Risky Business: From Digital Fabrication to the Abstract Workshop

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The risk associated with contemporary means of digital production, from digital fabrication, to parametric modeling, to the virtual prototype, is not risking the health, safety, and welfare of individuals, but the risk associated with the accountability of the material execution of built work. In other words, it is not the professionalism of the architect that is in question, but the very identity of the architect in the building process marginalized due to the separation of conception from execution through the legally drawn line separating design from the means and methods of construction. Crossing that line is risky business.

The legal boundary separating architects' conception from execution is broached through a new genre of workshop practices enabled by digital fabrication. The challenges and opportunities of these workshop practices and their reflection on contemporary design culture are made visible through a series of interviews I conducted between 2005 and 2008. These interviews help to position the pedagogical place of digital fabrication not as argument for the design-build process as I originally sought, but rather in the formation of the image of practice as an abstract workshop enabled through parametric design tools. Abstractions develop from real world objects and experiences becoming generalized, as abstractions, to apply to multiple scenarios and situations, taking the general from the concrete. Without the tie to the concrete physical construction of architecture, the digital design process in design education has become not too abstract, but in fact, far too literal of a procedure that extends from the directness of the tools themselves, rather than a larger disciplinary projection. Ideally speaking, then, the abstract workshop would be grounded by material systems but not fixed within one particular domain or application, and in so doing, can leverage scale in the way direct fabrication never could.

FROM CRAFT TO PROFESSION

Technology is not an isolated tool to learn, but a tool that develops from the history of a practice, and the development of a practices cultural life[1]. If put in this perspective, automation is connected to the very origins of architecture as illustrated by the mechanical devices in the Lodge Books of Villard de Honnecourt in the 13th Century[2]. The innovations in Brunelleschi's Dome such as the system of chains and vaulting without armature in the double shell design illustrate his understanding of general principles[3]. However, the dome could neither have been constructed, nor could the construction have been conceived without the large-scale models, full-scale templates, unique molds for bricks, and truly novel hoisting machines constructed through Brunelleschi's workshop[4]. These artifacts act as an interface between design and construction in which "designing the dome" was not separate from "building the dome"[5].

This is not to glorify the romantic image of the architect as master-builder, but rather the interaction between conception and execution. After all, Brunelleschi did not lay one single bring nor was he even a master mason, nor was the term architect even in use in the middle ages. The profession of the architect in this country marked the shift from craft-based know-how to design representation as this became befitting of a gentleman because it involved intellectual labor rather than physical labor[6]. In the best sense, the gentleman architect occupied a position of great trust between client and craftsmen. In actual practice, then as now, this tenuous relationship creates distrust between architect, client, and contractor, and consequently the built environment suffers. Bridging the gap between conception and execution has enormous potential not only in the design innovation of built work, but projects an image of practice closing the gap between design as abstractly conceived and design as practiced and experienced. Rather than a digitally enhanced representational formalism, the power of parametric tools is to build a real-time conduit between design as abstractly conceived and its material execution. Rather than a linear if legalistic separation between design and construction, as a *constructed* conduit between conception and execution, parametric design enables the reciprocity between conception and execution *folded into* the design process. In other words, forming the conduit between design conception and execution is a critical part of constructing relationships embedded into design conception.

RESEARCH PRACTICES

Architect and Professor Scott Marble, began teaching in Columbia's paperless studios in the 1990's in which he saw the computer as a tool that redefines the whole discipline[7], a position he and others still hold today[8]. In my interview with Marble, he refers to bootstrapping as "a small amount of very strategically placed information that causes a rippling effect." The term bootstrapping is both technical and social, in which the connection between conception and execution enabled through the integration of the physical and the digital lies at the very agency and identity of the architect shifting from representation to actualization. In many of Marble Fairbanks Architects projects, minor elements of digital fabrication play out as major effects in the architectural space such as the Sciuscia Restaurant and the recently completed Toni Stabile Student Center. In these projects, Marble observes:

