CRAFTING MASS PRODUCTION:

EXPLORING THE ADVANTAGES AND CONSEQUENCES OF MODERN CONSTRUCTION METHODOLOGIES

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Crafting Mass Production: Exploring the advantages and consequences of modern construction methodologies.

Introduction

Prior to the introduction of digital design and machine production, the methodologies of the architectural profession were considered a form of craft.[1] Architectural skill once extended across every aspect involved in the design and construction process. Architects worked physically with engineers and builders to understand the structure's materials and the builder's techniques in the pursuit to understand their abilities and how to push them farther. However, since the introduction of machines and technology, the majority of manual methods of design and production have been exchanged with mechanization. Although many of these innovations provide leverage to designers' abilities, automated systems mask the user's understanding of each monotonous step involved in the process.

Architecture is evolving due to the profession's dependency on mass production. Advancing technologies of our "era" have lead a multitude of modern architects towards a reliance on the machine's abilities versus their own. For the majority of architectural firms, the once common drafting table has been exchanged for the computer. Architects no longer toil in the materials and physical processes involved in production, instead separate themselves from the control of their design through layers of software applications, drawings, and verbal specifications.[2] The increasing division of labor within the architectural practice itself has therefore fragmented the role of a single architect into separate specializations. In addition, the ability to produce more for less with mass production has transformed structures into a commodity argued by some as a form of anti-art.[3] While the evolving computer and machine technologies further impede on the architectural design and production processes, how can architects and designers embrace numerous technological advantages while still utilizing the notion of craft?

Today, the architect is no longer the "master builder". We must change the existing methods of mass production to encompass the everlasting importance of craft. In order to do so we must first understand the machine and its functions. Next, we must focus on breaking each design into smaller components to allow materials to be produced in a more effective manner. Using the modern advancements of our mass production abilities, architects can now affectively control the machines to manipulate materials to form products far more congruent with our original idea.

Changing Definition

Craft implies something clear, but its nuances of interpretations have stretched the meaning far too thin. Its definition varies constantly throughout time and even nationalities. In the western world, the term's technical definition reduces its meaning to merely making something by hand[4], however modern theorists claim its meaning more broadly. Although the interpretation of craft has become ambiguous, some aspects of its definition remain the same.

To many, craft is associated with quality. In most instances, craft within the architectural profession is exactly this. Quality can serve as a measuring stick for craft through comparison of their similar forms. Designers proudly label their products craft as symbolizing their care to its appearance and tactility, however craft is not affected by its aesthetics. The technological world has provided us with a new set of tools and design methodologies, changing our methods of production. Modern craft no longer rests on the abilities of human hands, rather the handling of our materials. Craft generally lies in the making part and every detail in our methods of fabrication defines its value.

Salvaged Clay Roof Tiling Detail – Safranbolu, Turkey

Revolution vs. Evolution

Up until only a few hundred years ago, constructing by hand was man's only option in fabrication. High craftsmanship was highly respected and dependent upon the skill of hand, precision, and regularity.[5] For example, the enormous scale of the Egyptian pyramids possessed a symbol of power, however they were achieved through the geometric symmetry and the diligent construction. Architects of these ancient times possessed multiple skills, establishing them as master builders. Architect Filippo Brunelleschi was a master builder of his time, having total control and responsibility for the fabrication of the dome of Santa Maria del Fiore in Florence serving as the architect, builder, engineer, and scientist during its design and fabrication.[6] Each of these four disciplines provided him the ability to create all the innovative features of its construction.

The industrial revolution of the eighteenth century introduced the machine, altering present day methods of construction. For modernists, the transition of fabricating by hand to fabricating by machine became a new aspiration for building manufacturing.[7] The new technology provided architects with the ability to produce new structures with innovative materials that pushed the limits of scale, allowing builders to work faster, cheaper, and more accurately. The machine was dominated by precision, allowing all levels of production to be consistent. During the twentieth century, craftsmanship began measuring by efficiency. Architects, such as Le Corbusier, engaged the benefits of machine production, venturing to devise a connection between economies and social agendas to pursue a streamlined home development.[8] Foreseeing the vast benefits of the machine, efficiency became the new demand in fabrication and eventually introduced the off-site manufacturing method known as prefabrication.

