CAPSULE HOMES
CREATING SPACE WITHIN SPACE

By
Kimberlee Boonbanjerdsri

Submitted to the
Department of Architecture
in the Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Architecture

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ABSTRACT

Inspired by my final Studio IV project in 2010, the Capsule Hotel, and the growing demand for efficient housing due to overcrowding in developing cities, this thesis explores, examines and realizes the need for compact homes.

The need of reducing a small living space to the bare necessities, whilst allowing consumers to quickly transform and personalize the function requires great understanding of space efficiency and construction methods. Realizing a carefully designed space is one thing, but actually understanding how or why it is put together in a particular way is another. In this day and age, architects tend to create with the intention of purely design and often forget to consider and fully understand how the pieces actually come together, often leaving such tasks to contractors to "work out". What would happen to the design industry if consumers were not only able to customize and assemble their own apartment furniture, but at the same time get involved in the design of their furniture units? How would this impact consumers as well as the industry?

The driving force behind Capsule Homes is to design a product that will provide users with the everyday amenities that can be transformed and customized, whilst involving the consumers in the affordable construction process. My thesis acts as a design proposal for introducing a new method of designing and customizing living spaces, whilst involving the consumer in the process from ordering units to understanding the construction methods, to ultimately living in a customizable quarters. Based on my research and analysis, I will construct a ¼-scale prototype of thoroughly designed, flat-pack, customizable furniture.

Thesis Supervisor: Lawrence Sass

Title: Associate Professor of Computation & Design

ACKNOWLEDGMENTS

It is my pleasure to thank the many people who made this thesis possible.

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I would like to thank the many people who have taught me over the years. Without your knowledge, I would not be where I am today.

I am indebted to my peers for providing a stimulating, exciting and supporting environment in which to learn and grow. I am extremely grateful to my fellow thesis studio colleagues, roommates and friends for all the support and good memories that helped me get through my thesis.

Lastly, and most importantly, I would like to thank my parents, Suchat and Jan Boonbanjerdsri, and my brother, Kobi. From extremely far away, you have been an undying support and have made my whole MIT experience possible. To them, I would like to dedicate this thesis.

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INTRODUCTION

It is a fact that the world's developing cities are getting more and more crowded. Cities such as Sao Paolo, Bombay and Hong Kong, now considered 'mega-cities', are reflecting their enormous size and huge population growth. The main reason why these and other cities are becoming so crowded is mainly due to the growing economy. With the increase of job opportunities, there has been a rapid population increase in these mega cities, introducing many problems to the demography and geography of these cities – food shortage, limited resources and overcrowding. Buildings that had once been single-family dwellings have been increasingly divided into multiple living spaces to accommodate the growing populations. As apartments become less affordable, people are finding it more and more difficult to maintain the everyday necessities in a small single room.

Realizing a carefully designed space is one thing, but actually understanding how or why it is put together in a particular way is another. In this day and age, architects tend to create with the intention of purely achieving a design goal and often are unaware of how their designs actually become reality, leaving such methods to contractors to "work out". What truly goes into the construction and manufacturing process? What are the different types of joints and fasteners available for flat-pack design? How can we, as designers, involve consumers in this process of production, quality control and assembly?

Time must be dedicated to realizing the importance of the design cycle and understanding the various stages in which the consumer can have a role. The design process for a product requires a clear understanding of the functions and performance expected of such a product. Prototypes must be designed to simulate as closely as possible the conditions under which the product is being used to ensure the product is safely designed for manufacture and assembly.

The challenge lays here; how can these small spaces be designed in such a way that is comfortable for the user, yet include all the necessary day-to-day amenities, whilst including consumers throughout the fabrication process?

DESIGN BRIEF

The underlying concept behind Capsule Homes is to accommodate those in need of the basic necessities in response to the lack of accommodation in growing, overcrowded cities. Such a unit should account for the day-to-day needs of people and enable users to live in small spaces whilst having all the necessary functions and amenities of a regular home – a bedroom, a kitchen and a bathroom. Compact prefabricated construction will allow this product to be easily purchased and quickly transported and assembled with minimal impact on the environment and community or those living in the space. With rooms of limited square footage – how can these small spaces be designed in such a way that is comfortable and include all the necessary amenities? How can we ensure that natural light can reach all areas of the living space, or those spaces that would benefit from natural light, and yet maintain the prefabricated nature of these units?

The concept of Capsule Home is inspired by the Japanese Capsule Hotels, where the 'living space' is reduced to the bare minimum with the understanding that a single unit would provide a carefully planned space offering visitors a roof over their heads for a given amount of time. However, how can this concept be applied to the Capsule Home? The idea behind Capsule Homes is to design and develop a product that can offer users the ability to transform and personalize the function and layout of a single room, whilst being completely involved throughout the entire design and manufacturing process. With this in mind, careful consideration of the bare necessities is vital. Capsule Homes should provide a single bed, small desk/work space and

storage space for cooking appliances and supplies. However, the drive behind the interior layout and ambiance is driven by how consumers can "create" their own homes.

In order to accomplish such a design, it is important to understand there are many challenges when tackling the design cycle. First, when experimenting with fabrication techniques, various scales should be used in order to incorporate the necessary level of detail of the joints. Secondly, it is important to thoroughly understand the consumer's involvement throughout the design and manufacturing process of Capsule Homes. Thirdly, careful design and development needs to be considered for each individual unit – especially those that incorporate transformable components.

The ultimate goal is to design and produce a flat-pack product that can transform the interior architecture of a small living space, whilst accommodating for one person's daily needs.

OPPORTUNITIES FOR TESTING & EVALUATING

As part of the design process, it is important to test and evaluate the manufactured product in order to ensure safe and easy interactions between the user and the product. For the purpose of this thesis, I plan to test and evaluate my product at various scales in order to better understand the detail required for the construction of each unit. I will test the aesthetic appeal and ergonomics of the product by observing people interact with the pieces. The ease of industrial manufacture will be determined by analyzing the manufacturing process.

RESEARCH AND ANALYSIS

In order to design an effective product that will appeal to the target audience and consider the appropriate design and construction methods, it is important to conduct thorough research and analysis on existing products of similar/related type.

For the purpose of this thesis, I will carry out research on:

1. Shelters
2. Folding/Flat-Pack Furniture
3. Capsule Hotels
4. Manufacturing Techniques
    a. Prefabrication
    b. Knockdown Fittings
    c. Wood Joints
5. Ergonomic and Anthropometric Data

SHELTERS

What is a shelter? A shelter is a place giving temporary or permanent protection form bad weather or danger. A shelter is a basic human need. In the aftermath of disaster, people's whose homes have been damaged or destroyed will strive to obtain the everyday necessities: shelter, food and water. Due to global warming and the increase of natural disasters, people have been continuously designing and finding ways of creating small shelters to shield themselves and other people from harm and natural disasters. These shelters have been designed and organized in such a way that they can provide users with what they need in order to survive on a day-to-day basis.

Research on shelters is vital as they represent the bare necessities for everyday survival and are evidence of how little space people truly require. This information can be used to better understand how to efficiently design and organize a multi-functional

space. Such research will enable me to design and development my own product for small compact apartments.

Figure 1 KPod, KitHause

Name: K-Pod
Author: KitHause
Price: under $20,000
Size: 117 square feet
Weight: 5500 pounds
Material: Aluminum, Glass, Wood
Summary: These aluminum-framed modules can stand-alone or join together to create larger structures. This modern module is easy to assemble is built solid with a lightweight construction system. These modules are constructed on-site in a matter of days. Due to the lightweight nature of this unit, this structure can be placed on a various types of sites without the need for heavy equipment. The glass is dual glazed for better thermal performance. Sliding doors are used, as they require less floor area.
Pros: Can either be a stand-alone or aggregated structure. The large floor-to-ceiling windows allow plenty of natural light into the space.
Cons: The interior layout isn't necessarily space efficient. The K-Pod requires heavy-duty transportation for site situation.

Figure 2 Gypser Junker, Derek Diedricksen

Name: Gypsy Junker
Author: Derek Diedricksen
Price: $200
Size: 24 square feet
Material: Shipping pallets, castoff storm windows, discarded kitchen cabinets
Summary: This structure is primarily made out of scraps of discarded materials. This structure has transparent roofing.

Pros: The unit is extremely compact and forces users to only have the bare necessities inside this space. This unit mainly uses recyclable scrap materials and therefore does not require any 'new' materials.

Cons: This unit acts purely as a place to sleep. Such a small space may not actually be comfortable for the user. One-of-a-kind unit that means it cannot be mass-produced.

