Master's Thesis of Fine Arts • Design

Revisiting Modular System Strategies for Adaptable Lifestyle Generated Housing Design

라이프스타일 기반의 주택 디자인을 위한 가변적 모듈러 시스템 재고

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Abstract

Revisiting Modular System Strategies for Adaptable Lifestyle Generated Housing Design

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The current housing market in South Korea reflects a need for spatial diversity and user-centered design strategies. Demographic changes and shifts in housing culture, along with a growth of building technologies have created a unique opportunity to further explore the true potential of modular design as a flexible, user-centered design method.

This study tests the potential diversity of spatial conditions that can be created through a modular design method. Divided into two parts, the first portion of the study works to develop a definition of contemporary modularity based on studies of previous modular design methods. From the conceptual understanding of modules as described by Le Corbusier in *The Modulor* to the avant-garde explorations of modular urban systems in Archigram's Plug-in City, the theoretical premise of the study has its roots in previous experimentations in modular approaches.

The second half of the study is a series of experiments in designing a series of one-room housing typologies for a high-density urban environment using three different modular design methods. Firstly, the Kit-of-parts Method uses prefabricated programmatic modules which are selected by the users and composed as a unique floor plan. The Division Method uses spatial modules derived from dividing a given predefined area which are then rearranged and assigned program to fit the lifestyle of the user. Finally, the Compound Method is a hybrid of the previously mentioned design methods, using prefabricated spatial modules which are adjusted to fit the needs of the individual user. Each method has a unique modular language, as well as a different interpretation of modules, that test the potential flexibility and adaptability of spatial configurations of the one-room housing type. These methods looks at buildings from the inside out, analyzing user lifestyles to inform the final spatial form and organization.

Testing the different modular methods reveals the potential for creating non-rectilinear forms while maintaining the simplicity of a modular design. With newer building technologies, such as 3D printing or computerized numerical control (CNC) it has become easier to mass-produce

customized structures, thereby giving a new life to modular design methods. These advancements have created a new foundation which allow for the flexibility of modules to become more feasible in modern day construction. Therefore, the limitations of the modular method were not in the spatial forms, but in the technologies that allow for such developments of form.

Contemporary design culture provides a set of socio-technological conditions to explore modularity as not only as a production method, but as a complete design strategy. The modular design methods outlined in this investigation aim to be a formula for design processes, leaving ambiguity of the designs to reflect the needs and desires of a more general audience.

Keyword : Modern architecture, 21st Century housing, user-centered design, modularity, housing
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Chapter 1. Introduction

Built spatial environments act as the core to everyday life. As Christopher Alexander once stated, to understand the built environment, "we must begin by understanding that every place is given its character by certain patterns of events that keep on happening there."[1] These interactions among people, space, program, and culture range from the everyday to those reserved for a particular event or ritual. Different types of interactions result in varying architectural expressions and spatial conditions.

Among the different programmatic functions of architecture, domestic architecture plays an integral role in the everyday life of people. The current understanding of housing stemmed from the early adaptations of shelter that offer a "safe, secure place that provides both privacy and protection from the elements and the temperature extremes of the outside world."[2] What was fundamentally a way to protect oneself from the external elements has shifted into an exploration of self-identity, artistic expression, form making, and economic and social trends.

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[1] Christopher Alexander, *The Timeless Way of Building*, (New York, Oxford University Press, 1979), 55.

[2] *Healthy Housing Reference Manual* (Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Environmental Health, 2006), 1-1.

Housing is, without a doubt, the most critical aspect of human life, in terms of protection and comfort. Humankind has sought more permanent options after generations of period dwellings of the nomadic tribal societies.[3] This permanence has established a different relationship with the common shelter type dwelling, adding in a sense of personal identity to the basic functions of "home". Therefore, housing articulates experimentations in building technologies, but also style, culture, and artistic expression. Housing acts as crucial clue for understanding the lifestyle, environment and cultural trends prominent in a society at a given moment in time.

However, housing in high density urban environments is often the most formulaic in design- highly dependent on mass-production and prefabricated materials, cost efficiency, and cheap production. In South Korean housing market, for example, a large determining factor impacting housing design is real-estate value which is directly related to the economic conditions of the place rather than the unique needs of individual people.[4] Therefore, there are limited options when it comes to housing beyond size and cost. Additional design details are mostly from

[3] *Healthy Housing Reference Manual*, 1-1.

[4] Seong-Kyu Ha, "Housing Crises and Policy Transformations in South Korea," International Journal of Housing Policy 10, no. 3 (September 22, 2010).

prefabricated choices and materials, again looking at resale value, affordability, and current design trends. The oversaturation of poorly constructed, highly repetitive housing options reflect a dependence on mass production, trend sensitive attitudes, and economic optimization. Such consumptions patterns are the leading cause of the environmental deterioration in the Anthropogenic Era.[5]

There have been numerous technological advancements in recent years that have allowed designers to develop mass customization strategies to help better the quality of life, yet little has been done in actualizing the socioeconomic desires of people for more adaptable housing solutions. On the contrary, building culture has shifted to one of rapid consumption due to affordable building costs and faster construction techniques. It has become economically beneficial to constantly replace low cost, short lifespan structures than to build more expensive, long term solutions.

There is, however, an increasing demand for a simplified building system that can encompass the potential and flexibility of mass customization, the affordability of mass production, and simplicity of a kit-of-parts design methodology. Also, with

[5] Ellis, Erle C. "A Taxonomy of the Human Biosphere." (New York: Harvard University, 2014), 168-83.

computer based technologies, such as 3D printing, becoming more mainstream, there is added flexibility and possibility to the previously static modular trend.

1.1 Issues with Housing

There are various issues with the current architectural language that saturates the housing market. Repetition and rectilinear forms saturate the current building trends, focusing on the maximizing efficiency of land use. The grid formation of most urban cities aims to maximize the usable area of high density environments at the cost of geometric diversity.

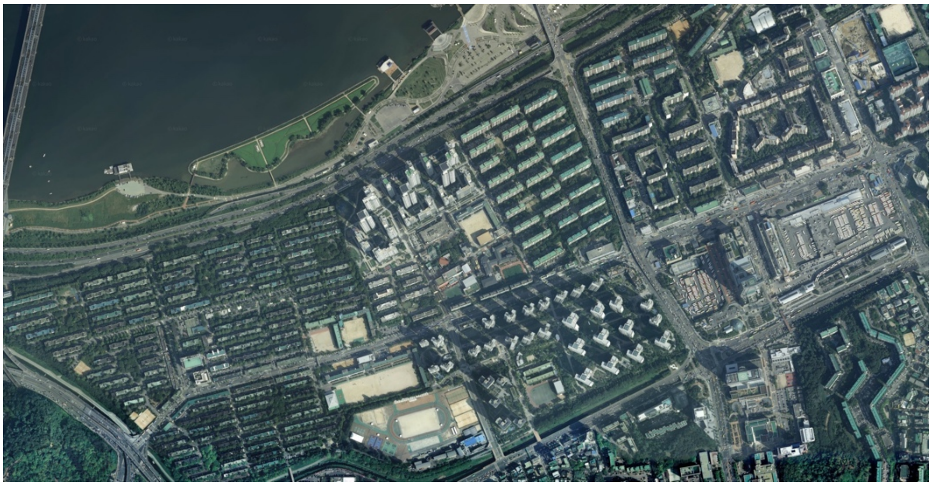

Figure 1 Satellite View of Banpo, Seoul South Korea. Google Maps 2019

The issue that arises from this type of urbanism is the lack of adaptability that creates an unsuitable environment for the rapidly changing demographics. Some major trends from the PEW Research Center and United Nations show the population is gradually aging (fig.2), though marital status is generally decreasing (fig.3). These changes imply that there is a growing number of single member households, a shift away from the previously family–oriented lifestyles. Furthermore, the growing trend towards global urbanism (fig.4) implies that there will be a growth of high density urban environments. The general move into denser urban cities implies a growing need for more small scale housing options, thereby pushing developers towards repetitive, easy to manufacture, housing options that maximize the usable space.

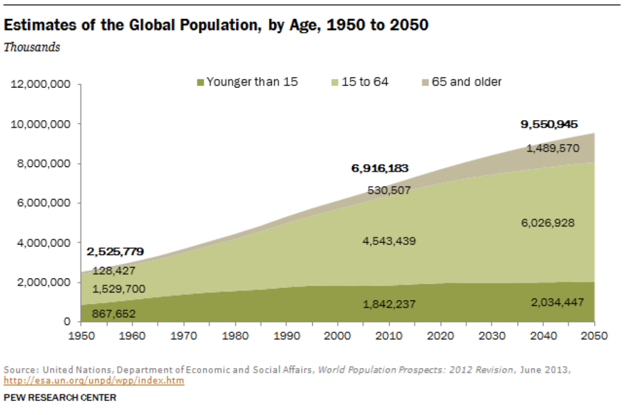

Figure 2 United Nations, Department of Economic and Social Affairs, *World Populations Prospects: 2012 Revision,* June 2013.

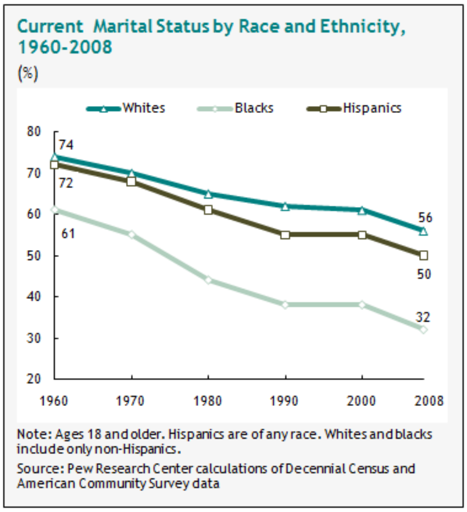

Figure 3 Pew Research Center Census 2008

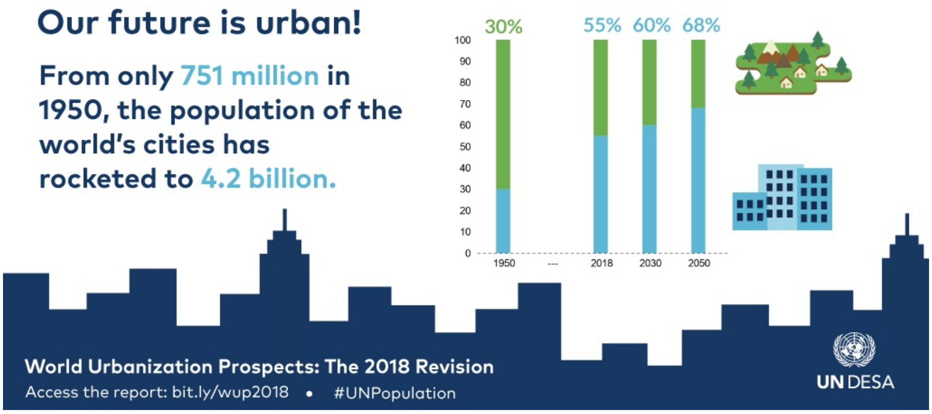

Figure 4 United Nations, *World Urbanization Prospects: The 2018 Revision* , 2018.

Another issue with the current housing practices is the environmental cost of the disposable building culture. Building lifespans have become much younger, thereby increasing the turnover of structures without planning for the possible gentrification and spikes in housing values. In order to create a much more flexible urban framework, the current market trends will not be able to support the lifestyle of the constantly changing demographics for much longer.

Growing construction technologies and a dependence on pre-fabricated materials leads to shorter building lifespans, not because of the structural issues of the building methods, but rather for the ease of replacement and rebuilding. Materials have become more affordable and easier to produce, meaning it has become easier to simply demolish and replace older structures. This pattern of demolition and reconstruction has led to a higher consumption of raw materials. According to the EPA, the U.S construction industry accounts for 25 percent of non-industrial waste a year.[6] Furthermore, the US Green Building Council has stated that the construction industry is accountable for 40 percent of worldwide energy use.[7] Therefore, it is more critical than ever to adjust current consumption patterns and toxic relationship with cheap materials. Sustainability and green-building are ultimately social changes, but the consumption pattern can be more immediately addressed by limiting the

[6] *Municipal Solid Waste in the United States: 2007 Facts and Figures, Executive Summary* (Washington, DC: U.S. Environmental Protection Agency, Solid Waste and Emergency Response, 2003).

[7] Jenny Snook, "How Does Construction Impact the Environment?" (Initiafy, 2019).

repetition of construction and demolition that occur with housing developments.

The post-war period saw a similar demographic shift towards a single member lifestyle as a consequence of World War I and World War II. Economic instability and the sudden demographic shift also led to a demand for affordable housing, yet the housing construction technologies were not yet able to produce an appropriate availability of small scale housing. A solution to the housing crisis in the post-war period was modular design, a method of utilizing interchangeable modules to maximize efficiency in terms of cost, construction, and minimal living. The British Building Research Station went as far as to promote modular construction research after World War II to develop a system to utilize mass-produced units.[8]

Modern architects quickly took over, further celebrating the victory of technology during the World War II. The ideas of efficiency and celebration of technological advancements were also adapted to the housing typology, introducing the use of prefabricated and manufactured materials. Modular designs are systems "constituted by elements or components from different

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[8] Henry Millon, "Rudolf Wittkower, *'Architectural Principles in the Age of Humanism'*: Its Influence on the Development and Interpretation of Modern Architecture," *Journal of the Society of Architectural Historians 31, no. 2* (May 1972), 83.

precedence ... collated in different types of buildings and in different contexts."[9] This building method usually makes use of universal joints to create flexibility and adaptability.[10] Modular design simplifies the design process to a simple kit of parts, thereby allowing for quick construction without the need for skilled labor.

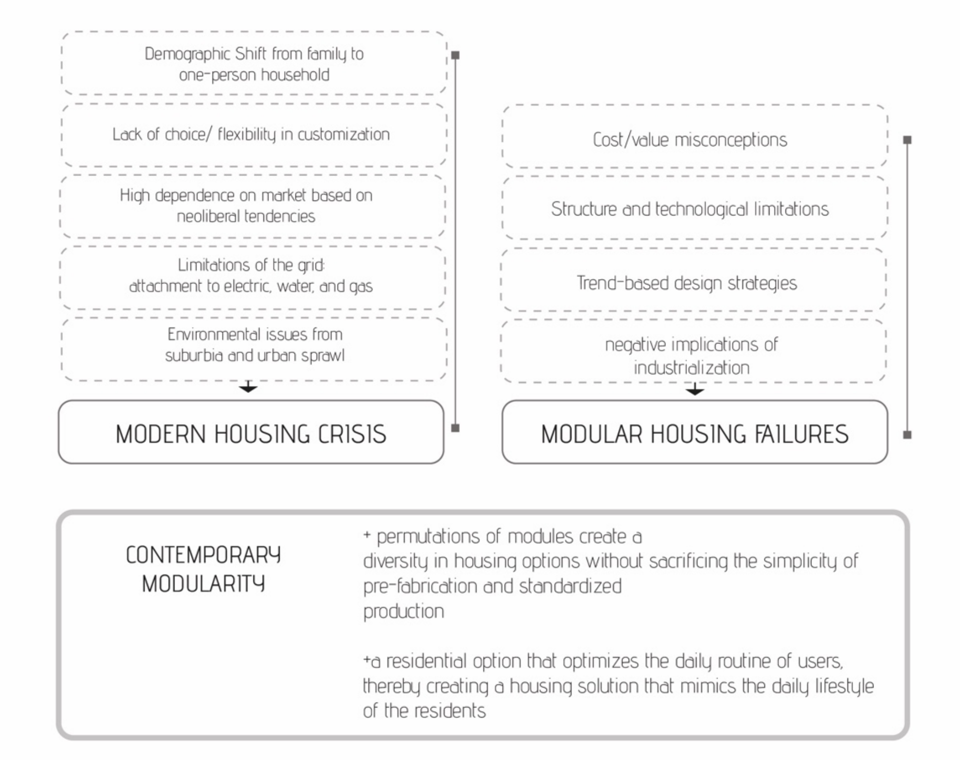

Figure 5 Issues with Housing

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[9] J. Salas, "From Closed System Precasting to the Subtle Industrialization of Building Construction: Keys to Technological Change," *Informes De La Construcción* 60, no. 512 (2008), 98.
[10] Salas, "From Closed System Precasting," (2008), 98.

Similar to the efforts to utilize modular design as a solution to the housing crisis, this study aims to design a modular design method that is better suited to the current human needs, demographics, market, and technology. The simplest way to approach the housing issue is to modify and adapt existing construction practices of repeating apartment designs and grid-based urban strategies. A modular framework and design method would provide a design strategy for a flexible spatial typology to develop with the opportunity for adapting to changing needs and conditions. A design language unifies the modular kit, allowing additional modules to be easily be substituted to better adapt to changing lifestyles. The simplicity of a modular language and the technology of computational design methods create a modular system with a more human-centered design approach. A hybrid of a kit-of-parts modular method and systematic modular method, the proposed Compound Method embodies not only the social and cultural trends towards mass customization and individuality, but also the technological advancements of the current market.

1.2 Purpose of Study

The purpose of this study is to reintroduce modular design methods in a the current context of high density urban cities as a potential solution to the current housing issues. Rather than looking at the specific structure of the modules, this thesis proposes a systematic approach to designing a modular design strategy or modular language that can address the ever-changing needs of the users.

The main goal of this study is to the explore the potential of repeating modular units to create customized housing forms. The premise of this study is that modular design is a form-making tool, breaking away from the rectilinear design process of the current grid-based design methods in urban architecture. This investigation also focuses on looking at housing and residential space to understand the relationship between spatial forms and program or use of the space. Rather than focusing on maximizing efficiency, commonly associated with modular design, this study looks to understand the potential diversity in form, scale, and materiality through a simplified design process.

1.3 Research Method

In order to design a new modular system, this study is conducted in two parts. The first section focuses on defining modularity for the 21st century in a way that best reflects the role of modules in the proposed modular methods. Modular design has often taken on different definitions throughout history, ranging from a study on human scale, such as Le Corbusier's *The Modulor,* to a fabrication method, as seen in the Nakagin Tower. Case studies identify different qualities of modularity and analyze their successes and failures of modularity. This historical and theoretical framework will serve as the foundation in which the proposed modular systems will be extracted.

Table 1. Case Study Overview

Modular Approach	Case Study	Goals
modular measurements	Modulor (1948) Unite d' Habitation (1952)	Standardization of measurements for prefabrication and ease of manufacture
modular building elements	Maison Dom−ino (1914) NENK system (1963)	resolving structural limitations for freely adaptable use of building elements
programmatic modules	Plug−in City (1964)	addressing the needs to replace programmatic elements at a pace faster than that of the building lifespan
capsule/ pod modules	Circular Tower (1964) Nakagin Capsule Tower(1972)	utilizing mass−production and prefabrication for faster construction and replaceable units

The second part of this study focuses on developing modular design methods and testing the validity of these methods in creating a spatial diversity, stemming from a user centered design approach. Specific design iterations are used to test the method and its potential in composing a variety of forms. The criteria of the proposed methods would be their potential in creating diverse spatial typologies rather than in maximizing efficiency of land use or production. The purpose of this part of the study is to better understand the full extent in which modular design can solve the various housing issues and to understand the limitations of modularity in today's context.

