Advancing Construction Technology within Communities of Practice

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PolyU UoA 38

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Body of Work Description

This Body of Work describes fabrication research done in collaboration with Communities of Practice in Hong Kong. The Author fabricates the prototypes and partial assemblies shown in both University facilities, and with assistance from external fabricators. The author situates research outputs in the context of residential real estate development, particularly at moments of developmental transition.

Knowledge exchange for technological development, particularly in contrast to industrialization pathways, contextualizes the research output. Research outputs experimentally probe Communities of Practice to understand obstacles to technological advancement. This testing delivers significant insight into researchers' pathways to help Communities of Practice surmount normative limits to their capability, through Up-Streaming, Tool Packaging, and Alternative Technique development methods. This insight suggests pathways for technological advancement translating industry-normative industrialization into collaborative knowledge exchange. These alternative pathways suggest models to avoid negative externalities of industrialization-based technology advancement in housing development markets.

The work is original in its application of advanced craft capability to interfaces with external Communities of Practice. The author uses industry survey to understand limits to a Community's capability, and applies advanced techniques and facilities to collaboratively surmount those limits. Researchers' technical support develops ways to integrate technological advancements sustainably into a Community of Practice and, by extension, a development market. Thereby, this work suggests new models for technological advancement with greater possibility of integration into a development context.

Collaboration with Communities of Practice is structured through rigorous research throughout those Communities to insure experimental fabrications address limits to practice concretely and surmount them in impactful ways. The work shows multiple pathways for technological advancement based on the multi-faceted constraints Communities of Practice face. The work displays rigorous foundation of technological advancements in an industry-survey based experimental methodology.

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Research Keywords

Construction Technology Research

Communities of Practice

Tai O Village

Autonomous Development

Knowledge Exchange

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Researcher Biography

Assistant Professor Daniel Keith Elkin is an architect and construction technology researcher. His research focuses on construction technology advancement within Communities of Practice, particularly to support autonomous real estate development. Traditional industry, demographic, economic, and sociological research supports his experimental fabrication research, seeking meaningful advancement to construction technologies that are suitable for deployment in owner-builder or small residential construction contexts.

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Core Question

How can researchers work with Communities of Practice to advance members' technological capabilities, while retaining their qualities and situational knowledge? How can researchers help Community members' achieve design intents relevant to developmental transitions?

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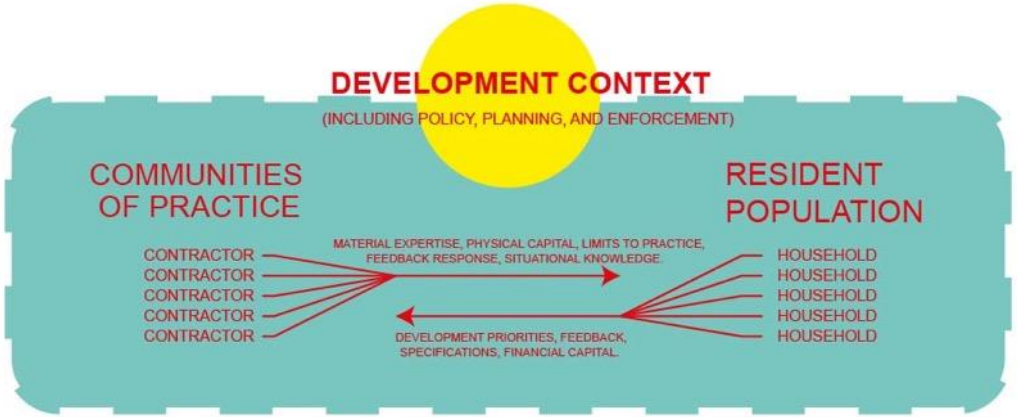
How do Communities of Practice function within real estate development and construction?

A diagram of a residential development context is shown at the right.

Communities of Practice, composed of many small contractors and fabricators, serve a Resident Population's material production needs.

Communities of Practice include many actors, locally situated and closely exposed to Resident Population feedback.

Communities of Practice fulfil Residents' needs as an ongoing economic and social exchange, over time constructing adaptive, material culture heritage.



