

A STUDY OF THE ADAPTATION OF PARAMETRIC COMPUTER DESIGN
AMONG LANDSCAPE ARCHITECTURE PROFESSIONALS
IN TEXAS

by

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Abstract

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Parametric design utilizes algorithmic-based software to produce computational, generative, responsive, and immersive three-dimensional models for use in landscape architecture, planning, and architecture (Cantrell & Holzman, 2016; Jabi, 2013). Advanced parametric software tools such as Rhinoceros and Grasshopper combine to create a robust system to express a set of customizable parameters that define and clarify the design intent and set of iterative solutions to a design problem (Jabi, 2013).

Although parametric design in architecture has been in use for over 15 years, it has not been broadly adopted by the field of landscape architecture. Current professional practices illustrate that software development within the design fields, including landscape architecture, are strongly trending towards augmented reality, open source software and building information modeling systems (Bentley, et al. 2016).

The purpose of this research is to understand the adaptation and implementation of the innovation of parametric design into the field of landscape architecture overall, then specifically to the practice and the speed with which the innovations are being adapted into landscape architecture firms in Texas. Research on this topic has the possibility to increase awareness of technological advancements in the practice and education of landscape architecture, architecture, and planning. In this study, the researcher documents the current understanding of parametric design in the practice of landscape architecture nationally and internationally through literature review, and then compares it to the practice in Texas by studying landscape architecture professionals' perceptions on the issue.

This research followed qualitative methods (Deming & Swaffield, 2011) to acquire the knowledge needed to understand the adaptation and implementation of the innovation of parametric design in Texas. In this study, this researcher conducted in-depth interviews to discover patterns in the acceptance or likely adaptation of parametric design in landscape architecture firms. The subjects were designers or managers of landscape architect firms that practice landscape architecture in Texas. The snowball technique was used to acquire the study population (Taylor & Bogdan, 1998).

Rogers' theory, Diffusion of Innovation, was used to design questions to be used while interviewing landscape architectural professionals to determine their level of adapting innovation (Rogers, 1995; Deming & Swaffield, 2011) to their design practices. Themes were drawn from the interviews using the Diffusion of Innovation categories, to document the overall rate of adaptation to the process of parametric design experienced from the participants in the interviews. The responses are studied qualitatively to understand where each firm or landscape professional stands within its process of innovation (Taylor & Bogdan, 1998; Deming & Swaffield, 2011).

In conclusion, this research assessed that adaptation is happening in landscape architecture firms in Texas, and summarizes its current usage and explores the technical, financial, and educational issues of adapting to these methods. The interviewees had a wide range of experience in professional management and practice. However, experience with emerging industry software and technology was more prevalent in the training of new staff than it is with upper management. Most firms agreed that technology changes are on the horizon, but there is no clear way of defining what that means for each practice using parametric design.

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Chapter One

INTRODUCTION

1.1 Introduction

In this chapter, the question is introduced regarding the extent to which parametric design (PD) has been adapted among landscape architecture professionals in the state of Texas. The technical terms associated with the use of PD are defined to aid in the understanding of the topic. The qualitative research method, Diffusion of Innovations (Rogers, 2003), is outlined and presented as the guiding principle in the creation of the main research questions, and the design of practitioner interview questions. The significance of studying PD as it relates to landscape architecture and the related fields of architecture and planning are outlined as well as the limitations of the research on this subject.

1.2. Problem Statement

Research suggests that advanced PD such as generative, responsive, and immersive design is emerging into the field of landscape architecture, and design schools are beginning to teach it, but it is still not widely sought as a competency for designers entering the job market (Bentley, et al. 2016). Many examples are showing compatible architectural uses of generative PD in the creation of public art, arbors, and other architectural amenities such as building tessellation or tiling. However, there are very few examples of these technologies extending into the field of landscape architecture (Bentley, et al. 2016).

Bradley Cantrell from Harvard Graduate School of Design, among others, believe responsive and immersive landscape design technologies are at the cutting-edge of academic research and commercial development respectively (Green, 2017; Tal, 2017; Bentley, et al. 2016). This research paper investigates the status of landscape architects in Texas, and where they are in the process of adapting to advanced parametric workflows. such as responsive and immersive design, as well as, accessing the adaptability of other parametric tools such as Geographical Information Systems (GIS), Computer Aided Design (CAD), Building Information Modeling (BIM), and City Information Modeling (CIM).

1.3 Purpose Statement

The purpose of this research is to understand the adaptation and implementation of the growing innovation of parametric design into the field of landscape architecture in Texas. Specifically the research attempts to understand the computer software tools that are adapted, similarities and differences in education and practice. And potential impediments in the adaptation of these new technologies among landscape architecture professionals in Texas. Through a qualitative research approach to interview questions and the analysis and conclusions to the interview data, the study draws a picture of the current level of adaptation to the innovation of PD into landscape architecture firms in Texas. Research in this topic has the possibility to increase awareness of technological advancements in the practice of landscape architecture, architecture, and planning; as well as influence both the communication channels of new innovations, and influence decisions of training at the academic and professional level.

1.4 Research Objectives

This research is an inquiry on the level of adaptation to PD by landscape architecture professionals in Texas. Research suggests that landscape architects in practice have slowly embraced software coding and computational logic (Bentley, et al., 2016). Furthermore, since landscape architecture tends to be an ecological practice, landscape architects have been the least active in the design arts to utilize digital technology in their practices (Pihlak, 2004). Designers can now use PD tools with the help of computer scripting methods and the availability of extensions and applications to customize programs and test landscapes over periods of time through simulation modeling. These new approaches can implement variables such as; wind speed, microclimates, drainage, social media, and marketplace metrics (Reed & Nister, 2016). Some design schools have begun to implement classes and workshops to study this form of design practice, but at this point, it appears to be an emerging subset of landscape architecture in the early innovation stage (Bentley, et al., 2016; Rogers, 2003).

Research in the review of the literature on this topic holds a deeper understanding of the history and current uses of parametric design nationally, and internationally (Bozdoc, 2003; Merideth, et al., 2008). Through a qualitative study of the social and technical aspects of this design practice within the contemporary design office, it is hypothesized that these new processes can aid in the creation and implementation of new landforms, spaces, management, and infrastructure for urban, suburban, and natural landscapes.

1.5. Research Questions

The questions emerging in this study stem from a desire for understanding what is considered parametric design in landscape architecture, and how is it being accepted and utilized into the field of landscape architecture. The subject group was established as landscape architecture professionals, licensed or non-licensed. It was decided to conduct interviews to determine themes in the practice of landscape architecture. The central questions in this study are:

1. To what extent is parametric design adapted into the field of landscape architecture in Texas?
2. What computer software tools are adapted for use in parametric design in Texas?
3. Are there similarities or differences in the level of adaptation of parametric design between education and practice? If so, what are they?
4. What is the most important factor of adapting to innovation in PD for landscape architect practices in Texas?

Additional questions such as the demographics within the firm or individual practitioners that, if any, are involved in the design process using computational software, will be noted within the interview process in Chapter Four.

1.6 Definition of Terms

Algorithm: Systematic procedures for solving mathematical problems. Algorithms usually have an input, go through a process, and then create an output solution (Jabi, 2013, p. 200).

Biophilic Design: Designing with the intent of affiliating with the love of life (biophilia) beyond the human condition, to incorporate natural forces such as the wind, water, sound, color, animals, in the built environment (Beatley, 2011).

Boolean Solids: A form of constructed solid geometry (CSG) used in 3D modeling to produce a complex surface or object. (Foley,1996). In regards to 3D computer modeling, it is used as a union of two or more objects or subtraction (Jabi, 2013).

BIM: Building Information Modeling. A computer aided method of conducting design alongside statistics such as the cost of materials, spatial relationships, and building components (Jabi, 2013).

CAD: Computer Aided Design, developed as a tool to create vector based graphics for drawing and structural analysis. This innovation is one of the most used designing tools in the world. Its usage varies from Architecture, to Landscape Architecture, to Mechanical and Civil Engineering.

CAM: Computer Aided Manufacturing initially designed for the Automotive and Aeronautic industries to develop three-dimensional drafting for use in manufacturing, and current 3D printer, laser cutters, and other manufacturing tools.

CATIA: Acronym of computer-aided three-dimensional interactive application used for Computer Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer-Aided Engineering (CAE) product lifecycle management (PLM), and 3D modeling (Bernard, 2003).

City Engine: Software developed by Environmental Systems Research Institute (ESRI) to convert 2D plan drawings into 3 dimensional buildings with the ability to store and change data based on parameters set into the City Information Model (ESRI, 2017).

Coding: A set of characters used to convey a set of instructions within a computer application. These instructions are the framework in which a software program runs on. Code that a programmer writes is called source code. Once compiled, it is referred to as object code. Code that is ready to run software is called executable code *or* machine code (Beal, 2017).

Computational: An algorithm that performs a predefined task such as creating standard geometry or computing data

Grasshopper: A generative modeling plug in for Rhino 3D CAD system that can perform advanced programming through visual scripting to explore 3D surfaces and forms, through the input of a visual programming interface (VPI) (Payne, 2008)

Generative Form: An algorithm that simulates a natural evolution in search of the fittest solution to a problem over the exploration of many design iterations (Jabi, 2013)

Geographic Information Systems (GIS): Computer Mapping System designed to overlap environmental conditions with economic and legal boundaries in Vector and Raster formats (Marsh, 2010).

Human Computer Interface: (HCI) A perspective between a computer or simulation table and a human that sets forth a design directive, then crafts new instructions to reach a design project solution (Cantrell & Holzman, 2016).

Mesh: A process of creating a "skin" over an object or the top of a non-prismatic shape or framework such as topology or geometric shapes for further computer design iteration. Unlike solid mesh, modeling meshes have less digital mass to them, allowing more precise modeling surfaces and shortening the rendering process later (Young, 2012).

New Urbanism: An urban design movement which promotes walkable neighborhoods, mixed-use, and transit-oriented development, and design practices standard before the rise of the automobile in the 1930s (Greenbelt, 2015).

NURBS: Non-Uniform Rational B-Splines: are mathematical representations of 3D geometry that can accurately describe any shape, from a simple 2D line or curve to the most complex 3D organic freeform surface, solid or mesh. Because of their flexibility and accuracy, NURBS models are used in any process from graphic representation to fabrication (Packerham, 2014).

Open Graphic Library: A software interface to graphics hardware consisting of a set of several hundred procedures and functions that allow a programmer to specify the objects and operations involved in producing high-quality graphical images, specifically color images of three-dimensional objects. Many OpenGL calls also pertain to drawing objects such as points, lines, and polygons, and animation framebuffer manipulation (Segal, 2010).

Open Source Software: (OSS) Computer software with its source code made available through a license by which the copyright holder provides the rights to study, change, and distribute the software to anyone and for any purpose. This software is sometimes available to the public for free to aid the process of innovation such as applications and extensions (St. Laurent, 2008, p.4)

Parameters: Set of variables within an equation that sets constraints on the possible outcomes of a given mathematical equation (Stover, 2016).

Parametric Design: Is a process, based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode and clarify the relationship between design intent and design response (Jabi, 2013, p.201). Parametric design as a process of not fixed metric quantities but of relationships between objects, allowing changes to occur in one of the objects then makes corresponding changes to the other objects (Merideth, et al. 2008).

Parametricism: Has its origin in parametric design, which is based on the constraints in a parametric equation it relies on programs, algorithms, and computers to manipulate equations for design purposes (Schumacher, 2010).

Parametric Equation: A set of equations that express a set of quantities as specific functions of independent variables, known as "parameters" (Stover, 2016).

Performative Landscapes: A way of designing with the aid analysis of physical systems such as the wind, water, the sun, and biology through analysis, then using that analysis to design better micro conditions for those physical systems (Hock, 2013).

Placemaking: A process of creating active plazas, walkable streets, and other attractive public destinations for the use of collective urban socialization (Project for Public Spaces, 2009).

Polygonal Mesh: A type of geometrical modeling using vertices, edges, and faces to help define an object in the form of triangles quadrilaterals or polygons (Smith, 2006).

Responsive Technologies: It is an interaction between environmental phenomenon and architectural space utilizing low-tech sensors and robotic actuators to test simulations and to communicate dynamic natural forces, social awareness, and the creation of new design iterations through a human-computer interface (HCI) (Cantrell & Holzman, 2016).

Rhinoceros: Also called Rhino, is a standalone 3D modeling program that offers precision and flexibility for anything from product design, to architecture and engineering. It is also the platform for Grasshopper and several other extensions (Packerham, 2014).

Scripting: A method of using algorithmic design to generate complex forms while maintaining the individual characteristics of pure geometry in the original form. It is taking the source code of software and refining it to solve a problem (Jabi, 2013). It can also be used to take on a geometric based ornamental quality or refine existing commands (Merideth, et al. 2008).

Shape Files: A spatial data format within GIS software developed by ESRI, developed to be shareable among other GIS applications and software products. These files can describe Vector features such as points, lines, and polygons that may represent anything from water sources, property lines, and other non-topological data (ESRI, 1988).

Smart Cities: Cities working towards better technological connections with available open data. It is the ability to influence anything such as maintenance, traffic, energy costs, and notifications for health risks and more (Cnet, 2017).

Smart Growth: Is development that better serves the economic, environmental and social needs of communities. Such as planning for mix land uses, compact building design, walkable neighborhoods, preserved open space, and community stakeholder collaboration in development decisions, among other things (Greenbelt, 2015).

Tessellation: In regards to geometry that refers to a process of tiling a repeating geometric shape surface with no overlapping surfaces (Jabi, 2013).

Tiling: Is the arrangement of repeating or relating planar shapes to cover any given area without overlapping or leaving gaps. Used to create urban hardscapes and patterning frameworks for glass and other materials in architecture (Jabi, 2013).

Visual Programming Environment: A calculation module within the structure of a software extension that interacts with the geometry of a CAD model using indicators or parameters to change the form or structure of a parametric model (Payne, 2008; Jabi, 2013).

1.7 Research Methods

This research utilizes a qualitative methods (Deming & Swaffield, 2011) to acquire the knowledge needed for this research. The research primarily uses in-depth interviews as data collection methods. The interview subjects were landscape architecture professional designers, or managers of firms that are practicing landscape architecture in Texas. The snowball

technique was used to acquire the study population (Taylor & Bogdan, 1998). The study uses in depth interviews with landscape architecture professionals to decipher themes in the adaptation or rejection of parametric design practices in landscape architecture firms.

Rogers' theory, Diffusion of Innovation is used to design questions to be used while interviewing landscape architecture professionals (Rogers, 2003). Questions were administered in person, on the phone, or online interviews. Themes were retrieved in the interviews reported by the interviewees. The answers were studied qualitatively to understand where each firm or landscape professional stands with respect to the Diffusion of Innovation of parametric design in landscape architecture (Taylor & Bogdan, 1998).

The overall rate of adaption to the process of these design methods were studied in a five-step process that is implemented into the design of the interview questions. Rogers' Diffusion of Innovation Theory qualitatively examines an Innovation implementation, or non-acceptance within a particular social system. This five-step rate of Innovation process is (Rogers, 2003).

1. Perceptions of Relative Advantage
2. Perceptions of Compatibility
3. Perceptions of Complexity
4. Perceptions of Trial ability
5. Perceptions of Observability

(Rogers, 2003)

Once the analysis is completed through investigating themes in Rogers' diffusion theory, the data from the interviews, as well as themes generated from the interviews will be used to answer the questions posed in the main research questions. Further clarification of Rogers' diffusion theory such as the elements of innovation, discussion of change agents, and the perceived attributes of the innovation (Rogers, 2003), as well as detailed methods and analysis, will be further explained in Chapter Three, Research Methods, and Chapter Four Analysis and Findings of this thesis.

1.8 Significance and Limitations

This study is about understanding the importance and limitations of adapting to the broader innovation of PD of Texas landscape architecture firms, and an investigation into the educational, technical, and the cultural factors of the modern-day landscape architecture design firm. The study has the potential not only to influence what is experienced as technical challenges in the modern day design office, but also it's visionary thinking about the future. This research has the potential to affect the decisions of faculty and administration that make up decisions about coursework and requirements for professional degrees at the university level. The research benefited from interviews from LA professionals with various levels of experience in Texas given that the interview pool was a small portion of landscape architectural professionals in Texas. At the end of the research, it was realized that the majority of the interviewees were not using parametric tools on a day to day basis. These interviewees were primarily in management positions.

Another limitation in the research was the definition and understanding of parametric design as a term, as well as a tool for landscape architecture professionals interviewed. Although this concern is minimized by providing a common set of definitions and a list of the available software tools for PD (See Appendix.C), the interviewees typically seemed to respond to questions with limited knowledge about the overall concept of parametric design.

1.9 Chapter Summary

The focus of Chapter One has been to give an introduction of the thesis question and intent, as well as defining the objective of the research questions for in-depth interviews. The technical terms were defined to make the topic more understandable. The research methods were introduced briefly to summarize Rogers' Diffusion of Innovation (Rogers, 2003). The perceived significance and limitations of the research were also discussed.

Through an intensive literature review in Chapter Two, the history, concepts, and research and development that led to past innovations is studied to understand the innovations of today and into the future. Chapter Three focuses on the research methods following diffusion of innovation theory (Rogers, 2003) and explains the procedures followed to study parametric design software with landscape architecture professionals in Texas.

Through the interview process, the adaptation of innovations past, present, and future in landscape architecture firms in the state of Texas are reviewed, analyzed, and summarized in Chapters Four and references with Rogers' Diffusion of Innovation Theory. Chapter Five summarizes the findings. Within those chapters, the research investigates the interviewees, and

the field topic of studying technological innovation. The results of the interviews are referenced through the lens of Roger's Diffusion of Innovations adaptation characteristics, Four main elements of innovation, and the innovation adaption categories, as well as the significance of the research as it relates to landscape architecture.

The research concludes with a qualitative analysis of the four main research questions. To conclude that parametric design is developing at various stages depending on the demands of the marketplace, future research, and vision for the future. The conclusion reflects on where PD is potentially heading for as a design practice in this changing world and workforce.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the literature review of the research on parametric design among landscape architecture professionals. The review focuses on history, definitions, and the technological background in parametric design. The study looks at the broader architectural design background, as well as the use of parametric design in the practice of landscape architecture. This review explores parametric design both in the United States, internationally, and Texas. A case study of the top award winning firms in the United States is reviewed to help give a framework in Chapters 4 and 5, to understand the adaptation of PD software and workflows into landscape architecture design firms in the State of Texas, compared to others in the United States.

2.2 What is Parametric Design?

The phrase parametric design as it refers to digital technology stems from the use of algorithms within a software system's coding to perform tasks between the human user and the digital computer. This algorithmic system enables parameters within the software to perform, define, and clarify relationships between design intent and design response (Jabi, 2013; Schumacher, 2010). These mathematical equations to a greater or lesser extent exist in most if not all software that expresses a set of functions. These functions control variables and parameters, and what decisions those variables and parameters are allowed to go through

(Stover & Weisstein, 2017). This study focuses on those software programs that fit this description that are specific to the field of landscape architecture.

Generative form in parametric design is a process built into the software that reduces the number of potential variables within an algorithm but maximizes its variability through the transformation of parameters within a design (Jabi, 2013). Popularized after the architectural legacy of formalism, and postmodernism, parametricism in architectural design seeks to discover a balance between clarity of visual form and its buildability from a manufacturing or construction standpoint (Merideth, et al. 2008). Parametric design can be expressed in classical Euclidian geometrical shapes in architecture, as well as expressions of biophilic design (Merideth, et al. 2008; Beatley, 2011). Biological form in the past fifteen years or more has inspired architectural PD. This inspiration has led to the scripting of three-dimensional models that attempt to emulate patterns found in biology and nature in general (Castell, 2002).

A paradigm shift has occurred in the past decade or more in architectural design that has opened up new modes of possibilities in landscape architecture and planning (Green, 2017). As sustainability moves forward as a mainstream design practice in landscape architecture, more traditional park design moves to the past. Progressive and younger designers are more likely to manipulate the parameters of a design to make a design a more contemporary, performative, regional, or ecologically sustainable environment (Margolis, 2008; Bentley, et al. 2016).

An example of a regional design would be with patterns found in nature. A familiar pattern of this sort is the Voronoi pattern. This mathematical pattern is found in cell structure as well as the micro-architecture found in bones (Bock, 2009; Li, 2012). This widely used

pattern has made an appearance in building facades and structures, urban street furnishings, and hardscapes worldwide (See Figures 2.1.1 and 2.1.2). These two examples illustrate the principles of generative form, biophilic design, and prototyping. Studying these conceptual landscapes, and built street furniture, we can see how landscape architecture has the potential to be customized from the ground up using parametric generative design.

