Pre.Fab: Myth, Hype + Reality

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Introduction

The purpose of this paper is to discuss and explain the nature of prefabricated construction techniques within both a contemporary and historical context. With an understanding of multiple significant architectural works, we will:

- Review common terms used in the industry and how they inter-relate with each other;
- Discuss how the faculty of the Association of Collegiate Schools of Architecture can educate students to best understand the current state of the construction modality;
- Discuss how we can work with professionals and the industry workforce to strengthen architectural design and construction in the future;
- Discuss typical building permit issues, budgets, schedules, transportation options, and site contracting;
- Analyze the diverse spectrum of products currently available upon the market;
- Explain why a few of the prototypes/production lines have significance; and
- Delineate what we may learn from each other both academically and professionally.

There is a lot of hype about prefabricated architecture. It has become the "Holy Grail" that students want to learn, and the environmentally sustainable methodology that many clients want to build. Scores of designers are promising high design, near instantaneous construction, and rock-bottom prices, which is rather skewed. This typology has a rich history that can teach us a great amount about construction processes, marketing and how the potential of mass customization plays into contemporary culture. Many feel that prefabricated construction is the way that we will all build in the future.

It is our intent that this paper will begin to dispel myth, clarify what is possible today with a number of prototypes worth deep investigation, and direct vision toward the future of architecture, with support of our sibling automotive, aerospace and product design industries.

To have a discussion about prefabrication, it is important to establish a common language. The number of terms that are bantered about, and the seeming interchangeability of one for another can become maddening. There is therefore no definitive nomenclature, but we intend to clarify the discrepancies as much as possible.

Prefabrication is simply a process of making a series of pieces in one location, delivering them to another location, and joining the pieces into a larger whole. Some professionals prefer the term off-site construction, as it differentiates architecture from processes used within the industrial design and furniture industries, as all architectural projects will have some amount of site related work.

Dwell Magazine, among other periodicals and significant museum exhibitions, has cut a path for design professionals to utilize. They have championed the prefabrication typology through the potential of mass customization and caused a huge surge in demand for contemporarily designed residential applications. With popular culture desiring to utilize this type of construction on vacant in-fill lots within the urban fabric, many cities are adjusting their regulations so that the pre-fab houses may be built. [1]

In contrast to all of the hype, the companies that have been building and dealing the actual housing stock for decades has primarily focused upon repetitive and homogenized "Levittown"-style planned communities in segregated non-urban sprawl zones. This has done little for marketable caché, and quite possibly is an even greater hurdle than their earlier "trailer park" stigma. These unfortunate aesthetic and urban design choices have obscured the excellent quality and life-cycle durability of the construction modality, which is why design professionals are needed as collaborators.

The manufactured home industry owns the market share, and design professionals must learn to work with them. The Manufactured Housing Institute [2] can currently state with confidence that their products will under-cut site-built home costs by 10-35%, without any impact upon future appreciation, due to trade labor efficiencies, and their volume negotiations for construction materials, interior finishes and even appliances. Intelligent consumers realize this, which is why 63% of all new housing is being built by builder-dealers (33% panelized, 23% production on-site, 4% modular, and 3% mobile) and only 37% is still traditional on-site construction. We need to understand the standardized practices with zero upcharges, so that we may design and create products that are not only competitive in the market place, but allow us to focus our energy on designing better living spaces, and not wasting it on bureaucratic hoop jumping.

Building inside a factory's controlled environment has many benefits, such as constant temperature, humidity, and no precipitation. Building in a dry, heated environment with kiln dried framing lumber reduces the potential for shrinking and movement in the finished building. This allows a prefabrication company to build cost-effectively in a fraction of the time required for site-built projects, and they are able to exercise a higher level of quality control over the materials and methods than is typically found with more traditional methods of construction. The process may use standard construction materials, so that the finished buildings are indistinguishable from site built, or they may integrate a composite of cutting-edge building products from around the world.

When traditionally building in the field, we have shied away from complex geometries that might require temporary scaffolding before structural resolution. In a factory, each building station has a series of hoists, lifts, cranes, and jacks that can hold structural elements in spaces, just like the mythical "sky hook" that was going to allow that 500-foot cantilever in your freshman designed project. You cannot defy gravity once on-site, but you can do so temporarily in the factory while assembling a chunk or module.

The rules that manufacturing companies follow are quite simple, which is why they have become so very profitable with modular construction of multi-family housing, hotels, and plan-booked single family homes. Anything within the standard rectangular volume can be tweaked slightly, but cannot alter any structural paths. Beams have to fit between head clearances and the top of the module. Anything outside of the rectangle is a site-built feature at the owner's additional expense, such as site work, bay windows, dormers, etc.

Fig. 1. Atelier Z, Karsten KE-03 modified, 2003.

Even if a builder-dealer has an interest in implementing vanguard processes, their existing factory layout will determine associated costs of constructing both the prototype and future production lines. Builder-dealers tend to organize trade groups by area in the factory, so it is less favorable to mix construction systems. If you want to do something really unique, then you have to commission them to do it at least a half dozen times, or it is not in their interest. They will mean no disrespect, but they have plenty of standard work, so they just do not need the associated headaches of trying something new. Your best bet for innovation will be with equivalent products that can be owner provided and contractor installed just like their typical finish materials or built-ins without altering staff or production-line scheduling. The issue is that when working on a production line, with twenty or more modules in various stages of construction at a time, inconsistencies due to design or material supply of a single module will cause the factory to lose valuable shop space, which another module is waiting to fill. The speed of construction is a great advantage, but it requires design professionals to do their job fully and not waffle about decisions.

A typical layout of a manufacturer's floor might be: the main production facility (framing area, cut and steel fabrication shop, plus trade crew areas: electrical, plumbing, HVAC, specialty finish, exterior finish, final finish, and cleanup), painting, specialty projects (masonry or other massive materials with 10 ton bridge cranes), receiving department (materials and storage), and pre-assembly (shop using a laser level to pre-bolt together completely a project just as it would be set up on the site). This is to help ensure efficient erection on site as well as top notch fit and final finish.

When designing a new product to go to market, try to work primarily within the manufacturing industries standards. But have some prototypical conditions (inside corners, outside corners, wall-to-roof, wall-to-floor, wall-to-underbelly), so you can test a strategy without completely reinventing the wheel.

We may either propose ideas to builder-dealers for their existing production lines, or hire them as constructors of our designs. If we do not, then the architecturally designed/site-built housing market will have a similar fate as Main Streets in the face of WalMart and Costco. There are lessons to be learned, and collaborative teams that may be formed here, as most of the currently hyped prefabricated "architectural" prototypes are coming in at 2-3 times the cost of traditionally site-built homes (or essentially 4 times the cost of existing manufactured stock). [2]

Pre-Cut Parts

Aladdin Homes was the first company to offer "Ready for Assembly" houses, and Sears Roebuck & Company harnessed the power of the emerging rail industry and Fordian production methodologies to proliferate prefabrication across the continental United States with their "Book of Modern Homes and Building Plans" mail-order catalogue.

