

History of Prefabrication: A Cultural Survey

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ABSTRACT: Prefabrication is a method of production in housing that has been harnessed to meet the needs and desires of different societies throughout the globe. Although the U.S. owns 26% of the prefabrication housing market, this is primarily due to the sheer quantity of growth in the country. The UK, Scandinavia, and Japan control the majority of the innovations in which prefabrication constitutes a larger majority of the overall production of housing in these regions. This can be primarily attributed to the social and cultural contexts that give shape to the tradition of construction and knowledge base that make up these construction markets. This paper examines the history of prefabrication in these societies in order to identify how the U.S. might reevaluate its construction ideologies, products and process in order to produce more affordable, higher quality housing.

INTRODUCTION

The premise for this paper is that prefabrication leads to positive sum gains for all the parties in a building project. Prefabrication is not the only solution to achieving both production and design quality, but is among the better solutions for such. However, prefabrication is only as good as the demands placed upon it and therefore requires an integrated process in order to deliver successfully. Sustainability in building is more achievable through prefabrication by offering a controlled environment in which to manage material flow and waste. Many projects over the course of history have implemented prefabrication for a myriad of purposes, some for innovation, in other cases it has been applied to simply reduce the cost of a project or deliver in a shorter amount of time. Housing constitutes the most explored building type of prefabrication experimentation that has resulted in both successes and failures. (Davies 2005, Ch. 1 &2)

In all of the innovations in housing prefabrication across the globe, the U.S. continues to lag behind despite its housing growth rate. At first glance the numbers would indicate that this is not the case, the U.S. owns 26% of all the prefabrication market around the world. (Global Industry Analyst) But this is primarily a factor of the immense manufactured housing industry, which constitutes 24% of the U.S. residential market and during the current recession does not see signs of significant slowing. (Freedonia 2008) But the problems with the environmental performance and durability of manufactured housing provide irrefutable evidence that long-term sustainability of this model is lacking. In a time of economic and environmental challenges, prefabrication holds potential to aid in fostering a paradigm shift in the construction industry in both the U.S. and other nations. But prefabrication already pervades in a few cultures by offering affordable durable housing. This paper will evaluate the history of prefabrication housing in the UK, Scandinavia and Japan in order to understand how these cultures have uniquely developed technology in order to serve society. The lessons from these national contexts provide important information for evaluating how the unique construction culture of the U.S. may adopt prefabrication as the process and product for housing in the 21st century.

Technology is Social

"Men may not, so this view goes, live by bread alone; but without bread there can be no life; and since it is the technology of a people that provides their bread, their means of sustenance, great or small, the nature of the technology of people is the key to an understanding of their entire society" (LaPiere 1965, p. 255)

Technology is social before it is technical. Technology is not something that determines the destiny of people, but is a manifestation of people. Society seems to have lost this fundamental truth or in its quest to be ever more technologically advanced, never considered the possibility. The misconception that technology has a life of its own is especially prevalent in building culture where the process of construction has not shifted dramatically in over 60 years. (Kieran 2004) Many of the technologies implemented by designers and builders are taken at face value, not challenged and innovation in new products is not demanded or developed. Design by product manual is both an outmoded model and fosters a lack of progress in the industry. Prefabrication is among these innovations in technology that has lagged behind in the housing industry in the U.S. Technology is an outgrowth of social needs and desires, not the other way around. Prefabrication is a technology that has uniquely emerged out of necessity and desires of societies in various nations and cultures. In the U.S. this is the exception and not the rule, with prefabrication in housing making a marginal impact compared to its Scandinavian, Japanese and British counterparts.

Individuals and communities have constructed shelter from the beginning as a matter of function. In order to build in remote locations, deliver buildings more quickly, or to build in mass quantity, society has used prefabrication, taking the construction activities that traditionally occur on a site to a factory where frames, modules or panels were fabricated. Beyond the prosaic, prefabrication in architecture is a story of desire for a better method of building, a critical questioning of the production norms of the construction industry, and a search for both design and construction innovation. The needs and desires of global society that have proliferated prefabrication as a concept and practice are couched in the developments of the industrial revolution that have affected all production industries and held the promise of the possibility of off site fabricating to benefit creating shelter. But nations have responded to the industrialization of contemporary society uniquely appropriate to their specific culture.

