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I, Wenhao Yu, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture.

It is entitled:
Home Craft Pre-Fab Customize Units

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Home Craft
Pre-Fab Customize Units

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In DAAP
by

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Abstract

The world around us is changing. Cars are running on every street, cellphones signals are sending back and forth to satellites every second, medicine is saving people from death on every part of the world. The way we are working, moving, talking is changed. As human beings, it is our nature to change the world, to discover new life. From the first industrialization, we have been through a second industrialization, standardization, mechanization, mass production, and automation. Now, we are stepping into mass customization. Compared to cellphones, vehicles, and visualization, architecture is behind the times. The industrialization 5.0 allows customer customization in every production but why can architecture not do the same? Among material, space, and circulation, we as architects are driving everything through our awareness of the world. We say “cozy homes” but it is only our believing. Do users really like it? How can we allow users to change and modify their home? Old construction progress wastes tons of materials, and the construct stage is being designed roughly, which is abusing time and man power. To determine a solution to combat these problems, I want to design an easily-assembled, moveable pre-fabricated, customized Unit-House. In term to finish the design, I need consider three major parts. 1) How to allow customers to design their space. 2) How to move the pre-fab house. 3) How to arrange public spaces in complex arrangements. I hope this project can become a prototype, which has a major influence on people’s lives.

Key Word: Moveable, Pre-Fab, Customization, Flexibility
Table of contents

Chapter 1: Research ................................................................. 5
Chapter 2: User ........................................................................ 8
Chapter 3: Case Study .............................................................. 10
Chapter 3: Design Project ......................................................... 13
End: Bibliography .................................................................. 23
Chapter 1 Research

After mass production, people are already moving into the next era, which is mass customization. We, as architects, are busy trying different materials on projects and continuing to find new ways to apply technologies into buildings, but it appears that we have ignored the very basic requirements of users: adapting, changing, and creating. This is the time to look back on what has gone wrong.

First, despite that the development is on high speed line, most of the materials are wasted during the construction progress, causing damage environmentally and economically. Construction workers are confusing how to assemble materials together. Also it is hard to calculate how much material is minimally required to finish the project. In the cycle of creation and costume, costuming wins. Neither the development speed is slowing down nor the rate of wasting material.

Second, life is not fair, but we are here to provide as much as we can to improve it. In person, I have plenty of food and good clothes. I live in a big apartment but during my childhood, life was tough. My parents did not have enough money to purchase a television, we did not have enough money to spend on fast-food such as McDonald’s, and we lived in a single small room without restroom and kitchen. I can remember that when we had moved into a small apartment, our happiness was beyond anything you can imagine. After that, we had moved into a bigger apartment, which I got my personal bedroom first time. I was so excited! It was a 5 m² bedroom. I had a bed, desk, and closet. However it was fully occupied and only a small gap allowed me moving in and out. I could not stop myself to color my own space with everything I had such as stamps, toys, and posts. In this world, nobody deserves a bad life. Poor people and refugees suffering are scarcely concerned by most of the people today. We are typically indifferent to their happiness. This is mainly due to the fact people are always marching forward, developing new technology, constructing new buildings, and collecting more money. Those illusions of development are blinding people that
some people out there need us to help.

Third, it is people’s nature to be creative. But we, as architects, take over the majority of pleasure, leaving so little for our user. Our client believes in us, they are always asking for our professional skill to create a perfect building, but for ordinary people, are they asked to be assigned a house? Do they really love it? Nobody knows except the users themselves.

All in all, is there any way to solve these problems? A moveable pre-fab unit house is jumping out in my mind, with various old and new technologies embedded in as complementary support, also presentations to show this content to hundreds of thousands of people both in this region and beyond. As a result of our productions, these audiences will gain an increased appreciation for sustainable building on this continent, for their modern local people, for the meanings of protection, our priceless world and environment, and concerned for our next generations.

In the John D. Quale’s *Sustainable Affordable Prefab*, he and his fellow students dig into cheap Pre-Fab housing. He intended to create a design research project and educational initiative that would be grounded in the realities of budgets and material while striving to address two most important challenges facing the next generation of designer: the significant environmental impact of building and the growing economic divide between high income and low income individuals. He believes this kind of new technology and design combination would challenge the existing architecture. He has tested his idea in many projects, most of which are small scale house designs. Because the prefab house is still on experiment, it is not ready to go into the open market yet.

