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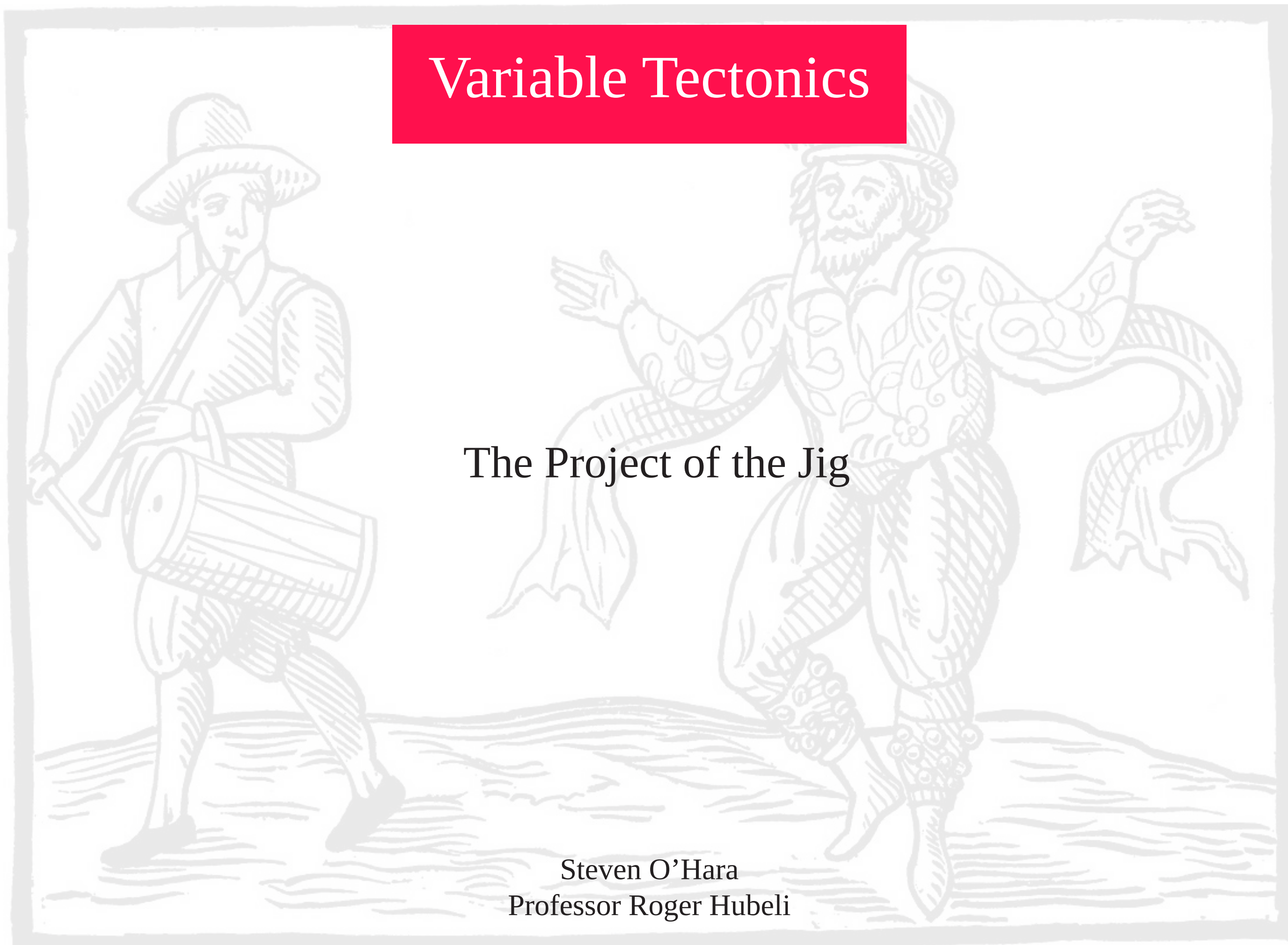
Variable Tectonics: The Project of the Jig

Steven O'Hara



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The Project of the Jig

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This thesis is an investigation into how the means of fabrication and construction influence architectural design. This study intends to question existing relationships between design and making, by proposing that the designer approach the field of tectonics through the lens of the process of jigging. This paper will outline theoretical and practical foundations of such a study by (1) analyzing how the architect engages with construction by looking at the divisions and operations of professional practice of architecture. The analysis will continue by (2) defining the process of jigging, looking into where jigging sits in the practices of fabrication, and (3) by categorizing how jigs work in constructional assemblies, and the values that emerge from the processes. Finally, this paper will propose (4) how this awareness can benefit architectural design, and (5) what has presently been done to demonstrate this thesis. These explications will comprise an introductory investigation into the field of variable tectonics, contending that architecture can exploit the rich variables of making as an agent in design by shifting the hierarchy of the role of jigging in construction and fabrication processes.

The importance of this thesis bears primarily on the interests of the architect, and his or her strategies in approaching the industries and economies of building. It is this project’s intention to provide a means of communication, or a more discursive relationship between the designers and makers—the ‘thinkers’ and the ‘doers’.

(1)

The contemporary architect works in an field of specialists in and around the building industry. It is the intention of this thesis to clarify how the architect works with these professionals, and to propose a productive challenge to the existing model. To understand the present model, we can observe the 5 phases of a project in professional practice. Beginning with schematic design, the architect engages with the largely intangible determinants of design, such as program, space requirements, site strategies, and many other optional decisions and conversations between the designer and user. One of the primary skills of the architect is put forth in the second phase, design development. Here, the architect must physicalize said intangible factors, and create spaces and assemblies that account for the proper human usage in a specific context. David Pye generalizes this process as the designer ensuring “that the intended results do occur, by selecting properties for its components, namely those required by the nature of the result, of the objects, and of the energy put in.” In these terms, the process of design is abstracted to flows of energy and possible results. In practice, it is during this phase that additional specialists are consulted in order to supplement the architect’s limited knowledge in the world of structure, systems, fabrication and construction. This is a meaningful moment in the analysis of the skills of the contemporary architect, because it represents the specialization of professionals—creating boundaries for their field of expertise, while delving deep into the chasms of possibility within those boundaries. Kieran and Timberlake describe the process pejoratively, stating that “the disjunction of the various elements of master building has been institutionalized over the past few centuries by means of separate educational programs, separate licensing and insurance requirements, and separate professional organizations.” In this view, the position of ‘master builder’ is taken as the ideal, organic position of the architect. Whether or not this is the case, the skill of the architect has shifted away from the capacity of making, toward the capacity to communicate with the makers. Such communication necessarily creates flows of knowledge between the two parties, engendering architecturally savvy fabricators, and