This study is not meant to address the economic, social, or cultural issues of current housing practices. Rather, it is a study on understanding the potential of modular design to adapt to changing conditions within the limitations of a one-room typology, a housing type prominent in the current rental market. The "growing population and dwindling natural resources call for a new global economy," with "a new emphasis on human resources and more effective production systems."[11] This shift in socio-economic conditions, as well as a growing demand for customization, creates an opportunity to test the flexibility and potential of a modular design system.

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[11] Vishaan Chakrabarti, *A Country of Cities*, (New York, Metropolis Books, 2013), 63.

Chapter 2. Modularity in the 20th and 21st Century

Different architectural movements defined modular design in different terms, blurring the lines between modularity as a design method and modularity as a production method. The most common usage of the term 'modular' came with its widespread popularity during the early to mid-20th century. With the growth of the Modernist movement in architecture, modularity played an important role in bringing together the industrialization of building technologies and the ideas of *existenzminimum*. Later movements, such as Post-modernism or Metabolism, have since moved away from maximizing efficiency to reintroduce the pleasures of living, comfort, and leisure.

Prefabrication and modularity, though often used interchangeably, are two distinct products of the industry. While prefabrication is the standardization of materials and styles, modularity is the standardization of a module- a module that is designed specifically for a certain spatial quality or programmatic use. Modularity suggests a movement or interchangeability in post-construction due to the use of uniform parts. In other words, whereas prefabrication relates directly to a type of material, the modules refer to a larger unit, allowing for a system to adapt and rearrange itself as necessary on any given system. Furthermore, modules are not limited to the dimensions and base units of prefabricated materials, but rather are limited to the modules themselves. Therefore, there is a flexibility in the development and redesign of the overall modular system regardless of the pre-existing components saturating the market.

Modules alone, however, cannot determine a modular design strategy. Rather, the modules are part of a unifying system that utilize the modules in the design strategy. Modularity, thus, can be understood as an adaptation of the kit-of-parts design mentality. A central system or framework, provides an important unifying tool that allows for individual components to have the freedom to adapt to varying needs and programs. In terms of spatial qualities, the modular system is what gives a sense of unity and wholeness to the arrangement of the smaller unit pieces. Therefore, the language of the individual modules transfers into a larger spatial relationship that encompasses the simplicity of a repetitive unit with a complexity of a much more organic method of designing. Such a method of design allows for the design system to be applied to larger scale projects such as those of urban settings.

The connecting system plays an important role in the organization of individual modules. While each module can identify as an individual unit, modularity implies a collection of modules to create a unified whole. Therefore, the network or system is an organization tool that mimics the overall languages of the modules. In other words, the network is an abstract version of the design rules that inform the module design. The network system cannot work as its own, just as the modules themselves cannot represent the entire system as a whole.

2.1 Human Scale Modularity

Human proportions have always been deeply embedded in architecture from the earliest constructions as the human body has been the first units of measure. They play a critical role in our understanding of space as human proportions are the physical basis for humanizing space.[12] Standards of beauty not only in the visual arts, but also in the building arts, have been derived from human proportions. Vitruvius, in this third book of

[12]Alfred Neuman, *The Humanization of Space*, (Boulogne-sur-Seine: Éditions de l'Architecture d'aujourd'hui, 1956).

Ten Books on Architecture, focusing on Temples, noted the proportions of temples reflected those proportions of the human figure. This was, in turn, to mirror "the proportions of his body [as] produced by divine will," as a way to "embrace and express the cosmic order."[13] The idea of these perfect geometries, such as circles or rectangles, with the appropriate ratios, allowed for designers to create stability and a sense of strength in the structures that were built.[14]

Spatially, these geometries are an important visual clue while the human scale gives a better sense of the dimensionality of the spatial conditions. As Le Corbusier commented, architecture "depends entirely on the movements of its user, ... [and] therefore be made to the human scale."[15]

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[13] Rudolf Wittkower, *Architectural Principles in the Age of Humanism,* (London: Academy, 1998), 14, 101.
[14] Wittkower, *Architectural Principles*, 22.
[15] Le Corbusier, *The Modulor: A Harmonious Measure to the Human Scale Universally Applicable to Architecture and Mechanics,* (MIT Press, 1968), 59.

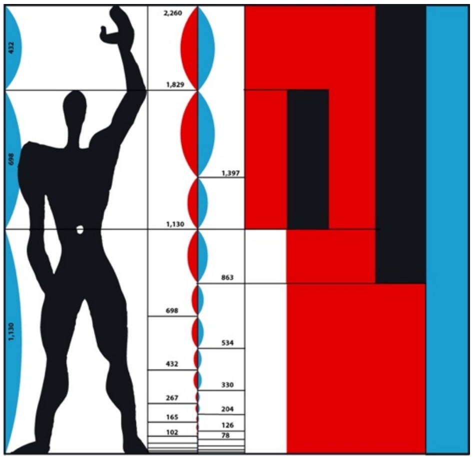

Figure 6 Diagram of the Modulor Man by Le Corbusier

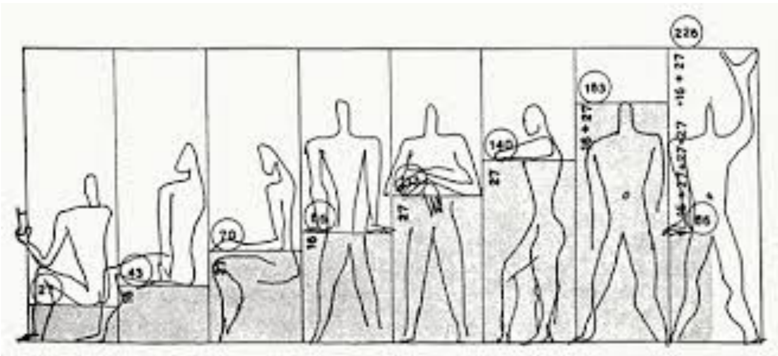

Figure 7 Diagram of the Modulor Man by Le Corbusier

To address the need for standardization of building methodologies, Le Corbusier developed 'Modulor' as a system of measurement based on human dimensions. The Modulor was a "measuring tool based on the human body and on mathematics," meant to aid in maximizing the efficiency of designed spaces.[16] Rudolf Wittkower described the 'Modulor' as "an example of a proportional system in modern architecture that for the first time

[16] Le Corbusier, *The Modulor,* 55.

combined anthropometric, geometric, proportional, and modular systems, and the Gold Section."[17] Le Corbusier's Modulor Man (fig.8) has become an iconic image, representative of the core ideas behind his use of human scale and proportion in his buildings.

In his book, *The Modulor*, Le Corbusier explores a mathematical approach to the standardization of architectural design methodologies while relating to human proportions as the base unit of measure. His work was deeply rooted in the standardization of materials and pre-fabrication, as a way to expand on the industrial aspect of architectural construction at the time. It was a way to perfect the measurements of human proportion to be applied to architectural design, correcting discrepancies in metric and imperial measurements. Furthermore, "the combinations obtained by the use of the 'Modulor' have proved themselves to be infinite," going as far as to state that "the 'Modulor' would, one day, claim to be the means of unification for manufactured articles in all countries."[18] This standardization would allow for building elements to be in harmony with one another, creating a simpler production system.

[17] Millon, "Rudolf Wittkower", 85.
[18] Le Corbusier, *The Modulor,* 55-56.

Figure 8 on left, Church of Sainte Marie de la Tourette (1956), on right Unité d'Habitation (1952)

Le Corbusier's development of the human-based modular form will later inform a large part of his work, such as Unité d'Habitation and the Church of Sainte Marie de La Tourette. Unite d' Habitation is the physical manifestation of the key concepts in *The Modulor*. Taking the human-scale model to creating the building blocks of the high density social housing, Le Corbusier composed Unite d' Habitation as a vertical city enclosed into a single building. The combination rectilinear forms allowed for a seemingly endless number of compositions to suit every distinct needs of a multipurpose housing structure. Interlocking L-shaped apartments, made with the same proportions as the rest of the structure, provided opportunities to introduce verticality in the units, increasing the diversity of movement the modular system could form. There were also overlapping private and public spaces that promoted interaction, a sense of community, and unity for the users. The use of concrete and prefabrication allowed Le Corbusier to meet the demands of the housing shortage after World War II and celebrate the growth of industry that allowed him to achieve the solution.

Relating back to human form, only fifteen measurements were repeated throughout the structure. Le Corbusier developed the units around human measurement because " in nature, every organism's dimensions are proportioned in relation to its surroundings," and the "building's size had been carefully calculated for collective living." Therefore, despite the mass of the structure, there was a relationship that connected back to the human scale, that made every space much more relatable on a subconscious level. It has achieved a livable high density affordable housing complex in a way that preserved the integrity of the heterogeneity of the human experience and urban network.

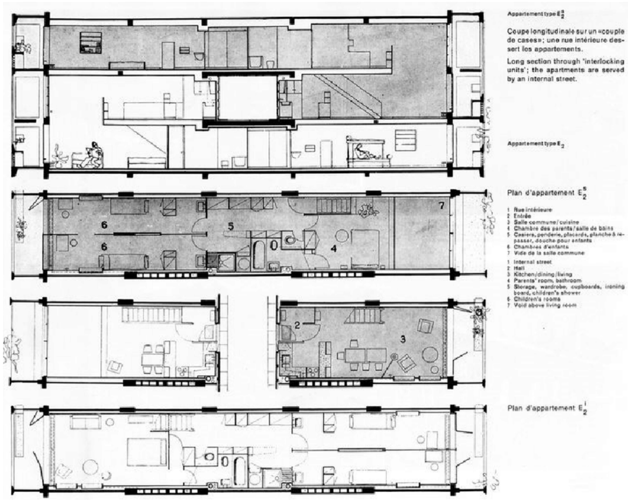

Figure 9 Section and plan, Unite d'Habitation, Le Corbusier

The use of modular measurements in Unite d' Habitation is what allowed Le Corbusier to utilize prefabrication and mass-production techniques. The standardization of measurements meant that there would be a harmony within the entirely of the design language of the building while maintaining a spatial diversity in the vertical and horizontal planes. Despite the limited number of measurements and use of standardized building elements, Unite d' Habitation still follows Le Corbusier's five points of architecture, including a pilotis for circulation below the structure and a rooftop garden space for socialization. In other words, modular measurements were used to simplify the construction and design process without limiting the opportunities for design.

2.2 Modular Structural Elements

A repeating base element, or the module, and a network system react to one another in modular designs allowing for an easier production process irrespective of the formal complexity. In theory, the repeating base module simplifies the overall production requirements and utilizes a standardized set of units. In Modern architecture, the growth of modular design in the late 1920's by Le Corbusier, was an effort to achieve total function and optimization.[19] Scarcity of materials and the high demand for housing pushed designers to pursue maximum efficiency through minimal living and faster production methods.

Social pressures for affordable housing provided an ideal atmosphere to celebrate industry. The factory process perfected during the War allowed for mass production to grow at an incredible pace. Mass production was a way to utilize the new technologies developed during the war and adapt them to fit the needs of the post war society after World War II. Therefore, mass production and modularity developed a symbiotic relationship in this time as a way to provide quick solutions in a faster paced environment.

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19 Annie Pedret, *Team 10: An Archival History*, (New York: Routledge, 2013)

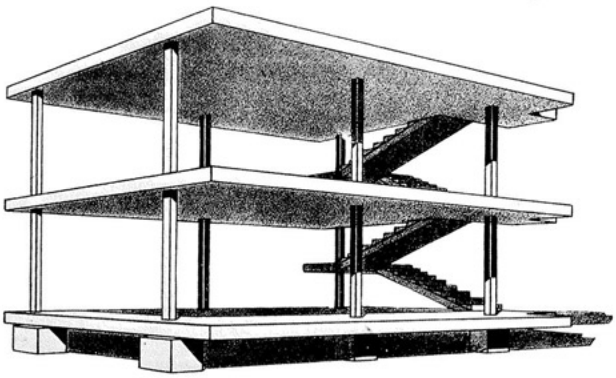

Figure 10 Diagram of Maison Dom-ino

Le Corbusier's Maison Dom-ino (fig.12) (1914), was an early experiment in creating a structural framework that would allow for mass production and customization. The structural system allowed for the floor plans of the house to be completely structurally independent, with the piers carrying the floors and staircase. This meant that different pre-fabricated and mass-produced elements, such as windows or doors could be added freely along the floorplan. It was a way to simplify the construction process to introduce "great variety in the grouping of the houses." [20] as seen with the Villa Savoye (fig.13) or the Weissenhof-Siedlung Houses 14 and 15. Le Corbusier's new method of construction ensured that construction could take place based "upon the order of the architect- planner or, more simply, upon the order of the client," noting the potential

[20] Pierre Jeanneret, "Maison Dom-Ino, Not Located, 1914,"

diversity and simplicity of a mass produced customizable building system.[21] While the Maison Dom-ino was conceived as a way to solve the problems of post-war reconstruction, it also outlines the immediate need for diversity and customizability even in the most pressing of housing crises.

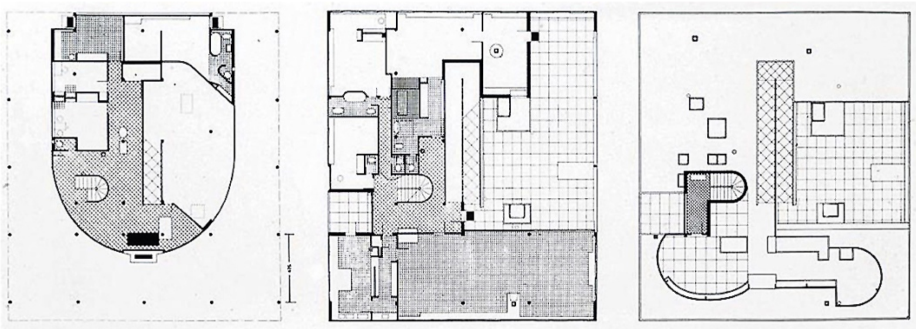

Figure 11 Plans of the Villa Savoye using the structural system of Maison Dom-ino. The independent structure allows for flexible internal floorplans, unrestricted by the upper or lower levels.

Maison Dom-ino played with the idea of modular building elements, such as slabs and piers, to allow for a flexible design without structural limitations. This freedom in structure meant that additional building elements such as windows and walls can be used independently, able to adapt and adjust to the needs of the user. The diversity of spatial arrangement of interior spaces was due to the fact that the modules, or building elements, were reacting to the network system, or the building structure. Rather than having a structure be directly impacted by the smaller

[21] Jeanneret, "Maison Dom-Ino"

building unit, the independence of the structure from the modules allowed the Maison Dom−ino to have an internal spatial diversity.

Similar ideas were also explored by other prominent designers after World War II in Britain. Starting from the Consortium of Local Authorities Special Programme (CLASP), Ralph Iredale and his team developed the NENK system, which incorporated a two−way span space deck, able to create complete flexibility in the placement of columns. It was "designed to include a systematic design procedure, a critical path program, the use of standard modular components, a computerized cost−planning method, an economic use of construction labor, and an assembly speed factor,"[22] to maximize the efficiency of not only the final output, but also the entire process of building. Pre−fabricated structural systems allowed for modular building elements to be added independently, much like the Maison Dom−ino.

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[22] Royston Landau, *New Directions in British Architecture*, (New York, 1968), 43.

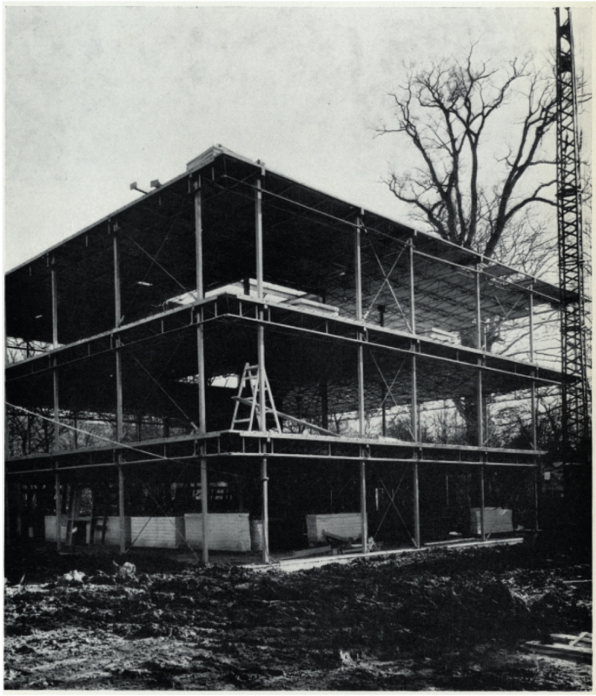

Figure 12 Sample structure using NENK space deck system

The system is similar to Maison Dom–ino in that it is also an experimentation to simplify the structural limitations of construction to add flexibility in the arrangement of interior spaces. However, the eventual goal was heavily focused on efficiency and productivity of the construction process and the design. It is evident from the efforts of Post–war British design attempts to mimic machine–like precision and productivity while holding onto as much flexibility and customizability in the design. However, with limitations in the availability of technologies, the outcome of such designs were more reminiscent of the rectilinear urban language which is prominent in urban plans in the modern day.

2.3 Modular Systems

The Archigram brought together the conceptual Plug-in City in 1964 as an experiment of a modular urban system. Manifested by Peter Cook, the Plug-in City suggested a hypothetical city system that would have modular residential units that can fit into a core megastructure. Archigram looked to a modular kit-of-parts system for its flexibility and adaptability. Simon Sadler commented on how Plug-in City "turned architecture inside-out to make its interior life anterior; expendable apartments were slung happily down the outside of the huge A-frame substructures, rearranged by the cranes sliding back and forth above."[23]

[23] Simon Sadler, *Archigram: Architecture without Architecture* (Cambridge, MA, MIT Press, 2005), 18.

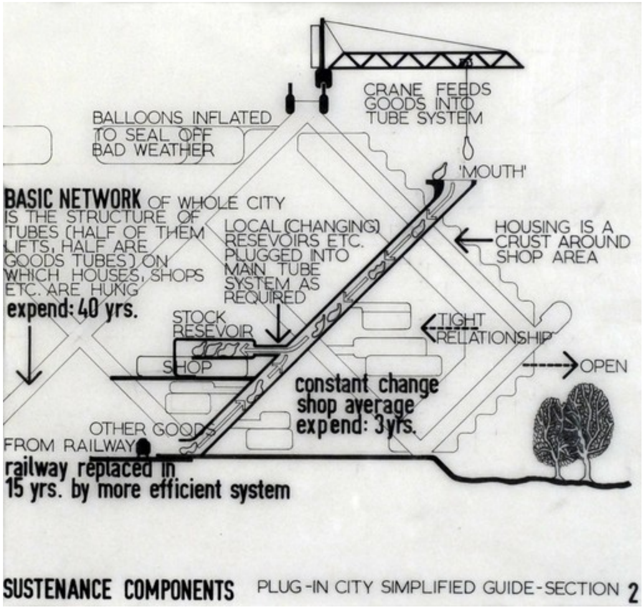

Figure 13 Simplified Section of Plug-In City

Plug-in City was an attempt to break away from the existing urban language of International Style architectural Modernism, while providing a solution for the fast urbanization that celebrated the industrial and technological developments of the time. Plug-In City explored the potential diversity and heterogeneity in the compositional ability of modular urban components, ultimately producing the provocative image of the Plug-in City. Modular residential units would 'plug into' the central structures that acted as the backbone to the entire city, allowing these units to be replaced to adapt to the needs of the city. The Lego-like character of the Plug-in City Concept produced "less didactic structures and even of bearing a responsibility for the decline in British engineering."[24] Compositional potential of modular units was a key component of the Plug-in City, with "units stacked into profiles that, far from being repetitive, bordered on the picturesque, clustered like coral and tumbling down the mega structural precipices like troglodytes."[25]

The temporary nature of the programmatic living modules of the Plug-in City address the "needs changing continuously at an ever-increasing rate," in which the building element is "likely to become obsolescent from a user point of view long before it becomes unsound and in need of physical replacement."[26] There was an underlying understanding that the urban city is everchanging, constantly growing and adapting to suit the current needs of the city. The idea that program modules are replaceable can be interpreted as an extreme of the current building culture to demolish and rebuild. Plug-in City is an exploration of the idea of disposable modules as a way to simplify the procedure of the making and rebuilding, without breaking away from the existing language of the urban network.