In Ryan E. Smith’s *Prefab architecture: a guide to modular design and construction*,

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1 Quale, John D. *Sustainable, Affordable,Prefab: The EcoMOD Project*. Charlottesville: University of Virginia
he believes that modern technology has changed dramatically, but architecture did not. Architecture often relies on uncoordinated and poorly integrated products supply references. He believes our world is developing super-fast, but the architect’s progress is slow. For instance, the profession is poor at saving material and controlling time. By taking the benefit of modern industrialization, the architect should follow up to catch up with the speed of human evolution.

In the *The Zed Book* Dunster believes that carbon is the source of pollution. The four core Zed standards principles are. 1: Make carbon history. 2: Design out fossil fuels. 3: Reduce demand – run on native renewables. 4: Enable a high quality life on a low footprint. Author

According to the book, the Zed is a standard that allows building to have low carbon or even zero carbon emissions. This standard, including construction detail, structure components, wind cowl passive heat recovery ventilation system, passive solar design, thermal mass, overheating solve method, low and zero carbon heating and hot water, low energy air conditioning, dehumidification and cooling, and renewable electricity supply. Also, this standard is being applied on different buildings, such as office, large scale development, old buildings, and new houses. They author believes that using this standard could reduce the carbon emission while also providing a comfortable living, working space.

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Chapter 2 User

This project aimed towards a multi-user group, which is including young working class, frequently moving people such as the construction team and oil workers, as well as those who have the spirit to design their own home.

Beijing is a metropolis and as people move into this city, it is getting crowded, most residents move out of city center to avoid high price housing and rental. Not to mention younger working immigrations. They are attracted by the metropolis but suffering the economic crisis. Their salaries are low, but their living costs are high. The apartment rental fee is taking a huge amount of their income. Also, in China, it is common to believe that a young male without a personal apartment or house does not have the means to get married. Many young people are gathering near the rim of city boundary, because the cheap price of house and relatively inconvenience transportation.

Those young working class individuals and immigrants call themselves “Ant Clan.” Beijing government had wiped out one of their “Ant Nest” but it turns out they were spread out and re-gathered in another place.
On the other side of world in the Middle-East, many people believe that the war is far away from them, except for when a bomb lands on their nearby block. It is too late to prepare to run, their beautiful home is set ablaze, ruins spread hundreds of miles. Many of them did not have the chance to open their eyes again. Some of them rushed out without any supplies, so many families teared up, they rushed into refugee camps seeking their family members, but their suffering is continuing after they finally made their way to the refugee camp. Tents are not good for protection against the elements. Disease is also threatening their lives.

Everyone wants to live in a good place, but it turns out to be a bad room with obsolete utilities, in a bad location, sometimes near the mechanical room, making it noisy. Worst of all, no sunlight and green space is seen at all. These people are looking for a place that they can live without so much trouble. Therefore, this project will address these issues. Four reasons are making this project in possible solutions for these types of people. First: Because this project is pre-fabricated in a factory, the price would be lower than regular houses. Second: Because the expandable components such as walls and structure, with some modifications and adding extra panels, it could change into a multifunctional house as well as adding modular spaces. Third, with different skin systems and utilities, it could effectively deal many conditions, such as bad weather, and energy crises. Forth: the flexibility would allow you go anywhere with your beloved beside you.
Chapter 3 Case Study

This is a project named Kasita, which is a good example of a moveable house.

3-1 Kasita house
Picture, from website
http://www.citationmachine.net/chicago/cite-a-website

3-2 Kasita house interior
Picture from website
http://www.citationmachine.net/chicago/cite-a-website
This project is not finished yet because the designer has not explored the potential of small space usage. One of the designers who calls himself professor dumpster had a whole year to spend in one single dumpster; to feel, to touch, and to change the life of being inside one dumpster, after that he has developed this production. This project can be located and moved in many parts of the United States. Thus, the customer does not have to worry about renting a new apartment while they migrate from one place to another.

