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Undevelopable

Metal, Curvature, and Tooling-Based Research in Hong Kong's Compressed Space

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***Abstract*— How does the spatial compression of Hong Kong Special Administrative Region (HKSAR) effect the relationship between designers and regionally established industries? How do spatial and real estate pressures and the "hollowing out" of Hong Kong's industry, effect tooling-based design research and design build practice? Hong Kong's history of industrial products exported to other parts of Southeast Asia and the world has made the city a seasoned player in international commerce since before British colonization [1]. Conversely, the "spatial compression" described by Michelle Huang is a relatively new occurrence produced by Hong Kong's focus on service and financial trades, ensuing policy-facilitated redevelopment, and increase in urban and sub-urban rents [2]. This compression serves the knowledge-economy elite of Hong Kong well as they participate in the financial capitalization David R. Meyer called the "global metropolis" [3], and rent new Class A office space throughout the city. This phenomenon simultaneously puts pressure on industrial small and medium enterprises (SME's) that, especially since World War II, have formed a large part of Hong Kong's socio-economic fabric. This research uses survey, qualitative interview, and design-research study to investigate the status and outlook of one such group of SME's, metalworkers in Hong Kong. Project staff's structured and semi-structured interviews provided insight on metalworkers' businesses, while prototyping research, tool cataloging and custom metal furnishing commissions allowed project staff to build trust, develop meaningful relationships, and understand more deeply how the realities of doing business in Hong Kong have effected these industrial professionals. Through this tooling-based research, the project works to make meaningful correlations between fabricators' tooling capacities, the industrial and real estate economy they occupy, and its effects on design practice in "Asia's World City."**

Keywords- Tooling-based Research, Design-Build, Design Representation, Design Agency, Local Economies

I. HOLLOWING OUT, REACHING OUT

Industrial surveys conducted by Hong Kong's governmental Trade Development Council (TDC), Industry Department, and the University of Hong Kong Centre for Asian Business Cases document a transition in Hong Kong's industries beginning in 1980s that strongly suggests the time for industrial capital located in Hong Kong is over. Instead, a cross-border economy of "economic complementarity" has come into being where Hong Kong's strength as a business hub leverages against Mainland China's strengths of cheap labor, inexpensive, broadly-available land, and expansive consumer markets. The Belt and Road Policy Agreement, and the Closer Economic Partnership Arrangement (CEPA) before it, foster this relationship and encourage cross-border specialization [4] [5] [6]. One particular study responds directly to the description of this movement as a "hollowing out" of the former industrial capacity of Hong Kong:

> The relocation of production processes and the sharp increase in offshore trade give people the wrong impression that Hong Kong's industry is 'hollowing out'. However, this trend of relocation is in fact favourable to the long-term development of the local economy and trade services. This is particularly true for high value-added activities, which has greatly strengthened Hong Kong's role as a business hub. [4]

Coupled with this sentiment, the government's significant investment in creating a "knowledge-based economy" [7], and the land seizures made for commercial and residential investment [2] give credence to the vision of Hong Kong as a service and trade economy, short on fabrication capacity and long on intellectual and coordination competency.

However, as with all redistributions of investment capital, the impression that the transition is unilateral, or unilaterally beneficial, would be mistaken. As industrial investment vacates its physical capital from the city and engages in the cross-border enterprise the Industry Department promotes, much of the low-value physical capital and cheap labor that characterized Hong Kong's competitive advantage throughout the early 20th century remains in the city. This is especially true at the low-to-medium level of capital investment for industrial firms. These professionals find themselves under spatial and economic compression of a globalization center described by Michelle Huang:

> I argue that Hong Kong as a global city is a space of dual compression. The global compression refers to the vast urban space restructured for Hong Kong to fulfill its role as a hub of transnational capital, for example, the construction of the new international airport and the landmark business buildings. The local compression means the

> consequences of the global spatialization such as the influx of foreign laborers and the severe housing problem for ordinary people who have to jostle for living space with the top-level professionals coming to the city with the global flows. [2]

This compression has specific and meaningful consequences for people engaged in industrial enterprise: increasing rents quite literally compress industrial workspaces, effecting the efficacy and range of industry. Local cable programs such as "Hidden Heroes" provide humanistic insight on these ageing industrial enterprises, of which light to medium metalworking businesses form a significant part [8]. This study sought first to make the business realities of these remaining metalworking enterprises concrete using the language, concerns, and biases of design research. The tooling available in the city's metalworking shops formed our primary concern, as this difference between Hong Kong and the Mainland forms, hypothetically, the transition in progress, as Hong Kong has fewer tools, and more knowledge workers. This research sought to provide qualitative and quantitative information on what it is like to work in this "hollowing out" industrial environment. Further, it connects starting biases framed by Huang to the social innovation works begun by designers in Hong Kong to propose consequences for fabrication-centric design practice under such change. Avoiding the humanistic imperative for keeping aging industries, this writing links Huang's rhetoric to value structures internal to design-build practice, and to many of the socially driven design projects driving it. To wit, this paper asks what changes to design practice, and to the urbanity housing it, can be projected due to this change in industrial character? How will the exit of tools and industrial capital influence the nature of the city and its design culture?