[24] Sadler, *Archigram,* 19.
[25] Sadler, *Archigram,* 18.
[26] Landau, *New Directions*, 69.

Though theoretical in approach, the underlying ideas supports the advantages of a simplified design language.

2.4 Modular Building Units

Archigram, in the later years, leaned towards prefabricated pods or capsules as a way to revise the larger ideas of replaceable units in the Plug-in City to become more feasible in the technological climate of Britain at the time. The modular language at urban scale was reduced in size, shifting the focus to "architecture [that] would be more like a refrigerator, car, or even a plastic bag."[27] These ideas later translated to pods or capsules that could be prefabricated and mass-produced, reducing cost and maximizing efficiency. The "point was to design complete units capable of reorganization, carried by the whim of the owner-operator," thereby maximizing flexibility.[28]

Other architects to explore the idea of manufactured modular architecture in the form of complete programmatic units include Warren Chalk's Circular Tower (1964), for instance, was composed of replaceable capsule units similar to that of Kisho

[27] Sadler, *Archigram,* 107.
[28] Sadler, *Archigram,* 107-108.

Kurokawa's Nagakin Capsule Tower (1970). Both towers had a central core system that prefabricated capsule or pod units could attach onto. This freedom in structure provided the opportunity to replace capsules as necessary.

The Circular Tower, developed simultaneously with the Plug-in City, utilized prefabricated dwelling modules that could be interchanged or updated as technology developed.[29] It played with the idea that the capsule dwellings would lock into place along the tower but still be replaceable, similar to the ideas of interchangeable parts in Fordism. These modules were carefully designed objects, suggesting an entire lifestyle, thereby able to "bypass many of the myths of urban design which depend upon hierarchies of incident and the treatment of housing as a folk art."[30] This places more importance on the capsules themselves rather than the entirety of the modular system. Therefore, the Circular Tower was often limited in its potential for spatial diversity beyond the scale of the modules themselves.

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[29] Peter Cook, *Archigram*, (New York, Princeton Architectural Press, 1999), 44.
[30] Cook, *Archigram,* (1999), 44.

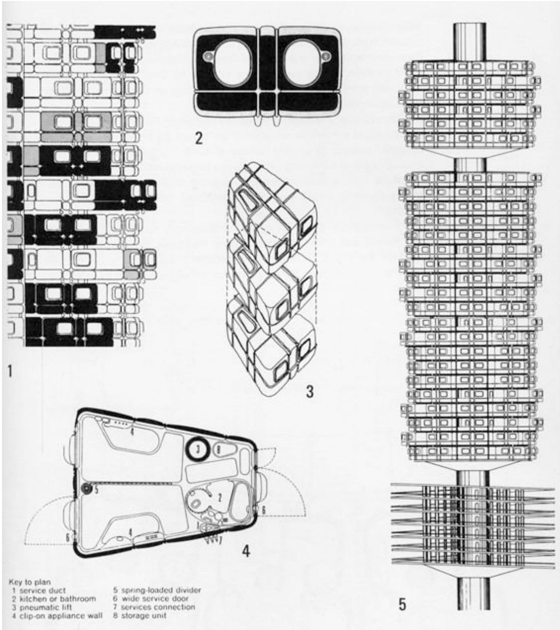

Figure 14 Warren Chalk's Circular Tower

The Nagakin Tower expands on the idea of replaceable units, adding to the idea the concepts of natural growth and decay– the foundation for the Japanese Metabolist movement. Metabolism focused on the ability to "extend and regenerate without limit," and thereby "continuously 'growing' and 'dying'."[31] This was a step beyond the idea of simple replacement, as Metabolism sought to understand urbanism and architecture as organic processes.

[31] Tomoko Tamari, "Metabolism: Utopian Urbanism and the Japanese Modern Architecture Movement", Theory, Culture and Society (2014), 208.

Figure 15 Kisho Kurokawa's Nagakin Capsule Tower

The simplicity of a modular approach made such capsule systems possible with the existing technologies. A major downfall to modular design in the post-war period was general attitude towards modular technologies was that "the postwar public wanted was choice," and prefabrication was a reminder of the austerity of previous generations an age where efficiency and industry were no longer the primary design factors.[32] While modular design, in theory, provided a diversity and flexibility beyond any other type of building technology, the limitations in

[32] Sadler, *Archigram,* 103.

the cost efficiency and the variation of prefabricated modules meant the systems were designed to fail. As Reyner Banham remarked, it is "now possible to live in almost any type or form of house," and with the technologies available today, there is a new opportunity to revisit modularity, focusing on expanding the ideas of flexibility and spatial diversity.[33]

2.5 Defining 21st Century Modularity

The shifting tone in the definition of modularity is related to the social climate and the availability of technologies of the time. Modularity was once regarded as the most efficient method of production, especially in a culture where minimalism and practicality were major design goals. Developments in available technologies, as well as the overall reduction of cost of mass-production, led to the use of modular design as an affordable solution with the potential for spatial diversity. Today, construction is no longer limited by materiality or building technology. Rather, the new acceptance of the fast developing construction methods create an opportunity to test the true potential of modular design as an affordable, customizable, and practical design solution.

[33] Sadler, *Archigram,* 113.

With growing criticism of mass production in recent years, there has been a growing need to look at modular design's potential as a design method outside of the main objective of efficiency. At the core of modular design are the base modules, or the repeating element, and the network system, or the language in which the modules connect. The benefit to using modular design comes from its core design characteristic of being able to start with a smaller unit and working towards a larger massing.

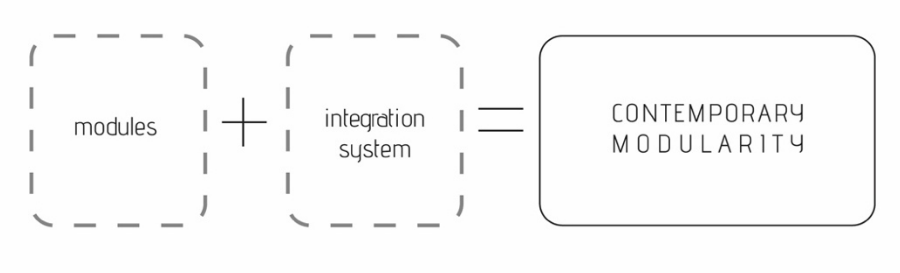

Figure 16 Contemporary definition of modularity

Modularity, in the context of this study, is defined as a design system that utilizes human scale modules. In order for the design method to be a modular method, there needs to be a presence of a repeating unit module and connection system. However, the unit modules do not need to be a repeating element, rather they must have the same design language that allows them to be interchangeable with other modules. The modular design method will focus specifically on housing typologies.

This study looks at using modular design, not as a way to maximize efficiency of production or spatial composition, but to explore the diversity and freedom in terms of spatial form that can stem from a simplified design process. Therefore, the focus of the study is not in simplifying the modular units, but to simplify the systematic language of the design process.

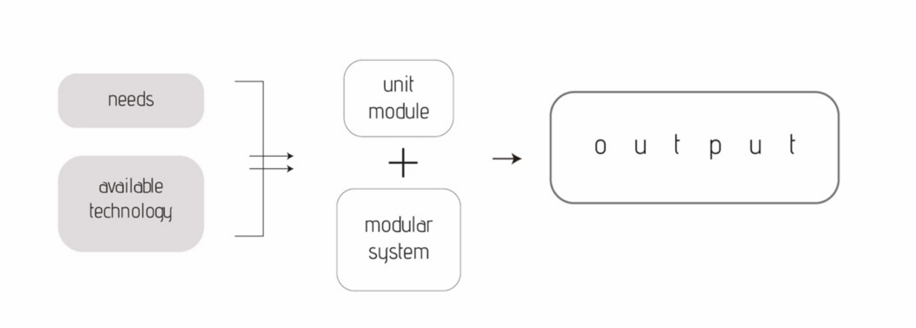

Figure 17 Modular design method diagram

The first step in developing the modular method is to first identify the designable factors and outline the nature of the modules and module system. As Henri Lefebvre stated in *The Production of Space*, real estate today "are volumes of space: rooms, floors, flats, apartments, balconies, various facilities," and "the fact remains that a home-buyer buys a daily schedule".[34] The study focused, therefore, on the daily routine of individuals and the basic necessities for human survival. Outlined in Le

34 Henri Lefebvre and Donald Nicholson-Smith, *The Production of Space* (Malden, MA: Blackwell, 2009), 338-340.

Corbusier's 'Manual of the Dwelling', the modular system must yield programmatic modules equivalent to that of a bedroom, bathroom, kitchen, and living room.[35] An abstract survey was also conducted to identify a sample lifestyle to be represented in the testing of the modular methods.

Christopher Alexander also introduced similar thinking in *The Timeless Way of Building*, looking at the pattern of movement. Alexander argued that "the life and soul of a place, all of our experiences there, depend not simply on the physical environment, but on the patterns of events which we experience there."[36] Therefore the patterns of interactions, relationship between user and space, and the lifestyle differentiate good space from the bad. It can be argued that the lifestyle of the individual, their own unique pattern of interaction, is what dictates the credibility and adequacy of the spatial form. More specifically, "there are surprisingly few of these patterns of events in any on person’ s way of life," averaging about a dozen.[37] It is not necessary to design for every single spatial desire or need, rather, it is more important to provide enough flexibility in the systematic connection so the modules to adapt

35 Le Corbusier and Frederick Etchells, *Towards a New Architecture* (Connecticut: Martino Publishing, 2014), 122.

36 Alexander, *Way of Building*, 62.

37 Alexander, *Way of Building*, 68.

to the different patterns of life.

Ezra D. Ehrenkrantz, in *Architectural Systems*, noted similar lifestyle patterns in the development of dwelling spaces. His book outlined spatial requirements for different spaces based on the programmatic elements of a typical dwelling. Different activities and different programmatic rooms have corresponding qualities and spatial needs to be adaptable and suitable for the user. He also suggested that "for the overwhelming majority of the built environment, flexibility must be provided by design and not by an abundance of extra space," again focusing on understanding the internal patterns and spatial relationships to maximize efficiency.[38] People are "becoming more sophisticated, more involved, and more active in participating in the formation of his or her own environment," thereby demanding a more customized method of housing design.[39] Modularity can provide the necessary flexibility and customizability to satisfy the needs and desires of people today. The challenge is in creating a modular set that can adapt to the different requirements both in terms of adaptability and feasibility of production.

Ehrenkrantz outlined key spaces and the different

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[38] Ezra D. Ehrenkrantz, *Architectural Systems: A Needs, Resources, and Design Approach* (New York, McGraw-Hill, 1989), 41.
[39] Ehrenkrantz, *Architectural Systems*, 40.

activities that happen in each space. Along with the list of activities is also an outline of different spatial requirements, minimum required spaces, for accessible and plausible rooms. In the case of one-room housing typologies, there is difficulty in establishing specific programmatic spaces due to the lack of available space. Looking at the current desire for irregular, more custom spatial arrangements, the break away from rectilinear form comes at the cost of the spatial efficiency. However, the general needs and requirements for the dwelling do not change with the different spatial compositions. Therefore, a modular program that is based on spatial modules, rather than programmatic modules, can help create a set of modules that are adaptable to act as multi-purpose spaces.

The study is composed of three different modular methods, each experimenting with a different type of modular system. While all three methods aim to understand the diversity and flexibility of modularity in creating spatial forms, the type of module and basic approach varies from method to method.

Table 2. Method Overview

Method Name	Approach	Module Unit Type / Module Lifespan	Case Study Referenced
Kit-of-Parts Method I	The Kit-of-parts Method uses programmatic modular units that compose an apartment typology based on the needs of the user. The apartments that are created from the programmatic units are stacked onto one another.	Programmatic/ module lifespan equals that of the building lifespan	Circular Tower Nakagin Capsule Tower, Kit-of-parts architecture
Kit-of-Parts Method II	This method uses the same system as the abovementioned 'Kit-of-parts Method I', but the apartment typologies are connected by a central core. The core acts as the main frame in which the modules can be replaced over time.	Programmatic/ module lifespan may be equal to or less than building lifespan	Circular Tower Nakagin Capsule Tower, Kit-of-parts architecture
Division Method	The Division Method begins with a given area that is then divided based on the space requirement. The divided spatial modules are rearranged and assigned a program	Spatial/ module lifespan equals building lifespan	*The Modulor,* Unite d'Habitation

	based on the lifestyle of the user.		
Compound Method	The method is a hybrid of the previous methods. Modules are derived from a previously defined space that is divided into smaller fragments. These fragments are then adjusted to fit different programmatic aspects. Users can decided the specific modules that best suit their needs.	Spatial / module lifespan equals building lifespan	Plug in City, Nakagin Tower

Chapter 3. Kit-of-Parts Method

Design study

The first method explores modularity as a kit-of-parts strategy. Using programmatic modular pieces, the user is able to pick and choose a selection of programmatic modules that best suits the lifestyle of each user. By selecting individual modules, the user has more control over the arrangement, composition, and scale of the final housing type. This method, therefore, creates and inside out design process, focusing more on the individual lifestyle of the user rather than the efficiency of land use. Predetermined program units ensures a continuity in the design language, while still maintaining the opportunity to create diversity in spatial forms.

3.1 Kit-of-parts Method I

The Kit-of-parts Method I focuses on developing a set of modules that utilize prefabricated materials and standardized building elements to establish programmatic modules.

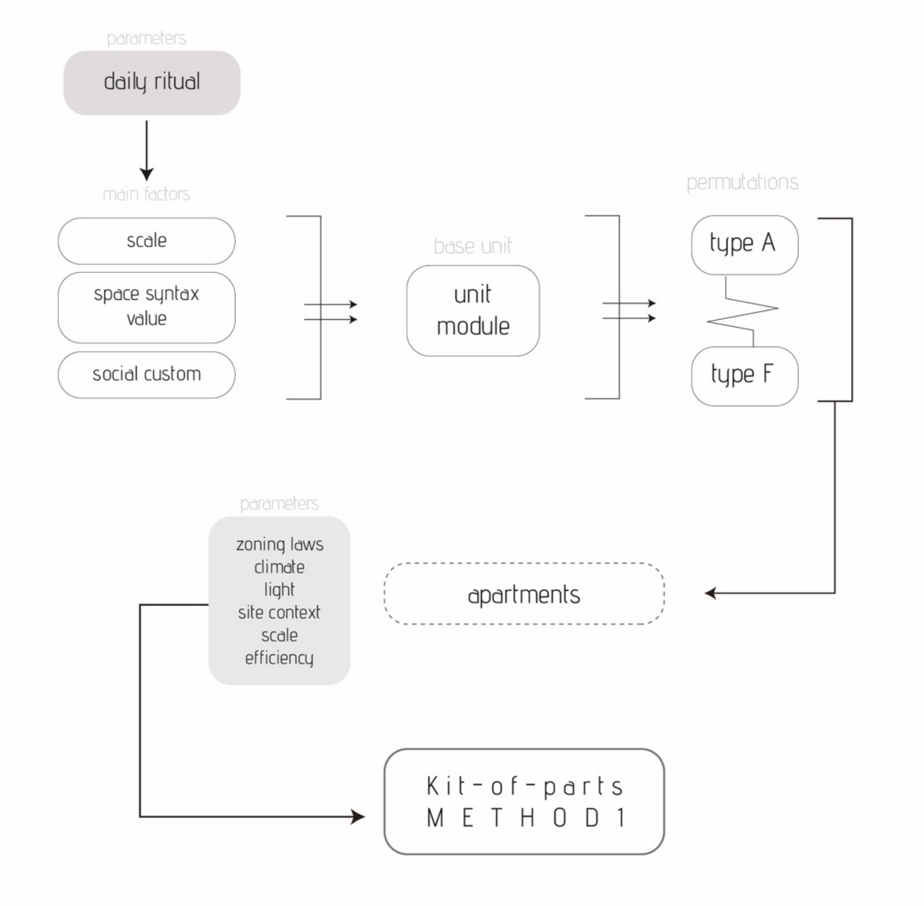

Figure 18 Kit-of-Parts Method I Outline

3.1.1 Module

Each residence, henceforth labeled as apartments, consists of a combination of unit modules. Unit modules are reflective of the different programmatic elements a dwelling requires- sleeping, cooking, working, leisure, and hygiene. Every apartment must consist of each unique programmatic module to ensure that basic needs are addressed. Therefore, at minimum, each apartment consists of a combination of three unit modules. Additional programmatic modules, such as work or leisure, may also be included in the combination, but are interchangeable with one another. The combination of these unit modules then create the larger apartment.

The module, in this method, consist of a repeating base unit that helps to define the spatial qualities within each unit. A 3foot-by-3foot base unit is used in the development of the modules, a measurement that reflects a compact space for a standard adult. A standard grid unit allows the modules to have a repeating element to make interlocking modules simpler. Program will dictate the number of smaller units that create a unit module. Different programmatic elements will have different spatial restrictions, which then identify the total amount of space each program unit will occupy.

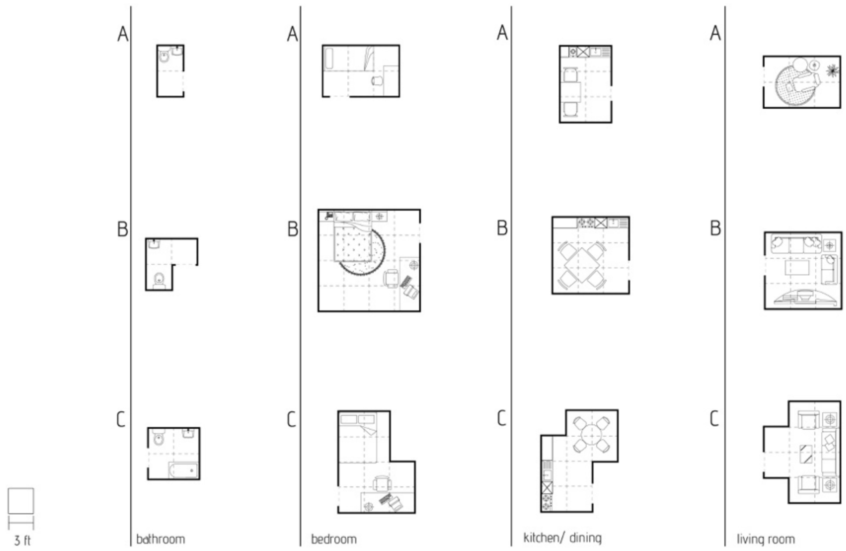

Figure 19 Module Types

This method of dividing the space into unified units allows the designs to have a continued sense of regularity and allow the modules to interlock with one another without wasting unnecessary spaces at the intersections. The smaller unit itself relate to an understanding of personal scale, in a way that ensures each programmatic unit is able to translate into a spatial quality that is easily understood in relation to the human or individual scale.