A KASITA prototype is currently located in East Austin. The KASITA is approximately 270 square feet with 9-foot ceilings. I be able to live in a KASITA by late 2016. KASITA is designed for a variety of individuals at different places in their life. From college a kid who is in need a student housing, to urban millennials, to those enjoying retirement.\(^5\)

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\(^5\) KASITA https://kasita.com/
This project is showing that the moveable house is ready for an open market, but for the customer, this is not enough. He or she wants better flexibility and adaptability.
Chapter 4 Design project

This chapter contains 3 major parts: moveable unit, customization, and organization (test).

Section one, moveable unit: How to move this unit from one place to another? Also, what if the unit could be moved up and down or shift right and left?

1) First, is transportation on the road allowed by laws? It is not necessary to move the whole container in one piece. However, it is possible to shift the whole container on the truck, and the size of this container is designed to sit on the vehicle. According to the Traffic Code of China, any shipment less than 4 meters is under special transportation regulation 1, which is allowed on the road but must request permission first. However, because this project is design to be customized, every single component, from base plate to ceiling to wall panel to utility fixtures are designed to be installed. The size of a regular truck can be 40 feet long, so the biggest single component is less than 9 meters (cover and protection material included), but, what if the customer wants a special panel? The frame and structure system is predesigned, all those panels and beams are modularized as well as special component ordered by customer. Therefore, transportation on truck will not be a problem. But, how about transport by human or by cargo carrier ship? Transporting by human power is not necessary, but some places on earth such as India or China, the price of human power is cheaper than machine power, especially somewhere that people need to find a job to feed their family, selling their strength is the easiest way. On the other hand if this production needs to transfer on cargo carrier ship, because this kind of unit is slightly bigger than regular container, demanding larger shipping space, however, the unit has its own structure system, if you decided shipping production by unit, it can stack by itself. Also, to maximize space-use during transportation, small components can be inserted into the gap of many big components, or, stack on top of the big compounds. This allows for two shipping methods; one is for transfer as a whole; another is for transfer in disassembled components.
2) Second, once all units and packs arrive, how to install these? From the perspective of mechanics, there are two methods to move container from ground to upper level. The first method involves using a lift machine. The lift machine platform is designed to be the size of regular tow units of panel (4m x 8m). Lift machine is a system that is working similar as auto-parking system, once you have unit on platform, the platform can shift unit to the plot. The second method is human power, which is unnecessary, because machine power is far better than human power in many ways. However, if a project is located in a high-populated area, based on economic and salary payment, human power is one alternative option. Also, from an engineering perspective, the joint design is very important, because this project is meant to be flexible in order for the customer to change their home component as their wish, the system has been set up, panels and components can be switched. To fully explore the flexibility, those panels and joints have many problems. How easy is it to install and uninstall a panel? Can people assemble panel by single person or need help from other people? How heavy is it? There are many joints, but what kind of joint is perfect for this project? There are walls, panels, structure components, and utility components, but can these different components share same kind of joint? Also, this joint allows the panels fixed on structure, also can be handled by single person. Because the home modification usually happens in small scales, the family is a decent group to do it. So in one family, dad and mom might be the only one who has the strength to move a panel. Children, on the other hand, are sometimes not strong enough to move the large, heavy panels. At most, a friend or two can help to assemble them. The size of panel can also be can various, too. The joint element should be easy to understand by the customer and worker. The door is a good existing example, people know how to use door handles to open the door and this kind of design becomes a symbol that represents this object that can be opened or closed. An easy to understand and easy to use joint to capitalize the main theme “flexibility.” Another joint is between frame and unit, which is working not only to fix the unit on frame, but also allows the unit moving. In the high density sites, stacking apartments into one building is a common
scene. Using a machine to move the unit is a better option, because the equipment and electricity power is not restricted in those areas. If a regular H channel steel is used as structure, it is hard to fix the unit on frame, neither moving the unit. Considering the metal alloy has better adaption and flexibility, the strategy of using steel structure is not closed yet. When it comes to moving the whole unit, how easy to move unit from vehicle to slot? What kind of joint is good for moving unit from slot to slot and from vehicle to slot? From prescriptive of physics, gravity is main factor to design this joint, as well as from friction force. To maximize two kinds of factors, adding surface area, especially the surface where unit meet structure and vehicle. Using a channel to prevent the unit to move horizontally, and use chain splice to prevent the unit from moving back and forth. Once the unit slides into the slot, the only way you can move the unit out is using a control panel.