Mass production of the parts reduced their associated costs, which was then passed on to the homeowners. Plus, by using this tested system of pre-assembly, the catalogues of homes boasted that people could build their entire home with near zero waste in 352 hours (about 9 weeks), or 231 hours (40%) faster then traditional construction. Cost and time savings are still the primary driving forces for prefabricated construction today. It is estimated that with concurrent site and factory construction that pre-fab projects have a 30-40% reduction in aggregate time. [2]

Between 1908 and 1940, over 70,000 of these mail-order homes were sold, were pre-cut in Southern Illinois, had their 30,000 parts nested neatly on palettes in railroad boxcars, were transported around the country, and were hauled to site on horse-drawn carts over makeshift roads, to be assembled on site by families and friends with unique finishing touches. Since the homeowners had to drive each nail, paper each wall and make a countless number of other personal decisions every day of the nine week construction process, even though the mass-produced "bones" are all the same, each of the homes have a personal flair, sense of self, and pride of ownership. This ability to mass-customize became lost in the post-War era manufactured home process.

The number of components that we build with continues to increase, but the process of intelligent design, clear vision, excellent management, precise craft, and efficiencies in both transport and assembly continue to this day. During the twentieth century, there was much theoretical debate about the validity of mass-production and associated technologies in relationship to architecture. Such visionaries as Gropius, Greenberg, Heidegger, Tange and Wright highly recommended that we investigate how to approach this technology to enable a sense of individuality within a society teetering upon banal mass consumption.

Nike has been using technology for years to design shoes in a virtual environment, and then "unfold" the individual parts into flats for nesting, cutting, planning and/or production. Architecture tends to be much less complex in form than a sneaker, as architecture tends to be faceted and not have genuine hyperbolic curvatures. With the potential of digital technologies such as performative modeling, rapid prototyping, and 5-axis milling, which allow the mass customization of industrially designed products, many companies will offer interchangeable options for their customers with no inconveniences in the future. But for now, it is rare in the building construction industry.

Over the decades, the ability to maximize the number of individual parts from stock lengths/sheets of raw material has created computer numerical control (CNC) manufacturing of parts, layout and cutting practices with improved environmentally sustainable practices. This process is called nesting, as the software puzzles together two and/or three-dimensional pieces within limited constraints. From linear elements, like 2x's for roof trusses, there is an average 10% efficiency, which means less waste and a healthier planet. We may also use this same software to pack elements in a flat or volumetric matrix, much like the game "Tetris," to "nest" these multiple elements into the most compact volume for shipping. Ikea is the poster child for this process within popular culture. [3]

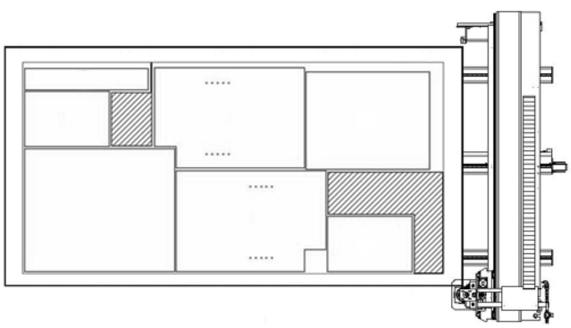

Fig. 2. Nested Parts for CNC Cutting from Sheet Stock

Frames

Structural frames have been our primary method of building since the departure from load bearing masonry and the advent of platform and balloon framing. By pulling the structural paths out of the walls and floors into a defined matrix, frame systems open up the potential layout of spaces, much like le Corbusier's third point in "Vers une Architecture," 1929. In doing so, the frame is structurally determinate, and it is possible to add additional space or reconfigure the walls, insert a window panel, etc. without having to recalculate the engineering. This allows for a great adaptability over the life cycle of a building, as a family might grow, change or have different needs.

Kristian Gullichsen and Juhani Pallasmaa created a beautiful wooden frame system in their 1969-1971 Moduli 225 house project, which formed a precedent for the more recent use of Bosch Group's Rexroth 90x90H Series extruded aluminum structural framing profiles in Taalman Koch Architecture's iT House and Living Homes' production line from Kieran Timberlake Associates (KTA). [4]

The iT house by Taalman Koch Architecture is still under construction, and is built upon a slab on grade. KTA built their prototype Loblolly House in 2006 as a frame mounted upon a one-story pylon sub-structure due to site conditions, while the Cellophane House is on slab.

KTA has researched the full history of prefabrication and investigated the breadth of technologies currently available. By using the Bosch frame system, they were able to assemble the Loblolly House in merely three weeks, and the Cellophane House in under one week as modules. [5] Much can be learned from their gospel of integrated assemblies, performative modeling, and production scheduling.

Many designers are trying to emulate the Ikea model, where an entire product can be assembled with a single tool. KTA boasts that their entire Loblolly and Cellophane houses may be assembled and disassembled with a single socket impact wrench, which is impressive, even if not accurate. KTA also used electrical and plumbing supply quick-connects to greatly speed up on-site assembly and improved circuit organization for post-occupancy user problem solving.

Panels

In the mid-1900s Walter Gropius spent a good deal of his career trying to rationalize the home into a mass-customizable system. Gropius and his later partner Konrad Wachsmann developed a panel system that cut a home into a series of pieces that could then be flat packed on a truck's bed for transportation from a factory to the site. He found that it is possible to truck the equivalent of approximately 4-6 modules as panels on one truck, due to the removal of air space. With today's bar code tracking technology, the crane assembly of the panels on-site is quick. But there is logically more on-site labor than when a module has its panels assembled in the factory. Therefore, there is a balancing point between cost, scheduling, and weather between these two systems that needs to be explored on a project by project basis.

With the associated savings, there is potential to use more complex composite geometry for creative non-cubic forms, such as the work by Zvi Hecker and Buckminster Fuller.

Panelization, on-site or in the factory, integrates multiple features into composite pieces for easier assembly. Today's Structural Insulated Panels (SIP), and the smart cartridges used by KTA and others pay homage to these roots, and are used for 33% of current construction processes, which is the largest market share of all pre-fab methods.

Charlie Lazor has taken the frame and panel ideas of Charles and Ray Eames, Walter Gropius and Konrad Wachsmann to the next level with his Flat Pak system. By creating a simple steel grid system, one may lay out any quantity of square footage desired, and then enclose the floor area with a diverse series of infill wall panels. The first prototype was built for him and his wife Zelda in Minneapolis, Minnesota a few years ago. Since then, they have been able to build two others in the Catskills, New York and Aspen, Colorado. The gridded nature of the system does not allow creative flexibility in volume composition, but it is solid, works well, marketable and appropriately designed for mass production and transportation.