> *"Anytime you do this you are taking risk, huge risk...In the most simplified way, it is about the relationship between designers and fabricators. That is where there has to be some restructuring."*

Bringing designer and fabricator together at the very conception of a project is an approach that SHoP Architect's has taken on the Zinc cladding of the Porterhouse Condominiums or most recently on the undulating brick façade of 290 Mulberry Street. Through this approach, real world constraints become operative design criteria enabled by digital tools to manage risk and complexity through virtual prototyping. In my interview with Chris Sharples, he highlights the importance of this physical digital integration:

> *"The biggest tactical bridge that you have to make is the extraction process from the digital to the real. And that is why here in the office we have the 3d printer and the laser cutter, that everyone who is working on CD's or working on the design has access to those pieces of equipment. Because they have to think about how do I extract information from my virtual prototype into this first scale prototype. That to me is the first stage of the actualization of the building process. What is interesting about that is it is not a representational process, it's an actual process, whereas models and renderings are always seen as representational."*

The risky business of these two research practices is enabled through the tight integration between conception and execution afforded by the integration between the digital and the physical making risk manageable. In both practices there is a close relationship between designer and fabricator without conflating the two as one design-builder.

WORKSHOP PRACTICES

The relative affordability of CAM along with the close integration of digital tools and the geometric complexity they enable is opening up a whole new genre of workshop practices that bridge the gap between design office, design consultancy, and fabrication shop. Associated Fabrication and Situ Studio are full-fledged workshop practices, whereas designtoproduction operates as a digital fabrication consultancy on large geometrically complex projects. In each case they are quite clear that digital fabrication is their market opportunity. In the case of Associated Fabrication and Situ Studio, while the productivity of the CNC router makes their business solvent, their ambitions are to develop their own design practice enabled through their access to these tools. In all three cases, despite their intentions to work more closely with architects in the design process, the separation between conception and execution is illustrated by the fact these workshop practices are more often than not hired by contractors and fabricators.

REIMAGINING PRODUCTION: ASSOCIATED FABRICATION

The four founding partners of Associated Fabrication and their associated design practice 4-pli, graduated from Columbia University in 2005 just as the school was tooling up with digital fabrication. In speaking with Jeffrey Taras, one of the four founding partners, one thing is noticeably clear: architects are often poorly informed about these fabrication techniques and what it takes - and costs - to make such things feasible:

> *"I think the architect gets to a form and all they really care about is the form and so we have to figure out how to produce that form with the limitations that we have. Our shop drawing phase is the phase of reimagining for our means of production...most of the things we do are really one-offs and so we need to figure out [how] to do it before we do it and then we charge for that."*

This reflects not only many architect's lack of knowledge in realizing complex forms, but the bulk of the work in digital fabrication is not at the tool itself, but the process of reimagining the work for fabrication and assembly within the constraints of tools and materials (Figure 1). More than just a production shop, the development of knowledge in these workshop practices is connecting design with the anticipation of construction. This is still a form of design work that is as much intellectual labor as it is physical production. Tied to their own tools of production, Taras describes their opportunities as "really big furniture." To get beyond that scope of work, they need to exploit their accumulated intellectual experience without being tied to the limits of their own production. The investment in their own intellectual capital has allowed them to anticipate the scale shift in their work:

> *"The projects that are getting outside of furniture scale are going to be that kind of thing where part of it is our fabrication knowledge, part of it is just that our sensibility being architects and part of it is just our experience dealing with digital data and managing it and moving it around and getting stuff made out of it. On some level, we become like a facilitator, like a data manager."*

MODEL FABRICATIONS: SITU STUDIO

Situ Studio began in 2005 as a collaborative design space and workshop while the five founding partners were finishing their education at Cooper Union. They grew into their space and their company purchasing

