BUILDING INFORMATION MODELING AND SMALL ARCHITECTURAL PRACTICE: AN ANALYSIS OF FACTORS AFFECTING BIM ADOPTION

A Dissertation

by

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ABSTRACT

This research study posits that there are key factors related to architectural firm culture that affect the successful adoption of Building Information Modeling (BIM) at the small architectural firm level. It also posits that in order for small firms to adopt BIM they will be required to shift their firm culture, which is comprised of existing modes of practice as they relate to the people, processes, and technology. BIM represents a large innovation in the AEC industry with many beneficial potentials, but it also represents, as most innovations do, a disruption to an entrenched culture and associated modes of practice.

This study accomplished three goals; it created a data gathering instrument, measured factors affecting BIM adoption at the small firm level in the State of Texas, and by using the instrument analyzed the results and produced recommendations for small firm BIM adoption by employing a mixed methods approach.

Treating BIM as an innovation and following an example method from the literature review, the study used three abstracted variables related to knowledge based practices to quantify perceptions of firm culture in the areas of Human Capital, Relationship Capital, and Structure Capital. A survey instrument was created with fifteen independent variables, five within each abstracted measure, or category, to quantify perceptions of firm culture along with two dependent variables measuring perceptions of successful adoption and difficulty in adoption.

Results indicated strong correlations between specific dimensions of each variable suggesting there are elements of a firm culture that could be reinforced to better position a firm for successful BIM adoption. Results were consistent with the literature with regard to Structure Capital and indicate that firms reporting higher value placed on technology (hardware and software), processes, and training showed the highest level of correlation with successful BIM adoption. The results indicated correlations within dimensions of Human Capital related to complex problem solving and universal buy-in during change initiation. The results also indicated strong correlations within dimensions of Relationship Capital concerning roles of technology in design review processes and active searching for improved process of idea exchange among team members both internal and external.

DEDICATION

This work is dedicated to my family. My father John, without whom I would not have the unwavering tenacity and analytical acumen necessary to succeed. My mother Cindi, without whom I would not have the creative vision and determination to manifest ideas. My sister Katie, without whom I would not know patience. My brother John, without whom I would not know the value of loyalty. Lastly, to my daughter Hannah, without whom I would not know love.

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CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a dissertation committee consisting of co-advisors Professor Mark J. Clayton PhD and Valerian Miranda PhD of the Department of Architecture and Professor Anne Nichols PhD of the Department of Architecture, and Professor Edlemiro Escamilla Jr PhD of the Department of Construction Science.

All other work conducted for this dissertation was completed by the student independently.

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NOMENCLATURE

BIM	Building Information Modeling
AIA	American Institute of Architects
TSA	Texas Society of Architects
TBAE	Texas Board of Architectural Examiners
SBA	Small Business Administration
JBIM	Journal of Building Information Modeling
GSA	General Services Administration
EIT	Engineer in Training
NIBS	National Institute of Building Sciences

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CHAPTER I

INTRODUCTION

Building Information Modeling (BIM) technologies and processes hold great promise for the Architecture/Engineering/Construction (AEC) industry. In order to leverage the benefits promised by BIM many firms are being forced to alter well entrenched business processes, but are doing so without guidelines or a well-defined model.

Over half of professional architectural design services are done in a small firm setting as defined by the Small Business Association (SBA) and most firms retain a "small" status having nine or fewer employees. Additionally, over one third of firms nationwide have reported obtaining BIM software, but the majority of firms reporting using the software is limited to large firms (AIA, 2009). This indicates that architecture firms recognize the value of Building Information Modeling, but implementation and use on projects is most common in larger firms. Whether they are seeking to capitalize through innovation or are just keeping up with methods of design delivery, small firms will shift to BIM. This study posits that certain characteristics of firm culture can position a smaller firm for successful adoption and implementation.

Building Information Modeling is more than just a software shift; it is a cultural shift as well (Autodesk, 2007). Effectively implementing BIM requires a shift in thinking processes, a fundamental shift in business processes, as well as a technological change. Therefore, BIM can be thought of as both a process and a technology—an innovation in both the methods and the products of architectural practice.

An innovation is defined as “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003). Furthermore, Rogers defines an innovation in terms of human behavior as anything that is perceived as new to the unit of adoption regardless of its objective newness. This accepted definition situates this study as an investigation of BIM as an innovation with the unit of analysis being the small architectural firm.

Problem Statement

BIM involves new technologies and requires new processes that are forcing practitioners to redefine their business models (Smith & Tardif, 2009).

BIM technologies and processes are altering modes of practice in architecture and construction and are becoming increasingly more valuable (NIBS, 2016). Each change had opportunities and constraints forcing practitioners to consider altering how they design and deliver buildings. Historically, technological advancements in architecture were limited to increasing production efficiency by various levels of digitization of construction drawings. BIM represents a significant shift in this regard as it is not only a new software, but a new set of processes that are used to “produce, communicate, and analyze building models” (Eastman, Teicholz, Sacks, & Liston, 2008). BIM represents a shift past drawings and move toward integrated building models.

Small firms will need to transition to BIM as it permeates the industry, but they may be unprepared for the accompanying shift in business models and processes. BIM implementation can increase the quality of design services, but it is changing the methods of design delivery. This has a fundamental impact on the design services business model. “By far the most important yet least addressed aspect of implementing BIM is the corresponding change of business practices needed to optimize the opportunity afforded by BIM…”(Smith & Tardif, 2009).

Transitioning to BIM is more than just a shift in the design delivery process, a fundamental change in the tools used, or purchasing new software; it is a social and cultural change as well. It requires a fundamental shift in business culture. “Cultural transformation is a greater challenge to the industry than any technological transformation resulting from BIM.”(Smith & Tardif, 2009).

The problem then becomes identifying the cultural attributes necessary to best position a small firm to adopt BIM with the least amount of difficulty or interruption to the design and production process.

Research Objectives

This study had four central goals:

1. Identify the current state of BIM adoption in small architectural firms and the current perceptions and attitudes toward BIM in the industry.
2. Create an instrument that will quantify the perceptions of firm culture, BIM adoption, and adoption difficulty.
3. Use the data gathered to examine the relationship between the perceived firm culture and the reported perception of successful adoption and difficulty.

4. From the analysis of results create a framework for explaining reported aspects of firm culture and their relationship to adoption and adoption difficulty.

Research Questions and Hypotheses

This study generated a survey instrument that was distributed through the Texas Society of Architects (TSA) to all seventeen component chapters with the goal of addressing four primary research questions:

1. What is the current state of BIM adoption across firms in the State of Texas?
    a. What is the state of BIM adoption in small firms in the State of Texas?
2. What factors of architectural firm culture from the survey instrument had the largest correlation to successful BIM adoption and adoption difficulty?
3. What factors of architecture firm culture from the survey were shared by successful BIM adopters?
4. How can small firms use this information to better position themselves to adopt BIM?

The secondary research questions addressed in an open answer portion of the survey instrument were:

1. What are the general attitudes and perceptions toward BIM in Architecture firms in Texas?
2. Are there common specific factors influencing BIM adoption reported by respondents?
3. Are there common motivating factors affecting the decision to switch to BIM reported by the respondents?

The survey instrument contained fifteen independent variables in three constructs and two dependent variables. Hypotheses regarding the strength of association between the constructs and the dependent variables were formulated from the literature and are:

1. Factors of firm culture related to innovation are expected to show differing degrees of positive correlation with successful adoption and meaningful associations will be derived from the degree of correlation combined with the conceptual explanations of the measured constructs.
2. BIM adoption at the small firm level will show highest positive correlation with factors of firm culture within the construct of Structure Capital
    a. Sub-Hypothesis 2a—Structure Capital will have the most significant correlation with successful BIM adoption.
3. Difficulty in BIM adoption will show negative correlation rates with perceptions of firm culture related to innovation.

Significance and Contributions

Through addressing the research objectives and questions this study created a data gathering instrument focused on investigating aspects of architectural firm culture related to the people, the processes, and the technology. Using an innovation investigation framework from the literature the survey instrument contained fifteen independent variables related to firm culture within three categories of Human Capital, Relationship Capital, and Structure Capital. It also contained two dependent variables of successful BIM adoption and adoption difficulty. In addition, the survey contained open ended questions to gather specific qualitative data regarding BIM adoption as a way to provide a deeper, more detailed measure of the phenomenon in question.

The results are in line with predictions from the literature and indicate that focusing resources on the Structure Capital is important to successful BIM adoption, but they also suggest that focusing resources on the Relationship Capital aspects of firm culture are almost equally as important.

This study establishes a framework for future investigation to focus on specific elements within the categorical variables associated with architectural firm culture relative to innovation adoption.

The conceptual framework of the study operates on the premise that successful BIM adoption with minimal difficulties will be achieved when available resources are allocated to maximize the positive impacts of all three constructs of firm culture: Human Capital, Relationship Capital, and Structure Capital. The framework for BIM adoption produced by the study suggests that successful BIM adoption is most likely to occur when the firm culture places high priority on Structure Capital. Likelihood of successful adoption increases as resources are applied to more than one construct, but is more likely to occur with less disruption when priority is placed evenly on any two constructs simultaneously, particularly if one of those constructs is Structure Capital. For the small firm looking to adopt BIM under the normal business model of minimal effort for maximum return the framework suggests investing resources into Structure Capital and Relationship Capital. This mean focusing on aspects of technology and hardware combined with seeking new coordination processes both internally and externally.

Organization of Dissertation

This dissertation is organized into the following chapters

1. Chapter 1 provides an introduction to the investigation including motivations, goals, primary and secondary research questions, hypotheses and limitations to both reliability and validity.
2. Chapter 2 provides a literature review that defines BIM, situates it as an innovation, and explains the innovation framework used to generate the survey instrument.
3. Chapter 3 provides the methodology for the research design including a description of the survey instrument, the construct validity of independent and dependent variables within the study, and proposed correlation analysis methods employed.
4. Chapter 4 provides a presentation of the data and findings of the correlation analysis. It includes the demographic and descriptive as well as a presentation of the qualitative data in the form of the open answer questions.
5. Chapter 5 provides conclusions from the analysis findings as well as recommendations from the data for small firm BIM adoption and recommendations for further investigation.

Limitations, Reliability and Validity

This investigation employs both qualitative and quantitative research techniques. The unit of analysis of the investigation is an architectural firm, but relies on data from individual respondents to infer qualities upon the unit of analysis.

This study does not seek to establish a causal relationship between the variables in question. It seeks to establish and gauge the strength of relationship between the independent and dependent variables measured and provide conceptual explanations regarding causality. In studies designed to investigate non-causal relationships or those based on people's opinions, expectations, perceptions, or preferences, internal validity is not normally a concern (Schwab, 1999).

External validity is substantiated through the process of construct validation. "Construct validity is present when there is a high correspondence between scores obtained on a measure and the mental definition of the construct it is designed to represent" and the construct validation process follows the outline shown in Figure 1.1 Construct Validation procedure reproduced from Schwab (Schwab, 1999). The conceptual definition and meaning of each construct is explained the methodology section. Each construct is measured on a five point Likert scale. The logical analyses are explained in the results section of the study.

Construct Validation Steps

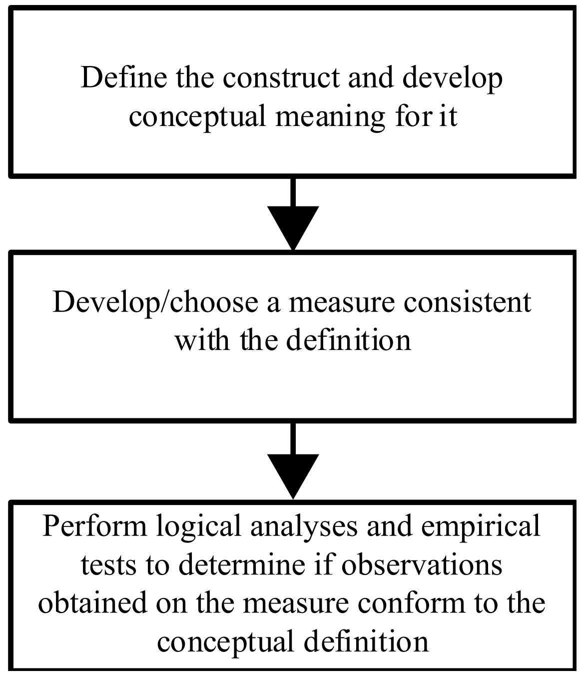

Figure 1.1 Construct Validation Procedure Reproduced from Schwab (Schwab, 1999)

This study addresses internal reliability through a common statistical process known as coefficient alpha, which “provides an estimate of the correlation coefficient that is expected between a summary score from a measure studied” (Schwab, 1999). The coefficient alpha for each construct, it’s variables, and the dependent variables were calculated using a statistical software package SPSS and are provided in the results section.

The survey instrument was distributed to members of the architectural profession through Texas Society of Architects (TSA). In the State of Texas there are seventeen chapters with the TSA and each chapter leader was contacted and asked to distribute the survey to their membership. The survey was not intended to be a random sampling, but instead a blanket sampling of design professionals. Not all questions were answered by all respondents. There were 92 complete responses within the independent variables being measured. Of the approximately 6000 TSA members this represents a 1.5% response rate, which is low for behavior studies research. In terms of academically focused research within the profession of Architecture this response is not terribly low. After discussion with several chapter presidents it was determined that a 2% response rate to surveys conducted within chapter membership is considered very good. The unit of analysis in this study was considered to be architectural firms. At the time of survey distribution there were 2,530 architectural firms registered to practice Architecture with the TBAE in the State of Texas. This represents approximately a 3.6% response rate. For purposes of generalization given the response rate at a confidence level of 95% the confidence interval would be 10. This means that the results are generalizable to the population of Architectural firms in the state of Texas with a 10% margin of error.

Measuring attitudes and perceptions, which are central to innovation adoption, is a very difficult process because they are not consistent across time or individual, which creates potential for errors. This study is considered to be "snap-shot" in time and captures a current state of the phenomenon under investigation.

A further limitation of the survey distribution method is the inability to track which firms were represented. To maintain a level of anonymity respondents were not asked to identify the firm they represented. This means that multiple people from the same firm could have responded to the survey. Given that the instrument was intended to measure an individual's perception of their firm characteristics and derive meaning from those responses this is acceptable. There was no way to ensure that one person did not fill out the survey multiple time, but as the instrument was distributed to a large group of professionals the assumption of ethical behavior is considered acceptable.

CHAPTER II

LITERATURE REVIEW

This chapter outlines the literature sources used to construct the theoretical framework for this investigation. The literature review is divided into three categories:

1. Definitions and concepts of BIM
2. Small firm processes as they relate to managing design production and how they are potentially impacted by BIM adoption
3. BIM adoption studies
4. Principles of innovation and innovation in small professional practices

Definitions of BIM

Building Information Modeling has undergone multiple evolutions since its inception in the 1980's. It has developed alongside computer science and has evolved at similarly rapid rates. The historical development of BIM from Building Product Models (BPM) and object oriented coding to current concepts has been well documented in multiple publications (Eastman, 1992; Kalay, 1989). Eastman describes the underlying idea for BIM and BPM as an effort "to develop an electronic representation/model of a building, in a form capable of supporting all major activities throughout the building lifecycle." (Eastman, 1999). Eastman went on later to define BIM as "modeling technology and associated set of processes to produce, communicate and analyze building models"(Eastman et al., 2008).

As developments in information technology continued to grow researchers began to show the value that these processes and technologies could have on the design and construction industry if the chain of data, knowledge, tools, technologies, and design and construction process were all integrated (Tolman, 1999).

To frame a better understanding of BIM technologies and their potential impact on practice it is useful to compare BIM to Computer Aided Drafting (CAD). CAD is generally accepted to be understood as software that creates precision drawings, illustrations, and 3D models in a digital format. CAD impacted the methods of architectural production by shifting the industry from manual drafting to computer drafting (Guidera, 2002). This shift made one of the skill sets of architectural production, manual drafting, a less profitable method. BIM and its object-based modeling represents a similar shift (Eastman et al., 2008). BIM production methods are more efficient that CAD methods and are thus, through competition, making CAD potentially less profitable. BIM provides value to design firm owners over historical methods of production by allowing design firms to leverage technology to increase profits by reducing project cycle times and increasing value in the delivered objects. (Smith & Tardif, 2009)

At current levels of hardware, software, and process development it is challenging to state an unambiguous and unassailable definition of BIM. Some argue that it should be appropriately coined “Building Information Management”. While the connotations of this may seem appropriate, the fundamental notion is lost and the verb to model, or to create is simply replaced with the verb to manage. This may seem inconsequential, but in fact is the root of the issue. Modeling implies creation and the process of retaining and leveraging structured information as the core value of BIM

(Smith & Tardif, 2009). Leveraging this value requires the generation and utilization of coordinated, consistent, and computable “information” in all phases of the building lifecycle (Clayton et al., 2009).

For purposes of this study BIM, in the scope of Architectural practice, is defined as the technological products (software and IT systems) and processes (computational process performed on analytical information contained in digital objects) combined with appropriate methods of application to create distributable instruments of service.

Small Architectural Firms

The literature suggests that innovation in small firms in the construction industry is markedly different from large firms (Sexton & Barret, 2003). Since architecture firms are generally considered part of the construction industry this sets the context for the small firm as a unique examination. The SBA defines a small business in architecture as one whose annual receipts are less than $7.5 million. According the AIA report in 2008 average net billings were approximately $100,000 per employee. This would mean according to the SBA a small architecture firm would be any organization with 75 employees or less. This does not align with the data presented by the AIA which suggests that over 95% of the firms that classify themselves as small businesses are firms with fewer than 20 employees (AIA, 2009). This definition is supported by Klein in which she defines a small architecture firm “loosely” as any firm with less than 20 employees (Klein, 2010) .

Klein goes on to enumerate three small architectural firm business models: Efficiency, Experienced, and Expertise (Klein, 2010). These three models are fairly comprehensive and summarize how small firms view work flows. The Efficiency model follows a faster, cheaper, better process and usually employs junior and technical staff to do projects that are not complex and have many repeatable elements. The Experienced model relies on an acquired knowledge base to accomplish projects. This firm's business model completes complex projects by applying accrued knowledge and usually employs a mix of junior and technical staff with experienced or educated staff. The Expertise model relies on a specialized knowledge or talent. They often serve as expert consultants and are sometimes considered design stars. Their employee base usually consists of highly experienced staff. For a visual explanation of this see the business model matrix in Figure 2.1 Business Model Matrix reproduced from Klein (Klein, 2010).

