

Think By Making

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Abstract

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Architecture

This thesis is an investigation into the use of model making in architectural design. This topic is supported by research into the historical development of model making and contemporary academic thought on physical representation. This thesis will also explore parallel fields of thought on the benefits of analogue inquiry in the fields of automotive design and developmental psychology. The goal of this thesis is to advocate the importance of physical exploration in architecture, as well as, understand the evolving role of model making in a contemporary design field dominated by digital media. This thesis is tested with an experiment in the architectural design process, where a given design problem is solved exclusively with the use of physical models. This experiment provides the opportunity to exploit the application of model building, and push the limits of how they can be used to explore, develop, analyze, and communicate design ideas.

Physical Translation

“Architecture is a series of negotiated translations”
-Nick Dunn

The most fundamental task of architecture is to represent ideas of three-dimensional space that have yet to be built in this world. While two-dimensional representation is useful to convey information about a design, three-dimensional representation is inarguably the most effective means of not only portraying, but also exploring and analyzing ideas about three-dimensional space. In the practice of architecture, whether professional or educational, this truth is easily forgotten. Professional practices tend to overlook the use of model making for design and presentation purposes due to financial and time restrictions. Students typically view the architectural model as something they have to do in order to complete a studio project. In the wake of digital design programs revolutionizing the practice of architecture, students and professionals alike have forgotten, or maybe never really understood, the benefit of exploring design through physical building. The effectiveness of developing and understanding spatial ideas through building three dimensional representations of space is strangely taken for granted.

Why Models?

Compared to other design-based disciplines, architecture is the furthest removed from the realization of the product. Architects have no interaction with the actual building they are designing until the building is constructed, well after the design has been finalized. Models allow architects to get as close to the reality of a building as possible during the design process. While digital modeling has become the standard in architectural

design, digital models do not reflect materiality, contractibility, or the understanding of space from the human scale. Digital models, as a design tool, are also restrictive in their allowance for intuitive space making. Since digital modeling has taken over architectural design, the physical model has often been tossed aside as a vestige of the past, but the benefit of physical model building in design cannot be overlooked. Models offer a vehicle for the expression of spatial ideas, which have inherent material and tectonic characteristics that digital models cannot consider. In this digital age, architects, especially students, must learn how to incorporate physical model building into the design process, as a translator from the virtual to the real. Evidence for this claim can be seen by tracking the development of model building throughout the history of architecture. Tracking the evolution of the use of physical representations can be useful in understanding how to effectively utilize the model in the modern practice and education of architectural design.

Models have served an important purpose in developing the built world. They have acted as a key tool in facilitating new technological and ideological developments in the field of architecture, by allowing the exploration of forms, materials, and structures through physical small-scale representations. Models have not only allowed designer to visualize unprecedented realities in the built world, but also test their validity as buildable structures, due to the model's inherent materiality and simulation of real forces. Digital modeling technologies have lulled modern designers into a false sense of security in realizing buildable structures. The digital model appears to offer everything that the physical model offers, and achieves this at a fraction of the time and with the added benefit of being easily edited. However, the computer screen still acts as a two-dimensional

translation between the digital model and the users eyes; therefore, it does not offer the same spatial understanding as the physical model, not to mention being unable to express materiality, texture, or contractibility. It cannot be ignored how useful digital modeling has become in the field of architecture, but architecture professionals and students must utilize physical scale representations to truly analyze and understand their work.

While model building is still somewhat prevalent in architecture schools, it is rarer to find professional firms that produce presentation models, let alone use them in the design process. Student and professional architects alike must stop viewing the architectural model as only a final presentation artifact, but as an essential and constant tool in the design process. New digital fabrication techniques, such as laser cutting, computer numerical control (CNC) milling, and three-dimensional printers, have given today's designers the ability to immediately translate the digital into the real. These technologies have greatly reduced the time commitment of making high quality and highly accurate physical models and offer the potential for model making to become an effectual and indispensable tool of architectural design.

History has shown the effectiveness of model building in advancing the built world, but evidence of the importance of physical representations can also be found in similar design fields. In the field of industrial design, virtually no product is manufactured and put on the market without extensive prototype testing and the automobile industry has a long history of using full-size clay mock ups to analyze design, even after the introduction of digital modeling programs. These types of models show not only the effectiveness of exploring design through models, but also the importance of proving the validity of design before financial investments are made or put

into production. Why would this process of testing and checking not apply to architecture? Why would architects and clients not want to fully realize and understand the space of the project before they invest in construction and allow user to live and work in their building?

History

Throughout history, various forces and technological developments have led architects to building physical representations of architecture. The first record of architectural model building in human history comes from Herodotus' Book V, *Terpsichore*, in the fifth century BCE. Here Herodotus references a model of a temple in Delphi, but it is unlikely that this model would have been used during design or construction because scale measurements were not practiced at this time (Herodotus, 2015). Rather, building construction was derived from natural proportions and cosmic measurements. Archeological discoveries have revealed similar, more commemorative models from this era. A fired clay model was discovered in Bulgaria from the Gumelnita culture of 4600 BCE. This model was more of a sculpture than an accurate representation of space, but there can be seen evidence of the inherent understanding of scale in a miniature compared to full size building (Astbury, 2014). This is evident in the proportions of the huts, the texture of the walls, and the sizing of the apertures.

The ancient Egyptians developed a model building style based on their beliefs in the afterlife. The Egyptians believed that a deceased soul would live on in the afterlife, maintaining the same status in society as they had on Earth. To facilitate a seamless transition into the afterlife, the dead would be buried with all the amenities and resources they would need, whether actual or representational. The

highest ranking members of society would be buried with painted wood models of shops, bakeries, granaries, stables, gardens, and boats, ensuring the dead would want for nothing in the afterlife (Smith, 7). While these models were not used in a process of architectural design, they show the beginnings of a culture attempting to imagine space that could not be seen. While modern architects use models to imagine spaces that have yet to be made, the Egyptians used scale representations to imagine the reality of an afterlife. Although these models were used as gifts or placed in burial tombs and not part of the design or construction process, they were still an important development in the human understanding of space and scale through the use of a miniature.



Egyptian burial model.

Credit: <http://www.metmuseum.org/toah/works-of-art/20.3.11>

Greek *paradeigma*

While the Greeks contributed a great deal to the history of architecture, they contributed relatively little to the history of the architectural model. The only aspect of physical making before construction was through the use of the *paradeigma*, or prototypes used to replicate architectural details accurately. There are no recorded architectural drawings from this period and no evidence of models besides the *paradeigma*; therefore, the process of architecture, from the conception of idea to the built form was immediate (Smith, 10).

Aristotle: *eidōs*

Aristotle theorized on the direct translation from idea to building, through material. In Aristotle's *Physics*, written in the fourth century BCE, he described the process of building as idea, or *eidōs*, giving form to material (Aristotle, Book 1). Material in this sense, can be seen as any medium used in the design process, not necessarily



Greek *paradeigma*.

Credit: <http://flickrhivemind.net/Tags/paradeigma/Interesting>

the wood and stone used in construction. Without a medium to impose ideas upon, a building can never materialize. Models are an integral part of this process of translation from idea to building, due their inherent materiality

Vitruvius

The writings of Vitruvius, during the age of the Roman Empire, show evidence of models taking on a new role in process of design and building. For the first time in history, the small-scale model was used as an interface with clients to help explain ideas of buildable structures. Due to the advances made in engineering during this time, the Romans turned to model building to help test mechanical operations in moving structures. In Vitruvius' tenth book of architecture he tells of an architect named Callias giving a public lecture in Rhodes.

Callias showed a model of a wall, over which he set a machine on a revolving crane with which he seized an helepolis as it approached the fortifications, and brought it inside the wall, The Rhodians, when they had seen this model, filled with admiration, took from Diognetus the yearly grant and transferred this honor to Callias (Smith, 14).

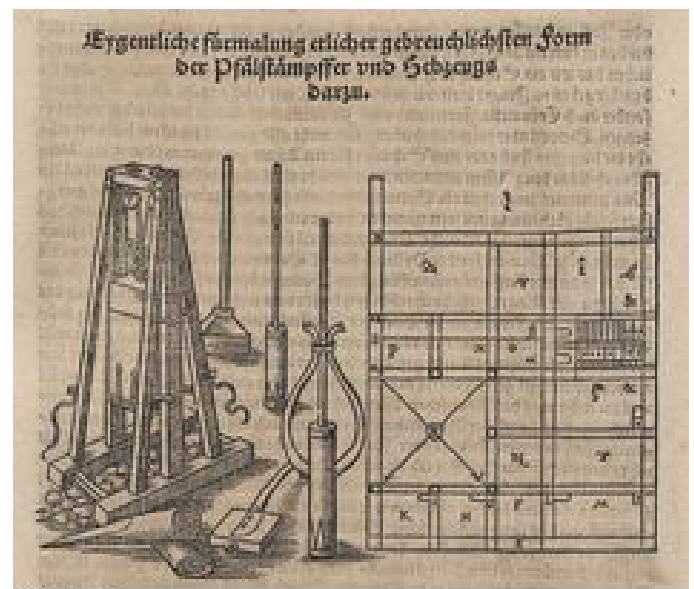
Vitruvius continues the account with the King Demetrius making war on the Rhodians with the help of a famous Athenian architect named Epimachus. He constructed a huge helepolis weighing three hundred and sixty thousand pounds. The Rhodians asked Callias to construct a machine to bring it inside the walls as he had demonstrated, Callias replied that this would be impossible.

For not all things are practicable on identical principals, but there are some things which, when enlarged in imitation of small models,



Roman siege engines.

Credit: http://en.wikipedia.org/wiki/Siege_tower#/media/File:Grose-Francis-Pavisors-and-Moveable-Tower-Assaulting-Castle-1812.jpg



Architectural drawings of Roman mechanism.
Credit: <http://quotesshared.com/g-cowan-nomadology-in-architecture-mcgill-unive>

are effective, others cannot have models, but are constructed independently of them, while there are some which appear feasible in models, but when they have begun to increase in size are impracticable (Smith, 15).

While these examples of models are meant to explore the use of warfare machinery and not architecture, several important developments are made in the use of small-scale models to understand full-scale constructions. The Romans not only understood the model as a presentation tool to convey an understandable reality to an untrained general public, but also as a persuasion tool to convince people to believe in new possibilities. Roman architects also understood the proportional strength of material in small-scale models in relation to full-scale structures.

Corinthian Column: “Model” as Inspiration

Vitruvius also presents an alternative idea of the role of the model in architectural design. Rather than a vehicle for translating idea into building, Vitruvius recounts the invention of the Corinthian order as an example of a “model” found in nature acting as inspiration for the formation of an architectural idea. Vitruvius describes the tomb of a maiden from Corinth, which had been adorned with a basket of the girl’s favorite things. The basket was protected from the elements with a roof tile, which was placed on an acanthus root. The flower bloomed in springtime, and grew up the sides of the basket until they were forced outward by the roof tile, forming volutes at the edges.

Callimachus passed by this tomb and observed the basket with the tender young leaves growing round it. Delighted with the novel style and form, he built some columns after that pattern



Corinthian Order.

Credit: https://upload.wikimedia.org/wikipedia/commons/b/b0/Corinthian_Column_Head_Jerash.jpg

for the Corinthians, determined their symmetrical proportions, and established from that time forth the rules to be followed in finished works of the Corinthian order (Vitruvius, Book IV).

This concept of model as inspiration for idea is an important development in the use of models. While the curation of the basket and leaves was not an invention of the architect, it served as a means for the understanding of space and composition of form. This speaks to the dual use of models in architectural design as not only tools for representation but also analysis. There is an important lesson here for any designer, that one does not always need to have a clear idea of what is being made, but the simple acting of making something and then evaluating the object can lead to architectural discovery. An idea does not have to precede a model, a model can precede an idea.

The Middle Ages

Between the fall of the Roman Empire and the Italian Renaissance, there is little historical documentation of the use of physical model building in architecture. Similar to many aspect of culture, there was little advancement made in the field of architecture during the Middle Ages. The role of the architect was to catalogue classical examples which were then applied and adapted in response to the wishes of the client. The only type of scale model building during this time was in the form of wood construction prototypes. These would have been used to estimate the cost of building materials or to test structural behavior (Dunn: ModelMaking, 14).

In *Architectural Model as Machine*, Albert Smith argues that the medieval Gothic Cathedral was itself a form of an architectural model. This position is based on the idea that the cathedral was a



Notre Dame, Paris.

Credit: <http://www.notredamedeparis.fr/spip.php?article383>



Notre Dame interior.

Credit: <http://foundtheworld.com/wp-content/uploads/2014/10/Notre-Dame-de-Paris-Interior-1.jpg>

formal demonstration of the Christian religion.

The building became a thinking mechanism for explaining the teachings of the church (Smith, 21).

The formal expression of faith was an important aspect of cathedral design due to the fact that most parishioners would have been illiterate. Also since books were not a household item at this time and most people would not have their own Bible, providing the faithful with a visual reminder of the presence of God was just as important as the verbal lessons delivered by the priest.

While cathedrals were not small scale representations used by architect to explore spatial ideas, they still exemplify an important aspect of model making, which is conveying an idea or a representation of a previously imperceptible reality to a viewer. This is the most fundamental goal of model making, reaching all the way back to the first models discovered in ancient Egypt.

Renaissance/New Forms

The Italian Renaissance brought the advent of the architectural model as we know it today, not only as a presentation tool, but also as a tool in the design process. Contrary to medieval times, Renaissance architects were beginning to explore new forms, while only borrowing fragments from classical architecture (Dunn: ModelMaking, 15). With no frame of reference or existing examples to work from, Renaissance architects relied on scale models to explore and test new architectural concepts. During this time the craft of model building expanded greatly, including a much wider array of materials, as well as a more refined attention to detail. This was the birth of model building as its own art form. The models were much



Cresti painting of Michelangelo presenting a model of St. Peter's to Pope Pius IV.

Credit: http://static.greatbigcanvas.com/images/singlecanvas_thick_none/corbis/michelangelo-presenting-the-model-of-st-peters-to-pope-pius-iv-by-domenico-cresti,2306343.jpg?max=540

more extravagant and often included detachable sections to allow internal viewing and dynamic presentation. This advancement in the use of models led to their incorporation in major building commissions, such as Michelangelo's St. Peter's and Brunelleschi's Florence Cathedral (Smith, 17).

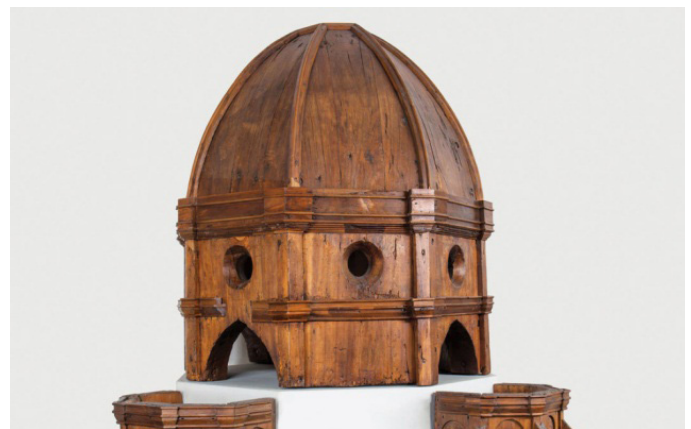
The architect during this time had a much closer relationship to the building than modern architects. They acted as foremen on the construction site as well as designers. This role created a relationship between design and construction that was ongoing, rather than separate spheres in the modern building industry; therefore, the prototype model had a dual function as an example for construction and also a tool for design exploration. Brunelleschi used models extensively in his work and designed primarily in three-dimensions. He carved wax and even turnips during construction to test architectural elements and convey them to his builders (Dunn: ModelMaking, 15).

