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ABSTRACT

Prefabricating Flexibility: Aggregate House

by

Kevin Jones

Prefabrication has become embedded in architectural culture and methodology over the last century. It has been widely successful in mass produced trailer homes and the fabrication of isolated systems used in traditional construction. Despite this, "prefab" has proved much more difficult to make financially viable for custom single-family homes. This thesis seeks to find a middle ground, where houses can be mass produced while maintaining the flexible nature of the custom home.

By focusing on the potential of the serial, prefabrication offers opportunities and potentials that could result in a construct that is greater than the house itself. This is done by creating a scenario that produces a series of homes based on one prefab logic deployed in a contiguous manner. This thesis creates a component based system that anticipates aggregation and is flexible in outcome aiming to provide architectural solutions that respond to adjacent formal, social and environmental site conditions within a typical neighborhood.
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"At this time, in this world, Ford’s “one size fits all,” no longer makes for a successful product, project, or service. In this century we desire choice, expression, individuality, and the ability to change our minds at the last minute."

Kieran and Timberlake from Refabricating Architecture

PREFabricating Flexibility: Aggregate House

I. INTRODUCTION

Prefabrication has become embedded in architectural culture and methodology over the last century. The idea of prefabrication in construction has always served as an alternative to the traditional form of piece by piece construction. In many ways though it has tried to replicate the outcome of those traditional construction methods but it has not been able to replace it.

Since the genesis of the suburbs, buyers have flocked towards having their own piece of the American Dream. In order to meet the demands of single-family housing developers
have streamlined the process of selling and constructing these houses at a tremendous rate. As a consequence though, resource efficiency and design have suffered as a result of meeting this demand. The typical mass produced single-family homes have been designed with generic clients and sites in mind despite the conditions under which it will be situated in the environment. As neighborhoods age though, the individuality of the user and site emerges when alterations to the original design occur.

Prefabrication has been widely successful in mass produced trailer homes and the fabrication of the components and isolated systems used in traditional construction. Despite this, "prefab" has proved much more difficult to make financially viable for custom single-family homes. Additionally, it has also mainly been associated with low-income housing resulting in an attached stigma of poor quality.
and temporality. This has also become one of the biggest reasons the idea of prefabrication has a lack of appeal to the average homebuyer despite the opposite being true. The process of prefabrication can actually yield a higher construction quality due to being constructed in a controlled environment. Further benefits are higher material use efficiency and faster output.

Many architects have contributed their own version of how a prefabricated house would look and function over the last century. These manifestations though remain experimental in nature which detracts from the marketability of their results. Buckminster Fuller's Dymaxion House is the perfect example of this. Where prefabrication has been successful, (trailer homes) these homes have basically replicated the form and idea of what a house is in people's mind, but they haven't taken advantage of what pre-fabrication truly offers. Their output always emerges as the lowest common denominator of form. A good example of this is the Katrina Cottage used to provide relief housing to victims of Hurricane Katrina. It is essentially a trailer home with a porch applied to the front of it and aesthetic is used as a method to cloak the fact that is was prefabricated.
100 YEARS OF PREFABRICATION

Prefabrication historically works in cycles primarily responding to new technological or historical events. Regardless of when they are produced though, each of these homes arrive with the promise of being contemporary and a response to the pertinent issues at the time.

1906
Aladdin Readi-Cut Houses produces a kit house of numbered, precut pieces

1923
Walter Gropius and Adolf Meyer develop "Building Blocks," a standardized system of housing.

1947
Industrial designer Henry Dreyfus and architect Edward Larrabee Barnes collaborate on the design of a prefab house for Vultex Aircraft Company

1950
Jean Prouvé commissioned by the French government to create mass-produced housing. Twenty-five units are produced and installed in Meudon, France.
1957
Norman Cherner publishes Fabricating Houses from Component Parts, a do-it-yourself guide book.

1965
Deborah Burke creates the Single Wide and Double Wide, two modular house designs, for developer Harvey Gerber.

1976
Mass-market retailer IKEA introduces its more traditional style Bo Klok house in Sweden.

2005
Marmol Radziner debut Desert House, a prototype for a steel-welded frame modular prefab system of living, shade, and deck modules.