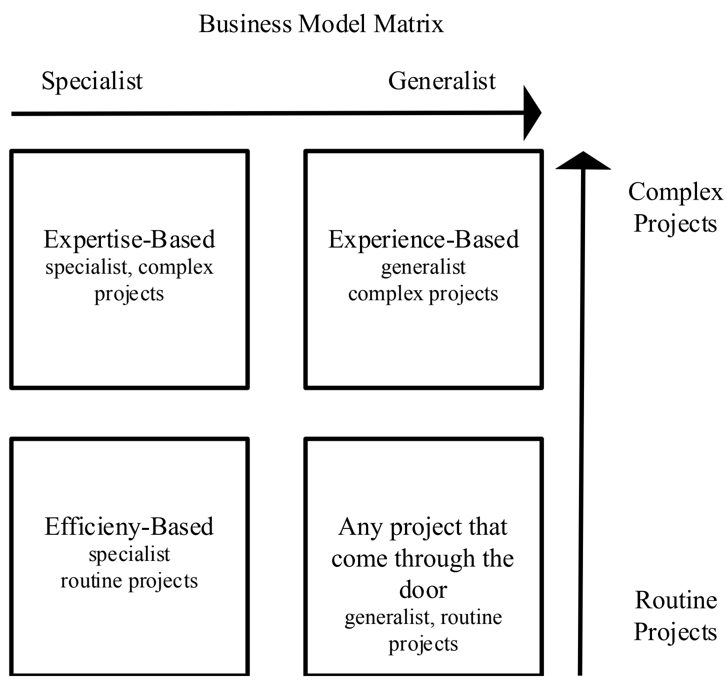

Figure 2.1 Business Model Matrix Reproduced from Klein (Klein, 2010)

This taxonomy of small firm business models is important as each firm type will generate similar workflows to meet production deadlines. Each of these firm types has a different culture and different method of design production, but there will be similarities across firms of the same model. This study posits that firm culture has an effect on BIM adoption and each of these models will adopt BIM differently, but there will be common cultural attributes across firm type.

BIM Adoption Studies

This section presents publications regarding BIM adoption in Architectural firms, their relevance to the study, and point of departure for this study.

In a report titled "Transitioning to BIM" published by Autodesk in 2003 provide recommendations for BIM transition based on a survey of Autodesk Revit users. The key findings of the study were that most respondents were grappling with issues of change in design process and deliverables (Autodesk, 2003). This is consistent with personal experience and other literature sources. This report made several recommendations for a smooth Revit deployment including:

1. Develop a sound, comprehensive implementation strategy
2. Assemble the right team
3. Select a suitable starting project

These recommendations are vague in their presentation, but generally include software training, assembling a BIM team with duties specific to software processes, and selecting an appropriately simple, typical project for transition as this limits the dimensions of learning. Key recommendations include emphasizing the use of templates and document standards, implementing software on actual projects not test projects, and educating team members about the benefits of BIM to combat the natural resistance to change. The summary of the report emphasizes the training issue, but this is not surprising as it is published by a software retailer.

In a white paper published by Autodesk in November 2004 authors Phillip Bernstein FAIA and Jon Pittman AIA cite that "barriers to wider adoption of BIM in the building industry extend well beyond the oft-cited relationships between software applications" (Bernstein, 2004). They go on to posit three interrelated barriers to BIM adoption in the industry:

1. The need for well-defined transactional business process models.
2. The requirement that digital design data be computable.
3. The need for well-developed practical strategies for the purposeful exchange of meaningful information between the many tools applied to industry processes.

The authors are reporting on industry wide adoption, but the concepts remain scalable. These barriers can be abstracted as advocating for well-defined business processes, robust data (digital object) creation, and practical exchange of meaningful information. This would scale to the unit of analysis of this study as defined and understood business processes, trained and knowledgeable staff, and processes for sharing germane project data.

In a Best Practices report disseminated by the AIA in 2007 author Lance Kirby outlines a set of best practices for small firm BIM adoption. This report advocates BIM as a cultural change as well and suggests all firm members contribute to the generation of the plan, but does not list specifics of that plan. Furthermore, much of the article focuses on the importance of technology and having someone who at least recognizes there will be a new system in place if not a dedicated CAD or manager or network administrator. The author does reinforce the importance of dedicated training over lunch and learns or hour long blocks of training. They advise that one not let the "specter" of a loss of billable hours keep the firm from committing time to training (Kirby, 2007).

Diane Bender published an article in JBIM Spring 2010 titled "Implementing Building Information Modeling in the top 100 Architecture Firms". In this article the results of a survey distributed to the top 100 Architecture firms as recognized by Architectural Record in 2008 were evaluated. It was focused on large firms, but stresses the same salient points: developing a strategy, starting with a known project type, assembling the right team, and educating senior leadership to combat resistance to change. The author also notes that BIM affects more than just technology. It is a change to "the design process, business practices, and means of collaboration with other stake holders" (Bender, 2010).

An article published in Automation in Construction in January of 2010 two authors report the findings of focus group interviews done about BIM adoption in the AEC industry in Australia. The study focused on the people, processes, and technology related to BIM adoption. The results of the study cite that technical aspects or a lack of practical knowledge in applying technologies was the main focus of the discussions. In the process area the major problems in adoption centered around a lack of knowledge about how BIM fit into current modes of practice. The people section of the study showed a general lack of awareness of BIM as an issue. The overall results of the study showed that there was a general lack of clarity on how BIM could be integrated into current business practices (Ning Gu, January 2010).

In another article out of Australia authors Yougsoo Jung and Mihee Joe created a framework for BIM implementation from an exhaustive literature review that focused on a detailed examination of the role of BIM in a project lifecycle through different dimensions of three constructs of ‘BIM Technology’, ‘BIM Perspective’, and ‘Construction Business Functions’. This study produced results that indicate Managerial issues in construction information systems showed more influence than technology issues, that maximizing the benefits of BIM requires the development of reasoning with embedded knowledge, and that implementation strategies and policies are necessary for successful BIM adoption (Youngsoo Jung, 2011).

In an article published in Design Intelligence in May/June of 2010 authors Charles Matta and Calvin Kam report the experiences of the GSA, the federal equivalent of a private sector owner/developer of commercial real estate, as they explored the benefits of BIM. The authors recommend a balance between six key points to be central to a strategic adoption plan:

1. Vision and value proposition
2. Insights and demonstrated evidences from pilot projects
3. Culture for constructive change that is shared across the organization
4. Training
5. Establish processes and partnering

6. Technology and alignment with proven and emerging software, scalable hardware, and infrastructure, as well as open standards

In this article the authors stressed the importance of the Human Capital or investing in the employees of an organization. This includes training and education on the applications and benefits of BIM. The most salient point of the report was that the authors state that “the cultural transformation of an owner organization’s human capital is key to successful BIM adoption” (Kam, 2010).

Innovation Studies

An innovation is defined as an idea, a practice, or an object that is perceived as new by an individual or unit of adoption regardless of its objective newness and that perceived newness will determine the reaction to it (Rogers, 2003). This is a crucial definition for this study. It implies that regardless of how long something has been in existence when someone first discovers it, it is new to them and their reaction will be the same. This establishes a common connection to the reaction as what can cause problems in the diffusion or adoption of the innovation. What affects that reaction most is the culture, or surrounding set of attitudes and beliefs that are characteristic of a particular social group or organization. This establishes the culture at the time when the innovation was introduced as potentially the most important factor in the measure of its adoption.

A succinct definition of innovation is taken from Lu & Sexton as “The effective generation and implementation of a new idea which enhances over all organizational performance, through appropriate exploitative and explorative knowledge capital which develops and integrates relationship capital, structure capital, and human capital” (Lu &

Sexton, 2009). Lu and Sexton's work provided a theoretical framework for evaluating innovation in small professional practices. Lu and Sexton's work was integral to this investigation as it outlined an innovation framework unique to small professional practices. The authors cited four principal characteristics of professional services from an extensive review of relevant literature:

1. Professional services are knowledge-intensive in nature.
2. Professional services are delivered by professional/knowledge workers.
3. Professional services are nonetheless co-produced between the knowledge worker and the client.
4. The majority of construction professional practices are provided by small firms.

Lu and Sexton outline two existing frameworks for innovation—resource based and market based. Through an analysis of a small professional practice they create a framework for a third type of innovation—knowledge based innovation. Knowledge based innovation is defined as "the effective generation and implementation of a new idea which enhances over all organizational performance, through appropriate exploitative and explorative knowledge capital which develops and integrates relationship capital, structure capital, and human capital." (Lu & Sexton, 2009).

This investigation approaches BIM adoption as a knowledge based innovation, which, according to the framework, occurs with the development and integration of Human Capital, Structure Capital, and Relationship Capital. This investigation applies a more specific definition to each one of these with regard to architecture firms and BIM. The definitions of each according to Lu and Sexton are listed:

- Human Capital (HC) – “is defined as the capabilities and motivation of the individuals within the small construction professional practices, client systems and external supply chain partners to perform productive, professional work in a wide variety of situations.”
- Relationship Capital (RC) – “is the network resources of a firm. It results from interactions between individual, organization, and external supply chain partners, including reputation or image. Relationship capital is the means to leverage human capital.”
- Structure Capital (SC) – “is made up of systems and processes (such as company strategies, machines, tools, work routines and administrative systems) for codifying and storing knowledge from individual, organization and external supply chain partners.”

Summation and Point of Departure

There are common themes that emerged through these definitions of BIM, studies and reports on BIM adoption, and references regarding innovation and innovation adoption. The focus of the BIM adoption literature started with investigating issues of technology. As that was not sufficient to explain or develop necessary strategies, studies began to focus on the processes and the people involved, culminating in identifying Human Capital as the key to successful BIM adoption. This stands in contrast to the study on small firm innovation done by Lu and Sexton as they identified Structure Capital as key to small firm innovation (Lu & Sexton, 2009). This could be explained by understanding that their extensive study focused on professional practices in construction and dealt primarily with technology in general; the BIM adoption reports dealt specifically with BIM technologies and processes. Nevertheless, these sources create a clear chain of investigations that this study continues.

Based on the definition of innovation and the importance of the culture that surrounds a unit of analysis at the time of adoption, this study was built upon the premise that a firm culture has a direct effect on the BIM adoption process and it's perceived difficulty.

Using the capital constructs provided by Lu and Sexton, a narrowed definition of each was generated based on the review of the BIM adoption literature.

Human Capital (HC)—BIM adoption— quantifies the capabilities and motivations of the individual, but focuses on how the firm cultivates and deals with individual employees.

Structure Capital (SC)—BIM adoption—is focused on the systems, softwares, tools and processes the company uses to create, store, and share knowledge.

Relationship Capital (RC)—BIM adoption—Includes both internal and external relationships. Internal relationships are those between individual workers and workers and their managers, or internal hierarchy. External relationships are those between workers and clients, consultants, contractors, and any other entity external to the company.

Using these constructs a survey instrument was developed with items quantifying five dimensions of each construct along with two independent variables. The construction of this instrument is explained in the next chapter.

CHAPTER III

METHODOLOGY

This chapter consists of three parts.

1. An explanation of the quantitative and qualitative methodologies employed in the study, the hypotheses and research questions asked, and the statistical methods used to analyze the data.
2. An explanation of the survey instrument, its construction, its content, and the construct validity of the contents.
3. Description of the survey deployment

Quantitative and Qualitative Methodologies

This study employed mixed methods approach in which both qualitative and quantitative data was gathered from a survey instrument. A survey instrument is used to gather numeric or quantitative description of trends, attitudes, or opinions of a population by studying a sample of that population (Creswell, 2003). Additionally, the survey gathered answers to opened ended questions related to the phenomenon under study. The open ended questions represent the qualitative portion of the study and were used to provide deeper insight into the relationships and their strengths produced by the statistical analysis.

The survey instrument was constructed of a series of questions and statements. The questions were used to gather demographic data and are straightforward in their nature. The instrument items used to measure the independent and dependent variables in this study were constructed on a summated scale, in which respondents were asked to express their level of agreement or disagreement with statements involving the constructs under investigation. This study employs a Likert Scale, which is the most common form of this summated scale of measurement (Emory & Cooper, 1991).

Likert Data is data collected on individual measures of variables, while Likert Scale Data are amalgamations of at least five Likert Data measures (Boone & Boone, 2012). There is debate in the literature as to whether Likert data and Likert Scale Data can be analyzed as ordinal or interval and whether or not the associated parametric or non-parametric analyses have an effect on the interpretation of the results (Murray, 2013). Due to Likert data being, at its base, ordinal, the main point of contention is that parametric analyses such as regression models are not as robust as non-parametric models such as Pearson and Spearman correlations. This argument has become somewhat academic and non-relevant as it has been shown that parametric measures are just as robust as non-parametric methods in the analysis of ordinal Likert scale data (Norman, 2010). This study has 15 Likert Data items (the independent variables) grouped into five Likert Scale data groups and uses non-parametric methods on individual correlations within the Likert data to describe the relationships between X (independent variables) and Y (dependent variables). Those results are then compared and contrasted to the results of the parametric methods performed on the Likert Scale Data, which was used to examine the relationships between the five scales (HC, SC, RC) and the dependent variables under investigation.

Analysis of the ordinal data was used to determine correlations and strength between them (Emory & Cooper, 1991). As this study was interested in non-causal relationships between the independent and dependent variables, because they are associated with opinions, experiences, and preferences, the statistical generalizations between the data were more important and more probable to obtain accurately than causal relationships. The study used SPSS, a standard statistical software, to produce descriptive statistics and non-parametric tests of mean, standard deviation, and Pearson correlation on the Likert Data. It used parametric tests of simple linear regression on the Likert Scale Data.

This study examined the relationship between characteristics of firm culture and the perceptions of successful BIM adoption and used the following directional hypotheses:

1. Factors of firm culture are expected to show positive correlation with successful adoption and meaningful associations will be derived from relative degree of correlation.
2. BIM adoption at the small firm level will have highest positive correlation with factors of firm culture within the construct of Structure Capital.
    a. Sub-Hypothesis 2a. Structure Capital will have the most significant correlation with successful BIM adoption at the small firm level.
3. Difficulty in BIM adoption will show negative correlation rates with perceptions of firm culture related to innovation.

Survey Instrument

The survey instrument consisted of 45 items in the following categories:

1. Demographic Information

2. Independent Variables
3. Dependent Variables
4. Control Variables
5. Qualitative or Open answer

In each section below the survey item is shown as it was presented to respondents.

Demographic Information

The intent of the demographic questions was to define the size and scope of the firm that each respondent represented and were phrased as questions. The questions and their answer options are:

1. How many people are employed in the firm?

1. (1) 2. (2-3) 3. (4-6) 4. (7-10) 5. (11-15) 6. (16+)

2. What is the annual construction dollar value of projects (in millions)?

1. (<1) 2. (1-3) 3. (3-6) 4. (6-10) 5. (10-15) 6. (15+)

3. Which term best describes your role in the firm?

1. (Drafter) 2. (Intern) 3. (Project Manager) 4. (Intern Architect) 5. (EIT) 6. (Architect) 7. (Engineer) 8. (Principal)

4. Are you a registered Architect or Engineer?

1.(Yes) 2. (No)

5. What type of professional services does your firm provide?

1. (Architectural) 2. (Engineering) 3. (both) 4. (Other)

6. How many years has the firm operated under the current leadership?

1.(1) 2. (2-3) 3. (4-6) 4. (7-10) 5. (11-15) 6. (16+)

7. Does the firm specialize in a particular architectural type such as commercial, educational, or healthcare?

1.(yes) *2. (no)*

If so, what type?

Independent and Dependent Variables

In these sections of the instrument respondents were asked to rate their level of agreement with statements based on a 5 point Likert Scale. Each statement was followed by the 5 point Likert Scale shown in Figure 3.1.

5 Point Likert Scale Construction

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Figure 3.1 5 Point Likert Scale Construction

Independent Variables of Human Capital

These statements reflect measures of the construct Human Capital. This construct is a quantification of the human factors within BIM as an innovation. The measures are:

8. (HC 01) The Firm encourages initiative in developing new solutions or processes.

9. (HC 02) The Firm has senior management that exhibits decisive leadership.

10. (HC 03) When the Firm initiates an innovation or change all employees are included in the decision process.

11. (HC 04) When the Firm initiates a change buy-in by all members is quickly achieved.

12. (HC 05) The Firm places a high priority on professional development with regard to tools and knowledge.

Independent Variables of Structure Capital

These statements reflect measures of the construct of Structure Capital. This construct is a quantification of the technologies, both hardware and software, within BIM as an innovation. The measures are:

13. (SC 01) Employees of the firm are provided extensive software training.

14. (SC 02) The Firm places a high priority on maintaining up to date technology of both hardware and software.

15. (SC 03) The use of software plays a pivotal role in the Firm's design process.

16. (SC 04) Workflows, or the systems by which the work gets finished, are clearly understood by the Firm.

17. (SC 05) The Firm makes extensive use of libraries, standards, and web resources.

Independent Variables of Relationship Capital

These statements reflect measures of the construct of Relationship Capital. This construct is a quantification of the relationships, or processes within BIM as an innovation. The measures are:

18. (RC 01) The Firm actively searches for a better process of communicating design ideas/solutions to clients.

19. (RC 02) The Firm actively searches for a better process of exchanging design ideas with team members.

20. (RC 03) The Firm actively searches for a better consultant coordination process.

21. (RC 04) The use of technology plays a pivotal role in the Firm's consultant coordination process.

22. (RC 05) The use of technology plays a pivotal role in the Firm's design review process.

Dependent Variables of BIM Adoption

The dependent variables in this study were used to measure perceptions of successful BIM adoption and difficulty in BIM adoption and the measures are:

23. (D 01) This Firm has successfully transitioned to a Building Information Modeling (BIM) platform.

24. (D 02) The adoption of BIM by the firm was difficult.

Control Variables

The control variables in this study were used to determine general demographics of the survey respondents with regard to BIM knowledge, perception, and methods. Additionally, they were used to collect and sort responses by opinions and perceptions of specific factors related to attributes of innovation and teamwork. These statements quantify perceptions related to cost, complexity, reasons for adoption, and time spent in adoption. The measures are:

25. (C 01) BIM Software is extremely costly.

26. (C 02) BIM is overly complex and ill-suited for the type of work of the Firm.

27. (C 03) The Firm employs BIM methods only when they are required by the client, consultant, or market.

28. (C 04) The firm shifted to BIM because a client requested/required it.

29. (C 05) The transition to BIM occurred over an extended period of time, training a few employees at a time.

30. (KC 01) The Firm has an exemplary project delivery process that is clearly communicated to all its members.

31. (KC 02) The Firm is a close-knit community, like a second family, in which the sharing of ideas and experiences is encouraged.

32. (KC 3) It is clearly understood and communicated in the Firm that both successes and failures are the result of team efforts.

33. (KC 04) It is clear who is charge of any given project or issue in the Firm.

34. (KC 05) Employees are encouraged to interact and learn from one another in the Firm.

35. (KC 06) The Firm works hard to cultivate a team spirit.

36. (P 01) This firm is very satisfied with a computer aided drafting (CAD) based delivery method.

37. (P 02) Building Information Modeling (BIM) is just another 3D drafting software.

38. (P 03) Building Information Modeling (BIM) is a method that integrates a software and process.

Qualitative Open Answer Items

The questions in this portion of the instrument were used to gather qualitative data specific to BIM adoption by respondent. It gave respondents an opportunity to share any specific issues they felt germane to BIM or BIM adoption. The data gathered in this section was used to form a deeper view of the issue under investigation. The questions are:

39. (O 1) If you believe there were any unique or important factors that influenced the Firm's decision to switch to BIM please take a moment to describe them.

40. (O 2) If you believe there are any unique or important reasons why the firm has not shifted to BIM please take a moment to describe them.

41. (O 3) If you believe there were any unique or important factors that contributed to the success of the Firm's BIM transition please take a moment to describe them.

42. (O 4) If you believe there were any important factors that contributed to the difficulty or failure of the Firm's BIM transition please take a moment to describe them.

