University of Cincinnati

Date: 3/31/2016

I, Craig E Moyer, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture.

It is entitled:
Vox Populi: The Crowdsourced Building

Student's name: Craig E Moyer

This work and its defense approved by:

Committee chair: William Williams, M.F.A.

Committee member: Udo Greinacher, M.Arch.
Vox Populi: The Crowdsourced Building

A thesis submitted to the Graduate School of the

University of Cincinnati

in partial fulfillment of the requirements for the degree of

Master of Architecture

in the School of Architecture and Interior Design

of the College of Design, Art, Architecture and Planning

by

Craig Ellis Moyer

B.U.P. University of Cincinnati

March 2016

Committee Chair: William D. Williams, M.Arch Harvard University
Abstract

Architectural Design is a costly and time consuming endeavor in terms of the process of generating new building designs. By reducing the time it takes for designers to create iterative building shapes, the costs associated can be dramatically reduced. This thesis investigates a computer-assisted crowdsourcing method for the design of buildings. A novel approach to User Interfaces as well as preferences of architects and non-architects are investigated through a dynamic User Interface which manipulates the building in real time. This thesis found through a sampling of 9 males and 9 females of varying backgrounds and demographic profiles that architects overwhelmingly prefer building forms with flat roofs, while non-architects prefer the latter. Additionally, the preferences of men and women were investigated and confirmed. Men independent of background were found to prefer curvilinear building forms with flat roofs while women overwhelmingly prefer sharp, angular forms with gabled roofs. While the crowdsourced method reveals that significant time savings can be had if the models are prepared correctly, this study also confirmed the architectural preferences of different demographic groups as they relate to building form.
This Page is Intentionally Left Blank
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables &amp; Figures</td>
<td>5</td>
</tr>
<tr>
<td>Preface</td>
<td>8</td>
</tr>
<tr>
<td>Problem</td>
<td>12</td>
</tr>
<tr>
<td>Background</td>
<td>14</td>
</tr>
<tr>
<td>Literature Review</td>
<td>18</td>
</tr>
<tr>
<td>Methodology</td>
<td>26</td>
</tr>
<tr>
<td>Outcomes</td>
<td>42</td>
</tr>
<tr>
<td>Client Culture</td>
<td>45</td>
</tr>
<tr>
<td>The Site</td>
<td>49</td>
</tr>
<tr>
<td>The Algorithm</td>
<td>51</td>
</tr>
<tr>
<td>Results</td>
<td>63</td>
</tr>
<tr>
<td>Conclusion</td>
<td>72</td>
</tr>
<tr>
<td>Bibliography</td>
<td>74</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Digital Collage Image by Author</td>
</tr>
<tr>
<td>2</td>
<td>Loren Carpenter Experiment SIGGRAPH 1991</td>
</tr>
<tr>
<td>3</td>
<td>Screenshot of User Interface by Author</td>
</tr>
<tr>
<td>4</td>
<td>Male/Female Split Ratio by Author</td>
</tr>
<tr>
<td>5</td>
<td>Age Demographics by Author</td>
</tr>
<tr>
<td>6</td>
<td>Educational Attainment Chart by Author</td>
</tr>
<tr>
<td>7</td>
<td>Participant Professions by Author</td>
</tr>
<tr>
<td>8</td>
<td>Participant Housing Expenditures by Author</td>
</tr>
<tr>
<td>9</td>
<td>Participant Relationship Status by Author</td>
</tr>
<tr>
<td>10</td>
<td>Participant Income by Author</td>
</tr>
<tr>
<td>11</td>
<td>Racial Profile of Participants by Author</td>
</tr>
</tbody>
</table>
Figure 12: Participant Shape Preference Data

Figure 13: Site Map by Author. Site Indicated in red

Figure 14: Trial 0 Site Plan

Figure 15: Trial 1 Site Plan

Figure 16: Trial Data Table by Author

Figure 17: Topography Blending Script by Author

Figure 18: 2D Component Blending Script by Author

Figure 19: Progression of Blend Between Topography by Author

Figure 20: UI Script Key Image

Figure 21: UI Script Part 1

Figure 22: UI Script Part 2

Figure 23: UI Script Part 3
Figure 24: UI Script Part 4  
Figure 25: Screenshot of Finished User Interface by Author  
Figure 26: Perspectival Rendering of Overlook Space by Author  
Figure 27: Site Plan of Combined Design by Author  
Figure 28: Analytic Serial Sections by Author  
Figure 29: Final Crowdsourced Design by Author  
Figure 30: Form 0 With a Flat Roof by Author  
Figure 31: Form 0 With Gabled Roof  
Figure 32: Architect vs. Non-Architects Preferences by Author  
Figure 33: Preferences of Males and Females by Author
Preface

I am a firm believer that no idea, concept, design, or creation happens in a vacuum. Context and background matter the most in my opinion, and this goes without saying in the context of architecture, and the intellectual growth and development of a young architect-to-be. This thesis is a result of such thoughts, and developed through a series of experiences in my own personal journey to becoming an architect. My personal history as it relates to my development as an architect begins with my lifelong love and practice of drawing—since I was a very small child I have always drawn and doodled. Throughout primary school and high school my drawing habits often interfered with my education. Instead of taking notes I would often draw whatever was on my mind. I first developed a true fascination with buildings when I was in high school where, mostly out of sheer boredom and curiosity took to photographing the industrial wasteland of my hometown of Dayton, Ohio. Dayton was once a manufacturing and toolmaking epicenter in southern Ohio. However by the time I was coming up in the early 2000’s Dayton, like many cities across the Rust Belt, was experiencing industrial stagnation which resulted in the city’s building stock being largely abandoned.

I would often wander around these decimated old manufacturing facilities sometimes with friends but mostly by myself. At the beginning I would take photos mainly to put on my blog to show off to my friends. Eventually I started to develop a true fascination with the buildings, and as this fascination grew my photography became more sophisticated. As my photography developed I began to understand more not just about the history and context of the buildings themselves, but I also began to understand what I was actually drawn to in the first place: the spatial characteristics and the sense of discovery. It was not uncommon for me to spend a whole day in one space, observing how the light changed throughout the day. I would
sleep in abandoned buildings often to be able to photograph the spaces in the best light, which I believe to be in the very early hours of the morning. It was during these times where I really experienced the true sense of joy and discovery in space. This sense of discovery and genuine interest eventually led me to serious prospects in terms of fine art photography, and I was able to travel to many places across the Rust Belt to photograph a wide variety of abandoned and disused buildings. In 2009 I participated in my first gallery show, a group showing of photographers in Cincinnati who took these type of photographs. I had my first solo showing entitled *Fleeting Landscape* in 2011. I believe my development as a photographer is really where my architectural sensibilities and interest came from. Photography is a way of seeing, a way of understanding composition and light. Louis I. Kahn once said, “Architecture appears for the first time when the sunlight hits a wall. The sunlight did not know what it was before it hit a wall.” It was photography that gave me an immense understanding and appreciation of the beauty and intricacies of natural light, and like Kahn I believe light to be a fundamental aspect of architecture.