Alberti: Idea to Building Through Model

Leone Battista Alberti in his treatise *On the Art of Building in Ten Books*, wrote extensively on the use of model building in architecture. Architecture was more of a theoretical pursuit for Alberti, rather than his profession, which led him to write on architecture and model building from the view of the client. In his writing, Alberti explains the process of architectural design similar to Aristotle's theory of idea becoming building through material, but with the important incorporation of model building (Smith, 22). Alberti understood the importance of model building in architectural design because it allowed a realization of a building prior to actual construction. This gave designers and patrons the opportunity to discover



Brunelleschi model of Florence Cathedral.
Credit: <http://www.latimes.com/entertainment/arts/miranda/la-et-cam-museum-of-biblical-art-brunelleschi-dome-20150428-column.html>



Brunelleschi model of Florence Cathedral.
Credit: <http://www.latimes.com/entertainment/arts/miranda/la-et-cam-museum-of-biblical-art-brunelleschi-dome-20150428-column.html>

any issues in contractibility or unintended spatial arrangements that were not previously evident.

Having constructed these models, it will be possible to examine clearly and consider thoroughly the relationship between the site and the surrounding district, the shape of the area, the number and order of the parts of a building, the appearance of the walls, the strength of the covering, and in short the design and construction of all the elements (Smith, 27).

In his writing, Alberti relates a story from ancient Rome, where Julius Caesar had a house on his estate destroyed and rebuilt because he did not approve of its design. Alberti was uncovering a revelation in building design where it was not only beneficial but possible to see a building before it was built. He recognized this process would have greatly benefited Caesar and other ancient patrons who were left in uncertainty until the building was fully constructed.

For this reason, I will always commend the time-honored custom, practiced by the best builders, of preparing not only drawings and sketches but also small-scale models of wood or any other materials (Smith 28).

While Alberti admired the architect's skill in using model building to convey architectural ideas, he also understood the dangers of misrepresentation or misinterpretation due to the scaling of space and materials in models. Albert Smith described Alberti's concern as a difference between illusion and allusion. Smith noted Alberti's understanding of the task of the model to allude to reality, to create a symbolic reference for the building, but various imperfections or inconsistencies in the model, intended or not, could give the viewer an illusion

or a false impression of the building realized at full scale.

The presentation of models that have been colored and lewdly dressed with the allurements of painting is the mark of no architect's intent on conveying the facts; rather it is that of a conceited one, striving to attract and seduce the eye of the beholder, and to divert his attention from a proper examination of the parts to be considered, towards the admiration of himself. Better than that the models are not accurately finished, refined, and highly decorated, but plain and simple, so that they demonstrate the ingenuity of him who conceived the idea, and not the skill of the one who fabricated the model (Smith, 30).

Education

Depending on a student's exposure to architecture before undergraduate studies, the university is likely where most students will be introduced to architectural studies, not only history and theory, but also how to design and think spatially. While skill in three-dimensional design may come naturally to students in architecture, the early years of education can greatly influence how students develop as designers and what tools they use in their design process. Fortunately, many universities understand the importance of these formative years, and require students to study spatial design before studying proper architectural design.

While every school of architecture requires model building as part of design education, some universities, more than others, focus on physical building as a key part of the design process. Even when a particular school encourages or requires extensive model building, the students may not necessarily understand why they are required to do so. They might simply view the model as a task they must complete to prove they fulfilled the work requirement. Seldom few schools take the time to convey the importance of model building as an explorative design tool, as well as a communication device to incite feedback from professors and reviewers. Nick Dunn, a professor at Lancaster University, recognized this issue in architectural education and conducted extensive research on the topic of leaning-by-doing in design education, culminating in his PhD thesis, *The Ecology of the Architectural Model*.

The goal of Dunn's research is to educate students on the various uses and benefits the model affords in architectural design. Dunn advocates that the model has an important role to play in the education of designers. Most students assume the model is simply a form of representation used in



Student exploration through making.
Credit: <https://aad.cas2.lehigh.edu/student-news>



Using models to communicate ideas.
Credit: <https://aad.cas2.lehigh.edu/student-news>

final presentations. He found that students were simply building models because they were assigned to do so, without understanding how to use the model to explore design concepts and also to communicate those concepts effectively. This issue emerged when he found that first-year students generally struggled to convey design intentions to their mentors, during the design process (Dunn: Ecology, 18). Once they were asked to build models of their ideas, they were able to communicate ideas much more effectively and therefore, allowed the viewer to respond more directly to the design concepts, without trying to interpret the student's intentions. Dunn refers to this form of translation through models as a process of encoding and decoding (Dunn: Ecology, 21). These terms refer to the application of real world information, like size, shape, color, and texture, to design ideas. This allows students more expression and specificity which reduces the task of the viewer to internally translate the intended design.

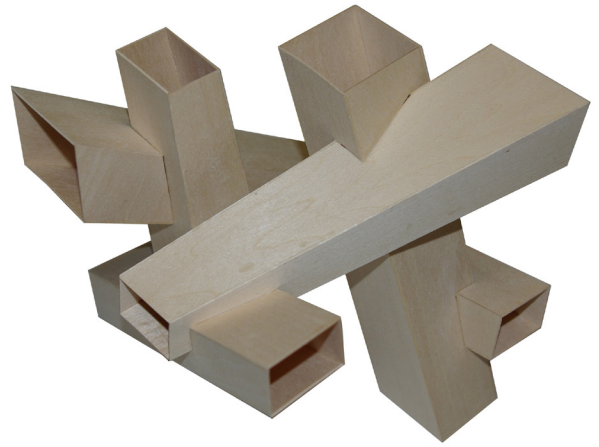
Since the 'language' of the model is so dense the encoding of each piece of information can be more compact, with a resulting decrease in the decoding time in our understanding of it (Dunn: Ecology, 25).

Nick Dunn later published *Architectural ModelMaking* as a source of reference for anyone undertaking a model project in architecture, from first-year students to well established professionals. It serves as a comprehensive guide from material selection to design intent and execution, which is greatly beneficial to those first learning about model building, but it is also effective in reminding veteran builders that models are versatile in expressing and exploring design concepts in addition to simply being a final presentation artifact.

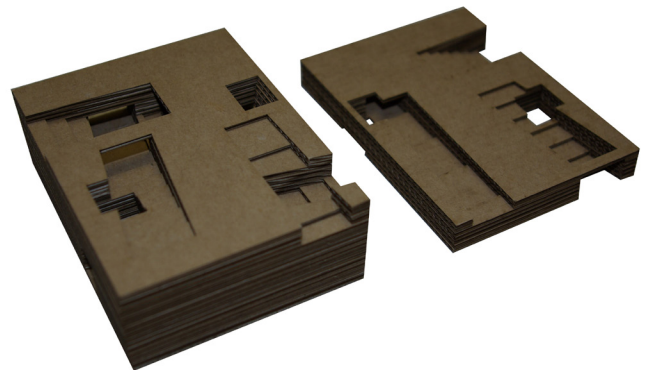
In Dunn's work he has catalogued and

classified virtually every possible type of model used in architectural design. He uses two systems of classification to help designers focus on what is most important in a specific model endeavor, which he has titled *Types and Applications*. His first classification of model types is based on the idea that, like drawings, models are incapable of conveying every aspect of a design. Therefore, it is important to identify the appropriate type of model to most effectively explore or communicate the intended aspect of the design. Dunn classifies these types as, Concept, Site/City, Block/Massing, Design Development, Spatial, Structural, Interior, Lighting, Presentation/Exhibit, and full-scale Prototypes (Dunn: *ModelMaking*, 30-32). While these terms are very familiar to most graduate architects, these could be alien to first-year architecture students, and are important distinctions to learn in the early years of architectural education.

All of these types of models might not be useful in every design project, but it is imperative for students to be aware of the types of models they have at their disposal. More important than learning about the types of models, is learning how to express and evaluate ideas in models. This suggests that the most important type of model to learn early on in architectural education is the Concept model. The concept model is very effective in visualizing complex ideas about space, and the exercise of trying to give form to an idea is an incredibly useful skill for young architects to develop, which can then be applied to other forms of models (Dunn, *ModelMaking*, 111). Through conceptual models, architecture students learn the invaluable process of thinking by doing, where they do not necessarily have to know exactly what they are making. The concept model allows them to access and realize creative impulses without needing to first resolve them architecturally. Learning to accept this lack of control and allow an intuitive process of forming



Concept model of intersecting programmatic forms
Credit: Joseph Moriarity, 2014.



Concept model exploring mass and void.
Credit: Joseph Moriarity, 2015.

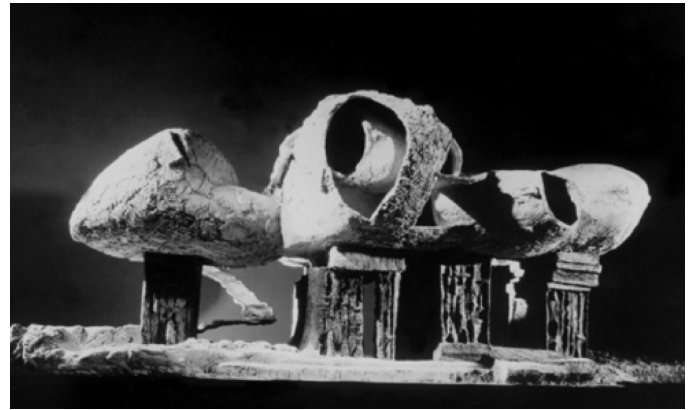
space is not only rewarding creatively but also effective in the exploration and evaluation of design ideas.

Idea as Model

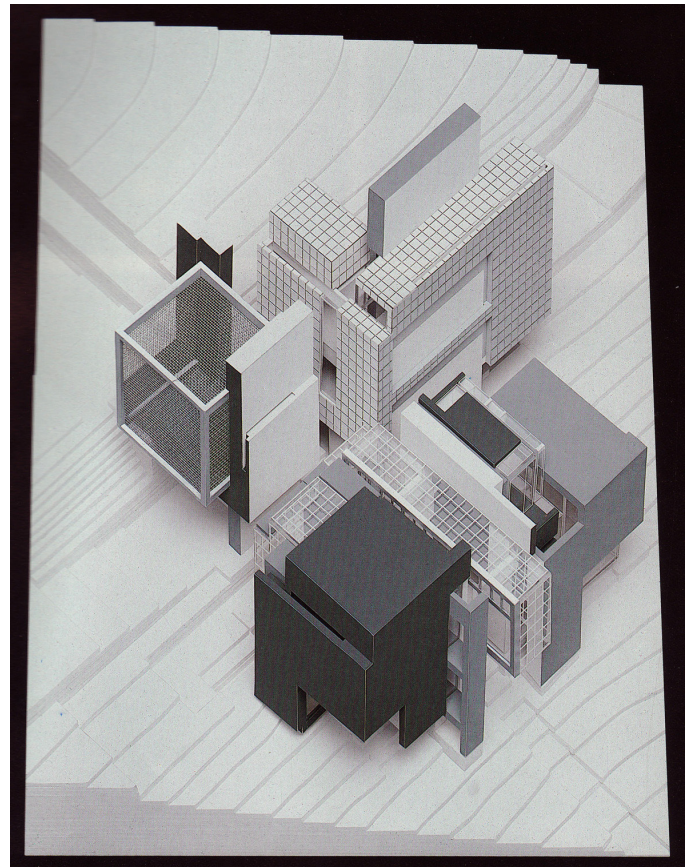
The concept model as a generative form of architectural design started to take root in the wake of modernist architecture. In 1976, The Institute for Architecture and Urban Planning hosted an exhibit titled *Idea as Model*, to provide an exploration of how architects were using physical models to express complex ideas.

The purpose of this exhibit is to clarify new means of investigating architecture in three-dimensional form. We do not seek to assemble models of buildings as propaganda for persuading clients, but rather as studies of a hypothesis, a problem, or an idea of architecture (Frampton, 3).

Richard Pommer, an architectural historian, reflected on the success of this exhibit and the general use of conceptual models by architects at this time. He noted that the exhibit was not received well overall, but it was effective in generating a discourse on the exploratory use of models, rather than client propaganda (Frampton, 10). Pommer reveals that four years after the exhibit, architects had begun to use models in a more conceptual and exploratory manner, in line with the original goal of *Idea as Model*. He cites Peter Eisenman's axonometric model of House X, as an example of this development. With this model, Eisenman was attempting to prove that drawings may contain deception that can only be uncovered through physical model making. The model of House X, at an elevated, front-on view appears to be a correct three-dimensional representation of the project, and at a lower angle, appears to be an axonometric



Endless House, celebrated model base design.
Credit: *Idea as Model*, 1981.



Eisenman's House X.
Credit: *Idea as Model*, 1981.

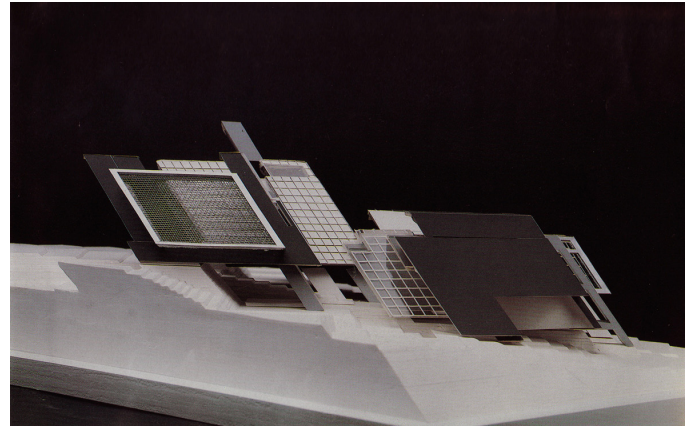
drawing. However, if one moves around the sides of the model, it can be seen that the architecture is flattened and slanted, giving the illusion of vertical planes.

In *The Ruins of Representation*, another response to the Idea as Model exhibit, Christian Hubert reflects on the use of models in architecture, especially their role in architectural education. He explains the process of model building as a surrogate experience of assembling and composing building parts. Hubert sees this as analogous to the classical training of architects, where apprentices of architecture began by studying stone cutting and woodworking as the first step into the study of architecture. He describes the importance of model building as a threshold between the representation of ideas and their realization (Frampton, 19).

For the space of the model lies on the border between representation and actuality. Like the frame of a painting, it demarcates a limit between the work and what lies beyond. And like the frame, the model is neither wholly inside nor wholly outside, neither pure representation nor transcendent object (Frampton, 17).

ETH Zurich/Spatial Richness Modeling/Deceptive Drawings

At the ETH Zurich Department of Architecture, Bernard Hoesli instituted a new design curriculum in the 1960's based on the Modernist movement. His goal was to find more effective ways of introducing new students, unskilled in architecture, to the concept of an architectural idea. One such exercise required first-year students to respond to a design brief with a model at the scale of 1:20, which is comparable to half-inch scale in the English system. A scale this large is rarely



Eisenman's House X.
Credit: *Idea as Model*, 1981.

used in architectural design, usually reserved for to study and explanation of key details, however it is almost never the very first scale to begin a design study in architecture. Not only did Hoesli require his students to immediately design at a massive scale, he restricted the use of case study examples and preliminary sketching. In *Architectural Models*, Rolf Janke examines the effectiveness of this studio structure.

The results were remarkable in that, scarcely a month after the beginning of the first term of architectural study, projects with very interesting spatial qualities were produced. Had the students worked in the abstract from plan and section, no such architecturally and spatially logical forms, evolving naturally from the essence of the brief, would have appeared. The drawings, prepared after the model was completed, show that a first-year student would hardly have been capable of representing, let alone inventing, such spatial effects with only the help of plan and section (Janke, 8).

A former student of Hoesli, Rudolf Wienands gave a lecture at ETH Zurich in 1974, addressing the various languages architects must use in design, from words to drawing to models. Wienands explained how these languages facilitate a thinking process to work through the complexities of architectural design, but the model being the most effective language due to its inherent three-dimensionality. He also commented on the use of models for presentation purposes, not only in the design process. In an academic setting students are presenting their work to professors and other jurors skilled in the field of architecture; therefore, while these reviewers are skilled in understanding architectural representation, the student must rely on their interpretation of the work. Again, the model

is the most efficient at presenting spatial ideas as close to the intentions of the student as possible.