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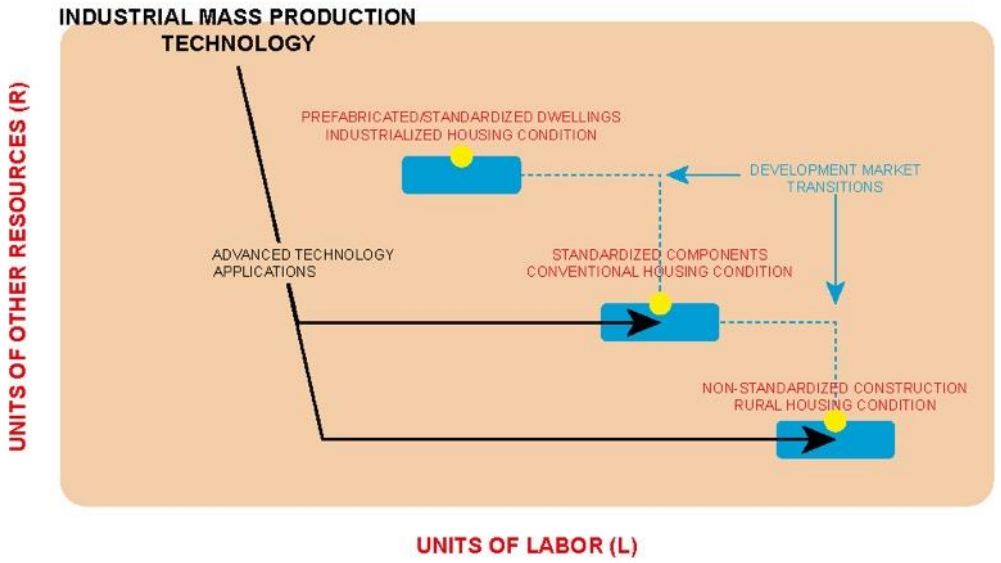
What does a normative model of construction technology advancement look like?

Zooming outward from the previous diagram shows a generalized construction technology advancement model for development markets, adapted from Ganesan, *et. al*.

As development markets change, particularly as they densify or industrialize, so do construction technology standards and norms.

The Construction Industry normatively deals with these changes by applying Industrial Mass Production Technology to reduce labour costs and improve delivery.

This process can push members of a Community of Practice out of a development market if they cannot apply more advanced technology and achieve newly-normative design intents.



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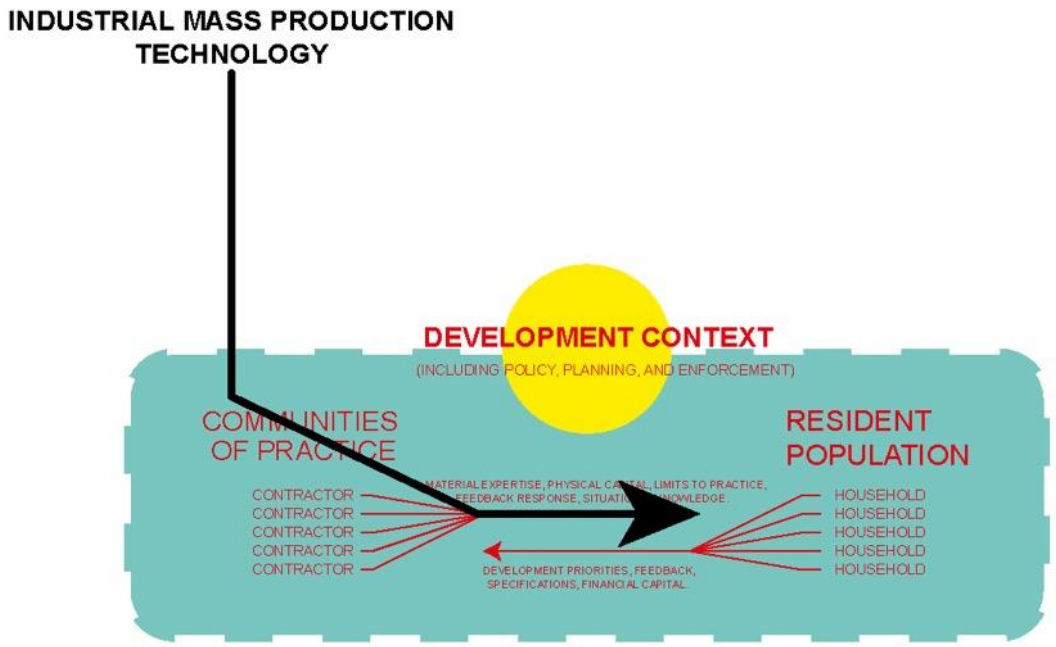
Why is advancing construction technology *within* Communities of Practice significant?