Since I had studied Urban Planning during my Undergraduate education, coming to study architecture in graduate school opened my eyes to a multitude of real factors concerning the creation of space. It was during graduate school where I had some eye opening experiences and realizations about the realities of architecture and buildings, which this thesis grew from. The three main tenants to where the idea for the crowdsourced building came from was my realization of the difference between architecture and buildings, the contemporary architecture of the spectacle, and the disconnection between those who design spaces and the people who occupy said spaces.
One of the biggest eye opening experiences I have faced in my academic journey to becoming an architect Architecture on a daily basis was the realization that the architectural profession is divided between those who build and those who build Architecture (with a capital ‘A’). My experiences are not unique in the sense that sooner or later, the architectural student has the realization. I was lucky enough to realize this during my studies, prior to entering the profession. Most laypeople do not live, work, or otherwise experience what architects consider to be “Architecture”. The reason why this disconnection is important to note in terms of this research project is that the proposed solution attempts to rectify this disconnection, with the idea being that by making the occupants of a building more closely involved in the development of the design of the building itself, with the logical conclusion being that the resulting space would be of higher quality in terms of occupant suitability.

Contemporary architecture has become a sideshow of spectacle with constructions built under the false pretense of profitability. A compelling example is what is known as “The Bilbao Effect.” In other words, buildings, architecture are constructed with the idea that by artificially creating scarcity through their design (i.e. a stunning or spectacular construction) drive up surrounding property values which, in turn, create profits for developers. The name “The Bilbao Effect” comes from the Guggenheim Museum Bilbao by Frank Gehry, where this phenomenon played itself out exactly. Another example is the structures built for the 2008 Summer Olympics in Beijing. Exemplary buildings from this example are the Beijing National Aquatics Center by PTW Architects, and the Beijing National Stadium by Herzog & de Meuron. These buildings serve as examples of what I call the Architecture of Spectacle. The reason and the relevance to this project is relatively simple: because of the relationship architects have to the Architecture of Spectacle, laypersons do not see the significance of architects or architecture other than the
creation of strange forms, spectacular structures, or at worst, the public can see these buildings are wasteful boondoggles. The problem with this is that the layperson rejects the role and work of architecture and the inherent good in the discipline, not to mention the necessity. This research project attempts to rectify this phenomenon by proposing a system to better engage those who are not involved in the process.

As previously examined, the critical difference between buildings and architecture, coupled with contemporary Architecture of Spectacle has effectively created an intense disconnection between those who design spaces, and those who spend their whole lives within these spaces. This is exhibited by the pessimism and cynicism of laypersons in terms of their respect for the discipline of architecture, and architects in general. A good example of this despondence is the episode of the Simpson’s entitled “The Seven-Beer Snitch” (See Figure 1) where Frank Gehry himself makes an appearance and “designs” a new concert hall to spite the neighboring town, Shelbyville, by crumpling up a letter to be discarded and being inspired by the crumpled up piece of paper. The crumpled piece of paper becomes the design of the concert hall which is prominently abandoned by the people of Springfield after hearing the first five notes of Beethoven’s Fifth Symphony, preceded by an atonal piece by Philip Glass.

Figure 1: Digital Collage Image by Author
DiNastuk, Matthew, and Bill Odenkirk. "The Seven-Beer Snitch."
**Problem**

While indeed comedic and obviously tongue-in-cheek, the Simpson’s example underscores the reality of the relationship between architects and laypersons. This growing discord and the resulting buildings and architecture inspired by it precisely is what this thesis is responding to. Imagine a building designed with the real input by outsiders, whether it be the client or the people intended to occupy the building. Imagine the potential time, and thus cost savings that could be achieved through a design process which is supported by the crowd. Through the development of a new design process, the aim of this project is to deliver greater cost savings, foster a more direct client-project relationship, and foster a better connection to laypeople within the design of the built environment; in other words, this thesis explores the design of the crowdsourced building.

In architectural design, considerable time and expense is spent by designers and interns developing designs, revising the designs based on changes or preferences of the designer or the client, or redesigning based on programmatic or requirement-based variables. In addition to these aspects which incur changes, there is also a tremendous amount of time spent engaged in trivial (secondary to the formalistic design of the building) decision-making processes such as material specification, specifying fixtures, selecting signage and wayfinding systems, etc. While important to the overall process of designing the building, or in extreme cases such as in the case of *gesamtkunstwerk*, these “trivial” matters become the features which contribute to the richness of the design itself. So how can designers better respond to these factors in terms of efficiency with time or costs?

---

1 *Gesamtkunstwerk* roughly translates from German as a *total work of art* as in the case of some architectural works, exemplified by works by Frank Lloyd Wright, among others.
Designers can indeed respond to these factors intelligently and efficiently by adopting a new process which is the result of this research: a crowdsourced methodology for building design. The idea is this: instead of spending countless hours revising and adjusting designs based on dynamically changing requirements (i.e. client preferences, shifting design variables, compromises on budgets, etc.), the designer instead defines ranges of preferences which are, in turn, voted on or selected by the designer or client. The system then combines the preferences selected by the designer and creates a predetermined number of designs or iterations of a given form.
Background

Through the integration of the crowd in the building design process, the role and relationship the architect has to the building and the client is inherently changed. This aspect subverts the common trope of architect as singular visionary leader in a design team, which is why instead of thinking of the architect as sole visionary leader, instead this research presents an alternate vision of who and what the architect of the future will be: Architect as Curator. By investigating a computer-driven, architect-led design process frees the architect from a variety of trivial or time consuming tasks and instead allows the architect to focus their efforts where they are most suited: design and coordination. In essence, the role of the architect becomes more or less similar to what a curator does: conducting research, defining limits of a given work within a style or building type, documenting buildings, constructing narratives, and obtaining clients.

To help support and illustrate this redefined role of Architect as Curator, some examples are employed to better illustrate the overall concept of a Crowd-Driven Architectural Design process. Two examples for which illustrate the nature of what this research project is discussing are as follows. The story of Francis Galton and his Ox, and the Loren Carpenter Experiment at SIGGRAPH 1991.

Crowd behavior is often thought of as chaotic and irrational. The word “crowd” often conjures images of panic and chaos and is perhaps the very last word one might come to when asked to think of words synonymous with order. This is precisely why, in 1906, Francis Galton stunned the participants of a Country Fair guessing game. The game was simple: the crowd was
asked to guess the weight of an ox when it was dressed and butchered. Roughly 800 people participated in the event and were required to write their guesses on tickets. The person who was closest to the actual weight of the ox won a prize. What Galton found was surprising: that not all crowd behavior was chaotic, in fact, if asked the right question the crowd could produce an answer that even an expert would get incorrect.\(^2\) Galton’s experiment was simple: he collected the tickets after the winner had been announced and ran a Linear Regression Analysis on the 800-some point sample size. The weight of the ox? 1,198 pounds. The average of the guesses? 1,207 pounds, or 0.8% percentile of error. This average figure was better than even the guesses of qualified livestock professionals within the crowd. Indeed, Galton’s observations proved fruitful and accurate, but more importantly, Galton discovered that certain conditions had to be in met before the trial could be scientifically viable. First, each member of the cohort must be able to gleam their own source of information about the subject at hand; second, each individual must act independently and must not be swayed by the other people in the crowd; and third a device must be in place that can collect and sort the guesses.