II. SURVEY DESIGN: TOOLING-BASED SURVEY

Metalworking firms surveyed occupy a number of Hong Kong's districts, with a higher concentration in Kowloon, particularly in Tai Kok Tsui. Most occupy first-floor shopfronts of either *tong lau* ("Chinese Building") or *beehive* type concrete buildings with residential apartments or second-floor shops above them. Project staff divided surveyed metalworking firms into four different categories describing their shop's tooling and, by extension, the formal complexity and size of commissions they were likely to accept. These categories include:

> Category One (1) Firms: which own primarily hand-forming and cutting tools, including tin snips, pliers, grinders, and hammers.
>
> Category Two (2) Firms: which own primarily machine-assisted forming tools including large folding and shearing machines.
>
> Category Three (3) Firms: which own digitally assisted cutting, punching, and

Figure 1. Survey respondent district locations. Numbers in parenthesis indicate respondent quantity by district.

forming machines with some mechanization or automation.

Category Four (4) Firms: which own die forming, stamping, hydroforming, or stretch-forming tooling.

From one to four the categories of tooling progress generally upward in size, cost, retooling complexity, and floor space investment required to purchase the tooling involved. This factor was critical to the projected design research study for the following reasons:

1. Available tooling affects the forms a fabricator can feasibly create, allowing discrimination in where and when to request commissions.

2. As tooling complexity, creation of custom dies and punches for stretch forming, stamping, or hydroforming increases, the costs of commissioning metal works become prohibitive for a small-scale research study.

3. As part of the Environmental and Interior Design research program, this project maintains architectural or environmental design applications as long-term goals, making scalability a critical factor and further reinforcing the need for "mass customization" and inexpensive tooling changes.

Figures 2-6. Metalworking shops and their products. Photo Credits: 2-5, Ada Chan. 6, Marco Lam.

With these criteria, project staff learned where metalworkers were located and what their status was, and insured they would be able to work with them productively at the scale and scope anticipated.

III. SURVEY RESULTS

Most metalworkers surveyed in Hong Kong fit into categories one or two, as described above. None surveyed were willing to answer demographic survey questions regarding approximate monthly revenue, number of employees, or age of enterprise, but anecdotally project staff note that these category one and two metalworkers resemble either sole-proprietor or SME business models. The Hong Kong government Trade and Industry Department recognizes businesses employing fewer than 100 employees in manufacturing as SME's [9], and this measure is ostensibly consistent with metalworkers surveyed. Some firms stated they employ the "shop in the front, factory in back" model with offices in Hong Kong and larger factories in Shenzhen, Zhuhai, or elsewhere in Mainland China. In these cases, actual firm employment is harder to measure certainly without direct survey information. Category 3 and 4 metalworking firms surveyed reliably operated this way, with the exception of Professional Stainless Steel Metal Engineering in Tai Kok Tsui, the only metalworking shop surveyed with computer-numerically controlled (CNC) laser cutter tooling physically located in Hong Kong.

Most firms surveyed in Hong Kong claim that "small fabrications" and "movable furnishings" comprise most of their business, with exceptions of one category 2 and one category 4 firm claiming that architectural paneling and structural framing made up much of their work. Wo Lee Steel, a Category 4 firm, is an outlier in this survey, and a multinational corporation. Anecdotal survey photographs from the field study indicate that much of the work metalworkers in Hong Kong do is the production of simple L-section frames and sheet metal pans, to secure air conditioners to the sides of buildings, cover access panels, or repair "hawker stall" shops. Larger shops tend to take on mechanical ducting commissions, fixed furnishings, or security door production if possible, though firms tend to this kind of fabrication in facilities outside of Hong Kong. Category 2 firms, the most common, will often maintain their business simply through continuous production of press-brake bent pans for cabinets or air handling.

TABLE I. METALWORKING SURVEY RESPONSES BY DISTRICT

District Name	**Metalworking Survey Responses By District**		
	Firm Name	***Tooling Category***	***Will you keep your business in HK? Why?***
North Point	Chit Hing Decoration Engineering	1	**Yes.** Unlike Tai Kok Tsui, not a lot [of metalworkers] in this area. [Hong Kong Island] Has advantages, but also disadvantages. Some people rather come here since it is

