Microstation	1	2.1%
VectorWorks	1	2.1%
Other	3	6.4%
Total	47	100%

Fifty out of the 52 respondents use CAD software in the design development phase. Of those 50, the three most frequently used CAD programs were AutoCAD, Revit, and AutoCAD Architecture. Fifteen companies use AutoCAD, 14 firms use Revit, and 13 firms us ADT. Four other programs are rarely used in the design development phase. ArchiCAD is used by two firms, SketchUp, Microstation, and VectorWorks were used by one firm each.

Table 26

What is the Most Frequently Used Software/Program for the Construction Document Phase?

Construction Document	N	Valid Percent
AutoCAD	17	34.7%
ADT (AutoCAD Architecture)	14	28.6%
Revit	11	22.4%
ArchiCAD	2	4.1%
Microstation	1	2%
VectorWorks	1	2%
Other	3	6.1%
Total	49	100%

As shown in Table 27, 43 out of the 52 respondents use CAD software in the construction administration phase. Of those 43, the two most frequently used CAD programs were AutoCAD and AutoCAD Architecture. AutoCAD was used by 15 firms, and ADT was used by 13 firms. Revit was use fell in this phase as it was only used by eight firms. Three other programs are rarely used in the construction administration phase. ArchiCAD is used by two firms. Microstation and VectorWorks were used by one firm each.

Table 27

What is the Most Frequently Used Software/Program for the Construction Administration Phase?

Construction Administration	N	Valid Percent
AutoCAD	15	34.9%
ADT (AutoCAD Architecture)	13	30.2%
Revit	8	18.6%
ArchiCAD	2	4.7%
Microstation	1	2.3%
Vectorworks	1	2.3%
Other	3	7%
Total	43	100%

As shown in Table 28, fewer architects are involved in the facility management phase, as 33 of the respondents did not answer this question or do not use CAD for this phase. However, of the 19 firms who use CAD, AutoCAD Architecture and AutoCAD are still used the most frequently as seven firms use each. The three rarely used programs are Revit, used by two firms, and ArchiCAD and Microstation, used by one firm each.

Table 28

What is the Most Frequently Used Software/Program for the Facility Management Phase?

Facility Management	N	Valid Percent
AutoCAD	7	36.8%
ADT (AutoCAD Architecture)	7	36.8%
Revit	2	10.5%
ArchiCAD	1	5.3%
Microstation	1	5.3%
Other	1	5.3%
Total	19	100%

Person Using CAD Program (Q11). The next question in the survey asked who most frequently uses the above software/programs for each of the design phases. It is important to note that like the previous few questions, answers were re-coded to "not applicable" if the company showed in Questions 8 and 9 that they did not use CAD in a particular phase. Also this question was asked to determine who most frequently uses the most frequently used CAD program per each phase. It is likely that offices use more than one CAD program in each phase, and that multiple job functions work on various programs in each firm. The following analysis refers to the title of the person who most uses CAD in a particular phase. Percentages noted are valid percentages.

From looking at the overall frequencies by job title in Table 26, architects do most of the work on CAD throughout the project (42.5% of overall CAD work) and their

involvement diminishes throughout the design process. CAD technicians' involvement in a project looks like a bell curve with their involvement peaking in the construction document phase where they are the job title who is most involved with CAD.

Table 29

Who Most Frequently Uses the above Software/Programs in Your Office for the Following Design Phases?

Job Title	Design Phase, Frequency					
	SD	DD	CD	CA	FM	Total (Valid %)
CAD Technician	3	13	22	10	4	52 (24.5%)
Project Manager	4	5	6	7	5	27 (12.7%)
Architect	24	22	14	15	5	90 (42.5%)
Project Architect	15	9	6	8	4	42 (19.8%)
Architectural Intern	1	1	1	3	0	6 (2.8%)
Other	0	1	2	2	0	5 (2.6%)
Total	47	51	51	45	18	212 (100%)

As shown in Table 27, 48 out of the 52 respondents use CAD software in the schematic design phase. Of those 48, architects and principal architects are most instrumental in creating designs using a CAD program. In 25 firms, or 51.1% of the sample, "Architect" was selected. "Principal Architect" was selected by 15 respondents, or 331.9% of the sample. In fact, if combined, their impact on this phase is 83%. "Project

Manager" was each selected by four respondents or 8.5% of the sample. "CAD Technicians" was selected by three respondents or 6.4% of the sample.

Table 30

Who Most Frequently Uses the above Software/Programs in Your Office for the Schematic Design Phase?

Schematic Design	N	Valid Percent
CAD Technician	3	6.4%
Project Manager	4	8.5%
Architect	25	51.1%
Project Architect	15	31.9%
Other	1	2.1%
Total	48	100%

In the design development phase, the CAD work begins to shift to the CAD technicians. Of the 51 firms using CAD, architects are still doing most of the CAD work with CAD in 22 firms, or 43.1% of the sample. At 13 firms, or 25.5% of the sample, CAD technicians were doing most of the CAD work. At 9 firms, or 17.6% of the sample, project architects are doing most of the CAD work. Project managers are doing most of the CAD work at five of the firms, or 9.8% of the sample. Architectural interns do most of the CAD work at only one of the firms, or 2% of the sample.

Table 31

Who Most Frequently Uses the above Software/Programs in Your Office for the Design Development Phase?

Design Development	N	Valid Percent
CAD Technician	13	25.5%
Project Manager	5	9.8%
Architect	22	43.1%
Project Architect	9	17.6%
Architectural Intern	1	2%
Other	1	2%
Total	51	100%

In the construction document phase most of the CAD work is performed by CAD technicians. In 22 of the firms, or 43.1% of the sample, CAD technicians are the ones who do CAD work. Architects, at a distant second, do CAD work in 14 firms, or 27.5% of the sample. Project managers and principal architects each do most of the CAD work in six firms, or 11.8% of the sample. In one firm, or 1.9% of the sample, architectural interns work on CAD.

Table 32

Who Most Frequently Uses the above Software/Programs in Your Office for the Construction Document Phase?

Construction Document	N	Valid Percent
CAD Technician	22	43.1%
Project Manager	6	11.8%
Architect	14	27.5%
Project Architect	6	11.8%
Architectural Intern	1	1.9%
Other	2	3.9%
Total	51	100%

As shown in Table 30, in the construction administration phase architects again use the selected CAD program the most. "Architect" was selected by 15 of the respondents, or 33.3% of the sample. "CAD Technician" was selected by 10, or 22.2%, of the respondents. Project Architects do most of the CAD work in eight firms, or 17.8% of the sample. Principal architects do most of the CAD work in seven firms, or 15.6% of the respondents. Architectural interns do most of the CAD work in three firms, or 6.7% of the sample.

Table 33

Who Most Frequently Uses the above Software/Programs in Your Office for the Construction Administration Phase?

Construction Administration	N	Valid Percent
CAD Technician	10	22.2%
Project Manager	7	15.6%
Architect	15	33.3%
Project Architect	8	17.8%
Architectural Intern	3	6.7%
Other	2	4.4%
Total	45	100%

Like the previous question, most of the firms do not work in the facility management phase, leaving 34 or 65.4% of the firms leaving this question blank or not using CAD in this phase. Because there are so few firms working in the facility management phase, the numbers below are not statistically significant. Table 31 shows that Of the 18 firms using CAD for this phase, project managers and architects most frequently use CAD in five firms each. In four firms each, CAD technicians and project architects use CAD the most.