Organization (test): This project is being designed as multi-functional, testing in low density areas such as vast and flat areas, using units to make a community. Mid density area use stacked units to make a temporary house. And high density complex use frame and support structure in city area. To fully explore the flexibility and adaptability of a unit, experimenting unit in various conditions is very important.

1) Single & Flat Plan solution. The first test is using this kind of unit to make a community. The question is how to provide water and power? The units design is different, which has enough possibility to create a community, but the utility requires supporting infrastructure which in turn require some of those units into other functions, such as the electric generator unit or water purified unit, which can afford the daily require of needs. But what can single unit do to fulfill the needs of daily life? The extension panel includes solar panels and a simple water purifying utility core, and the heater is depending on the season and location. There is no solid “structure” in this kind of arrangement, the container only needs a flat minimum 4m x 4m ground to be put on or an equal size man-made support structure. Talking about the site, what if the site is located on a mountain or somewhere sand based soil. The mountain for
instance can either dig a flat platform to put the container on or use some material to build supporting columns. This community group only happens in particular situations, it needs some preconditions, such as vast ground, registered land use as residential, heavy and giant structure cannot be built on this ground (sand or sludge), or extreme climate condition (north & south pole area, desert, even outer space). In this community, some unit groups making a block, and in between the block is road, the block size can be changed, according to the condition of project area, in refugee camp, the block is thinner and longer, two line of unit stay back facing back, for disease control and better living condition, the block is not too big. Another situation, such as oil rig factory, they have vast no-man land, they can have as much units as they want, even a swimming pool unit. For temporary working class and continuing moving user group who has no land crisis, this is the best solution for them. The community could be changed by their interest, looser or denser, circle or square. Also, facility of this community is flexible. This project is providing various different units that could fulfill their wishes.

2) The Mid-Density solution (4-1) (4-2): in some county and area. Also for construction worker, who always need to move from one site to another, but they only have a small area in which to live. What kind of units do they want to have? This mid density solution is using regulation of design and the production attribute of this project to maximize usable space as well as providing a solution for a certain kind of user group. According to the production attributes, the structure imbedded in each unit allows it to stack up to five floors high, but according to regulation of building, the building that has three floors or more needs to have an elevator. So this kind of solution allows the unit be stacked up to
three floors high without an elevator. When stacking units, the utility core for water pipes, electric wire lines, drainage, and heater lines are becoming a problem. To fix this, there are two solutions. First: No utility core, this solution is for construction worker or the user group who does not need private bath and kitchen. It is because they share the public restroom and public kitchen and dining hall. Individual rest rooms are merely adding cost. However, if they insist to have their private right, they would better looking for another solution that every single unit has a utility core that allows water, electricity, internet, and heating. A big water tank could be put on the top of stacked units, because five floors is maximum of stacking height, so the water tank’s dead load can be distributed by the unit inner structure. But they need to purchase extra stairs and hallways.

3) The high density solution: Some areas of the world are crowded, so much so that even people are stacking themselves during the time known as “Rush hour.” The Metropolis is a wonder of a machine as well as full of sadness. People here are working so hard to earn themselves a place to live, many young working class people have no ability to buy an apartment renting a small room sharing whit other peoples. It is not their wish to lose their privacy. Their colorful world faded away because of lack of living space. So this third solution is designed for them, and for others who would love to “design” their home. The high density needs the units to be stacked high enough, but, the structure of the unit itself is not strong enough to support the entire load. A structural system could be a good solution. This kind of structure has regular columns and beams, fire stair and elevator, hallway, and egress. The first difference is the shape of whole frame are various according to different situations and the needs of each user group. The second difference is the whole building is
“empty”, such as a book shelf without books, except structure, all the space between column and beam is empty, and the unit could be inserted into those spaces. Because the whole unit has the utility core, (even for the unit does not need it) the pipes are not a problem, and for empty space, it will be inserted flat platform to close the hall way and to make sure the pipes go through without problems, and egress way is pre-settled in the building. Now, we are looking into the organization part different spaces other than living. Because the whole building will be crowded with people, who are sensitive animals, they need green space, public space, and they want to stay with other people who share similar interests. As an architect, how is architect play their role in this project? The architect will classify certain areas as public space. After you choose your unit slot, you cannot move in and out at your wish. However, there will be a regular shifting day that allows everyone to move their slot, to extend or to shrink their space. Due to the system, there is only allow the slot be stacked from base to top. The structure will move a single vertical line of container to top of building, then moving the rest of the container by using this empty slot, like the puzzle game. The system will calculate the easiest way for people who want to move.