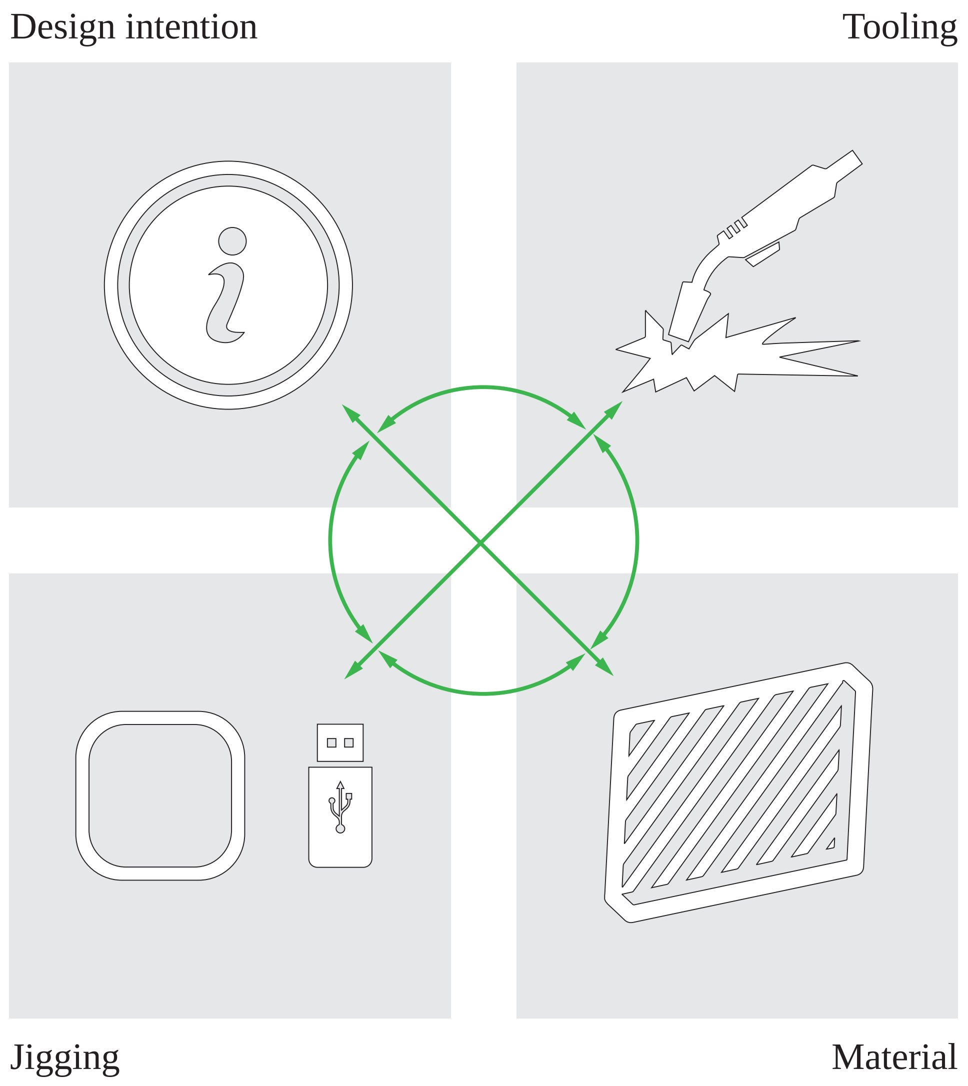
constructionally savvy architects. To insert itself into the life of the contemporary architect, the project of the jig intends to reframe the dialogue of these exchanges, offering a concrete medium through which the architect can propose unconventionality.

While it is during design development that information flows between specialists, construction documentation is the recording of results of such collaborations. These serve as guides for the men and women in the field to actualize the drawings created by the designers. Here, the question of representation comes into play. As the influence of specialists and other forces tends to hold increasing determining forces on the contents of drawings, one must identify precisely what the architect contributes through his or her representations. Further, the architect often carries less responsibility than the builder over the quality of the physical project. While this frees the architect to specialize in making drawings and providing the service of design, it also limits the architect’s control to the intangible, giving greater decision making power to the contracted builder. Kieran and Timberlake hold that “architecture requires control… not merely of an idea, but also of the stuff we use to give form to the idea.” The architect is (conventionally) strictly delimited from investing design thinking into the process (or means and methods) of construction, and therefore has little stake in questioning the existing state of tectonics. The concept of variable tectonics proposes an alternative to this static relationship between architecture and the building trades. And, by investing designing the jig, it proposes a means through which the architect can become invested in the process of making, without losing his or her specialization and identity as a designer.

The final two phases are not in focus for this thesis, but are worth mentioning. Bidding/contract negotiation and construction administration would certainly be impacted by a changed process in the former three phases. The real implications, however, must be determined in practice. By understanding the existing relationships, and their variations, between the architect and other building professions, one may begin to distinguish the position of this thesis as a subtly different mode of operation. This operation is distinguished by an investment in the design of process, from which qualities emerge into spatial, programmatic, and formal manifestations.

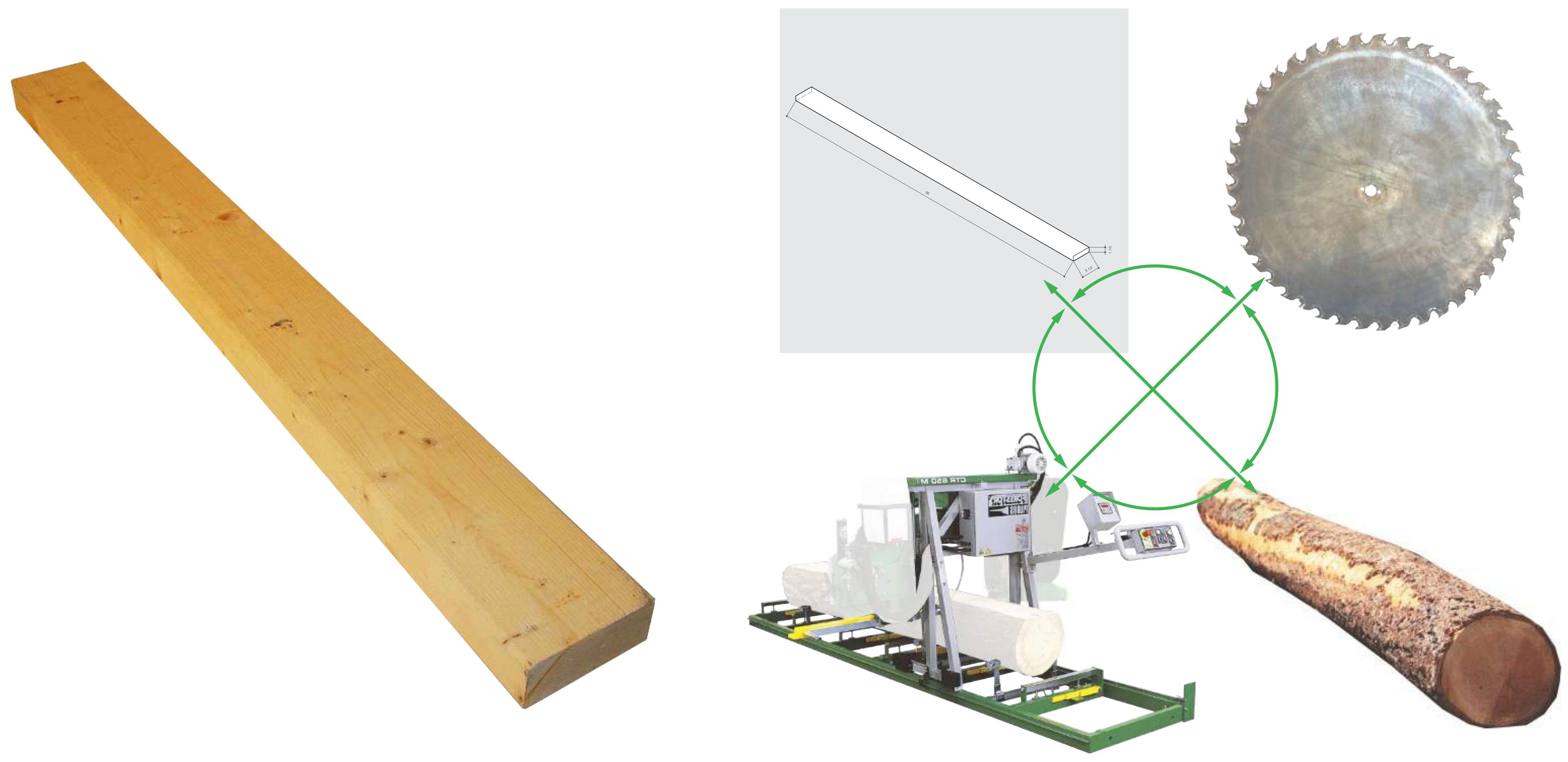
(2)