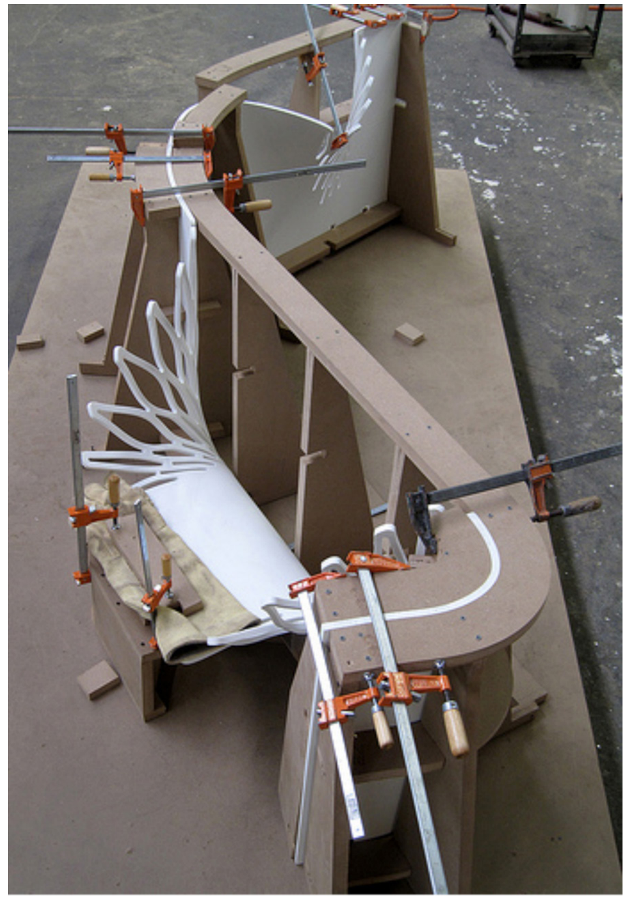

Figure 1. Combination of digital fabricated jig and mold for thermo-formed Corian for Vito Acconci's bench for Bronx Museum, design consulting and fabrication by Associated Fabrication.

tools as jobs allowed, including a basic CNC router similar to what many schools have, but considerably less industrial than the router at Associated Fabrication. The equipment they have purchased helps Situ Studio experiment and test ideas at full scale, but they do not want to be tied to production. As co-founder Wes Rozen notes,

> *"While we enjoy making things, and definitely keen on digital fabrication, we have other interests. We are trained as architects and plan on moving more and more to our own design and research projects, and the digital fabrication will be very much a part of how we do what we do, and how we collaborate and interact with the architecture world."*

In a short period of time, Situ Studio has made inroads into a number of high profile architectural firms through making geometrically complex architectural models for these firms, something that is profitable for them but does not match their ambition. As fabrication consultants for the entry lobby for One Jackson Square in New York City, a major condominium development designed by Kohn Pederson Fox (KPF), they are able to fit into a more desirable role bridging conception and execution. This included milling material studies and producing a full-scale prototype as a proof of concept in their shop, and developing the complete digital design development of the files for fabrication (Figure 2). However, unlike Associated Fabrication, Situ Studio was only interested in taking the actual construction to the prototype stage, while they continue to manage the production of the project functioning as consultants from design to construction management. As Rozen describes:

> *"It is a good example of prototypes that come out of our office, and fabricating as a way of demonstrating to the client, and then to begin a relationship with a larger shop to do the fabrication."*

Figure 2. Completed lobby of One Jackson Square by KPF Architects with Situ Studio as design development and fabrication consultant for bamboo walls.

While their largest project to date, the now conventional laminated fabrication approach illustrates a lack of material feedback in the design process, and they acknowledge this is an extremely materially consumptive process. Because they did not have ultimate control of the design conception of this free form wooden canyon, they were only able to minimize waste through nesting, and through coordinating a two-step fabrication process to first profile cut and laminate these profiles and then to surface mill this laminated material stock for the final finish. As designers and fabricators for a series of experimental pavilions, Situ Studio was able to push back on the design geometry inverting the process from material, to fabrication, to design including a "zero-waste mandate" as a precondition of their design to utilize the entire sheet of material they are working with. Through this give and take relationship between design and material fabrication, they challenge the notion of ideal geometries and fixed form toward a bottom-up process of how an economical material system can inform form including a basic set of assembly rules to be installed as a self-organizing system to unfold on the site without a predefined plan.