3.1.2 System

Looking at the larger language of this design method, the underlying strategy is to utilize permutation designs and interchange the programmatic modules based on the individual needs of the user. Simply put, the process approaches housing design from an inside out approach.

	bedroom	kitchen	bathroom	living room	office	dining room	other
social	y	y	y	y	N	y	N
relax	y	y	y	y	N	N	N
work	y	y	y	N	y	N	N
creative	y	y	y	y	N	N	y
healthy	y	y	y	y	N	N	y
mixed	y	y	y	y	y	y	y

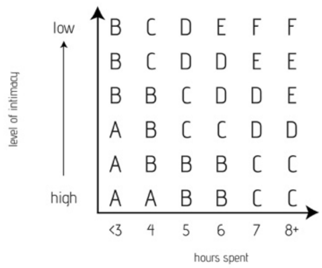

Figure 20 Preference Matrix

As depicted in the above figure (fig. 16), the preference matrix represents the type of data that can be acquired by activity trackers or personalized surveys. The different levels of intimacy within a space will help to dictate the type of organization of the housing type as a whole, as well as to best understand the general massing for each part of the program. From this data, the modules can be designed from the inside out with a standardized minimal block to keep the spatial proportions relative. There is the benefit here to arrange different modules and programmatic in almost limitless combinations and permutations.

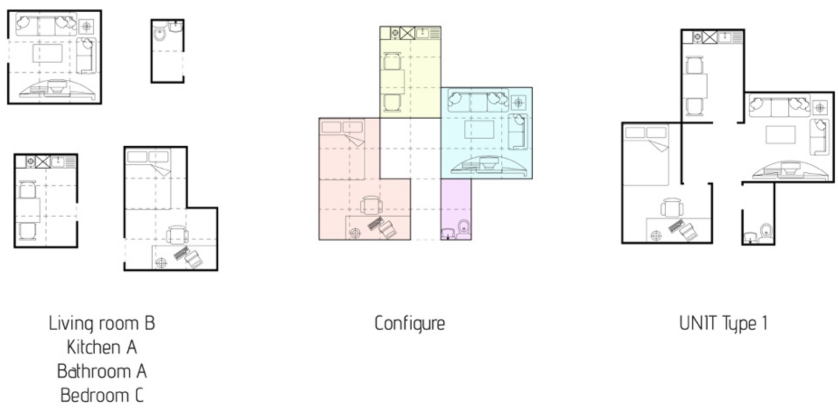

Figure 21 Apartment Configuration

Figure 22 Sample Apartments

The different modular units come together, configured to increase efficiency based on the general movement pattern of the users. In many cases, the units are organized around a central atrium space that leads to the entrance of the structure— mimicking a triangular or circular webbing pattern of movement. However, in cases where intimacy or privacy are preferred, the apartment unit may be arranged in a linear fashion.

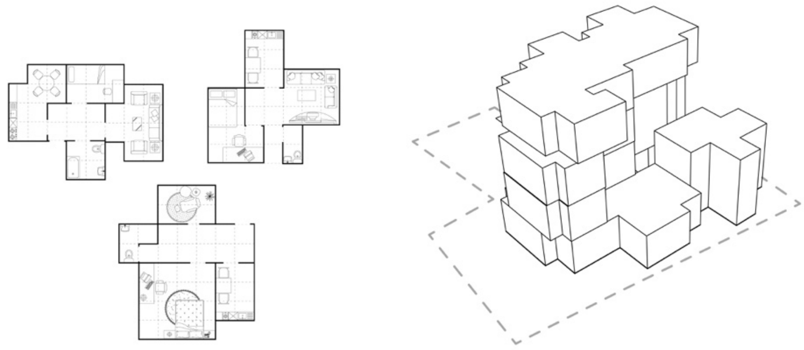

Figure 23 Site Placement

Through space syntax and optimization algorithms, a variety of permutations will be designed to then inform to larger structure. Each apartment unit, a total of fifteen for the particular iteration, are arranged onto the site that best utilizing the landscape potential while respecting the zoning laws. A separate algorithm will be designed to reflect the context of existing conditions and neighboring urban language to further increase efficiency.

3.1.3 Further Diversification

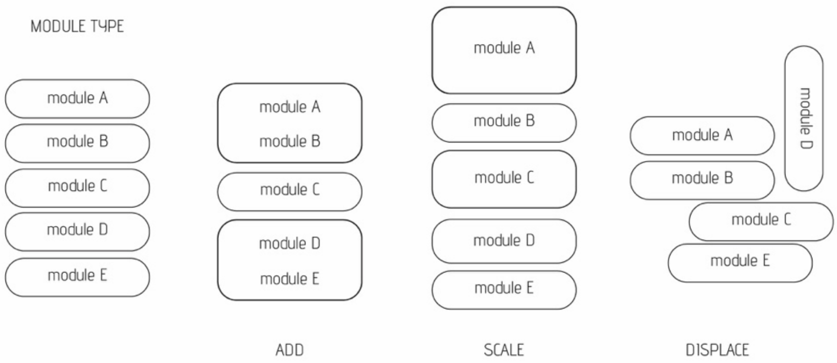

Figure 24 Module diversification strategy

To further increase the potential efficiency and spatial diversity of the repeating modules, the individual unit modules can further be adjusted through a simple set of operations. These adjustments are made to better establish connections between module and module. The available manipulations are classified into three different operations– addition, scale, and displacement. With these different operations, a systematic language will be developed to simply the production process and help aid in keeping within the boundaries of the architectural parameters for the project. The advantage of utilizing permutation in design is the diversity that is created through the repetition of a singular element. Rather than creating a specific floor plan for each unit to best increase flexibility, the plan only requires a small re-configuration of the modules. This project will focus on these three operations, specifically, to simplify the systematic approach of the project and focus on the developing of the unit modules themselves. In essence, the module is a measuring unit for the arrangement of space and spatial qualities. There is a strong relationship between human scale and the module, and then the module to the site. This intermediate state of relationships is what allows for the user to become directly integrated into the site design process, to optimize the use of the space.

3.1.4 Analysis

The Kit-of-parts method, though simple in context, oversimplifies the conditions of each individual user. Firstly, there is the given assumption that the initial grid, 3 feet by 3 feet, is a comfortable dimension for all users. Therefore, the unit modules that develop from said initial grid may not be applicable to all users. While there is the benefit of ease of manufacture and affordability that comes with the simplification of the module design process, the highly limiting nature of the scale itself can cause problems that cannot be resolved through a reconfiguration of the unit modules.

Secondly, without the manipulation of the unit modules, the original method creates a repetitive output that diminishes spatial diversity. Stacking each apartment also causes problems in creating a unified organization of apartments within a single housing complex. While smaller housing structures require less organization, larger housing structures require a more unified system to ensure the safe transfer of shared utilities such as gas, electricity, or plumbing. Therefore, without a central core or grouping of utilities, the simplification of the production process increasing complexity in the construction process.

3. 2 Kit−of−parts Method II

The Kit−of−parts Method II is an adaptation of the initial Kit−of−parts Method I to address the more pronounced issues.

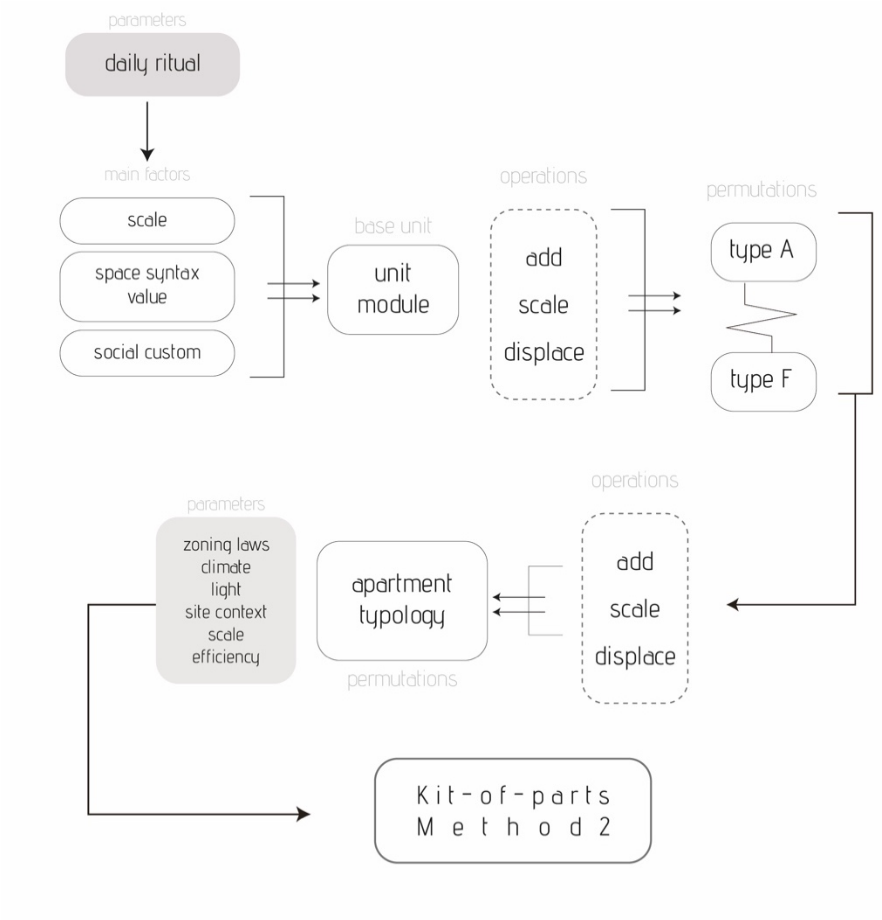

Figure 25 Method Outline

3.2.1 Module

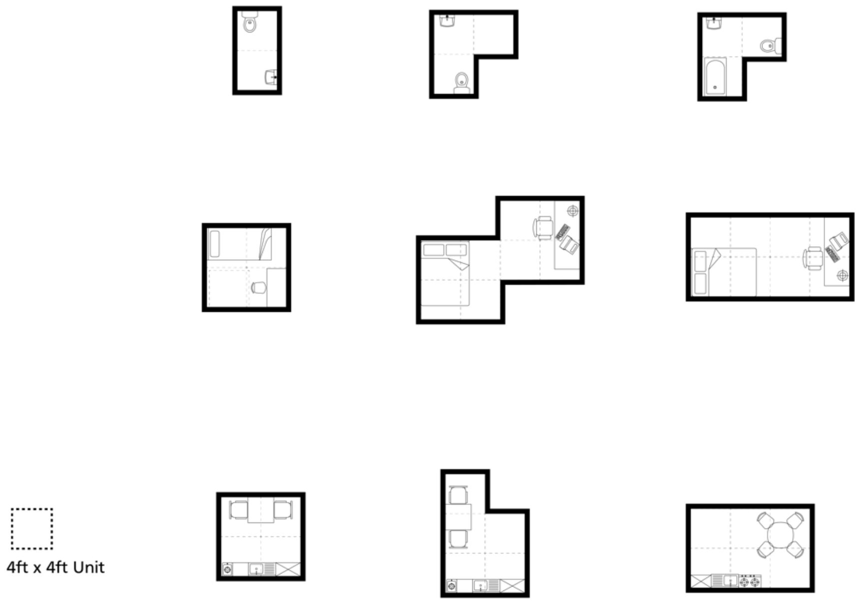

Figure 26 Module Types

Similar to that of the previous Kit-of-parts Method I, the Kit-of-parts Method II begins with a set of existing unit modules, each with a specific function and program. Derived from standard building material scales, each unit is a 4 foot by 4 foot square, with different programmatic elements requiring different variations of these units. The 4 foot scale is a reflection of the standardization of materials available rather than human scale.[40] This is in attempt to simplify the production

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process while being able to accommodate a diverse set of occupants. Through using prefabricated materials, there is also an underlying acceptance of the existing building culture as to limit the disruption of existing housing typologies and lifestyles.

3.2.2 System

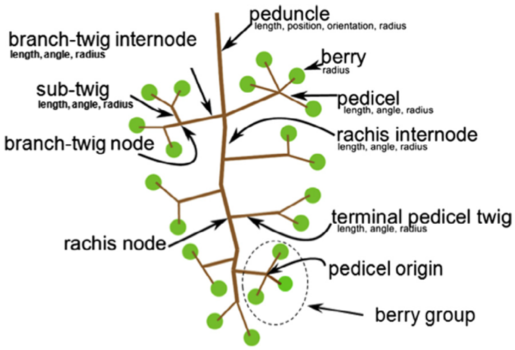

Figure 27 Principal example of a grape cluster's architecture (Florian Schöler, Volker Steinhage)

The Kit-of-parts Method II incorporates organic processes for energy transfer to address the issues of overly complicated shared utility networks. Mimicking fruit formation, or more specifically berry formation, the unit modules are encased in a larger building envelope. The arrangement of the smaller programmatic modules is based on sequencing that can be seen in grape berry formation which ensures an equal transfer of energy. Also, the sequential arrangement of spatial

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Stephenson pg 130-137

qualities provides a deeper understanding of the relationship between privateness and publicness with a natural spatial hierarchy that stems from said branching formation. This pattern of organization is also the major conceptual approach of Space Syntax, commonly used in computational analysis of spatial conditions.

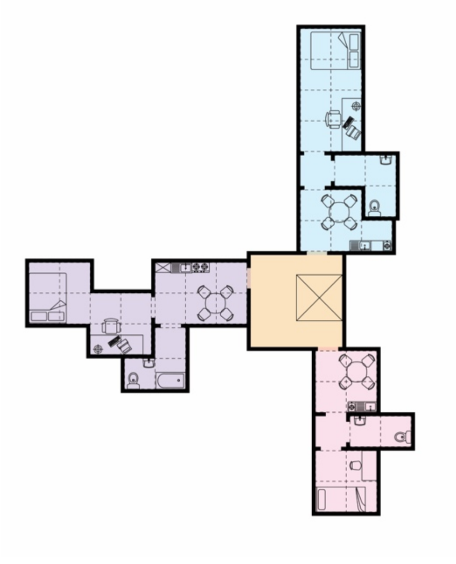

Figure 28 Module arrangement around core

What differentiates this method of design from previous modular experiments is the use of consistent arrangement of spaces based on the energy and spatial hierarchy within a user's specific routine. The concept is deeply related to energy transfer and the movement within the spatial conditions rather than simply arranging programmatic elements around a central heart or core of the housing. Often times, the central room is used as a way to encourage social engagement, but in the case with the growing demographics of single member households, this social element is no longer a major artery in the programmatic understanding of space.

A large part of the early dismissal of modularity came with the shift in attitudes towards housing and mass production. While issues with building technologies have since been addressed in recent developments, the strong impressions of a stiff and overly simplified housing option has averted advancements in modularity as a design tool. In order to address the social skepticism of modularity, this design approach mimics tree growth to introduce a more organic and natural design process to a highly manufactured production method.

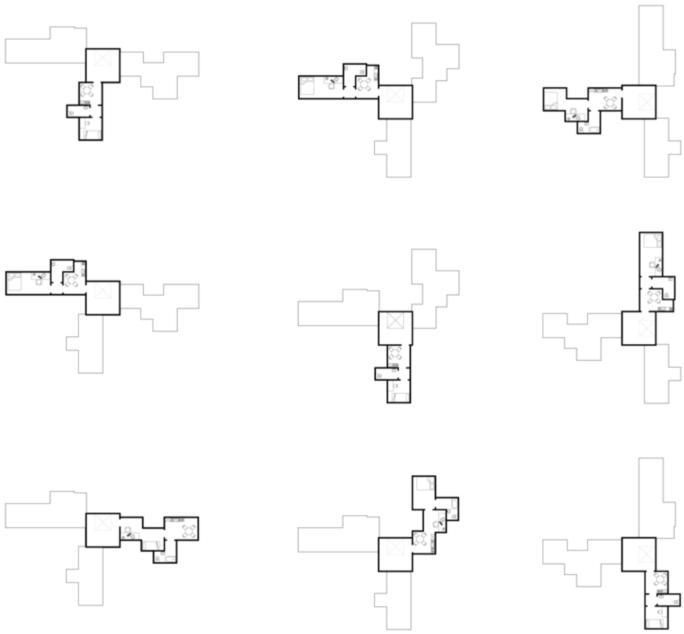

Figure 29 Apartment configurations around core

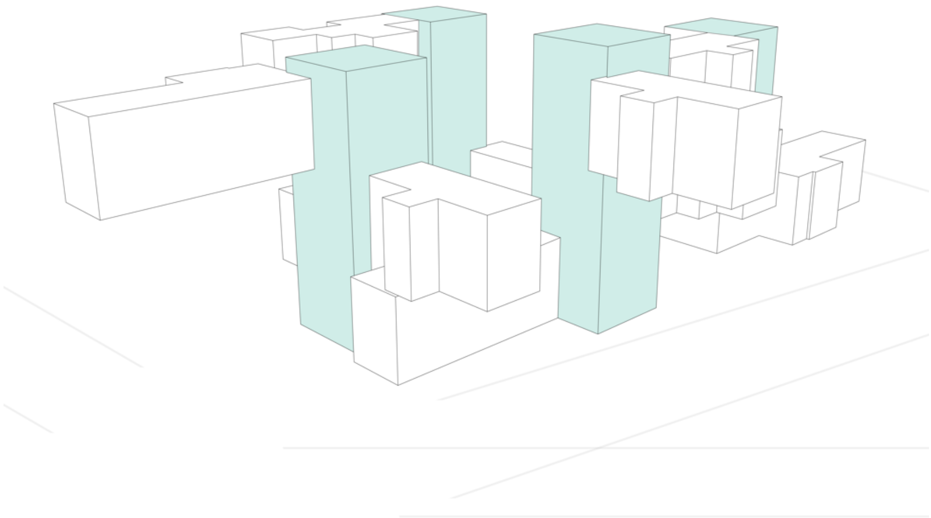

Figure 30 Apartment configurations on site

The core, in this case, is a transportation mechanism— to move inhabitants from point to point and the transfer energy from the urban grid. Structurally, the cantilever system will require additional support beyond that of the central core. Looking at natural tree formations once again, the relationship between trunk thickness and height provides clues to understand the structural requirements. Therefore, in order to achieve height, there must also be subsequent horizontal growth to accommodate additional structural stress and energy loads. In other words, while a horizontal sprawl is possible, achieving vertical growth post initial construction would require a similar horizontal growth in the central core. Current trends towards high rise structures are able to showcase the growth in technologies to achieve such height, but in the case of modularity where the stress is unpredictable with evolution, the core language should be simplified to allow for the most variations in the modules themselves. An overly complex system will not be able to support the constantly evolving modular language.

3.2.3 Analysis

The Kit-of-parts Method II focused more on the connection between apartment and apartment, whereas the Kit-of-parts Method I focuses on the connection of the interior unit modules. Method I was an introductory experiment to understanding the role of modular design in multi-unit dwelling typologies. The density of the multiple dwelling, however, changes the requirements the modular design strategy must fulfill. Requirements for a high density structure would differ than that of a small scale multifamily structure. Therefore, while the Kit-of-parts Method II begins to outline the potential solution to adapting the modular system to fit in the urban context, it does not offer a feasible solution as simple as that of the initial production process.