When speaking of the processes of fabrication and construction, there are limitless examples of different methods and styles. The substance of these methods can be understood in several fields of operation. These fields are design intention, material, tooling, and jigging. While the former three are fairly intuitive



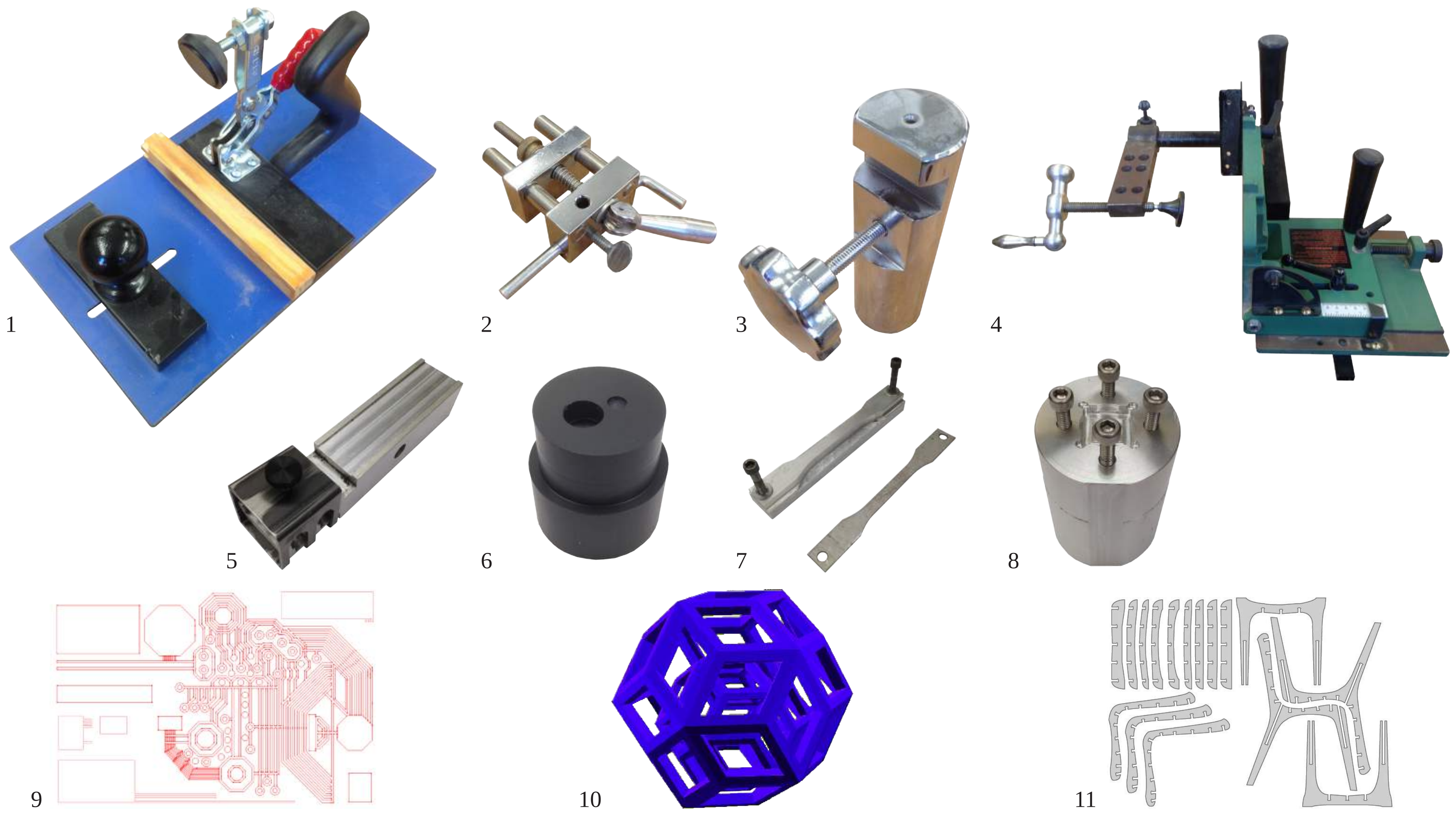
in their definitions, jigging is defined as ‘a device that holds a material and guides a tool path’. In practice, the jig is the device that allows the tool to precisely and accurately interact with the material in order to actualize the design intention. The jig may be temporary and improvised, or permanent and finely tuned, or interactive and adjustable. This thesis contends that a jig may also be digital, where the jig becomes embedded in the specific file formats derived from digital models that guild the tool path (and sometimes extrudes the material) of a digitally controlled tool system. Typically, the jig a contraption that is created through a process of deductive reasoning, i.e. through knowing the materials, tools, and design intentions, one can deduce how one must jig the system to create the desired output. If there is a hierarchy of value on these four fields of fabrication, the jig is conventionally on the order of last. However, this project intends to use the jig as a design generator for the architect—as a language of communication between the designer and maker. The hierarchy would then be inverted to favor the development of the logic of the jig, allowing material, tooling, and design intentions to emerge from such development.

As previously noted, this communication is an important aspect of the contemporary architect’s skill set. Neil Leach discusses the architect’s relationship to making by drawing two broad categories, based on Felix Guattari and Giles Deleuze’s references to the historical disciplines of architecture. The first of these