The two-dimensional picture of a three-dimensional object (space) requires great skill of the viewer in order to interpret and imagine the space described; it is often said that architect's drawings can easily deceive or mislead the viewer (Janke, 10).

Joel Shack/Tectonics in Design

In Joel Shack's essay, *Tectonic Ways of Seeing, Thinking, Making*, he advocates the study of building tectonics as a means for teaching students how to design and appreciate quality architecture. He argues that often times, architectural concepts are conceived through formal investigations prior to the consideration of material and how that material will affect the experience of the architecture (Shack, 1989). This leads to architectural concepts that do not hold up at the human scale. To teach students how to think architecturally in a manner that would yield materially and conceptually rich projects, Shack had his students at the University of British Columbia, construct large tectonic models at a 1"=1'0" scale.

This tectonic model became a key design tool towards developing the "indivisibility" of seeing, thinking and making (Shack, 1989).

In this studio, students were asked to cycle between different scales of working, switching focus from overall concept to design details. This process allowed the part to inform the whole, the reality to inform the idea, and vice versa. Shack's studio model is an effective learning experience for students to develop skills in not only thinking but also working through problems, or making through

problems. Architecture students often think they must have every detail figured out before a model can be made, but it is important to disprove this theory to enable students to use making as a means for thinking. It takes a fair amount of courage for a student to simply start building without a clear idea of what they are making. Many design students fear not being able to explain what they are working on, they believe they must have a unique creative idea to justify their work, but it is a truly freeing and eye-opening exercise to allow one's hands to do the thinking, giving way to intuitive discoveries in the formation of space.

Psychology of Education: Kinesthetic learning

Studies in the psychology of learning styles in education reveal supporting evidence for the importance of learning to think by doing in architectural education. All sources on the subject agree on three major categories of learning styles, Auditory, Visual, and Tactile or Kinesthetic. Studies of students from various age groups have shown that most young students are inclined to learn according to one major style of absorbing information, but over time, students are able to strengthen their various skills in receiving and obtaining information. This leads to what some psychologist refer to as a Renaissance Learner, which is well-balanced student capable of learning through all three learning styles (McLeod, 2013).

Even though not all architecture students are primarily tactile learners, the subject matter lends itself to be absorbed and explored in a kinesthetic manner. Kinesthetic learners retain information most effectively by having a hands-on experience with the subject matter. In Howard Gardner's *Frames Of Mind: The Theory of Multiple Intelligences*, students who have a predominantly kinesthetic learning style have realizations through

doing, rather than thinking before taking action (Gardner, 18). This is very pertinent to the idea that model making allows architects to explore and express design concepts more effectively than drawn or digital counterparts; therefore, it is important for architecture schools to reinforce this type of learning in the early years of architecture education, by introducing students to the various uses and types of models.

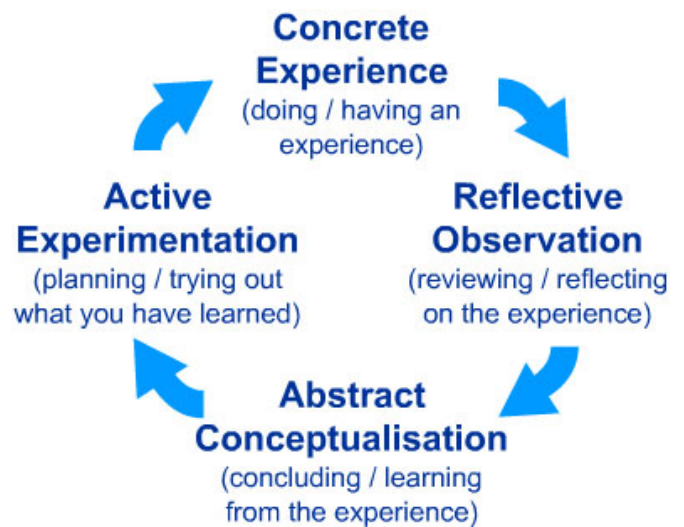


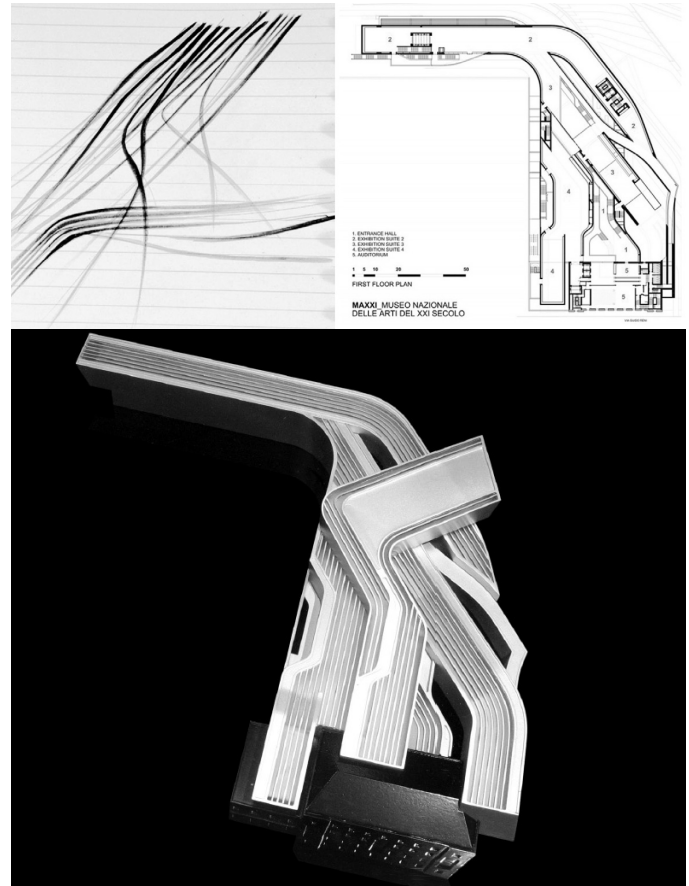
Diagram of effective learning cycle.
Credit: <http://www.simplypsychology.org/learning-kolb.html>

Practice

Compared to other design-based disciplines, architecture is the furthest removed from the realization of the product. Architects are only minimally involved in the actual construction of buildings, during construction administration, at which point design has been finalized and only minor decisions are needed to resolve building issues. The vast majority of the architect's work is done through representation of three dimensional space. Traditionally this representation has been done through hand drawing and physical model building, but the emergence of digital design software has revolutionized the media architects use to represent space. Hand drafting has become extinct due to AutoCAD and other drafting software, but sketching remains an essential skill for architects because it allows a quick outlet for ideas.

Physical models were also seemingly doomed for extinction due to the immediacy of realizing and editing space in three dimensional design software. However, prolonged exposure to the two dimensional representation of the computer screen can cause skills in spatial understanding to atrophy, which is inarguably the most essential skill of the architect. Therefore, the role of physical model building in architectural design should be reexamined as an essential tool in not only representing and exploring space, but also testing and evaluating the forms digital technology enables architects to conceive. Digital fabrication technologies are essential in reestablishing physical models as an essential tool in the design process, but it is important to appreciate the value of discovery and exploration offered by analogue model building.

Parallels can be drawn between architecture and the automotive industry, since both are tasked with the design of a three dimensional reality based on the marriage of form and function.



Comparing mediums of architectural design.
Credit: <https://designmuseum.org/designers/zaha-hadid>.

The automotive industry experienced a similar revolution of design media with the advent of digital modeling software, and the long tradition of clay modeling was assumed to become obsolete. In his article “Future of Auto Design Still in Clay Modelers’ Hands”, Michael Wayland relays how clay modeling has persisted in car design despite these new technologies. In the 1990’s the automotive industry became internationally competitive, causing many companies to rely on digital design and fabrication to cut costs and expedite the production process. Joe Dehner, the head of Dodge and Ram Truck exterior design believes that this led to “lackluster vehicles being produced due to a lack of hands-on interaction and being unable to effectively evaluate design” (Wayland, 2015). Instead of replacing clay modeling, digital design and fabrication has found its place as an important tool in automotive design, alongside traditional analogue techniques.

Wayland explains how contemporary automotive design is characterized by a dialogue between digital and hands-on tools. Design typically starts with a series of sketches that are then given to a modeler who produces small-scale clay prototypes. These clay models are refined until the design is ready to be finalized. Half of the car is then modeled at full-size, which is then scanned into a digital model. This digital model is then fabricated by a CNC machine to complete the full-size prototype.

In Joseph White’s article, “One Thing Isn’t New in Car Design: Clay Prototypes”, he offers further evidence for the continued importance of clay modeling in car design. White states that the most important impact the clay model achieves in car design is selling the product to executives, “three dimensional imaging technology that allows executives to don headsets and see a virtual vehicle in a computer generated cityscape, but the top brass



Credit: Wayland, 2015.



Credit: Wayland, 2015.

won't sign off on producing a new car, a decision that can involve spending a billion dollars or more, until they see full-size physical models" (White, 2014). Executives in the auto industry play a similar role to clients in architecture, in the sense that they have the final say in design approval because they are financially backing the project.

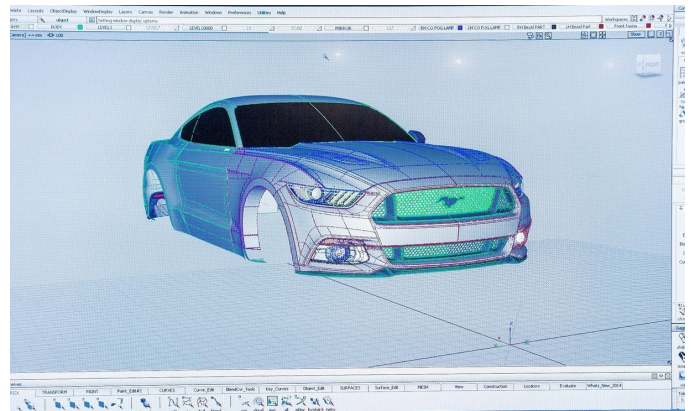
While a building does not cost as much as a line of cars, it has a much more significant impact on the lives of the people who use it; therefore, buildings deserve the same real world analysis and evaluation as shown in the car industry. Since realizing a building full size is not possible, model building and scale physical representations are the best possible way to analyze and develop architecture before construction begins.

The combination of digital and analogue tools, in automotive design, allows a synthesis of speed, accuracy, and hand-crafted finesse, resulting in high quality design that is still competitive at the pace of an international market. Architects can learn from this model of working through design. Rather than allow architecture to exist only in digital space until it is fully realized, it is important to understand the project in three dimensional reality in order to be effectively evaluated.

While model making in contemporary architectural practice is not the norm, there are some practitioners who employ physical models as an essential and prevalent tool in the design process. In his article "The Model is in the Making", Sarosh Mulla states, " nothing explains the intention, form, use and materiality of a piece of architecture like a well-crafted model" (Mulla, 2014). Mulla writes about his experience at the University of Auckland in New Zealand and how model making became a key tool in his education as an architect. He argues that the act of making is integral for students to develop design skills, and should not be left behind



Credit: White, 2014.



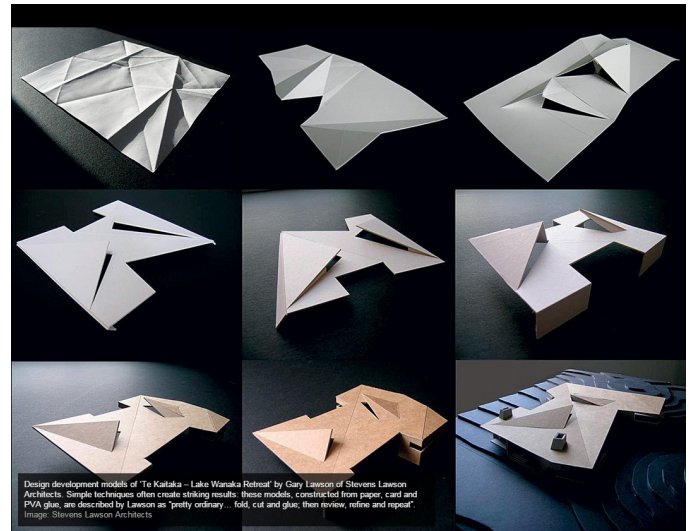
Credit: White, 2014.

when graduating into professional practice.

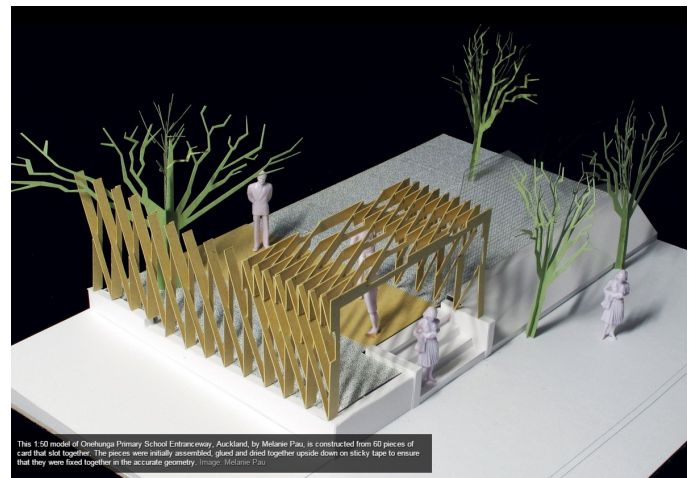
Mulla cites the experience of his mentors in Auckland as practitioners who incorporate model making into every project, with the belief that physical exploration and evaluation leads to more successful architecture. Andrew Barrie, a self employed architect and professor at the University of Auckland, developed his process of design which relies heavily on model making, while working for Toyo Ito in Tokyo. Barrie's process, especially in the early stages of design, utilizes model making by printing drawings on cartridge paper that can then be assembled in quick iterative models. This method allows Barrie to quickly realize and evaluate each design option before moving forward (Mulla, 2014).

Gary Lawson, a protégé of Barrie, uses a similar design method in his practice, Stevens Lawson Architects. Mulla cites Lawson describing his use of models in his practice, "models have been hugely important to our design process, they allow us to explore ideas in three dimensions reasonably quickly and they add a richness and sense of discovery" (Mulla, 2014). Lawson also states that the presentation model is the keystone of every project because it is the most effective tool in selling the client on the design.

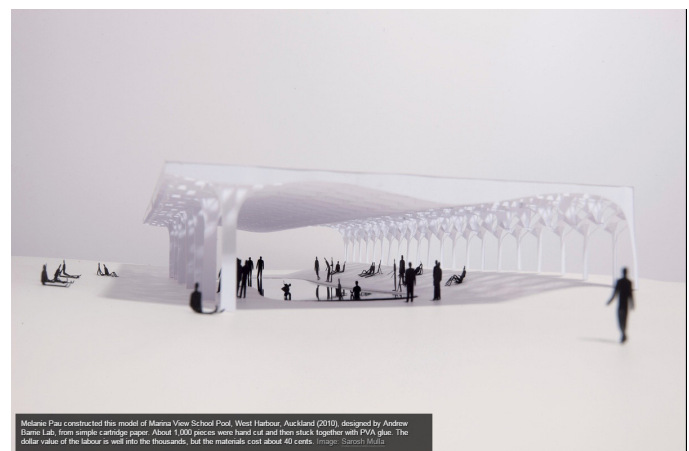
In "Thinking with Matter" Mark West presents an argument for the use of analogue making in a field overrun by digital dependence, "unable to fault the computer's ability to provide complex calculations for the fabrication of forms, the fidelity and investigative potential in the reality of the physical model has yet to be surpassed" (West, 51, 2008). West founded the Center for Architectural Structures and Technology at the University of Manitoba, which is dedicated to the creative exploration of materials and building methods. West founded this department based on a rising trend where students and practitioners alike



Credit: Mulla, 2014.



Credit: Mulla, 2014.