Prefabrication relies upon social and cultural context: labor, factory ability, knowledge base, and especially market to determine what is developed. The greatest developments in prefabrication in the housing industry in the U.S. for example can be attributed to events that have spurred this on including the California Gold Rush, Tennessee Housing Authority, war time and post war housing, and most recently the energy and housing crisis of the late 20th and early 21st century. Just as America's solutions to prefabrication have come out of its immediate context, so have developments in other cultures. However, other cultures have been able to establish a holding of prefabrication beyond immediate needs into the very desire, or building for a better. We will evaluate prefabrication developments in relation to the history and culture of building in three areas that are far surpassed the U.S. in their ability to build with more efficiency while not sacrificing quality. These nationalities include the Great Britain, Scandinavia, and Japan. The history of building in these cultures explains the evolution of prefabrication as a result of both need and wants of society. The study of such is important in determining how prefabrication may become the method by which housing in the U.S., may become a rule, not the exception.

GREAT BRITAIN

Manning Cottage

The history of prefabrication in the west begins with Great Britain's global colonization effort. Settlements in today's India, the Middle East, Africa, Australia, New Zealand, Canada, and the U.S. required a rapid building initiative. Since the British were not familiar with many of the materials in abundance in these countries, components were manufactured in England and shipped by boat to the various locations worldwide. The earliest of such cases recorded was in 1624 when houses were prepared in England and sent to the fishing village of Cape Anne in what is now a city in Massachusetts. (Areiff 2002, p.13) The late 1700's and early 1800's was a time of Australian settlement of England. It is reported that the earliest settlement in New South Wales was home to a prefabricated hospital, storehouses and cottages shipped to Sydney arriving in 1790. These simple shelters were timber framed for structure and timber panel infill for roof, floors and walls. However speculation also suggests that infill material could have been canvas or a lighter timber frame infill system with weatherboarding. A similar system is reported to have been unloaded and erected a couple of years later in Freetown to build a church, shops, and several other building types. (Herbert 1978, p.6)

English colonial prefabrication building extended to South Africa. In 1820 the British sent a relief mission of settlers to South Africa, Eastern Cape Providence accompanied by three-room wooden cottages. Gilbert Herbert writes that the structures were simple shed-like, with precut timber frames, clad either with weatherboarding, trimmed and fixed on the site, or with board-and-batten siding. Door and window sashes were probably prepared as complete components. (Herbert 1978, p.8) These structures are not as extensively prefabricated as our contemporary understanding of off-site fabrication, however they represented a significant reduction in on-site labor to build houses from scratch using off-site work to build some of the most structurally and precision dependent aspect of the cottages, the timber frame and its complex joints and fittings.

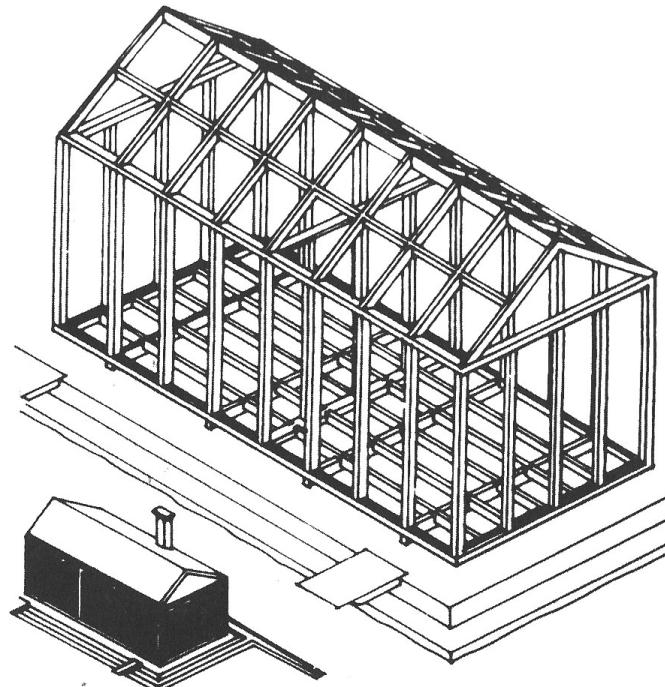


Figure 1: Manning Portable Colonial Cottage manufactured in Great Britain and shipped to colonies throughout the world.