District Name	Metalworking Survey Responses By District		
	Firm Name	*Tooling Category*	*Will you keep your business in HK? Why?*
			nearby in the area, but some rather just go straight to Tai Kok Tsui since there are more options over there.
	Hang Cheong Engineering	1	**No response.** Business is declining and often have nothing to do. However even if it is not busy does not mean they can just stop. Cannot just close business and change job since he is old already. Just have to live cheap and continue working.
	Wai Lim Aluminium Engineering	1	**Yes.** Even though not always very busy, business is steady. Enough to pay rent and living expenses.
Wan Chai	Wing Cheong Loong	2	**No response.** Able to supply different metal materials. Also colored metal sheets, which a lot of other stores does not offer.
	Ka Li Decoration, Furniture, & Materials Co.	1	**No response.** Been there in business for more than 30 years. Still some old customers but business is declining. New generation does not follow the business of parents.
Tuen Mun	Chung Tai Rolling Doors	3	**No response.** Main business is making rolling doors. However also have bend and break tools to work with sheet metal.
	Chan Yun Tai Metal	2	**Yes.** Unlike in Tai Kok Tsui, one of the few in the are for bending metal sheets in the area
	Wing Wo Aluminium and Steel Frameworks	2	**Yes.** Large company with several businesses around Hong Kong. Mainly fabricate frameworks for doors and windows etc. Can deliver on large orders.
	BD Metal and Glass	2	**Yes.** Quite a large business for metal door and window frames. Also does glass, which most others does not do.
Fo Tan	Kai Ah Electrical Metalwork	2	**Yes.** Fabricate profiles for other companies, often in large quantities. Therefore business is running well.
	Alcoa	2	**No response.** They have a metal sheet roller, which others often does not have.
	Yau Hung Rolling Doors	3	**No response.** Main business is making rolling doors. But has the tools to do some fabrications. However not aimed for that, as it is not their main business (only if company requires something beside the rolling doors).
	Chief Tain Engineering	1	**No response.** Main business is repairing machines, but can do small fabrication commissions.
	Chun Hing Metal	1	**No response.** Mainly repair or adjust metal products and electronics as well. Not really into fabrication commissions, but small and easy things might be done.
	Lee Fat Engineering	1	**Yes.** Not going to be rich but enough for living for now. Not sure anymore if the rent gets higher though.
	Cong Yip Engineering	2	[No response.]
Tai Po	Zit Lyun	1	**No response.** Not many in this area that accept fabrication commissions. So in this area they are known for that.
	Ka Hang Engineering	1	**Yes.** Small metalworker that accept fabrication commissions. Been there for a long time. Even though business not steady, still able to earn enough to live.
	Zung Yip Stainless Steel	1	**No response.** Sell pre-made metal products. Also sell metal materials as well and accept small commissions if it is some they are able to make themselves.
	Zi Shing	1	**No response.** Small metal store that sells metal materials, but also some other products as well. Besides also accepts some small fabrications in order to earn money. However only able do some simple stuff as doing fabrication commissions are not their main business.
	Shing Cheong Metal Engineering	1	**No response.** Small store doing all kinds of small commissions.
Sheung Shui	Shun Tat Aluminium and Steel Works	1	**No response.** Focused on making frames for windows and doors etc.

District Name	Metalworking Survey Responses By District		
	Firm Name	***Tooling Category***	***Will you keep your business in HK? Why?***
Yau Tsim Mong	Kan Kee Steel	1	[No response.]
	Lung Wo Hip	1	**No.** As long as he works there he will keep the business in HK. But thinks it will be lost in the future since the next generation are not following his footsteps as a metalworker.
	Wo Lee Steel	4	**No response.** Wo Lee has multiple businesses in Hong Kong and in China as well. Large company with clients from overseas.
	Hip Lee Engineering Products	2	**No response.** Have business in both Hong Kong and China. Expanded to China due to the growth of the company. (Cheap in China)
	Kwan Hing Company	2	**Yes.** Hard to switch to other business. Small company impossible to find companies to work with overseas. (Also language barrier)
	Dahua Stainless Steel Engineering	2	**Yes.** Trying to keep the business, but not sure since the competition is high. Especially in this area where a lot do the same thing.
Sham Shui Po	Yip Hing	1	**No response.** Business going steady, but focused on framing like for windows and doors.
	Yuk Fai Engineering Company	2	**Yes.** Rather do the commissions by themselves and not let people in China do, because if they do it themselves they can control the quality.
Cheung Sha Wan	Lun Faat	1	**No response.** Even though small business, can accept lots of different jobs like repairing and small fabrications. (Small things only)
	Tak Kee	1	**No response.** Small business for accepting small jobs. More reparation than fabrication.
Lai Chi Kok	Lun Tak	1	**No response.** Main business are selling metal ropes, but can do small fabrications.
Tsuen Wan	Cheong Hing Metal Co.	1	**Yes.** Instead of doing commissions often repairing things to earn money.
	Zi Yin (Location 2)	1	[No response.]
	Ming Tak Metal	1	[No response.]
	Zi Yin Metal	1	**Yes.** Started with only sales of metal products, but started doing a bit of small easy fabrications. (Usually only using profiles)
	Chiu Lik Windows	2	**Yes.** [No response.]
	Lo Kee Metal and Paper	1	**Yes.** Do different things in order to earn a living.
	Sun Cheong	1	**Yes.** Steady business in Tsuen Wan since not much competition in this area.
Kwun Tong	Millico Metal Stamping Ltd.	4	**Yes.** Company is focused on stamping. Their factory is in China and in HK only one of their office.
	Hap Lik Tools	2	**Yes.** Keep in Hong Kong and also have business in China.
	Cheung So Kee Metal Electrical and Machine	1	**Yes.** Does not earn much but is steady.
	Dynamic Way Ltd.	2	**No.** Main business are making rolling doors. They mentioned about also making them in China.
Tai Kok Tsui	Hung Tao	1	**No.** Very small business.
	Dat Ko	2	**Yes.** [No response.]
	Sheng Da Engineering Limited	2	[No response.]
	Wang Fu Stainless Steel Engineering	3	**Yes.** Main office in HK, but does not make things themselves. Outsource it to China.
	Fly Wing Engineering Company	1	**Yes.** [No response.]
	Cheung Ming Metal	1	**Yes.** Nowhere else to go, very small metalworker.
	Yung Kee Wing Cheung Metal	2	[No response.]
	Sze Cheong Engineering	3	**Yes.** Have business in Hong Kong and in China as well. One of the few laser cutters in HK so business is steady.
	Professional Stainless Steel Engineering	3	**Yes.** Not many CNC laser cutters in HK. Many metalworkers either come to him or goes to China.