2007
Rocio Romero offers the LV Home, a Galvalume-clad rectangular, flat-roof, glass walled home as a partial kit home.
PREFABRICATION CASE STUDIES

For prefabrication to be successful and competitive in the housing market, it must add something of value that the typical mass produced tract home cannot.

The initial form of prefabrication occurred with mail order homes such as the Sears Roebuck House which was distributed by rail and was the most popular form of mass housing until tract homes such as Levittown. Developer William Levitt used pre-cut pieces in an assembly line process to construct up to 30 homes a day using the balloon frame construction method. Around the same time period the short lived Lustron Factory Homes became the biggest developer of pre-manufactured housing with their porcelain enameled product. These homes were all products of mass production.

More recent attempts at prefabrication have started to introduce more variability within their system and output. Habitat '67, although a multi-family housing project, uses concrete prefabricated modules stacked on top of each other to create variety and diversity. The Dwell House which uses a modular system in order to create various spatial arrangements. The Flatpack House by Charlie Lazor is a modern
version of the Sears Roebuck House. Both projects gear themselves towards the middle class as a quality product.

Every prefabricated house must be transported from a separate location to the site of inhabitance. Due to limitations of the road, most houses arrive to the site in an incomplete state where it will then be assembled. Every prefabricated house can be broken down into three categories depending on their component type and assembly. The component types are individual, panelized or modular. Individual components are basically a 2 x 4 or similar. A panelized component is a flat object that basically operates in a two dimensional plane. A modular component is a volume that fills all three dimensions.

Levittown is based on individual components. Projects such as the Sears
Roebuck House and Flatpack House are both examples of a panelized system. Habitat '67 and the Dwell Home are structured on modular components. There are benefits and drawbacks to each system. Individual components are the easiest to ship but require more labor and time to assemble on site. Whereas modular components face more challenges during shipment but can be assembled much quicker since there are fewer pieces involved. The modules typically arrive to the site as finished as possible with minimal additions once on the site. Both methods have successfully found piece of the market in the production of homes today. The individual components play a large role in the typical tract home whereas the modular component is the choice of construction for trailer homes.
# Prefabrication Matrix

<table>
<thead>
<tr>
<th>Name</th>
<th>Individual Component</th>
<th>Panelized Component</th>
<th>Modular Component</th>
<th>No Aggregation</th>
<th>Single Unit Aggregation</th>
<th>Multiple Unit Aggregation</th>
<th>Horizontal Aggregation</th>
<th>Vertical Aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sears Roebuck House</td>
<td></td>
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<tr>
<td>Flatpack House</td>
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<tr>
<td>Lustron House</td>
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<td>Turbulence House</td>
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<tr>
<td>Levittown</td>
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<tr>
<td>Dymaxion House</td>
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<tr>
<td>Klip House</td>
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<tr>
<td>Dwell House</td>
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<td>Variable House</td>
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<tr>
<td>Habitat '67</td>
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<td></td>
</tr>
<tr>
<td>Desert House</td>
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</tr>
</tbody>
</table>
THE LUSTRON FACTORY HOME - BEFORE & AFTER
"One of the greatest failures of modularization attempts of the twentieth century was lack of variability. These elaborate kits of parts were unable to do more than assemble the one intended result. They did not improve upon existing paradigms."

Kieran and Timberlake from *Refabricating Architecture*

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**THE SUM OF ALL PARTS...**

Early forms of pre-fabrication would take an entire design and break it down into a series of components that would then be shipped to the site and be reassembled. Due to the technology of mass production at the time it allowed only one intended result which would then be reproduced over and over. This was one of the critical limitations of these early homes in that they were so complex, yet they did not produce anything greater than what was available on the market.
One solution towards providing individuality for the public is mass customization. This process refers to products coming off an assembly line that have been configured to meet individual customer needs. The same process can be applied towards architecture. So far it has become successful in product design as buyers are able to tailor a specific product to match their individual tastes.

Mass production produced sameness and over time differentiation occurred. Mass customization though gives us the technology to produce differentiation immediately. It also provides the possibility of variability within standardization.