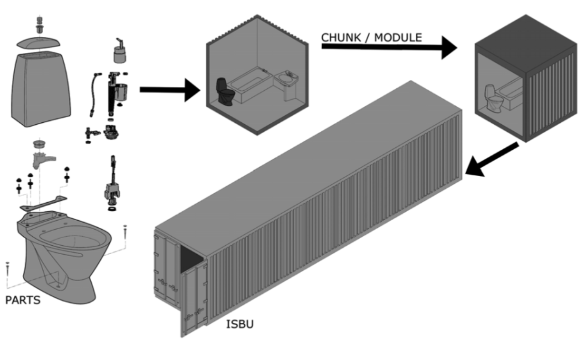

Fig. 3. Atelier Z, Radcliffe ISBU, 2008.

Integrated Assemblies

We now assemble wall or floor panels that have electrical, plumbing and HVAC integrated into them, window elements, or a full bathroom chunk, which once on site may be quick connected into the building. This is a process that combines a significant number of smaller sub-set parts into a larger component for ease of transport and management of specialized areas of construction. Stephen Kieran speaks of this process as "quilting," where skilled workers compose small parts into a larger piece, and then these larger pieces are stitched together by the next level of worker with potentially less specialized experience. By creating a series of these integrated assemblies, it is also possible to have higher tolerances between the edges where less skilled workers operate, and therefore have less potential joint failure. The aerospace and automotive industries typically create a series of composites (e.g., a wing, a dashboard or a door component), which are then grouped together into the final product. This happens at a range of scales with one set of assemblies becoming grouped with another as the sub-sets to a larger set, from parts to blocks to chunks to modules to whole. [6]

Similarly, you must maximize the intelligence of each part so that there are less on-site connections/penetrations. Fewer parts in the field typically equates to less associated labor costs. Similar to going backpacking, you want as many functions to fit into a small and light package for easy assembly. Most hyped systems are more like car camping strategies, where bulky items are lugged out and plunked down to thrill the owners, and not the field construction crew. Due to typical payment schedules and financing, the time it takes to seal a penetration in the factory actually costs you less than the same amount of time in the field. Plus, factory work will typically have higher quality and fewer inconsistencies.

Manufactured Units

In the 1950s, manufactured housing started to be produced in factories and shipped as near turn-key modules to customers. Eight foot wide units were typically considered mobile in nature. The most beloved of these are still the shiny riveted metal Airstream Trailers, which epitomize the American Dream. The wider 10-foot units became recognized as semi-permanent, and typically were mounted upon a car-jack height concrete masonry unit foundation. These became the quintessential feature of trailer parks around the United States. Since most municipalities still consider these homes to be "personal" property instead of "real" property, they cannot be taxed, which accounts for the lack of infrastructure development that stereotypically blights these communities.

In 1976, the US Department of Housing and Urban Development (HUD) code enactment further delineated the regulations for factory-built Manufactured Homes, while state and local authorities still regulated the Modular and Panelized housing markets with the Uniform Building Code (UBC) and now the International Building Code (IBC). The buildings are designed and built to meet the requirements for all the appropriate adopted codes where the structure will be sited. Plus, since they have to be trucked at highway speeds, they are engineered to withstand wind shear well over 55 mph. This makes modules much more stout than traditional site-built construction.

The process of construction permitting with prefabrication is not too different from the construction of a site-built home, since it is understood that the elements built off-site will become on-site elements, and must pass local codes and regulations. Some jurisdictions are still penciling this out, so you might need to do some legwork to coordinate in the meantime.

Mobile Units

These are completely finished products that can be hitched to your vehicle and driven right off of the showroom floor, or they might need to be transported to your site. These units are sometimes referred to as "pods."

After designing Airstream trailer homes for years, Christopher Deam took his years of experience in both minimal space design and transportation oriented construction to create a new line of residential/vacation products called Breckenridge Glassic Flats. These were one of the first production models on the market, and show how making a simple proposition with clear goals is quite attainable and affordable. Deam embraced the philosophy of "design kung-fu" and the "reality" of existing systems and bureaucracies. He has shown how a design-oriented architect may significantly influence the industry through collaboration, vision and marketing prowess.

Micro Compact Home is a prototype created through a series of academic, design and manufacturing partnerships. While it is a bit of an anomaly at only 76 square feet and will not have great significance a decade from now, it does demonstrate one of the best products currently available upon the market. It is highly refined, ergonomic, and easily transportable. This product has taken the design rigor of Kisho Kurokawa's 1972 Nakagin Capsule Tower and added a layer of zen chíc.

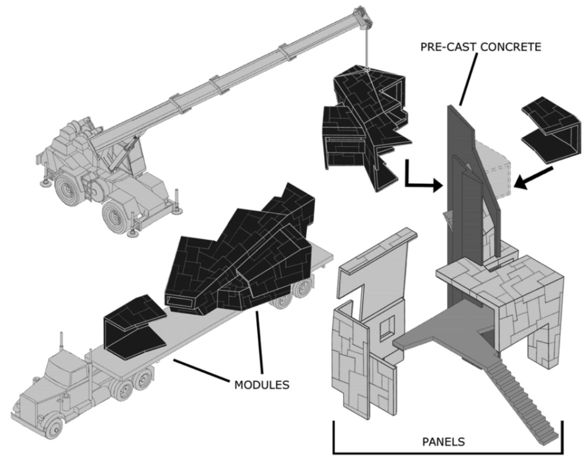

Fig. 4. Atelier Z, Honme Dwelling, 2004.

Modules

As the cost associated with road transit lowered [7], it became feasible to assemble a large number of pieces off-site in an enclosed environment as modules. Use of this system allows a near turn-key solution to clients, since after initial site work is completed, a factory-built home may be trucked to the site and craned into place with minimal effort. The widespread application of this construction methodology in manufactured housing has had difficulty in the public eye, which commonly relegates it to mid-income suburban communities planned by the home manufacturers themselves.

The reality is that builder-dealers can construct their stock modules with a low price point due to repetitive mass production. But even with their proven cost models, the manufactured housing industry does not consider prefab modules to be a viable market, and only invests 4% of their focus in this direction. It would serve design professionals greatly to work within the manufactured housing industry, as both a way to become familiar with their common practices, decades of research, financial pro formas, understand the reasoning behind such repeated choices, and find ways to innovate in small or great ways. The primary detriment of the module system is the shipment of empty volumes (air), which soaring fuel costs will potentially eliminate as an option, unless intelligent design and nesting optimize the shipping volumes. Specialty areas, such as bathrooms or other "service" modules with complex integrated systems, are most appropriate for the additional cost inherent per cubic foot.

Contemporary periodicals and museums have been doing much to redirect the stigma and bolster this type of off-site construction, so we will hopefully see continued innovation and optimism in this direction. The majority of hype-marketed products that proliferate the internet are in this category. They are quite often theoretical in nature or with a single prototype built that has a much higher associated cost. Even the notoriously sexy Glide House by Michelle Kaufmann Designs suffers from this supply/demand paradox. (See Table 2)

Before leaving Frank Gehry's office to start her own in Oakland, California, Michelle Kaufmann learned how to research materials and apply a selection matrix that balances cost, aesthetics and life cycle benefits. After building a prototype home with her husband, she was able to have BritCo build her first Glide House, and then a second one by Blazer Industries, which directly led to Sunset Magazine commissioning her for their temporary Breeze House. MK Constructs (her personal factory) reports that they have scores of patrons for their environmentally sensitive homes, but they have yet to be built. [8]

Conversely, Rocio Romero has created the LV Series, which has taken off like gangbusters. At this time they have dozens of these homes built across the country in varying climates and topographical conditions. But they are not actually modular, panelized, or even precut as they would have you believe. [9] The closest way to explain their system is that it is a "production on-site" performance model, just without single site efficiencies. By building the same house repetitively on different sites, they have a complete shopping list of stock materials needed for construction, so they can build quite quickly.