Prefabrication was generated by mass production and has been a continuously evolving methodology of building design construction intended to resolve a multitude of inefficiencies of traditional building construction. Internationally recognized architects such as Frank Lloyd Wright, Le Corbusier, and Walter Gropius stepped up to the challenge, each creating their own unique approach, however their designs were destined for failure before their pencils scratched the paper. Stephen Kieran, architect and author of *Refabricating Architecture*, elaborates:

> *Twentieth-century dreams of an attainable off-site architecture were underpinned and motivated by political agendas that ranged in ideology from Marxist to liberal to social democratic.*[9]

The reluctance to correctly focus their design towards solving a relevant issue soiled their opportunity to exploit their designs, inevitably diminishing the designer and client's desire to pursue prefab in the future. Although prefab's premise promised several rewarding opportunities, almost every architect's attempt to incorporate into mainstream housing system resulted in failure due to their restrictive agendas.[10] Most attempts at prefabrication have failed due to economics, market perceptions, and peculiarities of the home-building industry. Traditional construction methods have long been less expensive than prefab experiments, and perceived by the public as being of higher quality.

Buckminster Fuller's failure in his 1949 Dymaxion Prefab House Prototype resulted by his pursuit to commodity architecture.

By making it possible to create nearly worthless reproductions of formerly valuable works of art, the machine impairs the value of these items. Wright viewed these products of the machine as false beauty arguing, "Machine cheapens art".[11] Critical changes were made to mass production because of the innovations of the information age. Although Wright stood strongly against the mass production, his vitriol wasn't for mass produced objects, rather its methodology. Wright claimed any bad results of the Machine are due to misuse.[12]

Since the digital age, prefabrication has reemerged. In addition to the raising demand of sustainable solutions for architecture, off-site manufacturing has become a popular topic for its extreme precision using computer generation and fabrication. Since the mid 1990s, architects began integrating computer technologies into their practice foreseeing its speed and accuracy. Le Corbusier's vision is built by mass production. The computer, used as a thinking tool, allows architects to construct large quantities of unique shapes and sizes creating new forms of production that Kieran identifies as "Mass Customization".[13] Since the industrial age, a primary goal in prefabrication strives to regain greater cost and time efficiency in construction along with increased customization. Although we can rely on computers to produce with extreme levels of precision, it appears achieving both efficient and dynamic design simultaneously is still an ongoing struggle.

Today, architecture has become more of an interactive machine involving a webbing of electrical, mechanical, and plumbing connections throughout a network of building components that fulfill our modern needs. With the complexities of modern architecture, the role of the master builder has fractured into construction specialties. Today, architects no longer aspire to be the master builders we once had. Machinery often exceeds the ability of hand-craftsmanship in speed and quality. Several architects and designers are realizing and embracing the potentials of mass production, however they either forget or neglect the importance of traditional methodologies and how their control in design is affected.

Architects need to understand complexities of the construction process. Brunelleschi and other historical master builders better understood details and differentiated between designing and crafting[14]. Attention to the craft of construction allows architects to communicate the process to the engineers and builders who often misinterpret the design. Having a deeper understanding of the process, materials, and physics of all the steps of construction regains the architect's ability to confidently sculpt materials and win back their controlling hand of design.

New Tools Yield New Possibilities

So far we have learned that several advantages exist in traditional architectural mass production methods, however outcomes are repeatedly limited to simple stacked forms. Stephen Kieran and his firm argue that our earlier example of industrialization in American home building lacks the freedom of design. Due to the limits of vehicular and highway regulations, the shape and size of prefabricated home designs are limited, commonly resulting their appearances to an incongruous, boxy collaboration of single and doublewide trailers. Many architects believe embracing such a building methodology that limits artistic expression to homogeneous modular forms destroys their freedom of design, becoming "the death of architecture".[15] Although typical prefabricated techniques are restricting, Stephen Kieran and his firm have developed a possible solution.

Kieran's studio parallels fabrication of housing with that of automobiles. Initially, cars were fabricated individually by hand, piece-by-piece similar to building construction prior to the 1950s. Today, specialized workers fabricate car components in separate facilities with advanced robotics in quality-controlled environments. Once completed, the components are shipped to a main facility to be simply assembled in their desired configurations. The modified process improves accuracy, cost savings, and time efficiency while still allowing the final product to be customized to consumers' preferences. Instead of building an automobile piece-by-piece in a single manufacturing plant, components are assembled in remote facilities and transported back to a main assembling plant.