Table 34

Who Most Frequently Uses the above Software/Programs in Your Office for the Following Design Phases?

Facility Management	N	Valid Percent
CAD Technician	4	22.2%
Project Manager	5	27.8%
Architect	5	27.8%
Project Architect	4	22.2%
Total	18	100%

It should be noted that in the previous tables, there was no separation made between firms who employ CAD technicians and those who do not. From this survey there is no way of telling who employs CAD technicians. This analysis will then look at those firms in which CAD technician was chosen for doing the primary CAD work on the primary software in at least one design phase. This data is more revealing. An overwhelming 92% of companies in this sample have CAD technicians doing most of the work in the construction document phase. CAD technicians are doing most of the work in the design development and construction document phases in a little over half of the firms, 54% and 53% respectively. They are rarely the main drafters in the schematic design phase, with only 14% of the sample. This shows that firms that employ CAD technicians rely on them heavily for most of the CAD work after the schematic design phase.

Table 35

Frequency of CAD Technicians Using the above Software/Programs in the Following Design Phases per Firms Employing CAD Technicians.

Phases	Companies w/ CAD Techs	% Work done by CAD Tech	Valid Percent
Schematic Design	22	3	14%
Design Development	24	13	54%
Construction Document	24	22	92%
Construction Administration	19	10	53%
Facility Management	10	4	40%

In fact, when looking at the entire job titles for this smaller sample, a clearer picture comes into view. For this sample, CAD technicians perform a little over half of the CAD work in all phases. Architects do half as much CAD work. In this sample, project architects and architectural interns do relatively little of the CAD work in any phase. This is perhaps because firms that employ CAD technicians may not employ as many project architects or interns.

Table 36

Who Most Frequently Uses the Software/Programs in Your Office for the Following Design Phases? (Using Smaller Sample of Only Those Who Selected "CAD Technician" for at least One Phase)

Job Title	Design Phase, Frequency					
	SD	DD	CD	CA	FM	Total (%)
CAD Technician	3	13	22	10	4	52 (53%)
Project Manager	3	3	2	4	3	15 (15%)
Architect	12	7	0	2	2	23 (23%)
Project Architect	4	1	0	1	1	7 (7%)
Architectural Intern	0	0	0	2	0	2 (2%)
Total	22	24	24	19	10	99 (100%)

How BIM Is Used per Design Phase (Q12). Finding out how companies are using BIM is integral to the study. This question was a multiple answer, multiple choice question set up in a table format. Respondents were to select the all tasks BIM is used for within their company per each design phase. Since respondents were encouraged to answer multiple times, data for this question is shown in frequencies, and not percentages.

In the schematic design phase, BIM is being used most for helping clients to visualize their project (29 companies) and assisting in the overall design (26 companies). During this phase, BIM is rarely used as a shop drawing tool (one company), for help in scheduling the sequence of construction (two companies), for generating heat loss calculations (four companies), or with doing quantity takeoff studies (five companies).

In the design development phase, the most common reason to use BIM was to discover design options or solutions (25 companies). BIM is also commonly used for client visualization (24 companies), to increase drawing productivity (21 companies), and for resolving potential conflicts with consultants virtually, prior to construction (19 companies). It was rarely used for obtaining funding for a project (six companies), for generating heat loss calculations (six companies), for help in scheduling the sequence of construction (two companies), or as a shop drawing tool (one company).

In the construction document phases using BIM as a way to increase productivity was the most common way BIM was used (23 companies). BIM was also commonly used in this phase for helping to discover design options or solutions (19 companies), for resolving potential conflicts with consultants (18 companies) and contractors (17 companies) virtually, prior to construction, and for generating structural drawings (16 companies. During this phase, BIM is rarely used to generate heat loss calculations (6 companies), as a shop drawing tool (three companies), for help in scheduling the sequence of construction (three companies), or to assist clients to obtain funding (two companies).

In the construction administration phase, BIM it is evident that BIM is used less frequently than in the other phases, as fewer categories were selected with reduced frequencies per category. The most common way BIM is uses in this phase is for resolving potential conflicts with contractors, virtually, prior to construction (17 companies). Next most common is for BIM to be used as a productivity tool (14 companies). During this phase, BIM is rarely used to discover design options or solutions (six companies), client visualization (six companies), to generate structural drawings

(four companies), generating quantity takeoffs (two companies), estimating (two companies), to assist clients to obtain funding (one company), and for help in scheduling the sequence of construction (one companies). No companies used BIM for generating heat loss calculations.

It appears that BIM is rarely used in the facility management phase. The most frequent ways that BIM is used, however, is to increase productivity (4 companies), client visualization (four companies), and for resolving potential conflicts with contractor, virtually, prior to construction (three companies). There was only one selection for each of the following: for help in scheduling the sequence of construction; for resolving potential conflicts with consultants, virtually, prior to construction; estimating; generating quantity takeoffs; and to discover design options or solutions. No company selected the following options: funding, shop drawing tool, HVAC/heat loss, or structural.

Table 37

How BIM Is Used Per Design Phases

Task Used For	Design Phases, Frequency					
	SD	DD	CD	CA	FM	Total
Productivity Tool	17	21	23	14	4	79
Time Scheduling	2	3	3	1	1	10
Client Visualization	29	24	14	6	4	77
Funding	9	6	2	1	0	18
Shop Drawing Tool	1	1	3	10	0	15
Consultant Discussions	13	19	18	10	1	61
Contractor Discussions	8	11	17	17	3	56
Estimating	10	15	13	2	1	41
Quantity Takeoff Studies	5	15	13	2	1	36
HVAC / Heat Loss	4	6	6	0	0	16
Design	26	25	19	6	1	77
Structural	13	16	16	4	0	49
Other	2	2	2	0	0	6
N/A	8	6	9	10	17	50
Total	147	170	158	83	33	591

Key to 'phase' abbreviations:

SD: Schematic design phase
DD: Design development phase
CD: Construction document phase
CA: Construction administration phase
FM: Facility management phase

Shift toward BIM (Q13). The next question is the first in the section on future BIM use. The simple, yes/no question asked the respondents whether or not they see a shift toward BIM in the various design phases. An overwhelming majority of respondents feel that BIM will be used more in all design phases. There doesn't appear to be any significance comparing whether a shift is more anticipated in one phase versus another. In each the schematic design and construction administration phases, 40 or 76.9% of the respondents felt there will be a shift toward BIM. Forty-four respondents, or 84.7% of the sample, believe there will be a shift in the design development phase. Forty-five respondents, or 86.6% of the sample, believe there will be a shift in the construction document phase. Though the least positive responses were received for a shift in the facility management phase, still 32 or 61.6% respondents answered that they see a shift toward BIM.

Table 38

Do You See a Shift toward BIM in the Following Design Phases?

Design Phase	Yes (%)	No (%)	Omit (%)	Total
Schematic Design	40 (76.9%)	11 (21.2%)	1 (1.9%)	52 (100%)
Design Development	44 (84.7%)	6 (11.5%)	2 (3.8%)	52 (100%)
Construction Document	45 (86.6%)	6 (11.5%)	1 (1.9%)	52 (100%)
Construction Administration	40 (76.9%)	8 (15.4%)	4 (7.7%)	52 (100%)
Facility Management	32 (61.6%)	10 (19.2%)	10 (19.2%)	52 (100%)

Drivers of change (Q14). Most respondents feel that the architect's desire to improve return on investment and product was the single greatest driver of the shift toward BIM. Technological advances and clients were seen as the next biggest drivers of change. "Architect Desire to Improve Return on Investment and Product" was selected by 19 respondents, or 36.5% of the sample. "Clients" was selected by 13 respondents, or 25% of the sample. "Technological Advances" was selected by 14 respondents, or 26.9% of the sample. Only three respondents, or 5.8% of the sample, believe contractors are driving the shift toward BIM. Only one respondent, or 1.9% of the sample, believe that consultants are driving the shift. One respondent, or 1.9% of the sample, did not answer. This could be because they do not see a shift.