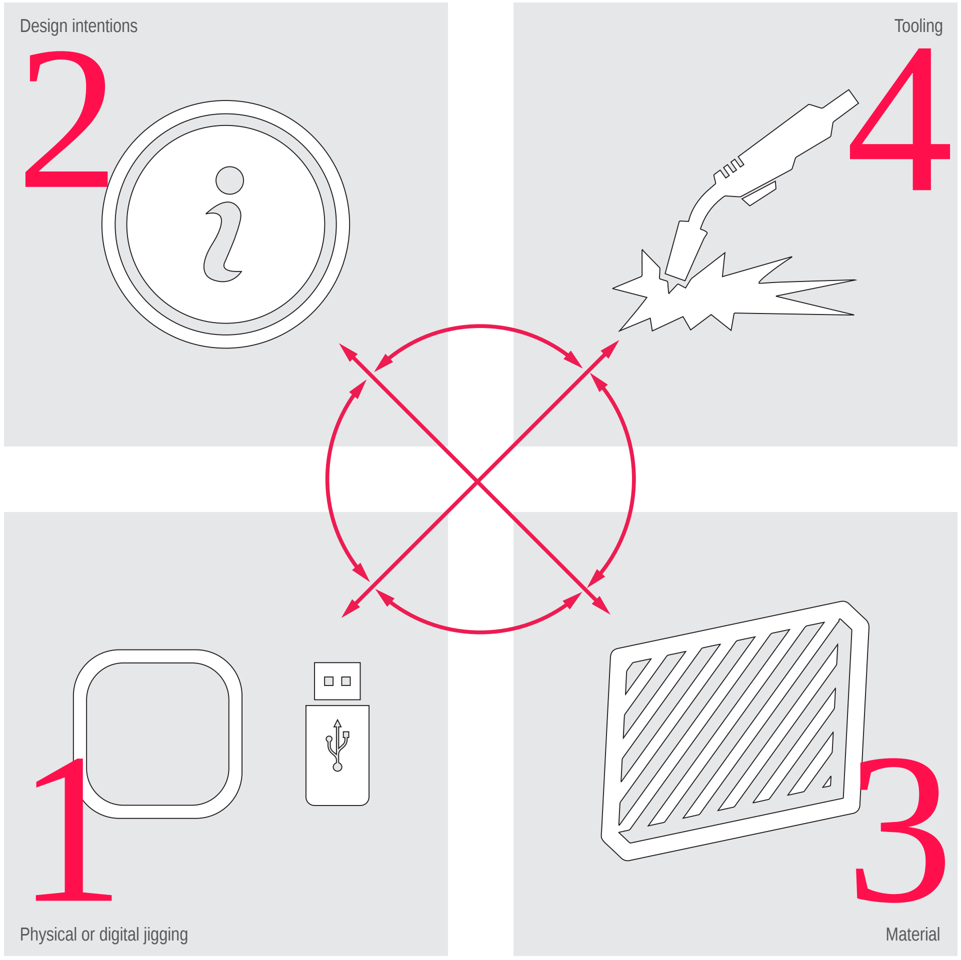
categories is 'romanesque' which is described as "any outlook which focuses on appearance over performance." Examples of this category tend to dominate contemporary architecture, but also extend to many of the classically derived architectures. The second category is broadly defined as 'gothic', described by Leach as, "a way of designing that privileges 'process' over appearance." The 'gothic' discipline emphasizes method over style, dynamic comprehension over static, emergence over derivation, and evolution over crystallization. The designer's role in a gothic discipline is that of 'fast-forwarding', iteratively evolving the design to adapt to given specifications and forces. The 'gothic' process is a thematic concept in this thesis. This dynamic understanding of forces, methods, and process is the lens through which tectonics is approached. This concept also reshapes practical understandings of the relationship design and construction (tectonics), and focuses on the evolution of a project through the medium of the jig.

Jigging is a rich field, and essential in both large scale manufacturing and unique custom fabrication. Jigs achieve a spectrum of conceptual ambitions in fabrication: accurate repeatability, complex and irregular geometries, consistently precise dimensioning, etc. David Pye describes the importance of jigging in terms of the invariable or determining systems that they establish. He observes that jigs tend to invest in standardization and mass production, stating, "Prima facie it will always be cheaper to design for making



1 - Router milling jig
2 - Radial arm saw stopping jig
3 - Band saw milling jig
4 - Table saw dado jig
5 - Milling machine jig
6 - Drilling jig
7 - Milling machine wishbone jig
8 - Drill threading jig
9 - Lasercut file jig
10 - 3D printing mesh jig
11 - CNC file jig

with mechanical constraint than with skilled constraint because the working time will be less.” While this is a sound practical observation on the nature of jigging, there are also theoretical implications of the use such devices. Jigging is, anthropologically speaking, the distinguishing characteristic of humans. It was once believed that tool-use was the distinguishing characteristic of humanity, but it was soon discovered that some animals—primates and others—will also use tools in some capacity. It is humanity’s ability to abstract, to use a device to facilitate the use of a tool, that distinguishes us from all other lifeforms. The abstraction that a jig embodies in a process of making is analogous to the abstraction that architecture seeks to crystalize in the the ‘romanesque’ disciplines. The jig is the abstraction of ‘gothic’ process, as a manifestation of the methodology of experimentation. The jig, the thinking that went into its creation, and its relationship to human thought, holds the meaning and importance of the ‘gothic’ project. This thesis proposes to use this valuation, and shift the hierarchy of fabrication to favor the investment of design thinking into the jig, allowing design intention, material, and tooling to emerge from the process. This process then generates a dialogue, both practical and theoretical, between the fabrication and design of the component. It necessitates the architect’s awareness of the variables of fabrication, and the fabricator’s awareness of the design variables within their own process.



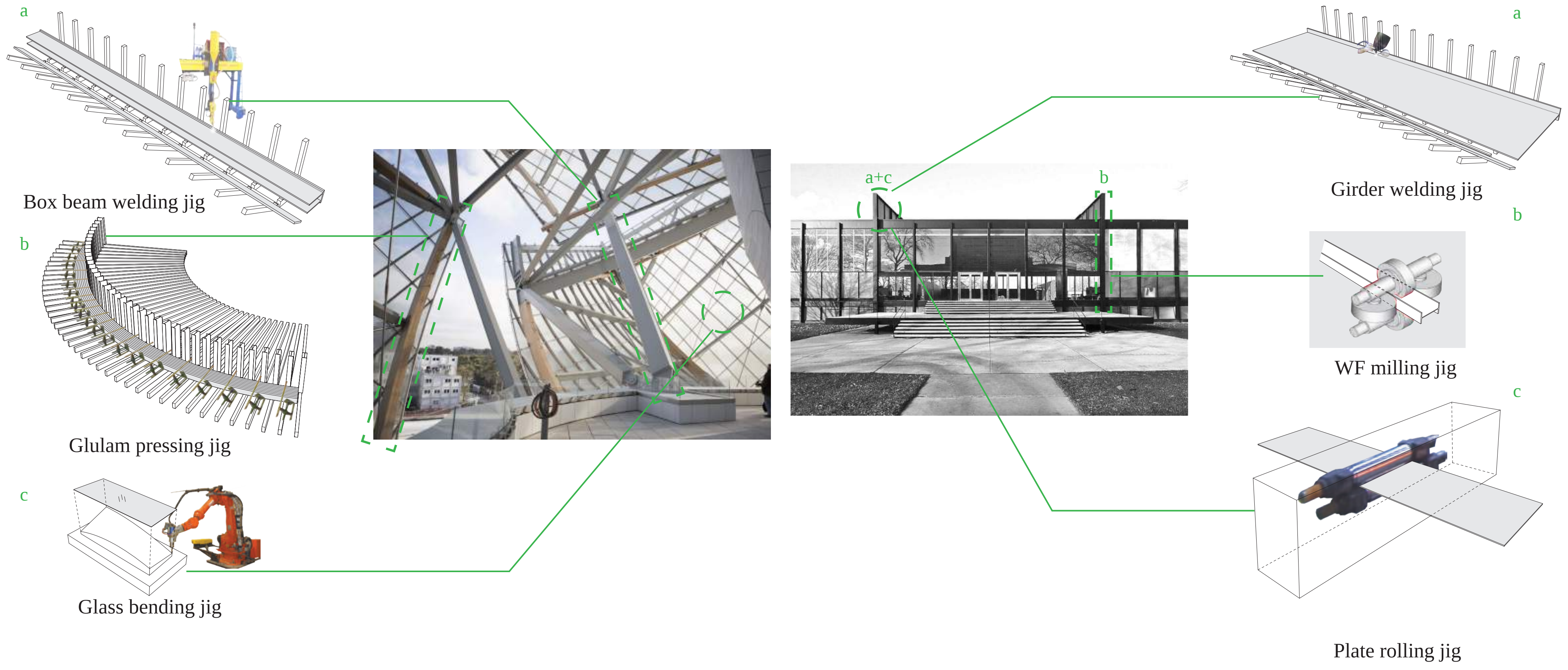
Jig as design generator

Emerging tectonic

(3)