The next example is relatively more contemporary. Computer graphics developer, co-founder and chief scientist of Pixar, many of Pixar’s animated films were created with the help of Loren Carpenter’s rendering engine, Renderman. Retired in 2004, Carpenter eventually was the Senior Research Scientist at Disney where he further developed graphics technologies seen in movies such as *Toy Story*, *Frozen*, and *Wreck it Ralph*, among others. However in the early 1990’s, Carpenter was unknown outside of the then developing computer graphics industry. Enter SIGGRAPH 1991: the premiere computer graphics conference both then and now. Many

new technologies in the graphics industry are premiered and shown at SIGGRAPH annual conferences, and in the early 1990s this was no different than today.

Standing in front of a crowd of over 5,000 people was Carpenter. In one hand was a cardboard wand which was painted: on one side red, the other side green. Carpenter instructs the crowd to organize themselves: either they are on the red team or green team. A camera connected to a computer running custom software developed by Carpenter is continuously scanning the crowd and displaying what it sees on the gigantic screen behind carpenter. The crowd responds by waving their respective colors, and the screen behind Carpenter lights up light a candlelight vigil on acid.

Figure 2: Loren Carpenter Experiment SIGGRAPH 1991


The crowd of computer scientists, programmers, and digital freaks need no introduction to the game in which Carpenter intends to play: Pong. Carpenter then instructs, “Okay guys. Folks on the left side of the auditorium control the left paddle. Folks on the right side control the right paddle. If you think you are on the left, then you really are. Okay? Go!”

What happens next is astounding. The crowd of over 5,000 individuals plays several rounds of relatively decent Pong. Carpenter decides to raise the stakes. The screen flashes and upon it is a map of the seats

---

within the auditorium. Carpenter draws a circle around the center of the auditorium which appears on the screen behind him. He asks the audience to make a green ‘5’ within the confines of the circle and the crowd organizes their paddles accordingly. After some time, a fuzzy image of a ‘5’ comes to sharp focus. Carpenter then instructs to make a ‘4’, then a ‘3’, and a ‘2’, and finally a ‘1’. On the screen emerges the image of an airplane cockpit and instruments. The crowd falls eerily silent. Carpenter instructs: “You guys on the left are controlling roll; you on the right, pitch. If you point the plane at anything interesting, I’ll fire a rocket at it.”

The plane is already airborne and moving in the direction of a wide, pink valley. Simultaneously, everybody yet nobody is in charge of the flight. The crowd is literally swarming, which is when beauty appears: the crowd averts the crash landing and instead does a barrel roll. “…and the thousands of fishes moved as a huge beast, piercing the water. They appeared united, inexorably bound to a common fate. How comes this unity?”

With the spirit of this quote and the above examples in mind, how can this collective beauty be harnessed for architectural form?

In order for the collective to be harnessed and controlled effectively, in order for architectural form to emerge from chaos, limits the system operates within must first be defined; after all we are not discussing using the crowd to design bathrooms, floor plans, or other intrinsically complex components of the building. What we are interested, in terms of this research project, are three aspects: design limits in terms of contemporary architectural form, the exterior envelope of the building, and the formalistic design of the corresponding plaza on the site.

---

Literature Review

Introduction to Literature Review

In order to adequately prepare the reader for a full understanding of the following literature review, it is pertinent to define a variety of concepts and terms used throughout the rest of this thesis. First and foremost is the concept of Conjoint Analysis. Second, the reader must be in full understanding with basic statistical concepts, namely regression analysis. With this understanding the reader will be prepared to discern the key topics as discussed within the reviewed literature, and more importantly understand the philosophical underpinnings not only of this research project but also the aforementioned research projects discussed in the following literature review.

Conjoint Analysis arose out of mathematical psychology and other fields where researchers were attempting to better quantify the idea of choices or preferences of individuals. Conjoint Analysis was developed in order to better understand these choices but more importantly, to quantify multidimensional choices, particularly in situations where partial features were required to be uncovered. To give an example, imagine a researcher is trying to quantify if a product is easy to use, and to what degree changes in the product make it easier to use. Conjoint Analysis is ideally suited for problems which are difficult to quantify, or describes relationships which have varying degrees of multi-dimensionality. Naturally, Conjoint Analysis is used most frequently in marketing and consumer research, but its application in architecture and engineering has yet to be tested.

The particularities of Conjoint Analysis must also be understood in order for it to be successfully applied to this research project. Conjoint Analysis is useful when researchers are

---

presented with conditions where the dependent variable reflects a tradeoff situation where a degree of change or variability is needed. In addition to this, the independent variable must be categorical in nature, and thus binary. In the context of this project, an example is provided:

Imagine a hypothetical experiment where it is found that architects have a strong preference for glass curtain wall facades while the laypersons in the study prefer brick walls with punched openings and double-hung windows. In this case, the divergence of opinion of choice between the two groups is the dependent variable. The dependent variable is the output or effect to be studied. In this case, the independent variable is thus the input data, or in other words the brick façade and the curtain wall. Conjoint Analysis comes into play here by describing, in mathematical terms, how much the two groups diverge. This is important in terms of this study because the goals of the research is to understand and rectify the divergent preferences of two groups in a building design situation, so that both groups can be effectively satisfied.

The second aspect which must be well understood prior to a useful discussion of the literature is the basic underlying statistical concepts not only in this research but also in the reviewed literature. In particular, the concept of regression analysis must be discussed in terms of the project and its application in architectural design. Continuing with the previous example of façade preferences, regression analysis is particularly useful in understanding, from a statistical point of view, the relationship between dependent and independent variable. While Conjoint Analysis is primarily concerned with the degree of separation between preferences, regression analysis describes the relationship of the preferences mathematically. Its power lies mostly in its identification of statistically significant correlations so that the data could be extrapolated and the choices of particular groups (architects or laypeople) could then be *predicted*. Regression
analysis is commonly used to infer correlation between dependent and independent variables. While the goal of this research project in particular is not to project forward the preferences of groups, the data collected in the project and the outcomes of the data analysis need to be described numerically.

With these concepts discussed and introduced, the reviewed literature can now be discussed. The first text to be examined is *Reconciling the Architectural Preferences of Architects and the Public: the Ordered Preference Model* by Fawcett et al. This text is reviewed for its relevance to this research project primarily for its methodological conceptualization of the problem of understanding the visual preferences of Architects and laypersons in terms of buildings. The study conducted in Fawcett et al provides a conceptual framework in which this research project can use in terms of research design, conceptual framework and the general approach to the research.

The second reviewed text is *Building Typology and Morphology of Swiss Multi-Family Homes 1919-1990* by Schwehr et al. This text reads mostly like an engineering report and comes from the perspective of the Swiss. The text examines the *average* multifamily Swiss building, from a sampling of a population and then proceeds to break down that average building into its component parts. For example, it examines the average building has a few different types of roof lines, has *n* number of stories, is configured typically in three different block configurations, has one of three balcony types, has openings (windows and doors) of three or four different configurations, and has a variety of central heating and cooling systems. The intent of this work was to provide data to the Swiss Government on what the absolute average multifamily housing building looks and functions like in Switzerland. It was then intended to be used somewhat as an

---

organizational framework for the creation of a modular building system which supers or landlords could order to retrofit their buildings for better energy efficiency. This piece is particularly relevant to this research project mainly for its graphical system it employs for the survey which was distributed to citizens, as well as its methodological approach to coding varying building types and variations amongst a theme.