Table 39

Who or What Is Most Driving the Shift Toward BIM?

Drivers of Change	N	Percent
Clients	13	25%
Contractors	3	5.8%
Consultants	1	1.9%
Technological Advances	14	26.9%
Architect Desire to Improve Return on Investment and Product	19	36.5%
Other	1	1.9%
Missing	1	1.9%
Total	52	100%

Limiters of Change (Q15). The two biggest factors limiters in the shift toward BIM return on investment and training. Twelve respondents, or 23.1% of the sample, feel that companies are not yet seeing BIM providing an adequate return on investment. Eleven respondents, or 21.2% of the sample, feel that existing employees lack training.

Table 40

In General, What is Limiting the Shift to BIM?

Limiters of Change	N	Percent
Clients not Demanding It	5	9.6%
Engineers Not Using It	2	3.8%
Contractors Not Using It	1	1.9%
Consultants Not Using It	1	1.9%
Technological Advances Are Not Where They Need to Be	4	7.7%
Existing Employees Lack Training	11	21.2%
New Hires Lack Experience	1	1.9%
Return on Investment and Productivity Is Not There	12	23.1%
Cost	4	7.7%
Momentum	5	9.6%
Other	3	5.8%
Missing	3	5.8%
Total	52	100%

Perception of BIM Use in Five Years (Q16). The question was, "How do you see BIM used in 5 years?" This was an open-ended question that allowed respondents to write in a short paragraph length answer.

Thirty-nine of the 52 respondents answered this question. This is a huge percentage for an essay question, and perhaps is indicative of the respondents' emotions toward the question.

Of those who answered with regard to amount BIM will be used, most believe that BIM will be the primary design tool in five year. Some feel that it will be used a little more than it is now. Several made comparisons between BIM and AutoCAD. They felt that BIM is at a place where AutoCAD was in the mid-1980s. As AutoCAD has dominated the architectural design field through many add-ons and modifications, it is likely that they feel that as BIM matures it, too, will take on modifications and changes. This includes add-on technology that will enhance the data side of BIM allowing it to be used for such things as code analysis, heat loss analysis, estimating, etc.

Of those who addressed how BIM will be used, the comments were almost tied between four categories: design, productivity, construction document phase, and facility management phase. This seems to indicate that the trend in using BIM will mean that BIM will become more widely used throughout the entire design well into the lifecycle of the building. Interestingly, no one addressed the potential collaboration to manufacturers and fabricators that could occur with BIM in, for example, the construction administration phase.

Of those who addressed drivers of BIM, half mentioned clients. Interestingly, this is different information than was found through Question 14, shown in table 35.

Another interesting discovery was that two of the respondents indicated that they suspect with government clients demanding BIM, that that will create a division between small and large firms as they will presumably be using different CAD software.

Several respondents commented that technological improvements to the software will allow BIM to be more widely used. This includes interoperability and additional data retrieval packages that would allow further building analysis. Others commented on how either contractors will take over how BIM is used, or that contractors will be demanding it to simplify the construction process.

Additional Comments (Q17). This was another open-ended question. This one asked, "Is there any else you would like to add?" Seventeen respondents answered this question. Answers varied widely from a simple, "Help" to many lengthy well-thought out comments. Some respondents feel that there will be other BIM software other than Revit that will allow more BIM functionality. Others stressed the need for standardization in using BIM to allow for interoperability. A couple stressed that BIM is not as user friendly for smaller firms for two reasons: cost of hardware and software and that Revit, a key BIM program, doesn't work well for custom residential. A couple respondents addressed education: that students need to be trained in BIM and that BIM education will be critical in the next few years.

There were a few worried responses. One respondent's comment was, "I've heard some rumbling about BIM, but have no idea what it really is. I suspect this is mainly for larger firms." Other stressed the dire financial implications this will have with this comment, "Firms are going to have to brace for the cost and turmoil BIM is going to cause. It's a nightmare that I expect and no one seems to be talking about!!!"

Analysis of Research Questions

Some of the research questions were analyzed by a pure look at one particular survey question. However, some require cross correlations between survey questions. The remaining research questions are be analyzed at the end of this section

Titles of persons using CAD software in the design phases. The initial research question was, "What CAD software is being used?" However, a more interesting task is to find out who is using what software in what design phase. In the schematic design, 24 firms have architects doing most of the CAD work. Of those 24, architects used the CAD more than any other job title. In six firms or 25%, AutoCAD is used by most architects. Revit used by architects in five firms, or 20.8% of the sample.

Table 41

What CAD Software are Architects using in the Schematic Design Phase?

CAD Software	N	Valid Percent
AutoCAD	6	25%
ADT (AutoCAD Architecture)	2	8.3%
Revit	5	20.8%
SketchUp	8	33.3%
Microstation	1	4.2%
Vectorworks	1	4.2%
Other	1	4.2%
Total	24	100%

In the design development phase, the three most popular CAD programs were AutoCAD, Revit and ADT. Of the 15 companies that use AutoCAD, the top two job titles doing the CAD work were architects and CAD Technicians. Eight firms, or 53.3% of the sample, have architects working on AutoCAD. In four firms, or 26.7% of the sample, AutoCAD is used by CAD technicians. Of the 14 firms using Revit, the top Revit users are CAD technicians and architects. In six firms, or 42.9% of the sample, CAD technicians are working on Revit, whereas in four of the firms, Revit work is done by architects. ADT is used by 13 firms. Of those, seven firms have architects doing the CAD work, and four firms have project architects working on CAD. The CAD technicians' use of Revit is somewhat surprising. As is the architects' reliance on AutoCAD.

Table 42

Who uses AutoCAD, Revit, and ADT in the Design Development Phase?

Job Title	AutoCAD (%)	Revit (%)	ADT(%)
CAD Technician	4 (26.7%)	6 (42.9%)	1 (7.7%)
Project Manager	2 (13.3%)	1 (7.1%)	1 (7.7%)
Architect	8 (53.3%)	4 (28.6%)	7 (53.8%)
Project Architect	0 (0%)	2 (14.3%)	4 (30.8%)
Architectural Intern	1 (6.7%)	0 (0%)	0 (0%)
Other	0 (0%)	1 (6.7%)	0 (0%)
Total	15 (100%)	14 (100%)	13 (100%)

In the construction document phase, the most used software was AutoCAD, followed by ADT and Revit. Twenty-one out of 52 firms have CAD technicians doing most of the CAD work. In other words, 42.9% of the CAD work done in this phase is being done by CAD technicians. Of those 21 firms CAD technicians are using AutoCAD and Revit most prevalently. AutoCAD and Revit were each used by seven firms, or 33.3% of the sample each. ADT was used by five firms, or 23.8% of the sample. VectorWorks was only used by one firm. Another interesting correlation to note is that when Revit was used in this phase, CAD technicians were doing the work 63.6% of the time.

Table 43

What CAD Software are CAD Technicians using in the Construction Document Phase?