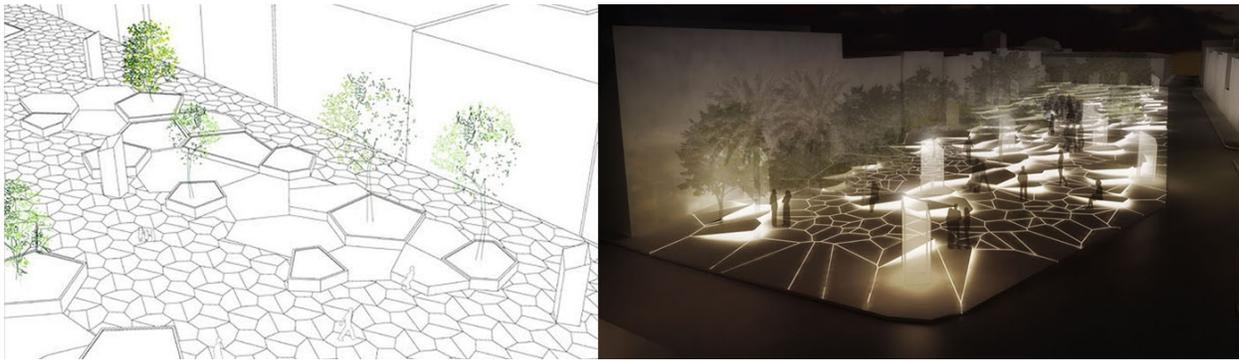


Figure 2.1.1 Voronoi Pattern, Landscape Esc-studio, Glorieta Juan Carlos I Mula, Spain (Source:WAN, 2010)



Figure 2.1.2 OSSO bench (Source: Factory Furniture, 2017)

Through advancements in prototyping technology, materials can be fabricated to individual project needs. Potential designs can be iterated many times over and still retain their structure and constructability through advancements in computer-aided design and manufacturing compatibilities (Jabi, 2013). These advancements have helped to make the design process more efficient and adaptable.

2.3. History of Parametric Design

Innovations in national defense, automotive, and aerospace industries in the 1950's and 60's have led the development of parametric design using computer technology. The mid-sixties saw the emergence of both machines that compute, and the software that they used (National Research Council, 1999; Merideth, et al. 2008). These technological developments, primarily in the engineering world, took around ten years to begin entering the mainstream.

During the early 1980's, technological developments started to further diffuse computer technology into the culture, making it more commercially desirable (Bozdoc, 2003). In 1995, there was significant development, change, and adaptation to the digital environment. The development of more user-friendly programming such as Microsoft Windows operating platform, and the advancement of central processor units (CPU) such as Pentium Pro from Intel Inc. (Bozdoc, 2003; Intel, 2017), led the development of more advancements in what could be done with software.

Industry standard software programs such as AutoCAD, Solid Works, Microstation, and GIS reached the pinnacles of their development in the mid to late nineties, and have continued

to provide their respective industries with consistent and reliable software solutions. This reliability helped universities to train the next generation of employees, and municipalities to request certain workflows as prerequisites when working with architects and engineers. As industry standard software made small changes to the layout and brought new tools into the twenty-first century, a whole new group of developers has created more integrated, open, collaborative, and user-friendly software to better synthesize disciplines, and iterate concepts more quickly and efficiently. (Green, 2017).

The last ten years of software development has seen a rise in building and city integrated modeling such as Autodesk's Revit, Vectorworks Landmark, and ESRI's City Engine among others. Visual modeling software has become more user-friendly, as well as offering a complete range of tools to customize the rendered output. SketchUp, 3Ds Max, and Rhino 3D are becoming the industry standards in top landscape architecture firms in the United States (Keating & Sumerlin, 2016; Green, 2017). Development of sensor technology, augmented reality, and digital printing is beginning to open up new specialties for design firms to consider developing future commercial markets in which to move forward in the culture of design and consumerism in the coming decades of practice (Keating & Sumerlin, 2016; Green, 2017).

2.3.1 Pioneers in Computer Aided Design and Manufacturing

The period from 1963 through 1981 saw a surge in software and hardware development of CAD and CAM innovation. The production aspect of cars and planes, as well as

developments in naval technology made for the explosion of this technology in the 1980's (Merideth, et al., 2008) The following section is an overview into the pioneers of parametric design tools and the computer hardware innovation that followed alongside it. Modern Computer Aided Design started in 1963 at Massachusetts Institute of Technology (MIT) University when Ivan Sutherland developed Sketchpad (madlab, 2016).

Sketchpad was a basic tool that was the first graphic user interface tool that could draw digital objects through pixels, polygons, and establish a special order between objects in space. The tool was run through a TX-2 computer that was essentially the predecessor of the minicomputer in size and the computing power of the early personal computers in the early 1980's to be popularized 20 years later (Henderson, 2009).

During this period companies such as Intel Corporation developed information-processing technology. Hardware development innovation at Intel started in the late 60's and gradually moved away from the giant room-sized computers of the 70's towards what we now know as the personal computer in the early 1980's. IBM collaborated in the development of several innovations to help with the speed and efficiency of the computer hardware (Intel, 2017).

Programmers at Dassault Aviation developed master geometry software to produce external geometry for design and manufacturing, for use in aviation design. CATIA was developed by Dassault starting in 1977, and after ten years of exploratory development, the goal to create a better and more efficient 3D and computer aided design manufacturing system was realized (Bernard, 2003).

The seventies was also the time during which companies such as Intel developed information-processing technology. Hardware development innovation at Intel started in the late 60's and gradually moved away from the giant computers of the 60's and 70's towards what we now know as the personal computer. International Business Machines Corporation (IBM) collaborated in the development of several Innovations to help with the speed and efficiency of the computer hardware (Intel, 2017).

2.3.2 Pioneers in Geographical Information Systems

Geo design utilizing computational modeling, later known as Geographical Information Systems (GIS) was rooted in research and development in the mid-60s. The invention of computer methods for analysis management and display of digital information started with Howard T Fisher and the Harvard Laboratory for Computer Graphics at Harvard Graduate School of Design (HGSD) between 1963 in 1965. Fisher, who was an architect by training, led the laboratory in the development of the Synagraphic Mapping System (SYMAP) with support from a development grant from the Ford Foundation (Figure: 2.2.1) (Steinitz, 2012; Wilson, 2014). Carl Steinitz joined the faculty at HGSD in 1965 and was able put this spatial analysis system to use to understand regional development, and conservation land uses on the shared peninsula of Delmarva (Delaware, Maryland, and Virginia)(Wilson, 2014).



Figure 2.2.1 Peter Rogers (left), Carl Steinitz (right) work on the Preliminary GIS model,
(Source: Esri, 2013)

In 1969, Ian McHarg published the book “Design with Nature” which fundamentally changed the teaching and practice of landscape architecture into a merger with regional planning, landscape architecture, and city planning. The three disciplines have shared a common history since the early 19th century when there was a large push to integrate planning for recreation, transportation, storm drainage, flood control, and wastewater management (McHarg, 1969). The merger of planning and landscape architecture was one that was not readily embraced by the typical culture of landscape architects of the time (Spirn, 2000).

Most projects at this time and arguably to some extent to this day were designed per site without considering the larger intentions of the region. Ian McHarg’s ideas became influential to regional planning in North America. The regional expansion of the highway system at the federal level had its effect on rural areas near metropolitan regions; this expansion primarily

shaped McHarg's earlier projects (Marsh, 2010). The ideas that were developed at Penn State under the direction of Ian McHarg the 60s and 70s led to the innovation of overlay and matrix. McHarg claimed to have invented the overlay method that Carl Steinitz Paul Parker and Lawrie Jordan utilized in the first moves towards developing a Geographic Information System at Harvard in the late sixties (Spirn, 2000).

This overlay and matrix methodology of organizing past present and future uses of land is preformed though layering integrated disciplines such as geology, topography, soils, hydrology, vegetation, current land use, and potential future use to identify the most suitable of locations (McHarg, 1969; Wayne, 2003).

Students developed systems of inventory for ecological conditions, calling it anything from the layer cake to ecological inventory. The inventory is a list, as standard categories using climate, geology, hydrology, soils, vegetation, and wildlife. McHarg believed that there should be an inherent environmental understandability necessary for intelligent design. If a designer knows the physiography, such as the history, geology, climate, and soils, and understands the interconnection between the plants and animals, he or she can predict how nature will react when changes to the landscape occur (McHarg, 1969).

The ecological inventory was, and still is, a diagnostic tool using a checklist of interrelated systems. Each new inventory can be adapted to its particular region to understand not only what is there, but also how a landscape functions currently, and how it might change moving forward. When it came time to link goals of the designer's plan to the implementation of a built project the term "adaptive strategies" was coined by Spirn (Spirn, 2000. p.109). This

strategy is a method of highlighting potential natural features and processes not immediately obvious to a particular client's consciousness (Herrington, 2010; Spirn, 2000).

In 1969, Jack Dangermound, and his wife Laura formed Environmental Systems Research Institute (ESRI) in Redlands California. The company later became the first to develop digital maps. Company growth was slow in the 70's and 80's with the use of mini-computers, workstations, then eventually with use of the PC. In 1982 the software became publically available and was named ArcGIS. This software becomes the company's flagship software (Helft, 2016). The software is used on anything from urban design, controlling disease worldwide, helping prevent natural disasters, or helping with the aftermath of a natural disaster (Helft, 2016).

2.4. The Development of Parametric Computation:

The 1980's to Present

Around 1980 CATIA developers started a move towards bringing their engineer driven software into the larger market as a more industry accessible software (Bernard, 2003). Autodesk entered the marketplace in the same year with AutoCAD and quickly became the leader in computer-aided design. Over time Autodesk developed most of the Innovation in the expression of 3D forms and drawing commands such as objectsnap, isometric views, attributes, the polyline, and Non-Uniform Rational B-Splines (NURBS) among others. This was also the time when the disciplines of CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) become more exclusive of one another (Bozdoc, 2003).

2.4.1 The Development of Parametric Design, 1980's through 1995

In the early 1980's both CATIA and AutoCAD were brought to market. Mike Riddle wrote the first version of AutoCAD in 1981. Initially, this program was called Micro CAD, and then later renamed to Interact. In November of that year, AutoCAD released the first CAD program to run off the PC. AutoCAD became more commercially available two years later in 1983 (Bozdoc, 2003; Kennedy, 2014).

In 1981, Dassault Systems, with roots in the late 60's aviation design market, allied with IBM to help bring their software to a larger audience. The development of CATIA continued until their 10th anniversary at which point they reached 2500 customers. In the same year, they acquired CADAM (Computer Augmented Design and Manufacturing) one of their competitors. Drafting was added to CATIA in 1984 allowing it to act independently from CADAM (Bernard, 2003).

In 1984 Bentley systems formed by Keith Bentley, created a prototype for the later workstation (Chouinard, 2017). The release of the Workstation came a year later, (see Figure 2.4.1), which allowed users to view IGD S (Interactive Graphics Design Software) drawings without needing Intergraph's software (Reynolds, 1987). Bentley Systems later merged with Intergraph to produce a new file sharing system called Design file (DNG). Autodesk's AutoCAD sales reached 27 million (Bozdoc, 2003). This is the first year that 3D capabilities

and polylines are introduced. CATIA became the leading drafting, 3D solids, and robotic friendly software for the aeronautical industry (Bernard, 2003).

In 1986, AutoCAD sold fifty thousand copies worldwide. AutoCAD became the leading software for computer-aided design for at least the next 10 years according to PC World magazine, a title it holds to this day (Kennedy, 2014). In 1987 AutoCAD developed an advanced user interface with the menu bar for the menus icons and dialog boxes and also designed auto lisp, ADS (AutoCAD Development System), and APIs (Application Programming Interfaces) (Hurley, 2017; Bozdoc, 2003).

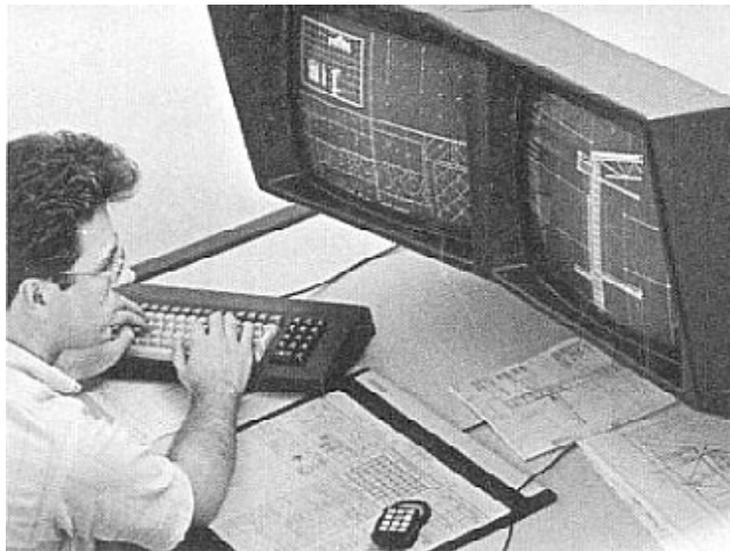


Figure 2.4.1 INTERGRAPH Workstation, 1983. (Source: Quondam)

In 1990, Bentley System's Microstation reached hundred thousand users in sales. In this same year, AutoCAD release 11 was introduced (Bozdoc, 2003). It offered paper space, animation, and shading technology (Hurley, 2017).

In 1991, Microsoft developed open GL for use with Windows NT. Open GL is application-programming interface (API) procedure software for producing 2D and 3D vector graphics; thus improving the software's ability to make points, lines, and polygons. It provided additional support for shading, texture mapping, lighting, animation, special effects, and greater depth of field (Segal & Akeley, 2010). Silicon Graphics Inc. developed this innovation, with strong ties to the motion picture business; it quickly became the standard for 3D color graphics and rendering. Applied Geometry (AG) consulted with McNeel software development to integrate their NURBS geometry library into AutoCAD as a plug in called AccuModel (McNeel, 2015).

The year 1993 produced promising results with the development of the first multipurpose software that looked like building information modeling (BIM). The software was similar to CATIA software that allows 3D design, engineering drawings, and analysis (Bozdoc, 2003). Autodesk developed 3D studio, and AutoCAD 12. Release 12 became their most successful release to date. The new release allowed several drawings to be accessed at once, improved graphic controls, and a provided a separate render window (Hurley, 2017).

McNeel and Applied Geometry changed the name of AccuModel to Sculptura in the first release of the software, then as McNeel took over as the lead developer and renamed it

Sculptura 2, and then nicknamed it Rhinoceros a few months later (McNeel, 2015). The company Solid Works Inc. was formed in this same year (Bernard, 2003).

In 1994, sales of AutoCAD reached the 1 million-user mark worldwide. The closest competitor's to Autodesk at this time were CAD key with 180,000 copies, and Bentley's Microstation with 155,000 copies. AutoCAD sales continued to soar through 1994 with sales reaching \$465 million (Bozdoc, 2003). McNeel releases Rhinoceros as a beta program (McNeel, 2015).

Research and Development of CAD and CAM for use in parametric design, as well as the development of the computer systems themselves, lead to consistently more efficient and reliable set of tools for the growing computer aided design world. AutoCAD continued as an industry leader in CAD software for a range of design uses as early as 1986 a title it holds for the near future. The popularity of AutoCAD has allowed for efficient sharing of construction documents for over 35 years (Kennedy, 2014).

2.4.2 Development of Computer Aided Design 1995 through the present

Computer development sped up from 1995 through 2000 as computer processors and other hardware innovation developed with an active marketplace (Intel, 2017). In this same time frame the internet becomes a conventional interest of the culture.

In 1995, Autodesk established themselves as the continued leader in computer aided design software, with 3 million copies of the software sold. This was the first year that they start to develop 3D Studio Max for the Windows NT platform. AutoCAD expanded its

accessibility to 150 file formats, added a correction cloud for viewing and redlining drawings. They also introduce advanced servicing, and NURBS technology, which stands for (Non-Uniform Rational Basis Splines). This new advance allowed math and form generation for surfaces and curves, allowing easier and more efficient workflows in three-dimensional modeling (Jabi, 2013), over previous multi-faceted surfaces (McNeel, 2015). This breakthrough helped to develop more interest in using the software as a true parametric design tool, as evidenced in built works of the mid-1990s’.

Continuing into 1995, Autodesk, Parametric Technology, and Bentley all released 3D parametric solid modeling software. AutoCAD Designer features AME models and exporting abilities into 3D studio. The company Parametric Technology releases a parametric modeling CAD/CAM program this is the first commercially available 3D solid modeling package (Choulnard, & Bell, 2017). Bentley also advances their Microstation platform in solid modeling in mechanical design in this same year.

The year 1996 was another big year for development. Bentley’s Microstation started focusing more on architectural modeling, plant engineering, and geoengineering. Unigraphics became the largest seller of CAD/CAM contracts in history to General Motors. The product greatly improved service modeling, assembly capabilities, and checking for interference. This year produced several innovations in 3D modeling lighting technology and rendering such as LightScape and LightWave by New Tek. AutoCAD brought to market its stripped down version AutoCAD LT selling 250,000 copies in one year. (Hurley, 2017).

The year 1997 was the first time Autodesk created a toolkit of meshes, fonts, and animation. AutoCAD release 14 came out with many improvements in 2D and 3D graphics, and the ability to run with other active X automation compliant applications. The American Institute of Architects, (AIA), produced a second edition of layering guidelines for AutoCAD to help aid the efficiency of CAD users. The guidelines seems to indicate a need for training that the Autodesk company is not meeting. Revit technology Corporation introduced the first commercially available parametric building information modeling system developed for the AEC industry (Bozdoc, 2003).

After several mergers and meager development over the course of three years, McNeels' Rhinoceros was purchased from the company Alias by Silicon Graphics. A decision was made to develop a standalone 3D modeling version of Rhino for windows. In 1998, Rhino version 1.0 was released in beta form. Within a year there are 150,000 beta versions being tested. Rhino was publically released in the United States in October 1998 of that same year, and also released for use in Japan and Korea in 1999 (McNeel, 2015).

In 1999, a company formed called @last, with a goal to make a powerful 3D rendering program that was easy and more intuitive to use. After a year of development, SketchUp was born in August 2000. The receptive success of SketchUp at the AEC Systems conference, and their collaboration with Google Earth to create a plug-in to geo-locate SketchUp models into space led Google to purchase the company in March 2006 (Donley, 2011). The ease of use and customization led to an early success to this 3D modeling tool.

2.5 Development and Use of Parametric Design

Development of computing software and hardware continued to evolve. Computer software has become more capable of advanced aesthetics and analytics, as well as becoming more intuitive to use. According to data compiled in the research interviews in this study, open source software platforms such as SketchUp, have enjoyed success in the design fields (Green, 2017); and it is now one of the main tools requested for new employees in landscape architecture (Bentley, et al, 2016). Open source software allows for an easier way to change what a software program can do versus the more traditional method of coding. Built into the source code of the software, it allows a copyright holder the rights to study and change the software to perform new functions (St. Laurent, 2008).

2.5.1 Coding versus Scripting

Coding and computational logic have become so integrated into the programs that designers and planners use that it has become easy to take them for granted (Cantrell & Holzman, 2016). Computer coding has been the primary force behind software development in the last 50 years, yet the past 10-15 years has seen the rise of a different method of writing and re-writing of software with the innovation of computing languages, and open sourced software and scripting (Green, 2017).

Computer coding is a method of designing or writing a computer program. Each coding language is unique regarding how it uses syntax within the language of the software program. In general, coding runs a program via syntax, algorithms define parameters, and the program

completes the tasks (Payne, 2008; Jabi, 2013). These functions can be manipulated through scripting within a program or by the development of extensions or applications (Green, 2017). This is technical subject into itself, which can take months or even years to understand, and is beyond the scope of this present research.

Scripting is a technique of using algorithmic design to generate complex forms while maintaining individual characteristics of simple geometry. Scripting is becoming more and more commonplace as software becomes more open sourced and capable of manipulation outside the domain of different software companies, to be customized not from the top down, but from bottom up (Bentley, et al. 2016). There is growing need for controlling project production, efficiency of materials, and implementation towards the final design. Scripting to customize the workflow using syntax language is one of the ways to influence how the computer can perform actions that lead to better outcomes for their use (Merideth, et al. 2008)

New scripting procedures are being adopted by leading landscape architecture firms in the United States, and abroad to write different methodologies to design spaces and its amenities. (Wilson, 2016; Keating & Summerlin, 2016). Scripting environments in 3D programs are varied and many in their syntax, and language. Parametric design landscape architecture and related fields are about logic, metrics, geometry, topography, and the interaction of those elements. Algorithms can be rewritten using different syntax. Older algorithm based 3D design was less user-friendly., if one part of a design was changed, the designer would need to fix things manually that were as a result of those design decisions. It is this inflexibility that scripting aims to correct (Frazer, 2017).