The Manning Portable Colonial Cottage for Emigrants focused primarily on making an expert system of prefabricated timber frame and infill system, described by John Loudon as consisting of grooved posts, floor plates, and triangulated trusses. The panels of the cottage fit between the grooved posts and were standard sizes and interchangeable. The system was designed to be mobile, easily shipped for furthering the colonial agenda of the British. Manning stated that a single person could carry each individual piece that made up the shelter. The Manning Cottage was an improvement of the earlier frame and infill systems by England in that it offered an ease of erection. The system was simply bolted together with a standard wrench, appealing to the abilities and availability of tools to the emigrants. Herbert writes, "the Manning system foreshadowed the essential concepts of prefabrication, the concepts of dimensional coordination and standardization." (Herbert 1978, pp.11-12) Manning's system used same dimensional logic with all posts, plates and infill panels being carefully coordinated. It built upon the need for a quick erection system for emigrants but relied upon the British carpentry skills in shipbuilding. This transfer from an already established construction culture made way for the likely success of the Manning Cottage. (Fig. 1)

The Portable Colonial Cottage made its way to many settlements by the British throughout the 19th Century. Its impact on the British settled North America and the future United States is uncertain, however it is assumed that the practices of timber architecture of Britain were the beginnings of the balloon frame in the U.S. Taylor is often credited with the invention of the balloon frame in its implementation in the construction of a church in 1833 in Chicago. The light frame timber construction including the platform frame and balloon frame resulted from two primary factors: a plentiful supply of timber in the new country and a rapidly expanding industrial economy with mass-produced iron nails and lumber mills. During this period, 150 houses were erected in one spring and summer alone. This development occurred so rapidly that Chicago was almost entirely balloon framed before the fire of 1871. The balloon frame infamy followed a building of the entire west, mostly in light timber. (Davies 2005, pp.44-47)

Corrugated Iron

The early 1800's also ushered in an additional innovation in housing by the British, corrugated iron. Although prefabrication of frames was relatively well developed in the early part of the 19th century, panel and spanning material was underdeveloped. The Manning Cottage and the cast iron trusses of the prefabricated iron buildings used traditional canvas or wood planking as a means of roofing. Corrugated iron provided a quickly constructed, affordable, and structurally efficient material for roofs and walls. Corrosion obviously presented problems until 1837 when many companies began to hot dip galvanize metals in order to protect them. Richard Walker in 1832 noted the potential for corrugated iron for "portable buildings for exportation". The corrugated sheet provided the ability to nest multiple layers in transit and were cut into 3' x 2' panels that could be easily handled by one person and fastened into place at the job site. Along with Manning's Portable Cottage, Walker's marketing and exportation of corrugated iron provided one of the first widely used prefabricated timber and iron building systems in the world.

Corrugated iron was employed in the Gold Rush of San Francisco in the mid 1800's. Because of the influx of people in search of new money housing was in urgent demand. Entrepreneurs on the east coast responded with using the latest iron technology from England and manufacturing simple shelters. Naylor from New York shipped more than 500 house kits made of corrugated iron. Many of these homes were advertised in magazines and other publications so that patrons could order the shelter of their choice directly. (Petersen 1965, pp.318-324) Corrugated iron in buildings did not end with the kits homes of the gold rush era. The use of the panel had a large impact on the proliferation of Quonset huts during the 2nd world war and later in its use in industrial buildings, storage facilities, and even rural churches. Corrugated iron is a common, widely used building material today. Considered archaic by contemporary construction standards, what is not generally understood is that corrugated iron has its roots in fulfilling a need in transportable, quickly erected architecture that was prefabricated and shipped to be erected elsewhere. Its affects on the aesthetic of the urban and rural landscape have continued since its inception. (Halloway 2007)

British Developments Today

Great Britain has been a leader in prefabrication in western culture from the beginning and continues to be so today. Most recently projects by Architect Nicolas Grimshaw and Sir Norman Foster have harnessed digital tools to develop performance and fabrication innovations in larger public structures such as the Waterloo Terminal, Eden Project, and the London City Hall. These examples are not housing, but illustrate the continued advances that Great Britain continues to make as a result of a search for a better and more innovative method of production. Fosters experiments with prefabrication began in the Hong Kong Bank in China from 1979-1986. Bathroom pods were prefabricated and placed into location. This process of finishing the most detail intensive portions of a building and then craning them into place was not economical, but innovative in achieving an increase in quality, and reduction in on site construction time. Most recently, another British innovation in housing is the Uxbridge Travelodge that employs a steel superstructure and shipping container modular rooms. (Fig.2)



Figure 2: Travelodge Hotel in Uxbridge constructed of pre-finished shipping containers; (www.bloggen.de)