CAD Software	N	Valid Percent
AutoCAD	7	33.3%
ADT (AutoCAD Architecture)	5	23.8%
Revit	7	33.3%
VectorWorks	1	4.8%
Other	1	4.8%
Total	21	100%

In the construction administration phase 43 of the 52 firms use some sort of CAD. Of those 43, AutoCAD is used most frequently by 15 firms, or 34.9% of the sample, followed by ADT which is use by 13 firms, or 30.2% of the sample. Revit is a distant third, with eight firms and 18.6% of the sample. The primary CAD work is done by architects in 14 firms, or 32.6% of the sample, followed by CAD technicians in 10 firms or 23.3% of the sample. See Appendix J for cross tabulation of Q10 + Q11.

It is interesting to note that of the 14 firms in which architects do most of the CAD work, five companies, or 50% of the sample use AutoCAD. Of the 10 firms in which CAD technicians do most of the CAD work, the type of software used is fairly evenly distributed between Revit, AutoCAD, and ADT, with Revit used a little more frequently at four firms, or 40% of the sample.

Table 44

Who uses AutoCAD, Revit, and ADT in the Construction Administration Phase?

Job Title	CAD Tech (%)	Architect (%)
AutoCAD	3 (30%)	7 (50%)
ADT	3 (30%)	3 (21.4%)
Revit	4 (40%)	2 (14.3%)
Other Software	0 (0%)	2 (14.3%)
Total	10 (100%)	14 (100%)

Comparison between location of company and BIM use. As WITC is located in northwest Wisconsin and as most of the students obtain jobs in that area and/or in smaller towns and cities, it was important to find out if there was any correlation between population and BIM use. Data from Questions 6 (population) and 9 (BIM use) were cross tabulated. Populations were grouped into two categories: over 200,000 and under 200,000 in order to get a fairly equal distribution. BIM use was divided into two categories as well. The first category marks that the company does not use BIM in any phase. The second marks that the company does BIM in at least one phase.

The results of the cross tabulation show that if a company is located in a town smaller than 200,000, there is a 50% chance that they either will not do BIM or will do some BIM. If a company is located in a city larger than 200,000, there is a two to one chance that the company will be doing BIM for at least one phase. Whereas the data was not statistically significant (Pearsons Chi-Square test = .137), the data is interesting.

Table 45

Is There Any Relation between Location of Company and Whether They Use BIM?

Population	No BIM (%)	BIM (%)	Total (%)
200,000 and under	12 (50%)	12 (50%)	24 (100%)
Over 200,000	8 (29.6%)	19 (61.3%)	27 (100%)
Total	20	31	51

Comparison between company size and BIM use. As most of the graduates for the architectural commercial design program find employment in northwestern Wisconsin and the companies located in that area tend to be smaller, it was important to find out if there was any correlation between company size and BIM use. To do this, data from Questions 5 (company size) and 9 (BIM use) were cross tabulated. Company sizes were grouped into two categories: 10 and less employees and more than 10 employees in order to get a fairly equal distribution. BIM was again divided into two categories as well. The first category marks that the company does not use BIM in any phase. The second marks that the company does BIM in at least one phase.

The results of the cross tabulation show that if a company has 1-10 employees, that there is a 60% chance they will not use BIM. If a company has 11 or more employees, there is 80% chance will be doing BIM for at least one phase. The data was statistically significant as the Pearsons Chi-Square test = .003, which is less than .05. In addition, the correlation is statistically significant by the Phi test as the value was .417 with approximate significance of .003. This tends to indicate that larger firms with more than 11 employees will use BIM.

Table 46

Is There Any Relation between Company Size and Whether They Use BIM?

Number of Employees	No BIM (%)	BIM (%)	Total
1 -10	15 (60%)	10 (40%)	25 (100%)
11+	5 (19.2%)	21 (80.8%)	26 (100%)
Total	20	31	51

Comparison between type of client and BIM use. As the architectural commercial design program focuses on commercial design. Therefore it was important to find out if there was any correlation between type of client (residential or commercial) and BIM use. BIM was again divided into two categories as well. The first category marks that the company does not use BIM in any phase. The second marks that the company does BIM in at least one phase.

The results of the cross tabulation show that if a company mainly did residential work, that there is a 2:1 chance they will not use BIM. If a company does mainly commercial work, there is 65.9% chance they will be doing BIM for at least one phase. The data was not statistically significant as the Pearsons Chi-Square test = .071, which is more than .05.

Table 47

Is There Any Relation between Type of Client and Whether They Use BIM?

Client	No BIM (%)	BIM (%)	Total
Residential	6 (67%)	3 (33%)	9 (100%)
Commercial	14 (34%)	27 (66%)	41 (100%)
Total	20	30	50

BIM and 2D use. Data has been published regarding the number of companies using BIM compared to the number of companies using 2D CAD or a combination of BIM and 2D CAD. In order to create a tabulation, questions 8 (2D CAD use) and 9 (BIM use) were hand tallied by the researcher. Three categories were created. The first was for companies who use 2D CAD for at least one phase and do not use BIM in any phase. The second was for companies who use both 2D CAD and BIM in some phases. The third was for companies who do not use 2D CAD for any phases and use BIM for at least one phase.

The results show that 9.8% of Wisconsin firms are only using BIM. This is similar to other non-scientific nation-wide studies. It is interesting to note that 39.2% of the companies are still only using 2D CAD, and that over half (51%) of the companies are using a mix of 2D CAD and BIM tools.

Table 48

How Are Companies Using CAD and BIM?

Tool	N	Valid Percent
Only 2D CAD	20	39%
2D CAD and BIM	26	51%
Only BIM	5	10%
Total	51	100%

Chapter V: Summary Conclusions and Recommendations

Summary

The purpose of this study was to evaluate CAD usage and trends among architectural offices in Wisconsin. As CAD software is used throughout the architectural commercial design program at WITC, keeping abreast of how the architectural industry is using CAD tools is essential for the effectiveness of the program. Two basic topics will be addressed in this chapter: analyses of survey data and analysis of research questions.

Limitations of the methodology

1. From the 87 architectural firms who received the email, only 52 responded of a desired 70 responses, leaving a response rate of 60%.
2. Not all architectural commercial design students work at architectural offices. As this varies from year to year, in the past five years approximately 21% have begun their careers at architectural offices. It is important to note, however, that some architectural offices hire only experienced drafters and that some graduates have since become employed at architectural offices.
3. The survey used to gather data from the architectural offices was created by the researcher. Even though every effort was made to reduce bias, there may be some unconscious motivation that has skewed the questions.
4. The study focuses on BIM. It is possible that another type of software will be developed in the future and become widely used. There are many individuals and companies developing software that may have application to CAD.

5. The study is generalizable only to other architectural programs within the Wisconsin Technical College System as it is focused on the small study of CAD use in Wisconsin architectural offices.
6. The survey was sent in May. As May is a busy time for architects, this may have a negative effect on response rates.

Conclusions

The following section looks at how the survey findings shown in chapter four relate to the research questions posed in chapter one.

Research Question Number 1: What CAD software is being used? This question is very far reaching. Therefore this question is looked at from many different angles. First of all, the survey found that, like other companies nationwide, that multiple CAD programs are used in individual architectural offices.

According to the Table 23, the three most popular CAD programs are AutoCAD, AutoCAD Architecture, and Revit, listed in order of popularity.