In the Loblolly House, Kieran's firm has adapted this process by breaking down the building's individual pieces into simpler components. By outsourcing the primary building parts i.e. structural framing, floors, walls, roof, etc. to individual manufacturers, specialized workers can build their components inside enclosed facilities, providing accessible machinery without interruptions of outside elements. Local craftsmen were also selected to fabricate specific parts such as stairs and exterior fenestration that provides the house with unique attributes. These components can be modified to fit the client's preferences or specific needs of the site. Once completed, the components are shipped to site to simply be "plugged" into the main building. Kieran states his views on the future of construction:

> *There can no longer be completely consistent ascending and descending orders through which parts are aggregated into wholes and wholes are disassembled into parts. What we can have, however, are integrated components, elements of solutions made in different locations by different entities.*[16]

The Loblolly House incorporates a blend of common and uncommon building components that were carefully integrated with each other, prefabricated individually off-site, and then later assembled atop a platform on site. Similar to earlier prefabricated homes, the house was erected swiftly and affordably, however the building's design discards all evidence of mass production's commonly repetitious and modular attributes. The pivoting point where designers of earlier mass production housing failed and Kieran's studio succeeded was realizing constructing a machine to live in requires "building it as you would a machine".[17]

Other evolutionary methods of crafting can be seen in the workshop of Shiro Studios. Three-dimensional printing has been a method used in science and medical fabrication for the last decade, generating solid forms that are typically otherwise impossible to fabricate, however they are typically limited to small scale. While some architectural firms, like Kieran's, create new methodologies with existing technologies, other firms have discovered new technologies while using existing materials. Shiro adapted the concept of three-dimensional printing and applied it to a much larger scale for constructing the Radiolaria Pavilion, bringing forth a new opportunity for mass production. The latest modeling software, associated with the parametric/scripting potentials that allow the designer to freely generate complex morphologies. Adapting the traditional three-dimensional printing's method of stacking thin layers of an inorganic powder, held together with an adhesive, Shiro Studios developed a massive printer capable of producing any desired form extending to a 3 cubic meter volume. The printer uses a newer compound of organic and inorganic materials to create new forms at any complex geometry otherwise impossible by traditional construction methods without the use of provisional, temporary or disposable, expensive molds. With this innovative three-dimensional printer, conventional materials can now be amalgamated into unconventional forms using methods once unpractical or unattainable by prior technologies.[18]

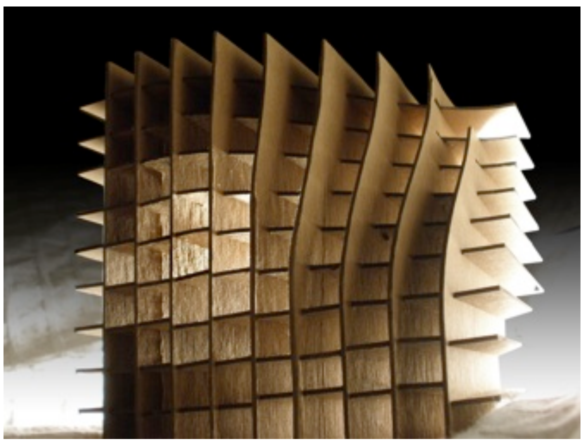
The Radiolaria Pavilion's form is constructed solely by layers of limestone and organic binding solution amalgamated stronger than portland cement.

The two case studies serve as an example of how craft can be deployed in modern ways. The Loblolly House utilizes existing construction techniques in newer ways while the Pavilion utilizes existing materials in newer ways. Both designs successfully understand and embrace the limitations of standard components and natural material while inventing new technologies and methodologies that extend our abilities of craftsmanship.

Modern Craft

In the modern world, craft's survival depends on quality. David Pye, author of "*The Nature and Art of Craftsmanship*", asserts to the fabricators that any form, either by hand or machine, must be designed and constructed to their greatest of abilities, otherwise any reason to continue is lost.[19] In order to analyze how craft can be effectively used in the realm of mass production, I implemented two experiments: one required skill with the machine while the other required the ability to build a machine. My understanding of how to control the machine would then potentially become clearer.

Experiment 1: Laser-Guided Cube



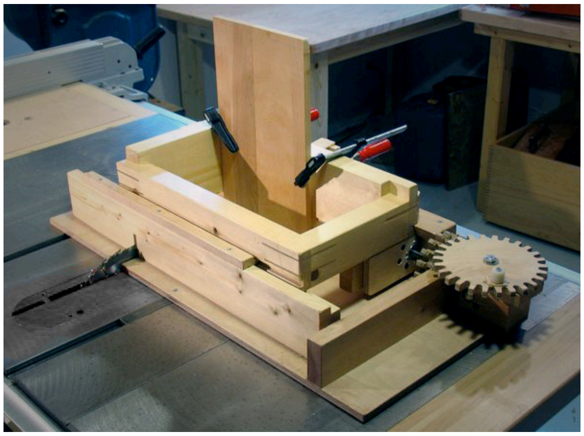
Waffle grid construction of laser cut cube.