Figure 3 Flake House, OLGGA Architects

Name: Flake House

Author: OLGGA Architects, France

Material: Clad, un-milled timbers, glass

Summary: This modern version of a log cabin is a small house that consists of un-milled timbers with a large single-plane window in at the rear of the structure. The house is composed of two parts so that it can be easily loaded for transportation purposes. Originally designed in 2006 for a competition bid, this house was installed on wood supports laid across the ground having minimal impact on its given site.

Pros: Large open plane of glass brightens the space, making the area more welcoming.

Cons: The large plane of glass gives less privacy to the user while they are sleeping or changing. The large open space within this structure requires loose pieces of furniture, thus minimizing the available floor area.

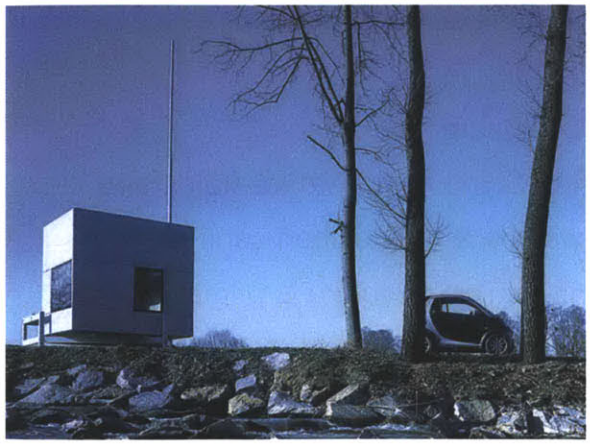


Figure 4 M-CH, Richard Horden

Name: M-CH

Author: Richard Horden

Size: 22.2 square feet

Summary: This modern micro compact home is a lightweight dwelling for one or two people. Its dimensions of 2.6m by 2.6m can adapt to a variety of sites and is fully capable of providing a space to sleep, work/eat and cook. Informed by aviation and automotive

design, the M-CH can be delivered throughout Europe with some custom changes depending on user preference. This compact home was designed to answer to the demand for short stay living for students, business people, sports and leisure use and for weekend trips.

Pros: This modular unit is extremely compact such that all the facilities have the ability to fold open and be stored away for other uses. This minimizes the floor area required. The dining table is built into the flooring of the unit, allowing for height variations within the space, or when not in use, can transform into another single bed. There is a window on every side of the cube providing natural light.

Cons: Such a small space may not actually be comfortable for the user for a full-time basis.

Figure 5 City Cottage. Verstas Architects

Name: City Cottage

Author: Verstas Architects

Size: 150 square feet

Summary: This city cottage offers the best of both worlds – the urban conveniences and the country retreat atmosphere. Although limited to 150 square feet, this unit can fit up to four people. As the footprint of the structure is small, this means minimal environmental impact in terms of construction and energy consumption.

Pros: Small homey shelter that has a large built in couch that can transform into a full size bed. There is a small kitchen facility. The large open pane windows allow sufficient daylight. Windows are strategically placed to ensure the users will have their privacy.

Cons: Due to the built-in permanent furniture, it makes this home extremely difficult to assembly quickly in dire need. This small home is not necessarily energy efficient and it requires electricity use throughout the day.

Figure 6 M Finity Micro Shed. M Finity

Name: M Finity Micro Shed

Author: M Finity

Size: 80 square feet

Summary: M Finity takes an eco friendly, low-cost approach to this unique modular product. M Finity Micro Shed employs sustainable, recycled, low-energy materials and fixtures to create functional, space-efficient design. Leading to the pre-fabrication industry, M Finity allows for personal customization and can be ordered bare of fully equipped with kitchen and bathroom facilities.

Pros: This shelter forces people to only have the bare necessities within this space.

Cons: Not very enticing. The interior space is very dark, thus evokes negative emotions. Unit appears to be designed for cost as opposed for luxury.

Figure 7 Micro, M Finity

Name: Micro

Author: M Finity

Size: 96 square feet

Summary: M Finity takes an eco friendly, low-cost approach to this modular product. M Finity Micro Shed employs sustainable, recycled, low-energy materials and fixtures to create a functional, space-efficient design. Leading to the pre-fabrication industry, M Finity allows for personal customization and can be ordered bare of fully equipped with kitchen and bathroom facilities.

Pros: Large foyer allows natural light to come through to the interior space. Lack of windows in some area adds privacy to this shelter.

Cons: No built-in furniture means that all the units on the inside are loose-standing and therefore take up more room on the inside.

FOLDING/FLAT-PACK FURNITURE

Modern day apartments are quite small in size making it extremely difficult to fit even the most basic furniture pieces. However, folding furniture has become quite a practical solution as it can be collapsed when not in use and can be easily moved around. Its lightweight quality and folding functionality comes in handy when living in small spaces as these units can typically be packed away in tight spaces. When designing a product for small spaces, it is vital to understand how a unit is assembled and dissembled due to the limited available area. The following research consists of examples of flat-packed and folding furniture that manage to conserve space and carryout a variety of functions.

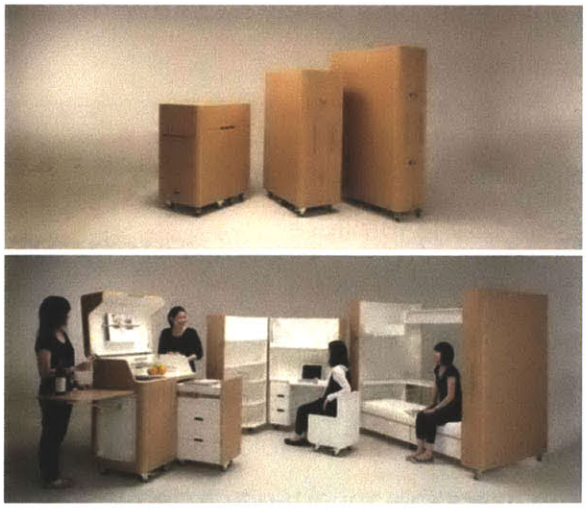


Figure 8 Room in a Box

Name: Room-in-a-Box
Details: Loose pieces of furniture
Material: Laminated wood
Summary: These room-in-a-box units are not intended to replace the conventional design of a space, but rather implement the available variations of layout that can be determined by the user. This type of architectural furniture may never become mainstream, but does provide a potential variation for users. These units on wheels can be moved around in any arrangement within any giving space.

Pros: These units not only force users to maintain the bare necessities, but also allow users to move these units around and customize the layout in their own manner.

Cons: Such small units may not actually be comfortable for the user. Users are forced to open these units apart and assemble them each time for use.

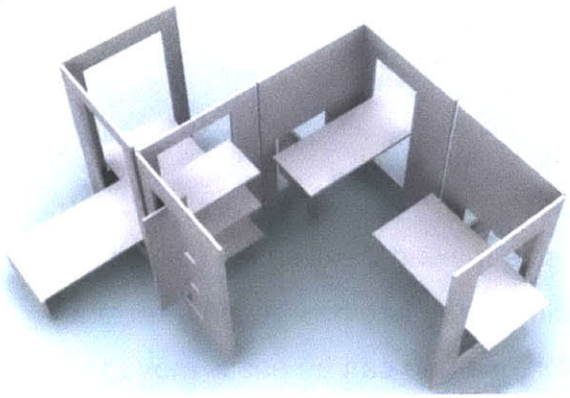


Figure 9 Flat Pack Furniture

Name: Flat-Pack Furniture

Material: Plywood

Summary: This flat pack unit blends together the practical, simple and functional aspect of design. Each unit in this flat pack collection is designed to be composed of two standard-size plywood boards folded flat together with a hinge holding them together. Selectively punched-out portions of their surfaces can bend and fold into various configurations that serve individual and joined purposes. They act as both separators and furniture in one.

Pros: This flat-pack unit can be folded down to sheets and then opened up into a 3D room. It is space efficient as it is constructed in sets of two sheets of wood to one unit, allowing users to set them up as they please.

Cons: Wood sheets are relatively thin and could potentially be a safety hazard. How can this unit incorporate kitchen and bathroom facilities?

Figure 10 Folding Kitchen Island

Name: Folding Kitchen Island

Details: Foldable furniture

Material: Laminated wood

Summary: This compact kitchen island is light in weight, portable and can be stored in small narrow spaces. The foldable concept gives the users the opportunity to leave the unit standing or stored away in narrow spaces when not in use.

Pros: Foldable, easy to clean and can be stored in small narrow spaces. Material is easy-to-use, easy-to-clean. Simple joints and fasteners uses, means easy for consumers to adapt to.

Cons: Requires the user to assemble and dissemble each time for use. Counter space is limited in relation to the input effort required.