Technological advancement can substantially change a development market's material culture, especially when motivated by development Policy or Enforcement decisions.

If technological advancement displaces members of a Community of Practice, situational exchange conditions between a Resident Population and those contractors or fabricators diminish.

Responsiveness to Resident Population feedback can drop, standardizing design intents and potentially lowering Residents' housing satisfaction.

A development market's character can substantially change, and culturally significant modes of production can be lost.



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What would an alternative model for construction technology advancement look like?

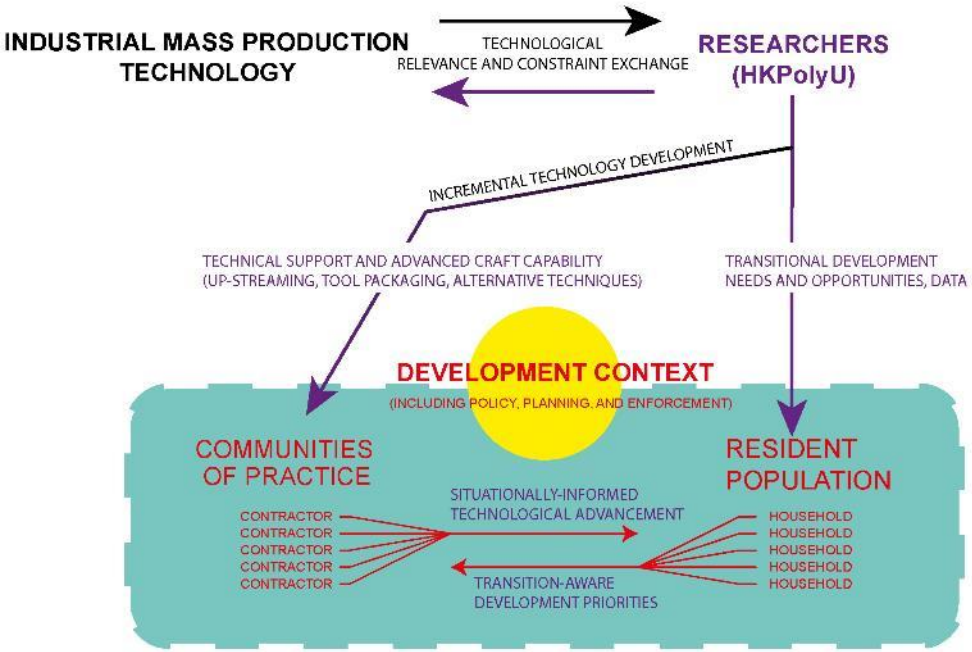
This Body of Work supports a research model for advancing construction technology in collaboration with Communities of Practice.

Researchers adopt technical knowledge and advanced craft capability through knowledge exchange with advanced industry and production.

Researchers apply technical support and advanced craft capability to collaborate within Communities of Practice.

Researchers simultaneously collaborate with Resident Populations, informing them of Transitional Development Needs and Opportunities, and providing data.

The following Research Output explores and develops this research model.



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What can researchers do to advance construction technology within a Community of Practice?

Researchers studied Hong Kong's metalworkers to understand limits to their practice through speculative fabrication commissions.

Researchers then developed methods to transcend those limits, including:

Up-Streaming: technical support through above-standard representation techniques, to reduce fabricators' risk and costs.

Tool Packaging: provision of advanced or purpose-built physical capital to surmount limits to practice.

Alternative Techniques: fabrication technique development to deliver advanced design intents within situational constraints.

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The stool prototype on the left shows a design intent delivered without these techniques applied.

Design researchers gave metalworkers an industry-normative drawing set.

Metalworkers returned the first-generation prototype shown at left using their own tooling and expertise.

For the prototype on the right, researchers Up-Streamed more advanced cutting and folding layout drawings.

Researchers also Packaged the design intent with advanced laser cutting Tooling and folding jigs.

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The bench prototype shown makes use of similar Up-Streaming and Tool Packaging methods.

Of note, many metalworkers would not entertain more sophisticated design intent commissions without researchers' Up-Streaming assistance.

Using these technical assistance methods, members of this Community of Practice achieved more advanced design intents within their existing context, constraints, and practice model.

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Double-curvature metal forming remained a limit to metalworkers' capability.

Up-Streaming advanced drawings did not convince metalworkers to accept doubly-curved design intents, such as the ergonomic seat design shown.

Researchers Packaged Tooling in the form of a digitally fabricated forming "buck," shown at left.