Industry Related Items

The questions in this section were asked to gather industry related information such as interest in Continuing Education Courses regarding BIM adoption as well as questions related to consulting services in order to assess perceptions of value related to BIM and BIM adoption. The questions are:

43. (IR 01) If consulting services were available for transitioning to BIM, would you be interested?

44. (IR 02) If Continuing Education Courses were offered that directly dealt with transitioning a firm to BIM would you be interested and would you be willing to pay for such courses?

45. (IR 03) If you would be willing to conduct a follow-up interview about your firm's BIM experience or BIM transition process please provide your name and contact information. This information will in no way be tied to the answers you provided in this survey. Thank you for your time.

45. (IR 04) If you are an architect located in the State of Texas, with which TSA Chapter are you affiliated?

Construct Validity

This study gathered measures on five independent variables in three constructs related to the culture of an architectural firm. In order to produce a valid study of these constructs it is essential to conceptually define the constructs in terms of its construct domain and nomological network (Schwab, 1999). This section conceptually explains the three constructs under investigation and each of the five factors within them with regard to their construct domain and nomological network.

Construct domain is essentially defined as the meaning of the construct as well as a conceptual explanation of what the study aimed at quantifying. The nomological network of a construct is an explanation of how the construct should differ across measurements and conditions as well as how it relates to other constructs in a broader network of relationships. This information can then be used to draw inferences about the constructs and their validity (Schwab, 1999).

Human Capital Construct Validity

Human Capital is defined as "the capabilities and motivation of the individuals within the small construction professional practices, client systems and external supply chain partners to perform productive, professional work in a wide variety of situations." (Lu & Sexton, 2009). This study narrowly defines Human capital with a specific relation to BIM in a firm setting as the capabilities and motivations of the individual, with a focus on how the firm cultivates and deals with individual employees. This definition is situated in the culture of firm by examining how an employee believes the firm values them personally with regard to the contributions of their knowledge, skills, and attributes. A firm that creates a culture where individuals feel valued for their contributions is more likely to approach the challenges of an innovation adoption such as BIM with a much higher degree of tenacity and resolve. Furthermore, employees of the firm that believe the firm has an interest in their professional development, and thus their future, are more likely to invest additional effort into learning something that may be a disruption to their normal, or previously learned processes. Measures of Human Capital are expected to be a reflection of the firm culture that can change over time with changes in leadership and individual perceptions of leadership decisions. High measures of human capital are inferred to be reflective of a firm that shows a level of trust and commitment in its employees because it believes in them and their individual capabilities and potentials.

(HC 01) The Firm encourages initiative in developing new solutions or processes. This dimension of Human Capital measures an individual's perception of the firm's dedication to individual innovation. If an employee is encouraged to find new solutions to processes or problems, then they are expected to feel trusted and valued and will report high agreement with this statement. Employees who are not allowed this latitude may feel stifled and restricted and thus are expected report low agreement with this statement.

(HC 02) The Firm has senior management that exhibits decisive leadership. This dimension of Human Capital measures an individual's perception of the leadership within the firm. A firm with decisive leadership is expected to see the value proposition provided by an innovation such as BIM and push employees toward adoption despite perceived challenges and difficulties. The framing of this question does not put a qualitative measure on leadership such as "good" or "bad", which could be a threat to its validity as the perception of bad decisive leadership could be just as damaging during an innovation adoption as perceptions of good decisive leadership. Nevertheless, the

perception of decisive firm leadership is expected to play positive role in innovation adoption.

(HC 03) When the Firm initiates an innovation or change all employees are included in the decision process. This dimension of Human Capital measures how much a firm values the input of its employees. Since the BIM adoption process requires employees to do new and often difficult things employees whose opinions are valued during the decision to adopt are more likely to approach the difficulties of the adoption process with a positive attitude. This positive attitude will potentially contribute to the overall success of the adoption process.

(HC 04) When the Firm initiates a change buy-in by all members is quickly achieved. This dimension of Human Capital is intended to measure how the firm culture affects the expediency of adoption by individual employees. The relationships that develop between individual employees has an enormous effect on firm culture. If one employee in a group three does not readily accept BIM adoption as a positive change they may use their ties of friendship to coerce another employee and affect a negative environment thus making the adoption process more difficult. If the firm has a positive measure in this dimension it is an indication of cohesion among the individuals of the frim and is thus expected to correlate positively with successful adoption. Low measures of this dimension are expected to correlate with high measures of difficulty in adoption.

(HC 05) The Firm places a high priority on professional development with regard to tools and knowledge. This dimension of Human Capital is a measure of firm culture that reflects a commitment to the individual employee's general professional

knowledge. The literature suggested that a lack of general knowledge of BIM could be a barrier to adoption. This dimension is intended to measure the firm's commitment to creating a knowledge culture.

Structure Capital Construct Validity

Structure Capital is defined in the literature as "systems and processes (such as company strategies, machines, tools, work routines and administrative systems) for codifying and storing knowledge from individual, organization and external supply chain partners." (Lu & Sexton, 2009). This study more specifically defines Structure Capital as it relates to BIM as the systems, softwares, tools and processes the company uses to create, store, and share knowledge. These could be simply defined as software, hardware, and processes or an even further reduction could be "technology". This construct is a measure of a firm's culture with regard to these systems and the priority it places on them. Firms that place a high priority on the technology and make it integral to workflow are expected to view innovation adoption as an easier process. A very high score in this construct could indicate that a firm sees an innovation in technology as necessary to survival regardless of how that technology relates directly or indirectly to their practice model. The firm culture that is reflected in this higher score is expected to put a value on up to date technology. This would indicate that they budget resources for this. Employees of the firm would see this culture manifest in new computers, new software, additional company sponsored training in both software and processes related to software or project delivery.

(SC 01) Employees of the firm are provided extensive software training. This dimension of Structure Capital measures a firm's dedication to employee software training. Firms that invest in training for their employees are expected to more easily adopt a BIM, because it is a technologically intense innovation. Employees who believe the firm invests in their training will report a high value in this dimension.

(SC 02) The Firm places a high priority on maintaining up to date technology of both hardware and software. This dimension of Structure Capital is a measure of a firm's dedication to committing financial resources to technology. Firms that do this will create a culture in which employees believe they are working with up to date software and hardware which can remove the barrier created by the perception of inferior equipment and software.

(SC 3) The use of software plays a pivotal role in the Firm's design process. This dimension of Structure Capital measures a firm's commitment to digital processes. BIM is, in part, a software and has tools that can improve the design process. A firm that shows a commitment to using a variety of softwares in their design process is likely to see the benefits of BIM and thus more easily adopt it into their processes.

(SC 04) Workflows, or the systems by which the work gets finished, are clearly understood by the Firm. This dimension of Structure Capital measures the perceptions of a firm's internal workflow structure. Designing an architectural project from inception to completion requires a series of developments, commonly coded and described by the AIA as Schematic Design (SD), Design Development (DD), and Construction Documents (CD). Each individual firm will develop a workflow within each phase as a

project progresses. Firms with clearly defined and explicitly communicated workflows are more likely to be able to adapt to the changes in these workflows required by BIM. Firms who report a low score in this dimension are expected to report lower rates of successful adoption and higher rates of difficulty adopting.

(SC 05) The Firm makes extensive use of libraries, standards, and web resources. This dimension of Structure Capital measures a firm's use of available standards and resources. Firms who use these types of things, whether inherited or invented are expected to report higher rates of successful adoption as BIM is structured to make use of standards and libraries to expedite document production. A firm that adopts this mindset prior to BIM adoption is expected to recognize this inherent structure of BIM technologies and thus more easily adopt it.

Relationship Capital Construct Validity

Relationship Capital is defined in the literature as "the network resources of a firm. It results from interactions between individual, organization, and external supply chain partners, including reputation or image. Relationship capital is the means to leverage human capital." (Lu & Sexton, 2009). The narrowed definition used in this study as it applies to BIM includes both the internal and external relationships cultivated by a firm. Internal relationships are those between individual workers and workers and their managers, or internal hierarchy. External relationships are those between workers and clients, consultants, contractors, and any other entity external to the company. Relationship Capital is important to a firm as it defines how a firm relates to the other entities involved in producing and delivering an architectural project. This construct measures how and how much a firm invests in the methods of relating to clients and consultants. Firms that actively invest in developing their Relationship Capital are expected recognize the benefits of BIM adoption. This could reduce the difficulty of adoption as well as lead higher reports of success in adoption.

(RC 01) The Firm actively searches for a better process of communicating design ideas/solutions to clients. This dimension of Relationship Capital measures how much a firm invests in improving quality and expediency of sharing information, ideas, and solutions with clients. Architects deliver solutions that are not always easily understood by their clients. This is a product of their professional deformation, such a narrowly and well defined view of their own professional specialty that it blinds them to things outside that view (Barrett, 1990). This deformation causes architects to see their solution quite clearly without understanding that their clients do not share the same education and training and cannot view it with the same alacrity. Therefore, firms that search for better ways of communicating design ideas with their clients are expected to have a vision past this limitation and thus will create a culture that is readily able to adopt an innovation such as BIM.

(RC 02) The Firm actively searches for a better process of exchanging design ides with team members. This dimension of Relationship Capital is a measure of firm's dedication to improving its internal communication processes. Firms that develop this as part of their culture are expected to see the immediate benefits of BIM and be willing to more readily adopt it and the changes it may bring to their established culture of communication.

(RC 03) The Firm actively searches for a better consultant coordination process. This dimension of Relationship Capital is a measure of firm's commitment to improving the methods by which it shares and exchanges information with its consultants. Design consultants play a key role in the production of a design project. They can consist of a myriad of specialists that depend on information from the architect to complete their role in the process. The quality of the service they provide is directly related to the information they get from the firm. Firms that continually seek to improve this process are expected to adopt BIM more easily as they are expected to recognize the benefits offered by BIM.

(RC 04) The use of technology plays a pivotal role in the Firm's consultant coordination process. This dimension of Relationship Capital is a measure of firm's commitment to using technology in the consultant coordination process. Firms that do not use technology in their consultant coordination are not likely to start when they adopt BIM. While BIM adoption does not depend on technology in the consultant coordination, it can greatly enhance this process. Firms already using technology in their coordination process are expected to more easily adopt BIM as they will see the benefits it offers this regard.

(RC 5) The use of technology plays a pivotal role in the Firm's design review process. This dimension of Relationship Capital is a measure of how much a firm uses technology to review its own designs internally. Firms that have entrenched internal review processes devoid of technology are not likely to easily adapt to alternate, potentially more efficient methods—their processes are entrenched. Firms that report

high measures on this dimension are predicted to report higher levels of successful BIM adoption because they already levels of technology imbedded in their processes.

Dependent Variable Construct Validity

This study had two dependent variables related to BIM adoption. The dependent variables were measured in the same Likert Scale as the independent variables. They assess a measure perception of successful BIM adoption and a perception of difficulty. What is key to this is the measure of perception. This is not an objective measure, but a subjective measure related to the experiences of the individual adopter. These measures of perceptions can then be correlated with the measured perceptions of the independent variables.

(D 01) This Firm has successfully transitioned to a Building Information Modeling (BIM) platform. This dependent variable measures perceptions of success. This is important because simply asking respondent if they adopted BIM does create a varied measure by which to associate with the measures of the independent variable. The strength of the correlations becomes important as these strengths, when compared to the construct validity, allow for inferences to be made about the value of single independent variables in the context of the relative strengths of the other independent variables and their association to successful adoption.

(D 02) The adoption of BIM by the firm was difficult. This dependent variable was measured this way for a specific reason. As the statements of the independent variables measured were all worded to imply a culture of innovation, attempting to measure a degree of difficulty had the potential to confound the study. A goal of the

study was to assess characteristics of firm culture that lead to successful adoption or made adoption more probable, the goal of introducing a measure of degree of difficulty would have added too many conceptual degrees to the study. Simply identifying certain firm characteristics as “difficult” was enough to provide a balance to the study.

Description of Survey Deployment

The survey instrument was created and hosted on the website Survey Monkey for eight months from May 2011 until December of 2011. The invitation, survey description, and link to the online instrument were distributed to members of the architectural profession through the Texas Society of Architects (TSA). In the State of Texas there are seventeen chapters within the TSA and each chapter leader was contacted and asked to distribute the survey to their membership. Reminder emails and follow up phone calls to chapter presidents were made two times through data gathering portion.

The survey was not intended to be a random sampling, but instead a blanket sampling of design professionals. Not all questions were answered by all respondents. There were 92 complete responses within the independent variables being measured. Of the approximately 6000 TSA members, this represents a 1.5% response rate, which is low for behavior studies research. In terms of academically focused research within the profession of Architecture this response is not terribly low. After discussion with several chapter presidents it was determined that a 2% response rate to surveys conducted within chapter membership is considered very good. The unit of analysis in this study was considered to be architectural firms. At the time of survey distribution there were 2,530 architectural firms registered to practice Architecture with the TBAE in the State of Texas. This represents approximately at 3.6% response rate. For purposes of generalization given the response rate at a confidence level of 95% the confidence interval would be 10. This means that the results are generalizable to the population of Architectural firms in the state of Texas with a 10% margin of error.

CHAPTER IV

RESULTS

This chapter presents the data relative to the research questions. All other data is presented in the Appendix. This chapter is divided into the following parts:

1. Demographic information
2. Descriptive Statistics of Independent and Dependent Variables
3. Reliability and Correlations of Independent and Dependent Variables
4. Summary of data

Demographic Information

Figure 4.1 shows a bar graph of survey respondents by TSA chapter affiliation within the State of Texas. There were four of seventeen chapters that had no

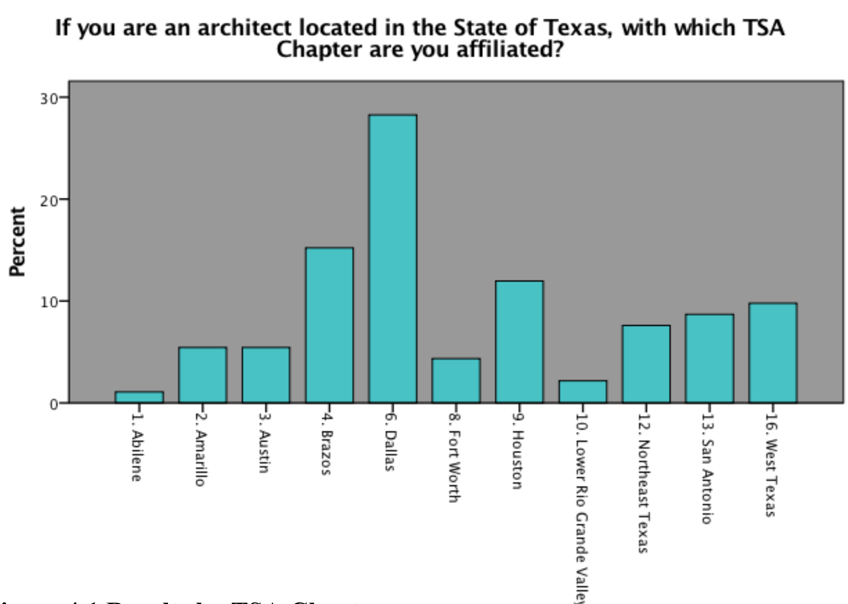

Figure 4.1 Results by TSA Chapter

representation in the responses: El Paso, Lubbock, Southeast, and Waco. Of the 92 respondents located in TSA Chapters, the Dallas chapter had the largest representation at 28.3%, followed by the Brazos Chapter at 15.2%.

Figure 4.2 shows the make-up firm size by people within the survey responses. Of the respondents 28.2% reported working in firms of sixteen or more people, 21.8% reported being in firms of 11-15 people, 14.5% reported being in firms of 7-10 people, 14.5% reported being in firms of 4-6 people, 12.7% reported being in firms of 2-3, and

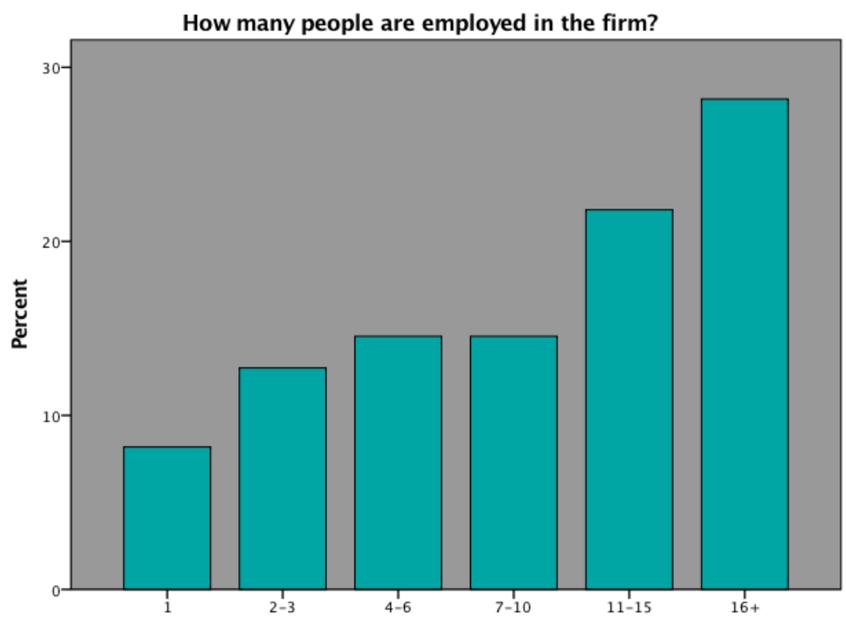

Figure 4.2 Firm Size by Employee

8.2% reported being sole proprietorships. For purposes of this study a small firm was designated as 15 or less people, which represented 71.8% of respondents.

Figure 4.3 shows the range of respondents' firm size rated in annual construction dollar value of projects. 43.6% of respondents reported being in firms of 16 million or more annually. This indicates that the upper range of smaller firms are working on larger projects.