With all of the press that the two have received, it is not surprising that most of the wanna-be architects have followed their pattern. The concept is quite simple, create a series of rectangular volumes with skins that vary from transparent to opaque, and arrange them along the X-Y plane. But don't believe the worshiped mythology without some investigation. They serve as an excellent precedent, as they are both simple, cost-effective and their rectangular volumes would maximize allowable transport dimensions as modules.

One of the most adventurous investigations of prefabricated construction is the 2003 xPAC house system. Lang Wilson Practice in Architecture and Culture inc. in Vancouver, British Columbia has been exploring a series of interlocking modules with plug-n-play skin components that allow for growth, adaptation and customization, much like ordering a pair of Nike sneakers, an iPhone or BMW Mini online. The interior rectilinear walls allow for inexpensive production, while the undulating exterior skin may be mass customized for the needs of the individual occupants. This skin is from the marine industry process espoused by such vanguard architects as Frank Gehry, Greg Lynn and Neil Denari. [9] While the current iteration of xPAC housing is entering mass production, it is much less rigorous and creative than the earlier vision due to patronage issues.

Containers

Amazing work has been done with ISO intermodal freight cargo containers, also known as international standard building units (ISBU). Not only are they expressly designed for such transportation, but they can also serve as the structural frame for everything from single-family homes to seven-story mixed-use towers. [11]

There are five common standard lengths: 20-foot, 40-foot, 45-foot, 48-foot, and 53-foot. United States domestic standard containers are generally 48-foot and 53-foot for intermodal rail and truck. Over 7.5 million 40-foot containers are currently sitting in dry dock storage as waste around the world. [8] It is possible to purchase one of these containers for approximately $2,500 on-line.

ISO containers are made of heavy 14-gauge CorTen steel framing and have a continuous weld to keep out weather during trans-oceanic voyages. Corner posts are designed for a 153,000-pound vertical load. Each unit and its floor structure is built to hold 65,000 pounds of weight when stacked up to seven units tall without seismic bracing, so with hi-cubes this is a 85-foot 6-inch tall structure. Plus, they have a remarkable tolerance of only 3+/- millimeters.

Unless using composting toilets, significant thought needs to be given to black-water returns, as there is no significant space between stacked units to run such large volume plumbing returns. (There is enough space though for pest infestation.) A potential solution is to create composite units between “served” containers and “service” modules that contain all wet elements in a tidy stacked shaft.

With all of the exposed steel, there is a great amount of thermal mass. While as this can have advantages for passive solar design, it can also cause problem when internal and external temperature differences trigger a dew point, and can potentially cause moisture damage.

Revered as the cult leader of shipping container fetishists, Wes Jones of Jones, Partners: Architecture, has been pushing the conversion of shipping containers into housing since 1995 with scores of theoretical projects on the boards. Even though these projects have not been built, there are excellent lessons to be learned about site leveling systems, nesting, collapsibility for compact transport, primary and secondary structural systems, marketing, cultural identity, amongst others. Jones' PRO/con (PROgram/conTAINER) system has pushed the envelope on the potential of ways to slice, dice and reorient containers. It is probably one of the greatest crimes of architectural patronage that his prototypes have not been built.

John Smith of Pentangle Consulting Engineers Limited has conducted a thorough study of ISBU application for housing, and has significant data related to cutting penetrations and lateral bracing systems. [12]

Container City in London, England and Tempo Housing's Keetwonen dormitory in Amsterdam, Netherlands have shown the amazing functionality and simple beauty possible with these modules. Their stacking matrix is readily similar to many contemporary mixed-use condominium and hotel projects in major cities around the United States. Nicholas Lacey and Partners designed the 37-unit multi-family housing project called Container City, 2001-2002, in London, England to demonstrate the potential of building with ISBUs. Urban Space Management has gone on to create twelve other projects with the same simple technology for institutional, commercial and residential tenants. [13] Similar to Container City, the dormitory in Keetwonen, Netherlands, demonstrates potential space planning variables that can be housed within limited dimensions. There are many more projects upon the horizon by both of these development companies.

Transportation

Since the key element to this type of construction is that it is created "off site" and then transported, it is very important to understand the intricacies and practicalities of the transportation industry. It is possible to design the best thing in the world, but if it is too heavy, or has a height, width or length that does not allow movement along typical corridors in peak transit hours, there are going to be permitting complications and cost increases. This is one reason to consider panelizing a modular design.

Within all modes of transportation, there are parameters for that which may be transported. In the rail and shipping industries, it is predominantly that which fits within an ISO container. But when it comes to trucking, it varies by both state and local jurisdictions. As an example, in the state of Oregon, a trucked load is allowed to be a maximum of 14-foot tall from the pavement, 14-foot wide and 80-foot long from tractor front bumper to tail of load (75-foot plus a 5-foot overhang). [7] The industry typically trucks loads slightly wider and taller then this, which is why you see all of the “over-sized load” flagging. There is a 40 ton gross weight maximum on highways, which has a 60% weight buffer over that needed for a typical timber framed house, with a code prescribed dead load of 60-pounds/square foot. It is important to plan for cranes or other off-loading equipment. If you cannot get a module off of the back of a truck and place it upon its foundation, then the entire exercise becomes moot.

Support + Leveling Systems

Site work has to be done for all projects, and is often the factor hidden away when product costs are hyped because of unique and less predictable conditions. Simple foundations systems, be they slab on grade or 18-inch foundations, will cost approximately 20-25% in addition to other project hard costs (those for physical construction only). Crawl spaces, fully excavated basements, structured parking, or more complex systems quickly can double the cost of a project. Part of this associated cost is due to pre-fab construction assuming that it will be placed upon a square and level foundation. Therefore, it is important to spend the extra time and money to have a concrete subcontractor who is trained with precise GPS surveying equipment. Otherwise, you will have to shim up the mudsill to receive the modules and/or panels. Alternatively, there are some very intriguing adjustable strut and spaceframe systems on the market, but the necessary enclosure of this ground space or finishing of the under-belly to prevent pest and/or moisture infiltration tends to make them less attractive options. A micro pile-driven system of interlocking 10-foot extrusions might become the solution in the next decade.

By expanding this neglected space vertically, le Corbusier called for a use of "piloti" as his first point as a way to span uneven ground with ease, minimize surface impact for stormwater infiltration, create sheltered recreational space, and vehicular circulation. The way in which a space engages the Earth has been a quintessential dilemma for architects of all time, and is an area that still needs much research and exploration so that building sections may further engage plan and elevation based designs.