Like the self-organizing system itself, indeed this is no blue-print for development, but is rather an insight that develops from their workshop practice which both makes visible the waste in the top-down digital fabrication process and inversely, the means and tools to critique this process through full scale installations. As a business model still being tested out, there is no ideal plan here either. While their primary ambitions are to develop their own design projects, and second to act as fabrication consultants bridging the gap between design, fabrication, and construction management, they are able to remain economically solvent through their services creating geometrically complex architectural models.

In both workshop practices there is a clear scale threshold that is difficult to cross due to the limits of the tools they are working with as well as their developing ability to manage complexity with the most advanced computational tools. Designtoproduction operates on a completely different scale of production. Without an actual fabrication shop they are not tied to the constraints of their own tools and the ability to manage a highly complex digital information chain is enabled by the computational expertise of cofounder Fabian Scheurer.

OPTIMIZING FABRICATION: DESIGNTOPRODUCTION

Designtoproduction operates as a specialized conduit between the most advanced and daring contemporary architects with the most sophisticated industrial fabrication shops neither of which have the computational expertise to organize, optimize and materialize the code to fabricate the thousands of discrete pieces these designs require. Although designtoproduction is not a workshop practice as is Associated Fabrication and Situ Studio, it did begin in earnest as a research group at the ETH in Zurich with several hands-on design-build projects. In these design-build projects, the design process was inverted taking the students to the end of the chain showing them the machine and the material they had at their disposal on the very first day. The knowledge of material and fabrication processes is necessary from the very beginning, if, as Scheurer notes, the project was to be completed on time and on budget. Although the students were familiar with laser cutting, it was their first exposure to industrial digital fabrication. The interesting thing, as Scheurer recalls of this experience,

> *"Is really to take the students out to the fabricators to actually talk to the guys in the sawmills who have a completely different perception of the world and get them into a dialogue in a way, which is really interesting because they just - they stand there and say, 'No, we can't do that,' and then they are able to explain why because the stick is too long for the machine or there is only a certain style of wooden beams available on the market, for example. How would you know? And all those little constraints come in on a 1:1 scale."*

While Scheurer is able to bring in this back-end and its associated tolerances, constraints, and fabrication logistics into a unique pedagogical process in a small design-build project, on the large geometrically complex projects he works on designed by architects from UN Studio, Renzo Piano, Zaha Hadid, or most recently his work with Shigeru Ban, these types of issues are not even considered until the project moves into construction illustrating the clear separation between conception and execution:

> *"In most of the cases where this fabrication [is] actually done, we're hired by either the fabricator or by the general contractor and not by the architect simply because when the architect is in the process, digital fabrication is not yet that issue. This is mainly a problem of the process itself.*
>
> *There's a straight cut between the design phase and the building phase, which means that there's no information coming from the backend of the process up the chain and informing the design process, which is a shame I have to say...Mostly because the architects don't have any budget to play with in the first place. Sometimes, and I don't want to be rude, but some of them are straightforward ignorant."*

Similar to the lack of knowledge in the profession that Taras experiences at Associated Fabrication, Scheurer summarizes, "In easy terms of economics, either you do it and save the money, or you source it out and pay for it. That's the thing that hasn't arrived in all the brains." The issue here is not simply the economics of paying for this expertise, but the material feedback necessary in the design process. Designtoproduction played a pivotal role in the execution of the timber gridshell in Shigeru Ban's Pompidou Metz. While hired by the timber fabricator, Scheurer's involvement cuts across surface shape and geometry, the intricate material constraints of each compound curved timber element, and the craft knowledge of the Swiss timber fabricators. There were over 1,800 unique pieces totaling 11 miles of custom fabricated glulam beams with each continuous lath segmented in a way that could be fabricated, transported, and installed on-site (Figures 3-4). Each glulam lath is nominally a 6" x 18" glulam, developed over the complex surface in a four layer gridshell and joined by a unique pin at each intersection. Developed over three months, Scheurer wrote a custom Rhinoceros plug-in with nearly 20 different variables to segment the beams taking into account the blank type of glulam stock (straight, curved, or doubly curved), segment length, where the lengths are segmented, and analyzing the given solution to stay under the maximum five degree cut angle to maintain the structural integrity of the wood fibers (Figure 5). The plug-in did not automate a single optimized solution, but gave discretion to the timber fabricator allowing him to explore possibilities and potential scenarios for segmentation and to manage each discrete piece. Scheurer summarizes,