In applying this study to architecture, one must also investigate how the theories of jigging apply to building assemblies. One of the distinguishing characteristics of building is it’s nature as an assembly of components, each embedded with different uses and results. It is one of the primary skills of the architect to be able to design these assemblies. There are existing modes in which the architect might operate, categorized for the sake of this thesis. First is variable assembly, which is the natural means of improvisational building, creating space through the most expedient means available. Second in this exploration is the modular assembly, which creates expedient assembly through careful dimensioning and off-site prefabrication. Third, conventional assembly uses standardized, mass produced building components and on-site construction methods. Fourth and lastly is the fixed assembly, which involves state-of-the-art methods of fabrication, to be precisely catalogued and positioned on-site—frequently highly complex geometries are the goal of this mode of assembly. These four modes of assembly will be investigated in their relationship to the architect and building economies, and analyzed for how the theories of jigging fit into such systems.

Variable assemblies are a mode based on pure expediency. They use local, often found components of linear and planar geometry, whether naturally produced or scraps of industrially produced materi-



als—anything that works. They are assembled through any means that suffice to provide some shelter for a limited amount of time, e.g. nails, weaving, lashing, etc., and constructed by few people using hand tools (if anything). They are often improvised due to the absence of resources, professional organization, or transportation. This system of assembly requires its own set of skills to accomplish. For example, the builder must choose particular items that he or she understands their adaptable uses and results produced. Artifacts might be chosen that are place out of their original context of design intention, but create acceptable results nonetheless. The builder must understand principles of structure and cladding, of weather resilience, spanning members, and connection details in rudimentary but real capacities. A variety of geometries are expressed with this method, as regularity and form are of little to no concern—it simply has to provide shelter and space, and the forms generated are a result of the geometries of the expedient components entangled in the assembly. While modern building can be praised for systematizing and progressing the variable assembly, an awareness of the skills of making and design determinants are important to understand. Additionally, variable assemblies can float anywhere amongst pre-industrial and industrialized economies, i.e. whatever is found can be natural, man-made, or mass produced, and it does not effect the nature of the assembly. The variable assembly could be classified as ‘pre-jigging’, because, although they still are created to this day,

Variable assemblies

Shack, Gaborone, Botswana
c. 2011



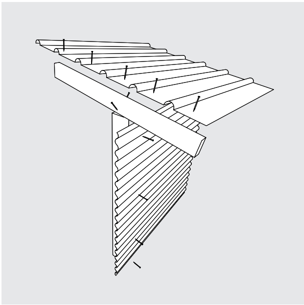

Floating Shanty, New Orleans, USA
Beasts of the Southern Wild, 2012

Shanty, Johannesburg, South Africa
Circa 2000




Refugee Camp, Dadaab, Kenya
c. 2000

Conventional tooling



Hand positioning

the mode must have begun before any systemization of construction. The tool-guiding jig is virtually non-existent in such assemblies, as the human hand is the primary instrument for such constructions.

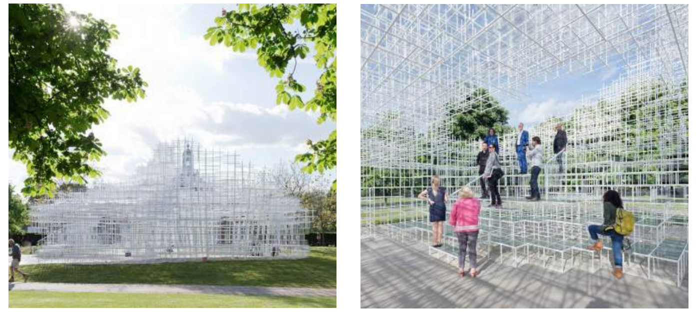
The modular assembly is somewhat similar to the variable assembly in it's ability to change; the design is broken down into discrete, transportable units, dimensioned and formed according to a repeatable module. The components used are specifically designed to be assembled in a singular manner, however, the total assembly is readily adaptable. This creates an important dynamic between 'on-site' and 'off-site' fabrication, and which must be anticipated in the design. Modular design has a rich history of theory and practice, primarily rooted in concepts of industrialization, Taylorism, mass production, etc. Le Corbusier writes, "…Our aim: to harmonize the flow of the world's products…prefabricated on a worldwide scale…freeing the methods of economic production." One of the most notable proponents of modular assembly and prefabrication, Corbusier held that such standardization would promote variety and elegance. An effective design for a modular assembly will integrate the practice of "pre-jigging" components for on-site assembly. This means that components are detailed in such a way that prepares them for fitting and fastening, essentially holding their position and guiding the assembly process. Such a process allows for two expediences: first, the tedium of cutting and drilling is performed in the controlled environment of an off-site shop,

Modular assemblies

Peter Zumthor, Steilneset Memorial
Vardo, Norway 2011

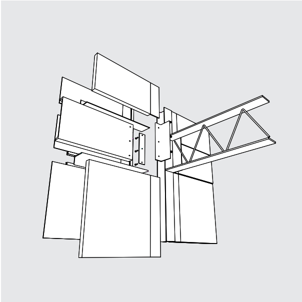
Le Corbusier, Heidi Weber Pavilion
Zurich, Switzerland, 1960-1967

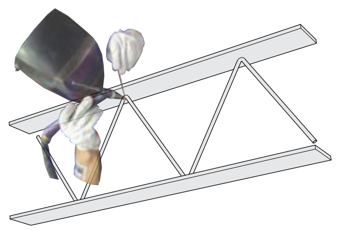
Charles and Ray Eames, Case Study House #8 (Eames House)
Pacific Palisades, USA 1945-1949

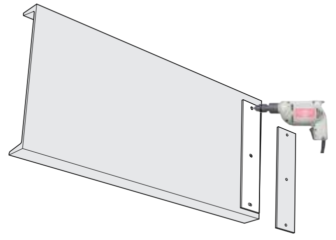


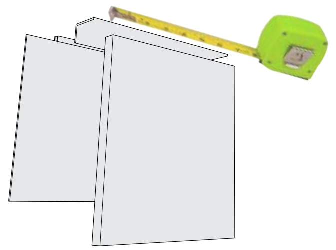
Sou Fujimoto, Serpentine Pavilion
London, England 2014

Typical factory components









Standardized panel dimensions

allowing for increased precision quality. Second, on-site fabrication is expedited, waste is decreased, and less skill is required. In turn, the modular assembly represents the architect’s attempt to follow the model of industrial production by exerting control over off-site processes.