Figure 4.4 shows respondent's role in the firm. 34.5% of respondents reported being the role of principal, while 30.9% reported being in the role of Architect. This

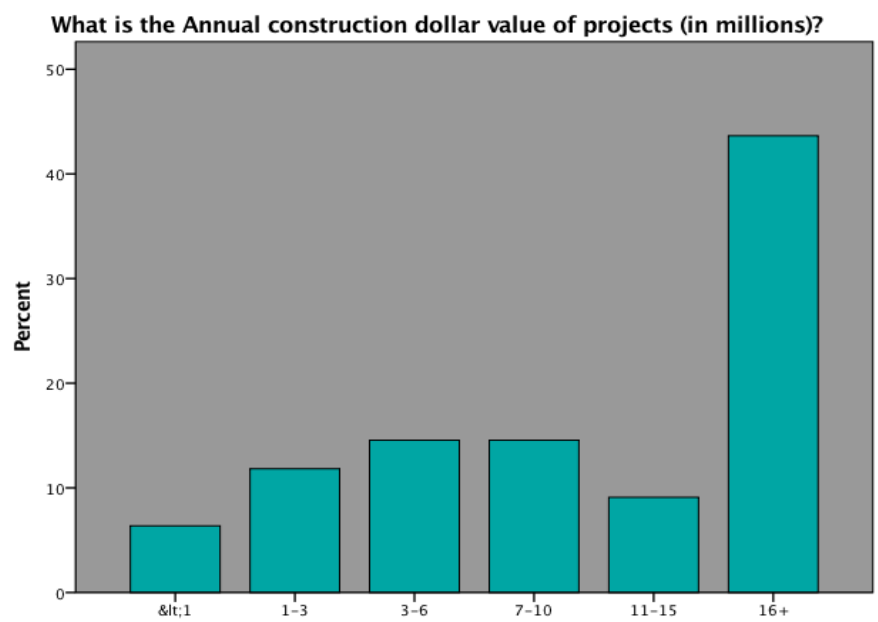

Figure 4.3 Annual Construction Dollar Value

response rate indicates that over 65% of respondents are potentially in a leadership or decision making role. 71.6% percent of respondents reported being a licensed Architect or Engineer. This correlates with the over 65% of respondents reporting being an

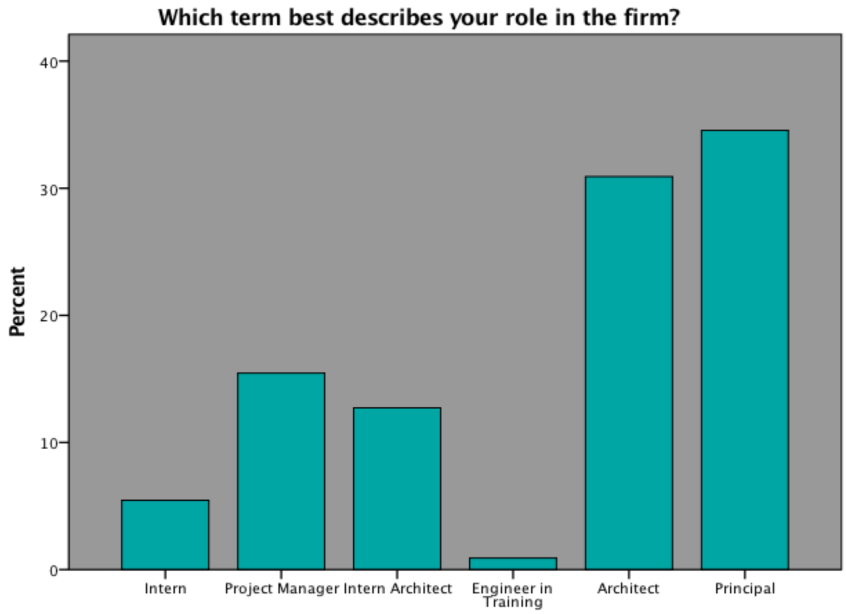

Figure 4.4 Role in Firm

Architect or Principal in the firm. It also suggests that the majority of respondents are answering the survey from the perspective of a knowledgeable professional.

Table 1 shows the response rate to the type of services offered in the firm. 79.1% reported offering architectural services, while 11.8% reported offering both architectural and engineering services. The Other Services offered were: Consulting services including building enclosure, cost estimating, and BIM training, commercial interiors, construction management, development services, general contracting, interior design, lighting design, urban planning, and owner representation. There were a total of 14 “other” types listed.

Figure 4.5 shows how many years the firm has operated under its current leadership. 57.7% of responders report their current leadership has been in place for sixteen plus years which indicates the majority of firms are well established in their services, work flows, and processes. The lowest percentage was reported in the 2-3 year range. Table 1 shows the types of services offered, Architectural, Engineering, both, or other. Respondents reported that 51.4% specialized in an Architectural type. This is about an even split between general practice and specialization. Areas of architectural specialization were quite broad, but included the expected areas of government, healthcare, educational, public work, and residential.

Table 1 Type of Services Offered

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architectural	87	78.4	79.1	79.1
	Architecture and Engineering	13	11.7	11.8	90.9
	Other	10	9.0	9.1	100.0
Total		111	100.0		

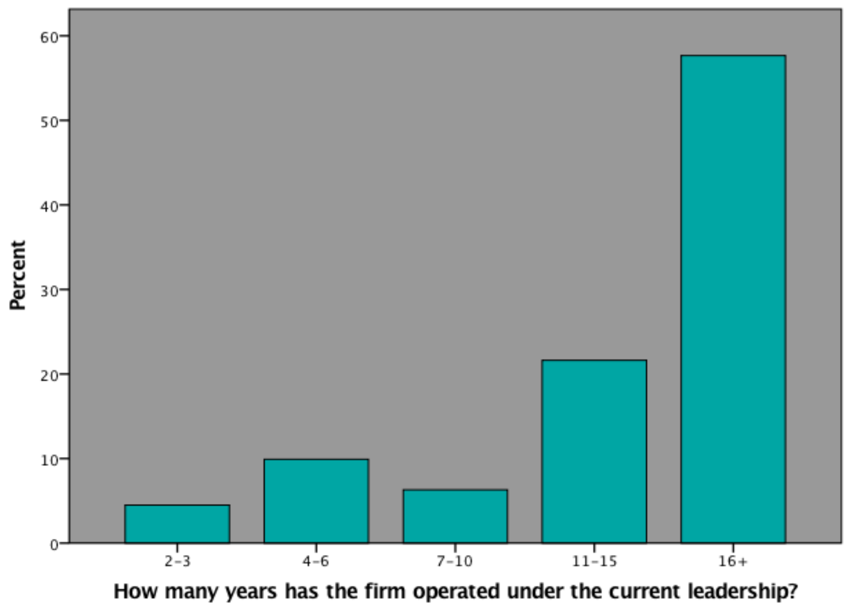

Figure 4.5 Years Under Current Leadership

Descriptive Statistics of Independent and Dependent Variables

This section presents the descriptive statistics of the variables in question, including their means and standard deviations. This shows the average response and the range of deviation from that response.

Table 2 shows the descriptive statistics of the variables under investigation. All variables showed an above average score, if only slightly in some cases. HC02 and HC05 show a higher mean combined with a lower standard deviation than the other variables in human capital. This suggests less variability in the responses to this question. SC03 and SC05 show the highest means in the Structural Capital scale, they

Table 2 Descriptive Statistics				
	N	Minimum	Maximum	Mean
hc01	106	1.00	5.00	3.9717
hc02	106	2.00	5.00	4.1604
hc03	106	1.00	5.00	3.3585
hc04	106	1.00	5.00	3.4340
hc05	106	1.00	5.00	4.0377
sc01	104	1.00	5.00	3.0385
sc02	104	1.00	5.00	3.8462
sc03	104	2.00	5.00	4.0769
sc04	104	1.00	5.00	3.7308
sc05	104	1.00	5.00	3.8846
rc01	97	1.00	5.00	3.8144
rc02	98	1.00	5.00	3.6837
rc03	97	1.00	5.00	3.7526
rc04	96	1.00	5.00	3.8750
rc05	97	1.00	5.00	3.5876
D01 Successful BIM Adoption	95	1.00	5.00	3.0842
D02 Difficultly in BIM Adoption	94	2.00	5.00	3.2872

also show lower variability as well. In the construct of Relationship Capital, the means are very similar, which indicates a level of homogeneity among the responses.

Within the dependent variables under investigation D02, difficulty in adoption, showed the higher of the two means. The dependent variable D01, successful adoption, showed a mean slightly above the average, with a high degree of variability. This indicates responses were toward the agreement end of the scale, but those that showed disagreement did so more toward the strong end of the scale. This suggests that overall respondents reported having perceived to have successfully adopted BIM. It could mean that they did adopt, but do not feel they did so successfully. The variability in this response could be explained by the higher average in the difficulty adopting variable. Respondents may believe they have successfully adopted BIM, but did so with much difficulty.

Reliability and Correlations of Independent and Dependent Variables

This section presents the measures of reliability, or Cronbach's Alpha, within the three constructs of the independent variables. It also shows the results of the individual correlations of the independent variables with the dependent variables within the different firm sizes.

Cronbach's alpha, or coefficient alpha, was developed by Lee Cronbach as a measure of internal consistency of a scale or test (Cronbach, 1951). It produces a value from 0 to 1 and is used to measure the extent to which all items on a scale measure the same concept or construct and is necessary for researchers to calculate to add validity and accuracy to interpretations made on the data sets. (Mohsen Tavakol, 2011). Acceptable values of alpha must be determined by each researcher, but typically range from 0.7 to 0.9. If alpha is too low the measurements are not consistent and if the value is too high, it could indicate that questions in the scale are redundant. Coefficient alpha was calculated for the three scales of Human Capital, Structure Capital, and Relationship Capital using SPSS.

Table 3 shows the alpha for Human Capital at 0.687. This value is less than ideal, but it is still an acceptable level. The literature suggests a low alpha could be the result of too few measures or homogeneity of the measures and suggest examining the inter-item correlations and determine if the alpha can be increased by dropping any items from the scale (Mohsen Tavakol, 2011). The inter-item correlations show removing any single measure from the scale of Human Capital will not increase the alpha score. This study accepted the alpha score calculated on Human Capital and used the construct validity to examine the correlations with the dependent variables.

Table 3 Alpha for Human Capital		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.687	.689	5

Table 4 shows the alpha for Structure Capital at 0.741. This is in the acceptable range and indicates a reliable measure of a construct.

Table 4 Alpha for Relationship Capital		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.855	.857	5

Table 5 shows the alpha for Relationship Capital at 0.855. This is in the acceptable range and indicates and reliable measure of a construct.

Table 5 Alpha for Structure Capital		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.741	.741	5

The product moment correlation coefficient *r* was calculated for each set of independent variables with each dependent variable. Commonly known as the Pearson correlation this process measures the linear relationship between two variables and will produce a pure number independent of units that will range between -1.0 and 1.0 (Cohen, West, & Aiken, 2003). A positive value indicates a tendency for high values in one variable to occur with high values in another variable, while a negative value indicates high values in one variable to occur with low values in another. The strength of the relationship is gauged by the absolute value of the score, thus a higher score indicates a stronger relationship.

Pearson values were calculated at three different firm size levels.

1. All firm sizes in responses set.
2. Small firms, or those reporting 15 employees or less (*small firm*)
3. Firms reporting 10 employees or less (*firm <= 10*)

The Pearson correlation values were calculated this way for two reasons. The first was to enable the use of maximum sample sizing. By calculating the values on all firm sizes a baseline correlation value was established on the maximum sample set. This established the relative importance of each independent variable within the three constructs under investigation irrespective of firm size.

The second reason was to establish trends in the data. By filtering the data and reducing the firm size in steps from all responses, to firms reporting 15 employees or less, then to firms reporting 10 employees or less a trend in the correlation values was established. As the results show specific independent variables within each construct emerged as having larger correlation values as the firm size got smaller establishing these independent variables as more important to small firm BIM adoption.

When comparing the correlations in the three constructs to the dependent variable of successful BIM adoption there was an expectation of positive correlation in all independent variables. Therefore, this study reported the one-tailed test because it was only interested in the single direction of the relationship.

When comparing the correlations in the three constructs to the dependent variable of difficulty in adoption there was an expectation of negative correlation values. Therefore, this study reported the one-tailed test because it was only interested in the single direction of the relationship.

All results are discussed in detail in the conclusions section in Chapter 5. The results show correlations on the entire data set, firms reporting 15 employees or less, and firms reporting 10 employees or less.

Table 6 shows the Pearson values for the independent variables within the construct of Human Capital correlated with the dependent variable of Successful BIM adoption. HC04 and HC05 showed the highest correlation values at 0.331 and 0.450

respectively. The lowest values were in the variables of HC02 and HC03 at 0.080 and 0.222 respectively.

Table 6 *r* value of Human Capital on Successful BIM Adoption							
		HC01	HC02	HC03	HC04	HC05	D01
D01	Pearson *r*	.285	.080	.222	.331	.450	1
	Sig. (1-tailed)	.003	.221	.015	.001	.000	
	N	95	95	95	95	95	95

Table 7 shows the Pearson values for the independent variables within the construct of Structure Capital correlated with the dependent variable of Successful BIM adoption. SC02 and SC03 showed the highest correlation values at 0.528 and 0.516 respectively. Both of these correlations were considered significant at the .001 level. The lowest values were in the variables of SC04 and SC05 at 0.151 and 0.305 respectively.

Table 7 *r* value of Structure Capital on Successful BIM Adoption							
		SC01	SC02	SC03	SC04	SC05	D01
D01	Pearson *r*	.481	.528	.516	.151	.305	1
	Sig. (1-tailed)	.000	.000	.000	.075	.001	
	N	93	93	93	93	93	95

Table 8 shows the Pearson values for the independent variables within the construct of Relationship Capital correlated with the dependent variable of Successful BIM adoption. RC05 and RC02 showed the highest correlation values at 0.536 and

0.446 respectively. Both of these correlations were considered significant at the .001 level. The lowest values were in the variables of RC01 and RC03 at 0.404 and 0.415 respectively.

Table 8 *r* value of Relationship Capital on Successful BIM Adoption

		RC01	RC02	RC03	RC04	RC05	D01
D01	Pearson *r*	.404	.446	.415	.425	.536	1
	Sig. (1-tailed)	.000	.000	.000	.000	.000	
	N	94	95	95	94	95	95

Table 9 shows the Pearson values for the independent variables within the construct of Human Capital correlated with the dependent variable of Difficulty in BIM adoption. HC04 and HC03 showed the highest negative correlation values at -0.268 and -0.187 respectively. The lowest values were in the variables of HC01 and HC05 at -0.098 and -0.103 respectively.

Table 9 *r* value of Human Capital on Difficulty in Adoption

		HC01	HC02	HC03	HC04	HC05	D02
D02	Pearson *r*	-.098	-.168	-.187	-.268	-.103	1
	Sig. (1-tailed)	.175	.052	.036	.004	.162	
	N	94	94	94	94	94	94

Table 10 shows the Pearson values for the independent variables within the construct of Structure Capital correlated with the dependent variable of Difficulty in BIM adoption. SC05 and SC03 showed the highest negative correlation values at -0.243 and -0.205 respectively. The lowest values were in the variables of SC02 and SC01 at -0.187 and -0.183 respectively.

Table 10 *r* value of Structure Capital on Difficulty in Adoption

		SC01	SC02	SC03	SC04	SC05	D02
D02	Pearson *r*	-.182	-.096	-.205	-.187	-.243	1
	Sig. (1-tailed)	.041	.182	.025	.037	.010	
	N	92	92	92	92	92	94

Table 11 shows the Pearson values for the independent variables within the construct of Relationship Capital correlated with the dependent variable of Difficulty in BIM adoption. RC05 and RC04 showed the highest negative correlation values at -0.239 and -0.207 respectively. The lowest values were in the variables of RC01 and RC03 at -0.106 and -0.139 respectively.

Table 11 *r* value of Relationship Capital on Difficulty in Adoption

		RC01	RC02	RC03	RC04	RC05	D02
D02	Pearson *r*	-.106	-.176	-.139	-.207	-.239	1
	Sig. (1-tailed)	.155	.045	.091	.023	.010	
	N	93	94	94	93	94	94

Table 12 shows the Pearson values for the independent variables within the construct of Human Capital correlated with the dependent variable of Successful BIM adoption on the filtered data set for firms with 15 or less employees. HC05 and HC01 showed the highest correlation values at 0.441and 0.327 respectively. The lowest values were in the variables of HC02 and HC04 at 0.088 and 0.235 respectively. HC05 remained the highest correlation, but the strength is slightly less. HC01 rose in strength over HC04 at the small firm level, while HC04 dropped to the second lowest correlation value.

Table 12 *r* value of Human Capital on Successful BIM Adoption *small firm*

		HC01	HC02	HC03	HC04	HC05	D01
D01	Pearson *r*	.327	.088	.263	.235	.441	1
	Sig. (1-tailed)	.003	.239	.015	.027	.000	
	N	68	68	68	68	68	68

Table 13 shows the Pearson values for the independent variables within the construct of Structure Capital correlated with the dependent variable of Successful BIM adoption on the filtered data set for firms with 15 or less employees. SC02 and SC03 showed the highest correlation values at 0.681 and 0.645 respectively. The lowest values were in the variables of SC04 and SC05 at 0.212 and 0.243 respectively.

Table 13 *r* value of Structure Capital on Successful BIM Adoption *small firm*							
		SC01	SC02	SC03	SC04	SC05	D01
D01	Pearson *r*	.482	.681	.645	.212	.243	1
	Sig. (1-tailed)	.000	.000	.000	.043	.024	
	N	67	67	67	67	67	68

Table 14 shows the Pearson values for the independent variables within the construct of Relationship Capital correlated with the dependent variable of Successful BIM Adoption on the filtered data set for firms with 15 or less employees. RC05 and RC02 showed the highest correlation values at 0.648 and 0.501 respectively. The lowest values were in the variables of RC01 and RC03 at 0.404 and 0.470 respectively.

Table 14 *r* value of Relationship Capital on Successful BIM Adoption *small firm*							
		RC01	RC02	RC03	RC04	RC05	D01
D01	Pearson *r*	.404	.501	.470	.472	.648	1
	Sig. (1-tailed)	.000	.000	.000	.000	.000	
	N	67	68	68	67	68	68

Table 15 shows the Pearson values for the independent variables within the construct of Human Capital correlated with the dependent variable of Difficulty in Adoption on the filtered data set for firms with 15 or less employees. HC03 and HC02 showed the highest negative correlation values at -0.177and -0.145 respectively. The lowest values were in the variables of HC05 and HC04 at -0.049 and -0.073 respectively.

Table 15 *r* value of Human Capital on Difficulty in Adoption *small firm*							
		HC01	HC02	HC03	HC04	HC05	D02
D02	Pearson *r*	-.133	-.145	-.177	-.073	-.049	1
	Sig. (1-tailed)	.142	.121	.076	.280	.346	
	N	67	67	67	67	67	67

Table 16 shows the Pearson values for the independent variables within the construct of Structure Capital correlated with the dependent variable of Difficulty in Adoption on the filtered data set for firms with 15 or less employees. SC03 and SC02 showed the highest negative correlation values at -0.266 and -0.193 respectively. The lowest values were in the variables of SC01 and SC05 at -0.156 and -0.165 respectively.

Table 16 *r* value of Structure Capital on Difficulty in Adoption *small firm*							
		SC01	SC02	SC03	SC04	SC05	D02
D02	Pearson *r*	-.156	-.193	-.266	-.189	-.165	1
	Sig. (1-tailed)	.105	.060	.016	.064	.092	
	N	66	66	66	66	66	67

Table 17 shows the Pearson values for the independent variables within the construct of Relationship Capital correlated with the dependent variable of Difficulty in Adoption on the filtered data set for firms with 15 or less employees. RC05 and RC04 showed the highest negative correlation values at -0.192 and -0.177 respectively. The lowest values were in the variables of RC01 and RC03 at -0.055 and -0.094 respectively.

Table 17 *r* value of Relationship Capital on Difficulty in Adoption *small firm*							
		RC01	RC02	RC03	RC04	RC05	D02
D02	Pearson *r*	-.055	-.134	-.094	-.177	-.192	1
	Sig. (1-tailed)	.331	.140	.225	.078	.060	
	N	66	67	67	66	67	67

Table 18 shows the Pearson values for the independent variables within the construct of Human Capital correlated with the dependent variable of Successful BIM Adoption on the filtered data set for firms with 10 or less employees. HC03 and HC05 showed the highest correlation values at 0.413 and 0.400 respectively. The lowest values were in the variables of HC02 and HC04 at 0.193 and 0.224 respectively.