Afterwards, one metalworking shop was willing to accept the doubly-curved design intent, with the delivered result shown on the right.

The resultant fabrication is typically beyond the capability of this Community of Practice.

Furthermore, if researchers left this Packaged Tooling in metalworkers' possession, the design intent would remain accessible to their practice.

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Particulars of double-curvature metal forming makes developing **Alternative Techniques** for such design intents that are relevant to the Community of Practice complex.

Doubly-curved metal forming design intents typically either require skilled, high-risk workmanship through hand forming (left), or plant-intensive, high-volume driven industrial stamping (right).

Hong Kong's metalworking Community of Practice faces high rent pressures and generally low capitalization, suggesting that Alternative Techniques relevant to their practice must be:

More Certain: requiring less-skilled workmanship for delivery.

Lean: requiring low tooling and re-tooling cost in terms of space and plant.

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The following pages detail researchers' Alternative Techniques for doubly-curved metal forming.

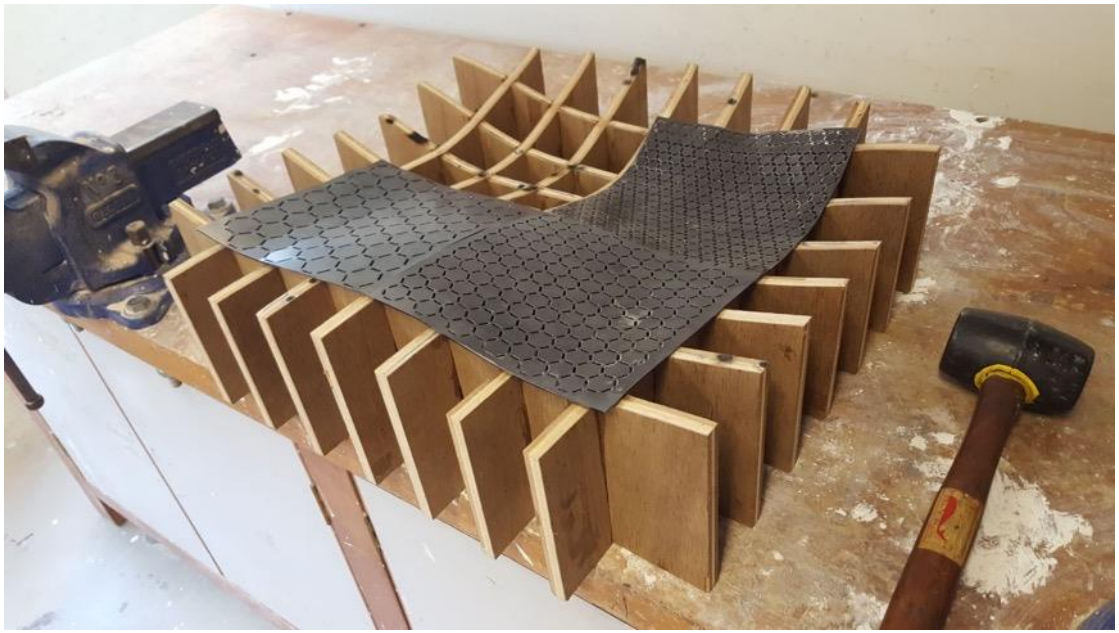
Though these techniques have a narrower form capability than hand-forming, they offer more certain delivery with less skilled workmanship.

Though these techniques sacrifice some certainty compared to industrial stamping, they are less capital intensive and leaner in terms of re-tooling.

Researchers used a high wattage laser cutter to perforate metal sheet into hexagonal grid, shown here.

This allowed hammer-forming of thicker metal sheet with more certain delivery.

Since different patterns can be laser-cut without re-tooling, this production method is also considerably lean.



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Researchers found that laser-perforated metal sheet, folded into compression flanges at the edge of a panel, could create doubly-curved architectural panels.

This technique is highly certain – if fabricators cut the correct curvature into the compression flanges, the curvature of the panel's primary face after folding develops predictably.

The lack of re-tooling cost for laser cutting allows lean production of virtually any doubly-curved panel design intent.

Since high wattage laser cutting is available in Hong Kong, the metal panel shown is within the capability of the metalworking Community of Practice discussed previously.