District Name	Metalworking Survey Responses By District		
	Firm Name	***Tooling Category***	***Will you keep your business in HK? Why?***
	Wai Leung Engineering	2	**Yes.** More going to China, but still lots of people in search for metalworkers in HK. Doing it in HK is faster and easier to communicate, easier to check the quality).

Metalworkers were more willing to answer qualitative questions such as "Can you explain why you will or will not keep your business in Hong Kong?" or "What would help you take on more complex fabrication commissions?" Responses varied widely, and often included other anecdotal information, such as metalworkers' prognosis on their ability to stay in Hong Kong, estimations of the future of their work, or their understanding of what differentiates their work from others in their district or in Hong Kong as a whole [Table 1]. Unique tooling or product specialization is a strength for the surveyed metalworkers that own the only welder or profile-rolling machine in their neighborhood or district. There is also considerable capacity for informal work among surveyed metalworkers, with some that accept custom commissions, while others focus on repair or are diversifying into hardware retail. Complaints about rent increases and the decline of the industry are frequent, but not ubiquitous. Some metalworkers cite their proximity to the consumers they service and their ability to control quality as competitive advantages, as they are able to adjust to client demands more quickly. Others note that competition is intense enough, especially in Tai Kok Tsui, that price and proximity are the only advantages their business has over other firms located in the same neighborhood.

IV. Interpretation and Design Research

Survey results formed a picture of metalworking firms in Hong Kong, especially those with all of their physical capital located in the city. The picture is consistent with Turner's characterizations of Hong Kong's industries [1], and the competitive disadvantage manufacturing in Hong Kong experiences in comparison to Mainland China [4]. Intensive physical labor characterizes most firm's work processes, even when improved tooling would prove advantageous. This is true even of some "shop in front, factory in back" firms with facilities in Mainland China. One firm with multinational reach and high profile public infrastructure projects, here referred to as "CPL" for confidentiality, provided a factory tour to the project team. During this tour, we discovered this larger firm also fit into category 3 tooling, with their competitive advantages coming less from tooling or intellectual property, and more from additional shop space, cheap labor in Mainland China, and greater capital investment. This firm's most significant tooling advantages addressed metal finishing rather than forming, with powder coating and enameling facilities on their factory site. The project team used this knowledge to develop a scheme for working with the metalworkers located in Hong Kong and nearby: stamping and tooling used to form double curvature in metal, short of the hammer and dolly, is practically absent in Hong Kong's metalworking community. English wheel, shrinking and stretching, rotary forming, and incremental forming tooling are absent from most metalworking shops. The project team took three approaches to design research to find ways to work with Hong Kong's metalworkers and add value to the relationship within this fabrication environment:

1. Develop metal design commissions that can demonstrate the facility and capability of Hong Kong's metalworkers using existing tooling, i.e., linear bending, while avoiding critical weaknesses in tooling or competency.
2. Develop software and tooling utilities for designers that can improve and expand metalworking design vocabulary, and reduce the likelihood of errors, delays, and loss of productivity.
3. Investigate lean-tooled methods of production that can produce more complex form types in Hong Kong's highly competitive, spatially compressed environment, and other environments where scalability of tooling and fabrication methods are critical factors.

These three vectors of the design research phase of the study provide hypotheses to external values and starting biases of the project team and many designers working with *local crafts*. The results are a series of prototypes that provide anecdotal data on what designers can and cannot do to improve design-fabrication relationships when craft industries are under demographic or economic stressors, and add value to clients and fabricators under these conditions.

Developing metal designs fitting to Hong Kong's toolset required the project team to improve their fabrication knowledge in the abilities and limitations of metalworking tools. In this way, our design practice progressed steadily closer to design-build methods, as we prototyped or "up-streamed" our furniture commissions in-house to varying degrees of completion before commissioning them from others. We designed movable interior furnishings as a means to manage the scope of the commissions we submitted and accommodate the team's product design expertise, while still generating designed objects that demonstrate what is possible in Hong Kong. We sought to challenge the formal complexity of what metalworkers in Hong Kong typically fabricate, while still keeping within the limits of their tooling, and to provoke the normative furniture morphologies we explored with notions of specific human behavior and formal surprise. The first design commissioned was a "ribbon" steel stool, designed for the hallway of an apartment building as a place to put on shoes. The underside of the stool is open for storage, and slots in the top accept umbrellas for drying before entering the home. In order to demonstrate and learn about the impacts of different tooling in Hong Kong, project staff commissioned two of this first prototype. Notably, we approached more than ten metalworking shops with sketch drawings and dimensions of the same design, and only four shops were willing to entertain the custom commission. Fortunately two of the shops selected allowed us to commission prototypes using significantly different tooling: the first opted to shear and hand-cut the pieces required, using a manual press-brake to form the stool, while the second opted to laser-cut the pieces of the stool and bend them with a CNC press brake. The first shop requested a concession of the design, changing the

radius-bends of the original scheme into sharp angles, and using machine screws in place of plug welds, as the shop did not own

Figures 7-9. "Ribbon" Stool Prototypes with and without laser cutting.