Both the Kit-of-parts Method I and II are constrained to the availability of the unit modules and standardized materials. The design of the initial unit modules will dictate the success or failure of the overall housing typology. To become a truly customizable process, the design of the unit modules should also be reflective of the occupant's lifestyle in the context of the larger environment and urban culture.

Chapter 4. Division Method

Design study

The previous methods focused on modularity in terms of a kit of parts production mentality— focusing on developing repetitive modules that can be prefabricated to cut production costs. In order to address the issues of a prefabricated system, the Division Method looks to developing unit modules from the daily ritual of each occupant. Rather than selecting a module based on program, the unit modules are uniquely designed for each individual user.

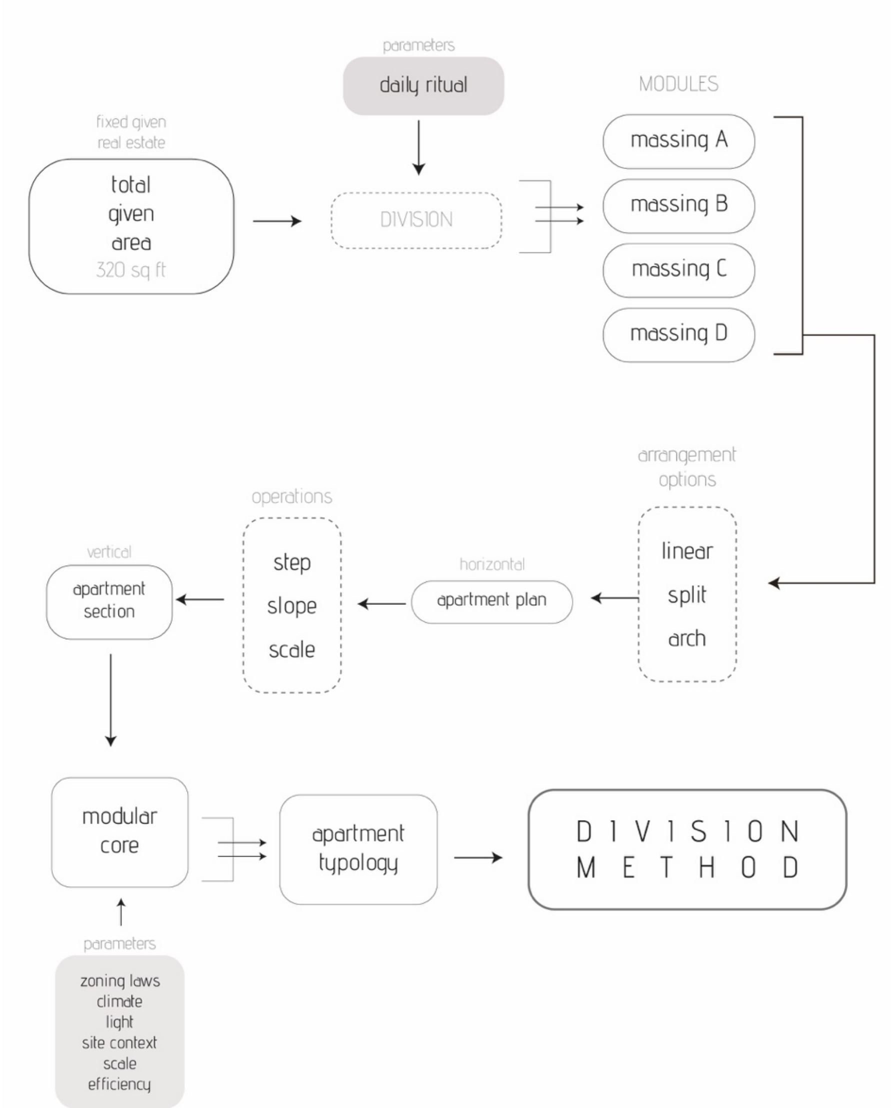

Figure 31 Method outline

4.1 Module

Starting from a fixed given area, a smaller grid is placed on the area. Looking at a plan view, the total given area is divided into a uniform 4-foot by 4-foot grid. The dimensions are based upon standard prefabricated material and the close proximity to a human scale. The grid, is the smaller units of prefabricated material that will act as the building blocks to general construction process. This grid is then cut into four distinct zones— rest, work, entry, and utility— each representing a different set of programmatic elements. Each cut, or division, through the grid must yield four sides, or four walls, to reduce triangulation in the design language. The figure below depicts the different potential division of the given grid.

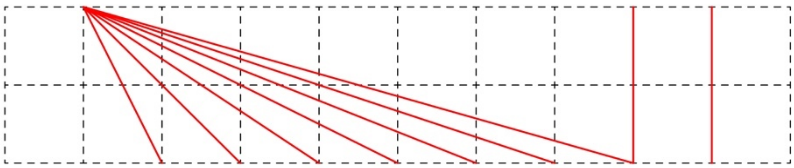

Figure 32 Cut diagram

Three cut lines result in a set of zoning masses. Each module is then composed of an arrangement of these four masses. Each arrangement follows a specific lifestyle pattern— linear, split, or arch. These four patterns are determined by the preference data of individual inhabitants. There is an opportunity, here, to utilize algorithmic approaches to optimize the floor plans at this stage. The organizational language helps to determine spatial hierarchy and the general circulation of each apartment.

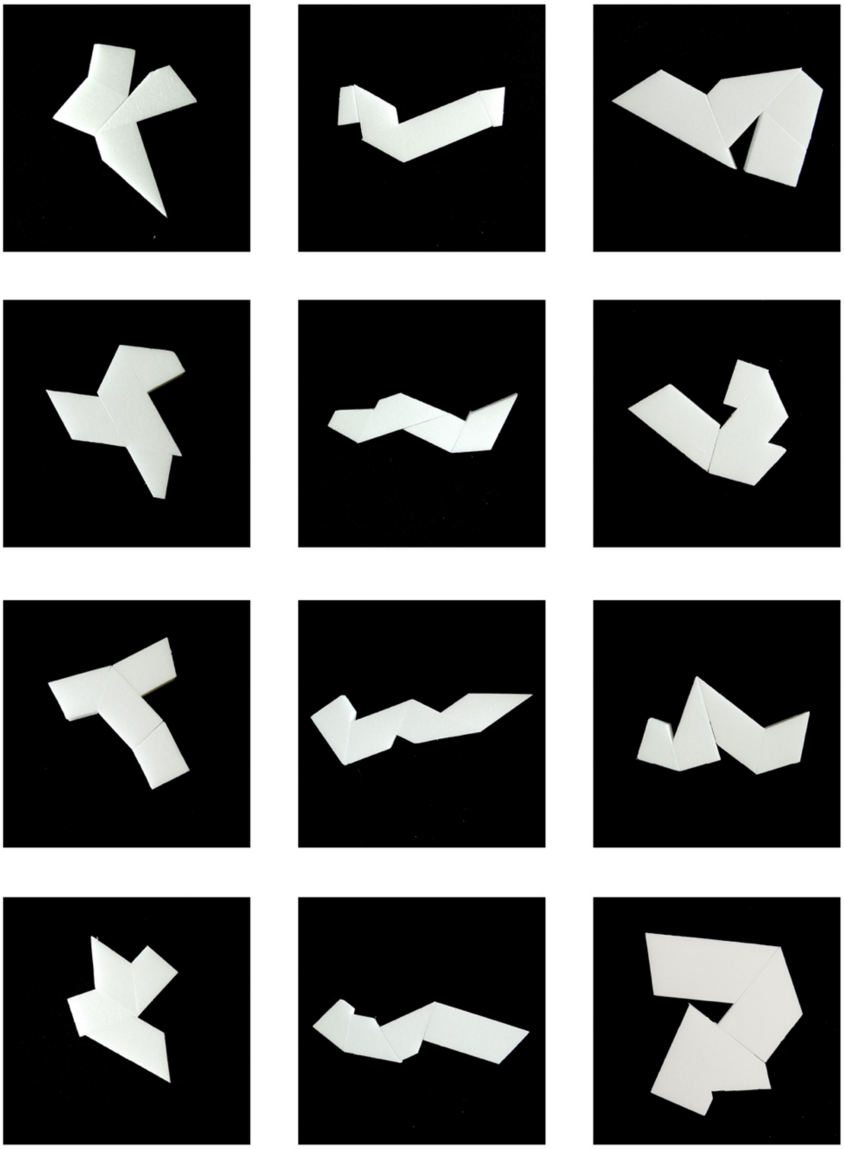

Figure 33 Massing Diagrams

4.2 Further Diversification

Table 3 Operations Table

Type	Operation	Effect
horizontal operation	Linear	creates a simple floorplan with a singular pattern of movement, simplifies circulation within the space if highly calibrated to the lifestyle of the occupant
	Split	creates a central focal point in the space, able to divide work and play or other contrasting programmatic elements
	Arch	creates a secured, private end to the space, different from the linear pattern in that the view of the entire space is blocked from the curved layout
vertical operation	Step	creates a vertical change with a flat roofline that provides opportunities for a rooftop garden or patio, works best to provide space for units going above or below given module, can be used to add additional levels
	Slope	creates a transition space from one vertical point to another, gentle transition operation, does not allow for buildable area above
	Scale	creates opportunities for changes in ceiling height, able add additional levels within the same floor area

The divisions form the base modules which are then put through a series of operations, similar to the operations used in the Kit-of-parts Method II- slope, step, and scale. Configuration of the unit modules are based upon the understanding of the movement of the occupant throughout the entirely of the apartment- working to maximize efficiency in terms of circulation.

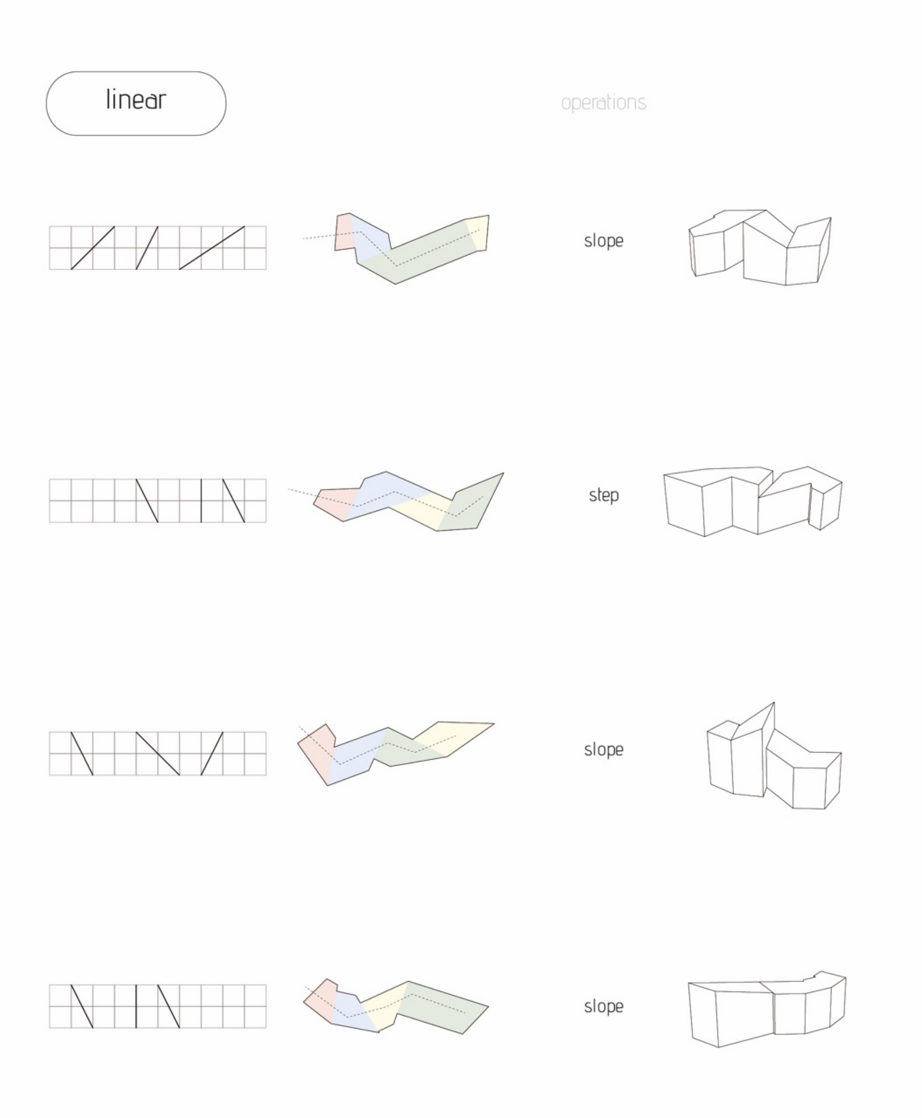

Figure 34 Linear family modules

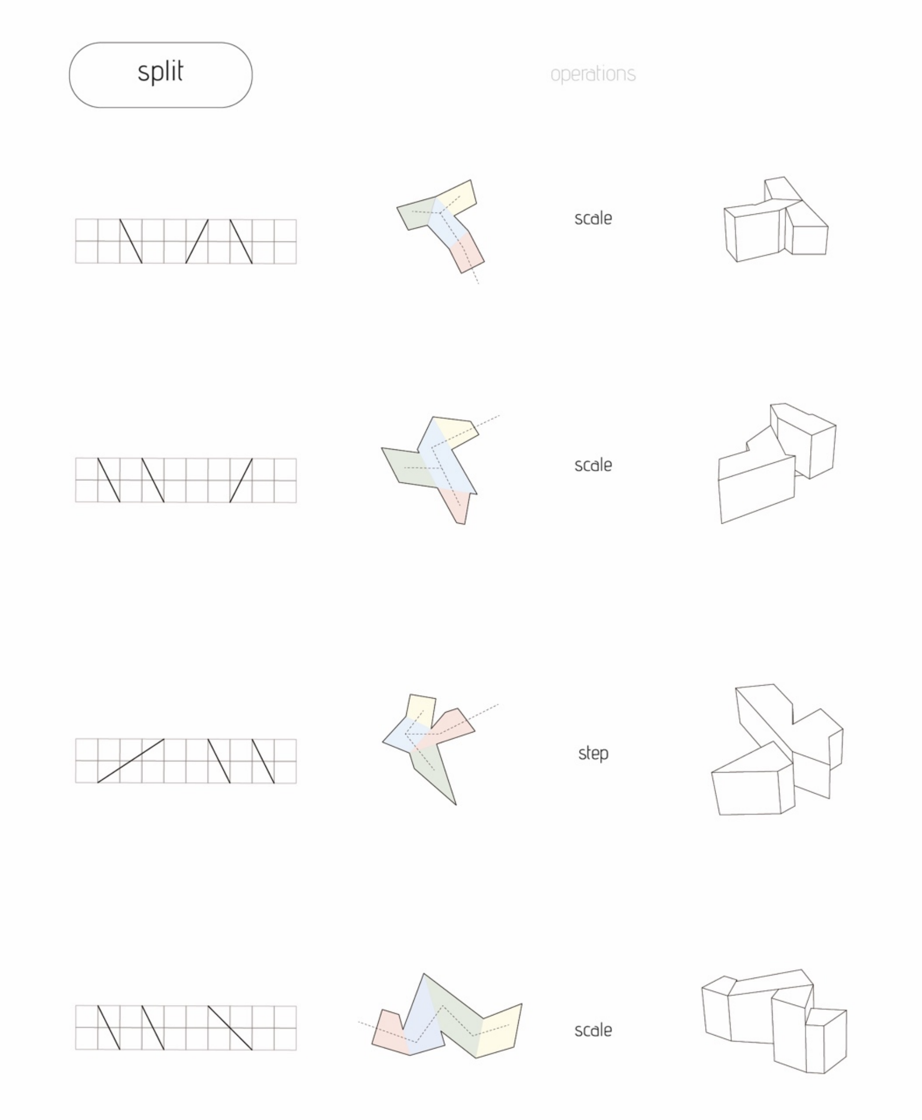

Figure 35 Split family modules

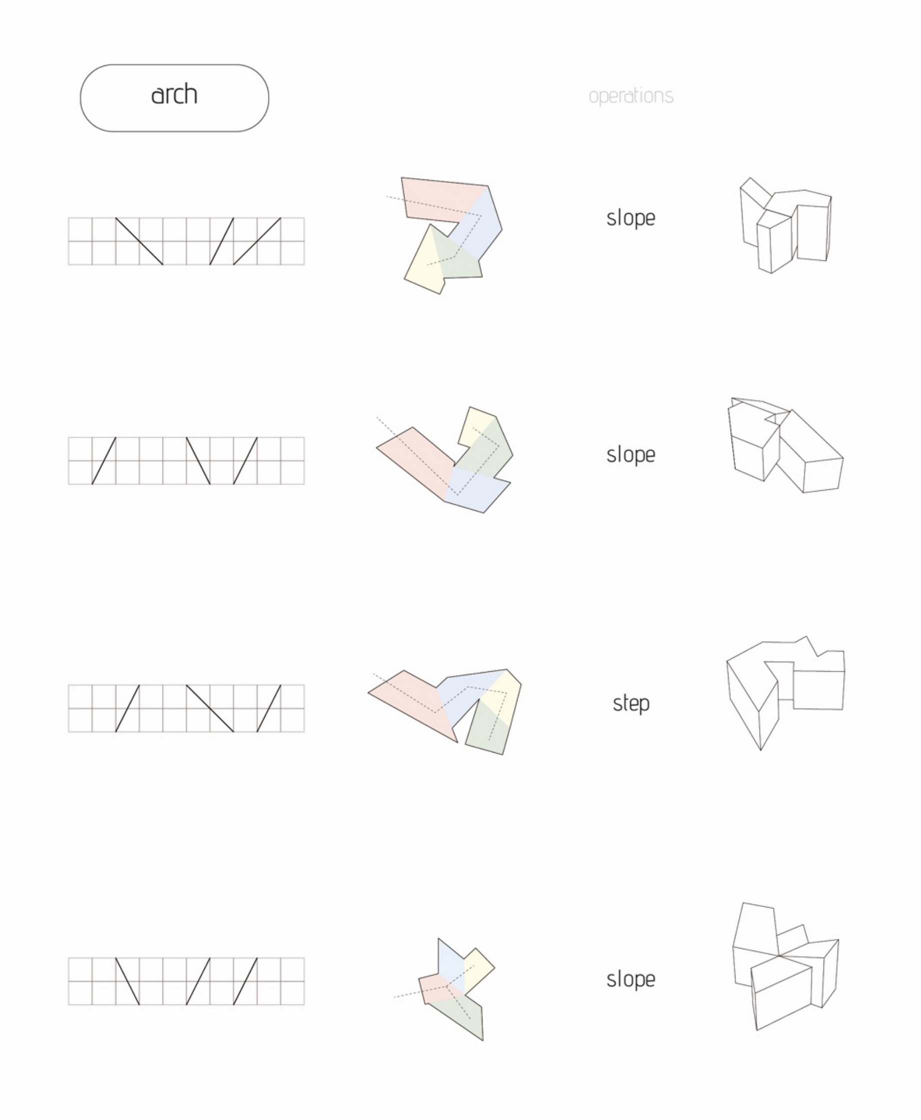

Figure 36 Arch family modules

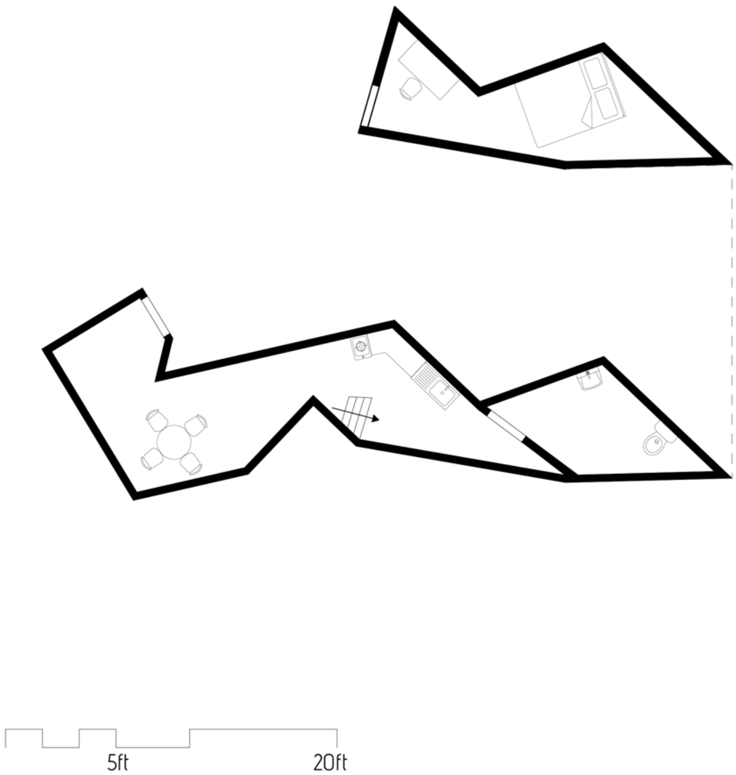

Figure 37 Plan (Linear Module x Scale Operation)