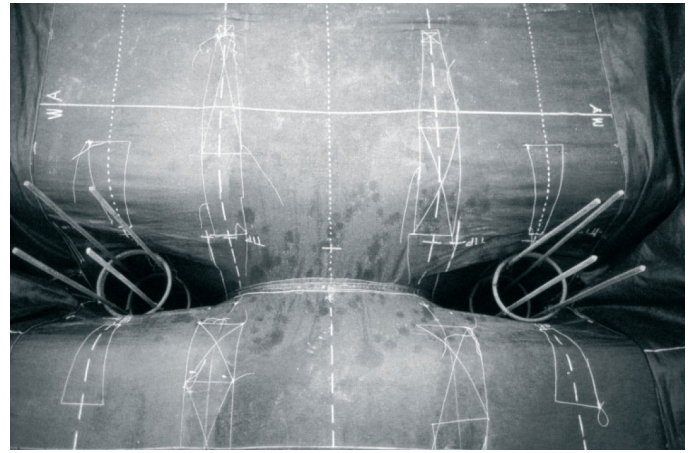
Credit: Mulla, 2014.

were unable to extract and realize complex digital designs made in the computer, “ behold the sorry scene of the architect with the digitally generated blob begging the builder and the engineer to figure out how to construct the marvelous design” (West, 53, 2008).

West attributes this issue to ability of the computer to create forms in a vacuum devoid of forces, where the origin of spatial ideas has no physically constructible reference. To remedy this situation, West conducts research through building explorations, where the act of making and responding to forces and materials creates form, “whatever form is found, we already know how to build it because the form was found by building” (West, 54, 2008). West concedes that while digital tools are essential in modern building culture, due to their quantitatively rich analysis and generation, the qualitative potential of models to respond to physical forces, and explore construction sequence and detail, should not be neglected.

Many contemporary architectural practices overlook model making, simply because it is too time consuming and expensive. While cheap materials can be utilized to cut down costs, the time requirement for model building is difficult to overcome. Digital fabrication technologies, such as laser cutting, CNC milling, and 3D printing, present a revolutionary set of tools for quickly and accurately realizing digitally produced forms. However, before architects adopt and standardize digital fabrication in design practice, it must be understood what role digitally produced models can play and that it is not a replacement for analogue model building.

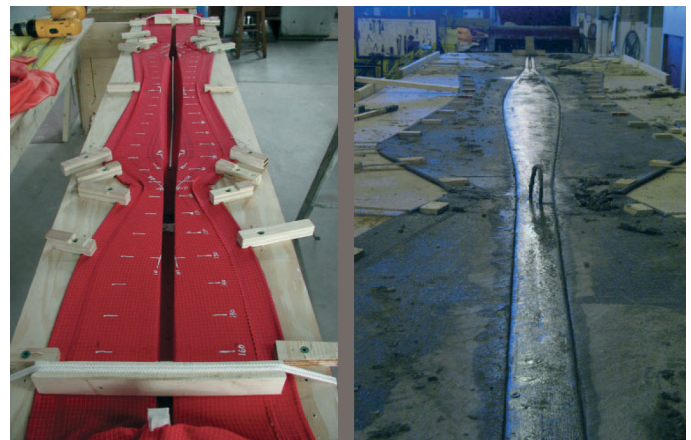
In “The Impact of Layered Technologies on Architectural Model Production and Use”, Luka Jancic takes a critical look at digital fabrication, specifically 3D printing, to understand the



Credit: West, 2008.



Credit: West, 2008.



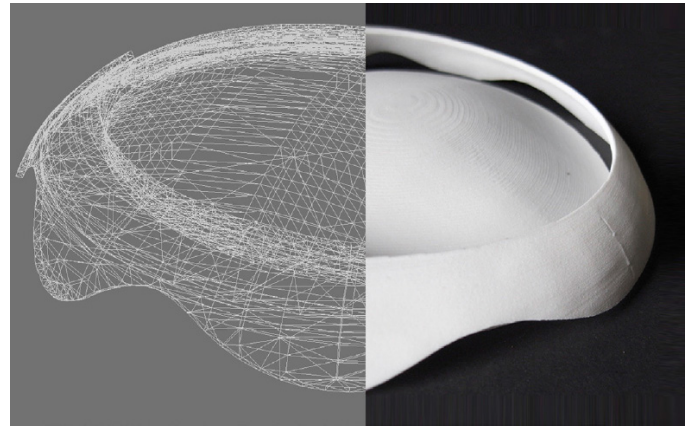
Credit: West, 2008.

opportunities and consequences in adopting these technologies in architectural design practice.

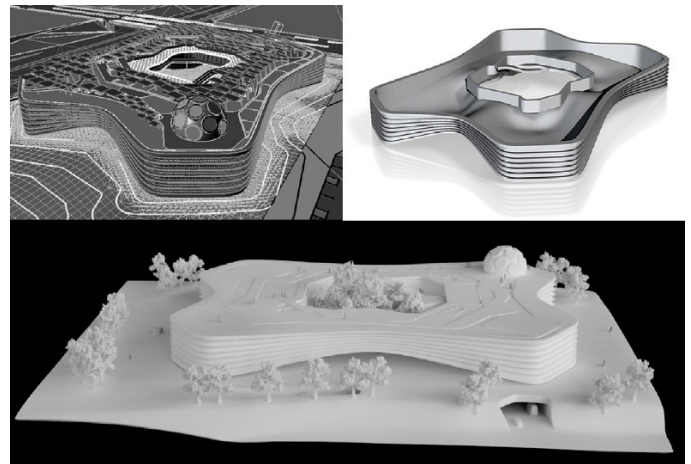
This research was conducted with the underlying belief that a combination of media is required in architectural design, “no single tool, software, material, medium or technique will suffice to achieve the kind of vigor and complexity that an innovative work of architecture necessitates” (Jancic, 68, 2013).

Jancic argues that the role of model building in architecture has shifted. Traditionally models were used to perceive space more effectively than drawing, but design software has become a quicker means of achieving this goal. Therefore, physical models have evolved into an analytical tool to test the digital designs, because the two dimensional computer screen is not sufficient in evaluating the results. This analytical role is made effective through 3D printing and other forms of digital fabrication, but these models do not offer the same outlet for creativity because they remove the process of making from the product (Jancic, 72, 2013). In fact, digitally fabricated models can even impede the design process because most digitally produced models require extensive design to translate the data into a form the technology can understand.

While this use of physical models is not as creatively rewarding as analogue techniques, it still helps resolve issues prevalent in design software. Foremost, digital modeling is done in real scale, but is constantly distorted due to the ability to zoom in or out through the software interface. This ability can create illusions or misinterpretations of scale in architecture, which is essential for creating effective, relatable space for human inhabitation. Secondly, digital software operates on sets of data, where every decision and shape created must be highly defined. This accuracy, especially in early design phases, can cause an unintended



Credit: Jancic, 2013.

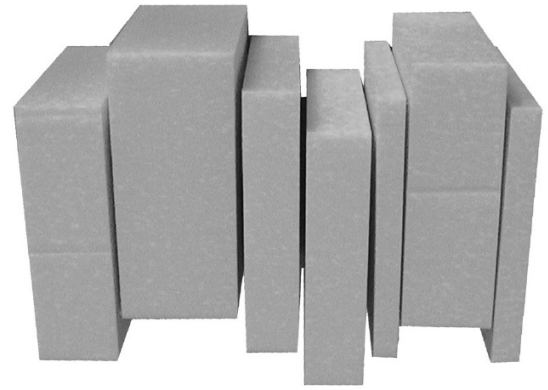


Credit: Jancic, 2013.

crystallization of ideas. This accuracy can confuse clients by giving the impression of a fully resolved building, when in fact, the architect is only trying to convey initial design decisions (Jancic, 69, 2013). Jancic argues that digital fabricated models are useful in resolving these issues presented by virtual modeling.

Similar to Sarosh Mulla and his contemporaries, Jancic believes that the process of making is arguably just as important in the design process as the product itself; therefore, there is no replacement for analogue model building (Jancic, 74, 2013).

The current state of architectural practice shows that it is certainly possible to design and evaluate architecture in virtual space until the building is eventually constructed, but the question is whether or not this is appropriate given the dimensional discrepancy between process and product. Parallels drawn with automotive industry show that confidence in quality design is only achievable through hand-crafted finesse. While digital technologies in design and fabrication assist in this process, they do not dominate the process. The articles from Mulla, West, and Jancic show contemporary examples of architects who appreciate the value of analogue model building and advocate their continued use in this digital age. While every architect and designer has a unique set of skills and perspectives, it is difficult to argue that an architect can be responsible for the built environment without working in the same dimension.



Credit: Jancic, 2013.

Project

The Design Experiment

The goal of this thesis is to build a case supporting the idea that models are an essential tool in the architectural design process. This hypothesis is challenging the design process rather than design itself; therefore, the most effective test of this idea is to examine and explore the design process, specifically in regards to the use of model building. Rather than conduct a design project where the program, in some way, supports the idea of model building, this thesis uses an existing architectural design project as a means to apply an experimental, model-based, design process. The project serves as a constant in this experiment, with given site constraints and programmatic requirements, while the design ideas serve as variables. The experiment is the design process, in which only physical models are used to explore, analyze, and communicate design ideas. While physical models are the primary form of expression and exploration, the benefit of using digital technologies to expedite the design process cannot be overlooked; therefore, these technologies are an acceptable part of the experiment, but only with the intent of assisting the physical realization of ideas.

Methodology

Aristotle's theory of eidos, or form, relied on the combination of idea and material, where a form cannot be realized without the use of a material to interpret an idea. However, the development of digital design technologies introduces a third element into this dialogue. The computer can be used to quickly generate and edit three dimensional form, but those forms cannot be fully understood until they are materialized. This design experiment seeks to explore the relationship of idea, digital form, and physical model, and show how models



Credit: Joseph Moriarity, 2015.

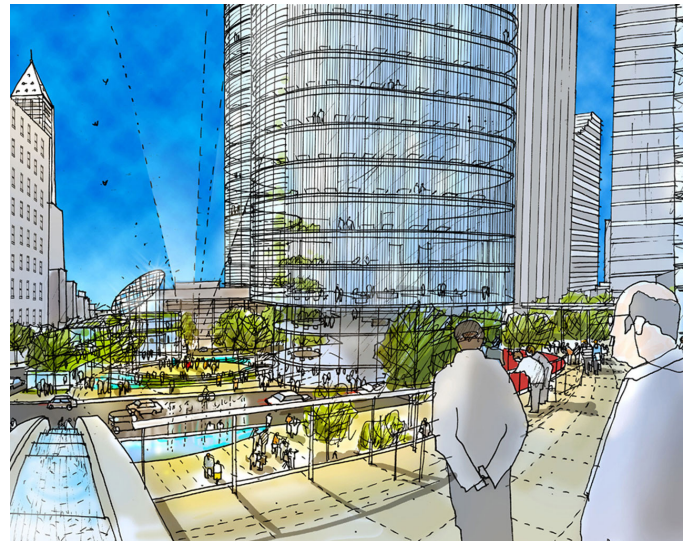
can be used to enhance this relationship. Therefore, this design experiment uses Aristotle's theory as a guideline for its methodology. The experiment is conducted as a series of model exercises, where each model attempts to explore and analyze the relationship between idea and material. While the end result of each model is not necessarily know, the initial criteria is a based on a decision of scale, abstraction, and material that most appropriately relates to the exploration of the intended design idea.

Project

The chosen project for this design experiment is to reexamine the Norman Foster proposal for Seattle's Civic Square, located on the south side of Cherry Street, between Third and Fourth Avenue. The project began in 2005 when the public safety building was torn down, leaving a whole the size of a city block in the heart of downtown Seattle. The property was purchased by the development group Triad Capital, who hosted a design competition for proposals for a mixed use tower. The design brief called for two hundred thousand square feet of office space and three hundred residential units, with a retail plaza at ground level. Foster + Partners won the competition in 2007, but funding for the project disappeared during the recession in 2008. To this day, the site is vacant. This project provides complex issues of site, context, and program that require thoughtful design strategies to resolve. Model building provides a diverse, explorative medium to resolve these design issues.



Credit: <http://www.fosterandpartners.com/media/News/277/img0.jpg>



Credit: <http://www.fosterandpartners.com/media/News/277/img0.jpg>

Site

No architectural design can begin without first understanding the site and context of the project. This study requires the compilation of many sets of data and drawings to fully understand topography, setbacks, property lines, and building footprints. This dense set of information is fairly easily communicated through drawings but not as easily represented with a physical model. Given the density of the area and the scale of the urban context, an adequate physical representation to understand the site would require building four or five square blocks of Seattle, an arduous and time consuming task even at the most basic level of abstraction. While an extensive and detailed model of the context is very useful in a typical design project, it is not as helpful in this instance.

The purpose of the site model is to quickly develop and analyze massing ideas in relation to the context. In this experiment, the goal is to exemplify how to effectively utilize model building in the design process, which inherently suggests an element of efficiency. The time it would take to construct a more typical site model, with a layered topography, curb and street differentiation, building massing, and tree cover, would inhibit the design process, especially in a ten week studio without the help of classmates. A scale of $1/64'' = 1'0''$ provides a feasible area of study to adequately analyze the massing of this project. To capture enough of the context at this scale, the site model is roughly 12 by 18 inches. Within this area there is roughly two hundred feet of grade change. Even with using two foot contours, a typical stacked topographic model would require one hundred layers of material $1/32''$ thick to represent the grade change. This is an outrageous amount of material and cutting time, which does not include the material for the building masses. Therefore, the site is quickly realized by



Credit: Google Earth



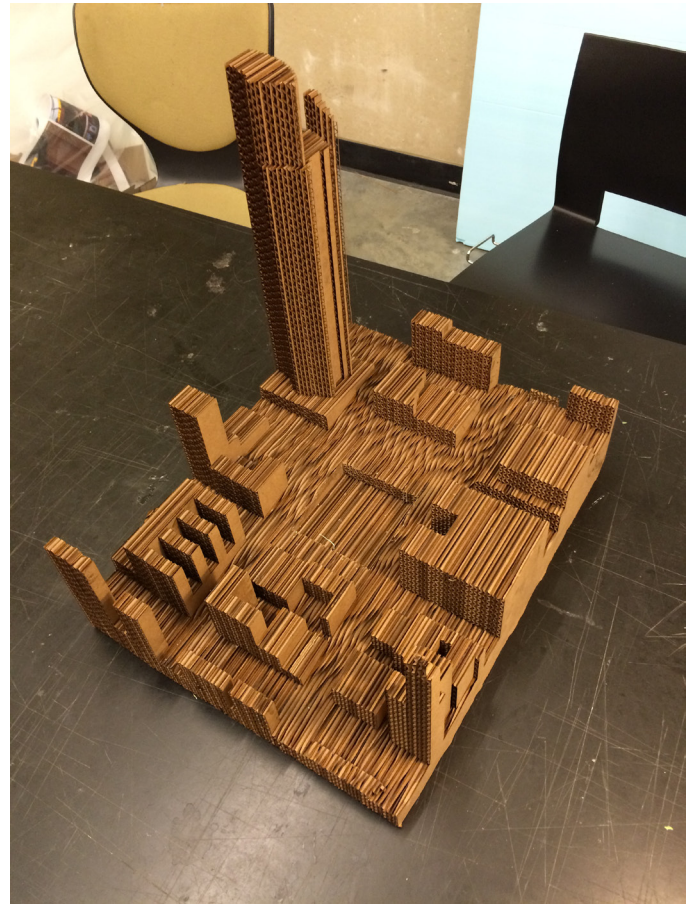
Credit: Joseph Moriarity

slicing a digital model into vertical sections, which are then laser cut out of 1/8" corrugated cardboard. By cutting the site vertically instead of horizontally, the general change of topography can be understood with a thicker material without sacrificing accuracy. At this scale, detailed site information is not as important to convey as the general massing of the area and the landscape of the urban environment.