Wisconsin appears to be lagging behind the nation in BIM use. Doing a comparison between an unscientific study done by CADDmanager.com and this study's findings, shown in Table 49, the number of firms using only BIM is 2% higher in Wisconsin. That seems to align with the national average when extrapolating existing data. However, it is interesting to note that the number of firms only using 2D CAD is higher in Wisconsin compared to the national data, and that fewer firms in Wisconsin are using a blending of 2D CAD and BIM. This could be because of the large percentage of

small firms in Wisconsin, compared to the 2005 study whose sample group was presumably CAD managers, who as a general rule are only employed by larger firms.

Table 49

Comparing 2D CAD / BIM Use from 2005 CADDmanager.com Survey to 2008 Thesis.

	2005 (%)	2008 (%)	% change
Only 2D CAD	31%	39%	+8%
2D CAD and BIM	61%	51%	-10%
Only BIM	8%	10%	+2%
Total	100%	100%	

Additionally, BIM is being used by large firms in large communities who work on commercial projects. Also, of the firms surveyed, most of the work is done by architects and only a quarter of the CAD work is done by CAD Technicians.

As suspected from reviewing existing literature, it was found in this study that architectural firms use different CAD programs for specific design phases (Table 23) and presumably specific tasks. Overall, BIM software tends to be used by architects in the first two design phases, and then peters out. However, since the purpose of this study focuses on the education of two-year associate level students, it is important to specifically look at the phases in which CAD technicians are most used. According to Table 29, the greatest share of CAD Technicians' work is done during the construction document phase. During the construction document phase, CAD Technicians use both

AutoCAD and Revit equally. However, they use Revit 11% more than all job titles, including CAD technicians, combined. AutoCAD Architecture is still used quite a bit throughout all phase

Table 50

Comparing CAD programs in Commercial Document Phase Used by Everyone to Those Used Only by CAD Technicians. (Tables 24 and 41)

Phase	Person Using CAD Program, in Percentages		
	Everyone	CAD Techs	Difference
AutoCAD	35%	33%	-2%
ADT (AutoCAD Architecture)	29%	24%	-5%
Revit	22%	33%	+11%
All others	14%	10%	-4%
Total	100%	100%	

Research Question Number 2: How are the five design phases affected by model-based CAD? The 2005/2006 AIA/AGC survey is the only survey done to date that has at BIM use within the various phases. Although the phases from the AIA/AGC study do not directly correspond with the phases in this survey, parallels can be made. Table 51 shows that in 2006, most of the firms were only using BIM for the schematic design phase. After that, BIM use dropped. Two years later, in Wisconsin, BIM use is strong throughout the first three design phases. This is significant because CAD technicians do most of the CAD work in the construction document phase (See Table 32). It can be

assumed that as BIM becomes more widely used in that phase, more CAD technicians will be using BIM.

Table 51

Of BIM User, How is BIM Used in the Design Phases in Wisconsin and Nationally. (Tables 4 and 19)

Design Phase	BIM Use, in Percentages		
	Nationally	Wisconsin	Difference
Schematic Design	98%	97%	-1%
Design Development	34%	94%	+60%
Construction Document	34%	90%	+56%
Construction Administration	34%	61%	+27%
Facility Management	12%	26%	+14%

Research Question Number 3: To what level are they using model based CAD? For example, is it to increase production and efficiency or as a communication tool? According to Phair's definition of BIM as, "...the holy grail of modeling is a single model that is created at the time of a building's inception, built up throughout the design and construction process, and eventually maintained and enhanced." (2002) Wisconsin firms are not using BIM to its full potential. BIM is being used for a number of reasons

in the first three phases of design, but is not used widely in either construction administration or facility management. Some of the findings in the literature review hold true for these finding. For example, as was found in the literature review, BIM in Wisconsin is used for assisting the design process, communication between contractors and consultants. Some benefits of BIM were not addressed in the survey such as quality of drawings and shortening construction times. Other widely found benefits of BIM in this survey were using it as a productivity tool and assisting with client visualization.

Wisconsin firms are not using BIM widely throughout the lifecycle of the building. However this could be because the concept of BIM is fairly immature. Several of the respondents noted that they fully expect BIM to be used more in situations that require additional data-related software that will be able to create estimates, perform code reviews, create heat loss calculations, etc.

Research Question Number 4: What are the drivers behind the implementation of model-based CAD? For example, is it client-driven, production-driven? In this survey, it was found that Wisconsin architects are using BIM for three reasons. The first was to see an increased return on investment. In other words, the reason that they see BIM being used is self-motivated: to make more money and to become more productive and profitable. The second reason listed as a driver for change was the technological advances. Some respondents felt that it was the creation of the technology that is driving the shift toward BIM. Others felt that the distributors and resellers are pushing the use of BIM (Table 39).

In the literature review, clients, or owners, were the primary driver of change. However in this survey, clients were found to be the third driver of change. Perhaps this

is related to company size. Roughly half of the respondents to this survey were working in small firms with less than 11 employees. Small firms tend not to have extremely large government funded projects. For some government work, BIM is being required.

Looking at the obstacles to, or limiters of, change is perhaps just as important as looking at what is driving change. Interestingly enough, the very same thing that is driving change is holding it back: return on investment. It appears that many firms feel that switching to BIM would negatively affect their return on investment (Table 40). Some feel that the learning curve is fairly steep. Others feel that since there is so much BIM can do, that they will end up putting in more work without getting paid more. A good share of the respondents also felt that there were not enough existing employees trained in BIM.

Research Question Number 5: How will model-based CAD be used in 5 years? It is evident from this study and from the literature review that there is a shift toward BIM (See Tables 8 and 38). What needs to be decided is how BIM will be used in five years. It appears from this study that BIM technology is expected to improve to the point that various types of building analysis can be created. Also, architects seem to feel that owners and contractors will be encouraging, if not demanding, BIM. It appears that if BIM is used more throughout the design process that CAD technicians will be more and more involved in BIM (See Tables 35 and 36). As the training obstacle now is occurring with existing employees and not new hires, it is assumed that those who lack training will have received it in the next five years. However, as this is an unfolding field, education will have keep up with the changes in order to best suite the industry.

Recommendations

Most of the recommendations address the use of specific CAD programs within the architectural commercial design program's curriculum. It is not just a simple choice of which software to use. Because of the intricacies of how offices are using software, students must also know the benefits and deterrents of each and be able to determine which should be used when. They must also be able to smoothly use multiple types of programs per project.

1. Software in the curriculum. The survey findings indicate three programs are used most frequently: AutoCAD, Revit, and AutoCAD Architecture. All three are currently used in the architectural commercial design curriculum. It is recommended that the instruction of AutoCAD in the first semester be maintained as it is still the most prevalently used program (see Table 23). A greater percentage of CAD technicians are using Revit than are using ACA (see Table 50). Therefore, Revit instruction should replace the current ACA instruction: Revit should be introduced in the second semester and applied in subsequent semesters. There should be two options within the current Case Studies for Architecture course offered in the fourth semester. The first would focus on ACA. The second would allow advanced study of Revit regarding creation and editing of families.

2. Using multiple CAD platforms. It is obvious from the survey findings that architectural firms use different CAD programs for different phases (see Tables 23 through 28). Therefore it is imperative that architectural commercial design students are able to navigate and interoperate between various CAD programs. In addition, students must be able to use critical thinking to decide which software is best for which task. This

ability should be stressed in all lab courses and should be practiced in the fourth semester Architectural Drafting Studio course. It is in this course when the students work on a community-based service learning project in a team environment. Software choice for various tasks should be integral to the outcome of their projects.