Conventional assemblies also take advantage of an off-site and on-site dialogue, but with a penchant for on-site construction over prefabrication. This mode of assembly is perhaps the most dominant and visible in modern industrial methods, exemplified in the methods of many architects and general contractors. Conventional assemblies make use of industrial production, by the standardization of building components, e.g. dimensional lumber, typical steel sections, rectilinear formwork, standardized connections, etc. Simply by squaring geometries and flattening surfaces, using specific jigs that create such geometries, components assemble with increased efficiency and flexibility. The architect can plan for on-site workers can make simple modifications to a full palette of materials to manifest a fairly wide range of design intentions. This being the case, the conventional mode of assembly does not highlight the use of jigs, or pre-jigging, in the actual assembly, as the construction uses the skill of workers to carefully position the assembly according to the architects drawings.

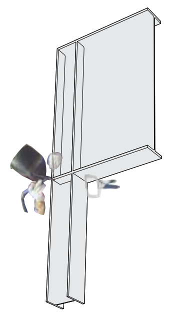
Last is the fixed assembly. In this mode, the designer exerts a high degree of control over the fin-

Conventional assemblies

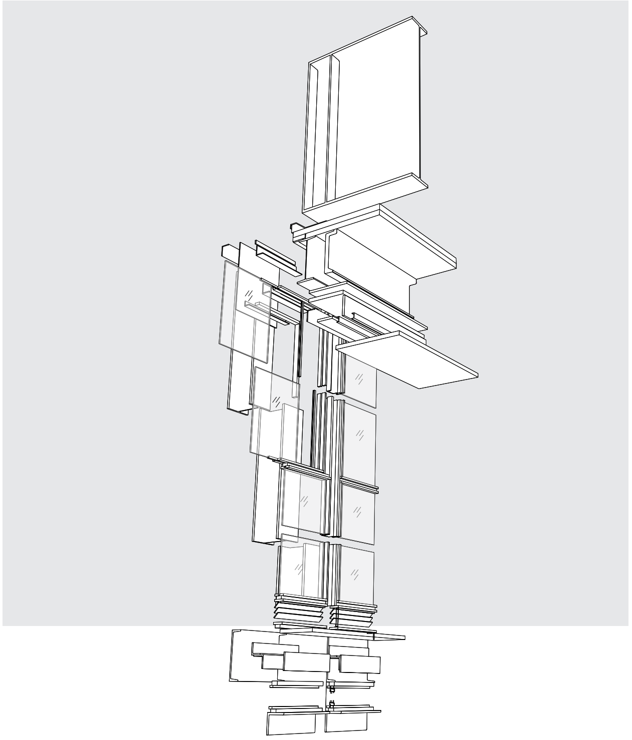
Vernacular typology,
Cape House
New England, USA c. 1980

Ludwig Mies van der Rohe, S.R. Crown Hall
Chicago, USA 1950-1956

Frank Lloyd Wright,
Rosenbaum House
Florence, USA 1938-1940



Specific positioning and tooling



On-site fabrication

ished product. The design is such that conventional components must be custom fabricated to actualize the design intentions, which involves intensive detailing, cataloging, systematization, and coordination between all building professions and trades, toward the goal of actualizing a complex project. The unique qualities of such designs requires significant investments of engineering and fabrication know-how. Projects demonstrating the fixed mode of assembly are often highly complex and formally inspired, using state-of-the art computational power to create non-regular geometries both on-site and off-site. Because of their complexity, the designer must be aware of the limitations of on-site precision, and communicate/draw the details of the assembly to be embedded into the prefabricated components. In this way, the fixed assembly is pre-jigged, to be assembled and fastened using the guides of the components themselves. Unlike the modular assembly, however, the combination of components is fixed into a singular product, and is not open to on-site adaptation.

These modes of assembly are a broad categorization of the intricacies of building and architecture. Each mode might coexist within different areas of a single project, depending on the thousands of forces placed upon the contemporary architect.

Fixed assemblies

Asymptote Architecture,
Yas Viceroy Hotel
Abu Dhabi, UAE c. 2008-2010

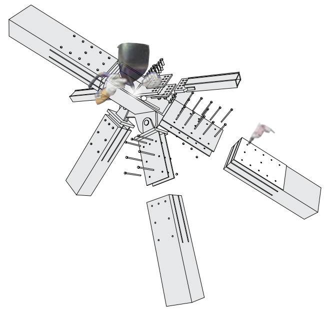
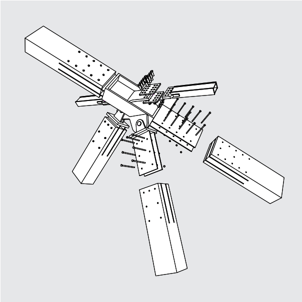



Zaha Hadid Architects,
Heydar Aliyev Center
Baku, Azerbaijan 2013

Morphosis, 41 Cooper Square
New York City, USA c. 2004-2009




Frank Gehry, Fondation Louis Vuitton
Paris, France 2006-2014

Components pre-jigged for assembly

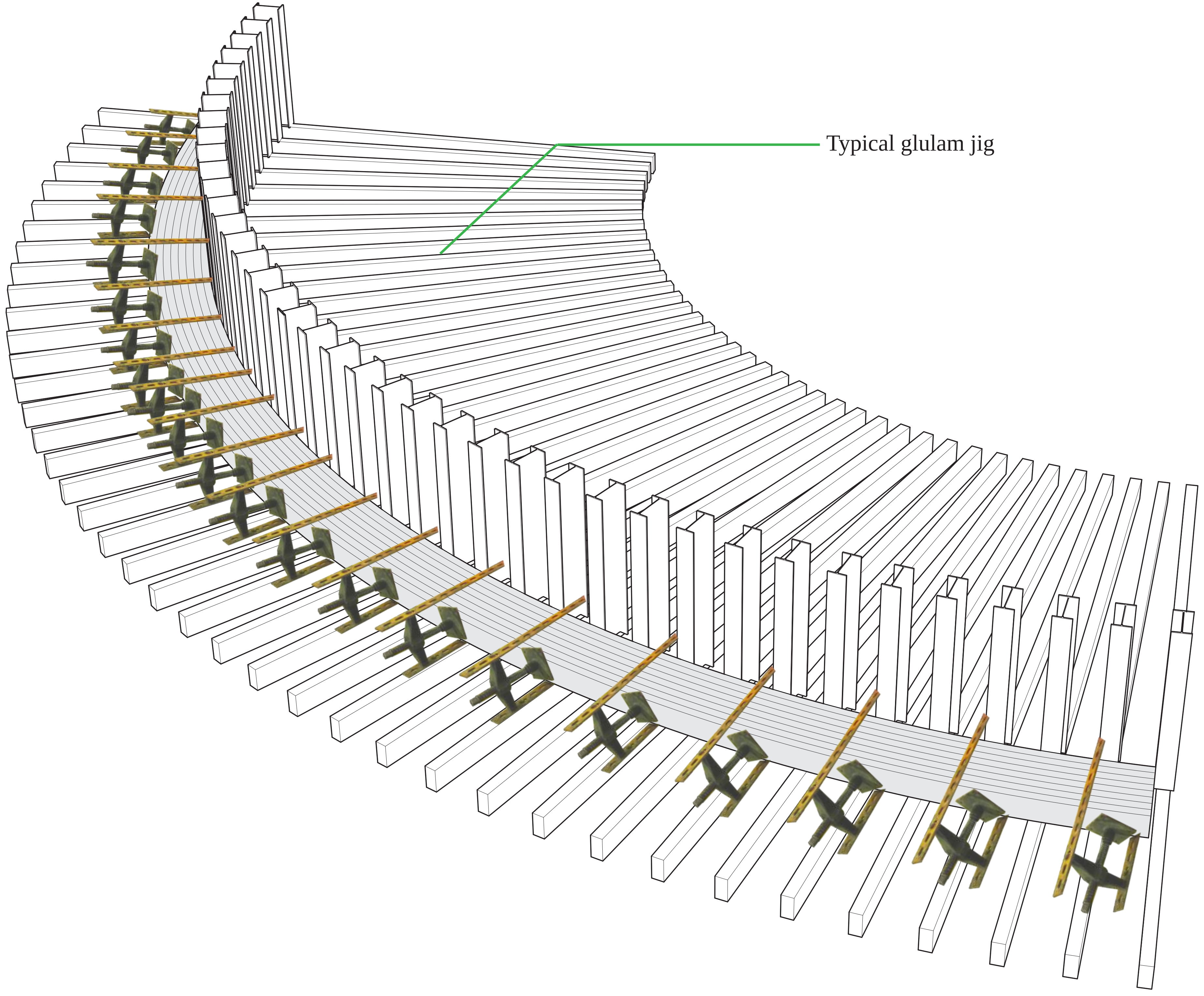
(4)