The hotel was not designed by architects, but design/built in a joint venture between Buro Happold, the innovative structural engineer, and George & Harding, a builder, 86 containers were outfitted in China with electrical wiring, bathroom plumbing and finishes and finish gypsum board. They were shipped to Uxbridge and installed by bolting them together. Windows, interior decorating, and exterior cladding were finished onsite. Although able to be demounted at the end of the lifecycle, shipping containers are in large abundance across the globe without a foreseeable future use. Using two different sizes of container, the hotel accommodates 120 rooms and a dining bar area. The Travelodge in Uxbridge is seen as a revolutionary model for the production of lodging. Although seen as a permanent structure, the idea is being touted by the design.builder that the system may be appropriate for temporary construction including festivals, sporting events, etc. It is reported in the World Architecture News,

... traditional 100-bed hotel costs Travelodge around £5 million to build. Construction using shipping containers reduces costs by up to 10 per cent, making the bill for a hotel of the same size around £4.5 million. Using Verbus Modules also shaves approximately 25% off construction time, meaning a 100-bed hotel can be built in 30 weeks, instead of 40. Travelodge plan to build half of all future hotels this way and a second container hotel is already under construction at Heathrow and due to complete at the end of the year. (Young 2008)

SCANDINAVIA

Prefabrication in Scandinavia follows a similar pattern as other national contexts. Its developments have been around three major events: the industrial revolution, the war time and post war housing crisis, and today's resurgence of interest in utilizing CAD/CAM technology for customized produced architecture. The difference with Scandinavia including Finland, Norway, and Sweden is the use of wood in the majority of its housing construction. Outside of prefabrication, wood is used more frequently in Nordic architecture than in most other cultures. This is natural as it is estimated that 37% of the land area in Norway, for example, is covered with forest. But the fact that wood is the prevalent material of construction is not necessarily interesting in and of itself, rather the lessons to be learned from Scandinavia are in this culture's ability to perfect the methods of production of this material into prefabricated construction product.

It is a decision of the market, industry and ultimately the people whether prefabrication takes hold. The issues of market preparedness, a balance of design and production quality, and a good price point are all factors that have seemed to align themselves for Scandinavia in the housing industry. Although Finland is noted for its current advances in timber CNC fabrication frames in building, prefabrication in building took hold originally in Sweden and Norway. Fredrik Blom was an architect and also colonel in the Swedish Navy in 1781. He envisioned a system of walls that could be demountable after construction and moved to a different location. Although transportable systems development was his primary goal, Blom's success is primarily attributed to the appearance of durability and permanence that they exuded. The houses were solid because they were built of all wood, were well crafted, and built by hand. This functional idea of mobile, mass produced housing was not fully exploited until the industrial revolution when sawmills made it possible to manufacture houses at an unprecedented pace. (Waern 2008, p. 27)

A housing shortage in 1917 expanded the need for prefabrication to be utilized to produce housing. Again, the production of these houses was in wood, using mechanization to cut kit homes including framing and enclosure, Scandinavia perfected its system of wood harvesting and production during this time. Catalog houses were produced by more than 20 manufacturers by 1930, all offering pre-cut kit houses. This process was also used to develop pre-cut public buildings such as churches and hotels. During the wars, the Swedes were able to further develop this technology by offering wooden homes in record times for a war-famished Finland. This interest in wood prefabricated housing extended to all aspects of society including the design world. It is reported that Alvar Aalto, after his visits to MIT, began designing prototypical "architectural" designs for prefabricated housing. It was not until the end of the war when the housing demand was the greatest it had ever been not only in Scandinavia, but around the world. It is estimated that at this time post World War II, nearly 70 companies were producing more than 50% of housing in Scandinavia. In 1947, 17,500 houses were prefabricated in Sweden alone. (Waern 2008, p. 28)

It was during the late 1940's and early 50's that prefabrication conceptually was understood by not only the building industry, but also society at large. This led to a myriad of prototypes, new methods of production, and experiments in partition wall prefabrication that integrated systems of electrical and plumbing systems. Prefabrication modules, again built in wood, became larger and larger, and prefabrication was being employed at commercial building scale in standard building practice. The 1960's were a time of radical experiments in prefabrication. Although housing was not needed as much as during the initial post war era, architects including Gullichsen, Mikkola, and Pallasmaa conceptualized post and beam wood structural system with various infill systems. Others that followed were Arne Jacobsen and Jorn Utzon. In all cases, these experiments failed as many of the U.S. experiments of the time. The notion that architecture was not limited to one off expensive buildings opened the door for a rapid social and cultural acceptance. Architect designed and developer instigated housing catalogs dominated the housing industry in the 60's and 70's. By 1980' prefabrication accounted for 85% of all homes built in Scandinavia. Unlike the mid century counterparts, these were not modern aesthetic high architect designed homes, rather a variety of styles and sizes to meet different needs of the market. (Waern 2008, p. 29)