Processing and MaxScript are the main programming languages in which 2D and 3D design programs typically use. Processing is for 2D software and takes advantage of being open source, and Java based. MaxScript is a 3D programming scripting system. Other 3D scripting systems exist for designers and architects such as AutoLISP in AutoCAD, Maya Embedded Language (MEL), Python, Generative Components (GC), Java, DesignScript, and Grasshopper. Maxscript and Design Script excel at 3D programming for designing software. MaxScript is the language in Autodesk's 3Ds Max software (Jabi, 2013). DesignScript also developed by Autodesk strives to combine several visual programming approaches to become a more flexible platform to build new programs (Jabi, 2013).

DesignScript represents a new way of scripting that incorporates form finding to parametric analysis. It is capable of combining variables such building performance to the form that the new structure creates. This type of scripting allows bridging of the two main traditions of programming language, imperative and associative (Jabi, 2013).

Imperative programming is the more basic language of the two; it directs the flow of variables and parameters. This is the type of programming in Python, C++, Java, and Processing computer coding language. Associative programming occurs in generative parametric software such as GC and Grasshopper. GC systems are defined by visual graphs showing relationships between variables, and how the variables are used. These variables are not necessarily under the explicit control of the user. DesignScript is a hybrid of these two languages. The hybrid script is used to solve design problems of interaction of materials, and

the ability to choose and change variables and parameters to more effectively design than either of the styles on their own (Payne, 2008; Jabi, 2013).

2.5.2 Contemporary Use of Parametric Design in Architecture and Public Art

The greatest challenge of parametric design in architecture is that form needs to have a purpose or cultural relevance. Parametric design cannot stand on its own as a game or algorithm; the designer must strive for a deeper or regionalism connection to the people or landscapes they are designing for (Merideth, et al. 2008).

Architecture tends to be more of a social-political and avant-garde style. The parameters of this cultural landscape can engage the full realm of its capabilities. To produce truly engaging structures takes a skilled background to interrelate the cultural, natural, and marketplace relationships between the places where people dwell and play. Parametrics will no doubt have a large role in the future of buildable structures, yet technology will not fix all our problems. Parametric solutions have the capability to become more inclusive, adaptable and less avant-garde, making for more socially relevant work in the years to come (Meredith, et al. 2008).

One of the ways this work is merging to the design fields is through the formation of design groups or workshops that often involve the participation of academia to further the spread of ideas and creative thinking (Vanucci, 2008; Brown, 2009). One such group is Parametric Applied Research Team (P.Art) out of the UK. This design lab was put together to expand innovation at the structural and civil engineering consultancy of Adams, Kara, and

Taylor in London. This research group brings together designers from a variety of backgrounds like architecture, structural analysis, computer science, forensic analysis, 3D visualization, and animation, to research parametric design. The goal was to develop the discipline of structural engineering using existing software and structural design, in multi-disciplinary collaboration (Vanucci, 2008).

The most recent shifts in architectural discourse have happened as the result of the evolution of computational software. Yet without easy integration into various disciplines of designers and consultants, new software can take years or even decades to integrate into ordinary practice. The new order of design using generative form making, allows geometry within the parameters to interact and change in a predictable fashion with the other variables that it is associated within its equation, to aid in post design problem solving analysis towards workable, buildable solutions (Meredith, et al. 2008; Simmonds, 2008).

These equations or smart models have a fair amount of flexibility and have started a shift in how things are designed. This shift is from designing specific objects, to designing relationships between components within those objects. Parametric design has the possibility to develop more intricate systems of relationships between objects in a space. The tendency now is to develop the components that create the object first, versus the other more typical way around, where the spaces are created first, and then the objects within the space are designed (Simmonds, 2008).

The artist Antony Gormley utilized parametric design on several sculptures including work on the “Space Station “exhibition at the Hayward Gallery, London in 2006. A custom

computer program was written as a plugin to Rhino using c++ coding language. The purpose of the program created called Gormley Boxer program was to convert a full body scan of the artist into a series of boxes representing the overall shape of the artist in the fetal position. (See Figure 2.5.1) The sculpture was run through a structural analysis tool to avoid face buckling of the steel plates, and corner crushing under all the weight of the sculpture. Once the analysis passed, the software reverse assembled the sculpture and numbered the pieces with adjoining information listed on the face of the pieces. The information was sent off to a fabricator to produce the pieces for final assembly of the piece (Simmonds, 2008).



Figure 2.5.1: Antony Gormley, “Space Station” Steel, 2006 (Source: Gormley 2007)

The French Architect Marc Fornes has a firm entitled “THE VERY MANY” in which parametric tools are used to design plates are fastened together with bolts to create elaborate and playful architectural installations (see Figure 2.5.2). The installations take on the form of branching coral or floral like patterned like pavilions. Many of these installations are built

using 1 mm thick aluminum plate allowing flexibility in the form and rigidity of the structure. The pieces combine enclosure with structure and the connecting points, create variable ornamental patterns or apertures of light. One of the ongoing goals of the project is to create a standardized production of the installations (Jabi, 2013) through a fabricated part construction method (Stacy, 2013).



Figure: 2.5.2 “Chromaphasia (Rhythm of Colors) from “THEVERYMANY”, Marc Fornes, Denver Botanical Garden, Denver, CO. (Source: Chad Paulson)

For now, such pieces are highly customizable and labor intensive to build (Fornes, 2016). Fornes starts each new project writing code and prototyping the projects using 3D modeling. A computational change had to be made because the software could not model the

multi-dimensional configuring needed by Fornes. By changing the NURB surface parameters, the artists' team was able to create a form-finding algorithm that emulated the flexibility of the material to smooth and relax. The shapes forming the structure are then unrolled in the software to create manufacturable pieces to be cut using a CAM operated laser cutter (Jabi, 2013).

Architect Frank Gehry firm created software technology based on the CATIA platform called "Design Project", which is used to work on geometry and structure at the same time simultaneously. Design Project has been used in Gehry's biomorphic public architecture. It is capable of several methods of working parametrically such as, framing, surfaces, measuring stress points, and in branching structures, like the work of Frei Otto (Vanucci, 2008)

An example of this branching analysis is found in the collaborative team effort at P.Art., which stands for Parametric Applied Research Team. This design lab organized by Adams Kara Taylor (AKT) lab brainstorms innovative design strategies to be incorporated into architectural works. The parametric software iterates several design solutions (see Figure 2.5.3). The software can to compute the angle between branches, the number of branches linked, and the displacements of nodes in the space. It also determines nodes in architecture, reference points of structural load, and active space on the ground floor. This part of the design process is a roughed in sketch of the possibilities, also referred to as design iterations. (Vanucci, 2008)

Parametric design in architecture is heavily led by geometry and algorithmic methods, which take simple forms and make them more complicated. Creating form with parametric

tools is easy but making it simple for the human psyche to understand or effectively manufacture is much more difficult. The designer's role is to create a meaningful selection of elements and procedures to come up with a final solution (Meredith, et al. 2008).

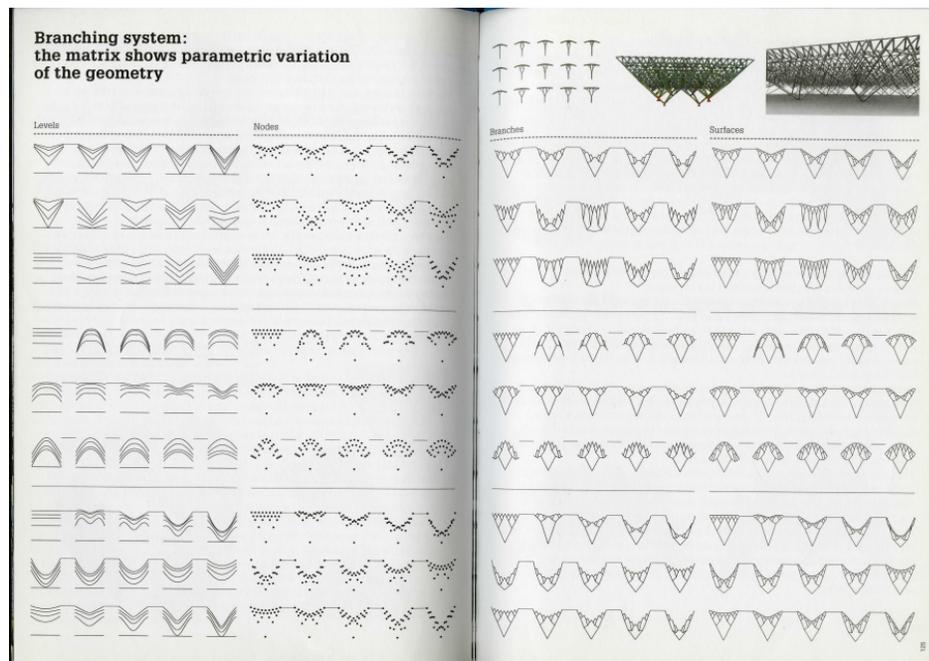


Figure 2.5.3 Branching Structure Iterations. (Source: Meredith, et al. 2008)

Renzo Piano's building in Berne, Switzerland called the Zentrum Paul Klee incorporates a changing curvature within the roof structure. Parametric tools were used to modify the incline angle of the roof structure and the curvature of the supporting beams (see Figure 2.5.4). In a double curved surface, each curved window in the structure has to be designed parametrically to be prototyped or manufactured later on (Stacy, 2013)

Tiling, another methodology of parametric design and architecture, is noted in Renzo Piano's Peek & Cloppenburg Weltstadthaus department store in Cologne, Germany (see figure 2.5.5). The structure was filled in with window (tiles) of various sizes over a double curved surface (Meredith, et al. 2008).

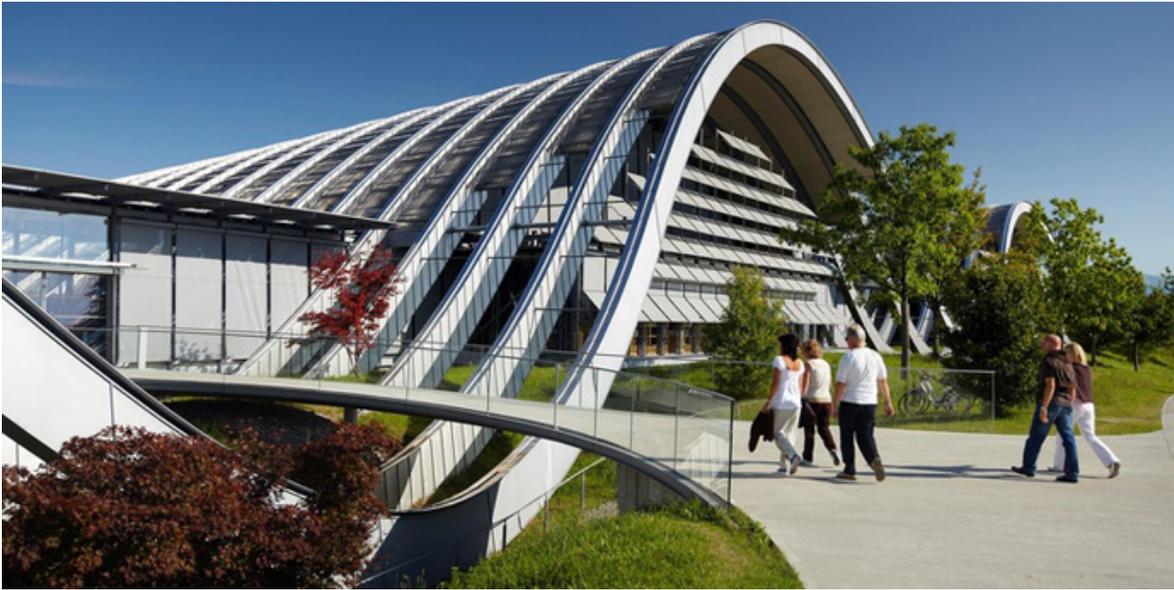


Figure: 2.5.4: Zentrum Paul Klee, Berne, Switzerland, Architect: Renzo Piano (Source: designrulz, 2017)



Figure 2.5.5: Peek & Cloppenburg Weltstadthaus dept store, Cologne, Germany, (Source: pinterest, 2017)

Another example of tiling is found in Dallas, Texas at the Perot Museum of Nature and Science, designed by Thom Mayne of Morphosis Architecture (see figure 2.5.6). The surrounding facade of the Perot Museum was designed to convey a cross section of geological strata through parametrically designed fabricated building tiles (Texas Society of Architects, 2011).

Talley and Associates of Dallas, Texas designed the landscape surrounding the Perot museum to have plants and microenvironments representing a cross section of five ecological zones expressed through several stories of abstracted hardscape and native Texas plantings (Texas Society of Architects, 2011). The architecture and landscape was designed to be one continuous whole, this is part of the larger urban context design approach at Morphosis.



Figure 2.5.6 Perot Museum Dallas, TX. Morphosis, Talley and Associates (Source: Chad Paulson)

Thom Mayne talks about giving shape to the changing social and political environment of the urban society, and the complex interplay of human and natural forces shaping our cities

today. Mayne believes designers must plan for flexible and more adaptive spatial design. He speaks of a new methodology that links process to product through research. To seek practical and poetic urban solutions on spatial and systematic operations as a way of developing form. With a new merger between architecture and human experience, parametric modeling helps to facilitate an evolving set of user or stakeholder interests (Mayne, 2011).

New developments in computational modeling offer an endless variety of design iterations, including the ability to shape space three-dimensionally using dynamic volume and space rather than traditional orthographically oriented stacking. This development allows for highly individualized yet intricate spaces. Morphosis Architecture seeks to enhance the human experience in their architecture and to find a new sense of wonder and harmony in a fragmented urban landscape. (Mayne, 2011).

Advanced computational tools have allowed Morphosis Architecture to try new geometry. They work to embrace the cultural, behavioral, and diversity of cities by expressing these features organically. Parametric tools offer exciting possibilities, but they must be used with great care and thought in a design. “It is a great challenge in today’s world of urban design to combine the best qualities of traditional placemaking’s character quality and sense of place, with the latest technology, but to do it in a way that is neither random or overly simplistic (Mayne, 2011, p.35).”

2.5.3 Development of Geographical Information Systems

Geographical Information Systems (GIS) are useful tools for mapping and planning any number of scales from a city plot to a larger region. Computer advancements in hardware and software in the 1990s, as well as the development of the internet, expanded the availability and speed of geographical information worldwide (Gocmen, 2010).

Despite being readily available, GIS was largely underutilized in landscape design research from 1980-1995 (Nijhuis, 2014). GIS was new in the 1980s and 1990s, The early software was not particularly intuitive and required command line based operation that was not particularly helpful for the typical human computer interface (Gocmen, 2010). Furthermore, the database that was available for users in the 1980's was not extensive. The database initially created a constraint for widespread adaption of GIS into conventional planning departments (Gocmen, 2010).

In around 1997, ESRI released an innovation called the shape file that eased accessibility issues for the creation of open shared datasets between planning related fields. Shapefiles store non-topological geometry and other attributes for specific parcels of land. The geometry for these areas is described with the use of vector coordinates to define point, lines, and areas. Shape files use less memory than topological files and have the ability to be created or shared without the direct use of GIS software (ESRI, 1998). This development dramatically increased the volume of information available, especially on the internet.

Education and research institutes have had the important role of spreading digital knowledge on the capabilities of GIS applications for landscape architecture (Nijhuis, 2014). In

the mid to late 1990s, GIS became part of the planning curriculum in universities across the United States. GIS analysis lays the groundwork for individuals to study and practice spatial intelligence for regional and urban development projects. This groundwork is a multifaceted approach to designing, and it often requires multi-disciplinary involvement from ecologists, hydrologists, economists, sociologists, geographic scientists as well as other design professionals (Nijhuis, 2014).

GIS is used to synthesize geographical knowledge, this synthesizes data in the creation or refinement of a new design that is not apparent from physical observation. This knowledge can take the form of spatial structure, ecological, economic, and social contexts of a given plan or design. These observations can be broken down into, three-dimensional construction, site history, context, scale and evolutionary process (Nijhuis, 2014).

Single layers in GIS alone often have complex models and analysis behind them. GIS can use systems of weighting indexes for the best solutions such as the least cost path. This method is called suitability analysis. Most GIS design problems are very complex and are not easily understood through algorithmic means. Suitability is one method that allows for the optimization of decisions to be visualized and recreated as shape files (Steinitz, 2012).

If the model has spatial and temporal characteristics, the complexity gets complicated, as it becomes very difficult to program for the individual aspects. GIS design solutions can be solved using many different technologies. Carl Steinitz goes on to say design and planning are two names for the same thing. However, the ability to take a solution too far is very humanistic. “Parametric design is useful for algorithmic solutions are that already exist,” says

Carl Steinitz. “Computational modeling is most effective when going after design that is routine. Finding a balance between artistic and science-based solutions requires a more refined and inventive way of designing (Steinitz, 2012, p. 8).”

2.5.4 Development of Building and City Information Modeling

Building Information Modeling (BIM) is the use of 3D models to test and communicate building project decisions. The use of BIM modeling is growing in such a way that it is becoming the standard for governments, and organizations worldwide. In the U.S. the governmental agency the General Services Administration (GSA), the agency that builds and manages federal facilities, has been requiring BIM use since 2006, and the U.S. Army Corp of Engineers has required it for demonstrating plans for military construction projects (Autodesk, 2016).

There is a growing need for the architecture, engineering, and construction industries to collaborate, and thereby save time and costs. BIM provides the best way to connect design intent to fabricators, contractors, and stakeholders. It also has the potential to become useful in the rise of sustainable design iterations such as building performance design. This same sort of concept can be applied to the landscape adjoining a building to improve micro-climate and building performance together (Lally, 2014).

The concept of performative design in architecture is one that seeks to evaluate the efficiency of the architecture, as well as the natural system that is that it is surrounded by. Andreas Ruby states: “Performance does not ask how form looks, but what form is generated

from the energy factors in the spaces in between spaces. The question becomes not what something is, but what it does (Mayne, 2011, p. 41).”

BIM is more than 3D CAD it is a relational database technology that embeds data and relationships to create interactive, and intelligent models. BIM models contain the geometry and associated data of building component specifications. Building elements such as beams, pipes, and other utilities are imbedded with intelligence that allows them to interact with each other. The intelligence of the model allows for the characteristics of the individual materials to exist in the model in real time. This allows for structural analysis, project visualization, daylighting analysis, and cost estimation. Any design changes are automatically updated in the rest of the building. No additional effort is required to keep data in place and organized (Autodesk, 2017).

The use of BIM is considered one of the top services at architectural firms. Its use can result in reduced errors, improved collaboration between firms, reduced time in drawing, and lower costs to produce a set of construction documents. Additional benefits are the ability to increase profits, provide new service markets for firms, and the lower the potential for litigation (Autodesk, 2017).

2.5.4.1 Limitations with Building Information Systems

Research indicates that there are specific issues with BIM integration into the typical LA firm workflow, such as file shareability, and lack of tools to draw non-orthogonally. The benefits and limitations of BIM were put to the test when three different universities hosted

multi-collaborative design labs to look into the effectiveness of BIM as a design tool to design and organize in the combined environment (Pihlak, et al. 2011).

The collaborative environment included architects, landscape architects, and engineers. Engineers were from multi-disciplines: mechanical, structural, electrical, lighting, as well as construction engineers. The idea was to look into cross-disciplinary design and planning at the early conceptual stage. BIM's main advantage has been its ability to design efficiently and more cost-effectively. The architects tended to be more concerned with aesthetic and design quality, while the engineers tend to be more interested in the overall efficiency of the project (Pihlak, et al. 2011).

The scope of this study indicated that several different processes of integration between disciplines could be achieved. It did not however, create any particular workflow as a suggested integration of disciplines. The study did indicate that BIM could be incorporated successfully at either the lower or the upper ends of the design education. Collaboration between disciplines led to a richer, and better-informed design, however, it did not result in a significant increase in the aesthetic quality (Pihlak , et al. 2011).

All the studios indicated that the collaboration helped with the process of using BIM. It was encouraging to see in the research that practitioners looked at methods of using BIM to evaluate problems, not just determine solutions. The research reinforced the notion of “design engineering” as the means by which the integration of ideas happen from the outset, as a way to a more collaborative relationship between landscape architects, architects, and engineers (Pihlak , et al. 2011).