In an age where the internet is an integral part of business people expect to have access to whatever they desire or with the click of a mouse. Society has moved on past the limitations of mass production. The Legos Company has
developed an application that allows buyers to design their own objects using Legos existing inventory. Those objects would then be priced and shipped to the buyer. Architects Kieran and Timberlake are on the forefront of integrating mass customization into architecture. Their curtain wall at Levine Hall at the University of Pennsylvania consists of double glazed glass panels. Each panel works with the overall structural system, but there is room for play as each panel is different from the other.
THE PROJECT

In general this thesis is questioning the approach towards the process of prefabrication? Rather than taking a whole and reducing it to a set of components that have one intended result, is there a way to take a set of components and provide multiple variations or aggregations?

If that is the case then, in order for a set of components to be adaptable and aggregate in multiple outcomes, they must anticipate aggregation.

There are benefits to both individual fabrication and mass production techniques. This thesis is seeking a way to take the variation of individual custom fabrication while receiving the economies of mass production. While variation adds richness and value, it should not be done for the sake of it alone; it should be included as a way to architecturally respond to adjacent formal, social and environmental site conditions within a typical neighborhood.
INDIVIDUAL CUSTOM FABRICATION

Unlimited Component Variation
High Cost

Variations on Final Assembly
Economies of Mass Production

No Component Variation
Low Cost

MASS PRODUCED FABRICATION

AGGREGATE HOUSE
LARA PROPERTIES
Throughout Houston there are a series of neighborhoods that the city has outlined as having a high amount of undeveloped single-family lots. These neighborhoods provide a strong opportunity to operate in due to their need for single-family infill in addition to a rich variety of existing properties and context.
SCENARIO

In order to test a set of components that anticipate aggregation a scenario will be set up that is an alternative to the traditional form of execution for prefabricated single-family homes. The scenario would produce a series of homes for 5 individuals and couples that join together and buy land in an existing neighborhood. The homes would be based on one prefab system that has a serial production deployed in a contiguous manner. The idea is that by producing 5 versions of the house it allows the owners to receive the economies of mass production which a typical custom prefab design could not achieve, but it is also flexible in a way that a mass produced design is not.
Family w/ kid

Living Room
Kitchen
Dining Room
Master Bedroom
Master Bathroom
Bedroom 2
Bathroom 2

1440 sf

Family w/ 2 kids

Living Room
Kitchen
Dining Room
Master Bedroom
Master Bathroom
Bedroom 2
Bathroom 2
Bedroom 3

1650 sf

Couple w/ In Law

Living Room
Kitchen
Dining Room
Master Bedroom
Master Bathroom
Bedroom 2
Bathroom 2
Separate Bedroom
Separate Bathroom

1750 sf
**AGGREGATE HOUSE**

Aggregate House has no one single form. The representation of the house is one of the many variations for how it can manifest itself. The variations of each house represent a specific solution to the needs of the client, site orientation, environmental factors and social and formal adjacencies. It is based on a set of mass produced components designed to anticipate aggregation.

The house essentially consists of modular and panelized components. The components work together with the panels aggregating around the modules. Each house has a base core that is 8’ x 24’ which houses the kitchen, bathroom, washer/dryer, utilities and HVAC. These core functions are the most expensive part of a house. By isolating them and packaging them within this one piece it greatly reduces the overall cost and labor involved. There are additional bathroom or stair cores using a similar module that attach to the panels as well. The shell of the module is mass produced to reduce cost. The interior though is unique based function and need. Additionally, there is an opportunity to reconceive the way one classifies a house. What initially might be classified as a one or two bedroom house can now be specified as a one or a two core house.
THRESHOLDS

In addition to the modular cores, there are similar modules that can extend or connect the space created by the panel system. The relationship between the modules and the panels play a key role in the experience of the interior space. The modules essentially act as thresholds that divide up public and private programs. The is achieved by a material shift in the wall and roof planes in addition to a drop in the ceiling height creating a more intimate experience. The floor, however, continues on the same plane creating a sense of continuity as one navigates through the house. These subtleties are embedded into the logic of the house so that whatever arrangement may occur, the modules and panels will still have the relationship to each other and the user.