The understanding of the different modes of assembly is important to understand their effects on design intentions. One can relate the four modes of variable, modular, conventional, and fixed assemblies to the previously mentioned gothic and romanesque disciplines. This relationship becomes a spectrum, from the most emergent (variable/gothic) to the most predetermined (fixed/romanesque). Such a spectrum begins to demonstrate a valuation between designer and maker, in which the “pure maker” allows designs to emerge, and the “pure designer” exerts machiavellian control. Notwithstanding, this thesis contends that such a valuation is an unnecessary construct, and that the jig is a concrete means of exploring how the different modes of assembly can be approached as a gothic discipline. This means: the influences of the different modes of assembly on design create a fixed system of tectonics, fastening the design intentions to the chosen components and assemblies. The concept of variable tectonics aims to use a different means of exploration to create a ‘gothic’ relationship between designer, components, assemblies, and the correlated professions of the building industry. The project of the jig intends to focus the lens of the design to both off-site component fabrication and on-site assembly construction, and using the jig as the abstraction which guides the design of such a process.

The foremost intention of this exploration is to impact the built environment. Variability in tectonics has the potential to reshape the way we interact with buildings, and renew the way we experience architecture. Projects that emerge from these methodologies of design can contain qualities above their formal characteristics, giving added depth of abstraction and experiential understanding to a full gamut of scales, programs and budgets. In addition to these aspirations, the utilization of the jig as a medium of design and communication can be an important stepping stone for the future of the professional architect, and his or her relationship to other professionals in the building industries.

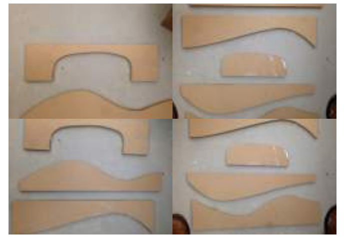
(5)

The present field of exploration for this thesis has been through the jigging of glue-laminated timber. This particular component represents fertile opportunities for several reasons. First, the material of timber itself relies heavily on jigging to create the standardized components and precise joinery that has developed over the centuries. The rich history of jigs in this field allows for an informed and culturally relevant study. Glue laminated timber (glulam) is a modern, “engineered” component that emerged in the 20th century as a result of developments in adhesive technologies. This began with the planar technologies of plywood, and

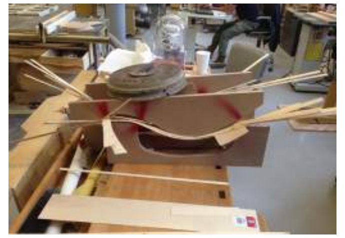


eventually continued into the linear element of the glulam beam. There are many precedents of vaults, trabeation, or lattices achieved with this technique, and the geometric flexibility of the process appeals to this study for investigation. Iterative experiments have been performed to test variations on the conventional uniformly tight-pressed, clean planed beams or arches. Different textures, twists, bends, de-laminations, interlocking laminations, and re-orientations and more were considered through the design of different jigs, and the appraisal of the resulting integrity and potential for assembly. Jigs were reworked, reoriented, and reconfigured to produce outputs of glulam unknown. The design process then became recursive in the design of the jig and the desired output, and challenged again in the process of considering a spatial assembly. Nevertheless, the jig became the generator for material configurations, geometries, and details, following the aforementioned intentions for the matrix of fabrications.

Combinations of jig curves

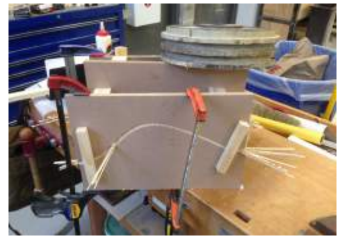


Random jig combination, random lamination



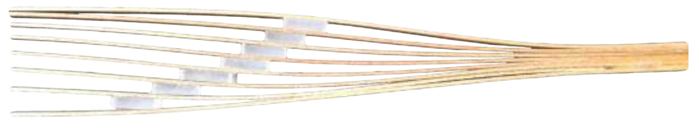
Lamination of sticks and surfaces

Single jig extending lamination to 3 dimensions



Interlocking laminations

Various thicknesses, delaminated



Acrylic spacers for delamination

Twisted laminations, selective gluing

These experiments have been configured into the design of a market shed, using the data of the glulam experimentation to inform the methods of variable tectonic thought. The shed itself is an amalgamation of different assembly modes, each holding some determining force over the content of the design, but orchestrated by and emerging from the dialogue with the process of jigging. Opened by this dialogue, there has been speculation on the flexible convergence of irregular geometries, exploration of prefabrication in non-modular and non-fixed modes, and consideration of the jig as both a design and fabrication medium. The success of such a project is determined by the degree to which a gothic discipline has been followed, learning from the experimentation of processes, and allowing the project to transpire from discrete lessons of practice. As Neil Leach describes, “The task for designers, then, would be to ‘fast forward’ this process, and to imagine how forms would have evolved so as to be totally adapted to their patters of colonization.” For this thesis, a relatively simple program of the market was chosen, so as to allow focus on the process of the designer’s discipline as much as possible.

Syracuse Regional Market structures are clear projects that follow existing guidelines of components and assemblies.