Climate

Along with digital design tools, architects now have the advantage of utilizing software like Ecotect and Radiance, which can simulate climate data and predict building performance. This data can be dense and difficult to understand without proper training, especially for clients and users to interpret. Physical models present an opportunity to distill this dense data and portray it in a spatial and understandable medium. Nick Dunn's categorization of models includes predictive and evaluative models which seek to materialize sets of quantitative and qualitative data to evaluate design (Dunn, 182). A predictive type of model is applied in this exercise to understand the relation of the site to the path of the sun.

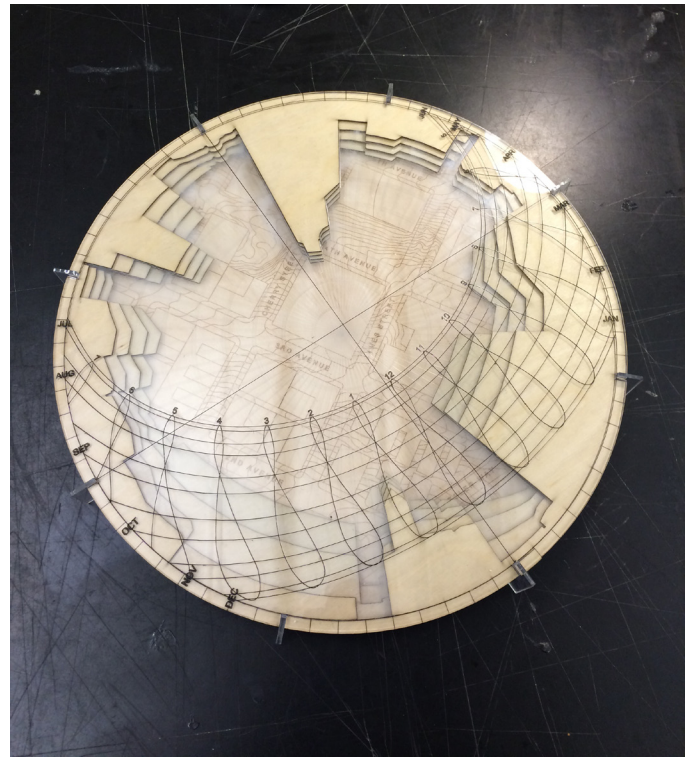
For the ease of building, the site model was cropped parallel to the grid of the city, which in this instance is not in line with the cardinal directions. The city grid of Seattle bends with the shoreline, maximizing views toward Puget Sound, but sacrificing solar exposure. These conflicting orientations are important to resolve in regards to the diverse program of business, residence, and public plaza. To understand these relationships, a simple line drawing of the site is scored onto a piece of wood. In this model, the site is cropped in a circle with the site in the center, which relates it to the path of the sun. The sun path diagram, at forty eight degrees latitude, is scored onto a



Credit: Joseph Moriarity, 2015.

piece of acrylic and then laid over the site. This relationship reinforces the understanding that the site is rotated almost forty five degrees from due south. understanding this orientation is important to locate a public plaza that necessitates maximum southern exposure. Looking back at the cardboard massing model shows that the building adjacent to the southernmost area of the site is an imposing one hundred feet tall.

While digital programs can simulate how the site will be shaded throughout the year, a more simple and complete understanding of the site's solar exposure can be achieved with a physical model. Ecotect is used to project the sky orb from a point on the southern tip of the site, which is similar to taking a picture with a fish-eye lens, while looking straight up from the site. This projection allows the surrounding site to be understood in relation to the path of the sun. The resulting profile is laser cut out of a wood sheet, which can then be placed under the sun path diagram. This information quickly shows that much of the sun will be blocked by the adjacent buildings throughout the year, suggesting that a plaza at grade would not receive the necessary sunlight in creating a successful public space. The three dimensionality of the model suggests that there is opportunity for exposure by raising the plaza above grade. Ecotect is then used to project another sky orb ten feet up from the original point. This profile is then laser cut and stacked on top of the original profile. By overlaying the sun path diagram again, it is evident that more sky is exposed at this elevation. Successive sky orbs are projected, laser cut, and overlaid until enough of the afternoon sun is exposed. This study reveals that a public plaza would need to be at least forty feet above grade at the southern tip of the site to receive adequate sunlight.



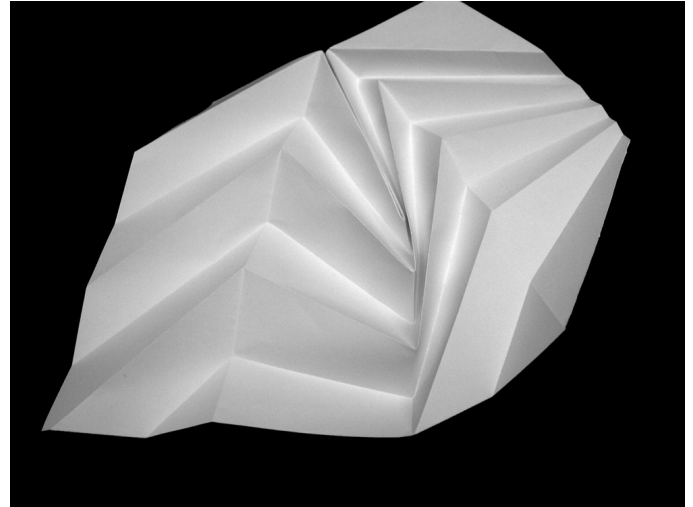
Credit: Joseph Moriarity, 2015.

Massing

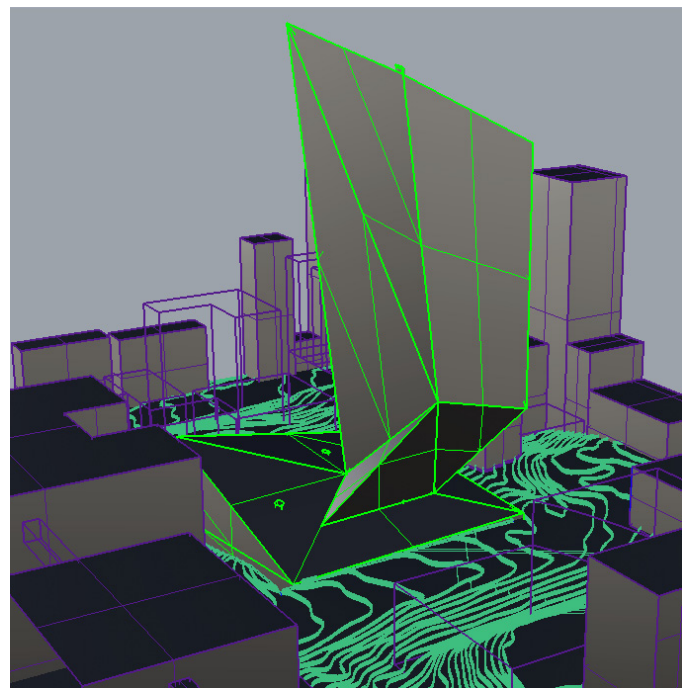
One of the most useful and under appreciated applications of the physical model is its potential for enabling and evaluating creative impulse. Intuition is difficult to quantify in architectural design and more difficult to defend. Most architecture students are taught that design ideas must originate from a sound point of reason, but this belief can cripple designers and inhibit them from exploring and evaluating design ideas. An important aspect to any design process is the element of the unknown. Designers must be comfortable with not knowing the answer, and discovering the solution from a process of testing ideas against constraints. Physical models can be essential in exploring ideas, as well as evaluating them.

Some designers utilize analogue model building techniques to discover design ideas. Zaha Hadid uses the act of cutting and folding paper to explore and discover form, but digital design has become so prominent that many designers now think with the computer to generate design ideas. Digital tools also enable designers to explore more complex forms that are not achievable by analogue techniques. However, without physically analyzing digitally generated forms, they cannot be fully understood. The conceptual massing study of the Civic Square seeks to explore the relationship of the idea, the digital form and the physical model.

One issue with starting a design in virtual space is the enforced precision of the program. This accuracy tends to make designers over-think design ideas or try to solve an issue with too many variables at once. In this exercise, very specific and limited constraints were taken into account to allow the quick, impulsive generation of design ideas in digital space. The software is then used to quickly generate model components that can then be laser



Credit: *Transcendent Architecture*, 2014.



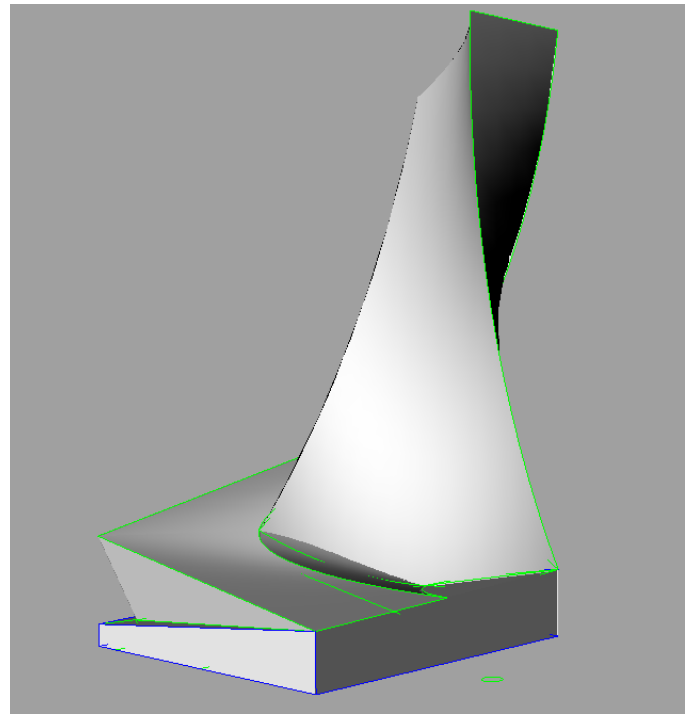
Credit: Joseph Moriarity, 2015.

cut, assembled, and evaluated on site.

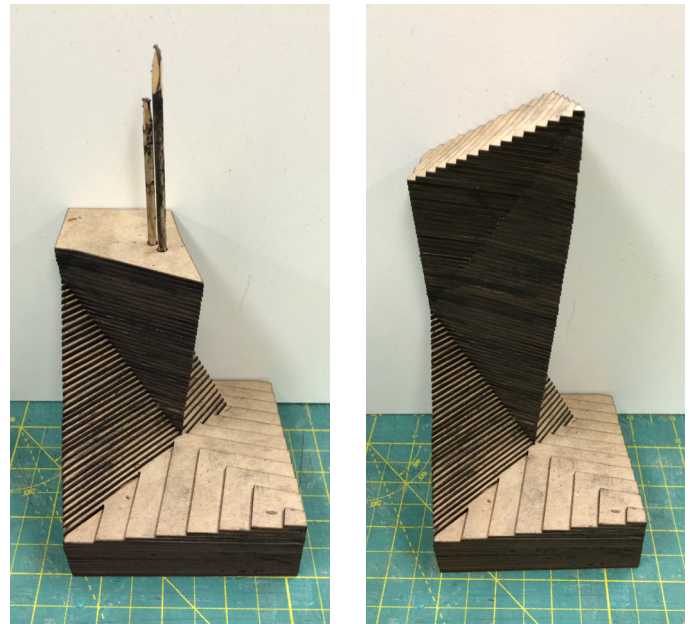
Each massing study starts with four boundary lines following the grade around the site. Then the southernmost tip is raised to forty feet, which was discovered by the sun path diagram model. In some of the iterations, the corners of the site are raised to match adjacent building heights. From here various sizes of floor plates, adequate for office and residential space, are set in space up to the height limit of four hundred feet. Various line and curve tools are then used to create forms by connecting these floor plates to the boundaries of the site. This basic form making technique establishes a concept for the tower, derived from a transition between the various geometries of the site and program.

Various methods and materials are used to realize these forms to explore the process of making the digital into physical. The first method utilizes a similar function as the cardboard site model to quickly generate contours of the digital form. This allows the laser cutter to produce pieces that can be stacked to suggest a fairly accurate reproduction of the form. The horizontal stacking also starts to suggest that these forms are made of an aggregate of floor plates, rather than perfectly smooth, single surfaces. While stacking these pieces requires some labor, an interesting understanding of the form is revealed by understanding how the floor plan of the building evolves throughout the tower. These observations lead to an analysis of each massing and begin to suggest which forms have potential as functioning floor plates, and which are simply too absurd to be feasible. This understanding is not evident in the digital form and requires its materialization to comprehend.

These pieces are cut out of a solid chipboard and a transparent acrylic to provide contrasting realizations of the digital form. Once complete the chipboard models are mostly black, due to



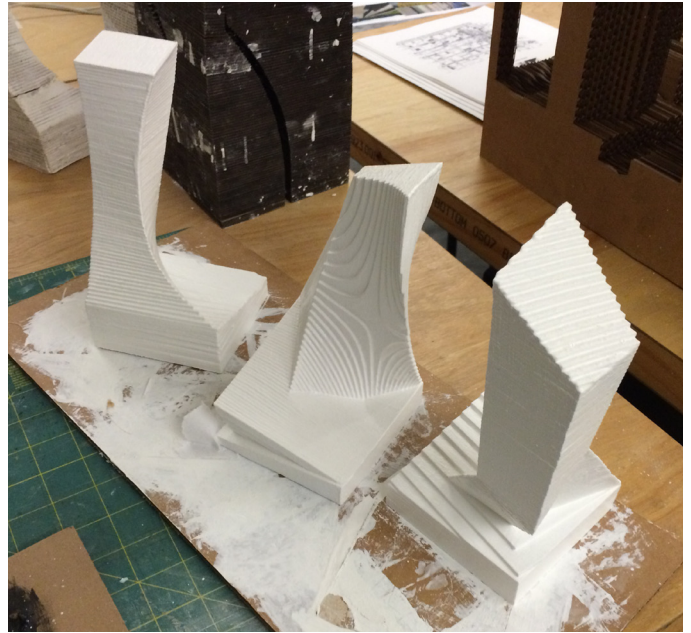
Credit: Joseph Moriarity, 2015.



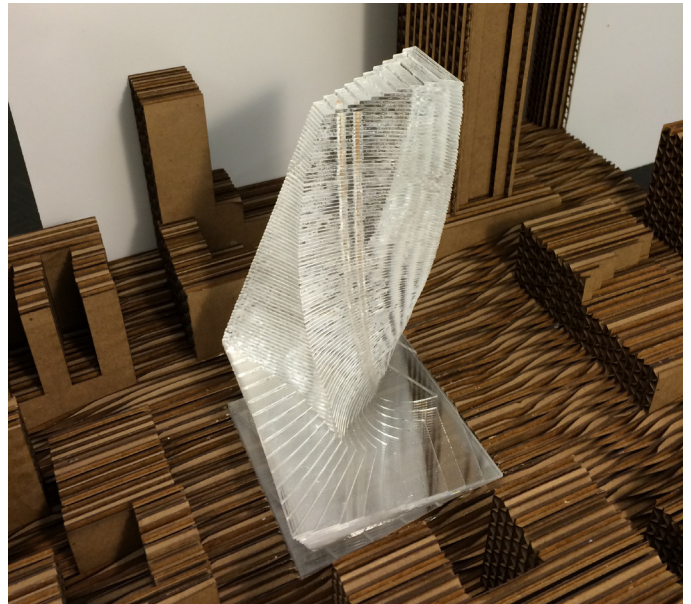
Credit: Joseph Moriarity, 2015.

the exposed edge of the laser-burnt material. This dark appearance obscures the detail of the form and inhibits its analysis; therefore, each chipboard massing is painted with several coats of gesso. This application blends the pieces to more accurately resemble the digital form, while the horizontal striations still register through the gesso, implying the aggregate of floor plates. The white wash also allows the play of light on the form, which gives a more thorough understanding of the massing as an object in space. The acrylic massing creates a less monolithic understanding of the form. The play of light and reflections within the layers of acrylic create varied surfaces with a wide range of colors and tones. The density of information created by this material allows an understanding of the form that is closer to the complexity of a building, rather than the monolithic chipboard objects. This simple choice of material drastically effects the understanding of the form and alters the analysis of the design.