Table 18 *r* value of Human Capital on Successful BIM Adoption *firm <=10*							
		HC01	HC02	HC03	HC04	HC05	D01
D01	Pearson *r*	.320	.193	.413	.224	.400	1
	Sig. (1-tailed)	.012	.090	.001	.059	.002	
	N	50	50	50	50	50	50

Table 19 shows the Pearson values for the independent variables within the construct of Structure Capital correlated with the dependent variable of Successful BIM Adoption on the filtered data set for firms with 10 or less employees. SC02 and SC03 showed the highest correlation values at 0.725 and 0.697 respectively. The lowest values were in the variables of SC04 and SC05 at 0.320 and 0.359 respectively.

Table 19 *r* value of Structure Capital on Successful BIM Adoption *firm <=10*							
		sc01	sc02	sc03	sc04	sc05	D01
D01	Pearson *r*	.517	.725	.697	.320	.359	1
	Sig. (1-tailed)	.000	.000	.000	.012	.006	
	N	49	49	49	49	49	50

Table 20 shows the Pearson values for the independent variables within the construct of Relationship Capital correlated with the dependent variable of Successful BIM Adoption on the filtered data set for firms with 10 or less employees. RC05 and RC03 showed the highest correlation values at 0.652 and 0.557 respectively. The lowest values were in the variables of RC01 and RC04 at 0.441 and 0.505 respectively.

Table 20 *r* value of Relationship Capital on Successful BIM Adoption *firm <=10*							
		RC01	RC02	RC03	RC04	RC05	D01
D01	Pearson *r*	.441	.545	.557	.505	.652	1
	Sig. (1-tailed)	.001	.000	.000	.000	.000	
	N	50	50	50	49	50	50

Table 21 shows the Pearson values for the independent variables within the construct of Human Capital correlated with the dependent variable of Difficulty in BIM Adoption on the filtered data set for firms with 10 or less employees. HC02 and HC03 showed the highest negative correlation values at -0.113 and -0.079 respectively. The lowest correlations were found in HC05 and HC04 of -0.007 and 0.027 respectively.

Table 21 *r* value of Human Capital on Difficulty in Adoption *firm <=10*							
		HC01	HC02	HC03	HC04	HC05	D02
D02	Pearson *r*	.070	-.113	-.079	.027	-.007	1
	Sig. (1-tailed)	.316	.220	.294	.426	.481	
	N	49	49	49	49	49	49

Table 22 shows the Pearson values for the independent variables within the construct of Structure Capital correlated with the dependent variable of Difficulty in BIM Adoption on the filtered data set for firms with 10 or less employees. SC03 and SC05 showed the highest negative correlation values at -0.319 and -0.242 respectively. The lowest correlations were found in SC01 and SC04 of -0.106 and -0.171 respectively.

Table 22 *r* value of Structure Capital on Difficulty in Adoption *firm <=10*							
		SC01	SC02	SC03	SC04	SC05	D02
D02	Pearson *r*	-.106	-.229	-.319	-.171	-.242	1
	Sig. (1-tailed)	.236	.058	.013	.122	.048	
	N	48	48	48	48	48	49

Table 23 shows the Pearson values for the independent variables within the construct of Relationship Capital correlated with the dependent variable of Difficulty in BIM Adoption on the filtered data set for firms with 10 or less employees. RC04 and RC05 showed the highest negative correlation values at -0.354 and -0.257 respectively. The lowest correlations were found in RC01 and RC03 of -0.132 and -0.158 respectively.

Table 23 *r* value of Relationship Capital on Difficulty in Adoption *firm <=10*							
		RC01	RC02	RC03	RC04	RC05	D02
D02	Pearson *r*	-.132	-.218	-.158	-.354	-.257	1
	Sig. (1-tailed)	.183	.066	.140	.007	.037	
	N	49	49	49	48	49	49

Summary of Results

The independent variables in this investigation were grouped into the three scales of Human Capital, Structure Capital, and Relationship Capital. The coefficient alpha for the scales of Structure Capital and Relationship Capital were in the desirable range for behavioral science research, between 0.70 and .90, and the Human Capital scale fell just below the desirable range at 0.687. This measure, while still in acceptable range for research, indicates some inconsistency in the scale indicating that the measures obtained on dimensions of this scale are not reliably measuring the desired construct. The Human Capital construct seeks to quantify the human, or people, aspects of the BIM adoption process and the inconsistency could be attributed to the mix of people and technology related items. Specifically, the overlap with the Structure Capital construct in the statements regarding education and training.

The Pearson correlation values for each scale were generally as expected. Dependent Variable of Successful BIM Adoption showed varying degrees of positive correlation across all three scales. Overall the scales of Structure Capital and Relationship Capital showed higher values than Human Capital. Similar results were found in the Dependent Variable of Difficulty in Adoption, again Human Capital showed the lowest negative correlation strengths. This could be explained by the lower Alpha score on that scale. The next chapter presents the correlation values in each scale across all firm sizes and discusses the results in the context of the construct validity.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, AND FURTHER RESEARCH

This chapter is broken down into the following sections:

1. Conclusions from the results of the data analysis, answers to the research questions, discussion of directional hypotheses, and results of open answer questions.
2. Recommendations for Small Firm adoption based on the results of the data analysis.
3. Recommendations for further research.

Conclusions and Answers to Research Questions

This study had four primary research questions:

1. What is the current state of BIM adoption across firms in the State of Texas?
    a. What is the state of BIM adoption in small firms in the State of Texas?
2. What factors of architectural firm culture from the survey instrument had the largest correlation to BIM adoption and adoption difficulty?
3. What factors of architecture firm culture from the survey were shared by successful BIM adopters?
4. How can small firms use this information to better position themselves to adopt BIM?

Current state of BIM Adoption across firms in State of Texas

Across all of firm size the responses to successful BIM adoption were evenly distributed showing almost as many negative responses as positive. Figure 5.1 BIM Adoption shows the results. This indicates that approximately half of all respondents indicate having not transitioned to BIM or are neutral on the matter. This also indicates that half of the respondents agreed to having successfully transitioned to Building Information Modeling.

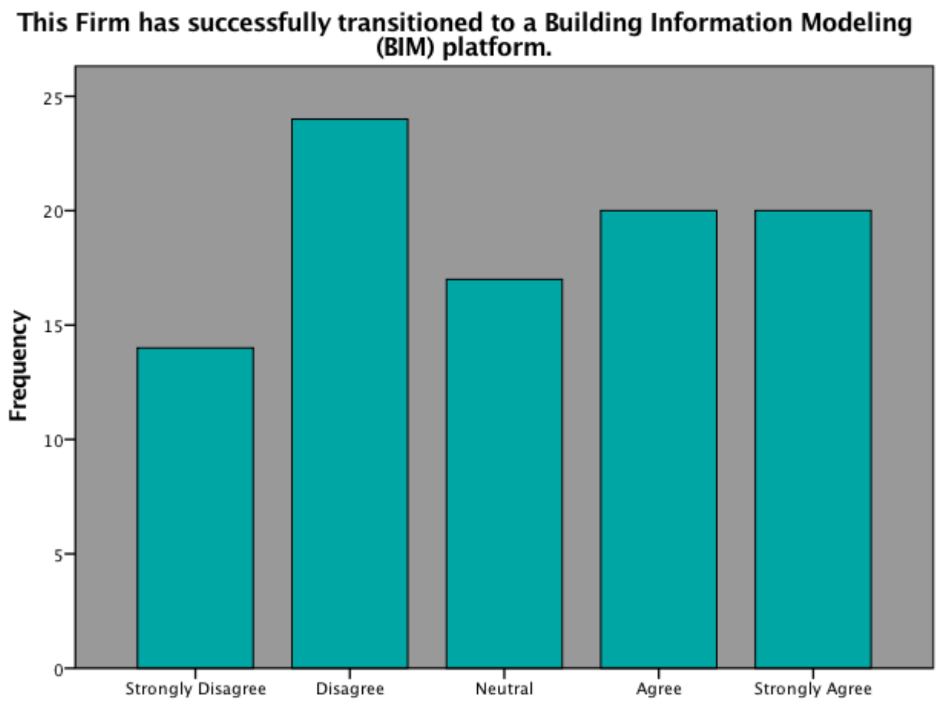

Figure 5.1 BIM Adoption

Factors of Firm culture related to BIM adoption

Figure 5.2 shows a bar graph of the Pearson r correlation values of the five measures within the Human Capital Scale on D01 Successful BIM adoption across the three levels of firm size. None of the values reached the 0.5 level, which is desirable for this type of study, but meaningful information can be derived from the relative correlation values and the values of each measure in the context of the construct validity are discussed below.

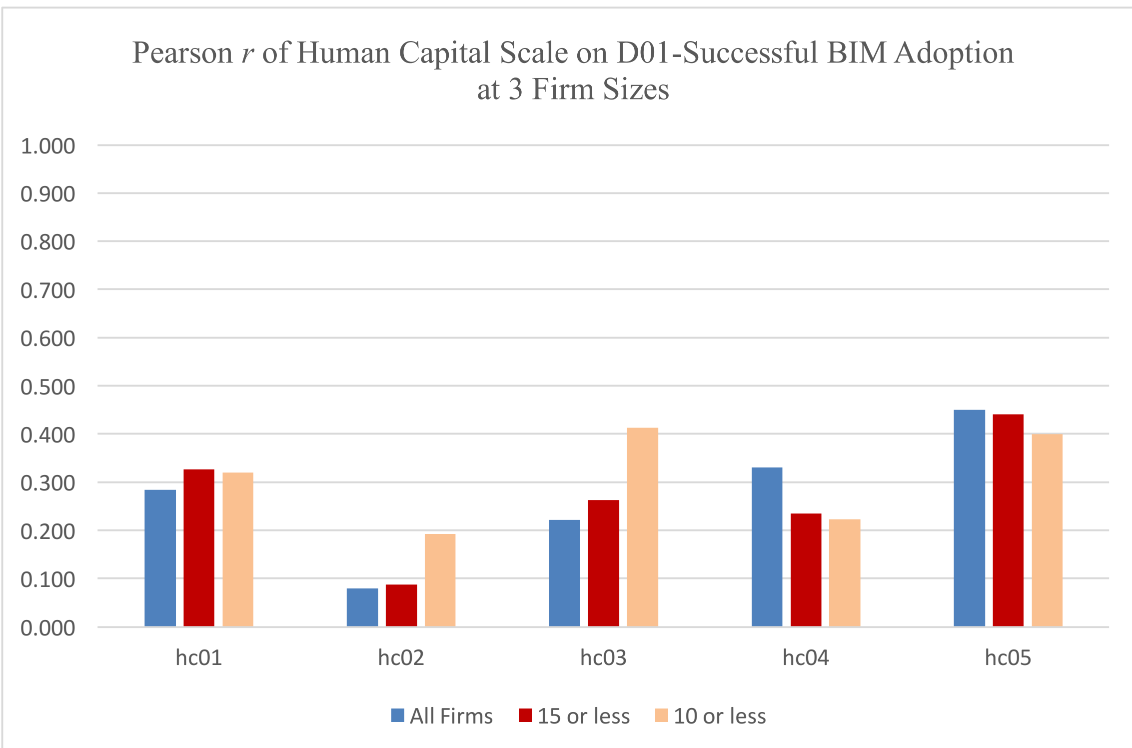

Figure 5.2 Pearson *r* of HC on Successful BIM Adoption at 3 Firm Sizes

(HC 01) The Firm encourages initiative in developing new solutions or processes.

The r values are not very high in HC01 across the three size levels, 0.285, 0.327, and 0.320. None of these values reach the 0.5 level indicating a strong relationship. The consistent values across firm sizes could suggests that working to develop trust and value in employees at any firm size plays a strong roll in successful BIM adoption.

(HC 02) The Firm has senior management that exhibits decisive leadership.

The r values in HC02 are the lowest across all dimensions of Human Capital and across all three firm sizes, 0.08, 0.088, and 0.193. This suggests that decisive leadership in senior management may be the least important measured factor of successful BIM adoption.

(HC 03) When the Firm initiates an innovation or change all employees are included in the decision process.

The r values of HC03 show an increase as firm size gets smaller, 0.222, 0.263, and 0.413, with a large spike at 10 employee and less firm size. This suggests that including employees in the decision to innovate plays a key role, especially at smaller firm size levels. As firms get smaller owners are more likely to work daily with their employees and are likely to be more vested in the day to day employee mindset.

(HC 04) When the Firm initiates a change buy-in by all members is quickly achieved.

The r value for HC04 decreases as firm size decreased, 0.331, 0.235, and 0.224. This indicates that this dimension of Human Capital is less important as firms get smaller. At first pass, this seems rather counter intuitive, but could simply mean that in smaller firms it is more challenging to achieve buy-in by all firm members. As smaller firms are likely to be amalgamations of like-minded people it may be difficult to achieve buy-in from everyone.

(HC 05) The Firm places a high priority on professional development with regard to tools and knowledge.

The r value for HC05 was the highest across all dimensions of the construct, 0.450, 0.441, and 0.400. Though the correlation values did get smaller as firm size got smaller. The literature identified Human Capital, specifically education about BIM, to be a potential factor affecting adoption. These correlation values suggest that a commitment to individual employee education and general professional knowledge shows the highest correlation with perceptions of successful adoption in the Human Capital scale. This is consistent with the literature and suggests educating employees about the value proposition of BIM adoption could be the most important Human Capital dimension.

Figure 5.3 shows a bar graph of the Pearson r correlation values of the five measures within the Human Capital Scale on D02 Difficult in BIM adoption across all three firm sizes evaluated. Overall the values in the data do not suggest a strong relationship as no single r value reached 0.5.

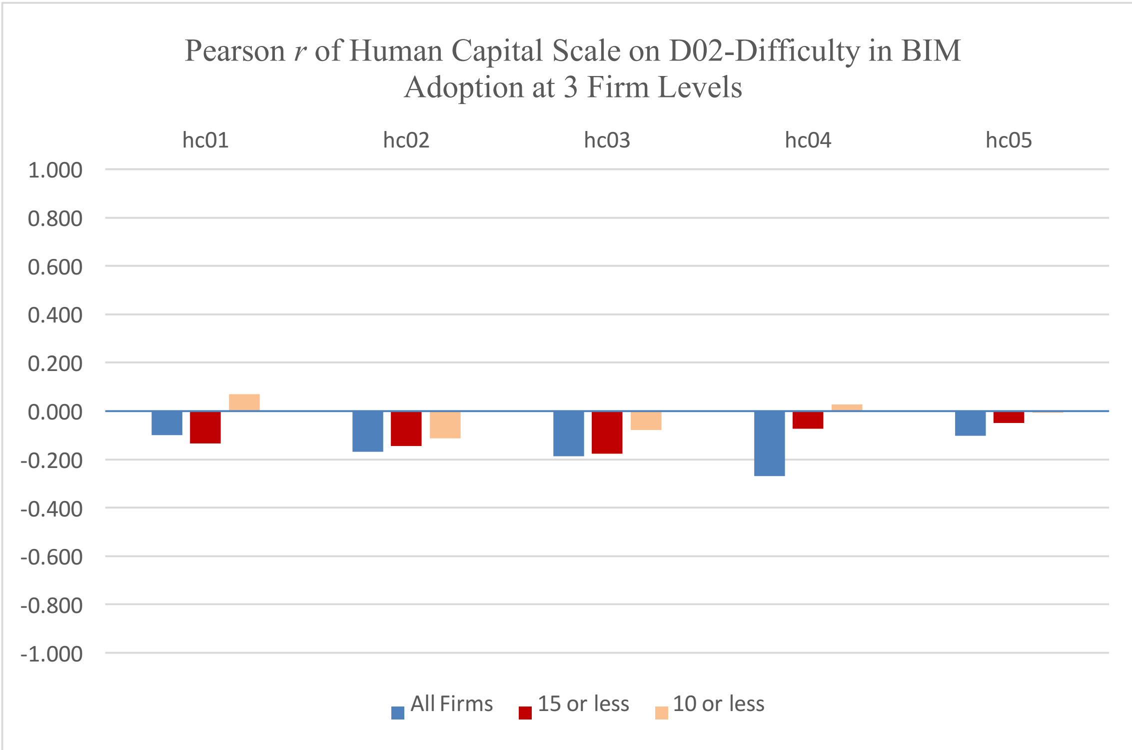

Figure 5.3 Pearson *r* of HC on Difficulty in BIM Adoption at 3 Firm Sizes

(HC 01) The Firm encourages initiative in developing new solutions or processes.

The r values in this dimension of Human Capital were negative at the levels of all firms and 15 employees or less, but then switched signs to positive at the 10 employees and less level. This switch to a positive correlation at the smallest firm size level suggests that encouraging the development of new solutions or process had a positive correlation with difficulty in adoption at the smallest firm size. This data suggests that at the smallest firm size, encouraging an employee to take time away from understood workflows to develop something new may be deleterious to the innovation adoption process. If a small firm only has a few employees and they switch to work that is not immediately productive it could have negative impacts on cash flow or production schedules thus giving the appearance of making the innovation adoption process more challenging.

(HC 02) The Firm has senior management that exhibits decisive leadership.

Lower agreement with this statement was expected correlate with increased difficulty. While the data suggests this to be consistent, the strength of the relationship is not substantia, but the appearance of a decrease of correlation strength as firm size decreases suggests that as the firm gets smaller this dimension has less significance. This could be explained at the smaller firm levels by accepting that as the number of employees decreases their reliance on the decisiveness of the leadership becomes less. A smaller number of employees will simply trust what their leadership decides, regardless of conviction or decisiveness.

(HC 03) When the Firm initiates an innovation or change all employees are included in the decision process.

The negative r values for this dimension were very small, -0.187, -0.177, and -0.113 and decreased across the levels of firm size. This suggests that not including employees in the innovation decision process can make adoption more difficult. The data suggests that this dimension has less impact on adoption difficulty as firm size gets smaller.

(HC 04) When the Firm initiates a change buy-in by all members is quickly achieved.

The r values for HC04 were negative at the first two firm size levels, but switch to positive at the smallest firm size. At the largest firm size this dimension showed the strongest negative correlation value which suggests that in larger firms not achieving buy in from all team members had the largest impact on difficulty in adoption. The declining r values suggest that at smaller firm sizes, achieving buy-in from all members is not as important as it is as larger firm size levels.

(HC 05) The Firm places a high priority on professional development with regard to tools and knowledge.

The r values for HC05 were negative in this dimension of Human Capital, but were very small, almost negligible at the smallest firm size, which suggests there is no relationship between this dimension of Human Capital and difficulty in BIM adoption. This would suggest that a lower focus on education and professional development did not make the adoption process more difficult than normal.

Figure 5.4 shows a bar graph of the Pearson r correlation values of the five measures within the Structure Capital Scale on D01 Successful BIM adoption across all three firm sizes evaluated. Overall, this is consistent with the predictions of the literature as structure capital represents a firm's investment in systems, softwares, tools, and processes.