The greatest variation of Scandinavia prefabrication developments when compared with U.S. is in the socially accepted technology of prefabrication. This might be because Scandinavia, and Finland in particular never had a "mobile home" that gave the method of production a bad reputation; rather the Nordic people have viewed prefabrication as just that, a different method of building - a better method of building. But in a region in which building methods and advancements in construction have been part of the culture from the beginning, through new developments in timber ship building to hand craft before mechanization, it is natural that the way in which something is made does not necessarily determine its worth or quality at the end of the day. Rasmus Waern states that in Scandinavia it is thought that the reason for its prefabrication success is based on two major factors. First, detailing, which has been the mantra of the architect in traditional custom design and construction has been taken over by standardized connections and machine fabricated joinery. This points to the reality that although the detail in architecture is important for expression of a conceptual parti, tight construction is valued more in the housing market. In short, prefabricated homes in Scandinavia are simply better built through prefabrication than not. Second, the market has become so accustomed to prefabrication as its method of production of building in Scandinavia that lower initial cost is more obtainable through the use of prefabricated timber construction. Simply put, the construction industry in Scandinavia cannot afford to build traditional onsite buildings. Prefabrication is more affordable. (Waern 2008, p. 30)

Prefabrication in Scandinavia extends into other areas of production outside of the traditional building industry. Sweden is the world's most prolific furniture manufacturer, IKEA. The company uses a system of working with

designers to conceptualize and map the production process. Materials selected are affordable and light, and the method for packaging and shipping further reduce the final price. Some in metal and polymer, but mostly in wood, customers pay a fraction of the cost of other furniture. IKEA also has a varied quality marketing strategy. Some pieces are dirt-cheap and they last about as long as you would imagine, while others are more expensive and result in a more durable life. But even in the modest, affordable, cheap pieces, materials are intentionally biodegradable and recyclable. It is no surprise that this factory giant, IKEA, now has a prefabricated kit house available. The home is a traditional Swedish timber home utilizing machine cut stacked timbers that are load bearing or a frame and infill timber system. (Fig. 3) (www.boklok.com)



Figure 3: IKEA BoKlok prefabricated house being craned into place and weatherized on site.
(www.greenlineblog.com & www.grassrootsmodern.com)

Today Scandinavian prefabricated housing continues to grow in Norway, Sweden and Finland. There continues to be ample availability of forestland and sustainable harvesting policies that will maintain this responsible growth into the future. Using glue laminated members, buildings small and large can be produced using CNC precision cut members and joints for frames, floors, and roofs. Today architects are using traditional methods of timber construction, but designing modern aesthetic architecture. The government supports prefabrication not only in timber but also precast concrete construction. Scandinavia's government, architects and peoples see prefabrication as the method to provide housing for all and affordable public buildings as well. The difference is that in Scandinavia it seems to be working for the mutual benefit of all. In the end prefabrication in Scandinavia is a story of perfecting a material product. By using wood as a medium by which to examine, refine, and maximize, Norway, Sweden and Finland have been able to translate what was traditionally crafted buildings into mass produced crafted buildings. This translation of vernacular is to be studied further and asked how can other cultures use the traditions of the past to inform prefabrication innovation for the future.

JAPAN

The vernacular method of construction in timber post and beam can be considered one of the earliest pre-industrial advances in principles of prefabrication. We have examined it in British construction by way of the colonial cottage and in historic and contemporary Finnish timber frame systems. Although built by craftsman through custom joinery, the methods of production in Japan historically were for all intensive purposes mass-produced. Typical details repeatedly crafted making way for expansion and contraction through scribe-fit and scarf joints. Tradition in standardization makes Japan's most historic structures durable and beautiful. Utilizing not only standardized joints, but also sizes of timber and structural grids known as the Ken a 1:2 relational proportion, infill shoji screens and tatami mats all followed these set grids, proportions and dimensions. The use of such standards not only has been employed in housing, but also in public and governmental buildings. These master carpenters developed methods of off site production of timber frames and infill panels in order to be assembled on site.