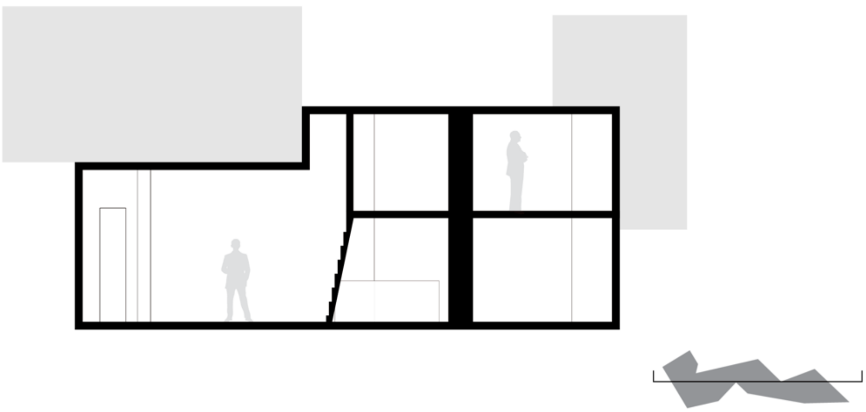

Figure 38 Section (Linear Module x Scale Operation)

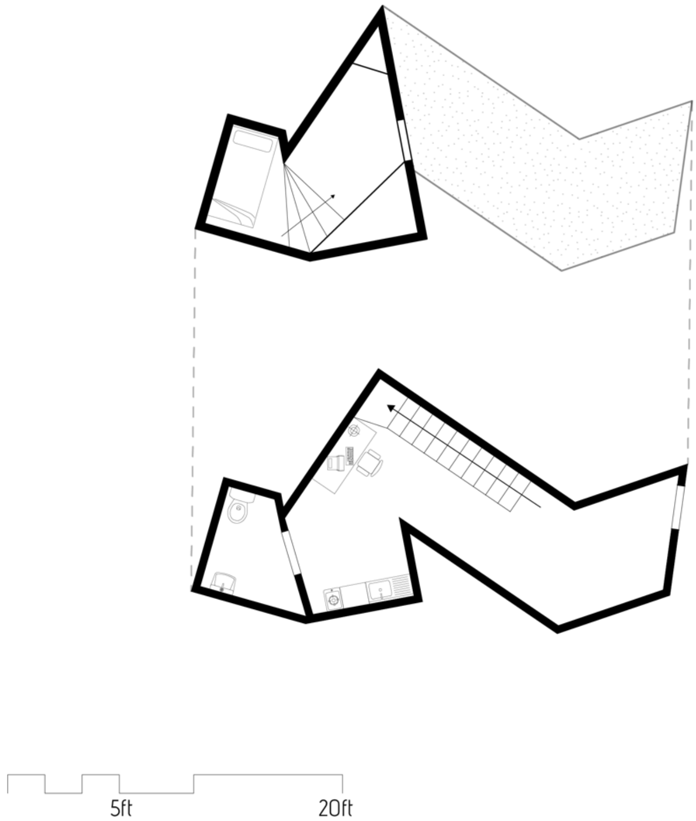

Figure 39 Plan (Split Module x Slope Operation)

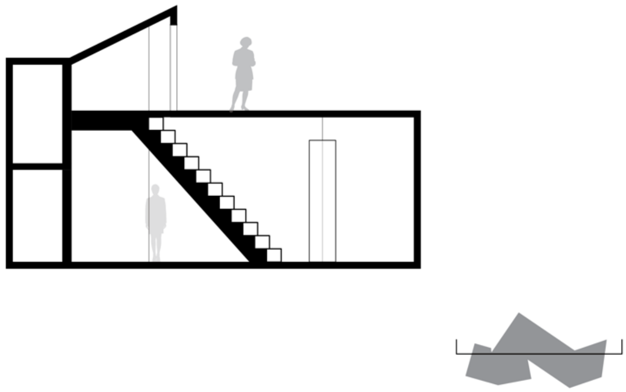

Figure 40 Section (Split Module x Slope Operation)

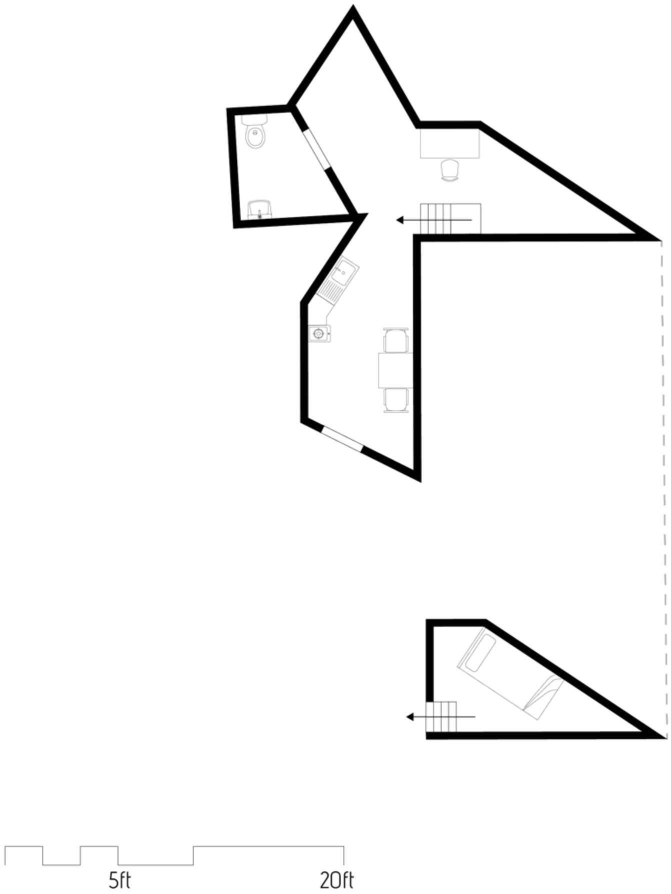

Figure 41 Plan (Arch Module x Step Operation)

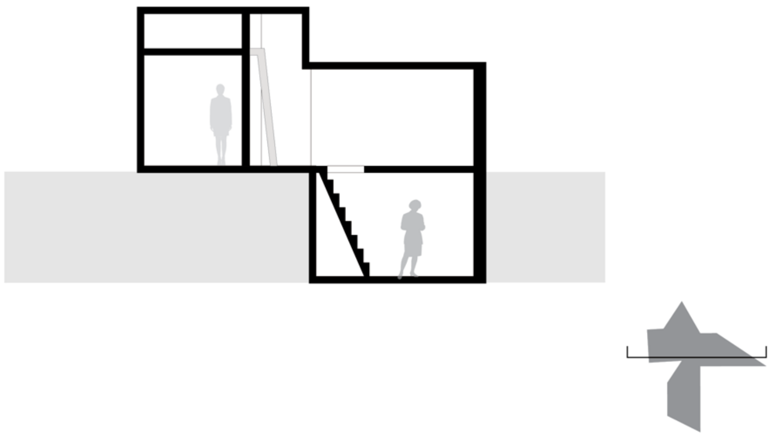

Figure 42 Section (Arch Module x Step Operation)

4.3 System

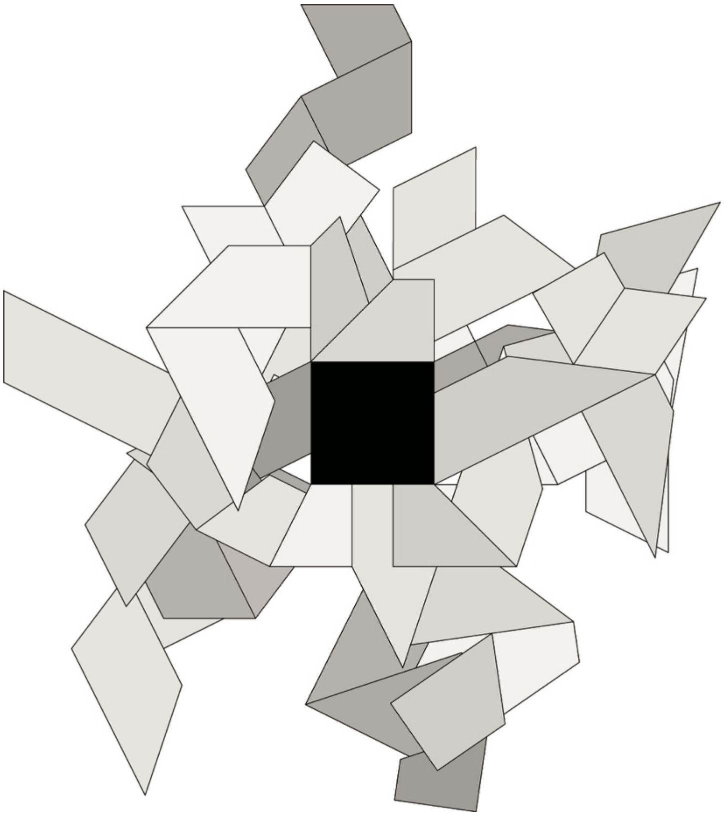

Figure 43 Top view of apartment system

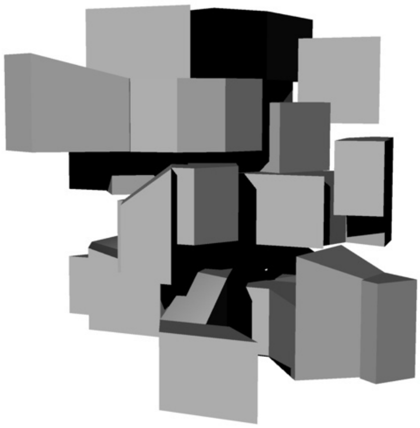

Figure 44 Side view of system, abstracted

The modular strategy continues with the idea of relating back to a central core that connects the dwelling to a larger urban fabric. In the case of this strategy, that central core acts as a trunk and the different apartment units mimic the process of leaf growth. Leaf patterns are designed to maximize sunlight absorption and stability in its connection to the branching pattern. The individual modules, in this case, are centered around a core and undergo three different operations– step, slope, or scale– to maximize natural sunlight or ceiling heights. In some cases, such as with stepping patterns, the shifting components provide accessible outdoor spaces between modules in an effort to expand the interior spaces into outdoor space.

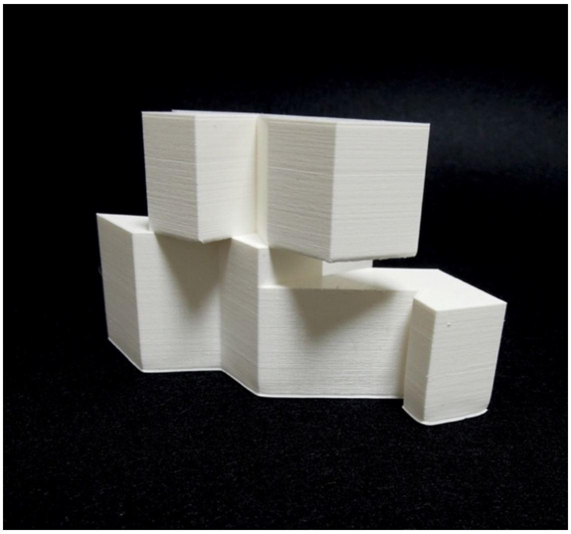

Figure 45 Form Study of Two Interlocking Modules

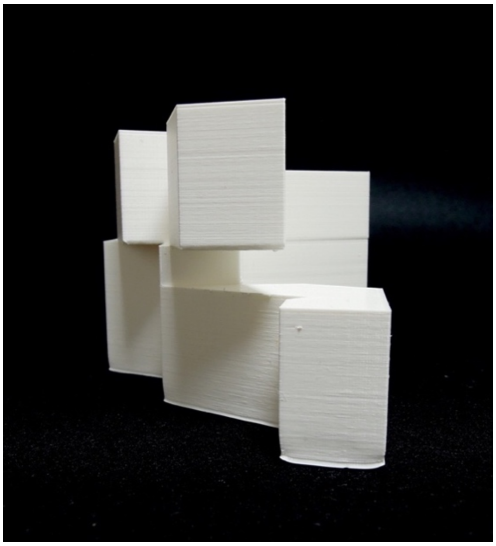

Figure 46 Form Study of Two Interlocking Modules

4.4 Analysis

The Division Method introduces the potential of a customizable design process from the initial start to finish. With mass customization techniques gradually increasing the cost efficiency of non-standardized production, there is great potential in the Division Method. However, in the current technological climate the cost of customized modules outweigh the benefits of such a method. While the modules are rooted in the base prefabricated material dimensions, the different operations create unique spatial conditions.

Technological developments in the near future, especially with 3D printing technologies or computer numerical control

(CNC) technologies becoming more mainstream, can resolve the issues of cost and construction methods. Therefore, the important factors to consider with the Division Method should be the idea of building from an inside out process, verifying the potential of a fully customized spatial configuration. The apartments that develop from the Division Method have more spatial diversity, not only in the interior spaces, but also in the exterior form itself. There are opportunities to design spaces that have a high efficiency, but also opportunities to create provocative spatial qualities at the cost of efficiency.

Chapter 5. Compound Method

Design study

The aforementioned design methods begin to shape a better understanding of the impact of modular design in the design of contemporary housing typologies. Though the cultural and technological climates are better adept at accepting the modular design process, the previous Kit-of-parts Method and Division Method do not incorporate the heterogenous character of modular design. Therefore, the Compound Method is based upon the idea of a modular system and modular kit of parts in its development of an inside-out design process.