CAPSULE HOTELS

A Capsule Hotel, also known as a "kapsuseru hoteru", is a unique style of accommodation that was inspired by the pursuit of efficiency of space and functional comfort. A typical Capsule Hotel is composed of two major sections – a public lounge space and private units for sleeping. The actual units are capsules made of reinforced plastic, intended to provide cheap, basic overnight accommodation for guests not requiring the services offered by more conventional hotels. The guest space is typically reduced in size to a modular plastic or fiberglass block roughly measuring 2m by 1m by 1.25m, providing just enough room to sleep.

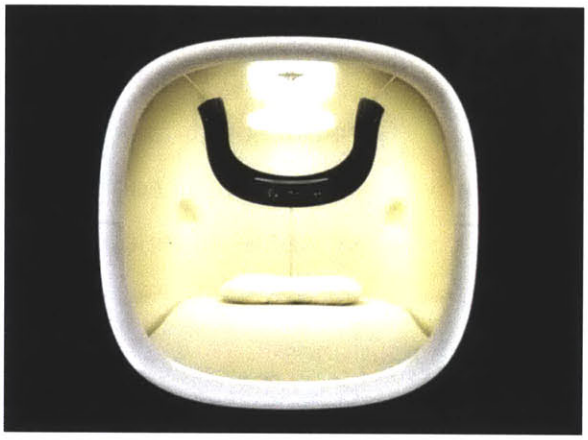


Figure 11 Capsule Hotel

Most Capsule Hotels provide a small TV, an alarm clock, a light and simple bed. Typically, these units are stacked on top of one another, with steps providing access to the higher units.

MANUFACTURING TECHNIQUES

PREFABRICATION

Prefabrication is the practice of assembling components of a structure off-site and then transporting the pieces to the construction site where the structure is to be

located. Prefabrication is usually used when fabrication of a machine or structure is transported from the manufacturing site to another location. Prefabrication is seen to save time and costs as construction tasks can be grouped and assembly line techniques can be employed.

- Advantages-
    - Self-supporting ready-made components – this means that the need for formwork and scaffolding is reduced.
    - Construction time is reduced and units are built at a faster pace
    - On-site construction is minimal
    - Less waste material

- Disadvantages-
    - Leaks can potentially form
    - Increased transportation costs for larger units
    - More attention needs to be directed to the properties of the materials.

KNOCKDOWN FITTINGS

Knockdown fitting joints are joints that can typically be put together very easily, normally with the use of standard tools. Although temporary, these joints are usually used to permanently join pieces together.

Cam Fittings-

- Uses: Shelving, Chairs, Drawers, Boxes
- Ease of Manufacture: The individual pieces are relatively easy to manufacture; however, the trouble comes when attempting to line the drilled holes to make sure the nuts and bolts will line up appropriately and fit together.

- Suitable Materials: Only suitable when solid sheet wood is used, as several holes need to be drilled in the center of the block.
- Appearance: It is evident that the joint is in place as there is a screw present in the middle of the piece of wood – this takes away from the overall smooth aesthetics that the finish product could possess.

Plastic Corner Block-

- Uses: Shelving, Coffee Tables, Boxes, Drawers, Additional Desk Support, and Book Cabinets.
- Ease of Manufacture: Likewise to the Cam Fitting Joint, many holes need to be half-drilled into the pieces; therefore the main difficulty lies in lining the holes up so that the screws will fit into the holes.
- Suitable Materials: As drilling half holes is required for this joint to work, the only possible material would be solid wood block.
- Appearance: Although easy to use, the Plastic Corner Block Joint does not possess nice aesthetics as there is a massive plastic case fixed to the inner part of the corner joint. This clearly takes away from the overall aesthetics of the temporary joint.

Corner Plate Joint-

- Uses: Tables, Window Frames, Boxes, Drawers, and Book Cabinets.
- Ease of Manufacture: Relatively easy as wholes can be lined up using the metal corner plate as a template.
- Suitable Materials: Likewise to the Cam Fitting Joint and Plastic Corner Block Joint, solid wood should be used as pieces need thorough, accurate drilling in order for pieces to fit appropriately together.
- Appearance: This joint does not possess unique, clean aesthetics, as there is a visible piece of metal in the corner.

Barrel Nut and Bolt Joint-

- Uses: Tables, Boxes, Shelving, Book Cabinets, Addition desk Support, Chairs.

- Ease of Manufacture: Not that easy to manufacture as all drilled holes need close attention in order for the pieces to line up accurately.
- Suitable Materials: Likewise to the other joints, solid wood would most likely be appropriate as deep holes are required in order for the joint to hold support.
- Appearance: Likewise to the Cam Fitting Joint, this joint too does not possess clean-cut aesthetics. We are blocked with screws on either side of the two pieces of wood – thus taking away from the design of the product. Nevertheless, the knockdown fitting is extremely strong, thus making this joint extremely practical.

WOOD JOINTS

Wood joints involve joining together two pieces of wood. Some types of wood joints require fasteners, adhesives or binding as wood joints are typically known for their strength, flexibility of clean-cut appearance. The type of wood joint is dependent on the properties of the type of wood and the desired appearance at the joint. Wood joints are typically permanent joints.

Spline Mitre Joint-

- Uses: Photo frames, Cabinet production.
- Ease of Manufacture: Spline Mitre Joints are relatively easy to produce as they can be manufactured using hand tools as well as large machinery.
- Suitable Materials: Like most joints, a range of timbers can be jointed using this type of joint. (e.g. MDF, Plywood, Chipboard)
- Appearance: The veneer strips add to the aesthetics of the joint whilst maintaining its function.
- Advantages: Clean cut with patterned design on the fleshed surface.
- Disadvantages: Veneer strips are easily broken as veneer is a very fragile timber unless layered. Time consuming.

Dowel Joint-

- Uses: Tables, Chairs.
- Ease of Manufacture: Dowell Joints are relatively easy to manufacture as they can be manufactured using hand tools as well as large machinery.
- Suitable Materials: Dowel Joints can be made of MDF, Plywood, Chipboard – as this particular joint can be made out of a wide variety of materials, this makes this joint more accessible for different purposes.
- Appearance: Dowel joints have a clean-cut finish due to the fact that the manufacturing pieces are actually hidden away from the exterior surface.
- Advantages: Clean fleshed surface finish with no fancy aesthetics.
- Disadvantages: Difficulty when having to manufacture the pieces – riling the correct sized hole and managing to fit the dowels inside.

Finger Joints-

- Uses: Drawers, Cabinet Shelving
- Ease of Manufacture: Very easy to manufacture
- Appearance: Finger Joints seem to look somewhat like a jigsaw puzzle where the two pieces are able to fit and hold into one another.
- Advantages: Clean, flesh cut, smooth surface finish.
- Disadvantages: Teeth may be too weak to support weight applied.

Corner Mortise and Tenon Joint-

- Ease of Manufacture: Corner Mortise and Tenon Joints are generally quite easy to manufacture as hand tools as well as large machinery can be used for the manufacturing process.
- Suitable Materials: Solid Woods
- Appearance: This joint also possesses a clean-cut fleshed surface as tenons stick directly into the joining pieces of wood.
- Advantages: Clean-cut fleshed surface when the pieces are joined together. Sturdy due to the tenon interlocking into the opposite pieces of wood.
- Disadvantages: Difficult to manufacture the hole for the tenon

Cross Halving Joint-

- Ease of Manufacture: Very easy to manufacture as both hand tools and large machinery can be used for manufacture.
- Suitable Materials: only possible with solid wood.
- Appearance: Possesses a clean-cut
- Advantages: Clean cut with patterned design on the fleshed surface.
- Disadvantages: Veneer strips are easily broken as veneer is a very fragile timber unless layered. Time consumption for the Splined Mitre Joint – may take a long time as many features need cutting.

Through Dovetail-

- Ease of Manufacture: Through Dovetail Joints can be manufactured using hand tools as well as large machinery.
- Suitable Materials: Only solid wood would be appropriate for this type of joint due to the way the tenons fit together.
- Appearance: Possesses a clean-cut finished appearance and suggests simplicity to the overall design. A dovetail joint adds more support to the overall design as the angle prevents the two pieces from slipping over each other. The dovetail also makes the joint more aesthetically pleasing to the eye.
- Advantages: Very strong as well as quite aesthetically pleasing.
- Disadvantages: Cannot typically hold a large load across the joints and may run the risk of collapsing which could potentially be a safety hazard. Fingers but be cut at the exact angle in order to ensure they interlock appropriately.