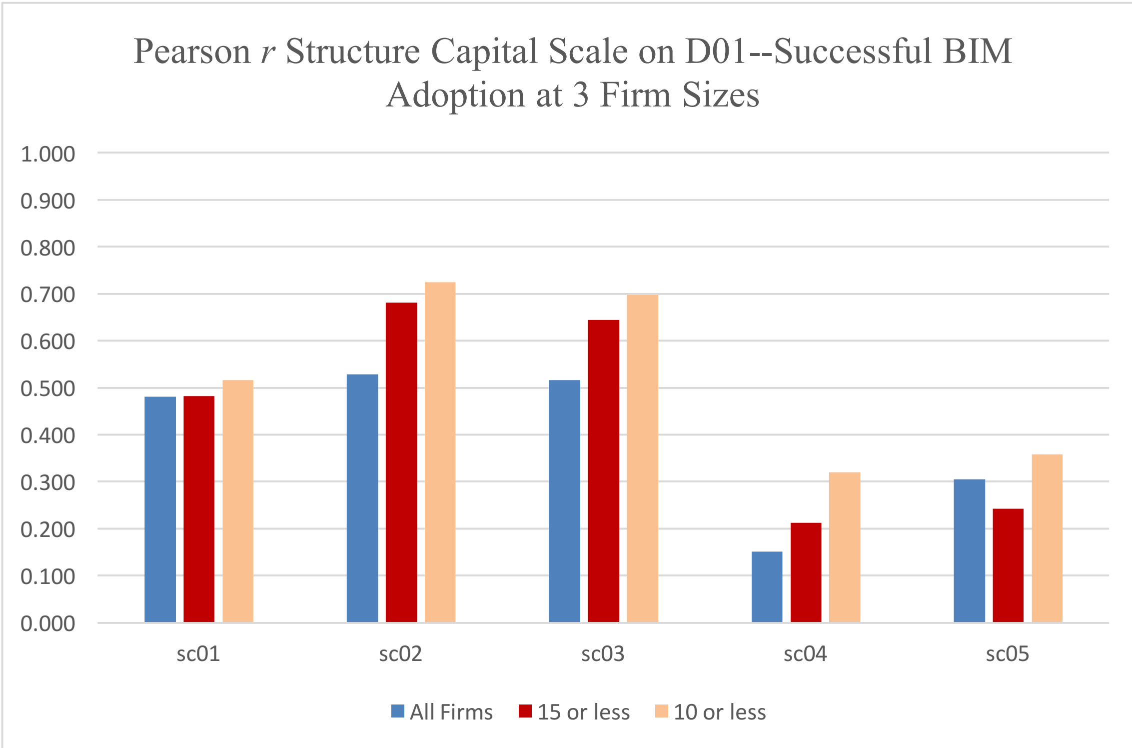

Figure 5.4 Pearson *r* of SC on Successful BIM Adoption at 3 Firm Sizes

(SC 1) Employees of the firm are provided extensive software training.

The r values for this dimension of Structure Capital scored high at three size levels, 0.481, 0.482, and 0.517. At the smallest firm size level, the r value crested the 0.5 value which suggests a strong relationship. This relationship is important especially at the smaller firm size level as BIM is a software intensive process. Having proper training and especially giving employees the perception of enough training to solve the problems that arise in the workflow shows to be a very important indicator of successful adoption.

(SC 02) The Firm places a high priority on maintaining up to date technology of both hardware and software.

The r values for this dimension of Structure Capital were some of the highest in the construct and crested the 0.5 level at all three firm size levels. This relationship was suggested by the literature and found in the experiment. This shows a strong relationship that got stronger as the firm size got smaller, 0.528, 0.681, 0.725. At the 10 employee and less firm size level the r value suggests a very strong relationship. This data indicates that maintaining up to date software and hardware could be the most important dimension of successful adoption at all firm size levels and small firms should consider committing sufficient resources to maintaining up to date software and hardware.

(SC 03) The use of software plays a pivotal role in the Firm's design process.

The r values for this dimension suggested a strong relationship at all three firms size levels, 0.516, 0.645, and 0.697. This relationship was also suggested by the literature and found in the experiment. As discussed in the construct validity, and supported in this data firms whose design process is linked to software usage show a strong positive correlation with successful adoption. This indicates that small firms should invest resources into understanding and implementing software supported design processes to increase successful BIM adoption.

(SC 4) Workflows, or the systems by which the work gets finished, are clearly understood by the Firm.

The r values in this dimension of Structure Capital were the lowest of all dimensions, 0.151, 0.212, and 0.320. No values attained the 0.5 level which indicates that there are no strong relationships. Although, the value did rise as the firm size got smaller. This trend suggests that clearly understood workflows are important to successful BIM adoption for smaller firms.

(SC 5) The Firm makes extensive use of libraries, standards, and web resources.

The r values for this dimension again did not reach the 0.5 level at any firm size, 0.305, 0.243, and 0.359, which suggest there is not a strong relationship between this dimension and successful BIM adoption at any firm size level. Although, the trend in the data shows the highest value at the smallest firm size which suggests that the use of standards and libraries may have some impact on successful adoption at the smallest firm size levels.

Figure 5.5 shows a bar graph of the Pearson r correlation values of the five measures within the Structure Capital Scale on D02 Difficulty in BIM adoption across all three firm sizes evaluated. No single measure in the dimensions of Structure Capital reached the desired 0.5 absolute value which suggests there are no strong relationships between these dimensions and difficulty in adoption. The individual values are discussed below.

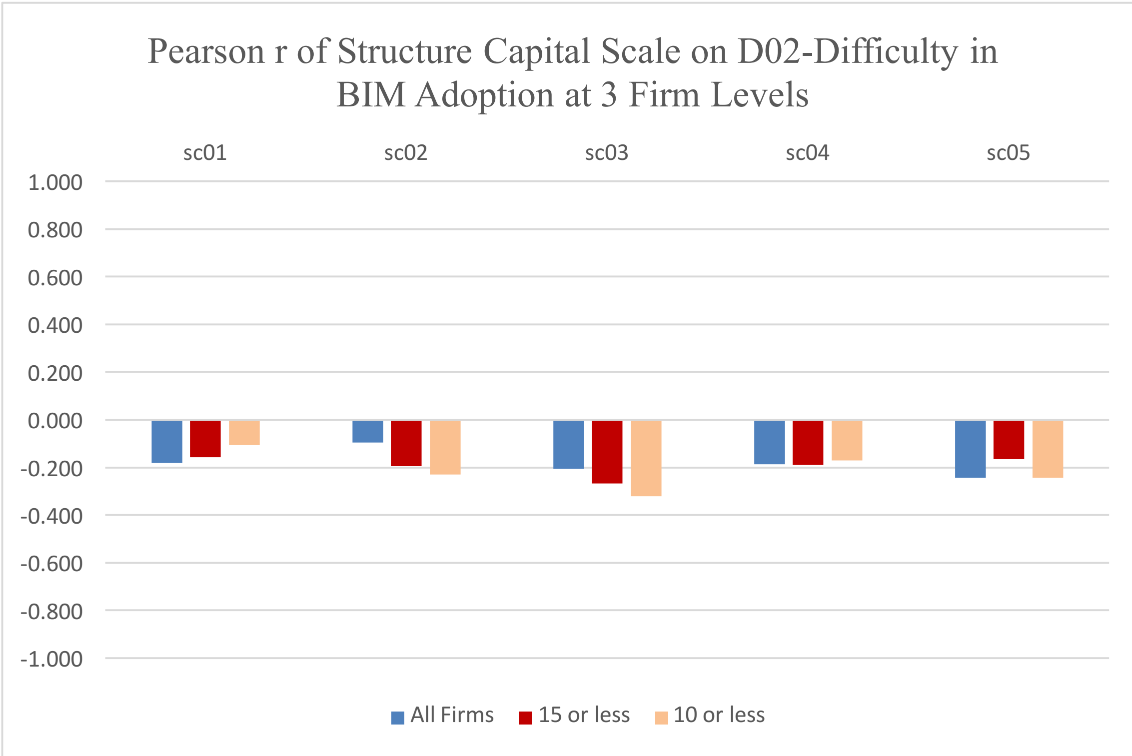

Figure 5.5 Pearson *r* of SC on Difficulty in BIM Adoption at 3 Firm Sizes

(SC 01) Employees of the firm are provided extensive software training

The r values in SC01 were some of the lowest in all dimensions of Structure Capital and decreased as the firm size got smaller. This indicates that respondents believed that respondents at the small firm level did not correlate difficulty in adoption to a lack of training.

(SC 02) The Firm places a high priority on maintaining up to date technology of both hardware and software

The r values for SC02, -0.096, -0.193, and -0.229, show that as firm size got smaller maintaining up to date hardware and software had a stronger relationship to difficulty in adoption. This would indicate that smaller firms that felt they didn't maintain technology found it more difficult to adopt BIM.

(SC 03) The use of software plays a pivotal role in the Firm's design process.

The r values for this dimension, -0.205, -0.266, and -0.319 show that this dimension becomes more important as firm size gets smaller. The r values indicate a low agreement with this statement correlates with a high agreement regarding difficulty in adoption. This is consistent with the expectations of the construct validity as firms who do not use software in their design processes, or simply view the software as the final production tool, would likely find the BIM processes supported by the software as unnecessary and burdensome. This value increases as firm size gets smaller. This could be explained by looking at the years under current leadership. The majority of respondents reported that they are in firms who have established leadership, which could indicate established design process methods that are not inclusive of newer software methods.

(SC 4) Workflows, or the systems by which the work gets finished, are clearly understood by the Firm.

The r values for this dimension were low and consistent across firm size levels, -0.187, -0189, and -0.171. These values do not suggest much of a relationship to difficulty in adoption at any firm level, but the consistent negative value indicates that no matter the firm size, well understood and communicated workflows have the same impact on difficulty in adoption. This is to say that poorly understood or communicated workflows have the same negative correlation with difficulty in adoption regardless of firm size.

(SC 05) The Firm makes extensive use of libraries, standards, and web resources.

The r values for this dimension were low, -0.243, -0.165, and -0.242. These negative correlation values indicate that disagreement with this statement correlates to higher agreement with difficulty in adoption. This is consistent with the construct validity predictions as firms that do not make use of libraries, standards, and web resources are not likely to see the immediate benefits software processes can offer. Additionally, the dip in the data at the 15 employee and less level could indicate that firms in this range did not value this dimension as much as larger or smaller firms. Based on the low correlation values, this statement could be reworded in another survey instrument to be more specific as to the type of libraries, standards, and web resources.

Figure 5.6 shows a bar graph of the Pearson r correlation values of the five measures within the Relationship Capital Scale on D01 Successful BIM adoption across all three firm sizes evaluated. All values in the Relationship Capital Scale showed consistently similar positive correlations, meaning that no single dimension stands out as extremely different. Although the correlations were not as strong as Structure Capital they appeared in areas that, when compared with the construct validity, make sense.

(RC 1) The Firm actively searches for a better process of communicating design ideas/solutions to clients.

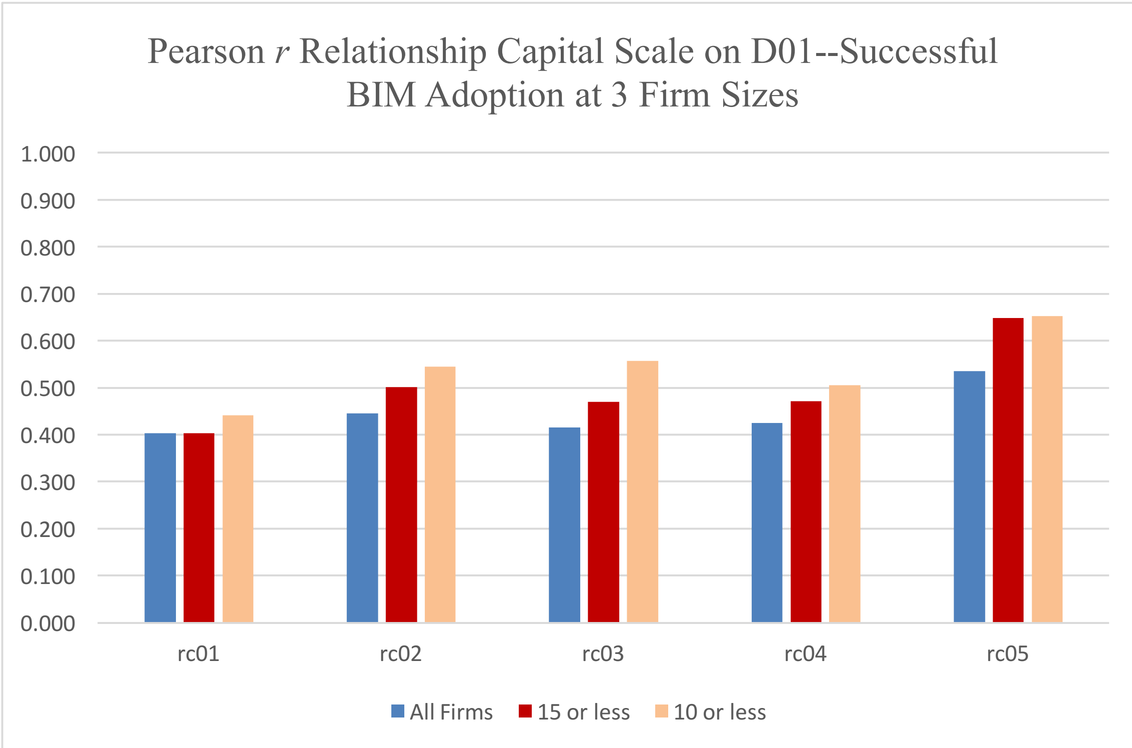

Figure 5.6 Pearson *r* of RC on Successful BIM Adoption at 3 Firm Sizes

The r values in this dimension of Relationship Capital were some of the lowest and most consistent across the construct at 0.404, 0.404, and 0.441. These values and the trend of consistency indicate that regardless of firm size the importance to searching for better client communication strategies was regarded with equal importance in the construct of successful BIM adoption. The slight rise at the smallest firm level could indicate smaller firms see a benefit to client communication and BIM adoption.

(RC 02) The Firm actively searches for a better process of exchanging design ideas with team members.

The r values in this dimension of Relationship Capital were high and reached the desirable 0.5 at the 15 employee and less and 10 employee and less ranges. The values were, 0.446, 0.501, and 0.545 at the respective firm size ranges. This dimension was expected to correlate positively with successful adoption and the data shows that as firm size gets smaller the strength of the correlation value grows. This dimension measured a firm's dedication to improving its own internal processes. This correlation in the data suggests that firms looking to adopt BIM should consider developing a process of staying current on information sharing ideas and methods.

(RC 03) The Firm actively searches for a better consultant coordination process.

The r values in this dimension of Relationship Capital reached the desired 0.5 value at the 10 employee and less size range. The values were 0.415, 0.470, and 0.557 in the respective firm size ranges. This data, and strong relationship at the smallest firm size range, indicate that consultant coordination is important to smaller firms. This dimension was expected to correlate positively with successful adoption. Consultant coordination is a process that requires extensive time and resources. As such, smaller firms would seek ways to streamline this process as it could have a direct effect on profitability, especially as firm size gets smaller.

(RC 4) The use of technology plays a pivotal role in the Firm's consultant coordination process.

The r values in this dimension of Relationship Capital, 0.425, 0.472, and 0.505 reached the desired 0.5 level at the smallest firm size, but again the data shows an increase in strength of relationship as firm size got smaller. This suggests that smaller firm's see the value of technology in the consultant coordination process and education in this dimension could positively impact successful adoption.

(RC 05) The use of technology plays a pivotal role in the Firm's design review process.

The r values in this dimension were some of the highest in the construct of Relationship Capital at 0.536, 0.648, and 0.652 respective of firm size. The relationships at all three firm sizes were strong as they all topped the desired 0.5 mark and showed the highest value at the smallest firm size. This indicates that high responses to this statement correlated with high measures of successful BIM adoption. This dimension of relationship capital is quantifying internal relationships that deal with how the work is getting done. It represents a measure of technological adoption that indicates a willingness to use different technologies to expand firm processes. Firms that are willing to use technologies in a process that is traditionally entrenched in established and often antiquated methods are extremely likely to successfully adopt an innovation such as BIM. These values suggest that as firms get smaller this dimension becomes more important and smaller firms should invest in education in this area.

Figure 5.7 shows a bar graph of the Pearson r correlation values of the five measures within the Relationship Capital Scale on D02 Difficulty in BIM adoption across all three firm sizes evaluated. All values showed negative correlation values as expected, but none of them were strong. All values showed a dip at the small firm level and then a rise at the smallest firm size. This trend could indicate that firms with 15 employees or less are more flexible or nimble as the literature suggests. This means they are willing to attempt new processes and see less difficulty adopting innovations because of this. Larger firms and very small firms are likely built around well-established methods in the dimensions of Relationship Capital and thus report difficulty in BIM adoption as those methods are challenged with BIM adoption.

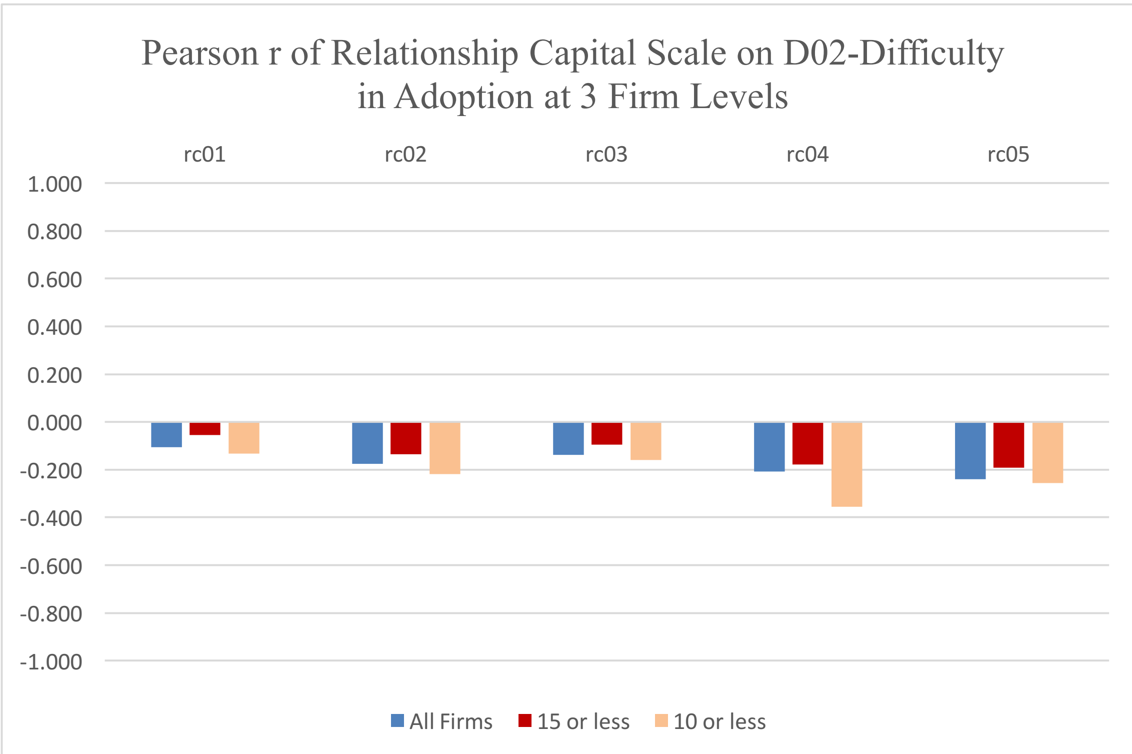

Figure 5.7 Pearson *r* of RC on Difficulty in BIM Adoption at 3 Firm Sizes

(RC 1) The Firm actively searches for a better process of communicating design ideas/solutions to clients.

The r values in this dimension were not strong at all and don't suggest much of a relationship at -0.106, -0.055, -0.132 respective of firm size. This data indicates that lower agreement with this statement correlated with higher agreement in difficulty.