Third and finally, the last reviewed text is Strategic Use of Representation in Architectural Massing by Akin et al, a text discussing the underlying processes behind the architectural design process in terms of massing design. In Strategic Use of Representation in Architectural Massing, the authors attempt to better understand the decision tree in which Architects use while they develop schematic designs of a building. This text is relevant to this research project in terms of understanding the procedural steps in which Architects undertake while developing the designs of a building. It is useful for organizing the analytical diagrams which organize and conceptualize this research project as it develops, and is particularly relevant in developing a method used in creating trial designs within this study.

Review of Key Text 1

Reconciling the architectural preferences of architects and the public: the ordered preference model is a resource tremendously relied upon for this thesis. Its authors are William Fawcett (MA, PhD, RIBA), Ian Ellingham (BArch, MBA, PhD, MRAIC), and Stephen Platt (BA, MSc, PhD), all of whom stake their affiliations with a variety of English universities. The text’s primary focus is conceptualizing the differences in judgement of buildings by Architects and Laypersons. It begins with a robust literature review outlining previous works on the subject of how Architects judge the appearance of buildings. The primary texts reviewed by Fawcett et
al will be (briefly) reviewed in this work. Fawcett et al begins its review with Nasar’s *Design by Competition* (1999) where the premise was established that Nasar took an adversarial position against architects in the sense of taking a position with the public rather than the side of the architects. Like the work of Fawcett et al, the work of Nasar in *Design by Competition* utilizes the method of Conjoint Analysis in order to survey the visual preferences for a particular building type amongst a certain cohort. Within *Design by Competition*, Fawcett et al highlights that indeed the underlying differences in preference between laypeople and architects could be rectified without a strict binary conclusion of one or the other, but rather through the use of Conjoint Analysis both parties (laypeople and architects) sensibilities can effectively be mediated and understood. In other words, Fawcett et al discovered that the visual preferences of laypeople can indeed be resolved with the visual preferences of architects still wholly intact. Both parties could effectively be satisfied through a combination of Conjoint Analysis and the Ordered Preferences Model.

Moving past the literature review of Nasar’s *Design by Competition*, Fawcett et al continues by identifying the context in which the text will be both in terms of design of a building but also the nationalistic and thus cultural assumptions underlying the study. The piece was produced in the United Kingdom and the survey was accordingly administered within that national context. The building typology explored in the study was divergent of the building type investigated in this work. Instead of investigating a multifamily residential structure, Fawcett et al investigated the preferences for an office building.

All these factors considered in the context of this work, this text is the most relevant work to this particular research project. It is the most relevant piece for three reasons: first and

---

foremost it provides an operational and methodological framework, its building typology is similar enough and perhaps more importantly is a building type which can receive a large amount of design intent. Third and finally, Fawcett et al is the most relevant text because it has a complete survey and thus methodology which, as an added bonus, is validated because the authors actually carried out the research.

Review of Key Text 2

Building Typology and Morphology of Swiss Multi-Family Homes 1919-1990 in the context of this research project serves as the secondary key text. Published at the beginning of 2010 by Peter Schwehr and Robert Fischer in collaboration with the International Energy Agency’s project Prefabricated Systems for Low Energy Renovation of Residential Buildings. This is important to note because the impetus (and funding) of the project comes largely from this project and establishes the operational framework for the project. Generally speaking, the project was undertaken in cooperation with the Swiss Government to study the requirements of a building modernization and rehabilitation program, directed at existing multifamily structures which needed to be modernized.

With that being said, the goals and operation of the project was centered on determining specific requirements of a modular, prefabricated system in which supers or landlords could apply to their existing buildings in order to make them compliant with modern energy efficiency codes and regulations. Thus, in order to develop an applicable intervention on a building scale the researchers first began by understanding the building stock in which they would be producing the kit of parts for. The authors’ intent was to cover the most frequently occurring typologies in Switzerland in the context of multifamily residential buildings. The survey they developed was
inclusive of many attributes related to buildings and their form. Parameters related to building form included: roof shape, balcony type, type of heating/cooling, shape of the building (courtyard type, rowhouse type, etc.), number of stories, period of construction, standalone vs. corner vs. end type, as well as opening types (windows, doors, etc.). The survey the authors developed was comprehensive in the sense that it incorporated and created an operationalized method for examining and coding a large dataset which effectively quantified the building stock of a chosen sampling of the Swiss population. Because the survey was distributed to a large swath of the Swiss population it was required to be easily digestible and understandable in order to receive reliable, self-reported data in which the researchers could use.

This text is of importance to this research project for three primary reasons: first and foremost the researchers created a novel and clear coding method which effectively mitigates ambiguity in describing building types. Second, the developed survey method graphically is extremely clear and accessible to laypersons thus ensuring hassle-free self-reported data collection. Third, the survey and methodology has been tested in real-world conditions and its validity has been proven in the context of surveys. This fact alone is enough to warrant investigation for the purposes of this research project, in addition to the other two aspects.\(^9\)

**Review of Key Text 3**

*Strategic Use of Representation in Architectural Massing* by Omer Akin and Hoda Moustapha is the third and final primary text reviewed for this research project. Hereby referred to as Akin et al, this text is of particular importance in the context of the way in which architects

---

operationalize massing design. In other words, this text is important to this project because it aims to understand how architects approach the design of the massing of buildings. It is important in this sense because this research project is primarily concerned with massing design and the decision process which architects undertake when given the challenge of designing the volume of a building.

The text begins by investigating the way in which experienced architects design the mass of a building. The authors identified a lack of literature investigating the process in which architects use to design the shape of a building, they begin their research by observing professional architects go through the process of architectural design. Their experiment considers architects using paper as well as computerized methods. The authors observed the architects work and coded their processes while they worked. The observation of the architects while working was coded into transcripts and thus data was created which could be analyzed later.

After the observational data collection, the authors summarized and analyzed the results of the data collection. The authors noted that particular patterns began to emerge in the data. These patterns the authors identified were that while designing, independent of medium (computer or paper), the architects were primarily finding mechanisms of operations common in the design process. These included but are not limited to: axes of symmetry, alignment axes, centers of rotation, diagonal proportional lines, bounding lines, etc. The authors identified that what the architects were doing when they were designing the mass of the building was primarily finding these types of elements from the site or context and using them as organizational elements, from which the design emerged. The authors asserted that these operators helped the architects manage structuring sub-problems, part-whole relationships, topology-geometry

---

relationships, and design hierarchies. It was found by the authors that most of these operations occurred while investigating the conditions in planform. Breaking from plan to elevation was rarely investigated in their research, which is important to note in terms of this research because the inaccessibility of typical graphics employed by architects.