Stopped Mortise and Tenon Joint-

- Ease of Manufacture: This joint is commonly found as a relatively easy joint to manufacture due to its ability to be manufactured using hand tools and machines.
- Uses: Tables and chairs
- Appearance: Once connected, the Stopped Mortise and Tenon Joints have a beautiful clean-cut appearance with no direct indication of any joint present.

- Advantages: Clean-cut finish, with no indication of any joint present.
- Disadvantages: An inlet hole is usually found to be difficult to cut as the hole does not go all the way through the piece of wood. In fact, the hold only goes through the main piece as the tenon stops halfway.

Stopped Housing Joints-

- Ease of Manufacture: Stopped Housing joints are relatively easy to manufacture as they can be produced using hand tools as well as large workshop machinery.
- Suitable Materials: Any type of timber.
- Appearance: Stopped Housing Joints generally have a clean-cut finish. There are no additional pieces required for this unit giving it clean and simple aesthetics.
- Advantages: This type of joint can call for adjustable shelving for book cabinets – this is a great advantage as it increases the function and capacity.
- Disadvantages: Depending on the depth of the slit for the shelving, this may affect the strength of the joint.

ERGONOMIC AND ANTHROPOMETRIC DATA

Adults and Children come in all different shapes and sizes. We all have different tastes in styles, shapes, colours and sounds; therefore all these factors must be taken into consideration when designing. All these factors contribute to the ergonomics and anthropometrics of the design. Taking ergonomics and anthropometrics into consideration is an important role as it helps to improve the usability of the products that designers and engineers develop. Ergonomists are usually involved in the manufacturing of vehicles, household products, clothing, along with many other products. Sizes must be carefully taken into consideration as everyone has a different body shape and size. Ergonomists accommodate to all body shapes and sizes. In the case of this thesis, when designing furniture, it is important to consider the way people interact with such a product in order to ensure comfort and to maximize efficiency. The

application of Ergonomics and Anthropometrics can result in products that are safer, easier to use and result in better procedures for performing tasks

DESIGN SPECIFICATIONS

It is very common for most people living in developing cities to live in small, tight spaces. This means that these spaces need to be efficient and user-friendly in order to maximize the internal space. For example, it is very important that the bed disappears; otherwise the bed would occupy the most dominant area of the home.

Throughout the design and development stages of Capsule Homes, it is important to consider the culture of such housing, the surroundings, and the system in which it should be established. From a cultural standpoint, it is vital to understand how it relates to the culture that it intends to the serve; from the natural standpoint, it essential to realize the influences of light and nature and from a systematic view, it is important to understand how the design of the system is influenced by fabrication and the way in which it is intended to be used.

The design of the Capsule Home must serve to answer:

- Cultural Aspects:
    - What is the need of the Capsule Home?
    - What is it that shapes the Capsule Home?
    - How does the Capsule Home relate to the culture that it serves?
- Natural Surroundings:
    - How is the Capsule Home situated in relation to its surroundings?
- Systematic Process:
    - What fabrication techniques should be used for the Capsule Home?
    - How can the growth of technology be used to create compact units?

In order to ultimately achieve the design of a home that is small yet user-friendly, limited yet efficient and compact yet accommodate all the daily needs, a certain dialogue between culture, nature and system must be accomplished – and only then will there be a realization of the Capsule Home.

INITIAL DESIGNS

In order to design the interior of a small apartment that will accommodate the daily needs of users, it was important to consider the bare necessities for each apartment unit.

- Kitchen unit – basic cooking amenities and storage space for fresh and preserved foods.
- Bathroom unit – the bathroom must incorporate a full shower.
- Sleeping unit – all bed measurements from a standard full sized bed.
- Closet/Storage unit

As there are many factors when considering renting or buying an apartment, optional units will be designed to accommodate those with more freedom of space.

- Storage unit
- Washing/Drying unit
- TV unit
- Library unit

For the purpose of this thesis, with the idea of flat-pack furniture in mind, I took various existing floor plans of small Hong Kong studio apartments as the base shell. Three sample floor plans of various sizes (250 square feet, 200 square feet and 130 square feet) were used as base constraints for the design and development of Capsule Homes. In order to determine the appropriate systematic approach to the design of

these studio apartments, various floor plans were sketched to find the best suitable layout for each apartment type.

FLOOR PLANS

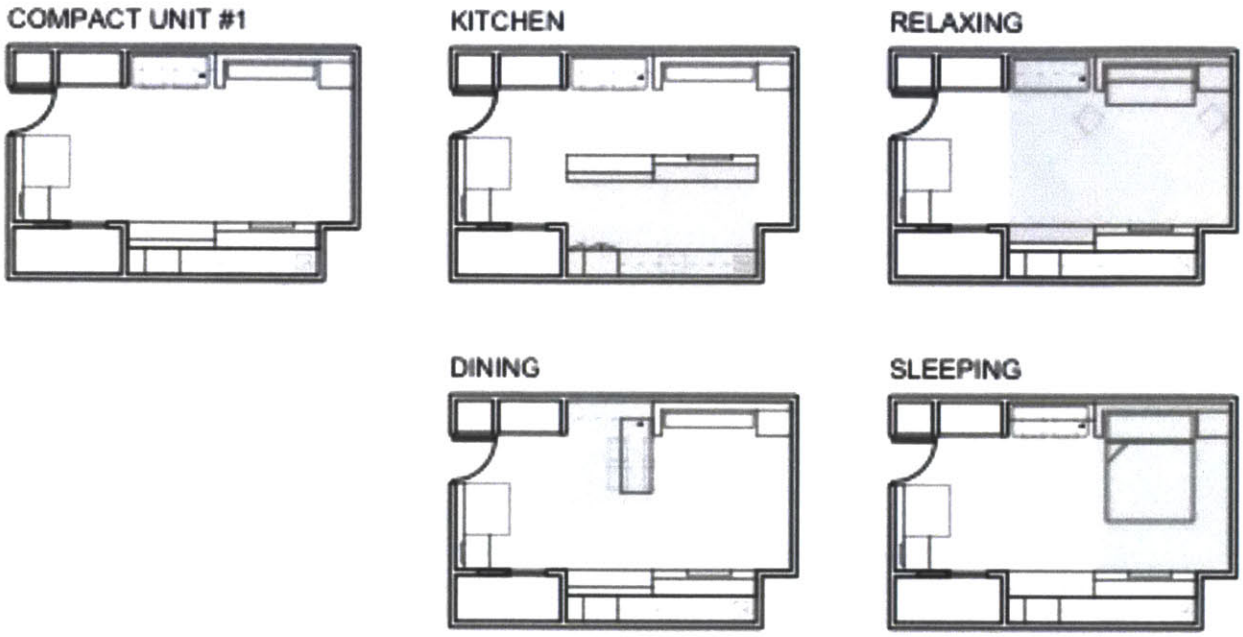
The initial design stage of my thesis was accomplished through various steps to ensure the cultural, natural and systematic design of Capsule Home was established. For each apartment type, the following was considered:

- Spatial Arrangement: Compartmentalizing the required area for user comfortable and compatibility is shown through the following floor plans for each apartment type. It is important to note that these areas are only approximate and can overflow into the regions not shaded. Careful thought went into the placement of the individual units of furniture to maximize floor area. Each unit was placed in the different apartments to demonstrate the flexible nature of the product.
- 3D Renderings: Floor plans fail to show the overall feel of the space, as they do not consider space in the vertical axis. These three apartment types have been carefully rendered to indicate the relationship of the units.

TYPE A

By initially starting with the largest apartment type - 250 square feet - there are very few spatial restrictions in terms of the design in comparison to the smaller units. The main spaces have been indicated below through the grey shaded regions.

Spatial Arrangement:



Total Area: 250 square feet

Number of Units: 7 units

Unit Types: Sleeping unit, Kitchen unit, Bathroom unit, Closet/Storage unit, Washing/Drying unit, TV unit, Library unit.