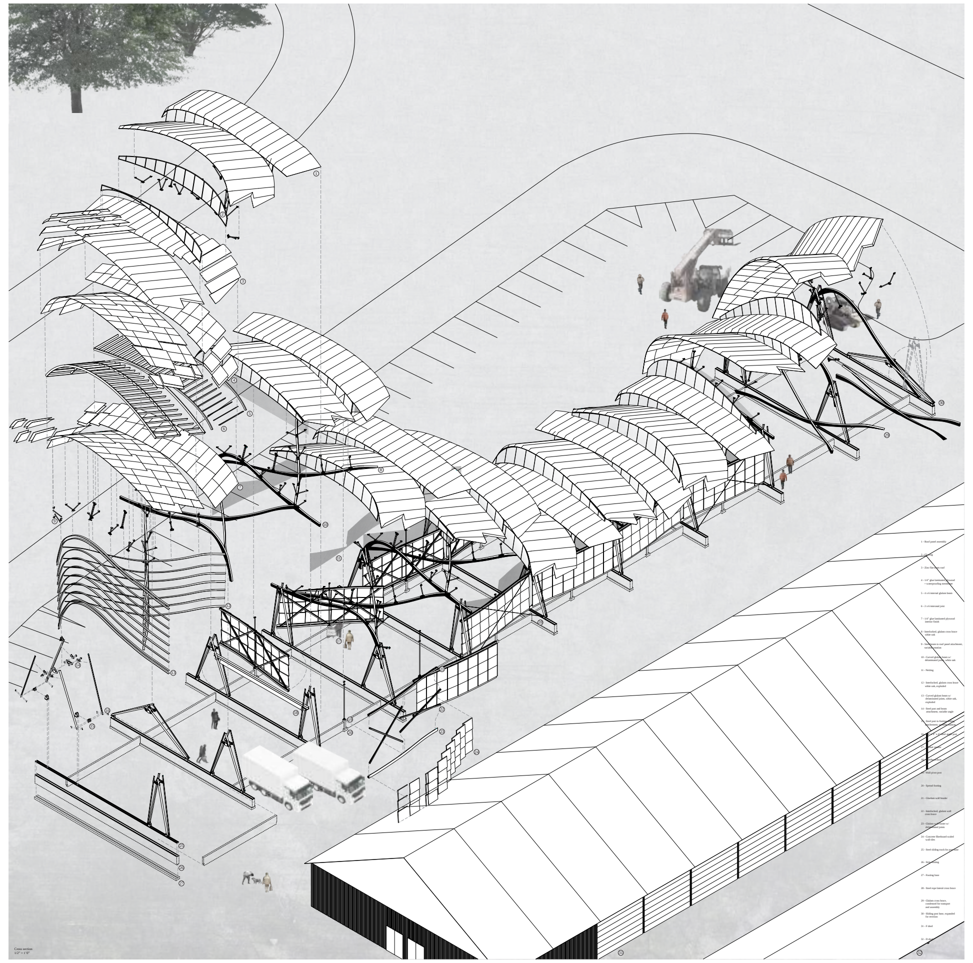

Shed A

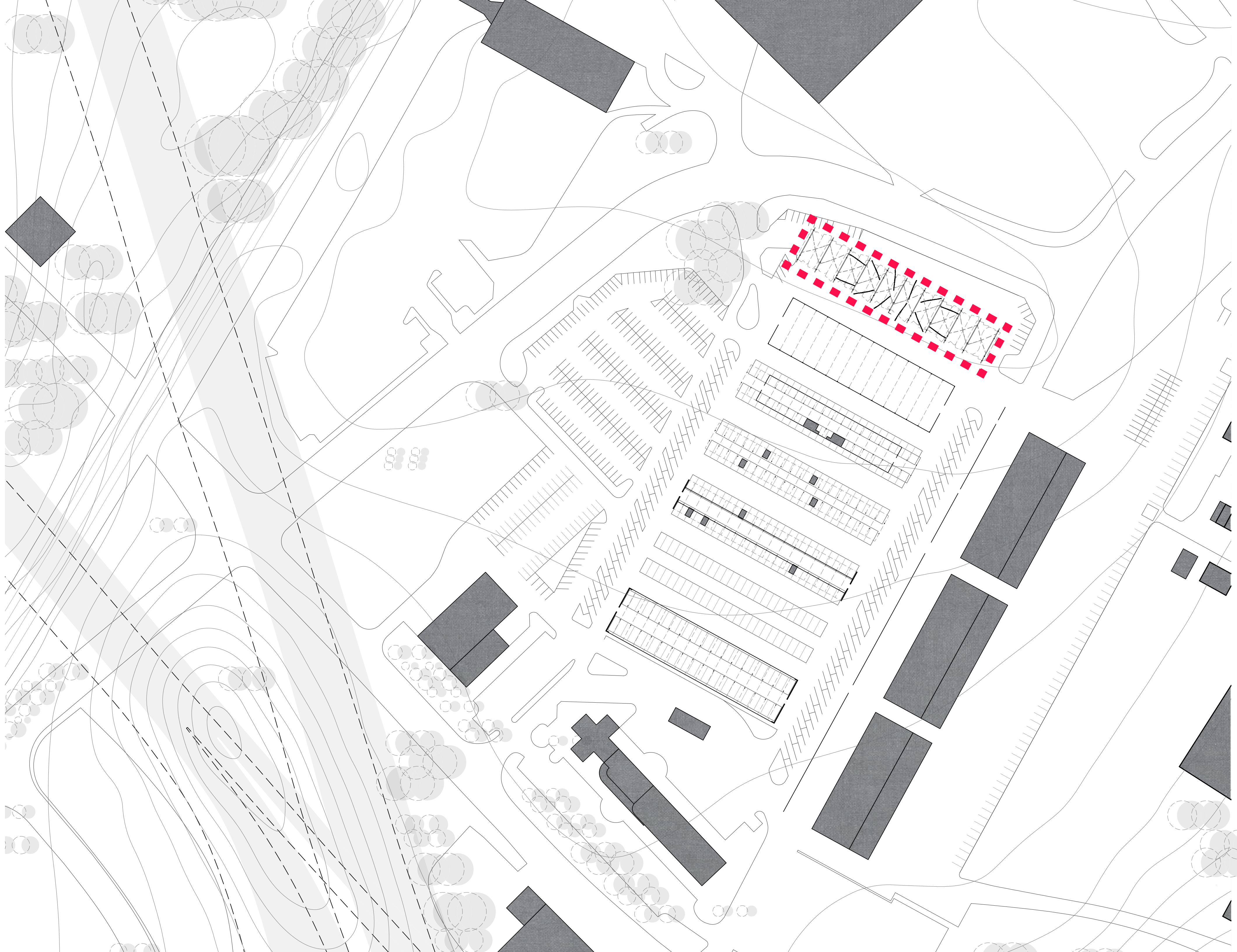

Shed B


Shed C + D


F shed

The future of this thesis could best be furthered by testing and application to real economies of the building industry. Given the awareness of the jig and its theoretical implications, the architect might strategize on how he or she inserts this method of design into conventional projects. The extent to which the architect is able to design and communicate via the jig can be a trial of how adaptable the industry might be to such a shift. Speculative projects can test different modes of jigging and lead to innovations in material and tooling languages. One important vicissitude that deserves attention from the concept of variable tectonics is that of environmental systems. So far, the project has been limited to primary structure, secondary structure, cladding, and various components for assembly. However, building plays an important role in human protection from the environment, and an architecture which neglects this reality will have a short life and small impact. Approached as a design tool, the project of the jig has the potential to reconsider anything that goes through a process of fabrication—that is to say, everything made by humans. ‘Gothic’ processes can re-emerge in contemporary applications, and themselves be transformed by contemporary economies and relationships in a world of specialization.





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