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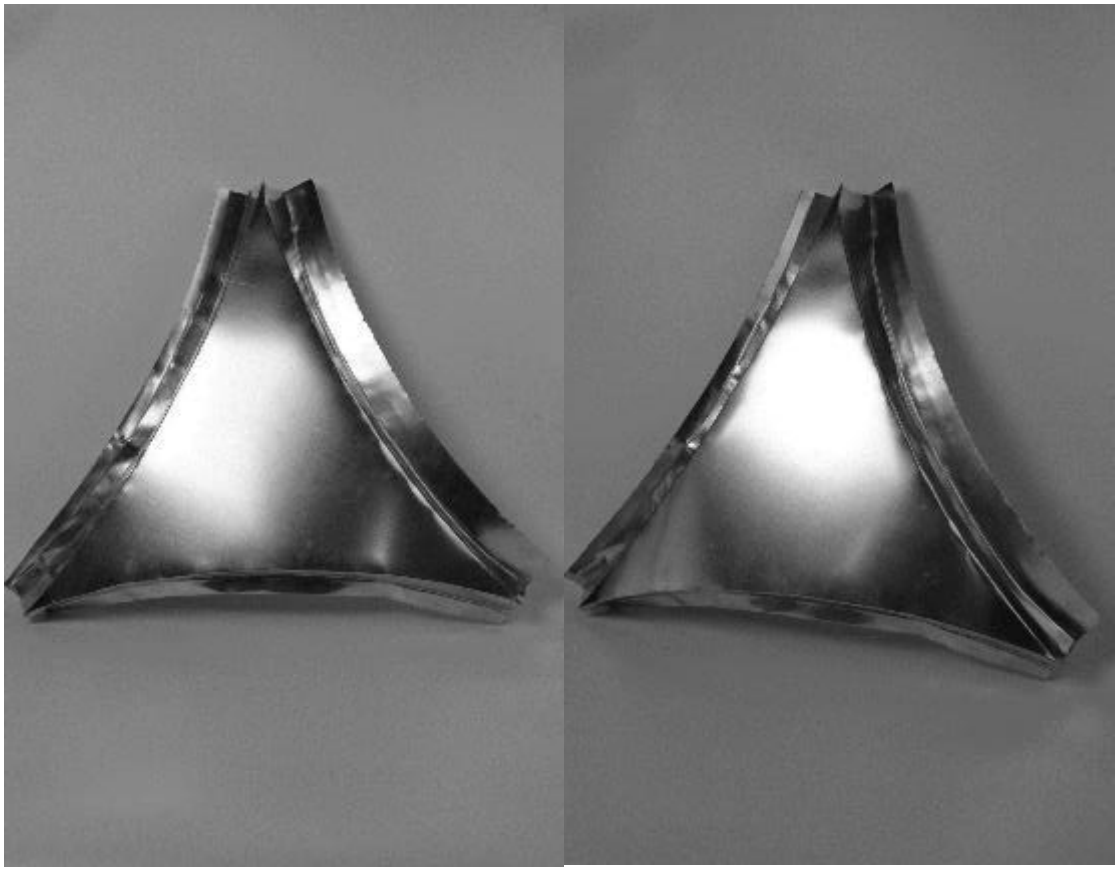
Researchers formed similar panels by bead-rolling compression flanges as shown.

This technique requires skilled workmanship to correctly roll the compression flanges, and is therefore less certain than laser perforation.

It is, however, less space and capital intensive, as a bead roller is a relatively inexpensive tool.

Bead rolling also requires no digital fabrication or drafting expertise.

As such, the metal panel shown is arguably more within the sustainable capability of Hong Kong's metalworking Community of Practice.