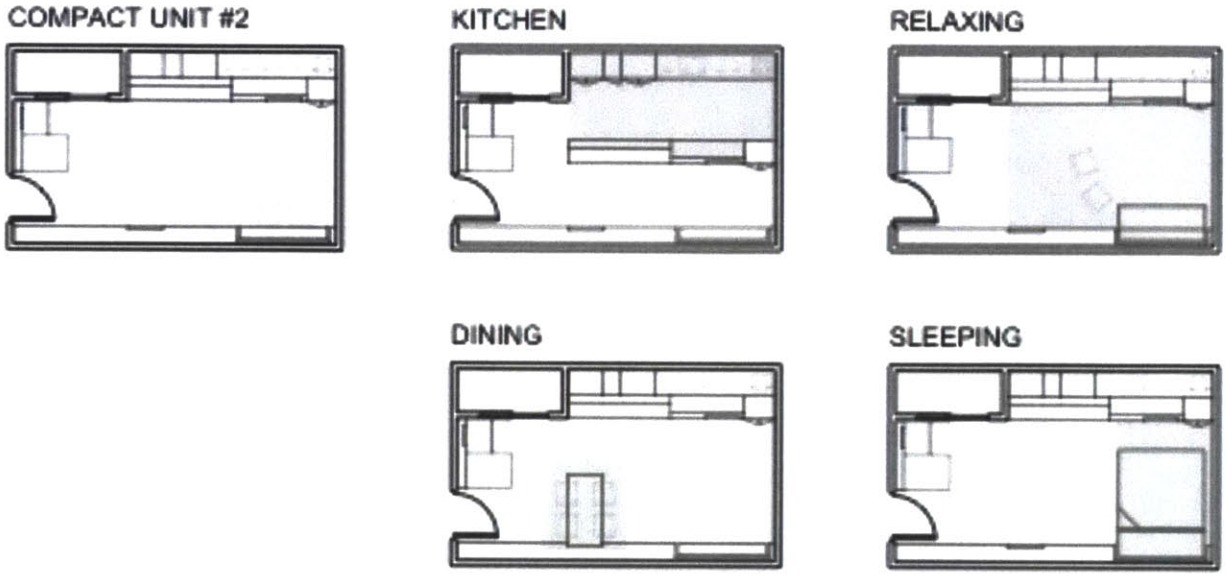
Notes: The swivel dining table allows users to twist the table out towards the central space of the apartment to accommodate additional users. The benefit of the swivel table is that it allows the chairs to be tucked neatly away underneath the table – maintaining the open space in the middle of the apartment. The units are placed in such a way that enables spaces to feel as though they are divided into their own areas without the need for actual walls. The shifting walls can be used for different purposes. The units that require plumbing are fixed units against the wall, whereas other units are freestanding.

3D Renderings:

TYPE B

By reducing the apartment sizes, the necessary and unnecessary units can be determined. For this apartment, the units have been designed to fit the smaller footprint, yet accommodate the daily needs of any person. It is important to note that the movable units that create the kitchen need to move far enough away from the fixed wall to allow access to the space.

Spatial Arrangement:



Total Area: 200 square feet

Number of Units: 6 units

Unit Types: Sleeping unit, Kitchen unit, Bathroom unit, Closet/Storage unit, TV unit, Library unit.

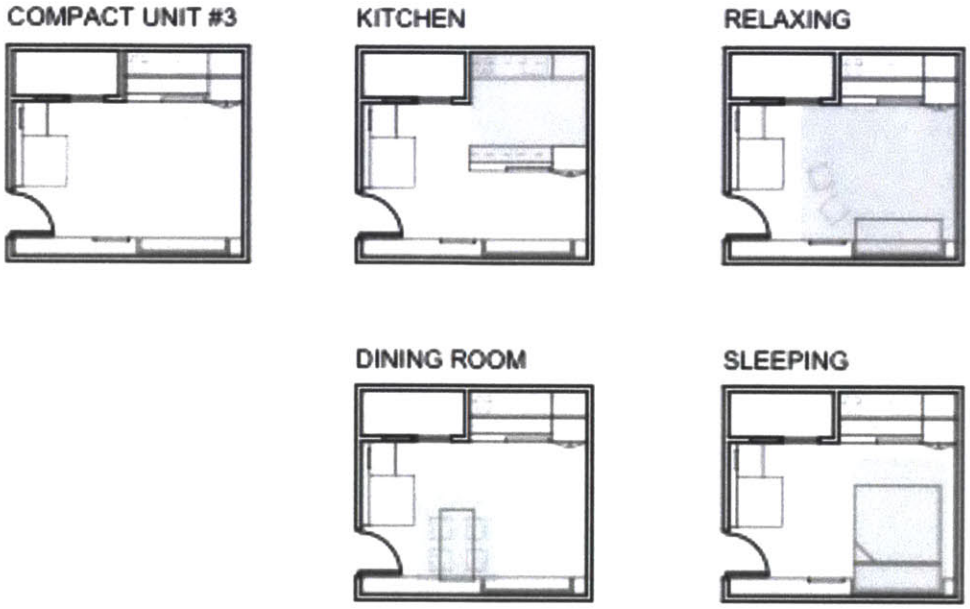
Notes: As this apartment has more space, this allows users to customize the space with the addition of optional units, giving the apartment more value. The fold-down table maintains a subtle appearance. However, this table may be unstable if too much weight is put at the end. The moveable units enable spaces to be condensed and more space efficient. As the bed is the largest, most dominant, feature of the room, it carefully folds up and out of the way so that it doesn't dominate the entire space.

3D Renderings:

TYPE C

Type C apartments, with 130 square feet, are the smallest apartments that my analysis covers. The large difference in square footage between Type A and Type C apartments indicates that the concept of shift-able, foldable and flat-pack furniture can be applied to a wide variety of apartment sizes and only relies on the boundaries of the existing shell of the apartment.

Spatial Arrangement:



Total Area: 130 square feet

Number of Units: 6 units

Unit Types: Sleeping unit, Kitchen unit, Bathroom unit, Closet/Storage unit, TV unit.

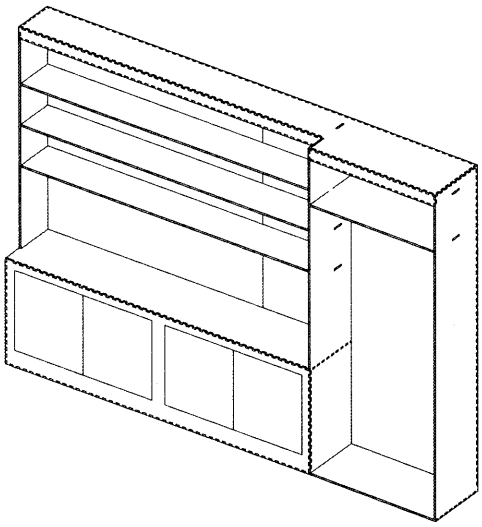
Notes: It is important to realize that due to having less space, each unit had to reduced in width. Due to Type C's square footage, this unit shows the daily needs of a typical user. Although space is quite tight in the unit, it is possible to accommodate for the daily needs of any user. Due to the limited space, it is vital that careful planning goes into the layout of this apartment unit to ensure that everything is included. The downside to the foldable table is that it cannot accommodate for the chair storage, like in the type A apartment unit. Also, due to the given space, when the table is unfolded, it might be too close to the corner of the glass shower stall. One way to solve this would be that if the user requested for a single bed, the table would be able to move further toward the center of the wall.

3D Renderings:

Having explored the spatial arrangement of three studio apartments, it is clear that the Capsule Homes can be instilled. Starting with the bare shell, theses units can be placed anywhere within the constraints of the walls. As each unit is designed against the edge of the apartment walls, with no features or amenities protruding into the central space, this ensures that the users have maximum open space in the middle of the apartment.

INDIVIDUAL UNITS

Creating a space is one thing; however, designing the units that creates the overall space is another. The following segment of the design and development phase was to explore the Capsule Home product as individual pieces and understand how each unit can create multiple means for creating space. In order to create units that are user-friendly, space efficient and easy to assemble, the following specialized units were fabricated at 1'=1/4" out of 1/16" veneer wood. Once analyzing the initial design of these units, they were then fabricated at ¼ scale of reality in order to develop the intricacy and detail of various joints and furnishings:

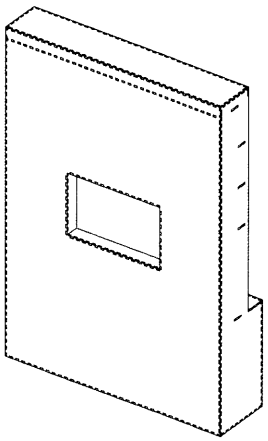


Kitchen Unit:

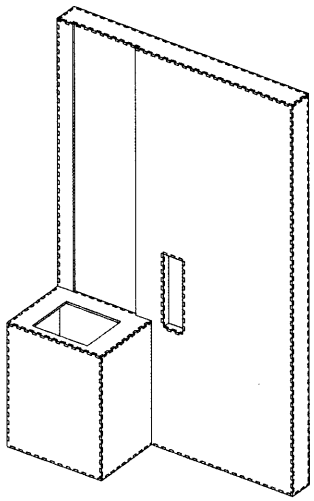
This kitchen unit was designed with the initial understanding of the basic needs in a kitchen. This unit accommodates for a full size refrigerator and abundant countertop space so that users can juggle a variety of tasks at a time. The deep countertops also allows for plenty of closed and open storage to ensure a clutter-free environment. To give consumers a more personalized touch, the shelves can be adjusted to their own choice.