> *"That was the interesting point here that, actually, we had a combined process of craft knowledge and tools that accelerate the actual construction of the thing."*

Figure 3. 11 miles of compound curved glulam pieces each digitally fabricated from a unique glulam blank.

Figure 4. Pompidou Metz Gridshell being assembled from prefabricated compound curved glulam beams.

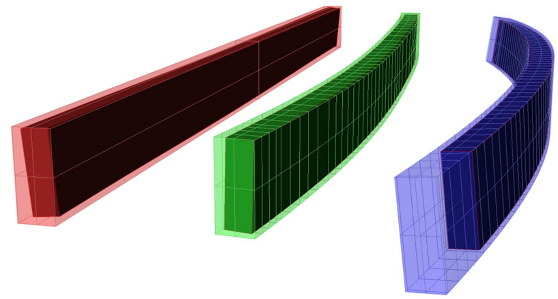

Figure 5. designtoproduction developed a custom plug-in for fabricators to segment each of the 1,800 unique pieces each one nested into a custom glulam stock either straight, single or double curved.

The shear scale, complexity, and precision within this process raises some serious questions about the nature of this production and how much of this back-end, should be brought to the front-end of design. Is this an expertise that an architect should know? Scheurer is slowing accumulating knowledge and experience with each project and new scenario thrown his way, beginning with the early design-build academic research projects to the many complex projects they have taken on since opening designtoproduction in 2006. While not a workshop practice such as Associated Fabrication or Situ Studio, the intent of forming a bridge between design and construction is very much their market opportunity. In some sense, not having direct access to the tools keeps designtoproduction aligned with the experts in industry:

> *"We would be completely lost without the fabrication experts because we don't have a workshop. We don't have the expertise in how to deal with it. The only thing we do is sit down with the fabricators and talk to them and sit down with the engineers and the architects sometimes and talk to them and try to match the ideas in a way. And, of course, the expertise is growing from project to project. We are on the second Shigeru Ban thing now and there were a lot of questions I didn't have to ask a second time. In the second project, we went in four weeks, the whole way, what took us three months in the first project, in terms of programming and actual planning because, of course, we can reuse the knowledge and we can reuse part of the programming anyway. So it is, of course, about knowledge."*

Through this accumulation of knowledge and their role as a bridge in the current knowledge gap between design and fabrication, Scheurer describes the role of designtoproduction as an abstract factory. The operation of designtoproduction viewed as an abstract factory enables them to bridge this knowledge gap by providing a general class of material, fabrication and logistics expertise to feedback into the particulars of a design problem, before the design itself becomes fixed over time. Through the combination of craft-based knowledge enabled through custom software-based tools designtoproduction is able to break the scale threshold necessary to realize these complex projects. In their realization of complex projects, Scheurer offers his most cunning criticism of architects that simply want to eschew the realities of construction:

> *"The complexity is not taken away from the designer just because there's a tool - it's more the other way around. The more sophisticated the tools are, the more complexity the designers can handle. But once the complexity is in the project, it doesn't go away anymore. You have to drag it down the whole way until the fabrication. So the less complex the project is in the first place, the easier it is to get it done at the end. If you put in the complexity at the beginning, you have to find a way of how to deal with it until the very end."*

Bridging this connection between design and fabricator is exactly what Scheurer intends to do as an abstract factory, but the primary issue, as Scheurer affirms, is in the industry itself,