Methodology

The methodological approach in this thesis will be akin to the methodologies as discussed in the literature review. Utilizing Fawcett et al’s use of Conjoint Analysis, the resulting survey will consist of a computerized User Interface which presents the building as it is transformed in real time by the respondent, which can be seen in Figure 3. This User Interface will be the primary means of data collection, with each trial shape (Rectangular, Bean, and Polygonal) being represented through a continuously variable adjustment system utilizing sliders to control the
“blend” of each shape. With this user interface it is possible to infinitely blend between chosen shapes the building may conform to. The role of the Respondent is simply to manipulate the sliders in the way in which they feel is appropriate to the surrounding area, or to their personal aesthetic tastes. In other words, it is fairly open-ended and intended to collect preferential-type data from an architectural context. Each shape blend results in a number from 0.00 to 1.00 with 0.00 representing 100% the first shape, and 1.00 representing 100% of the second shape. The resulting data is tabulated and included in the List of Tables of this document.

As seen in Figure 3, the Respondent is confronted with a very simple User Interface which consists of two windows: the larger of the two being the display window (entitled FORMforge) which displays the real-time changes being applied to the trial building design. The second window consists of a tabbed view of the manipulators. The manipulators are merely simple slider type of mechanisms familiar to everyone with the basic operation of a contemporary computer. The building form is broken up into the tabs in the FORM CONTROL window. There are ten tabs total, the first eight housing controls for each floor of the trial building, and the last two being controls for the roofs of each sub-mass of the building.

Prior to completing the preferences and manipulations in FORMforge, the Respondent first is given a short, ten question questionnaire which collects demographic information about the Respondents in the study so that the resulting forms and preferences of different groups can be recorded and analyzed. The researcher utilized the website: www.surveymonkey.com to administer and collect survey responses. The ten questions are as follows:
1. Please choose which gender you identify with:
   
   Female
   
   Male
   
   Other (please specify)

2. What is your age?
   
   18 to 24
   
   25 to 34
   
   35 to 44
   
   45 to 54
   
   55 to 64
   
   65 to 74
   
   75 or older

3. What is the highest level of school you have completed or the highest degree you have received?
   
   Less than high school degree
   
   High school degree or equivalent (e.g. GED)
   
   Some college but no degree
   
   Associate degree
   
   Bachelor degree
   
   Graduate degree
4. Which of the following best describes your current occupation?

- Management Occupations
- Business and Financial Operations Occupations
- Computer and Mathematical Occupations
- Architecture and Engineering Occupations
- Life, Physical, and Social Science Occupations
- Community and Social Service Occupations
- Legal Occupations
- Education, Training, and Library Occupations
- Arts, Design, Entertainment, Sports, and Media Occupations
- Healthcare Practitioners and Technical Occupations
- Healthcare Support Occupations
- Protective Service Occupations
- Food Preparation and Serving Related Occupations
- Building and Grounds Cleaning and Maintenance Occupations
- Personal Care and Service Occupations
- Sales and Related Occupations
- Office and Administrative Support Occupations
- Farming, Fishing, and Forestry Occupations
- Construction and Extraction Occupations
- Installation, Maintenance, and Repair Occupations
- Production Occupations
- Transportation and Materials Moving Occupations
Other (please specify)

5. How much monthly do you spend on housing?

≤ $250
≤ $300
≤ $350
≤ $400
≤ $450
≤ $500
≤ $550
≤ $600
≤ $650
≤ $700
≤ $750
≤ $800
≤ $850
≤ $900
≤ $950
≤ $1000
≥ $1000
6. Which of the following best describes your current relationship status?
   
   Married
   Widowed
   Divorced
   Separated
   In a domestic partnership or civil union
   Single, but cohabitating with a significant other
   Single, never married

7. How much total combined money did all members of your HOUSEHOLD earn last year?
   
   $0 to $9,999
   $10,000 to $24,000
   $25,000 to $49,999
   $50,000 to $74,999
   $75,000 to $99,999
   $100,000 to $124,999
   $125,000 to $149,999
   $150,000 to $174,999
   $175,000 to $199,999
   $200,000 and up
   Prefer not to answer
8. Are you White, Black or African-American, American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific Islander, or some other race?

   White

   Black or African-American

   American Indian or Alaskan Native

   Asian

   Native Hawaiian or other Pacific Islander

   From multiple races

   Some other race (please specify)

9. How many people currently live in your household?

    Fill in the blank

10. Do you rent or own the place where you live?

    Own

    Rent

    Neither (please specify)

A sample size of Respondents was collected from a combination of the Author’s Architectural Thesis class and the freshmen class of architecture students and interior design students. In total, eighteen respondents were collected with a 50% split between males and females. The following charts summarize the results of the demographic information of the Respondents, as well as their respective shape choices.
Q1 Please choose which gender you identify with

Answered: 18  Skipped: 0

![Gender Distribution](image)

Figure 4: Male/Female Split Ratio by Author
Figure 5: Age Demographics by Author
Q3 What is the highest level of school you have completed or the highest degree you have received?

Answered: 18  Skipped: 0

Figure 6: Educational Attainment Chart by Author
Q4 Which of the following best describes your current occupation?

Answered: 18  Skipped: 8

Figure 7: Participant Professions by Author
Q5 How much monthly do you spend on housing?

Answered: 18  Skipped: 9

Figure 8: Participant Housing Expenditures by Author
Q6 Which of the following best describes your current relationship status?

Answered: 18   Skipped: 0

- Married
- Widowed
- Divorced
- Separated
- In a domestic partnership...
- Single, but cohabiting w...
- Single, never married

Figure 9: Participant Relationship Status by Author
**Q7** How much total combined money did all members of your HOUSEHOLD earn last year?

Answered: 18  Skipped: 0

![Bar chart showing participant income by author.](image)

Figure 10: Participant Income by Author
Q8 Are you White, Black or African-American, American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific Islander, or some other race?

Answered: 18  Skipped: 0

Figure 11: Racial Profile of Participants by Author
Outcomes

The outcome of this thesis is ultimately the representation of a building, which includes rendered images, drawings, charts and data describing the building. The genre of architectural theses has a myriad of possible outcomes in terms of research projects, however most of the outcomes are more along the lines of buildings, or graphical representations of buildings. Inevitably the result of this research must be evaluated on architectural terms, thus the ultimate result are drawings and models representative of the resulting building. With that being said, the real outcomes of the research is that of a technology-assisted, collaboratively-based, dynamic architectural design process. In other words, the result will be dynamically changing human-computer interface which effectively connects a chosen cohort (non-architects, laypersons, stakeholders, etc.) into the design of a building in real time. The process is dynamic in the sense that it responds directly to the wants and needs of the group as the project progresses leaving room for revisions and changes while the building develops. The opportunities of such a process in terms of architectural practice are substantial. A considerable amount of work in architecture is done through revisions, so improving the process to negate revisions is a clear advantage to the process. Second, a considerable amount of time in architectural practice is spent providing decisions of somewhat trivial matters in terms of the design of the whole building. For example, considerable time and expense is devoted to the specification of materials. The process could save significant time in this regard by providing preselected materials the architects have determined to be appropriate or alternatively, up to specifications, budgetary constraints, or other “fixed” parameters. This offsets the trivial work of material specification to the client, user group, or other cohorts. The idea in this sense is that the architect can spend their time contributing value, while the client gets the carpet that they want at the price the architect is
required to adhere to. The majority of the value of this system or approach lies in substantial time savings.