While the values are small, the data suggests that being comfortable with current client communication methods may make adoption more difficult. If current methods are perceived to be sufficient the incentive to adopt and innovation will be small thus increasing the perceived difficulty.

(RC 02) The Firm actively searches for a better process of exchanging design ideas with team members.

The r values in this dimension showed the same trend, -0.176, -0.134, and -0.218 suggesting that entrenched methods of internal idea exchange could have a deleterious impact on BIM adoption by increasing difficulty. This would suggest that smaller firms should seek education on internal idea exchange methods to lessen the difficulty of BIM adoption.

(RC 03) The Firm actively searches for a better consultant coordination process.

The r values in this dimension were the second lowest in the construct at -0.139, -0.094, and -0.158 respective of firm size. This values do not indicate a strong relationship but do show the similar trend of a lower value at the 15 employee and less range, with a spike at the 10 employee and less range. This could indicate that firms in the middle size range of this study are open to new methods of consultant coordination and thus see less difficulty in adoption when faced with new methods imposed by BIM. This could suggest that the smallest sized firms should evaluate their consultant coordination methods and be open innovation.

(RC 04) The use of technology plays a pivotal role in the Firm's consultant coordination process.

The r values in this dimension show some of the highest values in the construct at -0.207, -0.177, and -0.354 respective of firm size. The trend in the data is the same, showing the dip in r value at the 15 or less range and a spike at the 10 or less range. While the r values are not strong enough to suggest a meaningful relationship they do suggest that smaller firms see difficulty adopting BIM when doing so requires them to alter entrenched methods of consultant coordination. This could be due to a lack of perceived benefit or, as the qualitative data supports, a lack of clearly worked out methods of technology data exchange.

(RC 05) The use of technology plays a pivotal role in the Firm's design review process.

The r values in this dimension are consistently the highest in the construct at -0.239, -0.192, and -0.257 respective of firm size. Again the trend in the dip at the 15 and fewer employees is evident. This relationship in the data suggests that the role of technology in the internal design review has impact on difficulty in adoption, but the 15 or less level of firm size shows the least relative impact. This indicates that something is happening at this firm size level that is having less impact on difficulty. Firms of that size range may have enough employees or a financial structure that allows them latitude in trying new methods, but regardless of size, the data indicates that small firms should invest in education on technology enabled design review processes to minimize the difficulty in BIM adoption.

Hypotheses

This study formulated three hypotheses:

1. Factors of firm culture related to innovation are expected to show positive correlation with successful adoption and meaningful associations will be derived from relative degree of correlation.
2. BIM adoption at the small firm level will highest positive correlation with factors of firm culture within the construct of Structure Capital.
    a. Sub-Hypothesis 2a. Structure Capital will have the most significant correlation with successful BIM adoption at the small firm level.
3. Difficulty in BIM Adoption will show negative correlation rates with perceptions of firm culture related to innovation.

Hypothesis 1

The factors of firm culture defined as Human Capital, Structure Capital, and Relationship Capital all showed positive correlation with successful BIM adoption. Not all correlations were strong as discussed in the previous section, but each factor showed dimensions that ranked higher in the relative evaluations. As the dimensions of each factor are examined, common trends emerge.

In Human Capital the dimensions that showed highest correlation were those that reflect a firm culture that includes employees in important decisions and invests in their professional development.

In Structure Capital the dimensions that showed highest correlation were those that dealt directly with maintaining up to date hardware and software as well as the dimension that deals directly with using software in the design process.

In Relationship Capital the dimensions that showed highest correlation were those that dealt directly with seeking better consultant coordination and making technology a pivotal part of the design review process.

Hypothesis 2

The findings of the data analysis support this hypothesis as the dimensions of Structure Capital showed the strongest consistent correlation with successful BIM adoption.

(SC 1) Employees of the firm are provided extensive software training

This dimensioned showed strong positive correlation at the smallest firm size. This is important as it suggests that software training at the smallest firm size will impact successful adoption.

(SC 2) The Firm places a high priority on maintaining up to date technology of both hardware and software.

This dimension showed the strongest correlation values with successful adoption at the small firm level. This is important as BIM is a technology heavy innovation and keeping up to date with both hardware and software will impact successful adoption. Extrapolating from the construct validity, this dimension could be the most important factor to successful small firm BIM adoption as employees see investment in the tools as a commitment to the firm's success.

(SC 3) The use of software plays a pivotal role in the Firm's design process

This dimension of Structure Capital showed a strong correlation and suggests that it has an impact on successful adoption at the small firm level. Small firms looking to successfully adopt BIM should devote resources to learning how to integrate software into their established design methods, or learn new emerging design methods supported by software. Additionally, small firms should invest into learning how to integrate these new methods into existing workflows or learning and developing new workflows around software supported processes.

Hypothesis 3

The findings of the data analysis support this hypothesis as the dimensions of each factor that showed the highest negative correlation dealt directly with seeking innovation in technology and processes.

In the construct of Structure Capital, the dimensions dealing with software showed the highest negative correlations. While they were not strong these relationships suggest that entrenched methods of design process can make BIM adoption more difficult. This indicates that small firms should consider revising methods and workflows rather than expect the new software and processes to conform to their established methods. Additionally, the negative correlation data suggests that failing to maintain up to date hardware and software can make adoption more difficult. This could suggest that small firms consider less time between hardware and software updates to minimize difficulty in adoption.

The strongest negative correlation in the construct of Relationship Capital, RC04, suggests the importance of consultant coordination in minimizing the difficulty in adoption. Again, this could indicate that smaller firms should seek newer or updated methods of consultant coordination supported by technology rather than expect the new technology to adapt to their existing methods.

Open Answer Questions

A brief content analysis was done open answer questions 03 and 04: factors affecting success and factors affecting difficulty.

(O3) If you believe there were any unique or important factors that contributed to the success of the Firm's BIM transition please take a moment to describe them.

The answers to Open Question 03 can be broken down into four categories: Benefit, Training, Commitment (of leadership and staff), and Culture of Innovation. Benefit—answers in this category showed that the respondent recognized a benefit offered by adopting BIM and did so for that reason.

Training—answers in this category reflected a belief that training played a large role in successful adoption.

Commitment (Leadership and/or Staff) – answers in this category indicated that the shift to BIM was motivated by a commitment on the part of firm leadership or firm staff.

Culture of Innovation – answers in this category showed that BIM adoption came from a general belief that it represented the next shift in design and production and the motivation to shift was predicated upon this belief.

There were 26 meaningful answers to O3 and they grouped as such:

Benefit – 6

Training – 2

Commitment – 13

Culture of Innovation – 3

This simple break down shows that a Commitment by either leadership or staff or both had the most responses followed by Benefit, Culture of Innovation, and Training. A complete listing of responses can be found in the Appendix.

(04) If you believe there were any important factors that contributed to the difficulty or failure of the Firm's BIM transition please take a moment to describe them.

The answers to Open Question 04 can be broken down into three categories: Cost, Leadership, and Difficulty.

Cost—answers in this category reflect a general belief that the cost of hardware and software comprised the main difficulty in adoption. BIM softwares are more costly than previous software tools and firms with financial models built around existing software costs would likely see the increased costs of BIM as a barrier to adoption. The literature suggests that firms should look at the benefits of decreased production times as a revenue stream to offset this cost rather than attempting to pass this cost on to clients.

Leadership – answers in this category reflected a general belief that the leadership of the firm either didn't understand what BIM is or how to use BIM or because leadership did not trust the staff to use it effectively because leadership did not understand BIM and how it was used.

Difficulty—answers in this category reflect a general belief that BIM, specifically the softwares involved, were too complicated and more traditional CAD methods were more efficient. It also reflects the belief of a disconnect between what the software does and how projects are delivered, or a lack of professional knowledge to properly implement the software. This category also captured answers that reflected a belief that the software was not developed enough to provide what it promised.

There were 20 meaningful answers and they grouped as such:

Cost – 5

Leadership – 3

Difficulty – 12

This breakdown shows that of the meaningful answers gathered a general belief of difficulty either in learning the software, applying it to established processes, or in performance, was the largest factor in difficulty of adoption. Belief of difficulty was followed by Cost and Leadership. A complete listing of responses can be found in the Appendix.

Recommendations for Small Firm Adoption

This section provides recommendations for Small Firm Adoption based on the findings of this study. Recommendations are broken into three categories associated with the structure of the study; Human Capital, Structure Capital, and Relationship Capital.

Any business organization faces challenges when adopting an innovation and Building Information Modeling is no different. Adopting BIM requires resources. These resources include direct capital expenditures related to technology, time spent, potential loss of income due to lost production. These recommendations are made based on the data in this study.

Human Capital

Over all three constructs, this was the weakest in quantitative data, but within the construct, three dimensions of firm culture emerged as valuable. The first was the dimension dealing with perceptions of professional development (HC05). The second was the dimension dealing with perceptions of trust in problem solving (HC01). The third was the dimension dealing with perceptions of individual value in decision making (HC03). Based on this rank order, firms investing resources into Human Capital should ensure professional development programs are made available to employees. These could include education on professional work flow or design related issues. Additionally, firms should create an environment where employees are encouraged to seek solutions to problems not just rely on inherited and entrenched methods. Lastly, before shifting to BIM employees should have an opportunity to be involved in the decision. They should be told of the driving factors and educated on the benefits of adoption.

Structure Capital

Over all three constructs, this was the strongest in the qualitative data and within the construct two dimensions emerged as most meaningful. The first was the dimension related to up to date hardware and software (SC02). This indicates firms shifting to BIM should allocate resources for up-to-date computer systems. BIM has a large software component that has computer resource demands. Firms not willing to invest in the required hardware will not see performance. Additionally, employees of the firm may see a lack of proper hardware and software as a lack of commitment on the part of the firm. Hardware costs are becoming an accepted part of the industry and budgeting must be adjusted to allow for this.

The second dimension within Structural Capital was directly related to the use of software in a firm's design process (SC03). As the literature notes and the qualitative data supports, BIM represents a fundamental shift in methods of practice. This means that entrenched methods of delivering projects are not likely to be compatible with BIM methods. Solutions to this include investing in education on software enabled design methods and training from experienced consultants, as was noted in the qualitative data. Simply receiving training on how to use software without a contextual link to a knowledge-based process will result in the software dictating the process rather than enabling it.

Relationship Capital

Over the three constructs values for Relationship Capital scored in between Human Capital and Structure Capital. The data suggests that there are three dimensions of Relationship Capital that are linked to successful BIM adoption. The first is the role of technology in the design review process (RC05). This indicates that understanding how technology can be leveraged to improve internal review processes has an impact on adoption. Employees that are forced to make newer methods of communicating and sharing information supported by newer technology conform to entrenched methods that rely on outdated technology can cause frustration and hinder both the adoption process and efficient design production processes. Firms should invest resources into developing work flows around technologically enhanced design review methods.

The second and third dimensions of Relationship Capital that affect BIM adoption deal with communication between internal and external team members. BIM has the potential to increase efficiency in these areas, but requires training on both how the softwares and processes are employed as well as training on professional issues regarding these exchange processes. This was supported in the open answer questions when it was noted that difficulty in adopting BIM came not from a lack of software knowledge, but a lack of how to solve the problem from a professional knowledge standpoint. Firms investing resources into these areas may consider getting BIM training in conjunction with their consultants as well as training groups of employees at a time.

Recommendations for Further Research

This study created and deployed a systematic method for quantifying aspects of firm culture related to innovation in the area of BIM adoption. In addition, it created measures of successful BIM adoption and difficulty in adoption. Through a methodological analysis of the data gathered, the study presented a series of findings that narrowed the aspects of firm culture related to BIM adoption.

Because of the nature of the study and the data gathered this research was not able to define direct cause and effect relationships, but the research was able to make correlations and assess their strength based on quantitative measures. From this methodology the research uncovered several areas that future research could improve upon.

There is a potential for stronger data and correlations with regard to the Likert Scale of measurement and methods of analysis. Since correlation values are taken from variance in the data, creating a Likert scale with 7 or 9 degrees of freedom allow for greater variance in the data and could add a depth to future studies by allowing respondents a larger range of agreement or disagreement.

The survey instrument in this study measured variables of innovation related to firm culture in three areas, Human Capital, Structure Capital, and Relationship Capital. It then measured two variables of BIM adoption and correlated the results. The survey instrument could be used to measure the same cultural factors related to different dependent variables of innovation adoption and correlate the results. This could allow future research into the impact of cultural factors related to any innovation.

The factor of Human Capital did not show a high degree of consistency. While the alpha measurement allowed for degrees of inference within the data, the internal consistency of this construct could be improved by a narrower focus within the statements reflecting the dimensions. Statements measuring human capital should be revised with additional specificity.

BIM is having an impact on design methods and workflows. This study did not address this aspect of BIM. Based on the findings of this study it would be beneficial to gather specific data on how BIM is affecting design methods and workflows within professional settings.

The last area of future research that has emerged from this study is the impact of BIM on business models of architectural practice. While these models are established in the literature, it is also clear from the literature that BIM is having an impact on these models that is not clearly defined or understood. This is because these models are built on tools that support a specific workflow in which information is separate from the methods of production thus requiring knowledge to be stored in the user, not the artifact being represented. When the information and organizing knowledge systems are stored in the artifact or design product, as is the technological direction of BIM, the architectural business models presented in the literature could become antiquated.

Final Thoughts

The principal investigator in this study was a member of small architectural practice that shifted to BIM in 2008. Since that time the principal investigator has assisted several other small practices in shifting to BIM by providing both software training and workflow recommendations based on an understanding of specific firm culture. Additionally, the author has taught BIM enabled courses at the university level since 2009. These experiences have impacted this study in explicit and important ways.

Through adopting BIM in a professional practice setting, then assisting other practices in BIM adoption it became clear that the cultural factors surrounding BIM adoption were equally as important as learning the software. The major barriers to adoption seemed to be a lack of knowledge of potential benefits and a workflow process tied to an explicit understanding of production methodology. The knowledge of how to make drawings as lines on paper drove the entire process. When adopters began to reshape their understanding to that of creating objects and allowing the technology to make the drawings, adoption became easier, production times decreased, and quality increased.

Through teaching Building Information Modeling in a university setting for over six years it was discovered that learning the software was challenging for two reasons. The first was that it represented a major shift in understanding. Students were no longer dealing with lines on paper as representations of architectural abstractions. They were now required to model those abstractions as three-dimensional computer based objects and tie the construction of those objects to dimensional parameters while leaving the computer to do the drawings. The result was the discovery that students are adept at making drawings, but lack any relative understanding of the objects they are drawing. BIM requires them to understand the objects, not the production method of the abstraction. They lacked a deep understanding of architecture, specifically, building assemblies, relation of structural systems, and function of building components. Without this deep understanding there is no impetus or ability to model accurate and meaningful information, which meant there was no impetus to learn the software. Therefore, it became very difficult to get students to want to learn it. Although, anecdotally, once students learned that they could get a higher paying job if they knew the software, the impetus returned and they attained a deeper understanding of architectural systems while learning BIM software and processes.

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APPENDIX A

Table A-1 Survey Instrument Descriptive Statistics

	N	Minimum	Maximum	Mean
Firm Size	110	1.00	6.00	4.1364
Firm Size in Dollars	110	1.00	6.00	4.3909
Responder Role	110	2.00	8.00	5.7455
Registered Architect/Engineer	109	1.00	2.00	1.2844
Type of Services	110	1.00	4.00	1.5091
Years Under Current Leadership	111	2.00	6.00	5.1802
Specialization	111	1.00	2.00	1.4865
HC01	106	1.00	5.00	3.9717
HC02	106	2.00	5.00	4.1604
HC03	106	1.00	5.00	3.3585
HC04	106	1.00	5.00	3.4340
HC05	106	1.00	5.00	4.0377
SC01	104	1.00	5.00	3.0385
SC02	104	1.00	5.00	3.8462
SC03	104	2.00	5.00	4.0769
SC04	104	1.00	5.00	3.7308
SC05	104	1.00	5.00	3.8846
Control 01	98	2.00	5.00	3.8571
Control 02	97	1.00	5.00	2.4330
Control 03	97	1.00	5.00	2.4433
Control 04	97	1.00	5.00	2.3505
Control 05	96	1.00	5.00	3.1667
KC01	99	2.00	5.00	3.6869
KC02	99	1.00	5.00	3.9697
KC03	98	1.00	5.00	3.7551
KC04	99	1.00	5.00	4.0404
KC05	99	1.00	5.00	4.1919
KC06	99	1.00	5.00	3.9495

RC01	97	1.00	5.00	3.8144
RC02	98	1.00	5.00	3.6837
RC03	97	1.00	5.00	3.7526
RC04	96	1.00	5.00	3.8750
RC05	97	1.00	5.00	3.5876
D01 Successful BIM Adoption	95	1.00	5.00	3.0842
D02 Difficulty of BIM Adoption	94	2.00	5.00	3.2872
Perception 01	96	1.00	5.00	3.2396
Perception 02	96	1.00	4.00	2.1875
Perception 03	96	1.00	5.00	3.8958

Table A-2 Responses by TSA Chapter

		Count
Valid	1. Abilene	1
	2. Amarillo	5
	3. Austin	5
	4. Brazos	14
	6. Dallas	26
	8. Fort Worth	4
	9. Houston	11
	10. Lower Rio Grande Valley	2
	12. Northeast Texas	7
	13. San Antonio	8
	16. West Texas	9
	Total	92
Missing	System	19
Total		111

APPENDIX B

Table B-1 Responses to Open Answer 01

Question: *If you believe there were any unique or important factors that influenced the Firm's decision to switch to BIM please take a moment to describe them*
1.Visualization for client. 2. Production of CD's is faster and easier.
A desire to provide the best and most efficient and effective service for our clients.
being a small firm having the best software is important to us, helps us in the delivery and coordination efforts
BIM is used on a limited number of projects
BIM only used for public (government) projects, who have been sold a bill of goods by the software producers. Our private clients are not interested or concerned. Neither community is willing to pay for the cost of using BIM -- measured both in actual money and time expended by our firm, and in terms of extra managerial time required while using BIM. It has proven to be a financial loser for us.
BIM provides greater speed in schematic design and design development. It also allows the firm to make presentations to clients with more realistic and understandable graphics and drawings. BIM enhances communication and coordination between architects, consultants, contractors, and clients.
Coordination issues being resolved in a fraction of the time and creating consistent drawings, reducing errors.
COORDINATION WITH CONSULTANTS
cost and training time
data base + modeling
Desire to be on the cutting edge of design, and convinced that the latest technology could get us there.
Desire to not be left behind.
Desire to stay in the forefront of technology mostly led the Firm to its decision to adopt BIM technology
Ease of revisions
expediting the work-flow. easy transition between documenting process and other tasks such as rendering.
Forced by the wave of compliance
good and accurate and a way to expedite facilities management
good tool for coordination. the wave of the future.
haven't switched because of the time and cost

In 1996 the principal decided to use Archicad over AutoCAD based on it's flexibility and efficiency over line drawings.
inherent awesomeness
maintaining up to date knowledge on programs, and desire to improve and control better the design/delivery process
N/A
na
NA
no
none clients not required bim yet
Not applicable
One very interested Principal
Owner committment to be on the leading edge.
Poorly coordinated 2D CAD produced documents
TAMU is requiring all of their buildings to be in BIM now, along with a couple other clients.
The desire to stay current
The software had the capability and it was easy to utilize the tools and components rather than line drawing.
to speed up the completion delivery time of a project (firm driven not client driven)
User interface, ease of use, comprehensive nature of the software
VW provides an integration of multiple software platforms: solar studies, 3d modeling (sketchup, form-z) presentation graphics (photoshop, indesign)
We have no need for BIM but I decided to buy a seat to experiment with it to see if I thought it had any potential to enhance and improve our work flow and thus justify the great additional cost required to implement it.
We have not fully integrated BIM.
We thought that was the way the industry was going, so we wanted to be out on the leading edge. Saw it as a way to better communicated the design to the client.
What was considered best for the practice and our clients
Young growing firm needed to move to BIM while still building a foundation for the firm.