2.5.5 Contemporary use of Parametric Design in Planning using City Information Modeling

City Information Modeling (CIM) is relatively new in the design and planning world, so new that there is no clear technology leader in the world market. CIM is similar to the structure of BIM but it is much larger, like the infrastructure scale of an entire city. Many professionals are touting it as CAD meeting GIS. (Beirao, et al. 2012).

There are many ways to facilitate City Information Modeling in the international development market, as well as in the United States (Khemiani, 2017). The current software products used in the international marketplace are Infra Works from Autodesk, ESRI's City Engine, Modeluer an extension for SketchUP Pro (Figure 2.5.7), Bentley's CIM products, City Planner from Agency 9, and Cyber City 3D among others.

Modeluer was used to win the "Smart City Challenge 2016" in Columbus Ohio, and ESRI's City Engine was recently used in 3D CIM models of Singapore (Khemiani, 2017; ESRI, 2017). Virtual City Systems has mapped the largest urban data set to date in Berlin with a mapped area of 900 kilometers square. Cloud Cities is another promising technology for city infrastructure modeling that is being developed in Switzerland (Khemiani, 2017).

ESRI has recently released a ninth version of City Engine (Figure 2.5.8). It interpolates well with GIS data. As an extension of the well-vetted ArcGIS platform, it is able to connect to shape files to build models that are dense with useful information. This should be one of the top contenders in the emerging CIM environment for years to come (ArcGIS, 2017).

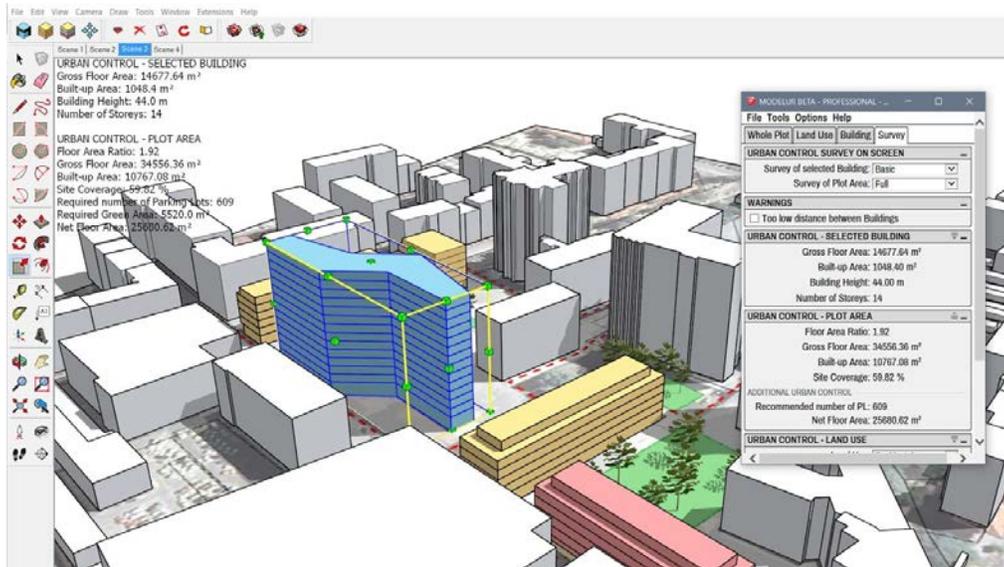


Figure 2.5.7 Modeluer extension for SketchUp Pro (Source: SketchUcation, 2017)

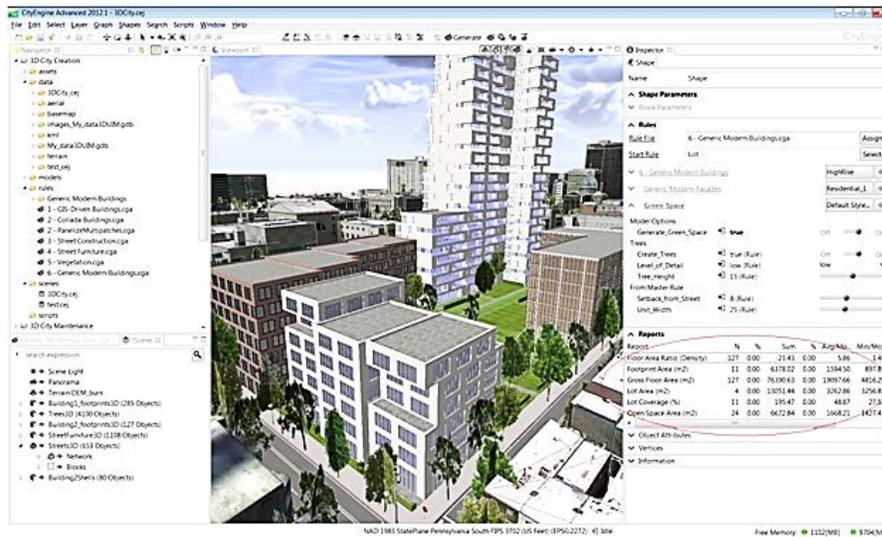


Figure 2.5.8 City Engine, (Source: ESRI, 2017)

City modeling is an exercise in form generation and information indicators, in other words, aesthetics vs. costs. Some of the basics involved are city codes like building heights,

zoning preferences, setbacks, flood zones and more (ESRI, 2017). Additional parameters that can influence the design such parking spaces, building square footage, plus any number of parameters such as green space, transit, new urbanism density, biophilic design, among others can be inserted as data points (ArcGIS, 2017). Custom CIM processes can also be scripted to bridge hybrid models from software such as Rhinoceros, Grasshopper, and GIS through scripting methods (Wilson, 2016).

2.6 Contemporary use and practitioners of Parametric Design in Landscape Architecture

As a measure of parametric design in landscape architecture a study was conducted by the American Society of Landscape Architects (ASLA) In 2016, 15 ASLA award-winning firms from 2013 to 2015 were contacted to participate in a study (Figure 2.6). The study was based on what software and graphics these firms used, especially for high-end perspectives. The survey was broken down into four categories. 2D drawing, 3D modeling, image rendering, and post processing. The typical workflow was a 2D drafting program used to build the site and plan. Projects are then transformed in three-dimensional space using 3D modeling. A rendering program was then used to improve materials and lighting and export as a completed as a 2D graphic. Final touchups to enhance the aesthetics were done in a post-processing program (Keating & Sumerlin, 2016).

Almost unanimously AutoCAD was the preferred 2D program of the 15 firms surveyed 14 used AutoCAD, the top three preferred software for use in landscape architecture 2D drafting were; Revit, Vector Works, and Civil 3D AutoCAD. In the 3D modeling area Rhino 3D was the unanimous winner with 87% of the firms using it. SketchUp Pro with was used by 53% of the firms, with Autodesk 3Ds Max coming in at third with 20% usage. Many of the firms that used Rhino 3D also used SketchUp Pro. SketchUp Pro was preferred with the project managers because of its ease of use, while production staff, and younger hires tended to be more favorable with Rhino. Both programs seem to be able to transfer models between the two programs efficiently. 3Ds max was not preferred as much because of perceived high learning curve (Keating & Sumerlin, 2016). A hundred percent of firms used Adobe Photoshop for adding entourage and adjusting overall lighting and saturation of colors in the final post processing process (Keating & Sumerlin, 2016).

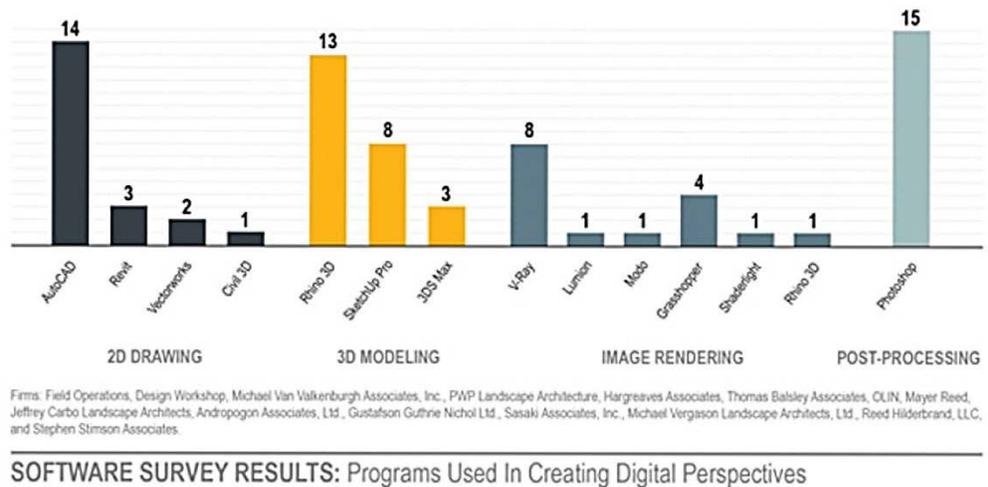


Figure 2.6 Software Preferences at Award winning Firms. (Source: Keating & Sumerlin, 2016)

Although the type and size of firm play a role in the decision of what software to use, the success of projects in the private and public realm, should be of value to understanding an efficient workflow for the production of high-end graphics for competitions and requests for proposals. Mastering advanced parametric tools should be very helpful towards landing jobs and winning competitions. The most interesting discussions within the survey results were opinions about the direction that software trends should go from here, and who steers that decision, is it client expectation, competing firms, personal interests, or production staff (Keating & Sumerlin, 2016; Green, 2017).

Professional firms are hiring program managers, sometimes even as entry-level production staff, to outreach with new methodologies to create revenue streams within their firms (Bentley, et al. 2016; Keating & Sumerlin, 2016). To the extent these technologies are reaching the workplace and making business infrastructure change, how they are being facilitated, and how they are adapted as innovations are some of the focus areas of the present research (Keating & Sumerlin, 2016) in this study of PD in Texas.

2.7 The Future of Parametric Design in Landscape Architecture

Many new prospects are turning up in the field of landscape architecture. The future holds much innovation in parametric design technology. The use of the cloud storage should change the way how and where people work collaboratively. Augmented reality will be the new way to show clientele design iterations, in a simulated environment. Sensor technology, already well adapted in lighting design, will be embedded into new things such as trash can

receptacles, making the management of parks more efficient. Microclimate sensory and climate amenities will change how we think and feel in new spaces. Lastly, parametric design will be the way in which the customization of landscape features are analyzed, designed, presented and built, thus changing the way that park designs are communicated to stakeholders, as well as creating more meaningful relationships into a design concerning sustainability, place making, biology, hydrology, and geology (Cantrell, et al. 2016; Lally, 2014; Margolis & Robinson, 2007).

2.7.1 Design Competitions

Literature review suggests that design competitions are great way for interns, students, and design firms to stretch their minds and build collective creativity and design methodologies within design firms. Over the past few decades competitions shown to be proven ways to insert innovative ideas and tools to design and planning fields. As it is covered in the review of Keating & Sumerlin in section 2.7.1 that various advanced parametric design software is already within the tool box of landscape architects in conventional design practices.

The Fletcher Studio from the Bay Area in California is a design-winning firm that has fully embraced advanced parametric design. In their winning design for Horse Shoe Cove Park, the Fletcher Studio used the visual parametric tools of Grasshopper inside Rhino 3D to model different scenarios (Figure 2.7.1) (Fletcher, 2017). As the team tested design ideas, they found that a slight change in slope in one area would influence ADA compliance in another area. The team credits the scripted software as a time saver and found that it also helped them

find solutions that they would not have thought about otherwise through the process of design iteration (Bentley, et al. 2016).

Literature review also shows that there are various other design competitions which push the limits of design professionals to not only offer creative product but also introduce innovative tools and process to design process. These competitions encourage designers to think outside of the box and apply lessons learned to innovation to designed works in the future (Margolis & Robinson, 2007).



Figure 2.7.1 Horse Shoe Cove Design Competition, San Francisco, CA (Source: Fletcher Design Studio, 2017)

2.7.2 Responsive Technologies

Responsive technologies is an emerging field that attempts to bridge environmental phenomenon and technology as a means to sense, process, visualize designs, and maintain

landscape environments. It is an interaction between environmental phenomenon and designed space. It has been in the experimental stage for the past two decades. This new work has come up in the form of installations, and landscape architectural features that use cross collaboration and new technologies (Cantrell, et al. 2016). It builds on a history with engineering best management practices (BMP) and sustainable design in landscape architecture.

Bradley Cantrell is a professor and researcher at Harvard University Graduate School, where he has been pioneering simulation studies on river deltas at the design lab. The lab uses a Microsoft Connect simulation tool to mimic waterways and use these methodologies towards designing new fluvial morphological systems. The lab finds moments in time where change starts to occur and watch its effect on the system as a whole (Figure 2.7.2). According to Cantrell this technology will be able to be used to mediate erosion control in watersheds. He believes that management teams of the future will consist of autonomous robotics working to maintain ecology and landscape architecture similar to the way a 3D printer makes a prototype (Bentley, et al. 2016; Cantrell & Holzman, 2016).

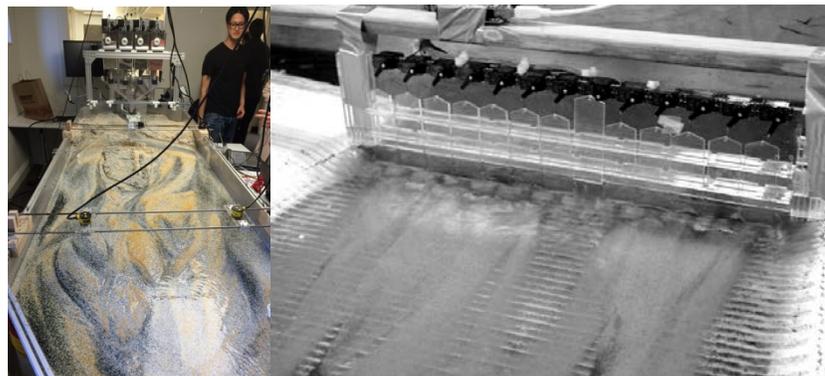


Figure 2.7.2 Fluvial Morphology Test, (Source: Harvard Graduate School of Design, 2017)

New technologies like low tech sensors and actuators like what you may find in a remote-controlled cars, are allowing low-cost technologies to iterate new design strategies in efficient amounts of time. New software and visualization tools, along with robotic kits are allowing designers to employ innovative solutions to urban and regional problems (Cantrell, et al. 2016).

Since matter can become programmable through the control of parametric devices, Cantrell and fellow researcher, Justine Holzman at the University of Tennessee, Knoxville predict there will be an inter-connection of biology and intelligent machines systems that will begin to coexist through connected technologies. Their goal is not to input computational programming within the landscape, but to set up a loop in which one could design and maintain environments in a more advanced way (Cantrell & Holzman, 2016).

The advancement of parametric toolsets such as the combination of three-dimensional drafting in Rhino 3D, along with the visual coding language found in Grasshopper, as well as computational modeling systems like City Engine, and data sources such as GIS; will change how design and physical resource management will be handled in the future of landscape architecture and related fields (Bentley, et al. 2016). This was also the time during which companies such as Intel developed information-processing technology. Hardware development innovation at Intel started in the late 60's and gradually moved away from the giant room sized computers of the 70's towards what we now know as the personal computer in the early 1980's. IBM collaborated in the development of several innovations to help with the speed and efficiency of the computer hardware (Intel, 2017).

Sensing, processing, visualizing, and feedback using parametric tools and analysis are not new to the process of landscape architecture design, but using these tools in this way is new to the methodologies of landscape and ecology design and restoration of natural spaces.

Cantrell believes that academic studies utilizing simulation and responsive technologies will likely lead to computer science and robotic breakthroughs (Bentley, et al. 2016).

Cantrell and Holtzman suggest a conceptual shift from the object-oriented understanding of technology to a holistic based hybridization of a landscape may become more prevalent in the future. Rather than having one model, a designer can have several iterations to encompass climate change, hydrology, geology, flora, fauna, and more. The models can run simultaneously to test out several design strategies at once to figure out the best strategy in a design (Cantrell & Holzman, 2016).

The advancement of responsive technologies has increased the scope of designer's tools, logics, and methodologies, to not only the design of protocols, but also the processes within programming logic. Cantrell states this is a good fit for landscape architecture as the basis of the profession is inherently responsive to the acknowledgment of regeneration, and interaction of the natural, biological, social and political worlds of landscapes (Cantrell, et al. 2016).

The landscape is a dynamic and changing environment. Responsive technologies have allowed designers to look at new ways to understand and experience the social, and natural singularities in the landscape. Landscape architects James Corner and Stan Allen collaborated

on a project entitled “emergent ecologies” it was a merger of intentional and unintentional dynamics to create new forms of life and design. They strived to not determine or predict the outcomes, but steer them based on understanding of their inherent nature, or what they call interdeterminacy of change. In 2002, the Field Operations proposal for Fresh Kills Park in Staten Island highlights phasing in indeterminacy as central theme of the design of a former landfill (Cantrell & Holzman, 2016; Reed & Lister, 2015).

Indeterminacy evolves the concept of distanced authorship. Practitioners and academics over time have sought to employ techniques to understand how landscapes evolve and interrelate. Not only are new methodologies such as data sets, analysis tools, and complex ecological relationships being used, but designers are also continuing to use the same tried and true traditional tools of drawing, modeling, and diagramming as they have been for the past several decades. Using new technology through a distance authorship is another way to look at ecological problems from a larger perspective (Cantrell & Holzman, 2016).

Technologies available that are flexible and adaptable but they are not evolving to the point that ecology has over time. Technology is putting pressure on design to become more adaptable and intelligent. An example of this is the MIMMI project (figure 2.7.3) that expressed the mood of an entire city via live twitter feeds and pocket park sensors. This landscape not only has a context to it but it also expresses a life of its own. Computational modeling is about finding new ways of maintenance, construction, and evolving a design. It is different from traditional design practice in that it interacts with its own systems as a design and ecology at the same time (Cantrell & Holzman, 2016).



(Figure 2.7.3) The MIMMI project, Minneapolis, MN (Source: INVIVIA, 2017)

Opportunities for responsive technologies are great but they are still being formed as possibilities. Many projects are speculative and demonstrate a new methodology of working beyond conventional definition or perception. The work questions, could it be possible to design an environment without destroying the ecology of it? Questions have come up as to how to integrate this into the curriculum, then to get it out into the buildable world. Potential uses for new design opportunities exist for new social, political, and ecological design solutions, but they must be prototyped rigorously, fine-tuned, and modified (Cantrell & Holzman, 2016).

Simulations in engineering are used to design complex materials and to understand material behavior through mathematical models of physical processes. Computational design incorporates these dynamic advanced physics models and tests them against building resilience,

and other dynamic forces. Dynamic models can be tested for an assortment of physical properties such as light waves, acoustics seismic activity, and even nuclear physics (Weinstock, 2006), can be tested in Bentley's Microstation, and Dassault Systems Solid Works and CATIA.

Testing the simulation parameters of objects can be modified to observe different behaviors in the structure. Simulation of sunlight has been incorporated into many software-modeling packages throughout the world; however, testing for other physics oriented problems requires adding a plug-in or adjusting the script or coding. Airflow and thermal dynamics through spaces is also a standard in engineering software (Weinstock, 2006). These are two directions that could be tested to optimize microclimates in a landscape.

Advanced engineering simulations, have been well developed, and suggest new directions in which landscape architecture could go. For instance, biomaterials in simulation are being used to study stress and fluid activity within the behavior of human tissue for advances in medicine. These simulations are very complex and can be scaled up to study physical relationships in landscape architectural design with adaptive intelligent environmental systems (Weinstock, 2006). This could be a research area for firms that are interested in the conservation side of landscape architecture.

2.7.3 Immersive Technologies

Immersive technology is perhaps the quickest way in which technology is entering our collective design culture. Virtual Reality (VR), and Augmented Reality (AR) could be solidly

into the culture within a few years thanks to advances in digital and cell phone technology. Virtual Reality has become affordable to the public and at some point may be adapted as a presentation tool as an interactive way of presenting and designing in real time.

Advancements and availability of gaming platform software such as, Unreal Engine and Lumion are leading the advancement and availability of virtual and augmented reality design (Tal, 2017). Both Unreal Engine, and Lumion have a learning curve that can be overcome by the adapted practice of the tutorial. It is possible to export a Lumion 360 degree model into a virtual reality environment to be viewed through a virtual reality headset, such as Samsung Gear VR or Facebook owned Oculus Rift google set among others (Tal, 2017; Barth, 2015).

Founded in Warmond ,Netherlands, in 1998, Lumion is a 3D acceleration software that takes a CAD drawing and gives the designer the ability to create animations, videos, images, and panoramic views in a quicker format than what is usually possible for 3D rendered graphics. The software was launched in December 2010, and has quickly become an industry standard in the 3D visual acceleration graphics software market in five different countries (Lumion, 2016).