TV/Counter-Top Unit:

Designed to have two functions, this unit acts as a TV frame as well as additional kitchen counter space on the reverse side of the unit. The TV side faces the inner central space of the room at all times, making the TV visible from most points in the room. The countertop is a continuation of the kitchen. The various shelves can be adjusted based on the user's preference. This first iteration of the TV unit appears bulky. To reduce costs and



improve the aesthetic appeal of the unit, the TV façade should be opened up to the users. This unit should be designed in a more space efficient manner. For example, although the façade of this unit is minimalistic, it does nothing to enhance the function of the unit.

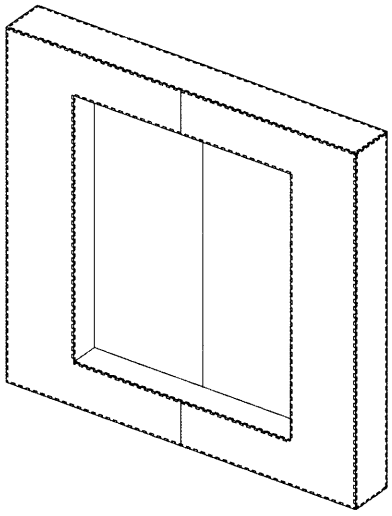


Bathroom Sink Unit:

This bathroom unit is designed so that it is compact and easy to assemble. The unit has a built in small shelving section in the shower space that allows users to store their soaps. The long built-in mirror makes the space feel much larger. The glass shower stall is designed for the space near the door, as the glass material is less intrusive than the sink area. The space under the counter allows consumers to use this space for storage. After conducting this analysis, only then can the method of joining for the shower stall be considered. The sealant needs to be chosen carefully to prevent any potential water overflows. The installation of the long mirror must be considered.

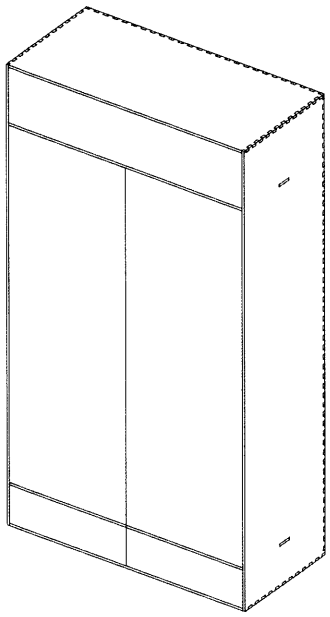
Bed Unit:

This simple unit is designed so that the bed is not dominating the central space. The bed is able to fold down and fold up to conserve the most dominate area of the room. This flat-pack unit is easy to assemble; however, needs to consider when visitors come – where will they sit? The next iteration of the bed should incorporate a couch for consumers to have visitors over. The mechanics of how a bed can rotate and fold out should be researched thoroughly so that the unit can be designed accordingly.



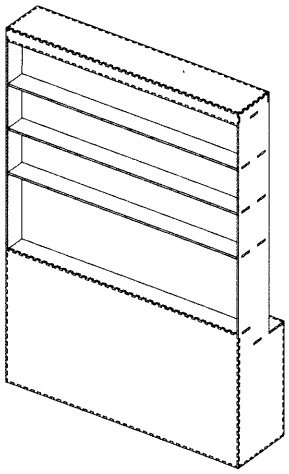
Closet Unit:

This flat-pack storage unit is quick and easy to assemble without the need for any complex joints or tools. This standard closet is spacious, allowing consumers to store their clothes on the rack and in the multiple drawers available. The notching system allows users to adjust shelves in order to accommodate the space that is needed. The division of the doors means that the consumer does not to need open the entire closet in order to get their stuff. The aesthetic appeal of this unit should be better considered. How can this unit not appear too heavy in material? What can be done to this unit to give it some aesthetic flair, yet maintain its general function of storage? Adding mirrors to the doors of this unit, would make the space not only feel larger, but also provide the consumer with a feature that would enhance their daily routines.



Library Unit:

This library unit was developed with the intention of matching the appearance of the TV unit. The front face of this unit provides library shelving for consumers to belongings. On the back face of the unit is a continuation of kitchen counter-top space. This unit moves on tracks so that the kitchen space behind the wall can be accessible. The space under the counter allows users to store their pots, pans and other kitchen supplies.



Some of the above units were combined into one, to depict how one unit would be able to serve multiple functions. Having built these units at a ¼ scale, it was important to analyze the aesthetic appearance and function of this set of designs. The following photographs show the modeling process and studies conducted using the ¼ scale model as I continued to analyze and redesign various pieces. Due to the scale of the model, I was able to physically sit inside of the model to gain another perspective on the relationship between the units and aesthetic appeal.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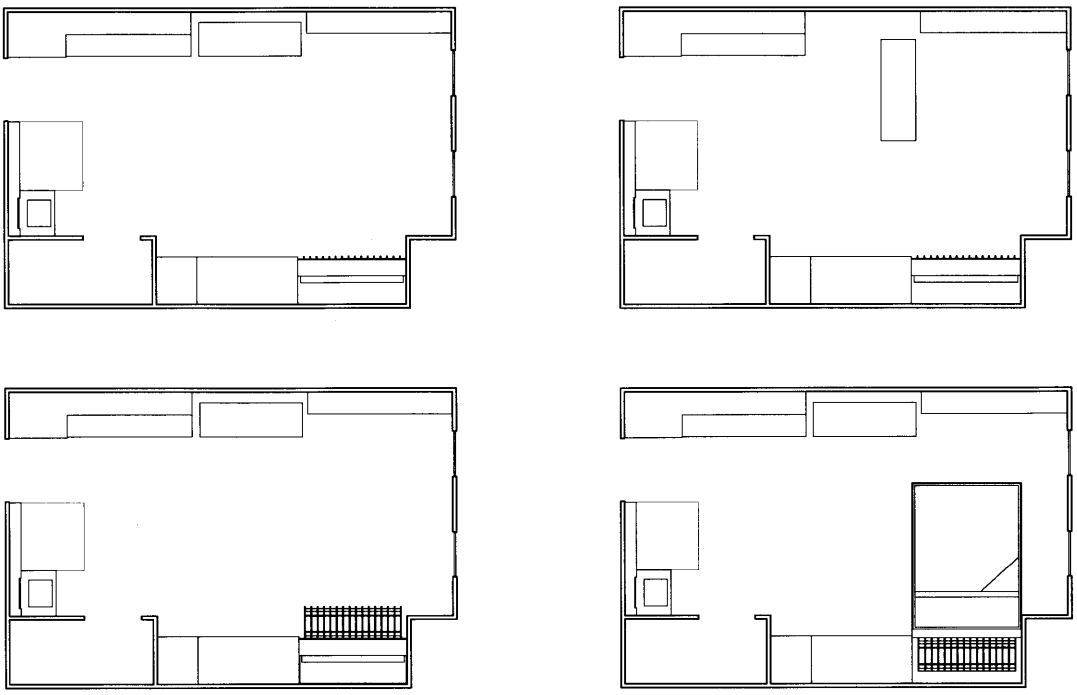
DESIGN & DEVELOPMENT

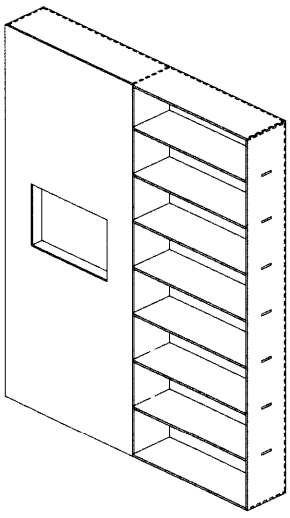
This stage of my thesis required a careful analysis of the initial floor plans, iterative designs and the initial ¼ scale model. Careful analysis based on aesthetic appeal, function, and durability went into the development process. For the purpose of developing this product further, apartment type A was chosen as the base shell. The following was considered throughout the design and development phase:

- Analysis of floor plan arrangement:
  - Was the initial floor plan the best layout for this product?
  - How could the floor plan be arranged to emphasize the benefits of such a product?
- Analysis of Individual Units: The connection of wood is important and vital when considering the detailing and safety aspects of any unit.
  - What is the relationship between the units?
  - How can these units be designed so that they conserve material, yet manage to create better functionality for the users?
  - How are these units going to be constructed?
- Second iteration model conducted at ¼-scale.