The goal of the first experiment was to create a unique three-dimensional form constructed in a fashion reliant on accuracy only possible by using the laser cutter. I designed a 5” x 5” block using computer-modeling software. The block was digitally manipulated on each side, creating a distorted shape. The cube was then sliced on two axes and the two-dimensional cutout shapes were exported to the laser printer to be printed out of chipboard. The computer guided my assembly of these pieces, which I was able to assemble by hand. The final product held together only through a specified friction that I achieved through numerous experiments. Although more rudimentary methods could have sufficed to achieve this form, the accuracy of laser cutting was necessary to achieve the desired friction between each joint precisely and uniformly. The project’s success relied on my knowledge of the technology and the limitations of the applied materials.

Experiment 2: Box Joint Jig

The goal of the second experiment was to manipulate a traditional method of construction to increase efficiency and flexibility, and to reduce the elements of human error. Knowing through experience, crafting box joints is a method very precise and heavily reliant on human skill. Originally, box joints were cut by hand using handsaws and chisels. More modern practices involve a basic fence with a positioning pin to which material is clamped. The fence and material glides across a guiding rail and through the saw blade. After the first cut, the material is repositioned using a guide pin and clamped again to prepare for the next cut. The process is repeated for the length of the material then again for it’s connecting piece. The combination of the fence and the table saw blade proves faster than its more traditional counterpart, however accuracy of these joints still heavily relies on human skill. In addition, each step across the positioning pin wears down the jig, rapidly diminishing accuracy and requiring constant rebuilds. Precise construction and positioning of the jig is necessary and slight deviations will result in improper fitting of the joints.

In this experiment, I adapted an updated jig design[20] utilizing the same basic method of modern box joint construction by passing repeatedly over a table saw, but also incorporates a series of added features to allow the user to more accurately visualize and modify the cutting process. Acting more as if a table saw sled, the jig is fitted with railings and a sliding carriage to which cutting material is clamped. Using a series of rotating wooden gears and a threaded rod, the carriage advances along the rails after each individual turn of the primary gear. After each full rotation, the carriage advances a precise distance before passing over the blade again.



Improved Wooden Box Joint Jig

After some time spent adjusting the mechanics of the jig, the results yielded extremely accurate and consistent joints. After the jig's construction, the time required to produce the same box joint proves seventy percent less than the modern box joint fence jig. Wear in the machine's occurs in each points of contact, however its wear was excessively slower than the modern jig and can be repaired through replacing minor parts instead of a complete rebuild. Through additional research, I expanded the abilities of the jig to produce features either unpractical or impossible by previous jig designs. Through the modification of components in the carriage, crank, and sled, I was able to achieve angled cuts, staggered joints, two foot wide pieces as well as multiple stacked cuts at once. Although this process requires less from the craftsman, the modified jig serves as an evolutionary tool using traditional materials in a more effective way.

From these experiments I learned that architects can use machines as tools for efficiency, however it is still possible to have control of the production of designs. Knowledge and creativity is required of the technology available to allow someone to have this kind of control, similar to our master builders of our past.

Conclusion

With the vast complexities of mechanics, physics, and engineering required in architectural fabrication, it isn't fair or practical for a single architect to be expected to understand and be responsible for each discipline. To more effectively control our process, we must form relationships with those specialized in their respected discipline to greater understand their abilities and limitations. Such knowledge allows the architect to develop a design process that considers all areas of architecture and the obstacles faced in the design from the initial idea to the final product.

The future of craft relies on time efficiency, quality, and surrounding competition. If architects simply enhance their knowledge diversity of the construction industry, their designs can be created in an even more effective manner. For the majority of consumers, affordability and efficiency are (and always will be) a primary driving force in residential and commercial development. Once this reality is accepted, we can find new methods to embrace our modern tools to create great architecture and new architectural styles. And much like the historic buildings today, we will be able to craft architecture that is no longer a disposable commodity and instead an architecture to be treasured.

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Notes

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[7] Kieran, *Refabricating Architecture*. pg. 5

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[9] Kieran, *Refabricating Architecture*. pg. 105

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Imagery

Image 1 – Turkish clay roof tiling. Photograph by author

Image 2 - Dymacion House by Buckminster Fuller. Photograph courtesy of Wichita Photo Archives.

Image 3 - Radiolaria Pavilion by Shiro Studios. Photograph courtesy of Dezeen Design Magazine

Image 4 – Laser-cut cube. Photograph and product by author.

Image 5 – Screw advance box joint jig. Photograph courtesy of Woodgears.