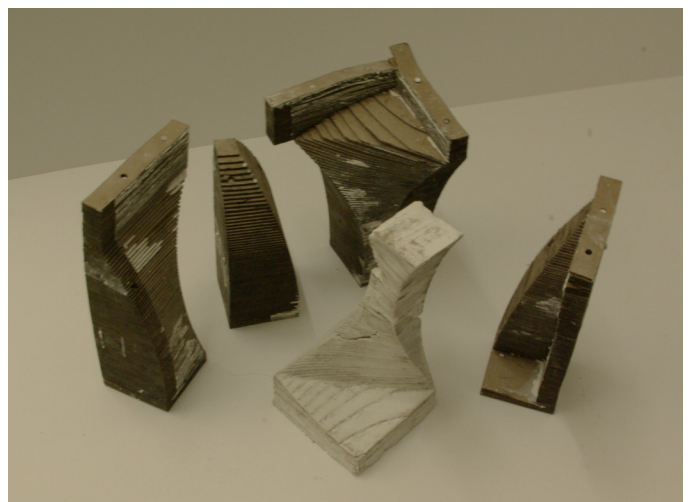
While digital design tools allow the generation of complex form, their accuracy and precision can potentially mislead viewers or clients, especially this early in the design process. These concept models were also digitally fabricated, further enhancing the perceived refinement of the design. To provide a counter for these precise representations, one digital model is used to create a negative form work, which is used to make a plaster casting of the form. While the form work is still digitally fabricated, the plaster casting creates a much rougher interpretation of the form. However, in this instance, the casting was not successful. The narrow neck of the tower prevented the form to be filled, resulting in three separate pieces. While the pieces can still be stacked to closely resemble the intended form, the crumbling pieces of plaster were too distracting to effectively evaluate the design idea.



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.

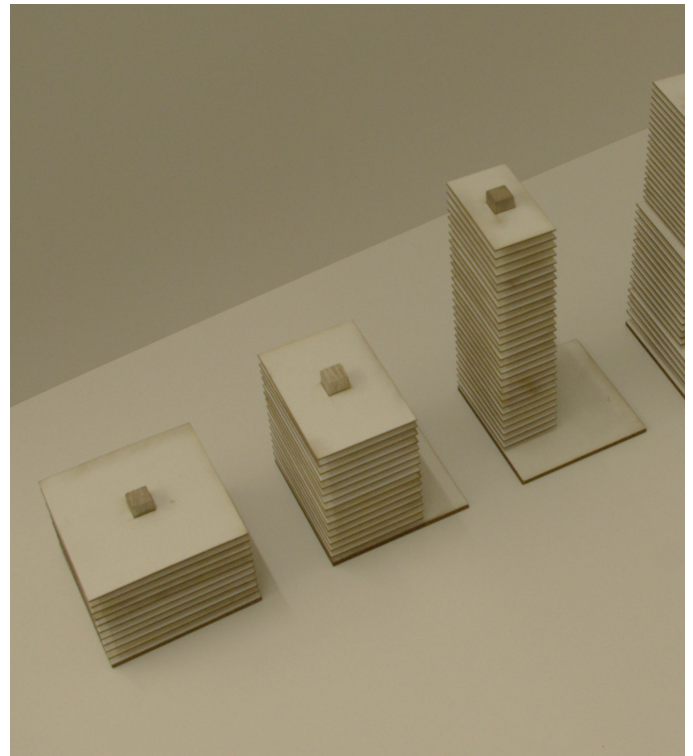
Zoning

The conceptual massing studies are effective in establishing a form making technique based on initial requirements of the project, but their success cannot be established without a more detailed understanding of the site requirements, specifically the zoning regulations. This site is zoned as Downtown Mixed Commercial with a four hundred foot height limit, and a floor to area ratio of ten. This site is also required to have thirty percent of the ground floor preserved for open green space. These factors are essential in realizing the potential massing of the project; therefore, another model study is conducted to methodically understand how each factor effects the overall form. The height restriction of the zoning code also requires an initial understanding of floor to floor height in the tower.

In typical high rise design, office levels generally require 14-15 feet in floor to floor height, while residences require 10-12 feet. For ease of construction these models are stacked similarly to the concept study models; therefore, the floor to floor heights are derived from the thickness of the material. For these models, a museum board is used with a thickness of 0.04 of an inch, which results in floor to floor heights of roughly 15'4" and 10'3" for the office and residential floors respectively.

The most obvious massing for this project is to simply extrude the footprint of the site based on the maximum floor to area ratio, resulting in a ten story building, roughly one hundred and fifty feet. However, these floor plates are far too deep to receive adequate day lighting for office and residential programming. The zoning also requires that thirty percent of the ground floor be preserved for public green space.

The next iteration is simply extruding seventy percent of the site based on the floor to area



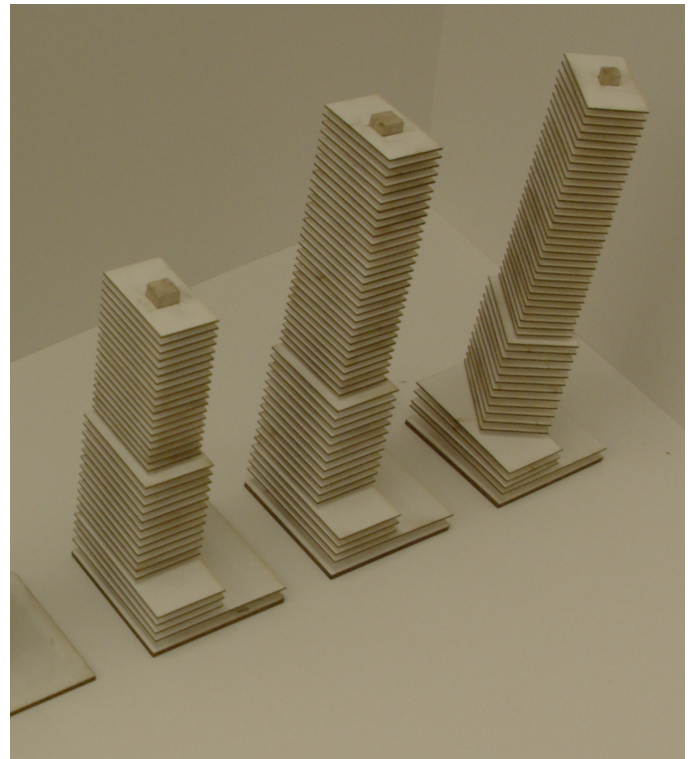
Credit: Joseph Moriarity, 2015.

ratio, while leaving the southern thirty percent for green space. This results in fourteen story building roughly two hundred and ten feet tall. These floor plates are still too wide for efficient office and residential floor plates, and the zoning code also requires that no building facade be wider than two hundred feet or seventy percent of the block width, whichever is greater.

The next model takes into account the maximum width of the building per the zoning code, as well as preserving at least thirty percent of the ground level for public space. This results in a twenty one story building that is roughly three hundred and fifteen feet tall. These floor plates are beginning to work for office space, but they are still too wide for residences, which require a narrower floor plate for adequate solar penetration.

In the next study, the floor plates are differentiated to accommodate the retail, office, and residential parts of the program. The number of each is derived from maximizing the height of the building, while respecting the floor to area ratio, as well as, preserving the thirty percent of open space. This results in a thirty two story tower that is four hundred feet tall. This is made up of three levels of retail, eleven levels of office space, and eighteen levels of residences. This result is close to an appropriate massing for this project that respects the various zoning requirements. However, thirty two stories is quite a bit less than the forty three story proposal from Foster + Partners. Further research into the zoning code revealed that while the height limit for this site is four hundred feet, an additional thirty percent of height is granted if the extra program is residential space. This exception is due to the adjacent sites which are zoned as Downtown Office Core, which have no height restriction, and an attempt to balance downtown living and work space.

The next iteration is too add residential



Credit: Joseph Moriarity, 2015.

floor to take advantage of this zoning exception. However, the floor to area ration must still be respected. Extra residential floors cannot simply be added on to reach the new height limit of five hundred and twenty feet, because this would exceed the floor to area ratio. Therefore the floor to floor height of the residential units is increased from 10'3" to 12'0". This allows extra residential floors, while maximizing the height of the building, and still respecting the floor to area ratio.

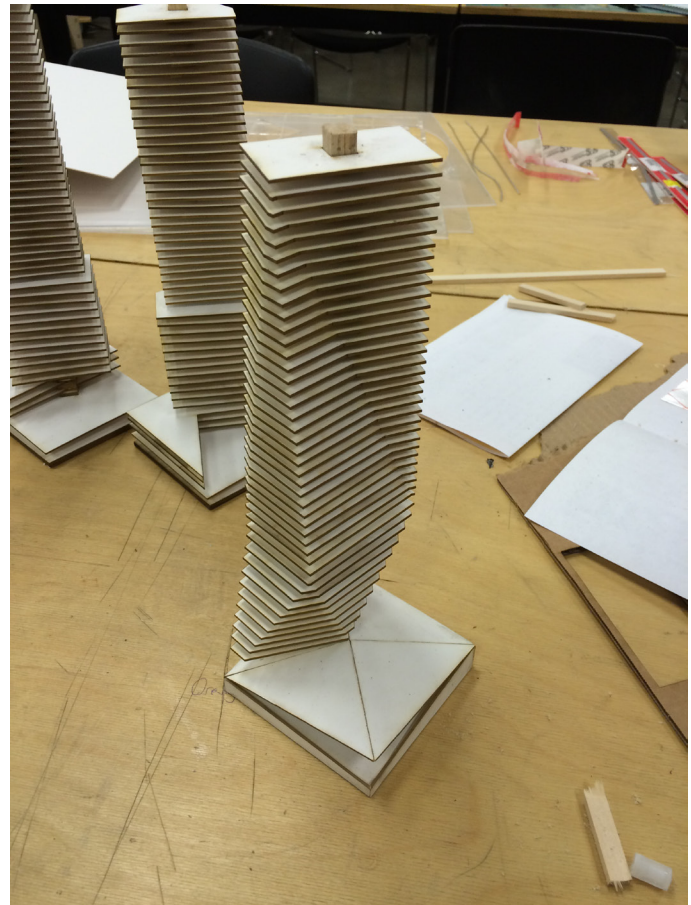
Once the general massing is established, based on the zoning requirements and spatial need of each part of the program, this can then be referenced with the initial conceptual ideas of transition and negotiation of cardinal and city orientation. The next iteration of the massing takes the previous model and rotates the whole tower toward due south. This creates a triangular void at the north end of the site, and there is no reference of the city grid.

The next model attempts to resolve this discrepancy by rearranging the floor plates so the one edge is perpendicular to due south, while the others are oriented with the city grid, resulting in five sided polygonal floor plates. While this from successfully negotiates optimal southern exposure and reference toward the city, the north and east elevations are quite imposing and relentless on the street front. Some consideration needed to be given to the view corridor along these streets, requiring the building to give some relief from the urban street wall.

The final two iterations utilize the form making techniques from the concept models to negotiate the discrepant orientations, while giving some relief to the urban street wall. This resulted in two interpretations, one using angular form making and the other curvilinear. After analyzing these two options, it was revealed that the angular version more successfully resolved all of the issues



Credit: Joseph Moriarity, 2015.



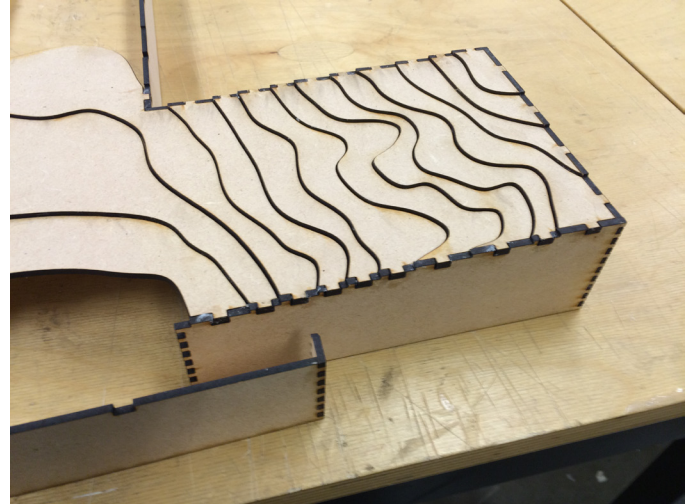
Credit: Joseph Moriarity, 2015.

of zoning, orientation, and function. The curvilinear option was successful in resolving the orientation with the zoning requirements, but the curves resulted in floor plates with sharp angles that would not be functional as office or residential space. The angular massing was chosen as the design idea to develop further.

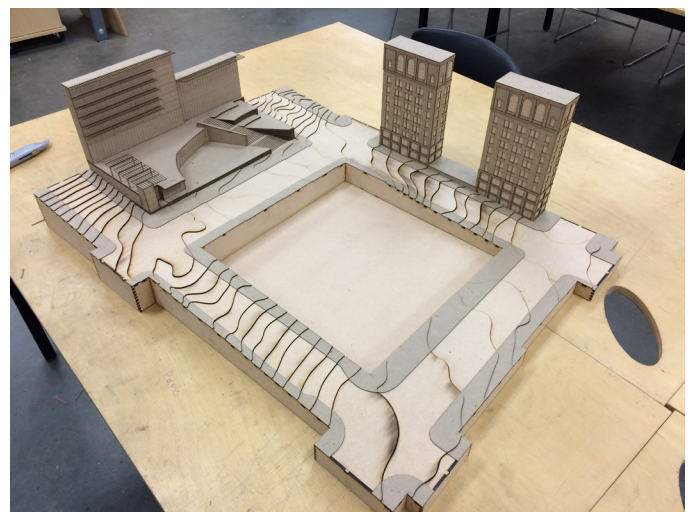
Site in Detail

In the previous massing studies the public plaza was simply represented as a singular surface that somehow negotiated grade and the height necessary for adequate solar exposure, but this space requires much more individual study to resolve various issues of landscape and public versus private access to the project. This type of study requires a more detailed understanding of the surrounding context.

The next model exercise is to create a detailed site model at $1/16'' = 1'0''$ with, street and curb information, as well as detailed elevations of the surrounding buildings. While this is a complex and time intensive production, it is necessary because it will provide contextual information to use in the development of the design for the rest of the project. By utilizing digital fabrication, this type of detailed model can be produced reasonably quickly, by etching facade details into pieces of chip board. A common mistake when laser cutting is not giving enough thought to the assembly process. The pieces may be cut precisely but the error of the human hand can sometimes make digitally fabricated models more time consuming than if they were produced by hand. By taking extra time in the digital drawing process of laser cut pieces, techniques of joinery can be utilized to assist the assembly process and remove the impact of human error. The vertical pieces of this site model are cut with notches to locate the horizontal layers



Credit: Joseph Moriarity, 2015.



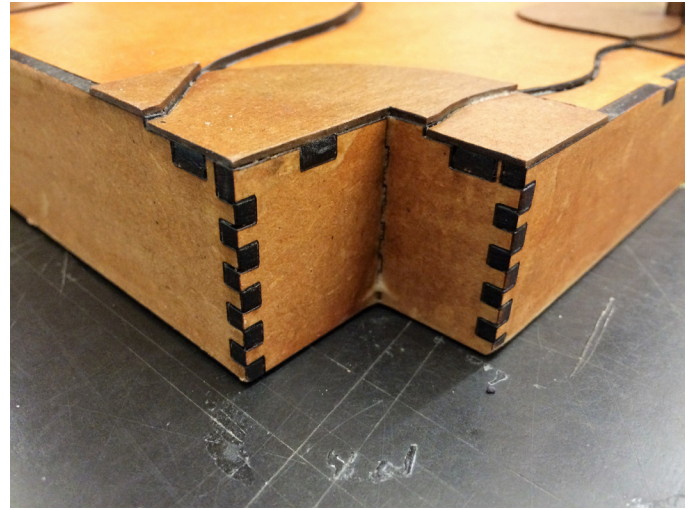
Credit: Joseph Moriarity, 2015.

of topography, this allows the model to inform the maker, rather than the maker having to back track to correctly assemble the layers. The vertical connections are also cut with a jigsaw pattern to assist the pieces in maintaining perpendicular corners, reducing the effort of the maker to precisely assemble the model.