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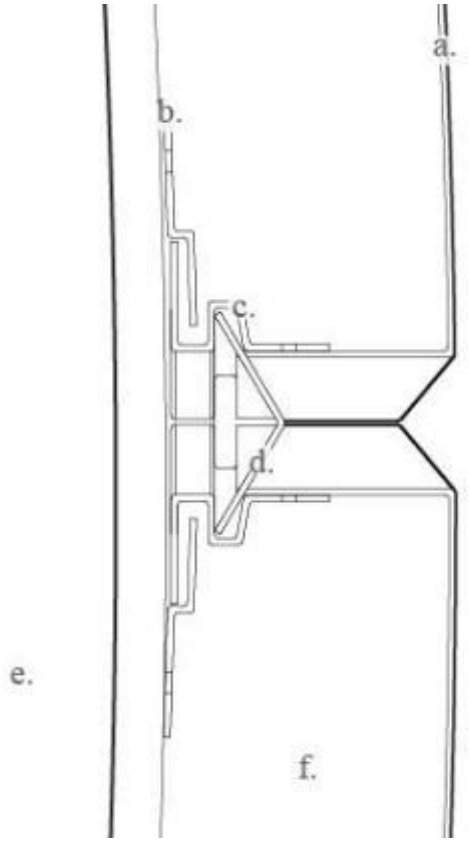
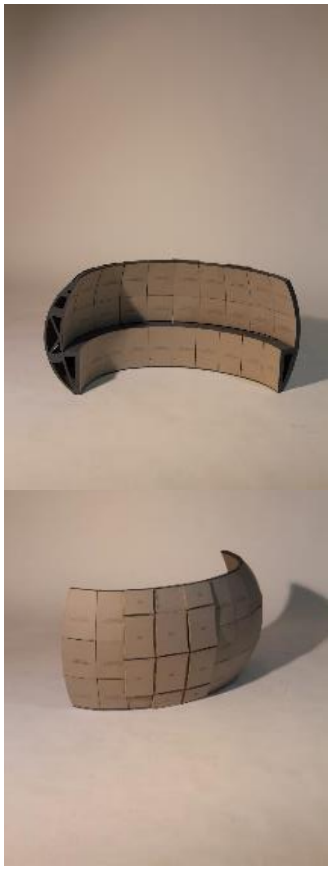
The speculative wall section shown at left connects bead-rolled, doubly-curved metal panels to a doubly-curved wooden substrate.

The scale model shown at right is a test of this technique.

Since the Alternative Techniques developed are responsive to the Community of Practice's situational constraints, this technique could allow double-curved wall sections in contexts where capitalization and expertise previously prohibited their implementation.





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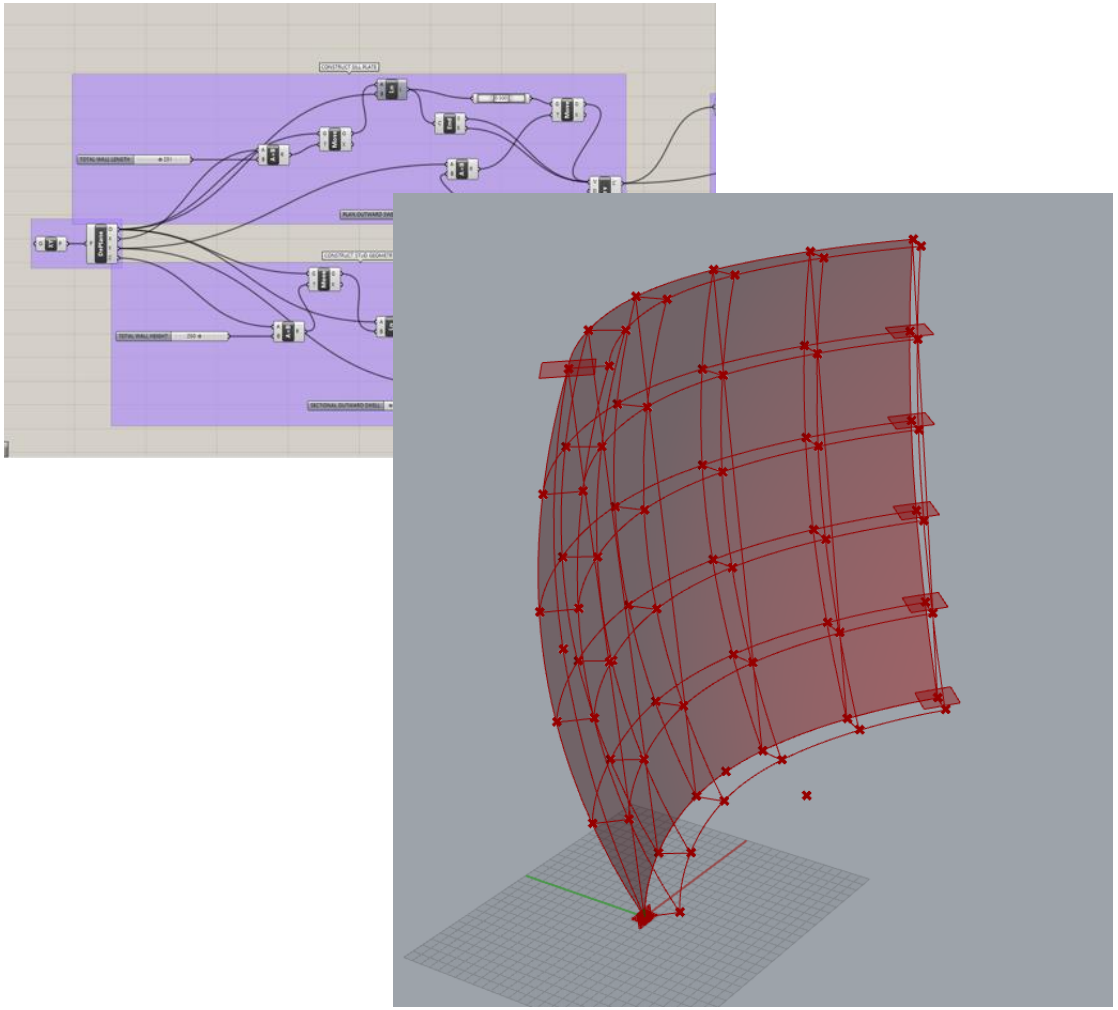
Sufficiently sophisticated digital fabrication scripts, like the one shown in Grasshopper software, could allow Up-Streamed drafting protocols to disseminate robustly.