Table B-2 Responses to Open Answer 02

Question: *If you believe there are any unique or important reasons why the firm has not shifted to BIM please take a moment to describe them*
...it's a more complicated keynote system. Often, the old ways work best on collaborative projects.
Because the software simply does NOT live up to the hype and deliver the goods. It introduces a host of multiple problems and difficulties that we can, very successfully, live without. For example, models that are 100 - 300 MB in size whereas, by our traditional methods, the complete project is about 8 - 10 MB. How do you email such a mess? How do you save it efficiently throughout the day? How do you share it quickly between multiple consultants? How do you work with consultants who do not have the software? There are major problems coordinating with consultants and major software limitations. Plus IMO, it is dumbing down a profession in which members used to be both artists and scientists. I cannot understand why the world of architectural academia, once concerned with promoting, preserving and enhancing the "art" of architecture has become so enamored with a computerized, mechanistic, limited process in which the architect is removed to the background where he is left peering over the shoulder of a CAD technician, watching as he manipulates a massive 3d model which, in the final analysis, is not even an accurate, up-to-date representation of the project anyway. We model only what we need if we have complex 3d geometry to evaluate but, this notion that, in order to design and decent building and minimize conflicts, BIM is absolutely necessary and the entire building must be modeled, is utter nonsense, as conclusively demonstrated by all of the great architects throughout history.
BIM is used on 80 - 90% of projects
Cost
cost and training
cost and training time
COST OF SOFTWARE COST OF LEARNING CURVE LITTLE INCENTIVE FROM CLIENTS
Cost of software and training
Cost of Software, and Cost of training/Learning curve to get everyone on new page
cost of transitioning the process and education of employees to a completely different method of design and production
Cost would be a factor if I had more employees.
cost, applicability to projects
Cost, both in terms of training and software.

Cost, learning curve, BIM as a total package
Costs. Essentially it is keep current employees, or go to BIM.
Expense and learning curve. Major client has not insisted.
Firms think the cost of the software, the hardware, and the training is too much. I would argue it is too much not to switch. Most firms recoup their losses within 1 year and see a 15% to 30% reduction of man-hours on a given job allowing them to either do more projects for less money, provide more value for the same money, or drastically increase the value for more money.
gradually converting to BIM
High cost of training, hardware, and software, lack of foresight/vision from firm principals, and predominance of renovation or addition projects are all deterrents to adopting BIM.
I produced a $256 million project in REVIT as the design architect with an architect of record and following are conclusions from my experience: the software, hardware, and training are too costly. It took an excessive amount of time in AutoCAD to make the 2D drawings (still required) to look right and readable. Most engineering consultants are not using it yet. The contractors are promoting it for their benefit - they want the architects to do their work and use the model for take-offs. Producing project CD's take more time, thus less (or no) profit and clients are typically not agreeable to paying more for a BIM produced project. There is also additional exposure and liability that is inherent in the BIM model. Again, the risk / reward scenario is already disproportionate and BIM makes it even more so. From my experience it's not an effective tool for the real world firm, at least not yet. The software companies have done a great job of lobbying the government and created significant ""marketing hype"" around BIM in order to have something new to sell and keep themselves in business.
is not necessary for most basic cad design
Learning curve
Much of BIM is not ""mature"" enough for small scope work.
n/a
N/A
NA
no
None
Not applicable
not unique: entirely because of cost and time
one partner has yet to switch. the cost in time is significant. switching is a bit of a paradigm shift.

Resistance among other Principals and difficulty overcoming misconceptions.
skills of the draftsman and time for the architects
Some projects (such as renovations) are too small or simple to require set up in BIM
The additional time and expense involved in the entire BIM process just increases our overhead expenses, not the firm's bottom line profits. The entire professional has become wrapped up in ""process"" instead of ""product"" -- and the quality of built architecture has been declining for some years. While the ""star"" architects seem to succeed at producing architectural fantasies with no regard to either cost or functionality, the rest of us are struggling to meet clients' expectations while cutting each other's throats in terms of fees actually charged and received.
The software is too expensive, too complex, and not easily integrated with our current CAD software. Our person that is now learning BIM is a part time CAD instructor, and he has gone to multiple BIM seminars. After each seminar, he has returned saying that BIM is not yet ready for us and vice versa.
The use of BIM is not important to our building enclosure QA consulting and testing services.
Unstable market and staff reductions
We are currently 80% residential (single family remodels) projects and there is too much in the plans that has been custom designed.
We have shifted.
We're all in with BIM!
Total

Table B-3 Responses to Open Answer 03

Question: *If you believe there were any unique or important factors that contributed to the success of the firm's BIM transition, please take a moment to describe them.*

allows us to manage projects that might otherwise be beyond our capabilities
As a small firm it is very easy to implement change for the entire office.
Being a smaller firm, transitioning the entire company was not as long and expensive as larger firms.
Classroom training was critical. The economic slowdown gave me time to learn the software without deadline pressure.
commitment to change

Complete dedication to the process and transition ""buy-in"" from the ownership. Lack of believe sabotages the implementation process. Belief fosters the growth and speeds up the transition process.
Cost of sofware and training
dive in completely
Firm owner's committment to move to BIM. Once we were over the initial break-in period CAD was deemed unacceptable. We had to take the CAD crutch away from our staff and do the same for consultants.
It seemed like the future of the profession, so it was not really optional.
More realistic renderings
N/A
NA
no
none
Not applicable
Not having to purchase a lot of seats (1 man firm), and being the only employee, I had no choice.... ;-)
Our firm is very open to new ideas and technologies. As a team, the architects in the office are constantly searching for new methods to improve the way we work and communicate within the office and with our consultants/clients/contractors/etc.
Our project architect dove in head first and took every tutorial available on Revit. She was committed to keeping the models like and correct, not abandoning them just to finish in CAD.
persistence + patience
Previous training of firm principal and active role of Principal in making transition
Quality of the staff on BIM Projects
See #2 above committed project architects who were learning the software and desiring to change the process of service delivery.
Since we have been using Archicad for such a long time we have been eager to adopt the incremental advancements of BIM software over the years.
Staff with limited Revit experience willing to devote time, effort, energy, and determination to finishing a project in Revit for the first time. Leadership that understood the ""learning curve"" and were committed to the change. Using a revit consultant to help us over the hump of getting our template and standards set up.
Upper level support and patience with the learning curve

Used outside training sources. It wasn't that one person learned it and then taught everyone else. We used outside training sources and brought on a consultant to help us create and implement a new office standard in revit
What was considered best for the practice and our clients
When work got slow due to the economy, there was time available to learn and begin to implement Revit. If we had been very busy, we would not be using it today.
where cad offers a digital drawing environment, bim offers a digital design/development environment. exactly HOW we do that is something that we are still working on. as with all things, it was learned on the fly with a project....it is a messy process but the only way to ensure motivation to learn, incorporate and innovate.
Wouldn't say it is completely sucsessful

Table B-4 Responses to Open Answer 04

Question: *If you believe there were any important factors that contributed to the difficulty or failure of the firm's BIM transition please take a moment to describe them.*

BIM is a complete change in process. It impacts management, staffing,
cost
Cost
Cost in software and hardware; learning curve that had to be dealt with on live projects (no chance to break for extensive training).
Expense. I would go learn it on my own if it wouldn't cost nearly as much as it does. Also, my personal computer is Mac and there is no Mac version that I am aware of. If it is developed, it most likely will require the same hardware as AutoCAD for Mac, which requires hardware newer than what I currently own. My hands feel tied because I greatly desire to learn the program but am unable to get access to it.
Firm principal not working in BIM as much as less experienced staff led to a lack of accountability with staff's performance.
Getting everyone trained
had one employee with BIM experience but not a firm understanding of architecture and the process. it was a disaster.
hard to learn for old guys
hesitatcy of older staff
I would have liked more formal training or guidance rather than a ""learn as you go"" process

It is a different way to work through the documentation process. It differs from CAD in that respect and long time CAD users are more difficult to adjust.
It takes too much time and expertise to build the families.
Lack of ""buy-In"" from the ownership.
Learning curve. No one in the office has previous experience with it.
Most work just requires 2D drafting. 3D and all the layers are nto necessary in most small firms
n/a
N/A
NA
no
none
None
Not applicable
Our difficulties have been: 1. Lack of ability of the MEP version of Revit to accurately portray MEP systems. It's way behind the architecture and structure versions. The manufacturer's promises of clash detection and the ability of BIM as a coordination tool are not yet as beneficial as the manufacturer's promises would suggest. It's getting better, just not there yet. 2. Simiar to above for civil and site though the latest versions of Revit and AutoCad Civil 3D have allowed us to better interact with the civil engineers. 3. Poor initial training programs by the software manufacturer. The online tutorials were good but the local software vendors taught only an overview but did not teach everyday fundamentals.
See #3 above.
There is not enough affordable training available for small firms.
we are finding that certain projects are not as well suited to bim and others.
We are using it and will never go back to 2-d cad.
We wind up serving the software more than it serves us

APPENDIX C

Table C-1 BIM Software Used	
What BIM software does the firm use, if any?	
2 seats of Revit	1
archicad	1
ArchiCAD	2
ArchiCAD 14	1
Archicad 14 & 15	1
Archicad by Graphisoft	1
ArchiCAD, but had to transition to Revit.	1
Autocad	1
AutoCAD REVIT 2010	1
Autodesk Revit	1
Autodesk Revit, Solidworks, ArchiCAD	1
Bentley Architecture & it is a painful waste of money so far.	1
Currently none.	1
DataCAD, SketchUp	1
Graphisoft Archicad	1
moving to Revit.	1
N/A	1
NA	1
no BIM at this time	1
none	5
None	4
None.	1
Not Used	1
own a copy of revit. don't use it.	1
revit	2
Revit	28

Revit 2011	4
Revit 2011 & 2012.	1
revit 2012	2
Revit 2012	2
Revit and Tekla	1
Revit architecture	1
Revit Architecture	3
REVIT ARCHITECTURE	1
Revit Architecture 2011	1
Revit Architecture 2011 and 2012	1
Revit Architecture, Structure, & MEP, Navisworks, 3D Studio Max, Ecotect, & Quantity Take-Off.	1
Revit, 2011-2012	1
Revit, SketchUp	1
Vectorworks 2010 Architect Renderworks by Nemeschek	1
vectorworks architect 2009	1
Vectorworks/Renderworks	1
We do not use any BIM software, but one member of the firm is currently learning to use Revit on his own time.	1

APPENDIX D

Table D-1 Sample Data Table

RespondentID	1436331058.00	1537641029.00
Firm_Size	6.00	6.00
Firm_Size_dollars	6.00	4.00
responder_role	3.00	3.00
registered	1.00	1.00
type_of_services	3.00	1.00
other_type_service		
years_under_leadership	6.00	5.00
specialization	2.00	1.00
type_of_spec		K-12 Education, Higher Education, Healthcare
hc01	2.00	4.00
hc02	3.00	5.00
hc03	2.00	4.00
hc04	1.00	3.00
hc05	3.00	5.00
sc01	1.00	5.00
sc02	4.00	5.00
sc03	3.00	4.00
sc04	1.00	4.00
sc05	1.00	5.00
control_01	3.00	2.00
control_02	1.00	2.00
control_03	5.00	1.00
control_04	5.00	1.00
control_05	2.00	2.00
KC01	2.00	5.00
KC02	3.00	4.00
KC03	3.00	3.00
KC04	4.00	5.00
KC05	3.00	4.00
KC06	2.00	3.00
rc01	3.00	4.00
rc02	2.00	4.00
rc03	2.00	4.00

rc04	2.00	4.00
rc05	1.00	2.00
D01_Successfull_BIM_Adoption	1.00	5.00
D02_Difficult_BIM_Adoption	5.00	2.00
Percep_01	3.00	2.00
Percep_02	2.00	4.00
Percep_03	4.00	4.00
BIM_Software	Revit	Revit
Open_01	We had a federal client that required the use of BIM to perform the work.	Increased coordination with in house MEP staff.
Open_02	Lack of commitment and an overall failure to standardize production and presnetation techniques. The effort required to make the shift is seen as not worth the investment. Mostly we just try to keep the workflow moving and not let the introduction of a new program or process slow us dow. Unfortunately, there is a growing gap in our cad literacy and BIM is seeming like a product that is further put of reach than ever. Our BIM experience has been extremely costly in terms of education and re-work of products to get the proper appearance.	Smaller projects do not justify the increased overhead requirements.

Open_03	The attempt was made to transition but it was a true failure.	Over a 6-12 month period, all staff including select principals in the firm were given a 3 day revit training session.
Open_04	There was no single source of responsibility for managing the process. Additionally, there was little enforcement when problems were discovered. Finding agreement and commitment to the rules is essential and because everyone was working just to learn the rules it was diffucult the then enforce them.	Individuals unwilling to make the transition were the biggest difficulty.
Consulting_services	Yes.	Yes - these services were used.
CE_courses	Yes.	No.
followup	979-492-1650	Jarrod Sterzinger 512.478.7286
Chapter	4.00	3.00

APPENDIX E

Survey Instrument

Demographic 01

How many people are employed in the firm?

1 2-3 4-6 7-10 11-15 16+

1

Demographic 02

What is the annual construction dollar value of projects (in millions)?

<1 1-3 3-6 6-10 10-15 15+

2

Demographic 03

Which term best describes your role in the firm?

Drafter
Intern
Project Manager
Intern Architect
Engineer In Training
Architect
Engineer
Principal

3

Demographic 04

Are you a registered Architect or Engineer?

Yes No

4

Demographic 05

What type of professional services does your firm provide?

Architectural

Engineering

Both

Other: specify

5

Demogrpahic 06

How many years has the firm operated under the current leadership?

1 2-3 4-6 7-10 11-15 16+

6

Demographic 07

Does the firm specialize in a particular architectural type such as commercial, educational, or healthcare?

Yes No

Is so, what type?

____

7

HC 1

Please indicate your level of agreement with the following statement.

The firm encourages initiative in developing new solutions or processes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

8

HC 2

Please indicate your level of agreement with the following statement.

The firm has senior management that exhibits decisive leadership.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

9

HC 3

Please indicate your level of agreement with the following statement.

When the firm initiates an innovation or change all employees are included in the decision process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

10

HC 4

Please indicate your level of agreement with the following statement.

When the firm initiates a change buy-in by all members is quickly achieved.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

11

HC 5

Please indicate your level of agreement with the following statement.

The firm places a high priority on professional development with regard to tools and knowledge.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

12

SC 1

Please indicate your level of agreement with the following statement.

Employees of the firm are provided extensive software training.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

13

SC 2

Please indicate your level of agreement with the following statement.

The firm places a high priority on maintaining up to date technology of both hardware and software.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

14

SC 3

Please indicate your level of agreement with the following statement.

The use of software plays a pivotal role in the firm's design process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

15

SC 4

Please indicate your level of agreement with the following statement.

Workflow, or the system by which the work gets finished, are clearly understood by the firm.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

16

SC 5

Please indicate your level of agreement with the following statement.

The firm makes extensive use of libraries, standards, and web resources.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

17

RC 1

Please indicate your level of agreement with the following statement.

The firm actively searches for a better process of communicating design ideas/solutions to its clients.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

18

RC 2

Please indicate your level of agreement with the following statement.

The firm actively searches for a better process of exchanging design ideas with team members.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

19

RC 3

Please indicate your level of agreement with the following statement.

The firm actively searches for a better consultant coordination process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

20

RC 4

Please indicate your level of agreement with the following statement.

The use of technology plays a pivotal role in the firm's consultant coordination process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

21

RC 5

Please indicate your level of agreement with the following statement.

The use of technology plays a pivotal role in the firm's design review process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

22

D 01

Please indicate your level of agreement with the following statement.

This firm has successfully transitioned to a Building Information Modeling (BIM) platform.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

23

D 02

Please indicate your level of agreement with the following statement.

The adoption of BIM by the firm was difficult.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

24

P 01

Please indicate your level of agreement with the following statement.

This firm is very satisfied with a Computer Aided Drafting (CAD) based delivery method.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

25

P 02

Please indicate your level of agreement with the following statement.

BIM is just another 3D drafting program.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

26

P 03

Please indicate your level of agreement with the following statement.

BIM is a method that integrates software and a process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

27

C 01

Please indicate your level of agreement with the following statement.

BIM is extremely costly.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

28

C 02

Please indicate your level of agreement with the following statement.

BIM is overly complex and ill suited for the type of work of the firm.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

29

C 03

Please indicate your level of agreement with the following statement.

The firm employs BIM methods only when they are required by the client, consultant, or market.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

30

C 04

Please indicate your level of agreement with the following statement.

The firm shifted to BIM because a client requested/required it.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

31

C 05

Please indicate your level of agreement with the following statement.

The transition to BIM occurred over an extended period of time, training a few employees at a time.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

32

KC 01

Please indicate your level of agreement with the following statement.

The firm has an exemplary project delivery process that is clearly communicated to all members.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

33

KC 02

Please indicate your level of agreement with the following statement.

The firm is a close knit community, almost like a second family, in which the sharing of ideas and experiences is encouraged.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

34

KC 03

Please indicate your level of agreement with the following statement.

It is clearly understood and communicated in the firm that both successes and failures are the result of team efforts.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

35

KC 04

Please indicate your level of agreement with the following statement.

It is clear who is in charge of any given project or issue in the firm.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

36

KC 05

Please indicate your level of agreement with the following statement.

Employees are encouraged to interact and learn from one another in the firm.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

37

KC 06

Please indicate your level of agreement with the following statement.

The firm works hard to cultivate a team spirit.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

38

BIM software

What BIM software do you use, if any?

39

Open Answer 01

If you believe there were any unique or important factors that influenced the firm’s decision to switch to BIM please take a moment to describe them.

40

Open Answer 02

If you believe there any unique or important reasons the firm has not shifted to BIM please take moment to describe them.

41

Open Answer 03

If you believe there were any important factors that contributed to the success of the firm's BIM transition please take a moment to describe them.

42

Open Answer 04

If you believe there were any important factors that contributed to the difficulty or failure of the firm's BIM transition please take a moment to describe them.

43

IR 01 Consulting

If consulting services were available for transitioning to BIM, would you be interested?

44

IR 02 Continuing Education

If Continuing Education Courses were offered that directly dealt with transitioning a firm to BIM would you be interested and would you be willing to pay for such courses?

45

IR 03 Follow up

If you would be willing to conduct a follow-up interview about your firm’s BIM experience or BIM transition process please provide your name and contact information.
This information will in no way be tied to the answers you provided in this survey.
Thank you for your time.

46

IR 04 TSA Chapter

If you are an architect located in the state of texas, with which TSA chapter are you affiliated?

47