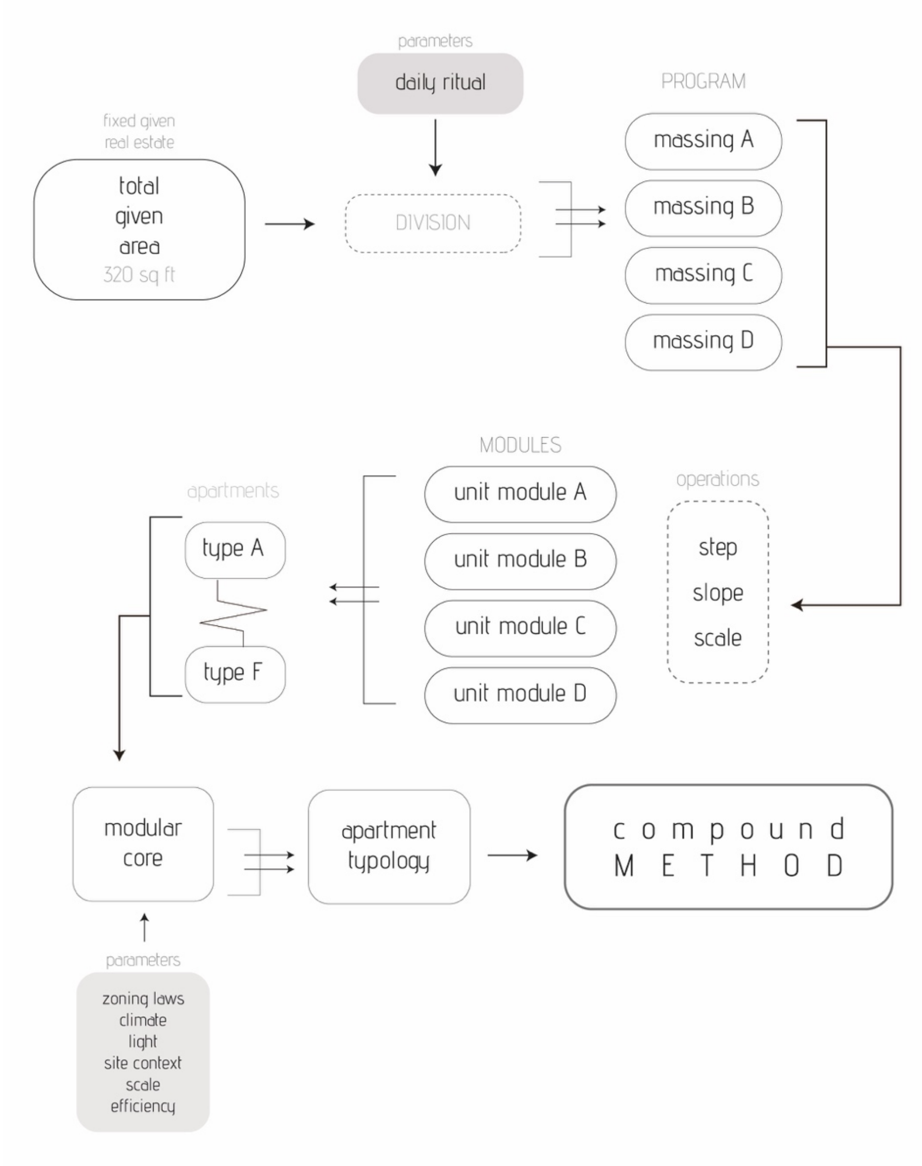

Figure 47 Method outline

5.1 Module

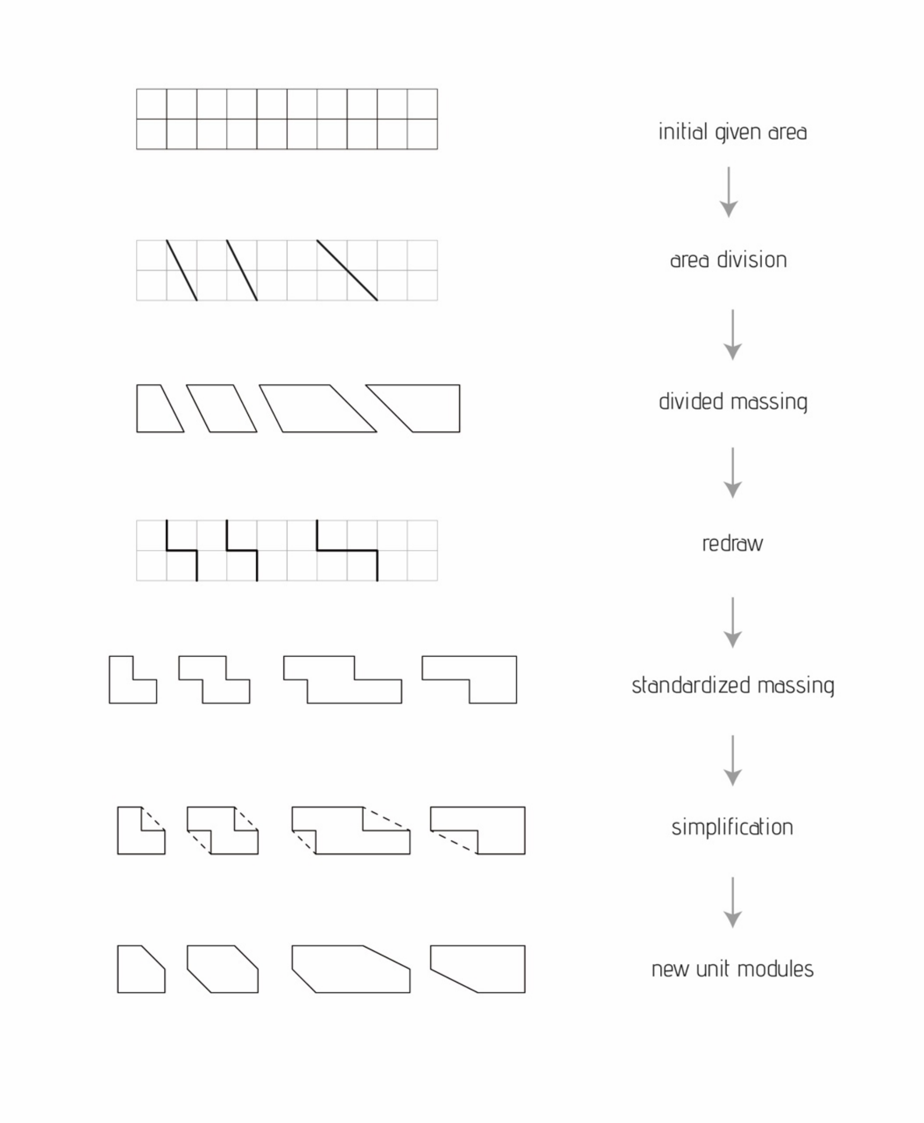

Figure 48 Module design process

The initial development of the individual programmatic modules is similar to that of the Division Method. An original area, based on the local conditions of the site, is divided into a 4 foot by 4 foot grid. The grid is then divided with three cuts, similar to that of the Division Method. Cutting the initial grid allows for a simplified division of the total area available to each apartment. Therefore, it begins to inform the design of the lifestyle of the occupants. Each programmatic space is then redrawn to fit into the exiting grid pattern. In other words, the diagonal cuts are redistributed into the grid form. This additional process ensures that existing prefabricated materials can still be used to develop the customized modules.

From the rectangular block forms, the interior corners of the modules are removed. This process creates a set of unique dimensions, but the grid process mentioned in the previous step simplify the number of customized pieces. The removal of the interior corners also increases the total area of the module without increasing wall area. In other words the total area of the space increases without having to add additional materials.

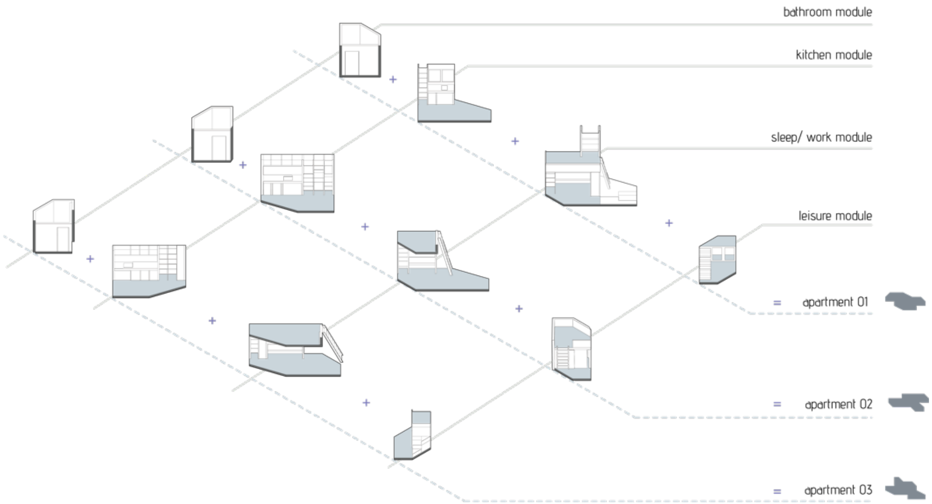

Figure 49 Module Connections

Another major difference with the Compound Method is that the unit modules are not unique to each individual user. Rather, the modules are developed to adapt to multiple users. This brings back the process of selection of the initial Kit-of-parts Method I. Unit modules for the Compound Method look at a survey of the demographics of the site, assuming the social culture of the environment dictate the lifestyle of each user. Simply stated, the assumption is that individuals looking for housing in a certain region share similar lifestyle patterns.

5.2 System

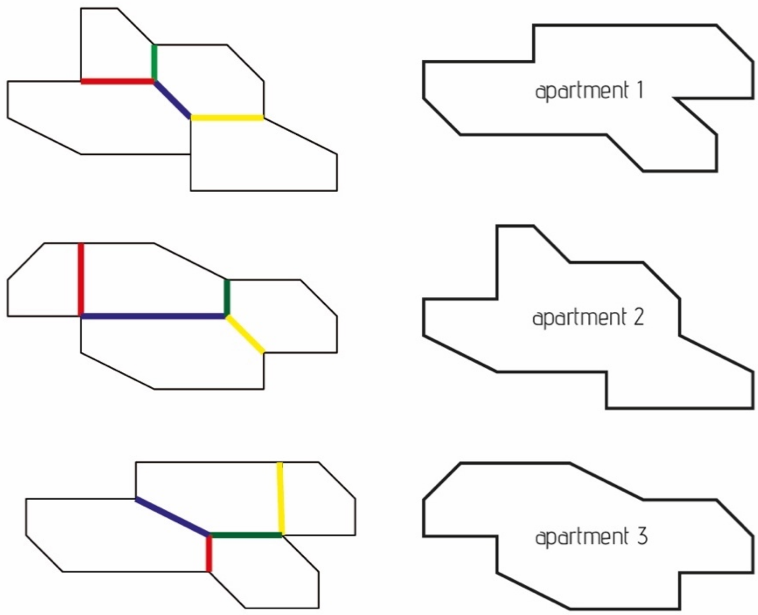

Figure 50 Apartment configurations

From the available unit modules, users can select the required configuration of modules that best suit their individual needs. These unit modules then go through a similar process of vertical operations to add variety in vertical spatial conditions. Lofted spaces divide the work and sleeping spaces while smaller unit modules act as reading spaces or storage spaces. Built in furniture, such as the floor to ceiling storage spaces, double as structural pieces to minimize the need for interior walls.

Each unit module connects to another through a shared edge. The shared edge provides a connection point in which the modules can click together, thereby simplifying the construction process. Shared edges also provide a sense of security in connecting the spaces, creating a uniform transition space from module to module to tie together the entire apartment together. The open floor plan also provides a vagueness in terms of circulation throughout the apartment to maximize freedom in the way each space is used.

5.3 Apartment Design

The following three apartments were designed to test the potential of the Compound Method. Table 3 outlines the design conditions and factors considered.

Table 4 Base Assumptions and Design Conditions

Factor	Defined Condition	Reason
Site	Not Applicable	The design strategy is meant to be applied to any set of site conditions, therefore for a specific site was not designated for the project. Rather, the project focused on understanding the validity of the process and the potential diversity of the output.
Cost	Considered: to use as much prefabricated material as possible	As a large part of the modular design process is dependent on cost efficiency, the project focused on minimizing the need for custom, non-standard pieces to remain plausible as a cost efficient solution. However, the overall goal of the method is not to focus on cost, but rather design potential of mass customization.
Material	Not Applicable	Material is no longer a limiting factor in housing design due to the massive growth of technologies and material availability. Therefore, no specific materials were assigned.
Lifestyle (of user)	Heavy Influence	The process is rooted deeply in the day to day lifestyle of unique users. A general survey was conducted to identify the overall tone for the project.
Number of Unit Modules	Considered: limited to four units	The number of unit modules allowed for each apartment was limited to four- sleep, eat, cook, and bathroom. This was to ensure

		that each apartment had the necessary requirements for a dwelling with an additional flexible programmatic space.
Number of Apartments within complex	Considered: limited to six apartments	Because larger multi dwelling complexes have different requirements, the project was developed as a smaller multi dwelling complex consisting of 6 apartments. This was in attempt to focus on the development of the interior modular connections rather than modular system. The larger system of connecting apartments reacts to site conditions and environmental factors that were not taken into consideration of the current project.

The vagueness of the given design conditions provided an opportunity to freely experiment with the design method and better understand the conceptual value of modular design. This final Compound Method was an attempt to compile the process of the previous methods and introduce the heterogenous character of modularity. Rather than focusing on efficiency of the modules, there was a heavy emphasis on creating diversity in spatial conditions in a way that best reflected the desire of the users for a unique form programmatic freedom. In essence, the Compound Method emphasized the power of choice over practicality.