The Grasshopper script shown processes any dimensions for a doubly-curved wall into cutting geometry for studs and lateral bracing.

However, this technique still requires devolution of digital fabrication expertise to disseminate into all but the most sophisticated Communities of Practice.



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Some Alternative Techniques can be Packaged into Tooling developed to work within a Community of Practice's constraints.

Without continuous intervention, researchers can provide Packaged Tooling to a Community of Practice for their continued use and feedback.

Free pressure forming, shown here, allows double curvature forming with lower capitalization, space requirements, and expertise.

The free pressure forming research shown works to obviate welding, and make the workflow more repeatable and capable.

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Attaching fluid supply for this technique without requiring welding is a significant technical advancement within the context of the metalworking Community of Practice.

Welding requires tooling many of Hong Kong's contractors do not have, requires skilled workmanship, and creates hazards, especially with pre-finished metal sheets commonly used in the Hong Kong metalworking Community of Practice.

The pictured prototype, adapted from a marine scupper plug, creates doubly formed metal panels without welding, stamping, or digital drafting expertise.

It is also considerably less hazardous than most metal forming techniques.

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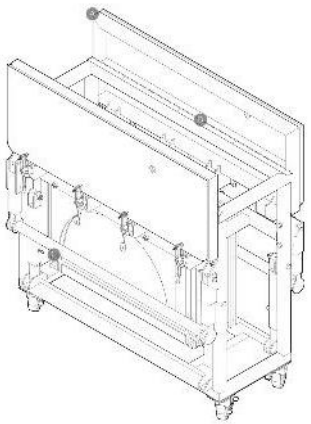
Die-driven pressure forming is more likely to produce reliable, useful results (left-most image).

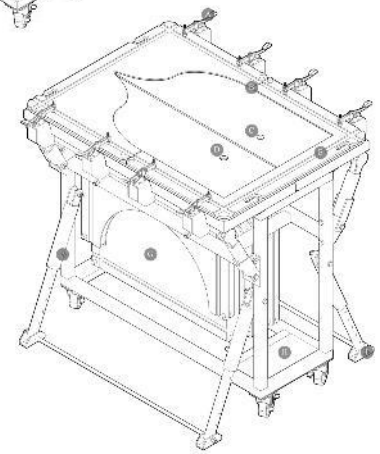
Packaging die-driven pressure forming Tooling into a forming rig (right-most images) may allow the technique to disseminate more readily.

For this to succeed, Packaged Tooling must respond to the Community of Practice's situational constraints.

For instance, the rig shown is mobile, collapsible, and features interchangeable dies to accommodate metalworkers' itinerant working space, small shop sizes, and need for flexible output.

Packaged Tooling may allow more sustainable adoption of Alternative forming Techniques in a metalworking Community of Practice.





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To test the relevance of this knowledge exchange to architectural research requires testing within a development market.

Tai O Village, a development market with a unique Community of Practice of “stilt house” vernacular builders, is also undergoing a development transition.

Tai O’s fishing economy is transitioning to a tourism-driven economy, and development may soon intensify.

Discussions with Tai O’s Resident Population will clarify technological advancements’ relevance to development transition changes.

Meaningful relationships between Tai O’s Community of Practice and Resident Population will connect technological advancements with development transition opportunities and threats.