For the purpose of this stage of the design process, more details have been included and more factors have been considered. The first step was to analyze the floor plan to determine whether or not the arrangement suited the intended function. The shifting units were removed, so that more time could be designated to the design process. For example, the kitchen unit was reduced in size and then moved to the wall that had the original plumbing systems in order to reduce costs and maintain good organization and circulation. The following diagrams show the rearranged floor plan:



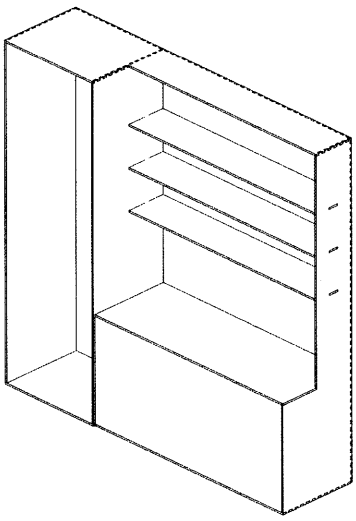
As the layout was changed, it was important to redesign each of the units to accommodate the change. The library shelving and TV unit was combined. Due to the aesthetic appeal, the faces that are visible to the user from the center of the apartment have now been designed with flat, clean-cut sheets of wood that are secured through dowel joints. This iteration incorporates:



Library/TV Unit:

With the change in floor plan, there was less floor area for actual units to be installed. This unit shows how the TV and library shelving combined into one unit. This unit is space saving as it cuts the excess material from the unit and at the same time, provides more functional space for the user to use. The notching system allows users to adjust and remove shelves where more space may be required. Although this unit has a clean-cut appearance, the way the TV portion of the unit is designed, takes up more space than necessary.

Kitchen Unit:



This iteration of the kitchen unit is a more condensed version of the first iteration. Although smaller, and more compact, the deep countertops provide consumers with plenty of space for storing, preparing and cooking food. A full size refrigerator can still be placed in its designated holder. The under counter cabinets provide plenty of storage for kitchen and cleaning supplies. The notching system allows users to adjust and remove shelves where necessary in order to personalize their kitchen.

Having analyzed the second iteration units, it was important to refer back to the original units to compare them based on their aesthetics, function, and ease of assembly. The flat-pack notching system was carefully reconsidered, as it was quite evident in terms of aesthetics appeal; the relationship from one unit to another was studied to ensure good circulation throughout the apartment; and then ease of assembly was tested to guarantee quick and easy set-up.


05/03/2012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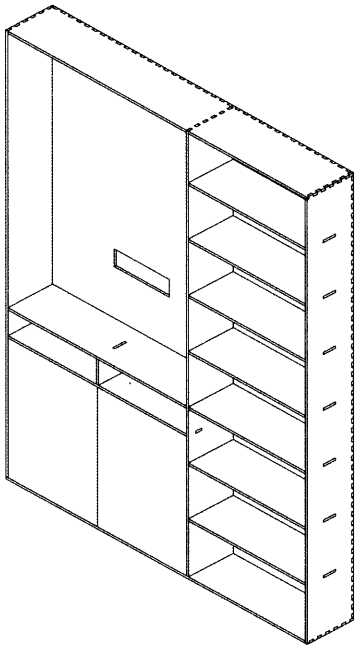
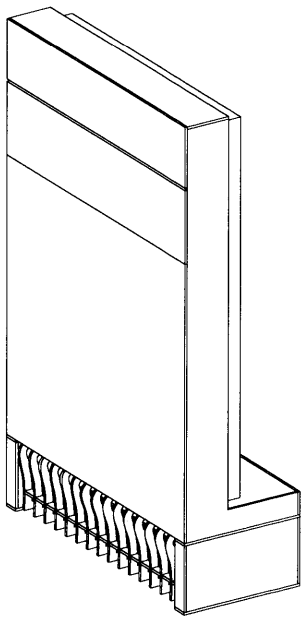
Having built the second iteration model at ¼ sale, it was important to focus on the easy of assembly, considering that users would be putting these units together themselves. Based on the above analysis of the second iteration units, two units were further developed for the purpose of my thesis.



TV/Library Unit:

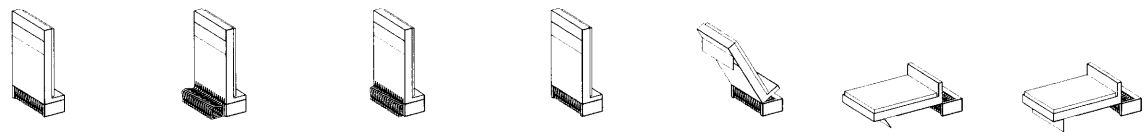
This TV and library unit gives the consumer plenty of space to store all their books, DVDs, photos and knick-knacks. The main change from this third iteration to the first and second iterations is that the TV unit is opened up meaning that less material is used and more storage space gives the unit more of an open-feel. Some storage sections are closed to hide clutter, whereas other shelves are open for decorative possibilities. The mounting device for the TV was carefully considered for this particular unit to maintain the flat-pack, easy to assemble nature of the Capsule Home products.

Bed/Living Room Couch Unit:

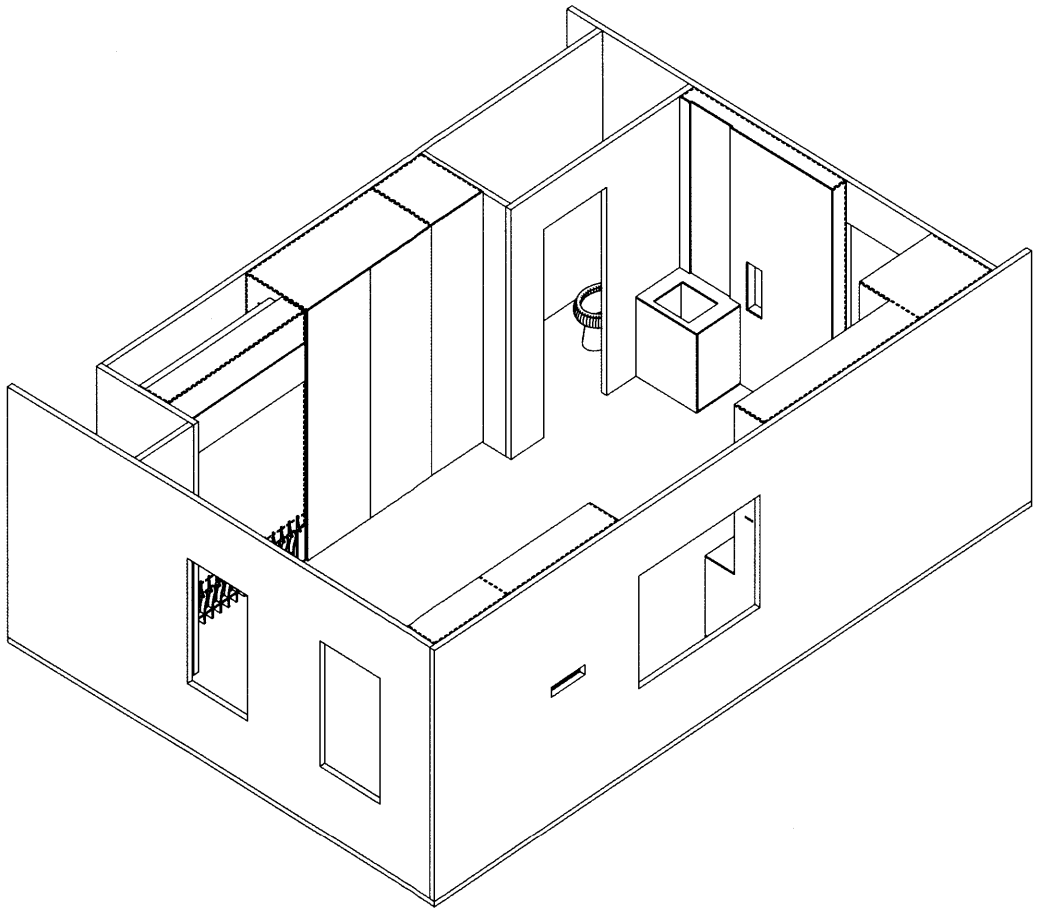


Developed from the first iteration of units, this folding bed now incorporates a way for consumers to use it as a couch when they have visitors are if they don't want to lay on the bed. This ergonomically designed couch gets pulled out from under the unit where an attachment of curved braces can be added to the base of the bed (also the back rest of the couch) to act as an ergonomic backrest. When more space is required in the apartment, the chair can be pushed back underneath the unit. The couch not only acts as a place for seating, but also acts as a home for magazines or even pillows and blankets while the bed is in an upright position. When the user is ready for bed, the bed can rotate on a set of hinges and a footrest can

lock out, providing a comfortable place to sleep. The following diagram shows the various positions of this unit and how they would appear at different phases of transition.