Unreal Engine is an open source gaming engine software that has incredible graphics. Is developed for use in creating video games, animations, and movies. It also can create stunning three-dimensional graphics for potential use in landscape architectural graphics (Epic Games, 2015).

Technology is developing at such a pace that it is now more of a necessity to have someone that is technically savvy on staff, knows how hardware works, what programs are out

there, and how it can be adapted into the culture of the office to create better efficiency, and clarity of new design ideas (Green, 2017). It is not uncommon in the culture of contemporary design offices, to find people who are searching for open source software that could be adapted into the culture of the firm (Tal, 2017). There seems to be a trend of younger designers that are having a say in the firms' work flow earlier than what has been common over previous years.

Not only are virtual-reality headsets becoming more popular, there seems to be emerging technologies within interactive tablet systems, and the ability to draw three dimensionally using virtual-reality in a simulated reality environment such as Google Tilt brush. Other digital simulations such as aerial photography can be performed via laser surveillance from unmanned drones, or weather balloons, can run the information through software such as LiDar, UNDET, and open source Autodesk Recap 360, that is available free, and then run the topography in a 3D model such as SketchUp or other computer aided design programs (Green, 2017).

2.8 Summary of Literature Review

New technology development is ongoing, and literature review on the professional trends in parametric design would seem to indicate that is next to impossible to keep up with all the new trends in technology. The research backs this claim that software develops quicker than the practitioners can use it, or be trained in new methods to try new and emergent workflows for particular design firms. It is not that firms are incapable of changing a workflow; it is more about the overall efficiency of everyone performing at similar levels and

skillsets. Educational and institutional issues have remained the top hurdles in the adaptation of software in the practice of design firms (Gocmen, 2010).

Despite the overwhelming adaption of digital technology into the modern culture, most people are still unaware of the principles and the innovation of algorithms inside the computational tools they use (Cantrell, 2016). As a new workforce has grown up with digital technology, it is becoming more important than ever to be technologically adept. Each new student entering the field of landscape architecture needs to make choices in the schools they attend, and the technology they would like to learn before entering the job market.

It is imperative that education has the heartbeat of the workforce and its technology in mind when designing curriculum. Innovations in computers, and computer technology have been a constant for over fifty years, it is as important as ever to be able to adapt to newer technology or workflows if the demand for it is there.

In summary, the literature review outlined the history, past innovations, and contemporary software tools for designers and planners working in landscape architecture and related fields. However, the coverage of such innovations in research and practice in landscape architecture seems to be limited and requires further scientific investigation. One thing that is clear in the literature review is the use of PD in landscape and related disciplines is expanding. It is imperative that design firms as well as educational institutions take a stronger note and understand where they stand in the changing workforce of landscape architecture, and the state of their parametric design experience moving forward. This research is an attempt to fill some

of this gap by understanding adaptation level of these innovations especially among landscape architectural professionals in Texas.

Chapter 3

RESEARCH METHODOLOGY

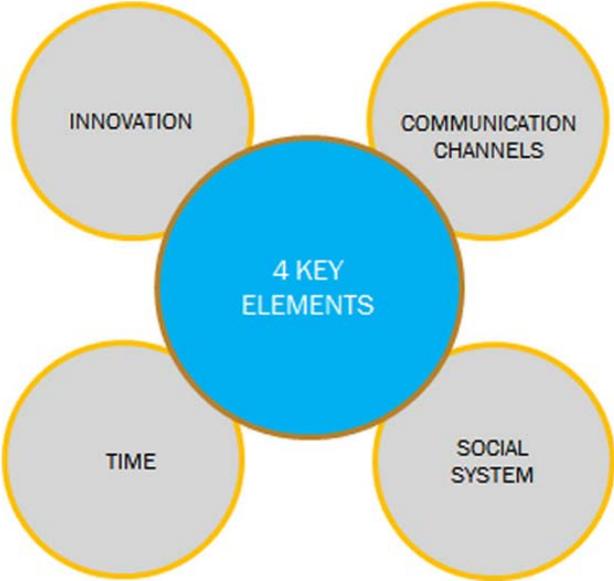
3.1 Introduction

This research follows qualitative methods to assess the adaptation of parametric design among landscape architecture professionals. The procedures in this research are informed by two broader scientific paradigms. The Diffusion of Innovation was the guiding theoretical framework to structure the interview questions designed to elicit information from interviewing landscape architectural practitioners (Rogers, 2003). Secondly, qualitative analysis techniques outlined in Taylor and Bogdan (1998), and Deming & Swaffield (2011), were used to decipher patterns within the data gathered from the research population during the in-depth interviews (Taylor & Bogdan., 1998; Deming & Swaffield., 2011).

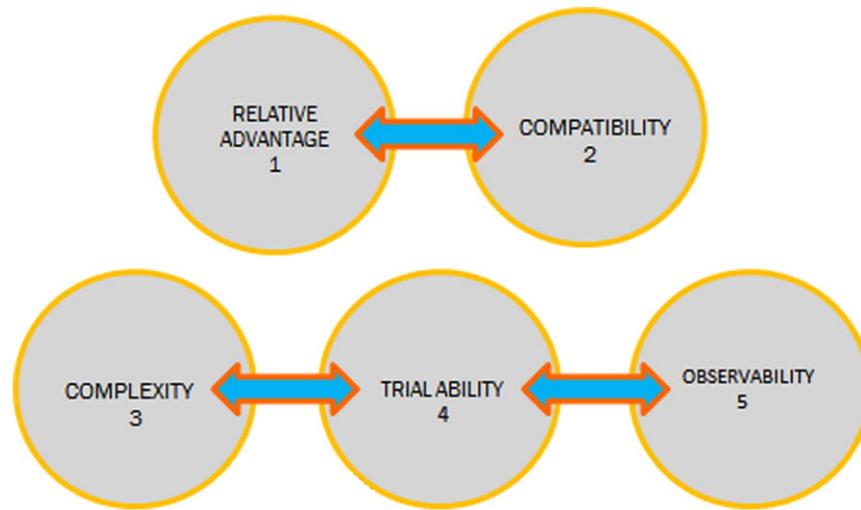
3.2 Research Design

The main research questions for the study were to understand the rate of the adaptation of parametric design among landscape architecture professionals in Texas. The researcher adopted the in-depth interview technique to collect the data (Taylor & Bogdan, 1998). The research questions were designed to answer information categories to Rogers' Diffusion of Innovation key elements, and five attributes of Diffusion of Innovation (figure 3.1) (Rogers, 2003). The study of the Diffusion of Innovation was the underlying framework in the organization of research questions. In particular writing questions then reflecting them back to the four key elements (figure 3.2), and the five stages of an innovation (figure 3.3) as described

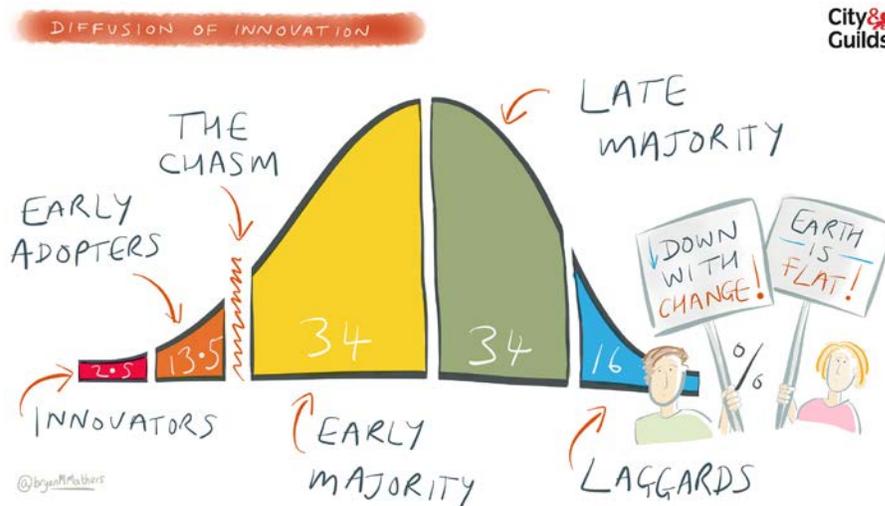
by Rogers' theory, the Diffusion of innovation (Roger's 2003). Analysis of the interview findings also utilized the same organizational structure.



(Figure 3.1) Four Key Elements of Innovations (Rogers, 2003).



(Figure 3.2) Rogers' Five Attributes of Innovations (Rogers, 2003)



(Figure 3.3) Five Stages of an Innovation (Source: Bryan Mathers, 2017)

3.3 Study Location

After some deliberation, it was determined to study landscape architecture professionals in the state of Texas. The study location decision was based on keeping the research focused on a subset of professionals operating within the same professional environment under somewhat similar set of professional circumstances. Moreover, the research involved in-depth interviews with professionals, which required extended amount of time for review of the issues and concepts in person, via e-mail or over the phone rather than a survey method. In addition, it was decided that spreading the research to a larger area than North Central Texas would provide a more comprehensive investigation towards understanding the complexities and similarities in this research study.

3.4 Study Population

In order to understand the level of adaptation in parametric design, landscape architecture professionals in Texas were selected as the study population in this research. The study population of Texas landscape architectural practitioners was identified using the snowball technique (Taylor & Bogdan, 1998) through a publically available website of registered landscape architecture firms at the Texas Board of Architectural Examiners (TBAE) in February 2017 (tbae.org, 2017), the researcher compiled an excel spreadsheet list of the 163 registered Landscape Architectural design firms available from the TBAE website. Each firm received a cover letter with a research study synopsis for distribution. This was part of a package of documents received the University of Texas at Arlington's Internal Review Board

(IRB) approval on January 30, 2017 (see Appendices A2 and A3). These two documents were emailed individually to each firm's designated contact person during the first week of February 2017.

Scheduling of interviews began as the list was distributed, and remained open until the interviews were transcribed and the coding of information began. The bulk of the interviews happened in the month of February. Sixteen subjects were interviewed, with five of the interviews conducted in person, five conducted over the phone, and six subjects responded via answering the interview questions through an email interview.

3.5 Data Collection Methods

3.5.1 Interview Procedures

After review of various research methods, the in-depth interview technique is adopted to collect data regarding the adaptation of parametric design among landscape architecture professionals in Texas. This method is embraced as opposed to survey in order inquire deeper understanding of the innovation and diffusion of parametric design among landscape architects. These methods give the researcher to opportunity to ask follow up questions in addition to primary questions to understand professionals understanding of the phenomena studied by the researcher.

The interviewees meet the researcher in person, on the telephone, or filled the interview out and returned it through email. In person interviews, either on phone or in person were digitally recorded with a recording device. Interviewees were asked five profile questions, ten

main interview questions, if there was additional time two or more questions were asked from the secondary question list. The online interviewees were given the same set of questions and directed to answer the first ten questions, and encouraged to answer the secondary questions if they wished to answer them.

Transcripts of those interviews, were analyzed using qualitative methods adapted from Taylor and Bogdan (1998). The research specifically studied why and when the landscape architecture professionals made the choice to innovate their workflow within their firms or individual practice.

The researcher collected data through email transmission of a Microsoft Word document, and digital recording of in-person and phone interviews using a Phillips Voice Tracer recording device. These interviews were transcribed by the researcher, then qualitatively analyzed to draw conclusions based on Rogers' Diffusion of Innovation theory.

3.5.2 Research Questions

1. To what extent is parametric design adapted into the field of landscape architecture in Texas?
2. What computer software tools are adapted for use in parametric design in Texas?
3. Are there similarities or differences in the level of adaptation of parametric design between education and practice? If so, what are they?

4. What is the most important factor of adapting to innovation in PD for landscape architect practices in Texas?

3.5.2.1 Landscape Professional Profile Questions

Landscape architect professional profile questions

1. What is your role/job title in the firm you are currently working?
2. How long have you been a landscape architecture professional?
3. How many landscape architecture professionals are on staff in your organization?
4. Which school did you get your LA degree from?
5. Do you have other architecture, design, or planning degrees?
 - 5.1 If so, what are they?

3.5.2.2 Landscape Professional Interview Questions

Primary landscape architecture professionals interview questions

1. Are new technologies being adapted into the culture and knowledge base of the firm that you represent?
 - 1.1 If so to what capacity?
2. To what extent is your knowledge or experience utilizing parametric design?
3. What part of the design process, do you or other staff members in your firm use parametric design?
4. What software do you or other staff members currently use for parametric design?

5. To what extent do you or any other staff members design or prototype 3D objects for the use in landscape?
6. Do you or any other staff members have the potential or knowledge to manipulate the coding or scripting of software to achieve different results in a parametric design?
7. Do you perceive an advantage to adapting to the latest software programs using parametric design or analysis?
8. Have you been introduced to Parametric Design in your education?
 - 8.1 How much of this knowledge is being adapted into your experience of the practice?
9. In your view, what level of parametric design is adapted in your firm?
 - 9.1 In Texas?
 - 9.2 Among LA professionals nationwide?
10. Is there anything else you want to add on the topic before we end the interview?

Secondary landscape architecture professional interview questions

1. What percentage of your yearly billable hours goes towards designing with parametric tools?
2. Do you foresee a technology shift within your firm within the next two years?
 - 2.1 In five years?
 - 2.2 If so how?
3. Do you, or any staff members in your firm, had an interest in trying to develop computational software to run customized simulations or use computational design in the maintenance, or design function of a landscape environment?
4. Are your workflows compatible with collaborators outside the firm?
5. Is educating staff on new software a barrier to implementing a new workflow within the firm?

3.6 Data Analysis Methods

3.6.1 Introduction of Research Theory in Study

The questions in the interviews were structured to find observable data upon a qualitative analysis of the results from the interviewees. The structure of the research was premised on the diffusion of innovation developed by Everett M. Rogers in the late 1950s' and published in 1962 (Rogers, 2003). There are several subsets of Rogers' theory, but the ones that remained consistent throughout this research are the key elements defining the process in which an innovation becomes adapted to within a social group.

Qualitative analysis of the interview data post interview was fashioned after the technique of ethnographic interviews and observations from the research of Steven J. Taylor and Robert Bogdan (1998). Other themes for analysis were drawn from Deming & Swaffields' (2011) research in *Landscape Architecture Research*. The data was analyzed into categories and themes were drawn out from the research of diffusion of innovations to determine statistics to answer the questions in the interviews in Chapter Four. In Chapter five the Data will be summarized into Rogers' five attribute categories (Rogers, 2003) it will then be analyzed against the four main elements of PD.

3.6.2 Rogers' Key Elements in Diffusion Research

Rogers' theory states that individuals or social groups adapt to Innovation in a consistent process. The decision to adapt to an innovation can be measured by studying four

key elements such as the Innovation, Communication Channels, Time, and the Social System.

These elements are described in greater detail are as follows.

- a.) Innovation: An idea, process, or way of working that is either new to a social group or individual for the presumed purpose of improving living or working conditions.
- b.) Communication Channels: The process of exchanging knowledge or awareness from one person, or social group to the next. This typically happens over larger social channels, mass media, or through interpersonal channels.
- c.) Time: It takes for a person, or a social group to adapt or reject an innovation. This can take anywhere from a few months to several years.
- d.) Social System: A group that shares a common interest in a practice or use of an innovation. The system's state of effectiveness can be studied through the acknowledgment of change agents, early adapters, and the percentage of late adapters within a social system (Rogers', 2003).

3.6.3 Rogers' Five Factors of Innovation

Rogers (2003), describes "the adaptability" of an innovation is based on several attributes. These attributes are effective in determining the speed with which an innovation is adapted by an individual or social system. The rate of adaption at the personal level happens much quicker than at an organization level, when more people are involved, the more complicated adapting to an innovation becomes. Furthermore, technology-based innovation

does not always happen quickly. Sometimes, innovation happens in a matter of a few months to a few years, and others may take decades to reach full diffusion into a social group. The five attributes of innovation are Relative advantage, Compatibility, Complexity, Trial ability, and Observability (Rogers, 2003).

3.6.3.1 Relative Advantage

Rogers' characteristic of relative advantage relates, "How the innovation has improved over the previous generation of objects or processes (p.15)". This characteristic explains how an innovation relates to an older and previously used innovation or process (Rogers, 2003). An example of this would be innovation in computer-aided 3D design. Less adapted software in landscape architecture, like Rhino and 3DsMax, challenge the older generation of software like AutoCAD.

3.6.3.2 Compatibility

Rogers' attribute of compatibility is, "The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adapters (p.16)". This attribute describes how designers perceive a new concept or method of parametric design, and whether or not the innovation is adapted by future users within that social system (Rogers, 2003).

3.6.3.3 Complexity

Rogers' attribute of complexity deals with the difficulty of adapting to an innovation. "Rogers notes that the higher the level of complexity, then the slower the rate of adaption (p.16)." This concept was used by the researcher to look at which designers are adapting to the innovation of parametric design quicker than others are. Some innovation are adapted quickly into a social system while others that are more complicated take longer to integrate. Being able to compare the ease of complexity of the innovation compared to earlier innovations, is also key to its adaption (Rogers, 2003).

3.6.3.4 Trialability

Rogers' attribute of trialability refers to the ability to test or trial an innovation (p.16). This attribute relates to the innovation of PD to be able to create opportunities for the innovation to be tested. Availability of an innovation as an experiment is necessary to achieve higher rates of adaption (Rogers, 2003).

3.6.3.5 Observability

Rogers' attribute of observability measures the extent to which an innovation can be experienced and reflected upon. The idea of experimentation with the innovation must occur to yield a higher adaption rate. The idea of being able to be experienced and observed is also crucial for the adaptation of an innovation (Rogers, 2003).

3.7 Significance and Limitations

This study furthers understanding the importance and limitations of developing an innovation, such as the educational, technical, and the cultural factors of the modern-day landscape architecture professional design office. The methods used to study this subject have been used in hundreds of studies (Rogers, 2003) worldwide and represent a well-vetted process into understanding a wealth of psychological behavior and adaptation to innovation.

It is limited in the sense that the information can only be drawn from the subjects that responded. Even though the study attempted to study a broad range of professional designers in landscape architecture, it may have been a wide belief that PD is an architectural design methodology. It may have also been presumed that the researcher was primarily interested in parametric design first, and adaptation of those innovations overall secondly. This belief, although not tested, could have influenced potential subjects into not participating.

Although, the study population is Texas professionals, the sample size is relatively small on the individual firm side to make generalizations beyond the sample size. Given that various subjects used different methods to respond to interview (in-person, phone, or e-mail) there might be limitations in their responses based on the techniques used to interview.

3.8 Chapter Summary

As it is highlighted in the beginning of the chapter this research follows qualitative methods to assess the adaptation of parametric design among landscape architect professionals. The procedures in Chapter Three and Four are informed by two research methodologies. First, the Diffusion of Innovation was used as a guiding framework to structure the questions for interviewing landscape architectural practitioners (Roger's, 2003). Secondly, qualitative analysis techniques outlined in Taylor and Bogdan were used to decipher patterns within the qualitative data gathered from the research population (Taylor & Bogdan, 1998, Deming &, Swaffield, 2011).

After covering research design, this chapter defined in more detail the key elements and attributes identified by Rogers and tested in numerous research studies. These elements and attributes form the outline for the analysis of the research population in Chapter Four Data Findings and Analysis, as well as the Conclusions in Chapter Five.

Chapter 4

DATA FINDINGS AND ANALYSIS

4.1 Summary of Findings

The findings in this research study resulted from qualitative analysis of data gained through in-depth person-to-person interviews. The purpose of the interviews was to assess the level of parametric design competency and usage among landscape architecture profession in the State of Texas. The interviewees were asked the same set of questions in person-to-person interviews, on the phone, as well as in emailed interviews. The answers were grouped to find percentages in responses, as well as recurring themes related to the diffusion of computer technology into the culture and practice of landscape architecture in Texas.

The diffusion of innovations of parametric design software and processes was explained through the lens of Rogers' Diffusion of Innovation Theory. The two segments of Rogers' theory, the four elements in the Diffusion of Innovation, and the five attributes of Innovation were the main devices utilized to summarize the data into conclusions that respond to the main research questions of this study.

The interviews were digitally recorded in-person, on the phone, or as a collected word document through email. A bulk of the interviews were recorded in February 2017, and in March. The interviews were dictated while listening to the recorded playback by the researcher.

4.1.1 Demographics of Landscape Professional Study Group

The subjects in this study were selected from a public website of Texas landscape architects. Contacts of 163 professional design firms in Texas were contacted via email. The snowball technique, reaching subjects through personal contacts, was utilized to build a study population of landscape architecture professionals experienced in working or managing with or without parametric design (Taylor & Bogdan, 1998). In all 16 subjects were interviewed, 10 in-person or on the phone, and 6 via online interviews through email. Observable patterns were noticed from mid interview process forward. Because of this, it was determined that an effective study group had been meet.