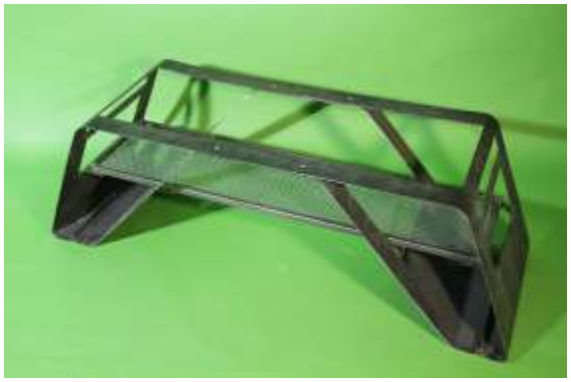
Design by Daniel Elkin and Marco Lam. Photo Credit: Marco Lam.

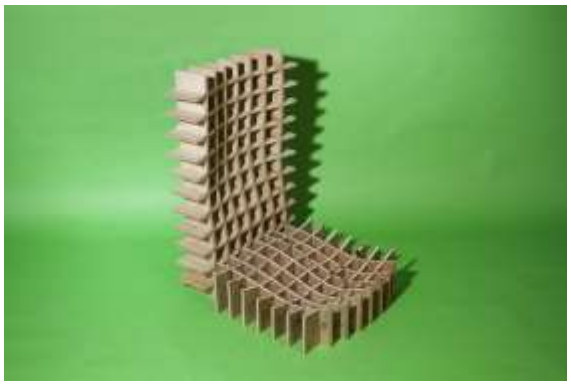
a welder. Ellipses cut by laser in the original scheme became circles cut by a drill and a jigsaw. The second shop made the more sophisticated prototype at its facility in Mainland China.

As the project team developed design commissions to test and cultivate relationships, we also wrote Python software utilities to simplify development of shop drawings and the work expected of the metalworking shops. Marco Lam programmed utilities to simplify paneling layouts, develop hammer forming or curvature modeling *bucks*, and economize laser-cutting layouts for bending complex curvature by cutting. We used these along with digital modeling software to speed the more onerous parts of commissioning the work, providing cutting layouts along with design intent sketches whenever possible. In cases where a design required double-curvature we fabricated hammer forms ourselves before approaching metalworkers. Tautologies of the process became evident over time: as the project team worked more in a design-build mode, we effectively took on more of the value added by the metalworkers until we reached two conclusions. First, that a high wattage laser cutter adds a substantial amount of value to metalworking design in Hong Kong. Hand-cutting workmanship was either very rough, too costly for the fabricator, or impossible given the thickness of metal required for most designs. Second, that even as our efforts reduced the metalworkers we worked with from crafts persons to tool-owners, we still found difficulty getting complex work made *in* Hong Kong. Anecdotes from fabricators we worked with, when asked why they declined or had to change a commission still came back to the high cost of labor, unfamiliarity with complex work, and the simple lack of space to do it. The first ribbon stool we commissioned sat out in the gutter in front of the shop that made it, since there was no room for it inside.

The team's workshops have marginally more space to work, and without the time and budget pressures that influence metalworking firms, project staff developed three prototype methods for forming undevelopable double-curvature in metal that are scalable, lean, and applicable architecturally. Early in the study, we circulated a sketch drawing of a singly curved, 100 cm square panel with a manageable radius of curvature and single flanges on all sides, predicting an architectural panel with more complexity in the future. Hong Kong firms willing to quote this project bid HK$2000 (Approximately US$260) or more for the single panel upon completion, and stated that their fabrication method would entail laser cutting top and bottom flanges to define the panel curvature, then hand-bending and welding the curved panel into shape. This method, arguably less scalable because of its high workmanship demands and necessary post-finishing, is essentially the same as that used by CPL, mentioned above, to complete infrastructure-scaled metal fabrication projects. This was also consistent with drawings provided to the project staff by Mainland Chinese firms, whose paneling techniques either followed this, *cut, bend to fit, and weld* method, or simply made use of metal shingling thin enough for workers to bend to tolerance and affix to a substrate on site. The challenge we set up, therefore, was to find methods that would pre-form these un-developable geometries with no welding, or only resistance spot welding, that were scalable in both their fabrication method and tooling.