The concept about how to stack the unit is coming from city plan, the city is a huge complex consisting of a school, hospital, shopping mall, garden, park, residential area, working zone, and special zones. But nowadays the people expanded their city to every corner of the world, the useable zone of city becomes less and less. What if we turn the city 90 degrees, so all those plan become vertical and collage those feature into a huge apartment, unit are the block, different

4-3 Concept
block means different part of city, we live in our community too long to ignore the sky we have not been touched yet. Shift and move all these functions of the city into an apartment, not horizontally but vertically.

1: Random small public (Pic4-4), this is due to lack of public control; the architect needs to think about it. If the architect allows the slot taken by the customer according to their wishes, this is what happen after the whole slot has been taken. Chaos, without order.

2: Taking a chunk of space (Pic4-5). A different chunk of space could be used for different interests groups, food, music, art, sport. The people tent to hang around with others. So these public space with right size will suit their needs.

3: Taking a big series of slots that allows each of those public spaces continues to go from the bottom of the building to the top. Because the public space needs to be connected, a single public space is not good enough to bring people together. (Pic 4-6)
Customization:

The unit is the core design of this project, with all those supporting design, people need to find their own space to live, their design, and their beloved home.

The design of the unit is aiming at different kinds of user groups. From the basic model to a highly flexible, fully functional model.

First, the customer chooses their base model. The base unit has many different models, single, double, loft, as well as models that have different built-in furniture. Some have better solutions but high price; some with flat plan but lack flexibility; some have normal solution and normal price. The advantages and disadvantages are weighed by the customer.

Second, after the customer has chosen their model, they will go to the next step - choosing the panels. Walls, ceiling, flooring,
windows, doors, all you can choose from the collection of the design, special furniture and paint finish need to be preordered.

Third, when the customer finishes the design of the indoor space, they are about to choose the outdoor extension panel, balcony (closed or not), extra green land, even another unit. Because all wall panels have a hole in the middle, which allows customer to add a bridge between the two units and connect them together, this project has potential to make a big apartment, although each single unit has 4 meter width only.

Not only the living unit, but also the function unit and infill unit(Pic4-10), the function unit is including MEP unit, flat panel, and transportation unit, those kind of unit works as support panel that allow the whole building to function better. The green land unit has plants and open space that if customer wants to have their own gardening space, which is the best choice for them.

In the unit, there is a wall system that allow people to design their own home, (Pic 4-11). The wall is panelized, each individual panel could be changed, electric wire line are hidden in the back side of the wall, so all fixture or electric panels are connected to the system, using this system, the owner can control all the fixtures in their house. All connected fixtures are showing on the center control panel.
The extension panel is the magic of this project. Because of its extendable design, the unit has potential to face extreme conditions, such as North and South Pole areas. The extra skin will be added to protect the unit, the solar electric system, and electric generator. The solar panels are easy to install, water clean system that allows refugee camp has better water to drink, the sound absorbing wall allows you to have your fanatics music land without disturbing your neighbors. Maybe in the future with the new skin system, this project could be sent to outer space to become the first extraterrestrial settlement.

After these tests, the questions and solutions from the experiments become beneficial in improving unit design. Experiment and improve, suck like cycle, testing this unit in different climactic situations, digging deeper and wider. Go back and forth to make this project become a future house prototype.
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