Prefabrication in the industrial age has been an extension of this tradition, a modernization of craft that has identified Japanese vernacular architecture. The utilization of mechanized factory in order to produce architecture was not fully realized until the post-war era in Japan. It is reported that various architects being inspired by the writings of Le Corbusier and the work of Walter Gropius developed a number of prefabricated housing schemes, usually in timber and based on a traditional ken grid. (Oshima 2008, p. 32) The houses were small and simple, but modernist in their aesthetic. Japan like Scandinavia and the U.S. at the time had its own series of catalog houses that marketed panelized and preassembled houses. Also devastated by WWII, Japan built thousands of these small under 500 s.f. dwellings to meet the need of the housing shortage.

Similar to Scandinavia, Japan experienced a 50's and 60's prototypical period of modern artistic houses intended to be massed produced. These included proposals by Kiyoshi Ikebe. He introduced a series of case study housing using standardized components that up until then had not been available in Japan, such as windows. A survey of the metabolist movement will not be covered in this paper, but it should be stated that Japan's least successful bouts with the practice of prefab in housing are outside of this movement. Beyond the

post war housing needs and the prototype period of the mid century, Japan would go on to become the world's most successful prefabricated housing industry. Even though the United States dominates 26% of the global prefabrication housing market, Japan is the fastest growing prefabrication economy." (Global Housing Market) In 2004, a total 1,160,083 houses were newly built in Japan. Among them, 159,224 houses were prefabricated." (Noguchi 2005) This translates into roughly one out of every 7 new homes in Japan in 2004 were built using factory-based methods. This number has undoubtedly increased in the recent years.

There are speculations for why Japan has become such a leader in prefabrication. Japan, similar to Scandinavia has made prefabrication a mainstream construction method. According to the "Government Housing Loan Corporation in Japan, the construction cost of a conventional home was estimated at 175,404 yen (US\$ 1,698) per square meter. A prefabricated home was at 190,033 yen (US\$ 1,840) per square meter." making the reality of affordable prefabricated housing much more in the reach in Japan when compared with other parts of the developed world. (Noguchi 2005) Japan also has a scarcity of land for which to build upon, yet the need for housing continues to grow. Out of the approximately 49.5 million homes in Japan only 2.2 million are of pre-war construction. Half of the wood-framed homes will have only a 33-year life span. The need for new, more efficient and durable homes is causing Japanese consumers to buy an existing home, level it, and build new. Yet, frustrations with poor construction and scheduling in the traditional method have driven many consumers to explore prefabrication as an option.

Today, most prefabricators in Japan use the modular method or a "skeleton infill" approach. A group known as the "Big 5" currently dominate the factory-built home industry in Japan. The companies, including Shiga Prefecture, Sekisui Heim, Sekisui House, Daiwa, and Misawa, offer varying products with equally diverse methods of manufacturing. Recently, however there is a new rising star in the industry that is backed by a very well known expert in manufacturing, Toyota Home. Although prefabricating housing since the 1970's, Toyota recently made a concerted effort in announcing on Jan 1, 2004 that it established a new branch to begin full-scale production of factory-built homes. That year Toyota Home built 4,700 homes. Each year since Toyota has increased its production and has a goal to reach 7,000 units a year by 2010. (Kageyama 2003) The company has transitioned its process into the home market by utilizing their world-renowned technique of lean manufacturing already discussed in previous chapters. By harnessing the principles of lean, especially by focusing on process, Toyota Homes and all the prefabricators in Japan have become prolific prefabricators of architecture. (Fig. 4)

Toyota's innovation of the lean manufacturing process began shortly after the Second World War. Many of Japan's industrialists were impressed by America's speed in which they could build aircraft and vehicles utilizing the Fordist mass production model of automation, assembly line, and economies of scale. Taichii Ohno and Shigeo Shingo of Toyota incorporated the Ford production process with a variety of customized techniques unique to Japanese culture. In starting anew with this these processes they could evaluate the shortcomings of the Ford model, with a new critical eye and develop their own process known as the "Toyota Production System" or TPS. (Liker 2004) This system has been highly praised and received awards around the globe for its focus on people through mass customization and utilization of economies of scope. Several industries other than the automotive sector have been using this production model as a basis in which to ground their own practice. (Fig. 3) TPS and lean manufacturing have become synonymous with efficient business practices as found in "Lean Thinking". (Womack & Jones 2003) Architecture prefabricators in Japan utilize the principles of Toyota, now widely adopted, in order to deliver product.