We developed forming methods based on Industrial Origami's laser cutting and folding process [10], which we quantified and economized through the Python scripts mentioned above and systematic testing of yield loads for folding panels by hand in relationship to cut lengths and spacing. Cut and fold tests, and the bead-rolled prototypes they engendered, develop doubly curved panel systems, as Hong Kong's metalworkers are proficient at forming straight-edged panels. Rotary forming machines are locally extinct, but an inexpensive way to form doubly curved paneling without significant custom retooling. The workmanship requirements for bead-rolling panels are substantial, but the nimble, form-parameter-responsive way in which we can design rotary-formed or laser cut and folded panels is scalable, cost-effective,





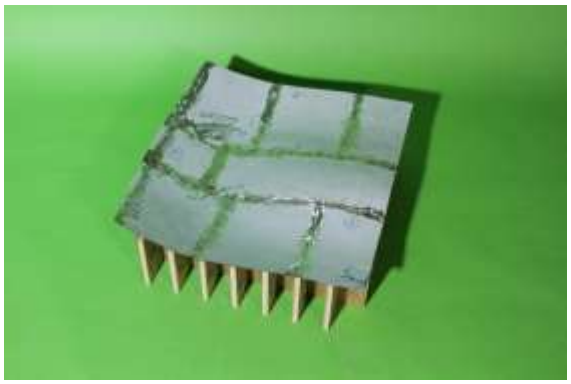


Figure 10. "Tension" Bench. Woven webbing seat incomplete.

Figures 11-12. Ergonomic Seat Metalforming "Bucks" and hammered steel seat.

Figure 13. Free-Internal-Pressure-Forming Test.

Design by Daniel Elkin and Marco Lam. Photo Credit: Marco Lam.

and promising for architectural applications. These forming methods are also non-marking on the principle surface of the panel, making curved steel panels with a black oxide "mill scale" finish or bright-surfaced copper panels more feasible. The same is true of the *do-it-yourself* free-internal-pressure forming [FIPF] setup we explored, similar to that used by Philip Ayres in his development of "Persistent Modeling" [11]. Along with obviating welding, project staff tested forming patterns designed to "program" the inflation of metal balloons into usable, stiffened panels, formed into shape by an inexpensive, portable water pump. All three methods propose rationalization for curvature as well, as the domed geometry created pre-stresses doubly curved panels against impacts or lateral loading, suggesting that thinner, lighter panels and typhoon resistant exterior cladding may be possible for small- and medium-scale projects engaged with Hong Kong's vernacular architecture.

V. Inferences and Conclusions

The capacity Hong Kong's small metalworkers show for doing informal work, noted anecdotally and in survey responses, is a meaningful characteristic of Hong Kong's urban environment, given Huang's conclusions about the change in character Hong Kong has expressed over the recent past. Huang's rhetorical argument relies on Saskia Sassen's *Global City* [12] and the spatial characteristics it proposes, contrasted through acts of walking:

> I argue that walking in the global city reveals the contradiction between everyday life and globalization. It is through walking that one witnesses vividly the oscillation between the yearning evoked by the ideology of open space and the dejection caused by the compression of living space as a consequence of capital globalization. [2]

The acts are different, and Huang's propositions of "walking" have fewer constraining factors than acts of industry or making in a globalization center. In spite of this, there is arguably something similar in Hong Kong's metalworkers' ability to take on small, informal acts of fabrication and design. If designers agree with Huang's rhetorical argument, and develop an interest in working on the "everyday" or vernacular parts of a city like Hong Kong, something in the nature of this industry provides context, business relationships, and critical design technic constraints for doing so. These firms invest in unsophisticated tooling, are distributed in their character, and reliant on price competition to maintain viable work. As a result, their tooling and design capabilities are limited, but in return, they are able to approach design as an act that is as "everyday" as walking. Despite their lack of sophistication, the welded-angle air conditioner trays these metal fabricators make, and the galvanized steel mailboxes they made in the past [8], are more part of Hong Kong's "everyday" than any sophisticated work of industrial design and mass-production.

The external values to maintaining a fabrication base in Hong Kong, or any other city, may be tautologies to designers and the clients they service. Lack of such starting bias, and the fact that much of the fabrication workmanship done in Hong Kong is inarguably poor, can both serve to make Huang's rhetoric, or similar texts such as *Kowloon Cultural District* by

Esther Lorentz and Li Shiqiao [13] seem esoteric. In spite of the cultural values of the fabrication context, working with metalworkers in Hong Kong is more difficult than working with their colleagues in Mainland China. It requires considerably more effort on the part of the designer, and often delivers a worse result. However, other writers' arguments provide concrete ways for designers to describe the value of such work, in how it informs both the content of practice, and its structure.

Ayres, along with Mark West in his essay "The Fore Cast" rhetorically frame their interests in free internal pressure forming of metal and fabric-formed concrete similarly, in that the technical development of their building methods came primarily out of a desire to view design and architecture as emergent practices. Mark West describes his movement from earlier "blackout drawings" to his fabric-formed work:

> But, despite [the blackout drawings'] compelling pleasures, these were only images. As a builder I wanted to make actual things, not illusions. Furthermore, these particular images were useless as guides to construction. Despite their compelling realism, they were not descriptions of anything, but rather the found results of a specific kind of action, an action of self-formation. The signal value of the drawing technique was its extreme simplicity – these things almost literally make themselves. Their ease was a hallmark, a temptation. Were there other simple analogous actions suitable to making/finding *actual* things in the world?
>
> The answer to this question came from a sculptural practice that was explicitly aimed at taking the lessons of collage and the Blackout drawings as prototypes of action in construction. During this work I stumbled upon the trick of casting plaster in a thin flexible sheet which was subsequently redeployed in various ways over the years. The solid/fluid, soft/hard, wet/dry things that resulted were truly uncanny. Much like the illusory figures that spontaneously emerge from a blackout drawing these were, in their own full-dimensional way, self-forming things- intricately defined figures that arrive with no assigned meaning. But unlike the figures that appear to us in clouds (or clouds of graphite), these forms were produced, or 'hallucinated', not by vision but by the materials themselves. Significantly, these objects arrived in full-dimensional material reality with the greatest of ease and, following a builder's intuition, were evidently capable of being built large if the small modeling materials were scaled up to tarpaulins and concrete. [14]