3. Applying CAD software to particular design phases. An indirect finding of the survey was that in office where CAD technicians are employed, the CAD technicians are heavily, and perhaps solely, responsible for work in the design development, construction document, and construction administration phases (see Tables 35 and 36). Therefore, instruction needs to focus on work done in these phases while maintaining an overall knowledge of work done in all phases.

4. Instructor knowledge base. When research began for this paper in 2004, the term BIM was not found in any of the literature reviewed. Soon after, articles and publications were flooded with the term. Now, it appears the discussion is not on what BIM is, but rather how BIM can best be used and developed. Currently there is much discussion on integrated design practice, which will undoubtedly change the work done in the traditional five design phases. In the future, a new tool or process is certain to be looming. Because the tools being used in the architectural field are changing so rapidly, it is imperative that the instructors of the architectural commercial design program keep abreast of new technological developments of tools and processes. This can be done in a number of ways. The first way is to maintain a general knowledge base by keeping current with publications in the form of internet newsletters and publications dealing with BIM and the design process. Second, instructors should attend webcasts, webinars, and

seminars available through software providers or professional associations. Third is to attend additional software training.

5. Continuing education. WITC might consider offering some sort of continuing education course to those currently employed in the architectural field. This possibility would have to be explored more in depth as the following would have to be determined: demand, mode of instruction (online vs. evening vs. summer all day), and topics to be address, etcetera.

6. Repeat the survey. Because we are in changing times, the survey should be repeated either annually or biennially for the next 10 years for a number of reasons. First, it would be interesting to track overall 2D CAD, 2D and BIM, and BIM only use in offices. Wisconsin firms are still rooted in 2D or a combination of 2D and BIM (see Table 49). National data shows that BIM is being used more each year (see table 8), but there is a perception that BIM will be used more frequently in the future (see Table 38). Second, it would be interesting to track any changes in BIM use among smaller firms and firms located in smaller communities. Third, it would be interesting to track any changes in who uses the software and how the software is being used in the various phases. Finally, questions for the survey will have to be modified as new technologies arise.

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Appendix A: CAD Software Survey

CAD Software Survey

Computer-aided drafting (CAD) software is in the Architectural commercial design program used at Wisconsin Indianhead Technical College (WITC). Providing CAD software training that applies to the industry is essential for the effectiveness of the program. National research shows there is an industry-wide trend toward using building information modeling (BIM).

The purpose of this study is to identify CAD software usage and trends in Wisconsin architectural offices. This will be done by studying the use of CAD and BIM in all Wisconsin architectural offices affiliated with American Institute of Architects (AIA).

This project has been reviewed by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46.

1. Please select your gender.

- ○ **Male**
- ○ **Female**

2. Please select your age group.

- ○ **20-29**
- ○ **30-39**
- ○ **40-49**

- ○ 50-59
- ○ 60 and over

3. Which category best describes your organization? (Choose one.)

- ○ Architectural
- ○ Civil Engineering
- ○ Contractor or Construction Management
- ○ Environmental Services
- ○ Governmental Agency
- ○ Surveying
- ○ Structural Engineering
- ○ Other

If Other, please describe your organization.

4. What best describes your title? (Choose one.)

- ○ Principal Architect
- ○ Registered Architect
- ○ Architectural Intern
- ○ Project Manager
- ○ CAD Technician, Drafter, etc.
- ○ Other

If Other, please list your title.

5. How many people are employed at your company? (If your company has more than one office, please include the total number of people employed at all locations).

- ○ 1-10
- ○ 11-25
- ○ 26-50
- ○ 51-100
- ○ 101 and over

6. What is the population of the community where your company is located?

- ○ Less than 10,000
- ○ 10,000-50,000
- ○ 50,000-100,000
- ○ 100,000-200,000
- ○ Over 200,000

7. Does your company focus mainly on residential or commercial?

- ○ Residential
- ○ Commercial

Overall current CAD use:

The next series of questions are about breaking down how different CAD software/programs are used for different phases.

8. Does your company use 2D CAD software for the following design phases?

	Yes	No
Schematic Design	○	○
Design Development	○	○
Construction Document	○	○
Construction Administration	○	○
Facility Management	○	○

9. Does your company use BIM software for the following design phases?

	Yes	No
Schematic Design	○	○
Design Development	○	○
Construction Document	○	○
Construction Administration	○	○
Facility Management	○	◉

10. What is the most frequently used software/program for the following design phases?

	AutoCAD	ADT (AutoCAD Architecture)	Revit (Revit Architecture)	Form Z	Sketch Up	Other
Schematic Design	○	○	○	○	○	○
Design Development	○	○	○	○	○	○
Construction Document	○	○	○	○	○	○
Construction Administration	○	○	○	○	○	○
Facility Management	○	○	○	○	○	○

If Other, please list software and design phase it applies to.

11. Who most frequently uses the above software/programs in your office for the following design phases? (Choose one.)

	CAD Technician	Project Manager	Architect	Principal Architect	Other
Schematic Design	○	○	○	○	○
Design Development	○	○	○	○	○
Construction Document	○	○	○	○	○
Construction Administration	○	○	○	○	○
Facility Management	○	○	○	○	○

If Other, please list who uses the software/programs and in what design phase.

12. How is the BIM used for the following design phases? Only answer for phases for which your company uses BIM. Please scroll to the right to view all options. (Select all that apply.)

Please reference definitions that are located below this table.

	Productivity Tool	Time Scheduling	Client Visualization	Fund-ing	Shop Drawing Tool	Consultant Discussions	Contractor Discussions	Estimatimatng	Quantity Takeoff Studies	HVAC/ Heat Loss	Design	Structural	Other	N/A
Schematic Design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Design Development	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Construction Document	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Construction Administration	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Facility Management	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

If Other, please list how software is used and in what design phase.

LEGEND / DEFINITIONS:

Productivity tool: Using software to speed up drawing time.

Time Scheduling: Using software to schedule the sequence of construction.

Client Visualization Tool: Helping clients to visualize the project via walk-throughs, fly-throughs, and vignettes.

Funding: Helping clients to get funding for their project (from banks, partners, tenents).

Shop Drawing Tool: Using 3D drawing for a reference (and possibly to be electronically shared with manufacturer) for complex shop drawings.

Contractor Discussions: Resolving potential construction conflicts with the contractor virtually, prior to construction.

Consultant Discussions: Resolving potential conflicts with consultants (MEP, etc.) virtually, prior to construction.

Estimating: Using software for generating project estimates.

Quantity Takeoff Studies: Using software for quantity take offs of various materials: finishes, windows, doors, etc.

HVAC/Heat Loss: Using the drafting software for generating heat loss calculations, R-values, etc.

Design: Using software to discover design options/solutions.

Structural: Using software to generate structural drawings (could include the ability to generate loading calculations and dynamic structural components).

Drivers behind change.

13. Do you see a shift toward BIM in the following design phases?

	Yes	No
Schematic Design	○	○
Design Development	○	○
Construction Document	○	○
Construction Administration	○	○
Facility Management	○	○

14. Who or what is most driving the shift toward BIM? (Select one.)

- ○ Clients
- ○ Engineers
- ○ Contractors
- ○ Manufacturers/Fabricators
- ○ Consultants
- ○ Technological Advances
- ○ Existing Training of Employees
- ○ New Hires with Experience with BIM
- ○ Architect Desire to Improve Return on Investment and Productivity
- ○ Other

If Other, please list who or what drives the shift toward BIM.