Conclusion

As the cost of fuel skyrockets, and discussions of removing federal subsidies to force American consumers to modify their driving addiction and the associated reliance upon fossil fuels, we are going to have to rethink these practices in the coming years. Our luxurious habit of designing large hollow modules on flat bed trailers will decline in favor of more compact panelized systems and integrated assemblies, in alignment with today's manufactured housing industry. It is highly unlikely that transportation systems will fully stall as our global economy is codependent, but as responsible academics and practitioners, it would be best for us to consider localizing material resources and production. But from the consumers' perspective, the romance of watching a 1948 Lustron truck leaving the factory loaded with their personal home, and driving directly to their site is timelessly appealing and decadent.

Fig. 5. Lustron Corporation, 1948.

Authors

Fredrick H. Zal, NCARB, Atelier Z, (www.fhzal.com), is a sculptor and architect who advocates dialogue in the fine + applied arts in the Portland, Oregon community. By striking a balance between praxis and theoros he passionately engages professional work with a focus upon empathy, morphology, and materiality. His architectural practice employs hybrid pre-fabrication techniques in commercial, institutional, single and multi-family mixed-use projects. As a guest professor at a number of institutions, Fredrick educates fine and applied art students about the impetus of their design pedagogy through speculation upon fundamental concepts of light, statics and kinetics, material science, land|form, and bodily movement by investigating their correlation to the spaces we form into our urban environments.

Kendra Cox is an assistant production manager at Blazer Industries, Inc. (www.blazerind.com) in Aumsville, Oregon, a wholesale manufacturer of custom modular and mobile structures. Since their first building in 1976, they have grown steadily to become the largest producer of modular space in the Pacific Northwest through innovative design and construction methods. They have shipped units nationwide, including Hawaii and Alaska, as well as to Mexico, Japan, Korea and China. Blazer has produced a wide range of buildings including offices, classrooms, daycares, retail, medical facilities including CT Units and MRI buildings, recreation, single family residences, assisted living facilities, communication shelters, pump stations, quicklubes, public restrooms and concessions. Blazer Industries looks forward to the opportunity to work with innovative companies and support any effort to build well-designed, affordable projects.

Figures

Figure 1: Atelier Z, Karsten KE-03 modified, 2003. This is the floor plan for a triple-wide set of modules for the caretaker's home at a vineyard in Carlton, Oregon. The original modules are a Karsten Homes KE-03 model, which have been modified with an extended dining bay, bay window, and numerous partition wall incisions by Fredrick H. Zal of Atelier Z. A full height basement, extensive decks, trellises and landscaping complimented the 'craftsman' style home.

Figure 2: Nested Parts for CNC Cutting from Sheet Stock, Thermwood Corporation CS45 7x12, 3-axis (X, Y, + Z) CNC Router for cutting plywood and other sheet goods. The software package allows the user to nest various parts into sheet stock. Some benefits of this particular package include better yield, mixing of different parts, label printing for the parts as well as off-fall, ability to re-use off-fall, etc. It will also display a graphical view of the nest to ensure it will suit the user's needs along with a yield percentage per sheet stock.

Figure 3: Atelier Z, Radcliffe ISBU, 2008. To compensate for the zero tolerances of ISBUs, it was determined that the best way to run plumbing lines was through a series of stacked "add-on" modules. These "wet" modules have all of the bathroom and kitchen plumbing integrated into them to allow for a quick-connect to the rest of the residential unit. Plus, the lowered ceiling in these modules will allow for the plumbing chase from the level above to be housed. This is an appropriate use of integrated assemblies as a pre-fabricated module. The project will be a total of seven residential units. At the front of the property will be a "2-over-2" unit, next to a "2x" vertical unit, and then two "2x" horizontal units stacked upon each other to create the full block. Similarly, at the rear of the property, behind a shared courtyard, will be two "2x" horizontal units stacked. This configuration will allow each unit private access and outdoor decks and/or patios.

Figure 4: Atelier Z, Honme Dwelling, 2004. Two of the complicated asymmetrical modules will be trucked to site and lifted by a boom crane to maximize off-site labor efficiencies. These two modules will be bolted onto a pair of pre-cast concrete fins that are post-tensioned into the ground. The remaining pre-fabricated shards are being constructed of Structural Insulated Panels (SIP) and clad with riveted zinc by Blazer Industries inc. The unfolding form of this dwelling is based upon a series of incredible discussions between the client and architect about space, form, sociology, aesthetics, the delicate warm light found in the film "La Double Vie de Véronique" by Krzysztof Kieslowski, the morphological systems of 1850s crystallography by Struver, concepts of materiality as it pertains to both contemporary Japanese minimalism and also Ned Ludd's theories of a luddite society experienced in the films "Brazil," "12 Monkeys," "City of Lost Children," and "Matrix."

Figure 5: Lustron Corporation, 1948. Lustron Corporation truck making a home delivery of the Westchester 02 Model. The Midwest Office of the National Trust has republished the original Lustron Westchester 02 Model "Erection Manual" in conjunction with Lustron Preservation. Their purpose is to help owners and advocates preserve Lustron homes by providing high-quality technical information and a forum for the exchange of information. Each Lustron Home came with its very own 193-page "Erection Manual," because Lustrons were assembled from a kit of parts; contractors built them following the manual rather than by using traditional floor plans, which were used for a conventional wood or masonry house. Films: "The Lustron Legacy: Saving an All-Metal Marvel in Arlington County, VA," and "Lustron the House America's Been Waiting For." www.lustronpreservation.org

Notes

1. Property Value + Taxation.

Some municipalities differentiate between "personal" and "real" property by whether a unit has a permanent foundation, and other delineate by non/recreational use per product marketing by the manufacturer. Only "real" property may be taxed appropriately to pay for infrastructure costs. (e.g., Oregon Ballot Measure 32 in 2004 deleted reference to mobile homes from provision dealing with taxes and fees on motor vehicles to become real property.) Since many municipalities now are considering manufactured housing to be "real" property, this has helped diminish their associated stigma, as with greater urban infrastructure, the areas that have a significant percentage of this historic housing type are getting revitalized and even fetishized within the contemporary Hipster, Retro, and Rockabilly scenes. Products such as Horden Cherry Lee Architects / Haack + Höpfner Architects "Micro Compact" module will really test regulations, since it is designed to be as easy to transport as be permanent.

2. Manufactured Housing Institute has published these statistics in the Automated Building trade journal.

3. Massachusetts Institute of Technology

Dennis R. Shelden of Frank Gehry's office pioneered nesting and surface grammar technologies during the construction of the Experience Music Project in Seattle, Washington for his Ph.D. "Digital Surface Representation and the Constructability of Gehry's Architecture", MIT, 2002. http://www.gehrytechnologies.com/research/DRS_Thesis_0902.pdf

Lawrence Sass at MIT's School of Architecture has been doing some interesting patterning work that applies this technology to replicating traditional and historic building languages with unskilled labor. The performative modeling software Revit was also developed out earlier student's MIT thesis work in Building and Information Technology.