The fluidity of this "making/finding," which we can term facility between design and fabrication, is a distinguishing value of design/build practices like West's and Ayres', and, arguably, a characteristic shared by environments with a present, distributed, industrial force organized by SME's. Tooling plays a major part in this environment. The fact that the low cost and progressive nature of free internal pressure forming allows Ayres, as the designer, to designate the precise moment at which hydraulic pressure should stop and complete the act of design motivates his interest in this tooling. Designers can apply the same measure of informality to their work by developing relationships with fabricators, but only to the degree to which tooling advances in complexity and re-tooling cost. In a sense, designers must pre-designate any project requiring stamping or advanced stretch forming, with all the contractual, representational, and design limitations this implies. Displacing the fabrication facility from one city to another, through organic or policy driven real estate valuation change, can only exacerbate this distinction.

What transgresses between these relationships, whether formally or informally, is the drawing. The design work here included relied substantially on 3-dimensional modeling software to provide design intent to the metalworkers we employed, and, depending on its efficacy, made use of automation through programming as well. Regarding flexibility as discussed above, the determinism between the design drawing and the fabrication result oscillated depending on the task and what we hoped to learn through either more or less control. Cutting became completely deterministic in almost every case, as the sheet metal thickness required for our work lead nearly every metalworker to suggest laser cutting in a "file to factory" manner. However, the subsequent bending, and hammering to double curvature even more so, tell that even more sophisticated and deliberate design representation will leave room for the workmanship of risk in a tooling environment like Hong Kong. Notably, as mentioned above, this element was still present in firms that fabricate large, international projects. This makes the forthcoming prevalence of "file to factory" manufacturing [15], and the subsequent obviation of both personal and spatial relationships between design and fabrication, uncertain for even larger works. At the small scale of this research, however, we did find that "tooling-based scripting" as we called it, was valuable for a design build study working to get more out of the local industrial capacity. Hong Kong's metalworkers, operating at considerable personal risk, were more willing to take on a commission if we provided better drawings, a hammerform, or a jig to begin the work.

This re-location of design-oriented programming or *scripting* from form generation to design communication changes the polemic import of its use and its deterministic quality. The team developed the programming software with specific tooling settings in mind, and with direct representation, provision of fabrication guides, and general robustness as constraints. In a sense, each program is more a self-contained tool for moving between drawing and fabrication under specific workshop conditions, rather than an interconnected representational prop or form generation protocol. Upon publication of these utilities in open-source formats, they may re-distribute design determinism they enforce upon fabrication by providing a generalized tool for moving between drawing and making. At their best, these programming languages can translate between minimal and sophisticated fabrication environments, and provide the improvement in form-agency that is drawing's greatest strength. The project team did offer to provide the scripts to Hong Kong's metalworking firms for their use, and this offer met with indifference in most cases, or software incompatibility. As the accessibility of such design representation approaches that of the smart phone application,

perhaps the contest between designer determinism and the emergence of vernacular design will self-resolve.

This upstreaming frames a model of practice, design-build, or an approximation of it, that is uncommon in Hong Kong. Sivaguru Ganesan, Greg Hall, and Y.H. Chiang describe Hong Kong's construction environment as markedly vertical and characterized by extensive sub-contracting. Architects take a managerial approach to design, partially due to the constrictive legal environment of the territory, and partially due to the prevalence of sub-contraction. Ganesan, Hall, and Chiang recommend flattening of this vertical structure to reduce inefficiency, and improve the value added by designers and contractors through design-build practice and investment in more sophisticated building technology [16]. Markedly, design-build practice is different from the contraction side, where greater technology investment likely entails construction plant that is more sophisticated and larger, whereas on the design side, design build entails differing structure of practice and possible purchase of any construction plant at all. For most designers more sophisticated building technology is more likely to mean better drawing and modeling tools than purchase of construction plant.

However, if Hong Kong's designers are to transcend the territorial atmosphere of creativity-stifling regulation [17], perhaps some of the industrial capacity becoming unviable within the city's borders could become part of their practice. The government's work to foster a competitive, knowledge-based economy [7] plays in well to visions of design as strictly a service discipline, increasingly enabled by file to factory practices that supposedly make design without the faintest acquaintance with fabrication possible. The continuing emergence of the maker movement and Dale Dougherty's book *Maker City* have made convincing arguments, however, that modest industrial capacity in the hands of such knowledge-workers is in fact critical to their ability to distinguish their work and add value [18]. *Maker City* and "maker spaces" pre-occupation with digital fabrication and electronics notwithstanding, Hong Kong's design-build practices would likely benefit from working with or purchasing this tooling capacity located in the city before it is dismantled, allowing them to add value through making-centric practices that privilege emergent aesthetics and high material competency.