15. In general, what is limiting the shift to BIM? (Choose one.)

- ○ Clients not demanding it
- ○ Engineers not using it
- ○ Contractors not using it
- ○ Manufacturers/Fabricators not using it
- ○ Consultants not using it
- ○ Technological advances are not where they need to be
- ○ Existing employees lack training
- ○ New hires lack experience
- ○ Return on investment and productivity is not there
- ○ Other

If other, what do you think is limiting the shift to BIM?

16. How do you see BIM used in 5 years?

17. Is there anything else you would like to add?

Thank you for taking the time to respond to this survey.
Please press the submit button below.

Submit | Clear

Appendix B: Cover Letter

May 9, 2008

Greetings! I invite you to take part in the following survey regarding computer-aided drafting (CAD) use.
http://survey.witc.edu/survey/cadsoftw/CADSoftwareSurvey.htm.

I am an instructor in the architectural commercial design program at Wisconsin Indianhead Technical College. I am working on my thesis at University of Wisconsin-Stout entitled "An Analysis of CAD Use in Wisconsin Architectural Offices."

The purpose of this study is to identify CAD software usage and trends in Wisconsin architectural offices. CAD software is used in the architectural commercial design program at WITC. It is essential for the effectiveness of the program to provide training in CAD software that applies to the industry. National research shows there is an industry-wide trend toward using building information modeling (BIM).

The survey is being sent to one person at each architectural firm in the state. Architectural firm names were taken from the AIA website and may not be inclusive of all firms. The project is exempt from review by the Institutional Review Board for the Protection of Human Subjects at UW-Stout. All of your responses to the questions will be confidential, and your responses cannot be identified in any way.

The survey consists of 17 questions and should only take a maximum of 10 minutes to complete. Please, click on the link below. You will be directed to the survey site. **The survey site will close Monday @ 8 a.m. on May 19, 2008.**

If have questions regarding the survey or if you are interested in an electronic copy of the results, please email me at dkutrieb@witc.edu. Thank you in advance for your participation!

Sincerely,

Deb Kutrieb
Architectural commercial design instructor
Wisconsin Indianhead Technical College
dkutrieb@witc.edu

Appendix C: Reminder Letter

Greetings,

Just a friendly reminder to complete the survey for my UW-Stout thesis entitled 'CAD Use in Wisconsin Architectural Firms.' The survey will close at 8 a.m. on Monday, May 19, 2008. So best to complete it before the weekend.

http://survey.witc.edu/survey/cadsoftw/CADSoftwareSurvey.htm

I thank those who have already responded. However, the survey is only as accurate as the number of respondents. It only takes 10 minutes. Please, if you haven't already, take out a little bit of your time today to take part in this statewide study.

If you have any questions, please do not hesitate to email.

Sincerely,

Deb Kutrieb
Instructor, architectural commercial design
Wisconsin Indianhead Technical College
1900 College Drive
Rice Lake, WI 54728
Phone: 715.234.7082 x5219
witc.edu

Real College. Real World. Real You.

Appendix D: Final Reminder Letter

Greetings members of the Wisconsin architectural community,

This is my final plea for survey participants. To date, I have 32 people who have submitted responses. My wholehearted thanks goes out to those 32! However, in order to make this survey completely generalizable, I need at least 10 more respondents.

Educators, like myself, need feedback from you in order to best educate the future members of our architecture community, Your input is valuable no matter who you employ or what software you use. The purpose of this survey is to get a snapshot of how architectural firms are creating designs. Without your view, your facet, your experience, the results will not include you, and woefully the results will not be as complete as they could have been.

So, if you would, please take a little time out of your day to fill out the survey. I dare say it will only take 10 minutes. The survey will remain open through the Memorial weekend.

http://survey.witc.edu/survey/cadsoftw/CADSoftwareSurvey.htm

Sincerely,

Deb Kutrieb
Architectural commercial design instructor
Wisconsin Indianhead Technical College
1900 College Drive
Rice Lake, WI 54868
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dkutrieb@witc.edu

Appendix E: Thank You Letter

Greetings!

Many, many thanks for the whopping 52 responses I received for my thesis survey.

I am in the process of analyzing the data, and it's pretty interesting! So many of you provided in depth comments on the open ended questions, expressing both trepidation toward BIM and a wide-eyed hope for what BIM will offer in the future. How wonderful to have such great feedback!

If you are interested in receiving an electronic version of the thesis complete with survey analysis, please email me.

Have a great and productive summer!

Sincerely,

Deb Kutrieb
Instructor, Architectural commercial design
Wisconsin Indianhead Technical College
1900 College Drive
Rice Lake, WI 54728
Phone: 715.234.7082 x5219
witc.edu

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Appendix F: "Other" Answers for Survey Question 15

15. In general, what is limiting the shift to BIM? (Choose one.)

If other, what do you think is limiting the shift to BIM?

row	**comment**	their number	my number	rationale
48	Although we own a number of Revit licences, we do not feel that it is ready for prime time. I have seen sets produced by other firms in BIM and see shortcomings in its graphic qualities. As the ability to make details look better and easier to understan	10	6	TECHNOLOGICAL ADVANCES
12	It's 'New Hires lack experience', but its not technological experience, it is building experience. Efficient BIM use means you are creating a building model that simulates the constructed building. Without adequate knowledge and experience in the buildi	10	8	NEW HIRES but with a caveat. A distinctive comment.
7	Architectural firm management lacks foresight to clearly understand the benefits. Also there is a sense of investment in office standards they are unwilling to walk away from though most so called standards can be left in place or are assumed and taken c	10	9	ROI
55	We do work primarily on existing structures. As the need/demand requires we would then move toward BIM as our design software.	10	9	ROI – I was torn between client and technological advances, but decided on ROI because I feel if this company saw that it would give them a ROI, they would use

				it regardless of client demand or technological advances.
19	Personal ignorance (mine)	10	10	No change. It doesn't seem to fall into another category.
33	See above.	10	10	No change. The above comment deals with why BIM is used, not on limiatations.
11	Architectural firms not wanting to shift software systems - too expensive	10	11	COST
16	Cost of software conversion and re-training of employees.	10	11	COST
21	Cost to change from BIM from AutoCAD	10	11	COST
52	Up front cost both in terms of software investment and training/downtime along with the overall impact on the schedule. If you are a small firm, the promise of longterm ROI (which may or may not come to fruition given the history) may not be enough to war	10	11	COST
4	Industry's tendency to not want to change...again this is an industry as a whole issue, not attributable to a single factor.	10	12	catch-all for MOMENTUM
6	I beliieve several things are slowing BIM adaptation: lack of training, fear of new technology, perceived difficulty of transitioning, fear of piracy of 'drawings' by others involved with the entire design/construction process, lower productivity expecta	10	12	catch-all for MOMENTUM

32	resistance to change	10	12	catch-all for MOMENTUM
25	I don't believe anything is limiting a move toward BIM. The technology is still relatively new and it takes awhile for any new technology to become pervasive.	nothing	12	catch-all for MOMENTUM
50	It's hard to pick just one because everyone has to move forward relatively at the same time.	10	12	catch-all for MOMENTUM
31	Software is progressing, but not ideal. Training existing employees is one difficulty at the moment.	10	10	If I could divide this response, I'd put half in '6' technology and half in '7' for lack of training for existing employees. Since I can't split the vote, keep it as '10' other.