Figure 4: Toyota Homes Project utilizing a steel manufactured frame and wood infill module system.
(Associated Press)

Architects from around the world are experimenting with different types of prefabricated systems, however gaining a significant market share by creating an efficient method for construction and manufacturing of architecture has been overlooked in favor of formal studies. Japan on the other hand has perfected the art of manufacturing. But not all of Japan's prefabrication is driven by the construction sector, by absolute efficiency, and reduction in cost increase in quality. In the recent past Japanese architects including Kuro Kishi, Osamu Ishiyama, and the most well known globally, Shigeru Ban have all used the principles of prefabrication

to create beautiful functional and excellent works of architecture. Ban's ability to take the rudimentary material of cardboard tube and turn them into disaster relief and pavilions for shelter is both innovative and humanistic. He has also developed a series of home that use wide prefabricated bookshelves to support a prefabricated flat roof. The houses have no hallways, making the bookshelves both load bearing elements and spatial elements. (Oshima 2008, pp. 34-35)

Many of these architects work to develop prefabricated options for oddly shaped sites or urban infill projects that require an innovative design and construction approach. Kazuhiko Namba has developed a legacy of prefabricated housing experiments that number over 117. Namba is quoted as saying that his Box House concept is to "achieve the basic performance of an urban house with a minimum number of substances." (Oshima 2008, p. 35) The houses are based on a set of parameters than can be tweaked for different sites and conditions such as shifting the overhang depending on orientation in order to passively heat and cool the house. These ideas are now employed in Namba's MUJI House (MUJI is the Japanese equivalent of IKEA in the western world) developed in 2005. The house uses a traditional timber frame; CNC cut in ken module proportions and employs options in the infill panels. (www.muji.com)

Because of its history in automobile manufacturing, Japan's ability to adapt digital and material technology for other purposes such building is very likely. In addition, Japanese culture, which focuses on collaboration and team building, is able to solve problems quickly and efficiently in order to produce better products. A focus on people and process that leads to products is the key to Japan's success. Because Japan excels in process, it is likely that they will continue to lead on the prefabrication front. Some of the recent experiments from this innovative culture include Namba and Ito's extruded aluminum surface honeycomb structure experiments. This falls into the category of material composites and technology that has been transferred from other industries to building. With buildings beginning to integrate systems in the factory flattening mechanical and structural and architectural system in one combination is a trend that is continuing. This can be most likely realized in an off site production scheme. And Japan is prepared to develop this. Japanese prefabrication has waned a bit in the recent years of the recession, but its history of process: being able to coordinate highly technical systems in a factory environment suggest that we have not seen the latest from Japan.

LESSONS LEARNED

As we move into the 21st century American architects, engineers and builders must ask the question where housing is headed. In James Woudhuysen's book *Why is Construction So Backwards?* he states that the current state of design, supply, construction and procurement without change, architecture and construction face a regressive future and more disappointment rather than success. (Woudhuysen 2004, p.63) This is especially of concern in the new financial uncertainty throughout the world. But the argument points directly to the problems in the U.S. with housing construction, that it is laden with inefficiencies, waste, litigation, risk abatement techniques, paperwork, and a sincere lack of innovation. The lessons from other cultures that have become proficient at prefabrication for both mass housing and customized buildings alike is that in order for innovation to occur it must be socially driven. The lessons learned are concerning ideology, product, and finally process.

Ideology

From the UK we learn that prefabrication can be a search for more technically adept buildings. The developments of both the portable cottage and corrugated iron point directly to the British desire to expand its influence in the 19th century. Although the ethics of this history are of concern, Great Britain was able to foster a culture of technological advancement by virtue of its desire for expansion. Buildings in Great Britain today in the case of architects Grimshaw and Foster are designed from a concept of harnessing technology to serve humanity better, to be more sustainable, more dynamic formally, in short innovative. We learn from these examples not to be afraid of technology and that architects are not only the users of it but are part of the society that shapes, directs and even creates it in some cases. In the U.S. we can use a good dose of attitude change about the role technology may play in our lives and in building. Of the recent past we are so concerned about what technology may do to us without recognizing that we are the creators of technology and shape its future for our use. An optimism concerning technology can aid us to create new technology and new methods for the production of housing.