Doubtless, such a premise of a design studio with a press brake in the back office has limitations, especially in Hong Kong. Mainland China's larger land area and cheap labor capacity are facts that frame Shenzhen, Zhuhai, and other cities as the "factor[ies] of the world" [5] for the foreseeable future. Hong Kong quite simply does not have enough space to do the work, a fact proven by the competitive advantage provided to many firms surveyed who simply had larger shops. Consequently, space as well as cost will form a constraint on any design build practice that purchases construction plant as a means to add value. Large-scale projects, where better construction plant in terms of both size and complexity provide economies of scale, will largely remain out of reach for such a design-build practice. A rotary-forming machine will likely fit inside a Hong Kong design office, and its investment cost around HK$20,000 (Approx. US $2560) makes it a more viable purchase for a design firm than a press-forming machine, even before re-tooling costs. Moreover, the comparative technics of architectural paneling formed using the bead roller versus stamping processes articulate values beyond aesthetics and price.

In one fabrication method, hands guide sheet metal through an inexpensive, off-the-shelf set of dies according to geometry determined either in drawings, or on site according to need. The resultant geometry, through a worker's dexterity, results in double-curvature fitting to almost any ambitious form. Workers can re-make miss-fitting panels again, as corrections require the simple revision of a folding line, and the resultant 3-dimensional shape has an intrinsic relationship to the 2-dimensional layout of the panels, and to the ductility of the metal. In the other process, drawings guide the milling and casting of dies in some factories, hammer-forming jigs in others, and either presses or hammers forcibly stretch the metal to shape. Workers must compromise each panel into position on site, mindful of the powder coating or enamel since any damage or revision necessitates replacement over geographically large and expensive supply chains, and contractual compensation thereafter. Summarily 2-dimensional relationships between the curvature the panels must make and the shapes they take on leave the designer with decisions as minor and non-agent as *rectangles, diamonds, or parallelograms?*

More critically, the differences in such design-build approaches to tooling affect how designers add value to groups experiencing challenges of agency, poverty, and lack of access to design expertise. Rural Studio, an institution famous for framing design-build practice this way, has made a marked transition in thinking of design-agency relationships systemically, marked in the transition to Andrew Freear's leadership:

> Freear has updated the studio's commitment to sustainability by stressing what he calls "sustainability with a small s," by which he means creating climate-sensitive, energy-thrifty, and easily maintained architecture using low-tech methods and hardware that can be easily repaired by local people with few skills. Plans are usually simple rectangles; there is a tendency to expose structure. [19]

Easy maintenance, low-tech fabrication, and use of commonly available materials help make Samuel Mockbee's ambition to free designers from being "lapdogs of the rich" [ibid.] a systemic proposition. Houses built for US$20,000 and from the waste of locally established industries, coupled with detailing that is considered, but as accessible as a rural vernacular [ibid.], articulate a practice that brings connections between design-build work and design agency from the extraordinary to the "everyday."

Similar ambition exists in Hong Kong's design culture, manifested in studio projects, publications, and competitions [13]. Asking the question *what can we fabricate with less sophisticated tools that take up less space and cost less to re-deploy?* is a relevant endeavor even without the rural context which generally makes such design-build work more viable or even necessary. The 2011 re-design of Hong Kong's metal

Figure 2. Repair and maintenance in Hawker Stalls. Property of the author.

"hawker" stalls, for instance, would have benefited from a closer understanding of the tooling required to make them, as the complex tooling of the powder coating designers specified has caused a crisis of repair and modification that undermines the project's altruistic aims. For all the ambitious, innovative work done to involve Hong Kong's street vendors in the re-design of their premises, the simple fact that maintaining the stalls or building them in the first place requires tooling that is too expensive for a street vendor to use, illustrates how deeply technic decisions can relate to the polemic ambitions designers have [20]. Notably as well, this problem would emerge whether fabrication took place in Hong Kong itself or through importation. This concern for tooling is critical for the rhetorical goals of the project, even if any "localist" efforts to provide agency to Hong Kong's metalworkers by employing them is set aside.

Hong Kong's designers, as evidenced in *Kowloon Cultural District* and other works, privilege the city's unique character and the "everyday" quality of its neighborhoods, especially the older districts [13]. Some of the design culture is sympathetic to Huang's polemic description of the city. Working within this environment, this vernacular, requires insight into the means of design's production as much as the results. The premise that the criteria for beauty may be different: that an object is better designed when it is imitable, repairable, and makeable by the people in and around its site of use. This requires sacrifice on the part of the designer. Suitable projects are mostly small in scale. They require the participatory approach of the hawker stall redesign, adopting voices outside the profession. They may require the assumption of risk usually consigned to the fabricator. More than this, they require deep understanding of the tool, the device connecting the making of an object, to the social, economic, and spatial context of its use. This may require abdication from the bright, exciting future of fabrication: simplified supply chains, clean, dry, fabrication, and file-to-factory simplicity. Perhaps in the ability to touch the substance of the everyday, and the emergent characteristics of design therein, will be suitable trade-offs.

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