Appendix G: Short Answers for Survey Question 16

16. How do you see BIM used in 5 years?

13 did not answer, 39 did answer

row	comments
1.	I think the term BIM will be far less prevalent because it will become mainstream and the way everything is done. It will have permeated all sectors of the industry and clients/owners will require it as the default.
2.	I see increase demand coming from owners as design build contractors communicate the advantages with owners.
3.	It will overtake the market by that time.
4.	Every aspect of construction documentation and facilities management. Easier coordination with data based specification programs and code analysis programs.
5.	It will be used start to finish in projects.
6.	BIM today is what CAD was in the mid 80's which is immature and a little ruff. It took time before all of the groups involved in a project were on board and all of the extra efficiencies that came with CAD were there for the groups that were involved. B
7.	I see BIM being a good and valuable product. Right now the software is not as good as it needs/should be. In 5 years it should be a mature software with the bugs worked out of it.
8.	integrating job costing and energy analysis
9.	As the primary design tool
10.	Taken over by contractors.
11.	Hopefully minimize 2d paper
12.	Unfortunate foundation of the industry.
13.	Will replace AutoCad and two-dimensional drafting as we know it.
14.	In 5 years I feel most of the architectural design industry will be using BIM as a design and productivity tool.
15.	We do not use BIM, thus we have yet to formulate an opinion.
16.	As another tool in delivering congent, complete contract documents and monitoring building performance.
17.	it will be the industry standard, much as 2D CAD has been in last 10 years
18.	Government work will require it. THis will further divide the services large and small firms provide.
19.	Same as today, only better software.
20.	Slightly more extensively than now, still concentrated in government and large corporate projects.
21.	As a way to see the building more as a whole and not a 2D detail.

Managing specific products.

Helping the owner visualize the project.

22. I anticipate that it will be the primary application used for design, documentation, and construction. I also expect that there will be more interoperability and integration with other applications than we experienced with CAD (e.g specs, estimating, pro
23.
24.
25. I see the maturing of the stated goals of BIM being more commonplace and accepted. Added to this, I expect that there will be a growth in advanced features pertaining to construction scheduling and 'just in time' design for those willing to be on the edge
26.
27.
28. 100% of our projects. MEP engineers using BIM as software is improved. Structural engineers are already using BIM.
29. industry will still be trying.
30. Don't.
31.
32. Industry standard
33.
34.
35. BIM will replace AutoCAD
36. Becoming more widespread assuming BIM is introduced into an academic structure first
37.
38. Ubiquitous
39.
40. Integrated Porject Delivery

Creation of better and verifiable building performance.

In 10 years? Self designing building systems and components.

41. Industry will push this with techno advances, contractors will desire this to make their work easier...

architects will have to provide, but question whether return on investment...more time, less fees, combined with LEED certification process only makes
42. Using BIM Model as Construction Documents.
43. Our entire office will be using it by this time. I think clients will demand it in order to get a better idea of what their building will look like when completed. I also think it is a much more productive software once you get past the learning curve.
44.
45. Primary deisgn and production tool.

46. I think you will start to see it used more in the next five years as government agencies push towards using it more.
47. It will be the standard in medium to large firms.
48.
49. Nearly exclusively
50. It will be more prevalent but I will not adopt for as long as I can due to the fact that it is a subscription service -once you purchase the software, you need to keep purchasing it to use it...
51.
52.

Appendix I: Short Answers for Survey Question 17

17. Is there anything else you would like to add? 35 did not answer. 17 did.

Q17 Comments

Revit seems to be the preferred software for using BIM. Others will follow. Making the switch from Auto cad architectural desk has a significant learning curve. Student coming out of school need to be trained on both or at the very least introduced to the Firms are going to have to brace for the cost and turmoil BIM is going to cause. It's a nightmare that I expect and no one seems to be talking about!!!

BIM does not currently offer much protection of proprietary information. We give out dwgs converted from BIM to AutoCAD or PDFs but are protective of our models as we have invested a significant amount of time into systems and family model development. Good luck on your thesis.

BIM will be the future as long as there evolves a clean set of standards for all of the players involved. Without this, each Architect, Engineer, Owner, Contractor and anyone else that is involved in this process will create content to their own standard Larger firms will dictate BIM's use; smaller firms will lag due to investment costs.

Not at this time.

BIM does not work for custom residential.....it is too time consuming to develop all the specific style details. BIM brings a lot to Larger Commercial design.

We use BIM software (ARCHICAD) but do not use it in the fashion it is intended for. Our CD's tend to be 99% 2D work. I think you will see a lot of firms modeling with BIM software but not actually use it with all the consultants. Our project timelines

No.

I've heard some rumbling about BIM, but have no idea what it really is...other than what the acronym stands for. I suspect this is mainly for larger firms.

We are finding that staff need to make decisions quicker using BIM. I believe it will be necessary to have more educated and experienced staff inserting design elements into the model at an earlier stage in the design process, rather than using technicia

Made the the shift 5 years ago.

Help!

We started using BIM (Revit) about two years ago and are still working toward getting our entire office to use it. The biggest problem by far is have the needed family content and the cost and knowledge needed to create custom content.

BIM education will be the fastest growing segment in 3 years. *The architectural community will be begging for experienced personnel including 2 year degreed individuals with real life building experience.*

We sometimes feel that architectural drafting software has taken a page from the Microsofts of the world in forcing the industry to continually invest in upgrades that often make marginal (if any) improvement in productivity because they stop supporting

Appendix J: Crosstabulation of Questions 10 and 11 with regard to Construction Document Phase

Q10: Construction Document * Q11: Construction Document Crosstabulation

			Q11: Construction Document						Total
			1	2	3	4	5	6	
Q10: Construction Document	1	Count	7	3	6	0	1	0	17
		% within Q10: Construction Document	41.2%	17.6%	35.3%	.0%	5.9%	.0%	100.0%
		% within Q11: Construction Document	33.3%	50.0%	46.2%	.0%	100.0%	.0%	34.7%
	2	Count	5	3	3	2	0	1	14
		% within Q10: Construction Document	35.7%	21.4%	21.4%	14.3%	.0%	7.1%	100.0%
		% within Q11: Construction Document	23.8%	50.0%	23.1%	33.3%	.0%	50.0%	28.6%
	3	Count	7	0	2	1	0	1	11
		% within Q10: Construction Document	63.6%	.0%	18.2%	9.1%	.0%	9.1%	100.0%
		% within Q11: Construction Document	33.3%	.0%	15.4%	16.7%	.0%	50.0%	22.4%
	6	Count	1	0	1	1	0	0	3
		% within Q10: Construction Document	33.3%	.0%	33.3%	33.3%	.0%	.0%	100.0%
		% within Q11: Construction Document	4.8%	.0%	7.7%	16.7%	.0%	.0%	6.1%
	7	Count	0	0	0	2	0	0	2
		% within Q10: Construction Document	.0%	.0%	.0%	100.0%	.0%	.0%	100.0%
		% within Q11: Construction Document	.0%	.0%	.0%	33.3%	.0%	.0%	4.1%
	8	Count	0	0	1	0	0	0	1
		% within Q10: Construction Document	.0%	.0%	100.0%	.0%	.0%	.0%	100.0%
		% within Q11: Construction Document	.0%	.0%	7.7%	.0%	.0%	.0%	2.0%
	9	Count	1	0	0	0	0	0	1
		% within Q10: Construction Document	100.0%	.0%	.0%	.0%	.0%	.0%	100.0%
		% within Q11: Construction Document	4.8%	.0%	.0%	.0%	.0%	.0%	2.0%
Total		Count	21	6	13	6	1	2	49
		% within Q10: Construction Document	42.9%	12.2%	26.5%	12.2%	2.0%	4.1%	100.0%
		% within Q11: Construction Document	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%