Product

From Scandinavia we learn the lesson of perfecting a product. This culture has taken the traditions of shipbuilding and its greatest natural resource, timber, and researched and explored its various methods of production and construction. Like the UK, the society of Scandinavia does not shirk at prefabrication, but in effect sees it as a way to produce affordable quality buildings. Scandinavia prefabricated housing is more affordable than the traditional onsite counterparts; therefore the market has made not only an ideological shift, but an economic and market driven shift toward prefabrication. This switch did not happen over night, but the market corrected itself as technological opportunities came along. The bettering of an old technology makes the shift from existing method in an evolutionary change. This gradual refinement of timber for construction from frames to enclosure systems uniquely identifies Scandinavia. The U.S. and other nations can learn to use existing traditions of construction, technologies within and without the building industry, and the history of produc-

tion unique to our culture in order to build upon tradition toward innovation with the result being to produce more effective architecture that achieves design and production quality.

Process

From Japan we learn perhaps the greatest lesson of all: that the bettering of process leads to advances in the construction industry. Prefabrication in Japan, like Scandinavia and Great Britain, excels not only due to an strong prefabrication ideology and the perfection of products, but primarily because of its people and process. The culture of collaboration, integration and perseverance distinguishes this construction culture from any other in the world. In fact, the TPS lean principles are just as much a manifestation of the culture of Japan than the ingenuity of the Toyota company itself. Dana Buntrock states that in her evaluations of Japan construction culture she noted the willingness and excitement of architects, fabricators and contractors to take advantage of new technologies, as they became available. It is also noted that the legal flexibility, and continual emphasis on craft and pride in ones work motivates this unique culture to prefabrication, bettering the construction process, and delivering quality architecture. (Buntrock 2001, p. 1-5) What we essentially learn from Japan is that the U.S. needs to find its own culture of collaboration, process, and focus on people in order to advance its capacity to prefabricate in housing effectively.

CONCLUSION

From the perspective of Americans, Scandinavia, UK and Japan were tighter, more homogeneous cultures during the industrial revolution in which prefabrication as a method of practice was developed. These advances have continued to develop on a tradition of construction based in innovation. As we have discussed, advances in the U.S. have not been as extensive, but no less impacting on the prefabrication across the globe. The developments of the U.S. steel frame technology, the pre-cast industry and the proliferation of the balloon frame wall throughout the world are worthy of noting. Light frame construction has expanded to Japan and other areas of the world as a preferred method of building because of its flexibility, bringing it into the factory for mass production. However, disappointingly, Kieran and Timberlake point out that the "US off-site fabrication, in giving the world the concept of "trailer trash", has done neither itself nor the domain of housing any favors." (Woudhuysen 2006) These advances in balloon frame were made decades ago and the question of what we are developing with regard to bettering the construction process for the 21st century housing lurks. Because prefabrication in housing has its success in the mobile home in the U.S., it is conceivable that there is a way to harness the ideology, product and process abilities of the manufactured home industry to deliver more durable housing.

The manufactured industry continues to grow. It is not favorable to the majority of U.S. but this is because it is really misunderstood. The mobile home does not profess to be more than it is and its owners do not expect more of it. Architects and society have misconstrued this housing type as competing with other housing options. Because of this, prefabrication, the method by which manufactured housing is realized has come under attack as a sub par method of construction for all housing. The lessons learned about prefabrication from manufactured housing are sometimes but not usually applicable toward other types of housing. It is just recently that manufactured methods of housing production are being harnessed to create many different options of manufactured housing and different degrees of construction quality, cost, etc. This can be most easily seen in the work of Michelle Kaufmann, a San Francisco Bay area prefabrication architect, Resolution 4, an architectural firm designing and fabricating modern modular homes and John Quale, with his modular fabrication program at the University of Virginia, School of Architecture. The key tenants of their work builds upon the advantages that manufactured housing industry has taught us, that building in modules with balloon framing considerably reduces the overhead, on site labor and can dramatically reduce initial cost, and the construction is infinitely flexible. Unlike mobile homes, Kaufmann and Quale have used modular housing to infuse a higher level of sustainability, quality control, and craft, simultaneously achieving production and design quality. However, these examples are exceptions and not the norm.



Figure 5: Michelle Kaufmann's Sunset Breeze House in factory production and finished on site. The prefabrication process mimics the manufacturing of mobile homes. Image: www.mkd-arc.com

Utilizing the already robust and developed system of modular construction in manufactured housing for the future of housing in the U.S. has real potential to deliver more affordable and higher quality building. Building upon the history of construction ensures that technology is an outgrowth of the society that develops and supports it. The balloon frame and the manufactured house is the history of housing in the U.S. Using what we learn from the UK, Japan and Scandinavia: that ideology, product and process must be the hallmarks of a prefabrication society, the U.S. may be able to hone its already interest and capacity for modular construction in order to deliver higher quality housing.

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