The series of sections to the right show how an alteration to one of these modules can affect the way it behaves within the house. These modules are able to create an entrance, connection or extension into the adjacent space affecting how it would be programmed. While the pieces are mass produced, which as history has shown creates sameness, the way in which each piece is used within the overall house allows for a vast amount of differentiation to occur.
DEPLOYMENT

The house is designed for maximum efficiency during transportation to reduce costs. The panels arrive flat and the modules arrive completely finished and ready to connect. The deployment process starts with setting foundation piers and setting up electrical and water onto the property while the components are simultaneously being fabricated in the factory. The foundation piers would have bolt attachment points and the core modules would arrive on site and simply attach to the foundations mechanically. The piers keep the entire system above the water line which makes the ground work a simple strategy of support and connection.
1) Install footers
   Locate electrical & plumbing stubs

2) Install basic core

3) Install remaining modules

4) Erect gasket panels

5) Install floor panels

6) Install wall panels

7) Infill gasket panel

8) Install roof panels
**HOUSE VARIATIONS**

There are many versions of the house's form depending on the collection of components chosen by the owner. The drawings below show individual configurations that demonstrate the extremes of which the system can be exercised. One owner might prefer to simply live in a box while another could go to the extreme of wanting everything on an angle. Not all configurations are ideal solutions, but it is important to understand the limitations and potentials of the system. Despite using a limited palette of mass produced components, the collection of the assembly reveals how variety is able to emerge due to the new approach of designing components that anticipate aggregation.
IV. COMPONENT FABRICATION

Aggregate House explores existing prefabrication techniques in addition to nontraditional materials and methods. The unique aspect of the house is the fiberglass core. While a traditional material in product design, it is not typically used at an architectural scale.

The combination of the two fabrication techniques, modular and panelized, drives the formal resultant. It is the dynamic between the two material systems that creates the visual language of the house. The nature of the materials themselves is reflected in the logic of assembly and in the formal aesthetic. A fiberglass surface has no joints so all corners are rounded and smooth. Whereas the panelized components are constructed out of more traditional materials that are produced flat such as 4' x 8' plywood. The resultant of the panelized system connecting is a rectilinear form producing a typical 90 degree joint.

Contemporary construction practices tend to skew the relationship between material and final form often times manipulating one material in order to appear as though it is another. The relationship between material and form in Aggregate House is honest by virtue of the materials behaving in their natural manner.
MODULAR COMPONENTS

The cores are constructed out of a hermetically sealed fiberglass shell that is reinforced internally. Using one material to construct the core allows a reduction in trades involved and also reduces the amount of joints necessary since a continuous surface is created. The process of construction benefits from the series because once one mold is made it then makes the subsequent pieces easy to reproduce.

The shell allows for stacking and direct load transference. Interior features such as cabinets and countertops are easily integrated reducing the added cost of custom millwork. Drainage and water shedding can be molded into the core as well to direct water away from the connection joints.
Bathroom Core

Wedge Module
PANELIZED COMPONENTS

There is one typical roof and floor panel that stretches between the cores with built in insulation, slope for drainage and chases for electrical. All panels are based on 4’ increments to economically and efficiently work with an industry standard dimension 4’ x 8’.

Mediating between the two systems is a gasket panel which creates a waterproof seal and connection between the modules and panels in addition to transferring electrical. The modules insert into the gasket and the panels hang off of it. The gasket can also accommodate connecting two adjoining panels. The idea is to produce one detail that has multiple implementations to reduce costs. When connecting the panels the gasket is hidden, but it reveals itself on the exterior and its form is then witnessed.

The wall panels complete the envelope and are interchangeable allowing for the client to choose the type of panel and locate it wherever they desire. There are three types of transparency. Opaque, screened and glass. The logic of how the panels fit together is fixed. The client though is given the opportunity to design the elevations without disrupting the system. Furthermore, the panels are shipped with finished surfaces on them to reduce labor in the field.
COMPONENT LOGIC - EXPLODED AXONOMETRIC
1. Module meets Roof Panel

2. Module meets Floor Panel

3. Panel meets Panel - Floor

4. Panel meets Panel - Roof

5. Floor Panel End Condition

6. Roof Panel End Condition
V. URBAN IMPLICATIONS

The collection of homes at the urban scale creates a dynamic that is greater than the house itself. There is cohesiveness amongst the compilation of homes due to the fact that they are all based on the same construction system. Each house is unique though as they have been arranged and tailored to meet the demands of the owner and the site. The basic core is visible from the exterior which provides a visual anchor when reading the collection of homes. While there is the expression of the individual, each house belongs to the city and the neighborhood.