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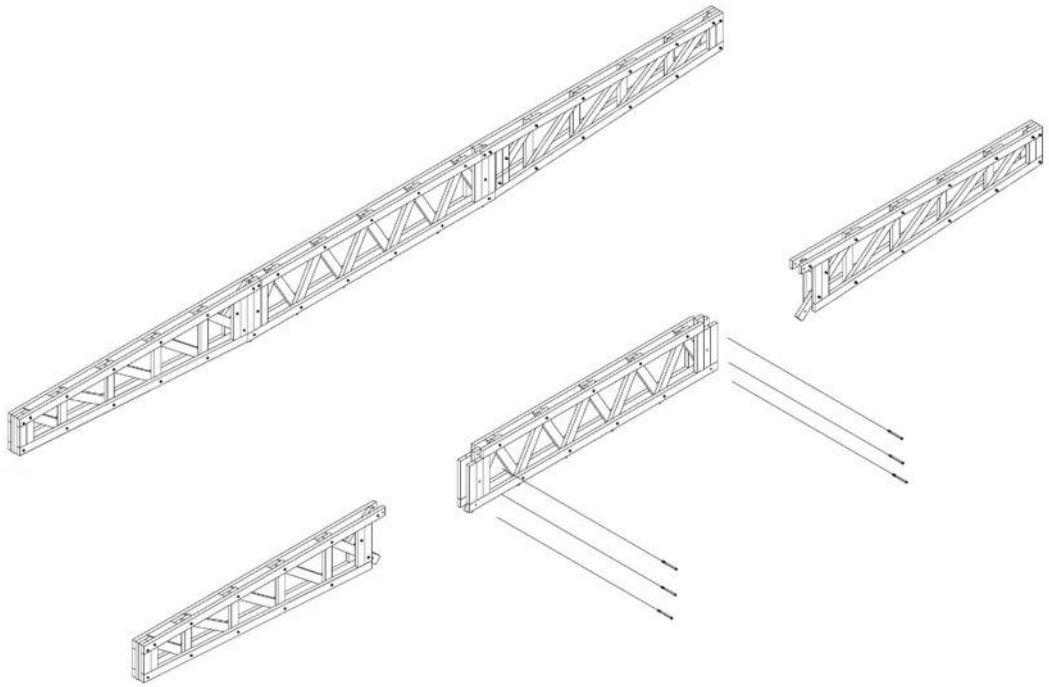
For example, authorities constrain Tai O residents' ability to take advantage of development opportunities, on partial basis of construction technology.

Site disturbance, sanitation, and fire resistance are most often cited.

Shown is a built-up truss prototype under development with Tai O's Community of Practice.

Tai O's site constraints suggested a segmented truss would be most useful to the stilt house builder Community of Practice. The segmented design is the product of a unique knowledge exchange in this context.

This Up-Streamed drawing package will help stilt house contractors to build a much longer sub-floor span than in typical stilt houses, reducing site disturbance and footing requirements.



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The mould shown combines Up-Streaming and Tool Packaging techniques.

Researchers digitally fabricated the mould to supply to a fiberglass boat repair contractor in Tai O.

With his help, researchers will Package the resulting mould into a Tool for stilt house contractors to pour footings with greater load capacity and higher resistance to settling.

Tai O's Community of Practice will participate in knowledge exchange for both development and use of the Tool.

Current research discussing tourism development priorities and opportunities with Tai O's Resident Population will likely reveal additional relevant construction technology advancements.

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Research Field Addressed

This work addresses **construction technology advancement**.

Normative pathways for construction technology advancement are supported by construction industry and production engineering literature.

These normative pathways are reiterated in architectural literature, particularly texts and projects focused on digital fabrication, prefabrication, and automated construction.

Constructing an alternative pathway for construction technology advancement depends on network theories of construction technology.

Network theories are advanced primarily in architectural and material culture theory literature, particularly Etienne Wenger and John F.C. Turner.

Turner's work on residential construction autonomy provides the literature basis to suggest and construct negative consequences to industrialization-based construction technology advancement.

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Conclusions:

Industrialization-based methods for construction technology advancement can destabilize relationships between a Resident Population and its Community of Practice, which supports its material culture.

Collaboration with a market's Communities of Practice can suggest more sustainable, less disruptive ways to advance construction technology.

Researchers' methods for applying their technical expertise, Up-Streaming, Tool Packaging, and Alternative Technique development, can allow Communities of Practice to advance their technological capabilities.

Input from Resident Populations regarding anticipated development trends can build a dialogue on development transition processes with Researchers as facilitators.

Research assistant Yu Chui Sang discussing up-streamed drawing packages with stilt house contractor, Mr. Sin.

Photograph by the Author.

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