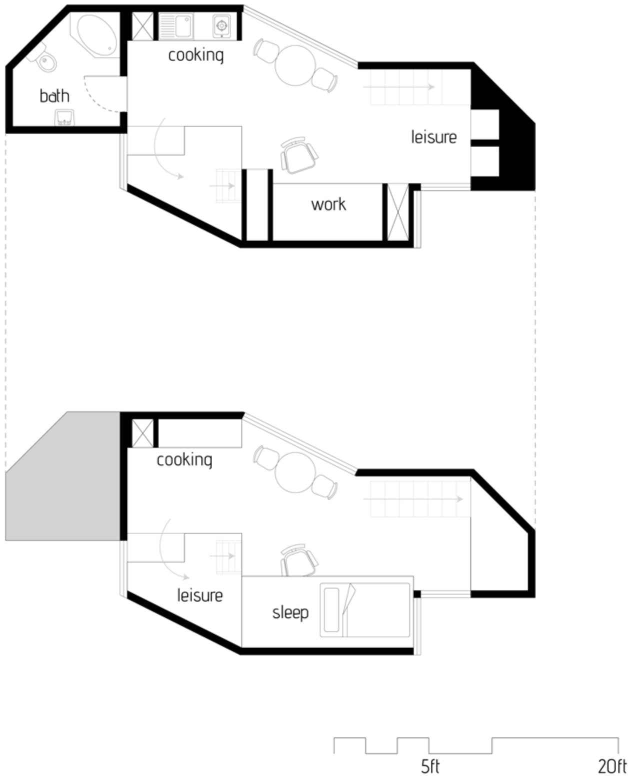

Figure 51 Plan, Apartment 1

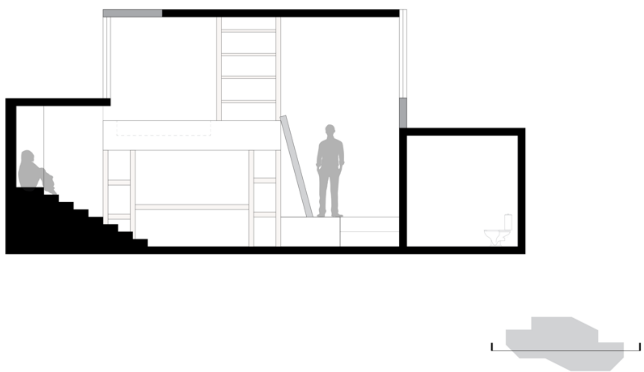

Figure 52 Section, Apartment 1

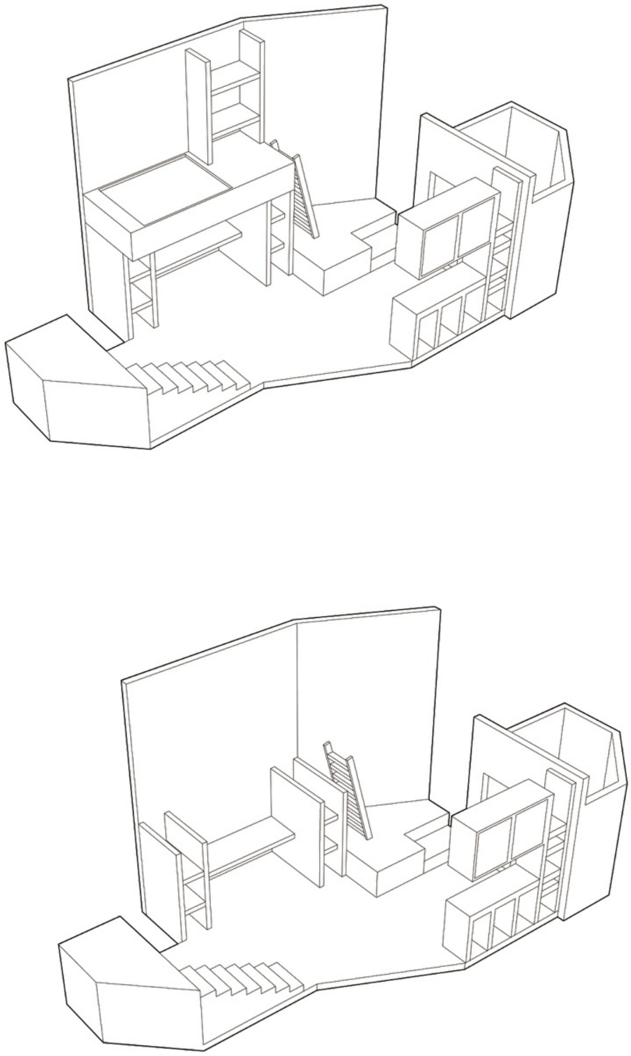

Figure 53 Perspective Drawing of Interior

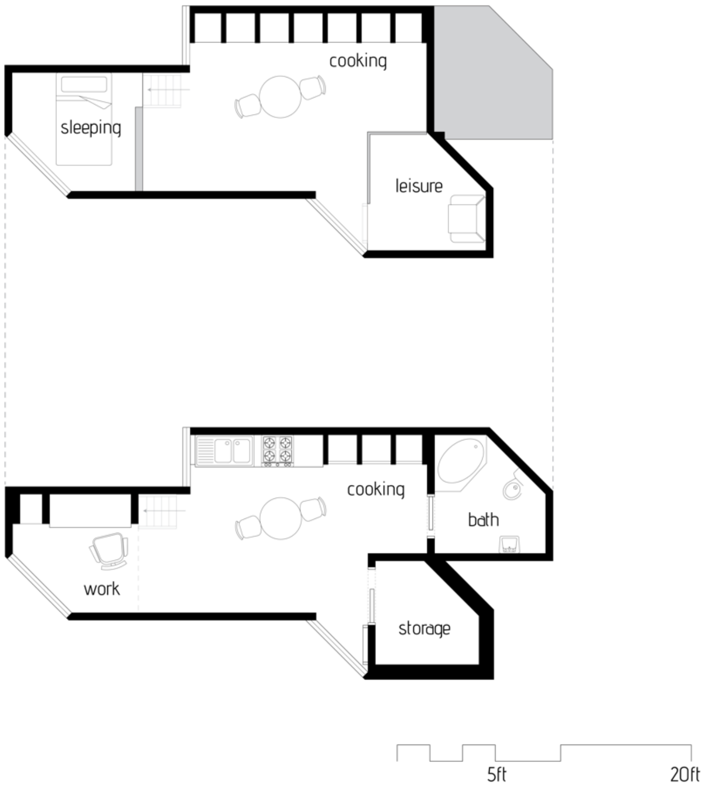

Figure 54 Plan, Apartment 2

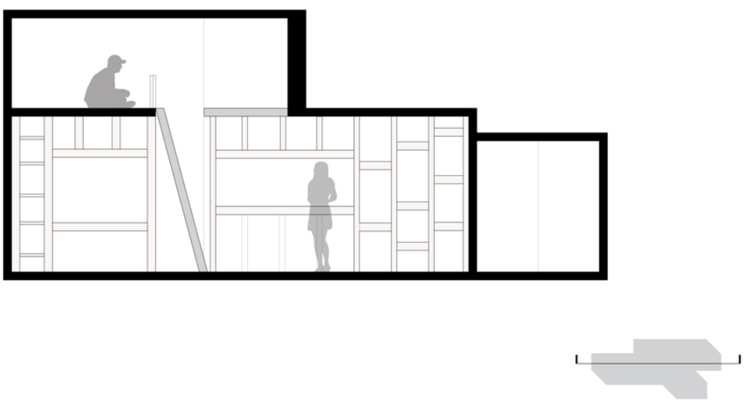

Figure 55 Section, Apartment 2

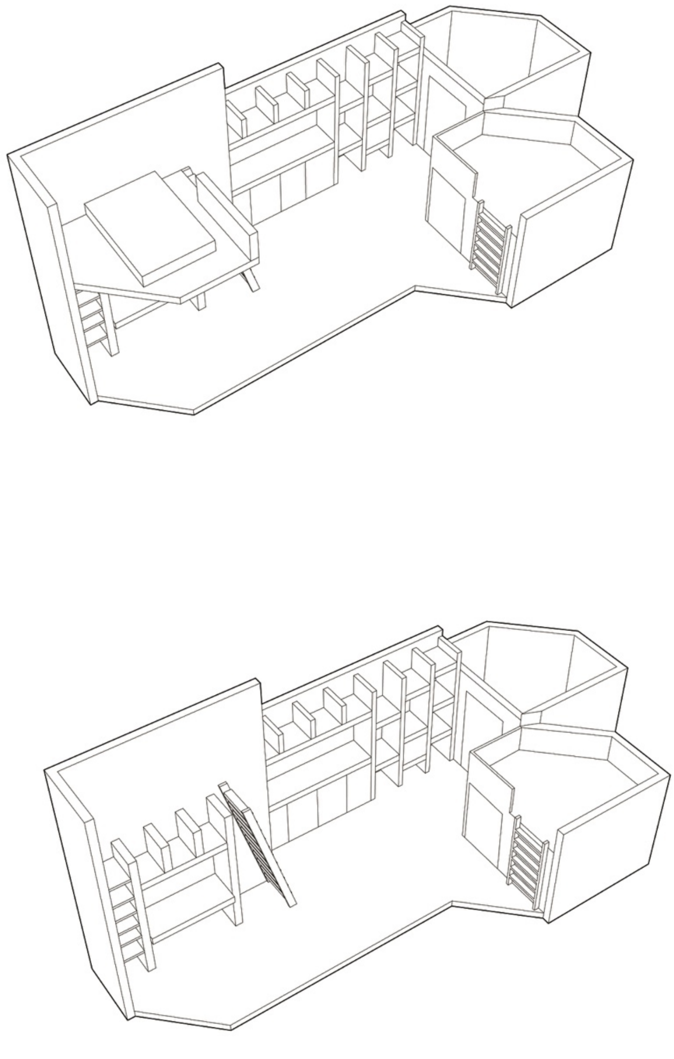

Figure 56 Perspective Drawing of Interior

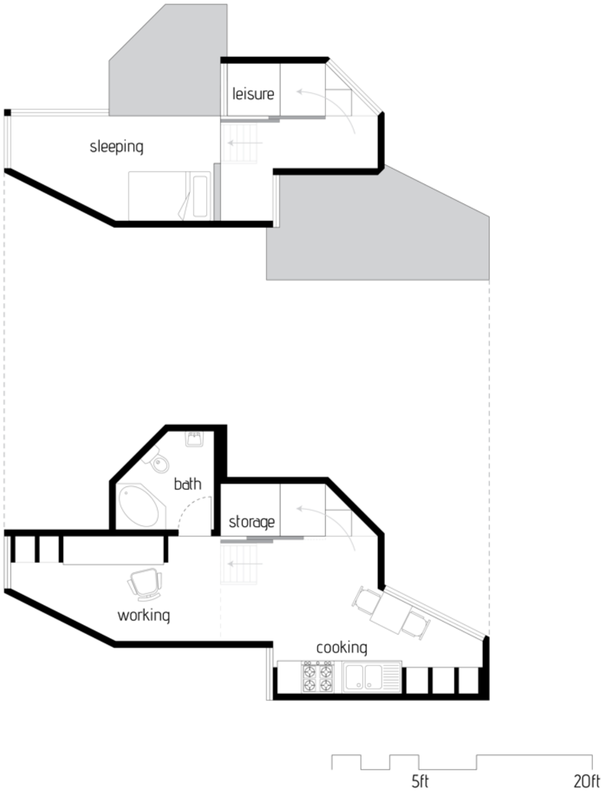

Figure 57 Plan, Apartment 3

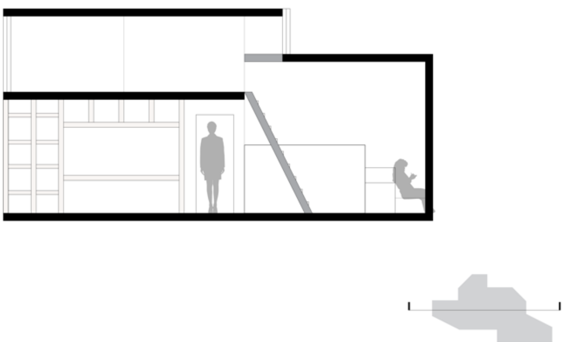

Figure 58 Section, Apartment 3

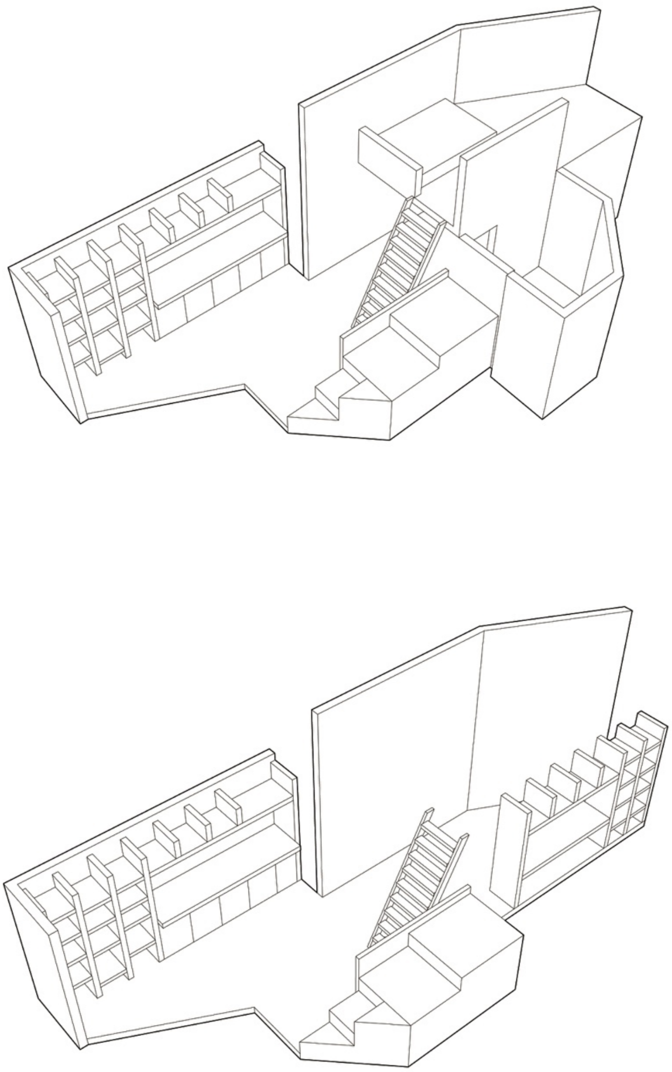

Figure 59 Perspective Drawing of Interior

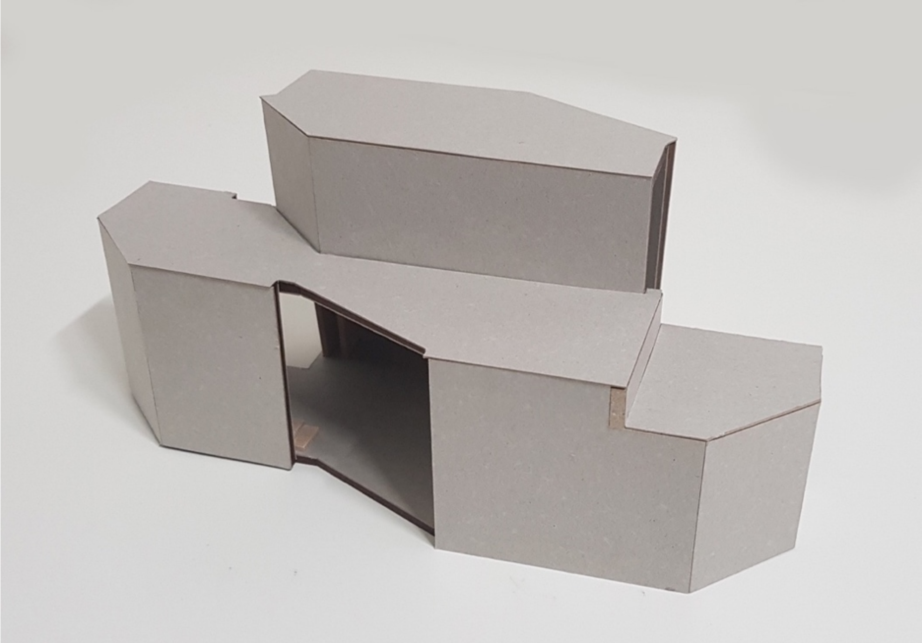

Figure 60 Apartment 1 Concept Model

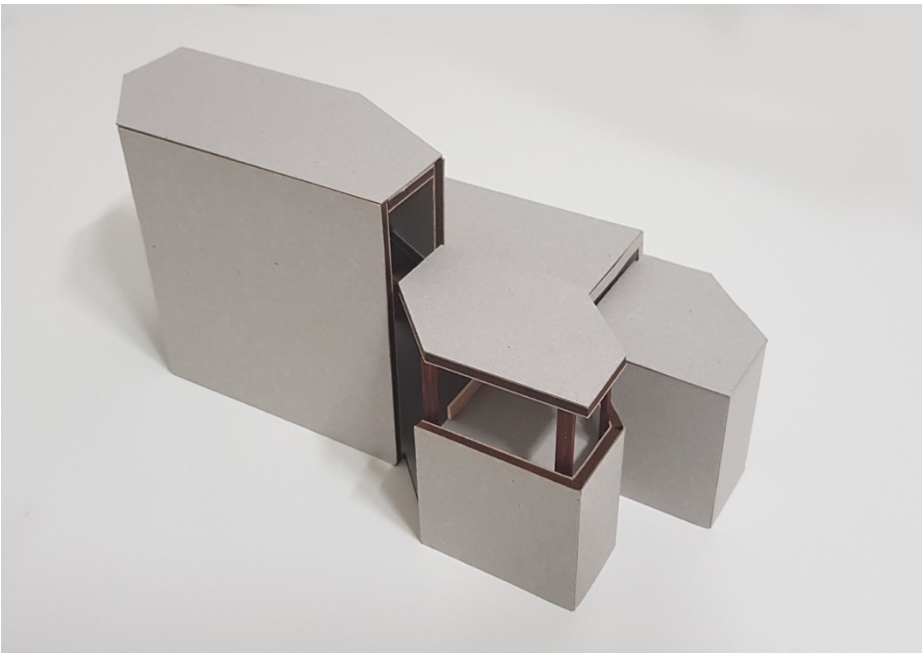

Figure 61 Apartment 2 Concept Model

Figure 62 Apartment 3 Concept Model

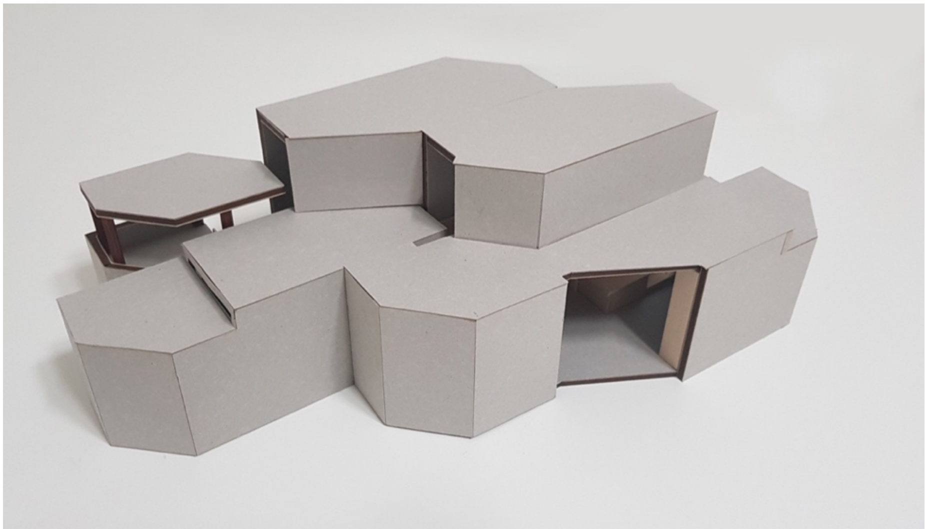

Figure 63 Apartment 1 + 2 combined massing model

Figure 64 Reading nook, lower level, Apartment 1

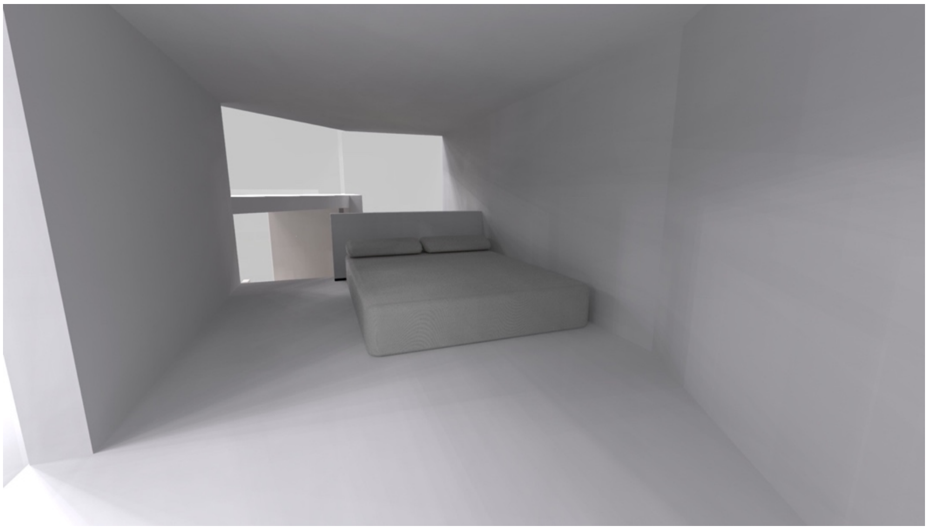

Figure 65 Bedroom loft, upper level, Apartment 1

Figure 66 Kitchen, Apartment 1

Figure 67 Kitchen, Apartment 2

Figure 68 Lofted bedroom and kitchen, Apartment 2

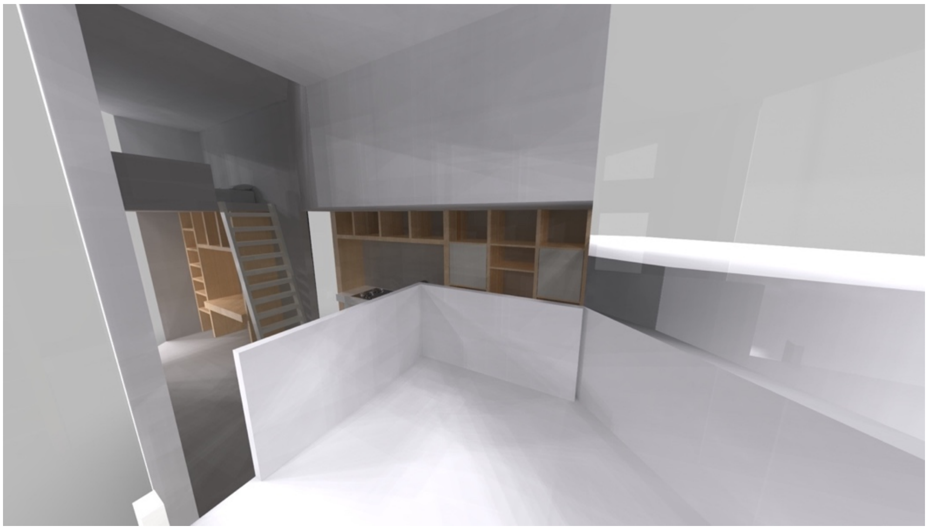

Figure 69 View from reading nook, Apartment 2

Figure 70 Lofted bed and reading nook, Apartment 3

Figure 71 Lower level, Apartment 3

5.5 Analysis

Each unit module goes through a unique vertical operation that creates a difference in ceiling heights between one module to another. This allows the interior modules to have an independent vertical system from the larger building envelope, thereby increasing the freedom in the configuration of modules for each apartment unit. There is also the added spatial awareness for the occupants to understand the different unit modules without a visual cue. In other words, there is a clear distinction from programmatic unit to unit without having to divide space using walls, adding to the openness of the small spaces.

Windows, entrances and exits were not marked in any of the apartment typologies because these details would differ based on the configuration of the larger apartment complex. However, the general tone of the enclosing system is to engage with rectangular, planar walls and more customized dimensions for windows and other openings. This allows for most of the construction to take place using existing box frame construction or board formed concrete. Materiality would depend on the existing site conditions available materials of the environment.

Conclusion

The issue of housing does not yield simple design project— rather it is a collective understanding of the relationships between people and place, daily life and space, and cultural value and politics. Modularity was ahead of its time, unable to keep up with the demand for flexibility given the existing technological advancements and overwhelming new-ness. Therefore, the current conditions with new generation of single-member households and a new technological dependence provide the best breeding grounds for a new type of modular architecture—one that works with the flexibility of our lifestyles as a whole. There is the opportunity to test permutational design, a solution that works on multiple scales across multiple disciplines, a true modular kit that works on the network of systems within urbanism rather than the physical reactions to site and built environment.

The contemporary modular design method is composed of two main pieces— the modules and system. The modules are a reaction to the existing spatial culture in existing housing types and the changing demographic conditions. Different modules are designed for different functions of a dwelling such as living, working, or leisure that are then put through three distinct operations– addition, scale, and displacement. Mimicking natural processes allow for the modules to grow and evolve to better suit the changing needs of the demographic. The proposed modular design methodology reflects the current social desires for a flexibility and environmentally conscious design solution and takes full advantage of the growth in building technologies. Currently, the role of designer is becoming much more intimate with the user as the do–it–yourself culture and mass customization practices spread. Therefore, it is important to understand that the contemporary designer is no longer the sole designer in any given situation, rather they are the bridge between pragmatism and individuality.

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초록

현대 사회 기술적 맥락에서 모듈러 디자인 재검토에 관한 연구

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현재 한국의 주택 시장은 다양성과 인간 중심의 디자인을 필요로 한다. 주거 환경에 나타난 인구통계학적인 변화와 건축 기술의 발전은 모듈러 디자인이 유연하게 변할 수 있고 사용자 중심적인 디자인 방법이 될 수 있는 배경이 되고 있다.

본 연구는 모듈러 디자인 방법을 통해 형성될 수 있는 공간의 다양성을 검증하는 것을 목표로 한다. 본 연구는 두 개의 과정으로 구성된다. 첫 번째는 과거의 모듈러 디자인 연구를 토대로 현대에 적용될 수 있는 모듈러 방식의 성질을 정의하는 것이다. 본 연구는 르 코르뷔지에(Le Corbusier)가 *The Modulor*에서 기술한 모듈의 이론에서부터 Archigram’s Plug-in City이 시도한 모듈러 도시 시스템에 대한 아방가르드한 탐구까지를 이론적인 전제로 두고 진행된다.

두 번째는 세 가지의 다른 모듈러 디자인 방법들을 적용한 소규모 공동주택 디자인 실험들로 구성된다. 모듈러에 대한 서로 다른 언어 및 해석을 지닌 세 가지 모듈러 디자인 방법들은 원룸 주거 방식에서의 공간 구성에 대한 잠재적인 유연성 및 적응성을 통해 검증된다. 제안하는 현대 모듈러 디자인 방법은 건축물을 내부에서부터 외부를

디자인하며, 이는 사용자의 라이프스타일을 분석하여 최종 결과물을 도출하게 된다.

앞선 검증 단계를 통해, 기존 모듈러 디자인 방법의 단순함을 유지함과 동시에 비선형적인 형태를 만들어낼 수 있는 가능성을 발견할 수 있었다. 3D 프린팅 및 Computerized Numerical Control(CNC)와 같은 새로운 건축 기술들은 사용자에게 맞춤화 된 구조를 더욱 쉽게 대량 생산하게 하고, 이를 통해 모듈러 디자인은 새로운 가능성을 가질 수 있다. 이러한 기술들은 현대의 건축에서 모듈러 디자인 방법이 지닌 유연성이 더 현실적으로 구현 될 수 있게 한다. 그러므로 모듈러 디자인 방법의 한계점은 공간적인 다양성을 만들어내지 못하는 것에 있는 것이 아니라 그것을 구현할 수 있는 기술의 발전이 제한되어 있다는 점이다.

현대 디자인에는 모듈러 디자인 방법을 제작뿐만 아니라 디자인 전략으로서 실험할 수 있는 여러 가지 흥미로운 사회-기술적인 조건들이 존재한다. 이 연구에서 제시된 모듈러 디자인 방법은 디자인 과정을 위한 공식이 되고자 하며 이에 따라 일반적인 사람들의 필요와 욕망을 반영할 수 있는 디자인의 가능성을 열어둔다.

주요어 : 모듈러 설계, 모듈러 디자인, 사용자 중심 디자인, 모더니즘,
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