When confronted with programmatic requirements for setting up the research problem, the chosen trial building had to fulfill very specific requirements, in order for the research to be successful. These choices have direct impact on program choice and requirements. In order to fulfill these specific requirements set by the research goals, a suitable program type is identified. The first requirement was that the buildings had to be developer-driven buildings. What is meant by developer-driven is that the type of buildings to be considered were to only be buildings in which were built for or by developers. The reason being that developers are driven by monetary means primarily and it is identified by the author that architects must respond to goals of clients in monetary terms. Since the goals of the project are to reduce time spent on any process during building design, and since time often equates to monetary terms, the program choice is largely thus driven by money. Since developers primarily are motivated by money, this research project is primarily concerned with buildings in which developers build: supermarkets, office buildings, retail space, speculative housing, multifamily housing, tract homes, data centers, storage buildings, et cetera.

Given the above discussed program types, certain buildings were eliminated outright because the author was simply not interested, or the author did not believe the buildings would lead to a compelling demonstration of the process. The buildings not considered for these reasons are as follows: retail spaces, data centers, and storage buildings or other non-dynamic buildings, or generic typologies. This leaves what is essentially housing and office structures. Working or living. The next question the author asked in terms of program requirements was what types of structures would be relatable to laypersons. Indeed spaces for living or working
certainly are relatable in the sense that these buildings occupy the fundamental aspects of life. The intent behind finding the most relatable building type is that in order for the research to be successful, a wide net or so to speak must be cast in terms of audience. Since a wide net of laypersons is intended to be targeted for the execution of the project, the program thus had to be relatable as possible. It is for this reason that the office building type was eliminated and only residential buildings were considered. The idea behind this limiting is that not every layperson can relate to an office building. A large swath of the population does not work in an office building so it is deemed not the most relatable. However, from a practical standpoint most of everybody can relate to living in some form of residence. While most Americans might not relate to living in apartment building, it is not a stretch to say that most people can “put themselves” in the building in terms of relating to the structure on a practical level.
Client Culture

The choice of relatability was deliberate both in the sense that the project requires a building type that dictates relatability on an occupant level but also a building type suitable for the client of the project. The client for this research is a moderately sized real estate developer with a specialty in creating student housing projects located in the immediate adjacent areas surrounding universities all across the United States.

The client’s goals are to produce quality, attractive, high-end housing for the discerning university student. Based on the immense growth in recent years taking place at the University of Cincinnati, the client desires to expand to new markets within Ohio and have deemed the area surrounding the University of Cincinnati to be their next target market. Because of these factors, the client has expressed that their target rent for each unit (gross) is to be no less than $1,200 dollars a month, or $14,400 dollars annually. Indeed while the client desires a relatively competitive rate given the context and rental market around the University of Cincinnati, the challenge lies within the architect to deliver a high quality environment at a relatively inexpensive price point. Based on these figures, the designer has created a breakdown of aspects pertinent to the building and the needs of the client. They are outlined as follows (emphasis by author highlighted in bold and italics):
1. Site
Latitude: 31.9 Degrees North, Longitude: 84.42 Degrees West | Climate Zone: 5 |
Buildable Site Area: 48,769 Sq. Ft.

2. Land Use Code
City of Cincinnati | SF-4 District | This sub district allows moderately high density single-family housing. The minimum lot size is 4,000 square feet | Multifamily Housing conditionally permitted with established precedent | Lot Area (Minimum): 4,000 | Lot Width: 40' | Front Yard: 20' | Side Yard Min/Total: 3/12 | Rear Yard: 25' | Maximum Height: 35' | Parking: 2 Parking spaces per unit

3. Program
Multi-Family Apartment Building | Community Gathering Space | Underground Parking Garage

4. Building Code

5. Construction Ethic
Parking Garage: Reinforced Concrete | Plaza: Slab on grade / Conventional Construction | Apartment Building: Structural Steel framing with partitions steel stud framing / conventional commercial construction
6. Floor to Floor

Apartment Building: 7' Ceiling Height Minimum + 3' Plenum Space + 2' Structure and Floor Combination = 12' Floor to Floor | 5 Floors @ 35' Maximum Height

7. Allowable Units

Gross Floor Area: 37,943.75 sq. ft. Per Floor Plate | 9,827 sq. ft. for circulation (37,943 X 25.9% = 9,827) | Net Sq. Ft. Per Floor Plate: 28,116 Sq. Ft. | Total Sq. Ft. Per Unit: 1,300 Sq. Ft. (derived from uptown average 2 bedroom rental size) | Units per Floor: 21 |

Total Units: 105 | Total Occupancy: 210 Occupants | Parking Spaces: 210 (2 per unit) |

Area of Parking Garage: 85,050 Sq. Ft. (210 spaces X 162 Sq. Ft. (9'x18'=162) = 34,020 X 2.5 (circulation) = 85,050 Sq. Ft.) | Total Floors parking garage: 2.5 (85,050 / 37,943 = 2.25 )

8. Structural Bay

Apartment Building: 30'x40' bay size | underlying concrete structure most economic form

9. Enclosure

For Opaque Sections: (Exterior to Interior) Panelized Cladding System, Air Gap, Rigid Insulation, Air & Moisture Barrier, Sheathing, Metal Stud, Gypsum Board | For Transparent Sections: Glazed Storefront Curtain Wall System, Double Pane (with air gap), Low E Glass

10. Fenestration

Minimum Glazed Portion: 11,246 Sq. Ft. (140,583 Sq. Ft. X 8% = 11,246 Sq. Ft) | 104 Sq. Ft. per unit

11. Entry

Minimum Entry / Exits: 2 Emergency, 1 Formal (architectural), 2 for Parking
12. Roofline

Roofline: Max Height: 35' | Options: Flat, Open Gable, Box Gable, Hip and Valley, Gambrel, Mansard, Dutch Gable, Jerkinhead, or any combination thereof

Taking these numbers into consideration allows the client to observe that the proposed construction matches their desired figures from an income standpoint. Taking the 105 unit count target at their desired $1,200 a month rental per unit leaves the building’s gross income, per month, at $126,000. Extrapolating out this figure to an annual level means the building will produce $1,512,000 annually. This figure breaks down, in terms of square footages, to about $0.92 cents per square foot. Indeed the proposed building on site fits the client’s monetary motivations and the clients’ goals, with the challenge to the designer to create an economically feasible design that is contemporary and attractive to students in the area.
The Site

The chosen site lies in Cincinnati, Ohio in the neighborhood of Clifton Heights. The site lies at the confluence of Ravine Street, McMillan Street, Fairview Avenue, and Old McMillan Street

![Site Map by Author. Site indicated in red](image)

This site was chosen for its particular aspects related to what the author has deemed to be positive traits associated with improving access to multifamily housing. First and foremost, the site lies within close proximity of a large college-age student population. The client has required that the site be in close proximity to a significant population of college-age students as that is primarily the client’s market sector in this region. Indeed a large population of college-aged students reside in direct vicinity of the chosen site. The site has a preexisting urban fabric and
framework in which it must conform to and be shaped by. This is perhaps the most important aspect of the chosen site condition for the following reasons:

The site is bounded on three sides by road conditions, and is thus a compelling corner site. Second, there is a variety of land uses directly to and adjacent to the site. There exist residential homes (both single family and multiple family, light retail, institutional (church across the street) as well as the configuration of the streets generally provides an interesting boundary condition representative of common constraining aspects of built-up urban infill sites. The site is steeply sloping to the north, and heavily wooded with a variety of scrub underbrush and medium to large trees growing on the site. It is bounded by West McMillan on the north, Fairview Avenue / Ravine Street to the east, Old McMillan Street to the south and Fairview Park to the west. All of these reasons combine to make the site attractive to the client as an idea site for development of multifamily housing in accordance with the growth seen in the vicinity of the neighborhoods immediately surrounding the University of Cincinnati.
Algorithm

The Plaza

The unbuildable portion of the site, the area immediately to the east of the buildable space dictated by the zoning code, is the site of the public portion of the project’s program: the public plaza. For the purposes of this project this part of the site is where the proof of concept that the scripts developed by the author actually work. It is an opportune space to experiment with the function and output of the process behind the Crowdsourced Building.

With that being said, and explanation of, generally speaking, how the whole process works is helpful to the discussion. First, ten participants are selected for the survey. For the trial design, which refers to the design of the plaza, instead of finding a sample of ten human participants, a sequence of numbers was randomly generated by the computer to serve as participant data. Each of the 10 participants vote once on each component of the trial design. For the design of the plaza, these components were as follows: Vegetation, Seating, Overlook, Gathering, Paths, and Topography. Two trial plaza designs were created by the author, entitled Trial Theta and Trial Epsilon. In order to better understand how the system works, and to show its potential in terms of mitigating competing factors in a design, Trial Theta (Trial 0) was designed to be as

Figure 14: Trial 0 Site Plan
“angular” and sharp as possible. Accordingly, Trial Epsilon (Trial 1) was designed to be as curvilinear as possible. For the sake of simplicity, each of the six components were simplified to the furthest extent possible.

The vegetative component is essentially placement of trees on the site in linear arrangements. The seating component consists of one area on the site with the sole function of providing a place to stop and sit. The overlook component consists of one area on the site devoted solely to observing and taking advantage of the steeply sloping site. The gathering spaces consist of three distinct spaces on the site where people can converge and relax. Paths connect all the spaces on the site and also connect to three points on the outside of the site. The paths are the only component not generated by the algorithm and is instead designed as a last step by the architect. Last but not least, the topography was designed to meet and support all the spaces on the site, and is designed to be walkable without the use of stairs.

Each component is voted on by each participant in the survey once. The participants are required to simply vote on if the component is appealing or not in a range of 0.000 to 1.000, with a vote of 0 meaning the participant prefers Trial Theta, and a vote of 1.000 meaning the participant prefers Trial Epsilon. The voting is done in real time where the participant can adjust the sliders independently and arrive at a combination of all the components that is pleasing to
them. For the design of the plaza the objective was simplicity and proof of concept so no human participants were used. Instead, a random series generator was employed where 10 numbers with a range from 0.000 to 1.000 were generated five times for each of the components. The average of each of the 5 sets of numbers was computed with the final numbers seen on the attached table.

<table>
<thead>
<tr>
<th>Component Name</th>
<th>Mean Score</th>
<th>Count of Votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>0.435</td>
<td>10</td>
</tr>
<tr>
<td>Seating</td>
<td>0.536</td>
<td>10</td>
</tr>
<tr>
<td>Overlook</td>
<td>0.685</td>
<td>10</td>
</tr>
<tr>
<td>Gathering</td>
<td>0.467</td>
<td>10</td>
</tr>
<tr>
<td>Topography</td>
<td>0.702</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 16: Trial Data Table by Author

Each mean score in the supplied table represents the final position of each slider for the resulting design. Each mean score is tabulated as an average of the votes generated by the random number generator.

The blended result is computed through the use of Grasshopper visual scripting environment within Rhinoceros3D. An algorithm was developed by the author in which to blend each shape in spite of topology variations. Blending the respective topography variations was the most challenging in terms of developing a script, and is explained in the following paragraph.
The script works as follows, first two meshes are selected. With respect to the attached image, number 1 is the first topography mesh to be blended, while number 2 is the second mesh to be blended. 2, the first mesh is evaluated and broken down to its vertices and faces. The vertices, represented as points are then fed into number 3, the pull point component which takes one set of points and calculates the distance and closest point to a given geometry, which in this case is the second topography mesh. Next, a vector for each point is computed from the difference between the closest point and the original vertices. These vectors are then multiplied by a range from 0.000 to 1.000 via a slider. This controls the degree at which the two geometries are blended. Number 6 takes the result of the multiplication and moves the original vertices to the computed new vectors. A new mesh (Number 7) is then constructed from the translated vertices and original faces. Finally, the resulting mesh is evaluated through the contour component where contour lines at 1’ intervals are generated.
To blend two-dimensional shapes such as vegetation patterns, gathering spaces, seating spaces, etc., an alternate script is employed through a slightly different process. First (1), the source and target shapes are input, in this case the geometry are surfaces in order to be evaluated from a point basis. Second (2), these surfaces are evaluated for their respective points within the bounds of the surface as well as their respective normal (to maintain z-height on the surface of the topography. From the points, a line is created (4) which is then fed into the evaluate curve (5) component. This component evaluates the curves with respect to one another. The slider controls the degree at which the curves are evaluated. The points included or not included are then fed into the convex hull (6) component which calculates whether or not a set of points is included within a certain boundary. The convex hull effectively combines the two point sets from the two surfaces. A curve is generated from the convex hull which is the final shape the intended component will be, as well as its location on the site itself. This portion of the script is responsible for generating the planar or two-dimensional components of the design.
Figure 19: Progression of Blend Between Topography by Author
The blending script for the building portion of the trial design process works precisely the same as the topography blending script as seen in Figure 17. The only difference between the two scripts is merely the input geometry. In the case of building forms the topology of the source and target meshes must be exactly the same. This means that both meshes must have the same number of vertices and faces and the order in which the vertices are placed must be in the same organization between the two meshes. This is an important difference between the two scripts and is not a trivial matter for the modeling portion and shape preparation is the most time consuming aspect of the project because of the geometric constraints of matching topology. Work in the future on the topic should focus on improving the efficiency of the modeling process.