The in-person interviews were done either in an office setting, or over the phone. Both methods used a digital recording device to capture the interview for later dictation. At first the interviewees are asked about their role and job title in current firms, then they were asked questions about their, or the firm they represented experience with parametric design. The last two questions were about education results of studying the demographics of the firm profile questions are in Figures 4.1 and 4.2 as follows.

Profile Question #1

What is your role or job title within the firm you are currently working?

75% of respondents interviewed were upper management with 10 years or more experience, 19% were new hires of zero to 5 years, and 6% were senior staff of 5-10 years.

(Figure 4.1). This also corresponded with the results in question number two about the experience in years

Profile Question #2

How long have you been a landscape architecture professional?

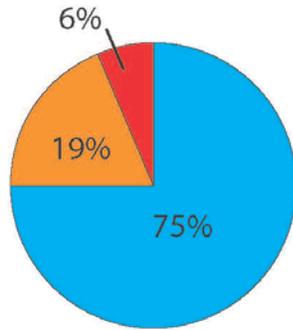
75% respondents being of 10 years or more experience (Figure 4.1). Within those of upper management, six respondents had 30 years or more experience, three subjects had 20 years or more experience, and three of them were in the category of 10 years' experience or more.

Three subjects reported having 2 to 4 years' experience, these respondents were not registered landscape architects. One subject represented six percent of the respondents as the sole subject, within senior staff in the 5-10 year range, as their position had changed to project management.

Profile Question #3

How many landscape architecture professionals are on staff in your organization?

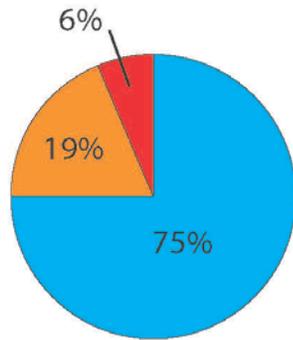
50% of firms were 12 professionals or more (Figure 4.1), 31% represented medium-size firms of 6 to 12 people, and 19% of firms in this study were six people or less. These categories were based on representing the averages the data from the subjects interviewed and not some outside measure



PROFILE QUESTION #1

ROLE OR TITLE IN FIRM

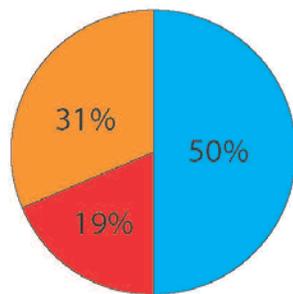
- SENIOR STAFF 5-10 YEARS
- DESIGNER/NEW HIRE 0-5 YEARS
- UPPER MANAGEMENT 10 + YEARS



PROFILE QUESTION #2

EXPERIENCE IN YEARS

- 5-10 YEARS
- 0-5 YEARS
- 10 YEARS OR MORE



PROFILE QUESTION #3

LANDSCAPE ARCHITECTURE PROFESSIONALS ON STAFF

- SMALL 0-6
- MEDIUM 6-12
- LARGE 12 OR MORE

Figure 4.1 Profile Questions #1-3, Experience

Profile Question #4

Which school did you get your LA degree from?

56% of the subjects received their master's or bachelors of landscape architect degree, or equivalent from a Texas University (Figure: 4.2). Additionally, 44% of them received their degree out-of-state. Of the 56% of the subjects that did get there degrees in Texas, 44 % went to Texas Tech. Texas A&M and UT Arlington held 22% of the degrees each, with UT Austin having 11% (Figure 4.2.1).

Profile Question #5

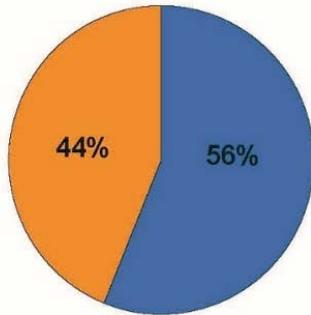
Do you have other architecture design or planning degrees, if so what are they?

Forty-four percent of all the subjects, reported having other degrees related to architecture, design, or planning while 56% of them did not have other degrees, or their extra degrees were not related to the design fields directly (Figure 4.2). Of those respondents with non-secondary degrees in related fields, two had advanced degrees, one in Psychology, and the other in Biochemistry. Two other respondents had additional training, one in irrigation, the other in LEED AP. Of the seven subjects that had double degrees within related fields, respondents #2, #8, and #13 could be identified as advanced parametric users as identified by software practices in professional questions #2 and #4, which asked about the respondents

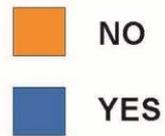
experience utilizing parametric design, and what programs they or their staff use for parametric design.

According to the data, the new hires directly out of school with five years of experience or less had a more comprehensive skill set related to advanced parametric tools. However, there was one exception of subject # 10, with 14 years' experience in landscape architecture, who claimed to have an advanced parametric skill set. This subject did not have a double degree in a related field, but was largely self-taught in three-dimensional design through a transition into product design in two economic turndowns, one of which was the recession in 2009.

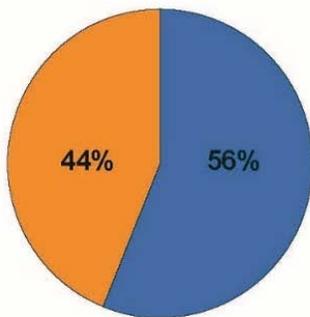
PROFILE QUESTION #4



DID YOU GET YOUR LA DEGREE FROM TEXAS?



PROFILE QUESTION #5



DO YOU HAVE OTHER RELATED DEGREES? ARCHITECTURE, DESIGN, OR PLANNING

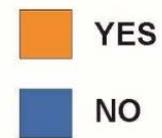


Figure 4.2 Profile Education Questions

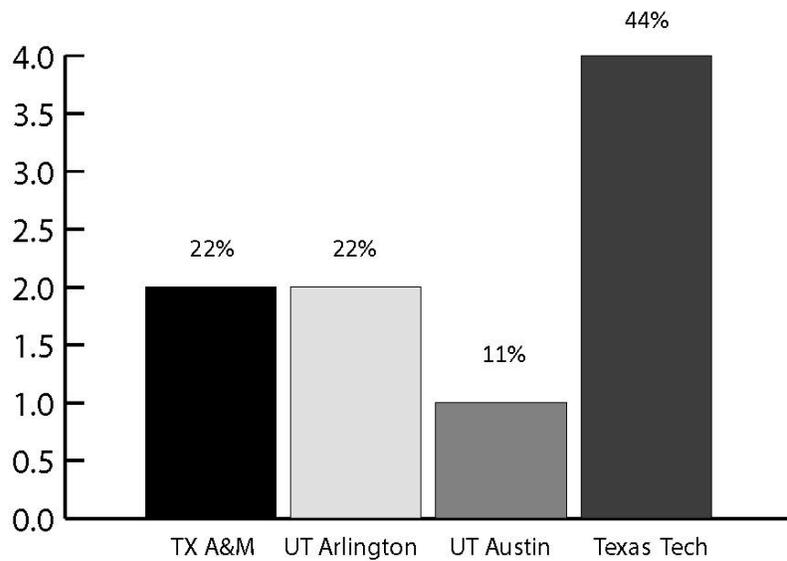


Figure 4.2.1 Texas School LA Degree

4.1.2 Findings on In-Depth Interview Questions

The interviews were digitally recorded in-person, on the phone, or as a collected word document through email. The Interview questions were a continuation of the interview process proceeding from the profile questions. The in-depth interview questions were the same questions that were asked during online interviews.

4.1.2.1 Professional Question #1

Are new technologies being adapted into the culture and knowledge base of the firm that you represent. If so to what capacity?

Seventy five percent of the respondents believed that new technologies were being adapted into the culture and knowledge base of their firms (Figure 4.3). However, the responses of what they labelled as new technology differed between something as simple as software updates, to experimenting with new technology such as digital graphic software, digital prototyping, or advanced 3D modeling software.

Most of the respondents indicated they would either, use 3D software more in the future, or integrate into a BIM system-modeling platform. The responses from this question were cross-referenced with professional question #4 regarding the use of software (Figure 4.5). Two respondents stated that they were not only adapting to new tools, but they were learning to use their current software better to improve workflow within the firm. Subject #3 just started a private sole proprietorship practice after 20 years working in a medium sized firm, and was trying Autodesk Infracore 360 for use in developing quicker analysis and design phase for residential and commercial land development. Subject #5 stated, “ We accept new programs, but only to the degree at which they can provide our firm with the ability to produce a better product, it is only then that we will integrate the program firm wide.”

4.1.2.2 Professional Question #2

To what extent is your knowledge or experience utilizing parametric design?

Of all the respondents, 75% identified as having entry level experience with advanced parametric tools (Figure 4.4) The use of AutoCAD, Photoshop and basic SketchUp are

Innovation that Rogers' theory would classify as full, or nearly fully diffused into the culture of landscape architecture design (Rogers, 2003) according to this particular interview pool. Other parametric tools that have been around nearly the same time, have not been fully integrated into the culture of this discipline of design. Advanced tools such as 3Ds Max, Rhino, Lumion, and Revit, are becoming more popular and in demand as time passes on. This trend is to some extent is market-based especially in regards to Lumion and Revit, where the clients are expecting to see metrics and concepts that are realistic earlier on in the decision-making process. Several subjects reported increasing requests for BIM capability in the past two years.

Growing majority of architects are now using BIM, this technology shift streamlines the design to the construction document phase, however, this benefit does not necessarily align with the experience of landscape architects, who speak of a dissatisfaction of using BIM-based systems. These systems do not recognize design parameters from the landscape architecture perspective, or parametric generative form for that matter.

Nineteen percent of the research group had developed advanced parametric skills. These are skills in computer graphics and 3D modeling which have not become fully integrated into either a design school training or implementation in the professional world. These subjects would be classified in Rogers' theory as change agents or early adapters. Of these four respondents, three of them were new hires with four years' experience or less. However, one individual had over 14 years' of experience in the field of landscape architecture and was largely self-taught in processes of 3D design.

The one subject that was identified as an intermediate parametric design practitioner reported that he was moving up the chain of management within the firm as a project manager. The subject self-reported a high level of skill in Civil 3D, AutoCAD, 3Ds Max, and some Rhino. They believed their software skills were diminishing because of a new program management role within the firm.

This result was also consistent with the beginner level of advanced parametric tools. The subjects in upper management had various experience levels ranging from 12 years to 41 years' of experience. A majority of these subjects were around for the early development of AutoCAD and had to learn this new technology either on the job, university extension classes, or at a community college or trade school. As the firms they work for develop their businesses, a marked majority of them also moved to upper management positions where the use of technology on a day-to-day basis was not as rigorous as it was before. The subjects also were more likely to comment that their experience in the marketplace was not demanding them to develop new technology skillsets.

4.1.2.3 Professional Question #3

What part of the design process do you or other staff members in your firm use parametric design?

Since the design process is relatively consistent set of steps, from inventory to site analysis, concepts, schematics, to final documents across different levels of experience, it is

relatively easy to assess in general terms where the subjects were using parametric design.

However, there is some subjectivity as to how often the subjects used PD as they reported in the interviews. With that being said, it is important to note that 57% of the respondents reported using parametric design in the conceptual stage (Figure 4.4). Each subjects' responses were qualitatively analyzed based on what they said in the interviews.

QUESTION #1 ARE NEW TECHNOLOGIES BEING ADOPTED INTO THE CULTURE AND KNOWLEDGE BASE OF THE FIRM THAT YOU REPRESENT?

IF SO TO WHAT CAPACITY?

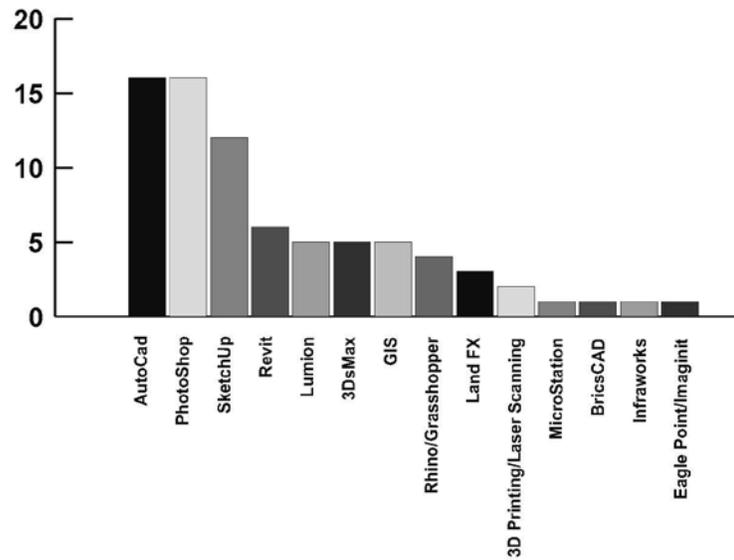
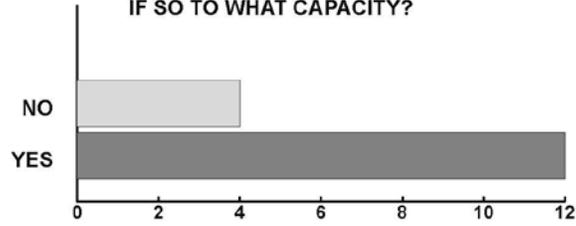
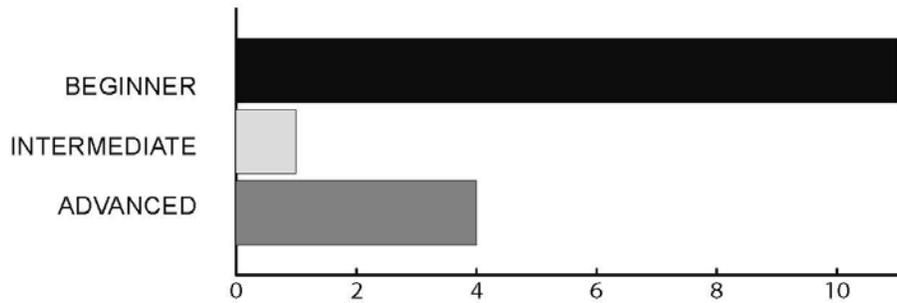


Figure 4.3 Professional Questions #1, New Technologies

QUESTION #2 TO WHAT EXTENT IS YOUR KNOWLEDGE OR EXPERIENCE UTILIZING PARAMETRIC DESIGN?



BEGINNERS: 10 OF THE 11 WERE OF UPPER MANAGEMENT OR 10 PLUS YEARS EXPERIENCED.

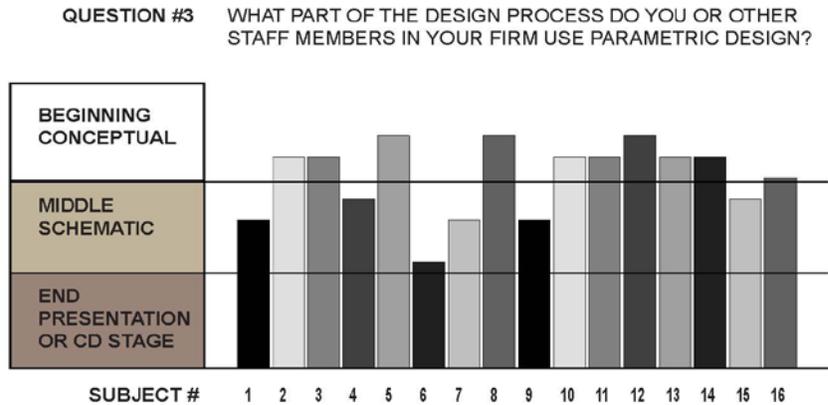
INTERMEDIATE: THIS SUBJECT WAS AT THE PROJECT MANAGEMENT LEVEL ALLTHOUGH HIGHLY SKILLED, FELT HIS SKILLS WERE GETTING RUSTY. WAS 8-9 YEARS OUT OF SCHOOL.

ADVANCED: THESE SUBJECTS WERE NEW HIRES UNDER 4 YEARS EXPERIENCE, THEY IDENTIFY USING LESS ADOPTED SOFTWARE AND TECHNOLOGY. ONE OF THE FOUR INDIVIDUALS WAS OF TEN YEARS EXPERIENCE OR MORE.

Figure 4.4 Professional Questions #2, Individual Experience

A common theme was using SketchUp to conceptualize things faster, or other 3D modeling to understand if a complex idea would work well enough to develop it further. Another theme was that each project might require a different means in which to conceptualize an idea. Subject #8 stated that the firm he works for has started to use 3D design in SketchUp earlier in the design process. “Parametric design was typically utilized in the final phase if at all. A few years ago it was more about hand drawing, but now 3D is used earlier and also becomes a new source of billable hours for the firm.” Subject #2 also stated they also used PD

earlier in the design phase. They also used SketchUp and Rhino, but this is done in the earlier stages as a means of determining whether an idea was buildable.



57% OF PRACTITIONERS STATED THAT THEY OR THERE FIRM USED PARAMETRIC TOOLS AS EARLY AS THE CONCEPTUAL PHASE OF DESIGN.

OF THOSE RESPONDING TO USING PARAMETRIC TOOLS EARLIER IN THE DESIGN PROCESS, WERE LIKELY TO USE IT TO UNDERSTAND SOMETHING THEY COULD NOT THROUGH DRAWING, AND TENDED TO USE MORE INTUITIVE TOOLS SUCH AS SKETCH UP OR RHINOCEROS.

Figure 4.5 Professional Questions #3, What Stage is PD Used

4.1.2.4 Professional Question #4

What software do you or other staff members currently use for parametric design?

The practice of using Photoshop and AutoCAD has reached what Rogers' Theory (2003) would describe as Critical Mass. This is a point at which any additional Innovation that occurs is part of a self-sustaining system. The respondents in this study all reported using both AutoCAD and Photoshop in their design practices (Figure 4.6). Also interesting to note, was that SketchUp is integrating relatively quickly into the culture and practice of landscape

architecture and related design firms. Revit even though it is stated as the fourth most common software, is a misnomer as most practitioners discussed within the interview that they had found a workaround to the incompatibility issues that come with using building information modeling in particular with Revit. The workaround was accomplished using Civil 3D CAD, or some form of a format change or written code to accomplish opening, working on, and saving the file.

Lumion, GIS, and 3Ds Max all shared the same statistic with about 25% of the interviewees reporting that they had used it or were using it in their design practice.

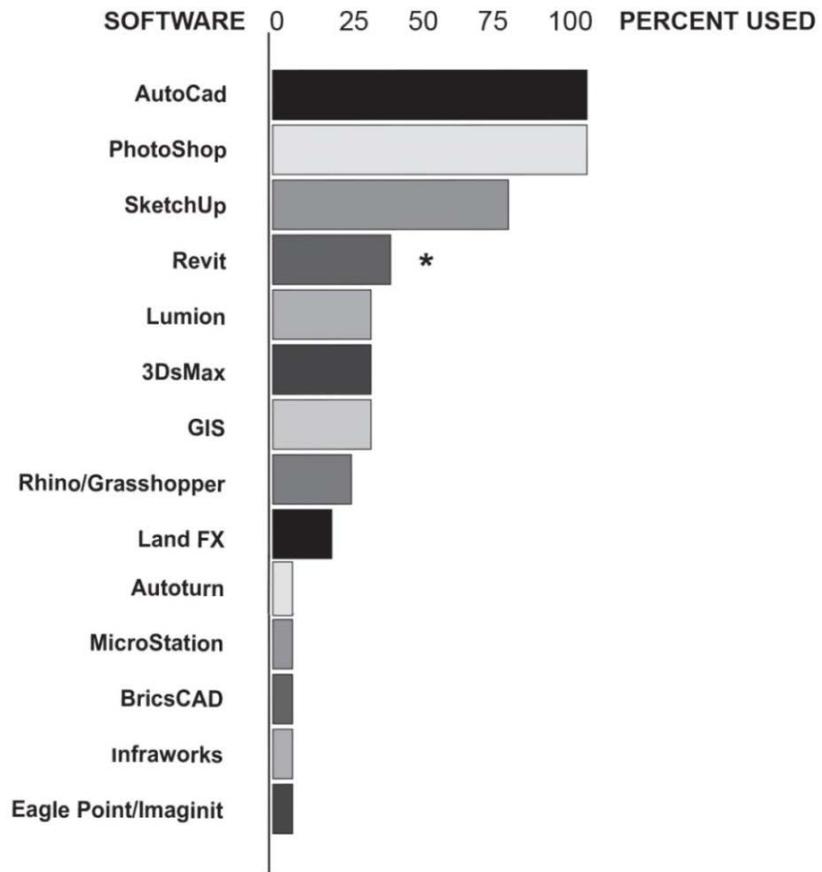
4.1.2.5 Professional Question #5

To what extent do you or any other staff members design or prototype 3D objects for the use in the landscape?