Based on the newly developed Capsule Home units, the following axon diagram shows the new placement of piece from a three dimensional perspective. The placement of these pieces have allowed the maximum floor area in the center of the apartment for user's use at their own will:



MANUFACTURING PROCESS

It is important to realize that there is a clear process to construction and understand that any change in the process will affect the overall production of these units. As these pieces have been designed in a way that they can be mass-produced, the manufacturing process is relatively speedy and extremely accurate – provided that the drawings are drawn correctly.

Although the manufacturing process for the ¼ scale model and full-scale model are very similar, different machines are used. The software used for both processes will be Rhinoceros 4.0 with the unit settings to feet and inches. The same original file of the units drawn at full scale can be used for both manufacturing processes. The two sections below indicate the steps taken throughout the two manufacturing processes.

¼ SCALE MODEL

Software: Rhinoceros 4.0
Units: Feet and inches
Material: Masonite sheets (32"x16"x1/8"), Acrylic Spray Paint of choice
Machines: Epilog Lasercutter 120W
Process Time: approx. 2.5 hours to fabricate on 120W Lasercutter

Process:

1. Draw units at full scale in Rhinoceros 4.0 – incorporate the appropriate notching and joints.
2. Scale all units down so that each slab thickness is 1/8" (1/4 scale of reality). Note/ it is important to group all pieces of a unit together to ensure that each unit is scaled accurately.
3. Unfold each unit so that they can be laid out on numerous cut sheets.
4. Set up Lasercutter to the appropriate settings for cut and score lines.

5. Lasercut all sheets.
6. Assemble units accordingly.
7. If additional appliances (e.g. a TV, radio etc) are required to finish, assemble accordingly.

FULL-SCALE MODEL

Software: Rhinoceros 4.0
Units: Feet and inches
Material: Plywood sheets (8'x4'x1/2")
Machines: CNC Router

Process:

1. Draw units at full scale in Rhinoceros 4.0 – incorporate the appropriate notching and joints.
2. Scale all units down so that each slab thickness is 1/8" (1/4 scale of reality). Note/ it is important to group all pieces of a unit together to ensure that each unit is scaled accurately.
3. Unfold each unit so that they can be laid out on numerous cut sheets.
4. Set up CNC Router to the appropriate settings for cut and score lines.
5. CNC all sheets.
6. Drill holes 1 inch deep where necessary for dowel joints.
7. Cut ribbed dowels for wood joints.
8. Assemble units accordingly.

THE FIVE-STEP ORDERING PROCESS

Proposing Capsule Homes as an online system where you are able to customize your home layout, it is important to understand the process in which the user, as well as designer, would undergo. The following indicates the steps that would be taken in designing, manufacturing and receiving the customized Capsule Homes product:

1. User sends floor plan PDFs of apartment to the designer. User indicates the types of units they want to install in their apartment.
2. Designer adjusts the desired unit types so that they fit the constraints of the floor plan. Designer manufactures a ¼ scale model of the types of units and then ships these flat-pack pieces to the consumer. Model allows users to visualize what their space will look like upon approval.
3. User assembles ¼ scale model off of a set of standard instructions and emails comments back to the designer.
4. Designer makes the necessary changes and then manufactures the unit at full scale. Designer ships full-scale flat-packed pieces back to the user, along with any necessary components.
5. User assembles the unit and places it where appropriate. Units are ready for use.

CONCLUSION

With new developments in technology, drastic changes in demography, and an increase in day-to-day expenses, the way in which living spaces are designed have taken a major turn. With apartments becoming less affordable, and online shopping and social media becoming increasingly popular, Capsule Homes is an easy-to-assemble, easy-to-use and space-saving product that connect consumers directly to the design and fabrication process. This relatively cheap, flat-pack product not only directly involves consumers in the fabrication stage of their own units, but also encourages users to customize their own living spaces, whilst having all the necessary amenities of a regular home. The prefabricated nature of this product means that it is easily purchased online via catalog, where custom prototypes can be quickly manufactured and then transported to the user. The Capsule Home product makes the designer as well as consumers truly aware of what is required to design for small living spaces, as it ensures that both parties are involved in the manufacturing process.

The final model as well as the research, prototyping and analysis presented with this thesis proves that any space can be created and transformed through the use of the Capsule Home as it provides the day-to-day necessities of any living space. The various iteration studies developed the units, bettering the user interaction as well function of the unit. The continuous modeling and sketching ensured that each detail was considered and that a good understanding of assembly was established.

The Capsule Home not only involves the consumer in the fabrication process, but also allows the designer to fully understand the construction and manufacturing process for such pieces. Capsule Home is a flat-pack product that can transform the interior architecture of a small living space, whilst accommodating for one person's daily needs.

APPENDIX

The following information explores the concept of digital fabrication and explores how it benefits the design industry today. Such research shows the key events of the development of software and technology which have lead to where we are today with digital fabrication techniques. Although this information is not the main idea of this research, its process and understanding of its current technologies is pertinent to my studies.

CURRENT DESIGN AND FABRICATION PROCESSES

Every designer has a slightly different way of representing and modeling their work. Many different forms of representation in the architectural design process exist – ranging from digital to physical, two0dimensional and three-dimensional – which are used to portray the designer's ideas. For the purpose of this paper, we will focus on physical models, in particular the process of Computer Numerical Control (CNC) and Rapid Prototyping (RP), which serve many purposes in the design process and enable a physical interaction between the user and the product[1].

DIGITAL FABRICATION: CNC AND RP

Computer Numerical Control (CNC) and Rapid Prototyping (RP) are the main processes used throughout the digital fabrication processes. The main difference between the two processes is that all CNC processes work via the subtraction of material whereas RP processes occur when materials are layered on top of one another in order to come to a finalized prototype.

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[1] *Breen, J., Nottrot, R., and Stellingweff,* Tangible Virtuality - Perceptions of Computer-Aided and Physical Modeling Automation in Construction 12 (2003)

It is important to realize that these processes were originally developed to be used in the industrial design and manufacturing processes. Such machines designed for use in the industrial shops are usually extremely difficult for architects and students to operate on their own. However, ever since Eli Whitney's invention of the milling machine in 1818, many of these processes have been compacted into smaller, user-friendly machines that are more suitable for architecture offices and studio environments, making it much easier for designers and model-makers to utilize.

CNC PROCESSES

Computer Numeric Control was first developed following the development of computers and milling machine tools. CNC Process involved creating an object by the method of removing material from a block, rod of sheet through computer-controlled movements. The machine automatically cuts through the material according to the digital directions it was given. There are five common CNC processes in the field of architecture:

I. CNC Milling: used to create forms from blocks of material. Using uses wood, metal, plastics or foam. CNC machines come in a variety of sizes and often do not require extensive training for operation. This process is usually used to manufacture small, unique components.

II. CNC Routing: is similar to CNC Milling; however cuts large flat sheets of material. In architecture, these are usually used to create site models.

III. CNC Water-jet Machining: is also used to cut large flat sheets of material. Water-jet machining is usually used to cut stone, glass or rubber.

IV. Laser-Cutters: also come in a variety of sizes. Laser-cutters are generally cheaper and more suitable for small offices and schools. These machines tend to cut sheet materials such as museum board, chipboard, veneer and thin plastics.

V. Roland CAMM-1cinyl-cutter: cuts extremely thin sheets of vinyl, paper, and in some cases foil by using a small cutting blade. This machine is good for small precise detailing.

RP PROCESSES

Rapid Prototyping fabrication is the layering of materials through computer-controlled movements. Once the file is sent for 'printing', the machine automatically builds up the material in layers based on the directions sent via computer. There are five common rapid prototyping processes used in architecture:

I. Stereolithography (SL): is when the laser draws a base layer of the desired object on the surface of the photosensitive liquid resin, which then solidifies in place. Each layer is coated and then recoated to ensure the resin solidifies in its appropriate place.

II. 3D Printing: is quickly working its way into the architecture design process. The printing head prints an entire layer of a given object with a water base binding fluid and plastic based powder. When the first layer is complete, the bed moves down and a thin layer of powder is spread over the freshly printed area.

III. Multijet-Modeling: prints with a head that releases tiny droplets of melted wax to create each print.

IV. Fused Deposition Modeling: draws on layer at a time with molten ABS plastic.

V. Laminated Object Modeling: creates objects by repeatedly laminating thin sheets of paper, plastic and/or composites. Each layer has a profile cut into it by a laser blade that is then laminated and onto the previous layer.

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