4. Bosch Group's Rexroth 90x90H Series extruded aluminum structural framing profiles www13.boschrexrothus.com/framing_shop/Product/View_Product.aspx?P artnumber=3842993083

Since the aluminum extrusions can be purchased online with exact specifications and variable end attachment conditions, this is quite a simple system to use. The 90x90H profile that they are building with cost $39.62 / linear foot ($0.13 / millimeter) plus a machining cost ranging from $4.50 to $22.50 per specified end conditions for the attachment of structural elements to each other.

5. Kieran Timberlake Associates, Loblolly + Cellophane Houses, Construction schedules

The Loblolly construction crew began erecting the frame on 24 September 2006 and finished up the envelope around 12 October 2006, just three weeks later. Since their prefabricated floor, ceiling and wall cartridges for the Loblolly House were unfinished on one side, it took another six weeks for the house to be buttoned up. The Cellophane House does not have many of the utility connections necessary for typical houses. Plus, it was delivered to the Museum of Modern Art as a series of modules, instead of the frame and panel system used for Loblolly. Living Homes is currently building another one-off prototype for the International Builders Show in 2009. It is highly recommended to read their texts and watch the associated DVD. Information verified in conversations with Stephen Kieran and Carin Whitney of KTA.

6. Integrated Assemblies

Whether talking about structural connections or electrical wiring, it is important to allow for both human hands, eyes and tools to have the access and range of motion that they need to do their job through the entire life cycle of the building. Have your manufacturer label things excessively with “insert Tab A into Slot B” and “Slot B to accept Tab A” style annotations, and leave enough slack to make the connections without causing any system failures. Site workers will quietly thank you by working more efficiently and having fewer gripes. If using spray foam insulation products, connection areas will need to be masked off during the insulation process. After on-site connections, the holes may be plugged if critical for sound or thermal penetration. There are many access panels and caps on the market that can become part of the design aesthetic, or they can be buried under finish materials. An honest, more industrial aesthetic, will potentially have more efficiency on-site then one that needs detailed finishing.

Give careful consideration to your systems and detail sections. Having to patch problems in the field will only lead to upset, change orders, upcharges and potentially denigrate the re-emerging pre-fab design intent.

7. Standard Road Transportation Issues

Today we commonly use road transportation systems for most projects. This change in modality from rails happened when federal subsidies shifted to the creation of roads and interstates in 1938. To create jobs and help provide economic relief to the citizens of the United States who were suffering through the Great Depression, President Franklin D. Roosevelt delineated the first eight superhighway corridors across the United States in conjunction with the Works Progress Administration. The Lustron Corporation also benefited from this financing, and began trucking metal houses ready to be bolted together in 1948.

Then by 1956, President Dwight D. Eisenhower authorized the National Interstate and Defense Highways Act to create a system modeled after the European Autobahn. Additional federal subsidies of fuel in the “Kerouac-y” 1960s made the single-modal use of semi-trailer trucks both economically feasible and ultimately convenient, as product did not need to transfer from one mode of transit to another and road speeds are typically faster then that of the rail or ship industries.

Oregon Administrative Rules, Department of Transportation, Highway Division, Division 75, "Movement of Over-Dimensional Mobile Homes and Modular Building Units," Section 734-075-0002. http://egov.oregon.gov/ODOT/MCT/OD.shtml

The State of Oregon's Department of Transportation defines “modular building units” to be a "structural building component designed to create a structure for human habitation or for business, commercial or office purposes, and are more than 45 feet in length or more than eight feet six inches in width. Modular units are transported or hauled on another vehicle instead of being towed on the unit's own axles or running gear."

Length:

Since this dimension includes the cab, and not just from the holland fifth wheel (the hitch radius point) to the trailer tail, it is important to minimize the depth of the tractor cab. Freightliner's Argosy, with its 63-inch cab over engine design is the most optimal truck for shipping of this type of load in the state of Oregon. There are other stock and specialized trucks available around the world that minimizes their driver cab dimensions, which then may maximize potential load length.

Width:

At 10-feet in width, an escort is required on two-lane highways but not required on the freeway. Manufacturers ship a lot of "over-sized" 12 and 14-foot wide modules.

Height:

Typical truck beds are approximately 3-feet tall, but there are dollies (wheels attached to a frame, instead of a standard truck bed), dromedary or gooseneck style trailers, and other specialized equipment that will allow for a few extra inches in height if necessary. Typically transported modules are under 13-foot 2-inches tall. (Note: this typical module shipping height is 2-feet taller than that allowed without a special permit.) The length is usually 64-feet, but up to 70-feet is possible. An 8-foot wide module can be trucked without an escort.

Variance:

Larger loads require special single trip variance permitting, potential road escorts, and limitations in the hours of the day/days of the week when it may be on the roads so that urban traffic is not adversely affected. It is recommended to call local trucking companies for specific regulations in your area. Factories are often located adjacent to Interstate Highways, but as the load approaches the residential site, the route classifications based upon width of street, height of tree canopies and overhead wires will change. This is another reason to design for the most restrictive condition, as a product is only good if it can be delivered to the site.

Weight:

There is expense that can be associated with the transport of mass itself, but due to momentum and inertia, it is less expensive to transport 3X pounds on 1 truck then to transport X pounds on 3 trucks, hence why you see triple-trailer trucks burning down the highways. Except for very dense steel components, the majority of building materials do not have a density high enough to over-weigh a truck bed even at maximum volume.

Structural Moving:

For large structural moves, such as historic buildings, you can temporarily take down power-lines and have a police escort from one site to another, but this type is just not practical for mass production and sales.

Cranes:

A minimal truck-mounted all terrain hydraulic crane with a smaller 25 - 70-foot boom can handle 22 tons, just under the weight of a standard home if it is in one module. A 30 - 100-foot boom crane can handle 33 tons. Larger and stronger cranes are readily available, but access of the larger truck will quickly become an issue on residential streets and alleys. Maximum weight allowed for truck transit is 600 pounds per inch of tire width, 20,000 pounds for a single axle, 34,000 pounds for tandem axles, or 80,000 pounds in gross weight. This 40 ton gross weight maximum on highways has a 60% weight buffer over that needed for a typical timber framed house, with a code prescribed deadload weight of 60 pounds/square foot.

Helicopters:

A Sikorsky S-64E Skycrane can "pick" lift 20,000 external pounds (10 tons), or move 18,000 pounds with a point-to-point road closure motorcade and refueling every half an hour (and if you think current automotive fuel costs are high, don't even ask what aviation fuels currently run!). Remember that the original Sears catalogue homes weighed in at 25 tons, which was due to having the shipped goods being fully dry, and items like plaster were troweled onto the lathe on-site. A contemporary house weighs in, per code, at 60 pounds per square foot. An urban home of 1,600 sq.ft. will be 96,000 pounds of dead load, or a minimum of six helicopter "pick" routes.

8. MK Constructs

Based upon conversations with Justin Brown and Rebecca Woelke of MKConstructs, and Marshall Mayer of Live Modern.