A constant issue with laser cutting is dealing with the effects of burning. There is a constant balance of quality and efficiency, especially with thicker materials. Cutting quickly often runs the risk of severely burning the material. In this case, much of the mdf used to create the topography was burned. A common technique for site models is to paint them white to give a uniformity to the context, allowing the project to stand out, but painting this model would obscure much of the facade detail and hide the careful attention that was put into the craft of the pieces. Therefore, the burns were sanded away and the whole model stained with a golden pecan wood stain. This finish helps hide the imperfections while accentuating the facade details and also unifying the mdf and chipboard with a common hue.

Landscape

Before the ground level can be analyzed, the core of the tower needed to be more accurately understood. An quick study of high rise regulations revealed that one elevator is required for every fifty thousand square feet of floor space. This building would require eleven or twelve elevators, given its gross square footage around 570,000 square feet. A quick drawing of a core with twelve elevators and two exit stairs was made and pasted on a sheet of museum board to serve as a place holder in a study model of the site. From the massing studies, the orientation of the smallest floors was toward due south; therefore, it made the most sense to orient the



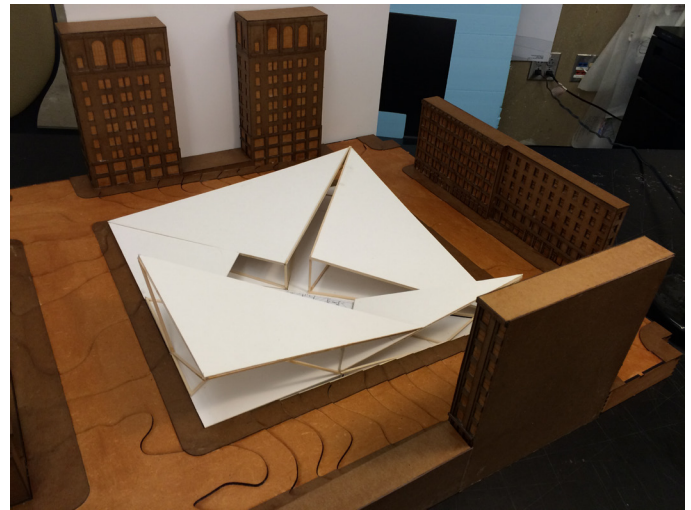
Credit: Joseph Moriarity, 2015.

core with the smallest floor plate, minimizing the effects of rotating floor plates with a constant core.

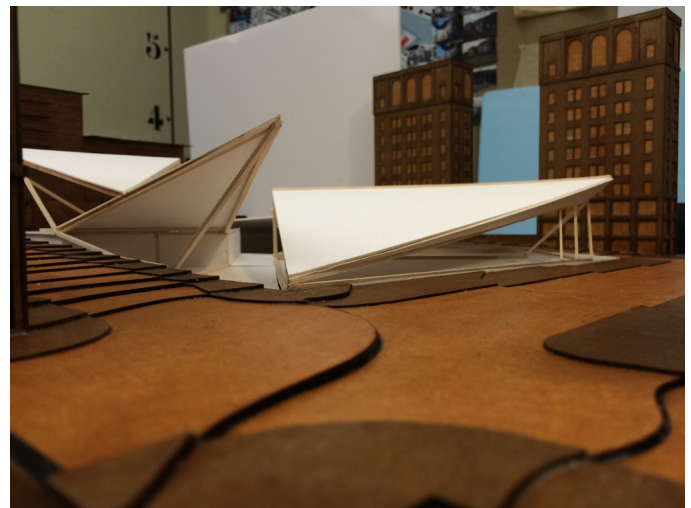
Once the core was established a model study began to resolve issues of access and landscape on the ground floor. Since all the models up to this point in the design process have been digitally fabricated in some way, this model would be constructed using traditional analogue techniques. This technique was used to study the act of making in the design process, since, in digital fabrication, the computer replaces the hand in the thinking process.

Using a combination of wood sticks and sheets of museum board, an idea for combining landscape and building to negotiate the grade change and provide points of access emerged. Since this model was not digitally fabricated, the end result was not known when construction began. Rather the process of testing and constructing ideas relies on a process of trial and error. Using an analogue technique at this scale quickly revealed that process was much slower than the generation of ideas. Once an element was finally resolved a new idea emerged. The resulting model was then a combination of dissimilar ideas, rather than a design strategy that synthesizes resolutions for various issues of the ground level.

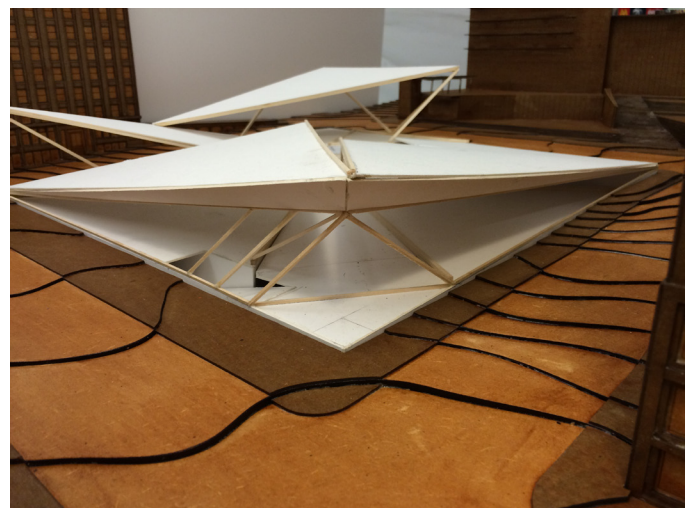
While this hand cut model was not successful in effectively exploring ideas about the base of the project, it did reveal key issues to consider in future design development. The first and most obvious was just how large the public space was being represented on the site. A plaza of this size would feel empty and unwelcoming; therefore, it became a design task to figure out how to break down the scale of the plaza. In this model, the plaza also acted as a roof for the facade facing 3rd Avenue, which revealed that the space underneath would be useless without some strategy for light penetration.



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.

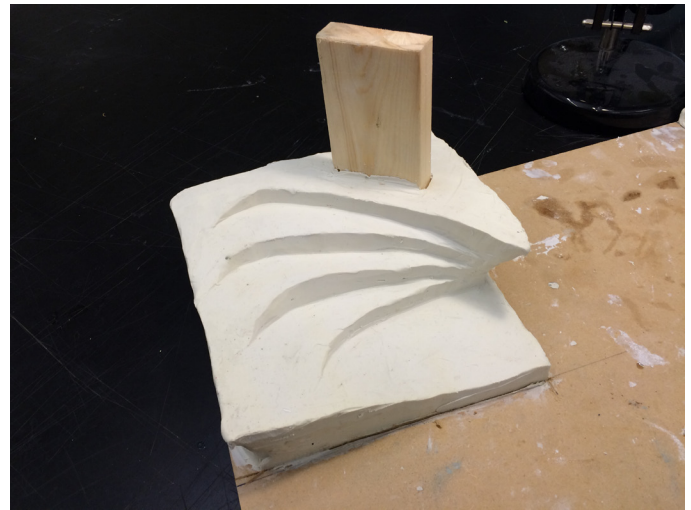
Learning from the failures of the previous exercise, the next model study would be important to utilize a technique and medium to quickly express and evaluate ideas. The analogue technique of cutting and gluing allowed the hand to be more involved in the thinking process, but the medium inhibited the effectiveness of the hand to quickly generate ideas. Therefore, the next model exercise utilizes techniques and mediums that allow the hand to immediately express ideas.

For the next model exercise the project was scaled back to 1/32"=1'0" to cut down on the amount of material necessary to express ideas. This exercise utilizes clay, wax, plaster, and stone with analogue techniques to alter and express ideas with the material. The chosen materials are not alien to architecture, but they are rarely used, especially outside the context of school. These sculptural materials are effective for this design task, because the goal is to resolve issues of transition from landscape to building.

Clay provided the quickest and easiest material to manipulate because the only tools required are the hands and a small scraping tool. The material provides an expressive medium to explore ideas of landscape transitioning to become building facade. These ideas would be difficult to realize with more traditional techniques.

Wax is another equally workable medium, with the only extra requirement of heat. Room temperature wax is difficult to work, but kneading the material quickly warms it up, becoming much more pliable. Its hardened state provides a carving material that holds its form more effectively than clay. These characteristics provide an array of working options that result in more refined expression that is also easily achieved.

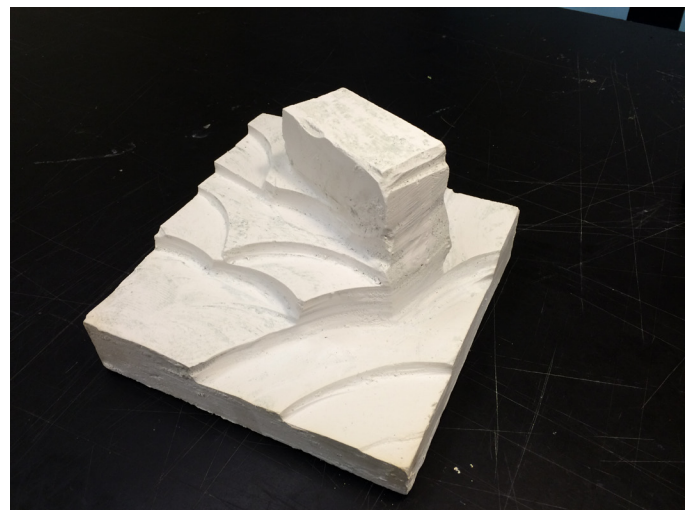
Plaster is traditionally a casting material, but this is essentially representation of a form that has already been conceived. As a carving material,



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.

plaster can be used to generate ideas in an intuitive manner. First a block was cast the size and volume of the site. Then, rather than slowly carving with chisels and hammers, an electric grinder was used to quickly remove material. In this model, detailed control is sacrificed, and the characteristics of the tool become a unifying design element. The wheel of the grinder was used to create curved facades and plateaus that wrap up and around the core.

This medium of carving was taken further by applying a similar technique to a block of soapstone, where the same grinder was used to remove material. Since the stone is more resilient than plaster, the process of carving is slowed, forcing a more deliberate use of the tool. This resulted in a more refined and thoughtful form, where the grinder simply ate away the plaster with reckless abandon.

This series of sculptural studies revealed several opportunities for creating a varied landscape of open space and building facade, as well as, techniques for negotiating the grade change across the site. They also revealed drawbacks of limiting the public space where solar exposure is the greatest.

Solar Shading Studies

In Joel Shack's studio, he deliberately asks his students to jump from small to large scale design explorations with the intent of drastically altering the perception of the project. This shift in perspective tends to lead to important discoveries in understanding the project. This concept is referenced by jumping to 1/2" scale to explore sun shading strategies. Since a core concept of this project is providing maximum southern exposure, it is also important to manage that exposure with adequate shading, making the spaces comfortable throughout the year.



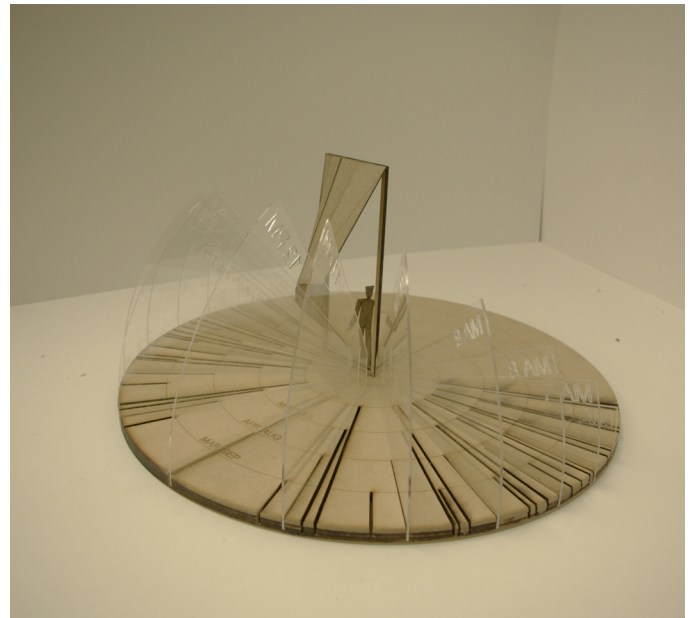
Credit: Joseph Moriarity, 2015.

Typically sun shading studies are done by calculating the altitude and azimuth of the sun at various target days throughout the year. This data is then used to generate planar surfaces that effectively block the sun at these target dates. New technologies, like Ecotect, can now generate dynamic shading devices that respond directly to the path of the sun. These forms are the result of complex calculations done by the computer and not the designer. By utilizing model building to understand the path of the sun in three dimensions, designers can respond directly to the sun in real time, without having to perform calculations or interpret data.

This study is achieved by laser cutting a disk with slots that represent the azimuth of every hour of daylight from March to September. The winter months are not necessary to model because daylight will be welcome during this time in Seattle's climate. The slots in the base correspond to acrylic fins that represent the altitude of the sun at each hour of daylight. The combination of these pieces results in a three dimensional representation of the path of the sun throughout a typical day in each month.

A generic window frame is then made to set at the center point of this sun dial. Dimensions can then be studied with various materials to explore sun shading devices that respond directly to the path of the sun. Since the Path of the sun is circular and the window frame is rectangular, digital software is useful for negotiating these geometries. By transferring data into digital space, sun shading devices can be explored and developed. These devices can then be laser cut to quickly realize complex forms, that can then be evaluated against the path of the sun.

While these individual shading devices are effective in blocking unwanted summer sun, they suggest quite extensive use of material, and



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.

effectively block some of the best westward views of Puget Sound. It is also difficult to conceive how these devices will appear in aggregate on the facade of the building. However, the benefit of this tool, is that it is scale-less. Any scale of model can be applied to the dial to test solar penetration; therefore, this tool will be useful to test later developments in the design process.

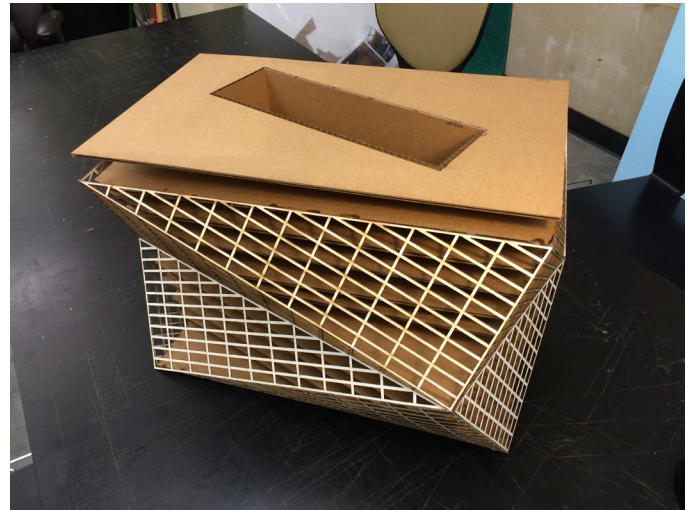
Spatial Studies

All of the models up to this point in the process have essentially been objects with little spatially experiential characteristics. This realization suggested a further design goal, to rethink the typical tower floor plate, and seek opportunities to create vertical, continuous space within the tower. These vertical spaces could act as lobbies or gardens, creating a more unified vertical community.