There is a site strategy where the houses aggregate in relationship to each other in addition to the components themselves. Each house then informs its neighbors of how to act and respond. In addition to the owners being able to choose how many components or what types they would like in their house, they are also able to choose how the house is situated on the site. Within the context of the series, it creates a dialogue between the owners about how each house is situated in order to maximize the potential for a certain type of desired space.

The physical aggregations have the ability
to shape exterior space. The houses are able to respond to each other to create shared or private spaces between the houses. By placing the houses closer together a more intimate space might emerge whereas by simply placing two u-shaped courtyards facing each other a larger collective space is constructed.

The typical mass produced house is an object in itself. Aggregate House in a sense is a collection of objects. Each object is smaller, but that increases the level of variety that accumulates as each house is created. The shape of the massing can also respond to orientation by shielding a south or western exposure. This is one of the benefits of a set of components that anticipate aggregation. In order to adjust to a site, the components themselves do not have to change. This way, the pieces can still be mass produced, but the final assembly does not have to be the same.
THE IN BETWEEN.....

Often times the space between two houses goes unnoticed in the design process and inadvertently becomes a wasted opportunity. Through the combination of the site strategy and the interchangeable components, the owners are able to negotiate the space in between the houses now. This allows a series of responses ranging from formal and social to environmental. The interchangeable wall panels can mediate these issues based on the level of transparency desired by the owner. Once the envelope is tuned, that will inform how the space is inhabited as either a place for privacy or meeting. There is a larger potential with this space that typically is wasted in a traditional suburban neighborhood, however, Aggregate House takes full advantage of it.
URBAN AGGREGATION MATRIX

The Urban Aggregation Matrix demonstrates the multiple urban scenarios that are possibilities with Aggregate House. There are three types of urban qualifications: private, semi-public and shared. The other qualifications are based on component types and quantity. The most economical would just have two module types, but to increase variety one could add more types which inflate the cost.
URBAN STRATEGY

INDIVIDUAL

SEMI-SHARED

SHARED

- BASIC CORE
- BATHROOM CORE
- EXTENSION
- WEDGE
VI. MATERIAL CUSTOMIZATION

Despite the materials or method of construction, the user would be able to customize their core or interior based on how they desire. While the core is fabricated out of fiberglass and might sound unappealing at first, interesting opportunities emerge that allow for new material possibilities to be integrated into the core. A base cabinet structure is built into it reducing the labor and money to purchase and hang shelves. Surfaces and appliances can then be applied to the specifications of each owner. The core would basically be designed to receive these materials by allowing for a slot to set the surfaces in.

The diagram to the right shows products and materials by the company IKEA that would work with this core. This takes advantage of off the shelf prefabricated products and integrates them. Regardless of the material or mass production of the fiberglass core, the owner still has a voice in how they can make their home theirs.

So far the houses have been represented diagrammatically, but it allows for a level of material customization that does not rely on the component logic. For instance, the exteriors could be any color or material. The interiors can also accommodate many different tastes regardless of how it was constructed.
Classic Country Kitchen
Bachelor Kitchen
VII. CONCLUSION

Prefabrication has become embedded in architectural culture and methodology over the last century. While often presented as an alternative to the present delivery system, prefabrication has been widely successful in mass produced trailer homes and the fabrication of the components and isolated systems used in traditional construction. Despite this, “prefab” has proved much more difficult to make financially viable for custom single-family homes.

By exploring the potential of the serial, prefabrication offers opportunities and potentials that could result in a construct that is greater than the house itself. This is particularly true when this approach is applied to a neighborhood setting. Infill lots provide a strong context for which to respond.

By creating a hybrid process of individual custom fabrication and mass production it is possible to achieve variety and have a realistic budget. In the case of Aggregate House, it found the middle ground that the average homebuyer is looking for. It also exercised a more responsible architecture. One that is sensitive to the environment that it is situated in and also creates a dialogue with the adjacent properties.
The very nature of prefabrication indicated that it was crucial to develop components that anticipated aggregation. The component logic of the aggregation set up an interactive process between the architect and the client. Additionally, the material fabrication created two specific component logics that strictly derived from their material logic. Aggregate House is a specific product of its fabrication process, but more importantly, it is a vessel for living that is flexible in outcome and provides architectural solutions that respond to adjacent formal, social and environmental site conditions.