9. Rocio Romero

Based upon analysis of Rocio Romero's multiple construction images posted on their website:

www.rocioromero.com/LVSeries/projects.htm

10. Lang Wilson, xPAC Housing,

"Architecture as a product" is an ongoing LWPAC R&D project to bring a high quality mass customizable prefabricated house to the market. In architecture choice and mass production are, as it seems, still at odds with each other. The idea of a building as a high quality product, intelligently designed, allowing for choice while being affordable is currently hard to come by. "Useful + Agreeable: the coolest trailer in the park", The National Post, Canada, 2003.

Each form is cut from solid blocks of rigid urethane foam using CNC 3-axis milling just a few miles south of Vancouver, British Columbia in Bellingham, Washington. Then the undulating surface is covered with two layers of 6-ounce fiberglass cloth and polyester catalyzed laminating resin, sprayed with a polyester primer and painted with automotive grade paints. Areas may also be left transparent or translucent, similar to the carbon fiber tower designed by Peter Testa. Aluminum structural ribs are glassed into the forms to provide vertical and lateral support.

		20′ container	40′ container	high-cube 45' container
Length	Exterior	20′ - 0″	40′ - 0″	45′ - 0″
	Interior	18′ - 10 5/16″	39′ - 5 45/64″	44′ - 4″
Width	Exterior	8′ - 0″		
	Interior	7′ - 8 19/32″		
Height	Exterior	8′ - 6″		9′ - 6″
	Interior	7′ - 9 57/64″		8′ - 9 15/16″
Door Aperture	Width	7′ - 8 1/8″		
	Height	7′ - 5 ¾″		8′ - 5 49/64″
Volume		1,169 ft³	2,385 ft³	3,040 ft³
Maximum Gross Mass		52,910 lb	67,200 lb	67,200 lb
Empty Weight		4,850 lb	8,380 lb	10,580 lb
Net Payload		48,060 lb	58,820 lb	56,620 lb

Table 1. Standard ISO Container Data

11. International Standardized Building Units

To facilitate intermodal transportation from rail to road to ship, containers were developed from 1948-1955 to replace the earlier use of boxcars. By the Vietnam War, Sea-Land Container Services, Inc., standardized their dimensions to what they are today per the international standardization organization (ISO).

As their predominant exporter, China has determined it is less expensive to build a new container than to have the used containers returned. The authors would like to see both environmental and economic lifecycle data that compares returning a container to China versus the mining and fabrication of a new container.

This is calculated based upon the empty weight of an ISBU is 10,580 pounds, and that International Building Code calls for 40 pounds / square foot uniform live load capacity for residential structures [(153,000 / [10,580# + (40#/sq.ft. x 320+/-sq.ft.) = 6.5 units or 6 units + 1 on top].

See Table 1.

12. John D. Smith's Ph.D.

"This dissertation provides an assessment of the feasibility of using ISO shipping containers as building components. ISO shipping containers are widely available and as various pioneers have shown, can be a low cost building resource. This document sets out to provide a view of the viability of this medium, together with an identification of problems that have occurred or may occur in implementing their use. It is the aim of this paper to show how shipping containers have been used, the methods employed, the locations in which they have been used and their purpose." © Smith, John D. "Shipping Containers as Building Components", University of Brighton, Department of the Built Environment, 30 April 2006. See Table 1.

www.cityzen.biz/containerresearch.pdf

13. Urban Space Management, Container City, 2002. Completed in 5 months in 2001, Container City I was originally 3 stories high providing 12 work studios across 4,800 sq ft. After high demand, a fourth floor was added, providing three additional live/work apartments. As well as being very cost effective, Container City I is environmentally friendly with over 80% of the building created from recycled material. Container City II was built adjacent to Container City I, with inter-connecting bridges, a new lift and full disabled access, Container City II was completed in 2002, providing a further 22 studios over five floors.