The User Interface relies on a Grasshopper Plugin developed by NBBJ Digital Practice / Andrew Heumann, which allows Grasshopper users to program their own customizable User Interfaces which can manipulate Rhinceros files in real time without the clutter and organizational complexities of the Grasshopper interface itself. In essence, the Human UI component circumvents the interface of Grasshopper and Rhino and in its place a User Interface designed by the designer/programmer. The advantages of developing a UI through this method is very little programming experience is necessary so UI schemes can be developed extremely rapidly by architects and designers not familiar with programming. Second, it allows the designer to directly connect the UI with the Rhino file in question and directly manipulate the file and contents. Third and finally, because all the components are contained within the Rhino/Grasshopper ecosystem there are a multitude of plugins, scripts, programming elements that can be directly connected with the UI scheme. However, this direction is not without faults,
and there are indeed downsides. First and foremost, it adds one added layer of complexity on top of an otherwise complex operation (developing scripts in Grasshopper). Second, since it is all contained in the Rhino/Grasshopper programming scheme it cannot be deployed to mobile devices and other computers besides computers that can run the software in the first place. This became somewhat of a hindrance in terms of this project because it limited the amount of people that could reasonably be included in the sample (the software was tied to a desktop computer, so participants could only perform the questionnaire in the studio of the author). Third, because of the added complexities and technical issues related to the implementation of the code for Human UI, extremely complex operations as in the case of this research project are extremely computing intensive and thus require considerable processing power. Further research should investigate how to implement the crowdsourcing UI independently via visual studio or other programming environments. A brief explanation of the UI script follows.

Figure 20: UI Script Key Image
Part one of the UI Script is simply an array of components which control the blending of the geometry. These work just as in the case of the topography blending script and are collapsed for clarity and ease of use. All of the floors are merged into one mesh and fed into Number 2 (see figure 20).
Part two of the UI script is where the actual windows are created within HumanUI. The pictured script above controls turning the whole operation on or off (the Boolean toggle), naming individual elements, screen dimensions, etc. The meshes as described previously plug into the “Create 3D View” component in the “Mesh to Display”.

Figure 22: UI Script Part 2
Part 3 consists of an instance of the first series (Part 1) of arrays. These components are copied because of how Human UI integrates the changes to the geometry that the user inputs. Essentially, what this part of the script is doing is telling the computer to update the first instance of the geometry. The components outlined in purple are the components which “listen” to the sliders as the user manipulates them.
Part four of the UI Script breakdown consists of creating the tabs within the view which controls the blending operations between each floor. All these elements are then fed into the “Add Elements” component which adds the elements to an already existing view/window created in the HumanUI environment. The remaining components not explained thus are simply handle other operations not pertinent to the functionality of the UI Script overall and will not be discussed. An example of this is coloring of the contextual models (context buildings, topography, etc) A screenshot of the complied User Interface is attached below.

![Figure 25: Screenshot of Finished User Interface by Author](image-url)
Results

*The Plaza*

The blended result of the generated design of the plaza were surprising to say the least. To begin, it was challenging to develop a script which generated topographic surfaces and blended between at least two, so getting something which actually worked well enough to use was a considerable challenge to the project. In spite of the fact that the dataset was generated randomly by the computer, it was assumed by the author that the spaces developed would certainly not reach any sort of human qualities of spatial or contextual awareness. It was found from the resulting blended design that indeed there was an expression of spatial awareness, no doubt from the original two designs by the author. However, the result was usable spatially and experientially so it is interesting to note. Please see the following pages for renderings and illustrations of the final design for the plaza.
Figure 26: Perspectival Rendering of Overlook Space by Author
Figure 27: Site Plan of Combined Design by Author
Figure 28: Analytic Serial Sections by Author
The Building

While the results of the plaza were a great demonstration of a proof of concept in the work, it was necessary to carry out a full demonstration of the system with real participants and real data in order to prove its effectiveness as a tool for architectural design. As stated previously, the study began with a sample size of 18 participants of which there was an even split of 50/50 males and females. Under ideal conditions an equal split of architects and non-architects would have lent more statistical credibility and perhaps more compelling results would have arisen. With that being said, the study did uncover as well as confirm what previous studies uncovered as discussed in the literature review. The final Crowdsourced Average form can be seen below in Figure 29.

Figure 29: Final Crowdsourced Design by Author
First and foremost what is most interesting to note is that apparent confirmation that the crowd did not sense the building as one distinct mass on the site as seen in Figure 30. Instead, the crowd perceived the solution to be two distinct buildings which sit on the platform that the parking garage creates. Even in spite of the overwhelmingly architecturally-slanted sampling, there are *some* architectural tropes missing such as the omission of the podium which is traditional of tall building design.

The second notable discovery is the confirmation of architects’ preferences for flat roofs. This is evident by visual inspection of Figure 29 where there is absolute minimum amounts of gabling seen in the overall averaged shape. Figure 31 shows Form 0 with a gabled roof for reference.
Third and finally, the last item to discuss in terms of the discoveries within this study is the preferential differences across genders and disciplines. While it was previously discussed that architects, or students who are architecturally trained have a preference for flat roofs, the study also confirmed the preferences of non-architects. Through visual inspection it can be seen in Figure 32 that architects prefer flat roofs overwhelmingly while non-architects have a tendency to prefer gabled roofs.
Note above the pronounced gable on the massing on the right. The mass on the left is the average of all the architects, while the form on the right shows the average preferences of non-architects.

Finally, examining the preferences of males and females also proves to be revealing in terms of preferences. Like the above, the study revealed a distinction between the formal results of males and that of females. See Figure 33 to see a comparison between the preferences of males and females.

Again, as evidenced as previously discussed, there is a visual difference between the preferences of males and that of females. Overwhelmingly, the female choices, independent of
training or background reveal that their preferences have a tendency towards more angular (Polygonal) shapes. Females also prefer gabled roofs in the study.
Conclusion

In conclusion, both to summarize the findings of this study as well as provide insight to future studies involving either shape grammar, crowdsourcing, architectural design, and preferential studies as they relate to architecture, it should be noted that the author believes this thesis could have benefitted from a more robust sample size and makeup. Because of the technical limitations of the chose UI scheme and structure, this ultimately limited the sample size to those who were physically available and willing to come in and do the experiment in the author’s design studio, on the author’s personal computer hardware. Further studies investigating the topic should consider an alternate UI scheme which allows for rapid deployment on mobile hardware or other personal computers.

Second, a larger variety of building forms, as well as the option to control the number of floors of the building should be explored in future studies. The author upon completing the study found the limitations of the building form to have a homogenizing effect on the results, in spite of the interesting discoveries as discussed previously.

Finally, studies involving this topic should consider widening their sample to adequately represent a larger cross-section demographically speaking. This would lend increased statistical validity and would provide more insight into a wide variety of preferences of a wide swath of people from a demographic standpoint.

In spite of all of this the study did uncover and confirm some interesting correlations, as well as proved that a crowdsourced building is at very least a distinct possibility. The study has confirmed that architects do indeed prefer flat roof conditions, and non-architects prefer more gabled conditions. The motivation of these responses is subject to debate in terms of whether the participants were responding to contextual issues (suggesting that the non-architects are actually...
more contextually sensitive than architects), or simply that non architects are more familiar with gabled shapes and thus have a preference for them. Additionally, the preferences of men and women, in spite of training, reveal that men have a tendency to prefer smoother, more curvilinear shapes with flat roofs, while women have a preference for more angular and sharp shapes, with a preference leaning towards gabled roofs (albeit slight). Future studies should work to improve what was discussed previously as well as confirm or deny the preferential choices as uncovered in this thesis.
Bibliography

Akin, Omer, and Hoda Moustapha. "Strategic Use of Representation in Architectural Massing." 
*Design Studies*: 31-50.


http://robotmonkeys.net/2013/11/03/emergent-pong/.