Responses to this question were touched on the previous question. Many firms are reporting that they were beginning to use parametric design to study 3D models (Figure 4.7). Two firms reported dabbling in three-dimensional prototypes for signage and furniture. One of those two firms had a 3D printer in an affiliated office in Texas, the other one tried out a manufacturer that could run computer models through a CNC router (Figure 4-7). Respondent #5 stated that their firm 3D prints objects such as boulders and other natural materials for use in model making, as they are time consuming and expensive to move. Firm #10 stated they were thinking of buying a 3D printer very soon. Only three of the 16 respondents were working in

three-dimensional prototypes and it was primarily in an experimental phase. These firms were consistent with the other more advanced parametric users as stated in question number two.

QUESTION #4 WHAT SOFTWARE DO YOU OR OTHER STAFF MEMBERS CURRENTLY USE FOR PARAMETRIC DESIGN?



* MOST REVIT USERS HAVE DEVELOPED A WORK AROUND TO USING REVIT AND DO NOT USE REVIT DIRECTLY

Figure 4.6 Professional Questions #4, What Software is Used

Responses to designing in three-dimensional space, however, were the opposite. Of the 16 subjects, 75% reported designing in digital three-dimensional space. Several firms had within the structure of their organization architects on staff that would typically do any sort of three-dimensional design in any number of programs, this may have swayed the reporting of three-dimensional design in landscape architecture. Respondent #1 stated, in regards to customization of furniture in architectural details that their firm tried to put their own personal touch on everything they do. Respondents with more years of experience tended to still favor hand drawing in the conceptual phase before using computers. Other more engineering-based firms might use three-dimensional analysis for cut and fill, or designing for underground piping.

4.1.2.6 Professional Question #6

Do you or any of your other staff members have the potential, or the knowledge to manipulate the coding or scripting of software to achieve different results in parametric design?

56% of the respondents stated that they do not have the ability to use code or script (Figure 4.8). However, 38% stated that they knew someone on staff, or they have access to people who can help them customize software to streamline workflows in either the software command level, or developing firm wide standardized workflows.

QUESTION # 5 TO WHAT EXTENT DO YOU OR ANY OTHER STAFF MEMBERS DESIGN OR PROTOTYPE 3D OBJECTS FOR USE IN THE LANDSCAPE?

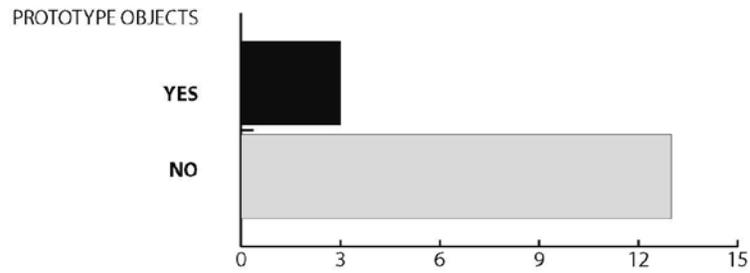
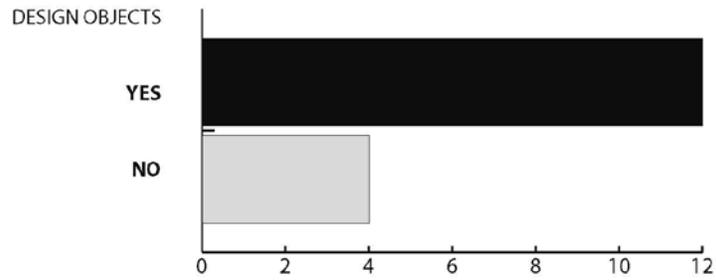


Figure 4.7 Professional Questions #5, Design or Prototype

The respondents in a third of those 38% firms reported scripting within Rhino and Grasshopper, this is what is known as visual scripting. Subject #15 mentioned being able to code within AutoCAD using AutoLisp language, and knew how to run novice level ruby scripting in SketchUp. Subject #5 reported having someone within another branch of the same firm that was able to do coding across the entire firm's business structure.

QUESTION #6 DO YOU OR ANY OTHER STAFF MEMBERS HAVE THE POTENTIAL OR KNOWLEDGE TO MANIPULATE THE CODING OR SCRIPTING OF SOFTWARE TO ACHIEVE DIFFERENT RESULTS IN A PARAMETRIC DESIGN?

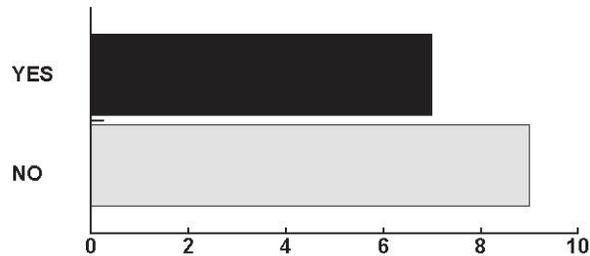


Figure 4.8 Professional Questions #6, Scripting or Coding

4.1.2.7 Professional Question #7

Do you perceive an advantage to adapting to the latest programs using parametric design or analysis?

Responses to this question were unanimously positive (Figure 4.9). There was some trepidation expressed as to whether or not software updates, or learning a new software program, would lead to more efficiency within an organization. Subject #1 stated, “Some people embrace change and want to see the new updates, while others fight it like the plague.” He went on to state, “it is not that people could not learn to adapt to new programs, because they are perfectly capable, they just resist it.”

Even though 87% of the subjects agreed there are advantages to adapting to the latest software programs, there were three main concerns expressed by respondents. The first concern was that new updates that were overly complicated influence the workflow. The second concern was with the workflow itself. Does the update or the innovation improve the efficiency within the organization? In other words, can the innovation improve efficiency within a reasonable amount of time? A third concern was whether an innovation or software update would influence the intuition of the design process.

Subject #5 responded. “I believe that there is an advantage to adapting technology to the way we work. I do not like assuming that technology fully replaces our “design intuition.” I think we still need both. No program can replace project experience, and likewise, no amount of longevity in this profession should prohibit us from trying something that can improve our analysis, design, and construct-ability. I do not think that parametric design is a replacement for imagination or imaginative connective conceptualization.”

QUESTION #7 DO YOU PERCEIVE AN ADVANTAGE TO ADAPTING TO THE LATEST SOFTWARE TO ACHIEVE DIFFERENT RESULTS IN PARAMETRIC DESIGN?

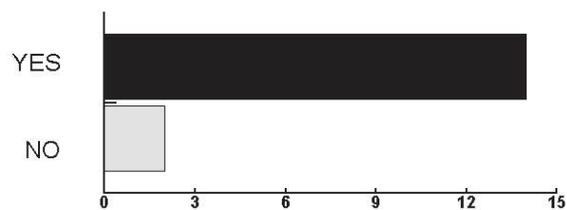


Figure 4.9 Professional Question #7, Advantage in PD

4.1.2.8 Professional Question #8

Question#8 Have you been introduced to parametric design in your education?

Nearly 75% of the subjects reported being upper management with 10 years or more experience and within that group 75% the majority have 20 years or more experience in the field of landscape architecture (Figure 4.10). These subjects have seen tremendous technological change over the course of their careers in technology. Many of them did not have a formal class in AutoCAD, and if they did, it was often in another discipline such as mechanical drafting or engineering. To some extent, this type of educational sharing within disciplines at the academic level still happens. The educational choices in the 1980s and 90s for any number of parametric tools listed in this study were largely inaccessible. Training through tutorials on the internet did not take off until nearly a decade later.

QUESTION #8 HAVE YOU BEEN INTRODUCED TO PARAMETRIC DESIGN IN YOUR EDUCATION?

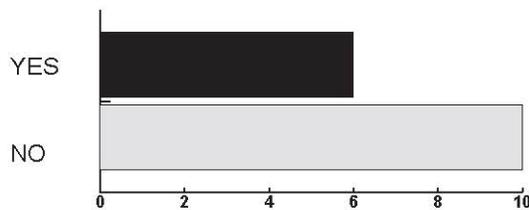


Figure 4.10 Professional Question #8, Introduction to PD in Education

With that being said, 63% of the subjects within the study stated that they were not introduced to parametric design in their education. Their adaptation over the course of their careers was more oriented towards learning AutoCAD and Photoshop. These landscape architecture practitioners believe that drawing out ideas is one of the better ways of thinking through the process of design. Because of their level of adaptation to this process, they have been resistant to change what they know, and what is efficient in their particular experience with landscape architectural design.

On the other hand, new hires of five years or less reported knowing a plethora of software. Most common were AutoCAD, Photoshop, Adobe Creative Suite, GIS, and SketchUp. Other skills include learning Rhino with Grasshopper, Revit, and 3Ds Max. Of the sixteen subjects in the study, five of them could say that they were introduced to parametric design within their design education.

4.1.2.9 Professional Question #9

Question #9 In your view what level of parametric design is adapted in your firm in relation to Texas. Then compared to LA professionals nationwide?

This question generated 14 responses from the pool of 16 subjects (Figure 4.11). 37.5 % believe their firm or their practice was above average in the state of Texas. Subjects #1,#2,#5, #8, #10 ,and #14 were singled out as above average according to their response and cross-examination of their various parametric software uses. These respondents also believed

that they were above average in their usage of parametric design, but behind in the development of parametric use within their firms when compared to the nation as a whole.

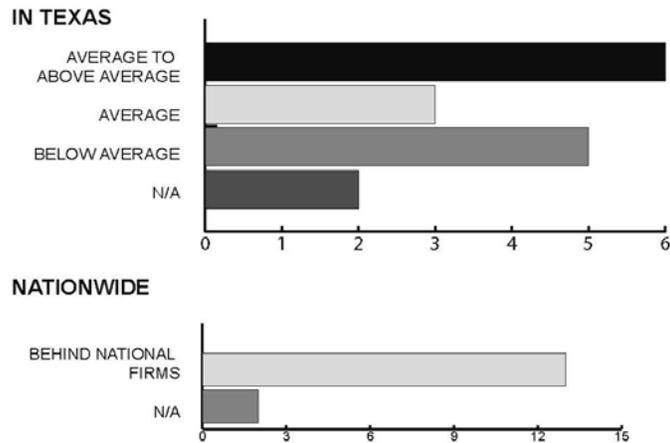
Three of the 14 responses to this question identified themselves as average users of parametric design tools. This assessment was based largely upon their own assessment of their firm in reference to the question. Subject #12 believed that Asian firms used to be the leader in parametric design and that the United States had caught up to some degree. Subject #15 believed that advanced parametric design, such as Rhino, 3Ds Max, was not being adopted at either the state or the national level.

Five firms identified themselves with being behind the curve of developing or adapting to parametric design. Subject #16 believed strongly that adapting to technologies is client driven. Subject #4 and #9 believe that larger firms were possibly doing more of it. Two respondents were unclear about whether or not the state of Texas was on par with the rest of the nation with parametric use in landscape architecture. Subject #11 believed there is a lot of progress of design work coming out of Texas, and that Texas A&M University was leading the charge in academic training. With that being said, he identified with his affiliated firm being behind the curve using parametric design.

Subject #2 believed that since the recession in 2009, smaller firms had gained a competitive edge against larger firms. This respondent believed it had to do with smaller firms having a lower overhead, and the availability of highly talented practitioners. As expected, the more internationally based larger firms were more tech-savvy in their day-to-day practice. They were more apt to adapt practices such as Rhino and 3Ds Max. An interesting note is that these

more tech savvy firms also believe that their firms were behind in use of parametric tools as compared to the East and West Coast of the United States.

QUESTION #9 IN YOUR VIEW WHAT LEVEL OF PARAMETRIC DESIGN IS ADOPTED IN YOUR FIRM? IN TEXAS? AMONG LA PROFESSIONALS NATIONWIDE?



OBSERVATIONS:

LARGER MORE INTERNATIONAL BASED FIRMS ARE MORE RHINO AND 3DS MAX FRIENDLY SUBJECT #14

DEMAND FOR GENERATIVE FORM IS LOW AND IS USUALLY DONE BY AN ARCHITECT SUBJECT #10

COASTAL FIRMS SEEM TO BE DOING MORE GENERATIVE FORM THEN IN TEXAS -SUBJECT #2

COULD BE MORE DONE HERE BUT IT IS BUDGET AND CLIENT DRIVEN -SUBJECTS #14,16

EVEN THE MORE PROGRESSIVE LEANING FIRMS STATED THE BELIEF THAT TEXAS IS SLIGHTLY BEHIND THE CURVE IN ITS USE OF PARAMETRIC DESIGN, WITH THE EXCEPTION OF SUBJECT #11,WHOM BELIEVED TEXAS WAS AS PROGRESSIVE AS OTHER STATES IN USE OF PARAMETRIC DESIGN. RESPONDENT CREDITED TEXAS A&M AS LEADING THE WAY IN TECHNICAL TRAINING

Figure 4.11 Professional Questions #9, Level of Adoption in Firm

4.1.3.0 Additional Professional Questions #2

A set of five interview questions was crafted to seek out additional information where information might have fallen short during the interview and interviews process. Of the five questions, three emerged as the most popular among online respondents and during the person-to-person interview process. Questions # 2, #4, and #5 were answered by half the respondents or more. Questions # 2 & #5 were the most relevant to this study.

Question #2 Do you foresee a technology shift within your firm within the next two years? Five years? If so how?

Sixty-nine percent of the subjects expressed belief that their firm or their personal practice was going to evolve technically in the next 2 to 5 years (Figure 4.12). Commonality between answers was rare. It essentially became a wish list of sorts for the future of the 12 subjects that responded to the question. Respondents that spoke of smaller shifts in technology, stated they would move towards more three-dimensional drawing. Subject # 3 wanted to learn more about SketchUp, while subject #8 believed there is only so far that you can take SketchUp. That subject also believed that CAD would remain the top used software for the next 15 to 20 years. Subject #10 believed he was going to move to a more adaptable open source CAD-based software called BricsCAD. He also was hoping to use Rhino more often. Subject #8 believed that a continuation of new hardware was necessary to keep up with graphic card based animation in Lumion. Subject #12 thought they would move from a civil 3D

platform into something like a Revit platform, while subject #2 believed we would see a lot more automation and their firm would still strive to become more organized as an innovation. Better Revit accessibility or usability was again referred to by subjects 12 and 16. Subject #15 believed that the firm he represented would move more toward a Lumion and SketchUp platform. Subjects 6 and 15 stated that any innovation that happened would still be based on market or client demands.

ADDITIONAL QUESTIONS #2 DO YOU SEE A TECHNOLOGY SHIFT WITHIN YOUR FIRM WITHIN THE NEXT TWO YEARS? FIVE YEARS? IF SO HOW?

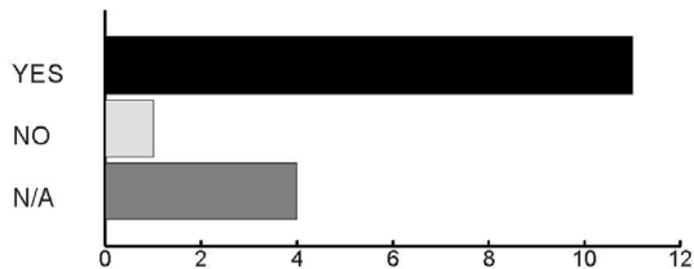


Figure 4.12 Professional Additional Questions #2, Future Technology Shift

4.1.3.1 Professional Additional Question #5

Question#5 Is educating staff on new software a barrier to implementing a new workflow within the firm?

Approximately 63% of those who responded to this question believed training was not a barrier to implementing new workflows (Figure 4.13). Subject #1 believed within his firm that it is hard to keep up with training members of staff at different levels of technical ability.

ADDITIONAL QUESTIONS #5 IS EDUCATING STAFF ON NEW SOFTWARE A BARRIER TO IMPLEMENTING A NEW WORK FLOW WITHIN THE FIRM?

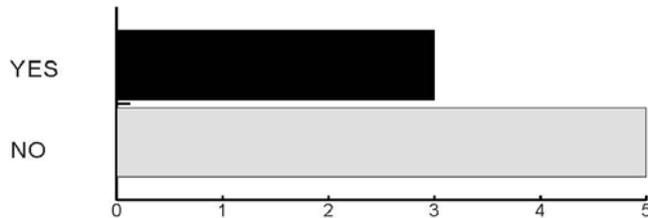


Figure 4.13 Professional Additional Questions #5, Education Barriers

Subject#2 stated that all their new hires go through a leveling of technology boot camp of sorts to assure everyone is at the same base level of technical ability. He also believed that it was imperative that the culture of the office peers aided in the learning process. Subjects #5 and #6 believed it was imperative that if a firm wanted to keep improving efficient deliverables,

and workflows, it needs to keep up with technology. Subject #3 noted that it was a lot easier to learn now with the availability of online tutorials.

4.2 Adaptation Characteristics of Parametric Design in Texas

According to Rogers Diffusion of Innovation Theory, all adaptations go through a series of phases. An innovation is an idea perceived as new by an individual or a social group, regardless if it a few months old or several decades. How well an individual or group perceives advantages over time within their group determines whether an innovation is diffused into that social group (Rogers, 2003).

4.2.1 Perceptions of Relative Advantage of Adapting to Parametric Design in Texas

In Rogers' theory, relative advantage describes the benefits of an innovation through economic, cultural, and social values. The greater the perceived advantage, the more likely it is to be adapted into a social group (Rogers, 2003). Subjects that identified more with an international reach within their firm found more of an advantage to adapting parametric design tools than the subjects that were more regionally based.

For instance, subject #2 reported that the use of Rhino was nearly an everyday occurrence. This firm was doing more international business before the recent downturn of the economy. However, is not certain to what level there were using Rhino prior to the recession of 2009, but some of the subjects had not even heard of Rhino before this study. It can be presumed that the software was not used within their professional design circles, so it was not a

sought after toolset for them to work with the people they normally work with. Awareness of an innovation is one of first steps towards becoming interested in adapting to it (Rogers, 2003).

Although AutoCAD can do generative parametric design work, it was perceived as a complicated tool to work with. This perception led to the innovation of other toolsets that have become popular over the years such as SketchUp, Rhino, and Lumion. There still needs to be a market demand for the toolsets to become economically beneficial to the landscape architecture firms that are seeking to use them.

A similar argument can be made for the demand of the building information software Revit. Subject #15 stated, “ BIM has been a big thing for the architectural industry just because of the way it works. In the level of detail that we need to get to, is not the same as most buildings.” They went on to comment, “there seems to be some potential advantages as far as speeding up production processes but as far of revolutionizing the way we work I don’t see much potential there it is really pushed from the client-side.”

According to the interviewees Revit is the tool that is in high demand from the architecture profession. Many municipalities prefer to work with this software to minimize the risks of budget and litigation problems. When it comes to landscape architects’ perspective on this, the economic advantage of such a system is certainly there, but from a billable time standpoint, the software does not work the way landscape architects need it to work. This has led to many innovative workarounds with different file format sharing, customization of software to read Revit files, and even software that seeks to offset these problems completely within a new software platform such as VectorWorks Landmark.

4.2.2 Perceptions of Compatibility to Parametric Design in Texas

Compatibility is the degree in which an innovation is perceived as consistent with sustained using experiences meets the needs of social group adapting to it (Rogers, 2003 p.240). Many of the subjects in the interviews believed there was compatibility with new technology in their LA practice. SketchUp for instance has become a very common software program, it is unique in its ability to aid in the conceptual phase of design. Typically a three dimensional tool would not be utilized until later in the schematic phase. This is filling a void in the design process that was not likely considered a design constraint for a majority of designers.

Compatibility is relevant in regards to what individuals or design firms are interested in achieving in their design works. High-end marketing graphics, and unique design work such as customized monuments, and arbors are two of the most compatible uses for advanced generative form.

The use of computational software such as GIS, BIM, and CIM, becomes compatible only if the market is there for the particular design firm, such as a planning driven landscape architecture firm. Since relatively few subjects in this study were oriented towards combined planning and landscape architecture firms, a proper assessment of the skill set was not possible. For instance, subject #15 was currently working in a planning firm that did use GIS from time to time but it was largely the responsibility of other practitioners that were more trained as planners. There was no mention of using CIM anywhere in this study.