Product Line	Architect / Designer	Type: Commercial, Farm, Residential, Office, Mobile	Prototype	Production Available	Fixed / Mobile	Recommended	Model	Manufactured, Modular, Chunks, Cartridge, Kit, Frame, Pre-Cut, Panelized, Site Built	Bedrooms	Bathrooms	Levels	Square Footage	Cost	Cost / Sq.Ft.	Note	Link
Historic	Aladdin	R	Y	Y	F	Y	Various	Kit, Site Built	-	-	-	various	out of date	-	-	-
Historic	Sears	R	Y	Y	F	Y	Various	Kit, Site Built	-	-	-	various	out of date	-	-	-
Historic	Montgomery Ward	R	Y	Y	F	Y	Various	Kit, Site Built	-	-	-	various	out of date	-	-	-
Airstream	-	M	Y	Y	M	Y	Classic 34-s/o	Manufactured	1	1.0	1	313	$99,965	$319	-	www.airstream.com
Airstream	-	M	Y	Y	M	Y	Classic 34	Manufactured	1	1.0	1	283	$92,632	$327	slide-out dining nook	www.airstream.com
Airstream	Nissan	M	Y	Y	M	N	BaseCamp	Manufactured	-	-	1	102	$28,000	$275	-	www.airstream.com
Airstream	Christopher Deam	M	Y	Y	M	N	D.W.R.	Manufactured	1	1.0	1	124	$50,000	$403	Design Within Reach furnishings	www.airstream.com
-	Benthem Crouwel Architects	R	Y	N	F	N	Almere	Kit, Site Built	2	1.0	1	700	unknown	-	-	www.benthemcrouwel.nl
Blazer Industries	-	C, R, O	Y	Y	-	Y	Various	Manufactured	-	-	-	-	n/a	-	Manufacturer	www.blazerind.com
Breckenridge	Christopher Deam	R, M	Y	Y	M	Y	Glassic Soho Flat	Manufactured	1	1.0	1	400	$45,000	$113	-	www.breckenridgefinerliving.com
Breckenridge	Christopher Deam	R, M	Y	Y	M	N	1246 SCE3BR	Manufactured	3	1.0	1	480	unknown	-	-	www.breckenridgefinerliving.com
BritCo	-	C, R, O	Y	Y	-	Y	Various	Manufactured	-	-	-	-	n/a	-	Manufacturer	www.britco.com
Butler	-	F	Y	Y	F	Y	Various	Kit, Manufactured	-	-	-	-	n/a	-	Manufacturer	www.butlermfg.com
Clever Homes	Toby Long	R	Y	N	F	N	CH1	Site Built	4	3.0	2	2,490	$747,000	$300	SIPs	www.cleverhomes.net
Clever Homes	Toby Long	R	Y	N	F	N	CH1.5	Site Built	3	2.0	2	1,980	$594,000	$300	-	www.cleverhomes.net
Container City	Urban Space Management, ltd.	C, R, O	Y	Y	F	Y	Container City	Manufactured	Multi-Family				unknown	-	Shipping Containers	www.containercity.com
Flat Pak	Charlie Lazor	R	Y	Y	F	Y	Charlie|Zelda - MN	Panelized, Site Built	3	3.0	2	3,456	$1,036,800	$300	-	www.flatpakhouse.com
-	Gláma-Kím	R	Y	N	F	N	Summer House	Manufactured	3	1.0	1	764	$171,900	$225	-	www.glamakim.is
Glide House	Michelle Kaufmann	R	Y	N	F	N	Glide House	Manufactured	2	2.0	1	1,344	$448,976	$334	[2] 14'x48' modules	www.mkd-arc.com
Glide House	Michelle Kaufmann	R	Y	N	F	N	Sunset Breeze	Manufactured	2	2.0	1	1,800	$575,040	$319	-	www.mkd-arc.com
Hive	MA Architecture inc.	R	Y	N	F	N	B-Line Medium 001	Modular	3	3.0	2	1,780	$356,000	$200	-	www.hivemodular.com
Hive	MA Architecture inc.	R	Y	N	F	N	B-Line Medium 005	Modular	4	3.0	2	2,108	$421,600	$200	-	www.hivemodular.com
IdeaBox	Jim Russell	R	Y	Y	M	Y	Northwest Modern	Manufactured	1	1.0	1	400	$74,750	$187	-	www.ideabox.us
IdeaBox	Jim Russell	R	Y	Y	M	Y	Confluence Modern	Manufactured	2	2.0	1	840	$85,000	$101	-	www.ideabox.us
iT	Taalman Koch	R	Y	N	F	Y	iT 1100	Frame	2	1.0	1	1,100	$377,000	$343	Bosch Aluminum Frame	www.tkithouse.com
iT	Taalman Koch	R	Y	N	F	Y	iT 1600	Frame	3	2.0	1	1,600	$522,500	$327	Bosch Aluminum Frame	www.tkithouse.com
Jeriko House	Shawn Burst		Y	N	F	N	Jude	Frame, Panelized	3	3.0	1	2,032	$508,000	$250	-	www.jerikohouse.com
Karsten	-	R	Y	Y	-	Y	KE-03	Manufactured	3	2.0	1	2,630	$165,000	$63	Manufactured Homes	www.thekarstenco.com
Living Homes	Ray Kappe	R	Y	N	F	N	RK1.1	Modular	5	3.5	2	3,100	$775,000	$250	Steel Moment Frame	www.livinghomes.us
Living Homes	Kieran Timberlake	R	Y	Y	F	Y	KT1.1M	Frame, Panelized	2	2.0	2	1,339	$443,322	$331	Bosch Aluminum Frame, MoMA	www.kierantimberlake.com
Logical Homes	Peter deMaria	R	Y	N	F	N	Pirkls Redondo Beach	Site Built	4	3.5	2	3,500	$437,500	$125	-	www.demariadesign.com
-	LOT-EK	C, R, O	Y	N	F	N	Mobile Dwelling Unit	Manufactured	1	0.0	1	320	unknown	-	-	www.lot-ek.com
LV Series	Rocio Romero	R	Y	Y	F	N	LV	Panelized, Site Built	2	2.0	1	1,150	$35,923	$31	-	www.rocioromero.com
LV Series	Rocio Romero	R	Y	Y	F	N	LVL	Panelized, Site Built	3	2.0	1	1,453	$42,115	$29	-	www.rocioromero.com
LV Series	Rocio Romero	R	Y	Y	F	N	LVM	Panelized, Site Built	1	1.0	1	625	$23,650	$38	-	www.rocioromero.com
LV Series	Rocio Romero	R	Y	Y	F	N	LV150	Panelized, Site Built	2	2.0	1	1,453	$45,225	$31	-	www.rocioromero.com
-	Marmol Radziner	R	Y	Y	F	N	Model 4	Modular	3	3.5	1	2,650	$809,200	$305	-	www.marmolradzinerprefab.com
Micro Compact Home	Horden Cherry Lee Architects	R	Y	Y	M	Y	m-ch	Modular	1	1.0	1	76	$50,000	$658	MoMA Exhibition	www.microcompacthome.com
mini-Home	Sustain Design Studio	R	Y	N	M	N	Solo	Manufactured	1	1.0	2	352	$135,000	$384	-	www.sustain.ca
Modern Modular	Jones Partners	C, R, O	N	N	F	Y	Yucca Valley	Modular	2	1.5	1	640	$96,000	$150	Shipping Containers	www.jonespartners.com
Modern Modular	Resolution 4 Architecture	R	Y	N	F	N	Dwell	Panelized, Site Built	2	2.5	2	2,042	unknown	-	-	www.re4a.com
Modern Modular	Resolution 4 Architecture	R	N	N	F	N	3-Bar Bridge + Guest	Modular	4	3.0	2	2,392	unknown	-	-	www.re4a.com
-	Office Mobile Design	R	Y	N	M	N	ShowHouse	Modular	1	1.0	1	720	$201,600	$280	-	www.designmobile.com
Pinc	Rutenskold Lionel, Ittur Koncerne	R	Y	N	F	Y	Sport	Manufactured	2	1.5	1	1,744	unknown	-	-	www.pinchouse.com
PowerHouse	John Rossi	R	Y	N	M	N	PowerPod	Modular	1	1.0	1	504	unknown	-	Solar Panels	www.powerhouse-enterprises.cor
quikHouse	Adam Kalkin	R	Y	N	F	N	Standard	Modular	3	3.0	2	1,920	$184,000	$96	Radiant Slab, Shipping Containers	www.quik-build.com
-	Chris Radcliffe	R	Y	Y	F	Y	42 + Sumner	Modular, Site Built	1	1.0	1	640	$32,000	$50	Shipping Containers	-
Safe-Green Blocks	David Cross	C, R, O	Y	Y	F	N	Hazelton House	Modular, Site Built	2	1.5	2	1,280	$38,400	$30	Shipping Containers	www.sgblocks.com
Tempo Housing	-	C, R, O	Y	Y	F	Y	Keetwonen	Modular	1	1.0	1	320	$16,000	$50	Shipping Containers	www.tempohousing.com
Tumbleweed	Jay Shafer	R	Y	Y	M	N	Enesti	Kit	2	1.5	2	681	unknown	-	Trailer Hitch	www.tumbleweedhouses.com
V2flat	-	R	Y	N	F	N	Flat	Manufactured	1	1.0	1	448	$89,600	$200	-	www.v2world.net
WeeHouse	Alchemy Architects	R	Y	Y	F	N	4x4	Modular	3	2.5	2	2,090	$319,000	$153	-	www.weehouse.com
WeeHouse	Alchemy Architects	R	N	Y	F	N	Pair 3Br	Modular	3	2.0	1	1,510	$219,000	$145	-	www.weehouse.com
xPAC	Lang Wilson	R	Y	N	F	Y	xPAC	Modular	2	1.5	1	1,507	$150,000	$100	Mass Customization	www.pacxhouse.com
Zero Cabin	Keith Dewey	C, R, M	Y	N	F	N	40ft Fitted, Deluxe	Modular, Site Built	3	2.0	2	320	$35,800	$112	Shipping Containers	www.zigloo.ca

Table 2. Market Products