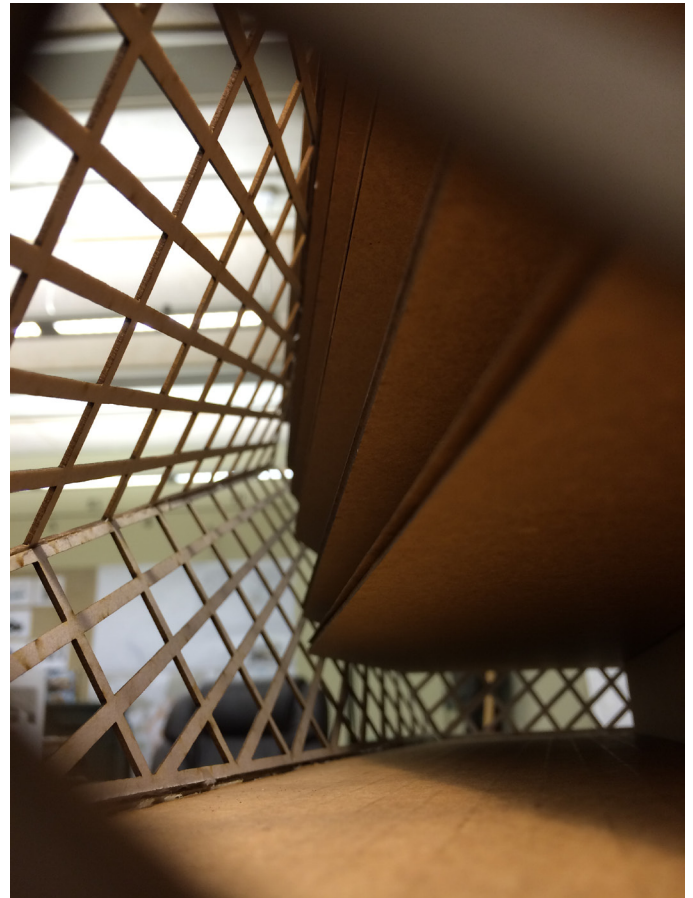
Modeling a spatially rich architecture environment would require a large scale model, at least at $1/16''=1'0''$, but preferably at $1/8''=1'0''$ or greater. Modeling the entire project even at $1/16''$ scale would be very time consuming and require an immense amount of material, but modeling the whole building is not required to explore spatial ideas within the tower. Therefore, a block of twelve floors was isolated to study the possibilities of creating vertical space at $1/16''$ and $1/8''$.

The initial concept and massing models were conceived as solid forms sliced up into floor plates, but this is not necessarily a requirement. There is opportunity to create vertical space by disassociating skin and floor. These models seek to exploit the spatial opportunities of peeling the skin away from the edge of the floors creating interior balconies and sky courts.

The laser cutter is again essential in quickly producing complex screens that serve to represent



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.

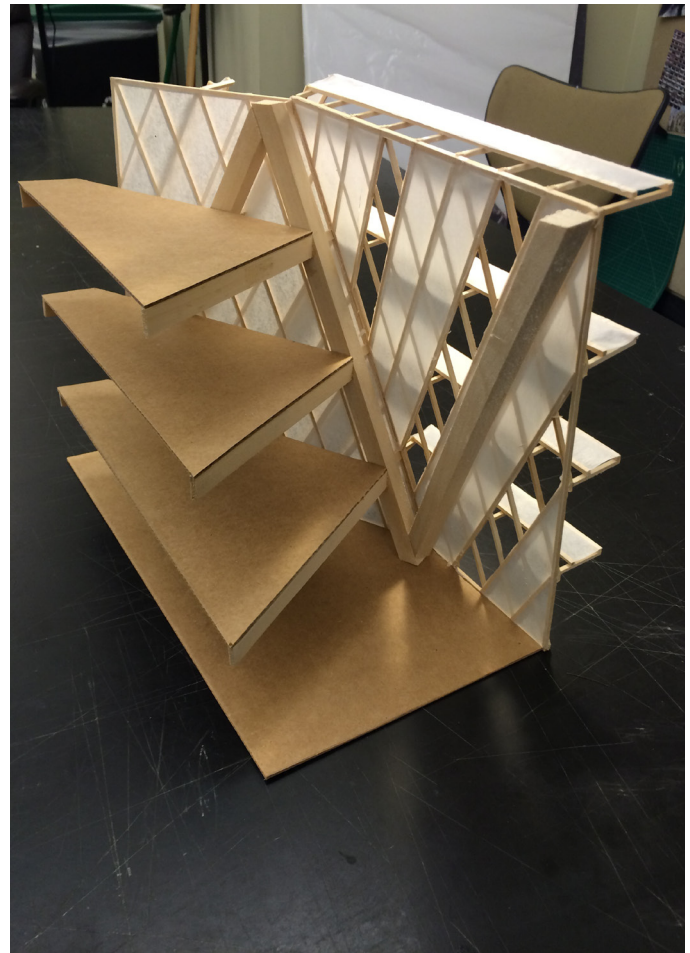
transparent curtain wall systems that can span between floors. Evaluating these studies in relation to the original concept models suggests a wholly different method of form making, alien to this project. While the spaces created and patterning of the skin are successful and informative to the project, the form making is abandoned in favor of a technique more in line with the original concept. These vertical spaces should be created by cutting away areas of floor, preserving the purity of the conceptual form.

Tectonic Expression

The spatial studies of skin and floor plate illuminate the issues of wall thickness in complex geometries. Even a single sheet of thin material cannot perfectly reconcile with an adjacent piece in a complex construction of irregular angles and planes. These spatial models were also built without any evidence of structure. Resolving a structural solution that coincides with the geometry of the project is essential for the design to succeed. These issues suggest further model exercises at a larger scale to explore and analyze how the components of the facade, structure, and floors will interact. This is again reminiscent of Joel Shack's teaching method, which emphasizes the importance of tectonic expression in architecture. This model exercise seeks to explore and discover tectonic expression appropriate for this design project.

In these model exercises, the laser cutter is actually not a useful tool because its z-axis is set to ninety degrees from the material. Resolving the interaction of the components in a complex geometry requires variation in the x, y, and z-axes. Therefore, handcrafted techniques are used to explore possible tectonic solutions in this system.

A section of the facade where two dissimilar planes meet is isolated to explore tectonic solutions.



Credit: Joseph Moriarity, 2015.

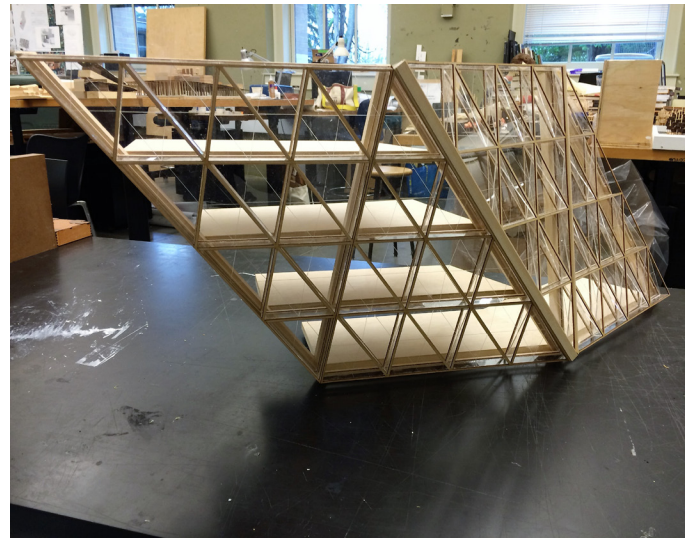


Credit: Joseph Moriarity, 2015.

Constructing a curtain wall with a triangulated pattern is difficult without laser cutting or tediously cutting triangles out of a flat sheet, however by responding to the medium of wood sticks, a bypass system can be utilized to construct the same pattern but with added depth. While this design decision comes from the medium of the miniature, it can also lead to applicable solutions in full scale construction. The structure of the curtain wall also follows this triangulated pattern, but negotiating the intersection of three foot thick columns is much more complex than the intersection of singular lines. Much trial and error is necessary to manipulate these columns until they fit appropriately in the system. This discovery in the model starts to suggest possible construction methods, where steel would likely be required to span the distance, but concrete could be used to resolve the complex intersections, as well as provide fire proofing for the steel structure.

These tectonic models also take advantage of the sun dial to explore possible shading devices that fit with the geometry of the system. The sun model is essential in quickly realizing a shading device on a complex structure, where even simple calculations would be difficult to achieve due to the irregular angles of the facade. These shading strategies, while effective, still detract from the purity of the overall form. The sheer volume of shading devices required to cover the facade of a five hundred and twenty foot building would be too complex and numerous to comprehend. However, the depth of the shading devices combined with the bypass system of construction suggests a double layered glazing system. By increasing the depth of the facade, some solar shading is achieved, and the double layer now acts as a natural ventilation system to help cool the building.

These discoveries of tectonic depth, structural finesse, and double layered glazing are



Credit: Joseph Moriarity, 2015.



Credit: Joseph Moriarity, 2015.

applied to a more complete tectonic model. Rather than simply creating a second glazing layer parallel to the first, there are two parallel frames, and the glazing angles between them, creating an element of depth in an otherwise monolithic facade. These slanting planes also create facets for sun shading and air intake. The lines of structure are also used to inform the cutting away of floors to create internal vertical space.

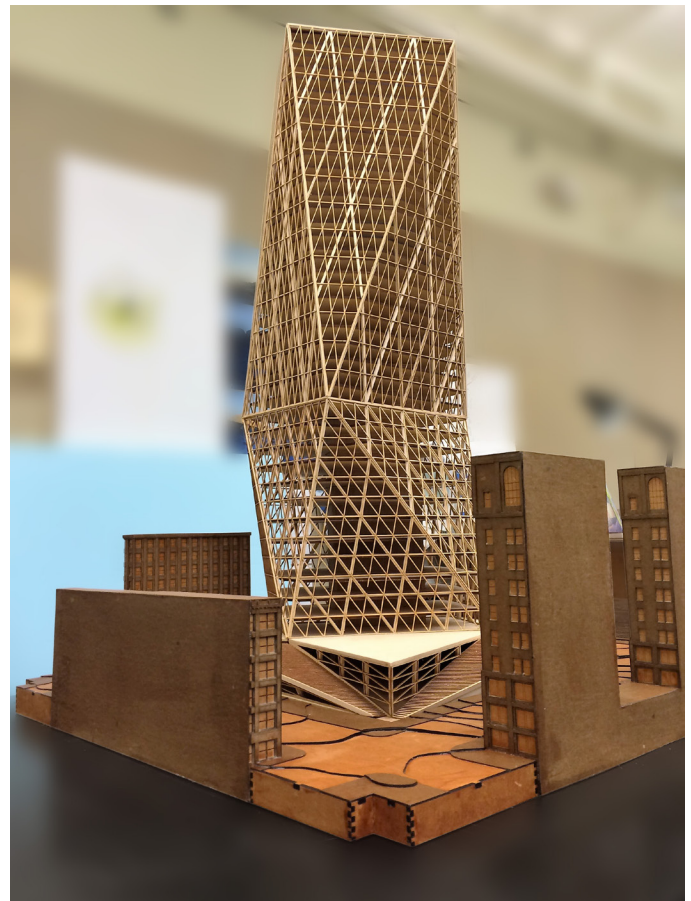
Presentation Model

Model building exercises have been utilized at various scales and aspects of the design problem, but the culmination of these ideas in a presentation model is the most essential application for understanding and evaluating the project. A mock up of the presentation model is done before starting final construction, to quickly evaluate the final iteration of the design. The concept for the massing of the tower was never fully resolved, but this mock up allows final resolution of the idea. The base of the tower is oriented toward due south, then rotates to become parallel to the city grid. This first section contains the office space of the program and the height is in the realm of the adjacent buildings, providing another level of reference for the context. The residential floors above then rotate back toward due south.

The final presentation model uses this resolved concept, in combination with the discoveries of landscape, public plaza, structure, tectonic expression, and vertical space. The resulting geometry from the rotation of the floors is a series of triangulated forms with an intuitive rhythm for structure and curtain wall system. The plaza uses a similar triangular form to connect the base of the tower to the southernmost tip of the site, creating a moment of prospect looking out over the cityscape. Public stairs are used to negotiate the



Credit: Joseph Moriarity, 2015.



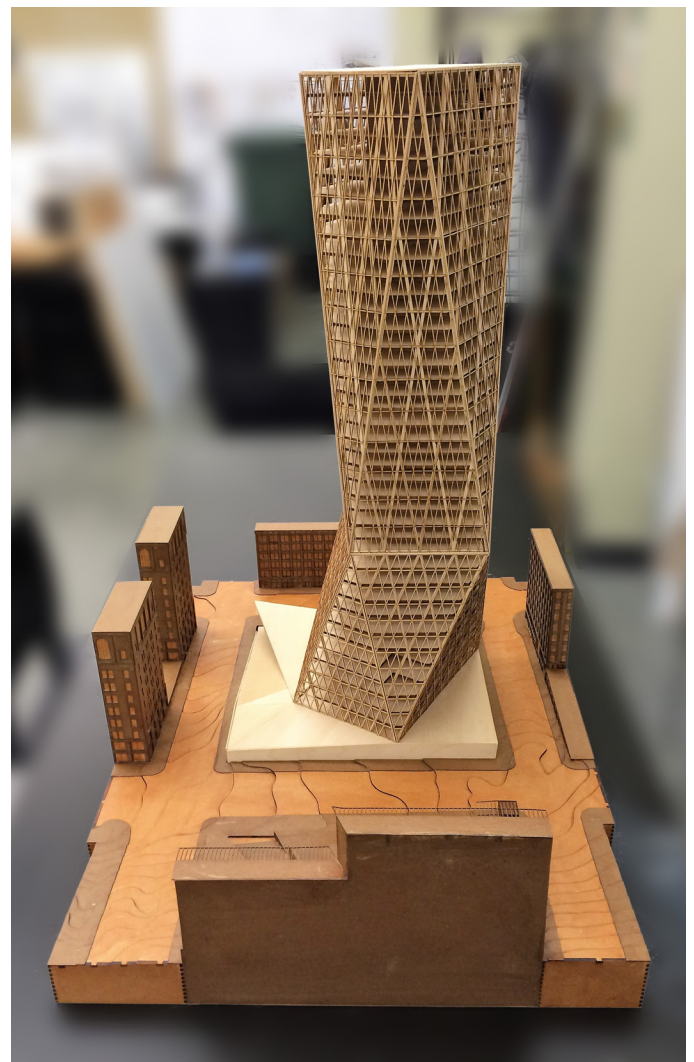
Credit: Joseph Moriarity, 2015.

grade change around the plaza and allow circulation throughout the site. The construction of the final model was a culmination of lessons learned from the various model explorations in the design process. Various digital and analogue techniques were employed where they were most effective. The pieces of curtain wall were laser cut out of thin sheets of wood to quickly achieve the density and accuracy, while the structure was cut by hand to accurately negotiate the complex, triangulated geometry.

Conclusions

This design experiment pushed the application of model building to explore, develop, and analyze architectural ideas. By seeking every opportunity to exploit a physical medium, the effectiveness of model making in the design process was truly tested. The most effective use of the model was communicating ideas. By making a physical artifact of each idea, a tangible progression of ideas can be easily understood. The least successful result of this experiment was utilizing model building to explore spatial experience from the human scale. This failure was, in part, due to the project chosen. The tower was simply too large of a building to examine holistically at a large scale. Another factor was the limitations of testing space in a physical medium due to the expense of material. While a mock up is an excellent tool in aiding the design process, it is too large of a medium to quickly test ideas. This suggests that perspective drawing and rendering is essential in studying the human experience. However, the model still surpasses two dimensional media in understanding form and contractibility. Perhaps the most successful, and surprising, result of this experiment was the use of model as a translator from digital to real. By constantly going back and

forth from virtual space to physical media, a much deeper and thorough understanding of the project was achieved. This dialogue of virtual and real tools also helped reveal, the strengths and weakness of each. Sometimes the laser cutter is better suited to realize an idea, but other times the intuition of the hand is essential. The ultimate realization is that the combination of these tools leads to the most successful understanding and execution of design.



Credit: Joseph Moriarity, 2015.

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