> *"In the first place, the process and the thinking has to change...The quality of the outcome can be much higher if the form, the shape, the design and the materiality match in a way."*

From the Abstract Factory to the Abstract Workshop

This synthesis between design, form, and material enabled through the digital tool-set is a pedagogical opportunity. The direct access to digital fabrication has opened a renewed interest in pursuing architecture as a workshop practice. These hands-on material design practices are liberated by the precision, speed, and variation within digital fabrication, and yet at the same time continually bump into a scale threshold often limiting the work to unique even if powerful features within a larger architectural framework. To cast digital fabrication solely under the purview of design-build practices does not capture the full disciplinary and pedagogical implication of these tools, and at the same time, without a connection to full scale fabrication and assembly these tools quickly become expedient means to represent form.

On the other hand, parametric design tools connected to material and fabrication constraints require a generalization or abstraction of material constraints as an operative design parameter. The argument for the abstract workshop is not to avoid the direct physical contact with materials and fabrication but in fact to extend this sensibility throughout the design process. As abstractions are best drawn from real world experiences, the immersion in the literal workshop is a critical step in the development of the abstract workshop. While rich experiences, they are limited in their scope and are often of only limited duration in a long education. The abstraction of material and fabrication parameters afforded through parametric tools leverages scale in a way direct fabrication never could.

Scale itself is an abstraction. Working across scales through a physical digital physical process is the best demonstration of the abstract workshop. However, the risk here is to not take any risk at all, which certainly is often the case as most physical models in design education today made through the "lazey cutter" are merely physical representations of digital form. In contrast, the models of the abstract workshop are physical prototypes testing the digital to physical translation process as the anticipation of actual fabrication. As such, the model-as-prototype can act as a simulation of fabrication and test of assemblies rather than a representation of form. When SHoP was asked to exhibit the model of their Camera Obscura, for example, because it was developed as a complete virtual prototype identifying each discrete piece for fabrication, the physical model was able to be laser cut at a smaller scale from the full-scale fabrication files, and then quickly assembled as a scaled prototype of the actual construction. From an educational point of view, parametric tools offer the potential to introduce a very basic tectonic system explicitly identifying tolerances and parameters of a general material assembly, to then play out these material logics in the context of a design problem including the scaled fabrication of the material assemblies as a physical simulation and verification of the digital physical translation. The abstraction of material assemblies afforded through contemporary digital tools is not only a technological matter, but acts as bridge between conceptualization and actualization shifting design education from the production of images to projecting an image of practice.

This alone suggests a rich pedagogical context for the practical tectonic understanding of material systems, while at the same time, can project further into the disciplinary opportunities than the practical orientation of tectonic systems alone. In my interview with Greg Lynn, he connects this disciplinary opportunity within practice and education:

> *"To me, it is very, very interesting the way somebody will take control of the construction of something by transmitting a 3d file, or 2d files. That makes architecture real interesting and puts the architect in the position to do more because they are actually taking on more responsibility, and risk. I think that is the real interesting thing about the technology. That is why building models and prototypes in the office is important, because we can go to somebody and instead of saying, 'Here is a shape, can you figure out how to build it?' We can say, 'We need to cut 25 sheets of plywood and here are the files that your machine will use. How much is it going to cost for you to output it?' If you have this stuff in house, or you learn this stuff in school, it gives you more opportunities because you are not asking somebody else to work something out, you are just asking somebody to fabricate it for you."*

As emphasized by Scheurer, the complexity designers are capable of as a result of 3d digital tools does not go away, but must be carried on down the line to the very point of fabrication. If thought of as a linear progression from design to fabrication, design education is not likely to get to the point of fabrication save for small design-build projects. Consequently, the inverse tactic from material detail to parametric strategy makes good sense. Through the strategic placement of material techniques and fabrication within the context of the contemporary design studio and the extended digital tool-set, the abstract workshop suggests that architects can be actively engaged in the construction process without being blinded by it.

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