4.2.3 Perceptions of Complexity of Parametric Design in Texas

Complexity is the degree in which an innovation is perceived as relatively difficult to understand and use (Rogers, 2003). The attribute of complexity is most often seen in a negative perspective of a potential innovation. An example of this within the study is the use of advanced parametric tools such as Rhino and 3Ds Max. Both of the software's have been publicly available since the mid-to late 1990s. Yet they are only beginning to become adapted into the culture of landscape architecture. If one were to compare United States design studios to other design studios on international level, a more wide scale use of both software programs internationally. There does not seem to be an easy explanation why these programs are more prevalent in one market over another. The software program 3Ds Max was stated by subject #2 as the most complicated design tool, this was also corroborated in the study, that 3Ds Max was the most complex of the software mentioned in this study.

Sometimes complexity leads to greater innovation. The perceived complexity of advanced AutoCAD and 3Ds Max, may have led to the innovation of SketchUp, and the innovation of SketchUp has led the development of other more user-friendly software particularly within the Autodesk community.

4.2.4 Perceptions of Trialability of Parametric Design in Texas

Trial ability is a term that relates to the innovation of software being adapted to the culture of both academia and the contemporary design firm (Rogers, 2003). Subject #10 for instance has had many opportunities to design using advanced parametric tools to the point

where he is becoming more comfortable using the tools, yet expressed the wish that there were more opportunity to use it on a regular basis. Academia perhaps is the best place to test whether innovation can work in landscape architecture design workflow.

If the opportunity does not arise often, enough, certain design skill sets become rusty and then the innovation loses its strength as a potential design tool. As technical innovations continue to arrive for trial, individuals need to determine whether this innovation will become useful to them or to their design firms in the future. To some degree, landscape architecture in general is now testing the trial ability of some of these more advanced generative, immersive, and information based systems. Subject #2 stated, “Advanced modeling skills are part of the next big thing, it’s relatively new, I would say the past five years that LA students have been taught these things at the academic level, architecture is still leading the charge in Parametric Design.”

4.2.5 Perceptions of Observability of Parametric Design in Texas

Observability is the degree in which an innovation can be seen by others. Some innovations can be easily seen and communicated, while others are difficult to observe, or to describe to other individuals or social groups (Rogers, 2003).

The more accessible new tools become, the more likely they are to be adapted into the culture of design, and the presentation of designs in landscape architecture. In the initial phase of adapting to new technologies, it may become more important for Texas design firms to show and tell a new design through a new process, rather than expecting the market to request a new

design service. Without the trialability of an innovation the opportunity to observe its use cannot be conducted. Subject #8 reported that the design firm has inserted surprise 3D renderings into presentations that sometimes lead to additional billable hours for the firm. Subject #2 stated, “as part of improving office workflow we encourage our staff to identify and do things in a more efficient matter. We actively encourage our staff to step up if they perceive a better way in which to improve the office workflow or improve project budgets.”

4.3 Chapter Summary

This chapter reviewed the findings from the interviews. The data was qualitatively evaluated and analyzed according to Rogers’ Diffusion of Innovation Theory, through the Attributes of Innovation (Rogers, 2003). This provided a check system to help further pull out themes with which to reflect back to the original research questions to be further examined in Chapter 5 Conclusions.

A common theme among the respondents expressed was the complexity in which adapting to advanced parametric tools presented. For example in the case of adapting to Revit, the software was observed to be incompatible in its initial form that prevented it from becoming integrated into the culture and practice of the landscape architecture design firm.

The use of more complicated geometry in generative form brought up issues of usability, and effective training in which to efficiently produce and market a design. Smaller design firms are cautious in the trialability of generative form, as they do not have a clear and present market demand to invest in a new technology.

Chapter 5

CONCLUSIONS

5.1 Introduction

The objective of this research has been conceived and carried out to provide an assessment of how parametric design processes are adapted among Texas landscape architecture professionals in the creation and implementation of new landforms, creative spaces, management, and infrastructure for urban, suburban, and natural landscapes. The research took a critical look at the history of parametric design, its current use, and future technologies to look for in the future. It also sought to achieve some understanding on what factors lead to a diffusion of parametric design innovation into landscape architecture professional's practice in Texas. In the following section findings are summarized through the lens of Rogers' Diffusion Theory, the main repeating elements in the interview questions are reviewed, and related to answering the four main research questions.

5.2 Summary of Findings

According to Rogers' Diffusion of Innovations Theory (2003), all innovations go through a series of phases as they are adapted into a new environment. Rogers' five factors of innovation reviewed in Chapter 3 section 3.5.2 identifies these phases as relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). An innovation is an idea perceived as new by an individual or a social group regardless of how long the innovation has been available for use.

Relative advantage of an innovation is one of the first steps towards becoming interested in adapting to an innovation (Rogers, 2003). How well an individual or group perceives advantages over time within their group determines whether an innovation is diffused into that social group. The greater the perceived advantage, the more likely it is to be adapted into a social group (Rogers, 2003). Subjects in this study that identified with an international reach within their firm, found more of an advantage to adapting parametric design tools than did the subjects that were regionally based.

Compatibility is another way in which an innovation is perceived as consistent with sustained experiences that meet the needs of the social group that is adapting to it (Rogers, 2003). The accessibility and learnability of a software program often determines its cultural value to adapting to it.

Complexity affects the rate in which individuals and design firms adapt to innovations (Rogers, 2003). This is evident in the way academia has made available programs for training in the fields of architecture, landscape architecture, and planning. According to the interviewees, whom are 10 years or less in the field, it appears as though the availability to learn alternative programs to the typical AutoCAD and Photoshop are becoming more available to students that are seeking these tools out. It is important to note that Rhino 3D was commercially available in the mid nineteen nineties and has according to subject #2 in the interviews has just become more prevalent in the past few years. This represents a shift in awareness of the perceived compatibility of Rhino for use in parametric design for landscape architecture.

Trialability is the degree to which an innovation may be experienced for a limited amount of time. Trying new technology or software is something that is not readily available outside of landscape architecture education. It is reported in the interviews that training in new software and the ability to be trained on the job are the biggest constraints to learning new software. The exception to this being the availability of open sourced software, beta releases, or open trials of commercially available programs. More often than not, learning new software becomes the responsibility of the individual to learn new techniques or processes outside of work time.

Observability of an innovation is central to whether a social group will accept it into practice or its culture (Rogers, 2003). Generative, immersive, responsive, and information based parametric design are all on the cutting edge of practices that will likely become adapted into landscape architecture in the future. The innovations that make it into the general culture of landscape architectural design will likely vary according to the interviewees in the coming 5-10 years as firms and individuals adapt to new systems of analyzing, designing, and creating three-dimensional modeling, and construction documents.

5.3 Response to Research Questions

At the beginning of this study is set of four questions to tackle as the core of the adaptation of the innovation of Parametric Design among landscape architecture professionals in Texas. The following section review's those four questions as a result of that research.

1. Is parametric design being adapted into the field of landscape architecture in Texas?

The economic downturn in 2009 has reportedly changed the bottom line on budgets across several typologies of landscape architectural practice. Thus, the efficiency of a design firm has become more important than ever. The research indicates that software that is more intuitive to learn, such as SketchUp, and Lumion are two of the faster adaptations to the practice of landscape architecture in the past five years.

According to the interview respondents and the literature review, the younger generation of designers is leading the charge for software innovation for several of the larger firms interviewed in this research study. Other less digital technology based firms are interested in adapting to SketchUp and are beginning to get ready to present designs in a more realistic way as the client demand may be shifting to viewing designs and construction in three-dimensional views.

The interview subjects reported adapting to new processes in PD, but this was a broad response in content between the subjects. The response varied from software updates, to trying more advanced strategies such as 3D mapping or printing. The overall sentiment was that Texas was not doing as much the firms on the coasts that may be reaching for the international market for design projects.

Parametric design is being adopted into firms in Texas at various levels. Adapting to PD is reported in the research to be largely client driven. If there is an

observed need for a new workflow or method of design, it is up to individuals and leaders in firms to take the charge to innovate.

2. What computer software is adapted for use in parametric design in Texas?

Rogers identifies five innovator adapter categories to help classify individuals within a social group (Figure 3.3), and the level at which they are involved in increasing an innovation's presence. The first of these are the innovators or change agents, they comprise 2.5 % of the group. Early adapters are next representing 13.5 % of an innovator's group. Early and Late Majority adapters compromise 34% of the process of innovation each. The late adapters or Laggards represent 16 % of social system involved in the critical mass of an innovation reaching its full immersion into the culture (Rogers, 2003). AutoCAD and Photoshop are two software programs that have reached critical mass with 100% use in the firms interviewed. SketchUp is in the late majority stage with 75% of the subjects using it to some capacity, while programs such as GIS, Revit, Autodesk Civil 3D, Rhino, Grasshopper, and 3Ds Max are in the early majority stage. Software in the 0-16% stage represents the innovators and early adapters. Software such as, Land F/X, Infracore, BricsCAD, Microstation, Imaginit (formally Eagle Point), and Autoturn represent this stage in this study.

Revit is adapted by 38 % landscape architecture professionals (Figure 4.3). The subjects that reported using Revit had to find work around solutions to be able to

“insert” their contribution to the design through using compatible software like Autodesk Civil 3D or SketchUp. Another method of working with a Revit file was to customize the workflow through scripting a procedure to collaborate with the Revit file. File conversion software also exists but was not shared during the interview process.

3. Are there similarities or differences in the level of adaptation of parametric design between education and practice?

It appears that the level of sophistication in CAD experience is higher at most Design firms, then in academia, as they use this software day in and day out. This is especially true in multidisciplinary design firms that are working in several projects at once. This researcher believes, as evidenced in the training of new hires in subjects #2, #8, #10, #14, and #15 that academia is more adapted in developing new skill sets in programs like Rhino, Grasshopper, and 3Ds Max, and Lumion. Both education and professional practice have constraints on the availability of training opportunities. Several landscape architecture programs are connected to a larger branch of education such as architecture. Because of this, it is apparent that the training is available, but it often connects to the curriculum of whichever program has the most momentum for the technology. The downside of knowing several software programs becomes a lack of technical aptitude in any one in particular. As noted earlier in the study, further training

in computer software is often the responsibility of the student or landscape architecture professional.

4. What is the biggest factor of adapting to Innovation in Landscape Architecture practices in Texas?

There seems to be three general concerns regarding when and how to innovate new design practices in landscape architecture. The subjects interviewed stated several times that the push to innovate or change workflows was largely client driven. Workflow efficiency improvement was another of the concerns for and against adapting to innovation. When a decision was made to make a change or update to newer software training, some members of the firms handled it with more ease than others. The time needed to learn new methods in PD, and the perceived advantage to learning were the leading answers from the interviewees as factors leading to adapting or not adapting to parametric design in landscape architecture.

An additional concern was not interfering with the intuitive design process. Subject #1 spoke of being able to know when it is appropriate to use PD in the design process when they said, “the tools that we use have changed but the processes remain the same. Thought pattern is still the same, sometimes you get limited by the tools and you have to do what it takes to get through the thought process. I’ve had two coach some of our younger landscape designer staff to turn off the computer and quit worrying

about the software, dig into the design, and study it however you need to and make the computer perform to show the design the way you want it to be.”

Training is the number one factor in adapting to other methodologies in PD. In the professional office, training can interfere with billable hours for the firm. There needs to be a base technical proficiency in which to work from in order to effectively work as a team. Any perceived interruption to that workflow is considered an ineffective way of running a design firm. When a firm decides to adapt to new software, the trainability of individuals can become a cohesion issue within the firms social structure. It is only through peer support and determination of an individual that adapting to new methods in parametric design is possible.

5.4 Conclusion and Discussion

Through the research on this topic in the review of literature, and interviewing professional landscape designers and architects in the state of Texas, the hope of this researcher is that an increase in awareness of technological advancements in the practice of landscape architecture, architecture, and planning, has happened. Leading national design firms have been seeking out emerging professionals that have knowledge of new software workflows and procedures (Bentley, et al. 2016). The study may also have educational outcomes by encouraging training of special processes or technology for those seeking degrees in landscape architecture.

While visiting professional design firms it became apparent that certain firms connect to certain universities based on the type of training that they are likely to receive from those schools in Texas. A continuing dialogue between faculty and administration at the academic level, and senior and junior level management at design firms should go a long ways towards bridging any training gaps in the future needs of landscape design firms.

Qualitative observation and analysis from interviewing professional landscape designers and landscape architects suggests that as software, presentation formats, and clientele requests change, design firms must adapt as best as they can. One of the bigger questions emerging from this research is that whether new ways of using computational software in analysis and design will be fully adopted to generate new land form solutions for landscape architecture in North America and in particular the state of Texas? Or will they remain as an avant-garde form of design within leading universities and design firms?

Innovation is a constant, there are similarities and differences in the types of software used at the state, national, and international level. It is imperative that a design professional or firm strategically plan for innovations when the time is right for their given practice. Interview subject #5 states the eloquence of this dichotomy facing design firms and academia today.

“I believe that there is an advantage to adapting technology to the way we work. I do not like assuming that technology fully replaces our “design intuition”. I think we still need both. No program can replace project experience, and likewise, no amount of longevity in this profession should prohibit us from trying something that can improve

our analysis, design and construction ability. I do not think that parametric design is a replacement for imagination or imaginative connective conceptualization.”

Perhaps what is most true about the innovation of parametric design is that innovation in landscape architecture is in a state of flux as a shift in culture is happening with the arrival of the Millennials into the workforce. Depending on the individual or firm perspective, this fluctuation is likely to manifest over time as cultural ebbs and flows decide what type of design innovation is appropriate and when.

5.5 Suggestions for Future Research

It became apparent through the process of researching this subject through the literature review that there is a new potential in design to customize the landscape. It is possible to infuse design with information or sensors to create more sustainable landscapes that adapt to changing environmental dynamics. Factors such as more desirable building to landscape connections, healthier air, healthier water, or better animal corridors to name a few. One tool that can handle such a task would be the combination of Rhino and Grasshopper albeit with some practice, and learning of visual scripting. This study could be taken in Biophilic Design, for instance using biophilic city parameters within a customized city information model to compare and contrast to standard building and landscape design practices.

A case study conducted into the usability of various Building Informational Modeling (BIM) systems, using interviews, survey data, or investigation of BIM from a design lab. A design lab could test the effectiveness of the BIM leader Revit, against the purported more landscape architecture friendly BIM system Vectorworks Landmark, and compare and contrast the two models to a custom model run through Rhino and Grasshopper platform or any other application that is more appropriate. The purpose of this kind of study would be to help the greater landscape architecture community develop a more efficient workflow that sets values to landscape elements the same way that BIM does for architecture.

One of the bigger questions emerging from this research is whether new ways of using computational software in analysis and design will be used to generate new land form solutions for landscape architecture in North America and in particular the state of Texas, or will they remain as an avant-garde form of design within leading universities and design firms? This research done here in this thesis could be conducted at the national level to test things such as parametric design preferences across the nation to determine patterns of innovations.

A study could be made into the similarities and differences between education and practice would be an effective way to assess what the future needs are to the current workforce as well as potential future trends to the landscape architecture practice to be facilitated from the academic curriculum side. This study could be conducted through surveys or interviews to determine mutually beneficial strategies for the future of the discipline.

APPENDIX A

Internal Review Approval

APPENDIX A



Institutional Review Board Notification of Exemption

January 30, 2017

Chad Paulson
Dr. Taner R. Ozdil
Architecture
The University of Texas at Arlington
Box 19108

Protocol Number: 2017-0366

Protocol Title: *A Study of the Adaptation of Parametric Design among Landscape Architecture Professionals in Texas*

EXEMPTION DETERMINATION

The UT Arlington Institutional Review Board (IRB) Chair, or designee, has reviewed the above referenced study and found that it qualified for exemption under the federal guidelines for the protection of human subjects as referenced at Title 45CFR Part 46.101(b)(2).

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, either directly or through identifiers linked to the subject; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

You are therefore authorized to begin the research as of **January 30, 2017**.

Pursuant to Title 45 CFR 46.103(b)(4)(iii), investigators are required to, "promptly report to the IRB any proposed changes in the research activity, and to ensure that such changes in approved research, during the period for which IRB approval has already been given, are **not initiated without prior IRB review and approval** except when necessary to eliminate apparent immediate hazards to the subject." All proposed changes to the research must be submitted via the electronic submission system prior to implementation. Please also be advised that as the principal investigator, you are required to report local adverse (unanticipated) events to the Office of Research Administration; Regulatory Services within 24 hours of the occurrence or upon acknowledgement of the occurrence. All investigators and key personnel identified in the protocol must have documented Human Subject Protection (HSP) Training on file with this office. Completion certificates are valid for 2 years from completion date.

The UT Arlington Office of Research Administration; Regulatory Services appreciates your continuing commitment to the protection of human research subjects. Should you have questions or require further assistance, please contact Regulatory Services at regulatoryservices@uta.edu or 817-272-2105.

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APPENDIX B

Study Population Cover Letter

APPENDIX B

To:

From: chad.paulson@mavs.uta.edu

Subject: Request for Landscape Architectural Professional Interviews.

Dear Landscape Architecture Professional,

I am a graduate student at the University of Texas at Arlington working on my Master's thesis entitled: "*A Study of the Adaptation of Parametric Design among Landscape Architecture Professionals in Texas*". The purpose of my study is to assess the diffusion of innovation of parametric design in landscape architecture professionals in landscape architecture firms in the state of Texas.

This research will have the potential to further the current understanding of the adaptation of parametric design among landscape architecture professionals and firms, influence the availability for further education for practitioners, and lead to further research in this subject matter.

I would like to request your participation in this research through an in person or phone interview, or online response to a set of interview questions. The interview will take approximately 25 minutes of your time. The ideal respondents for this research are landscape architecture professionals on staff, non-licensed or licensed professionals at any level (principles, senior, or junior staff) in a given firm, as long as they are involved in the design or planning of landscapes directly.

The information you provide will be kept strictly confidential. The only people that would be able to see the interview responses will be my supervising professor Dr. Taner Ozdil, thesis committee members, and I. No information allowing company and individual identification will be published without acquiring consent.

Upon your volunteered acceptance I will contact you to arrange a time for interviews, or dispersal of the interview questionnaire. Thank you for your time and consideration. Please let me know of your interest in participation from the contact information below. It is only through the generous support of people like you that research can be successful.

Best Regards,

Chad Paulson, MLA Candidate

The University of Texas at Arlington

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APPENDIX C

Parametric Design Overview

APPENDIX C

The term parametric originates from mathematics and refers to the use of certain parameters or variables that can be edited to manipulate or alter the end result of an equation or system (Frazer, 2016)

In laymen's terms, it is design that utilizes the computer to calculate form or function to the point one can make a decision on the likeability, suitability, or probability of it becoming a workable solution to the Landscape Design.

A software program is parametric if the designer interacts with the computer to figure out a design problem. Such as;

- ✓ The creation of 3D arbors, pavilions, custom retaining walls, islands, berms, furniture, non-Cartesian geometry (NURBS)
- ✓ Urban design; planning metrics, irrigation design, lighting design, planting design rendering, cut and fill.
- ✓ Building Information Modeling (BIM).
- ✓ City Information Modeling (CIM)
- ✓ Geographical Information Systems (GIS).
- ✓ Responsive technologies or simulation modeling.

Examples of Parametric Design Software:

3D Modeling or Visualization Tools

Autodesk's AutoCAD, 3D Maya, 3D Max, Civil 3D

Trimble's SketchUp, Layout, and Style Builder plus third party applications such as Modelur

Mcneel's Rhino and other applications such as; Grasshopper, Python, Weaverbird, Starling

AutoDesSys's Form Z

Adobe's Photoshop for use in 3D modeling or animation

Dassault System's Solid Works

Geographical Information Systems/ City Information Modeling

ESRI's Geographical Information System

ESRI's City Engine

Bentley's Micro Station
Holistic City's CityCAD

Building Information Modeling

Autodesk's Revit
Vectorwork's Landmark

Other gaming based simulation virtual or immersive modeling.

Act 3D's Lumion

Rendering Software

Accurender NXT
Chaos Software's V Ray
Cadalog, Inc. Podium

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Biographical Information

Chad Paulson grew up in Hudson, Wisconsin in the 1970's and 80's. His backyard was a prairie that connected to a riparian corridor that merged into a deciduous forest. The deep connection to prairie, woods, rivers, and lakes carried a sense of play into his adult life with an exploration of those elements and sense of play while earning a Bachelor's of Fine Art degree from the Minneapolis College of Art and Design in Minneapolis, Minnesota in 1993.

Life events brought Chad to the State of Texas in 2009, first as an escape from the cold winters of the Midwest, then for the pursuit of a Masters' Degree in Landscape Architecture from the University of Arlington at Texas, completed in May 2017.