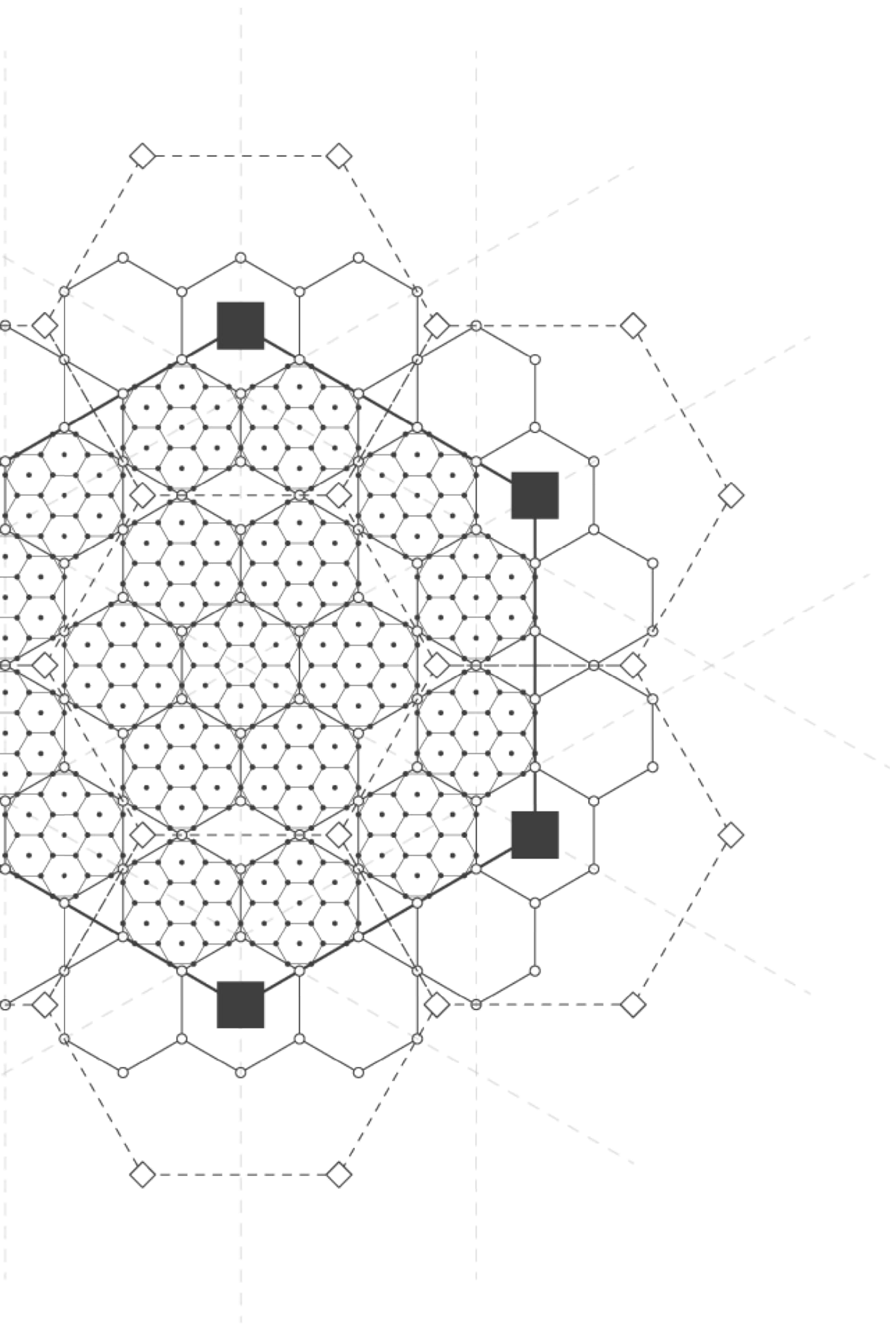
Cell, Parasitism, and Proliferation

Design framework of self-organization for architecture and urban design



Hsin-Yun Lai
2022

Aalto University
School of Arts, Design
and Architecture

Cell, Parasitism, and Proliferation

Design framework of self-organization for architecture and urban design

Master's Thesis for Master of Arts
Creative Sustainability
Aalto University
Helsinki, Finland

Hsin-Yun Lai
2022

Author: Hsin-Yun Lai
Title: Cell, Parasitism, and Proliferation –
Design framework of self-organization for architecture and urban design
Department: Design
Degree Program: Creative Sustainability
Year: 2022
Number of Pages: 109
Language: English
Supervisor: Mikko Jalas
Advisors: Filz Günther

Abstract

In this century of urbanization, cities have become complex systems that face diverse socio-environmental challenges. The task for planners and architects is to find suitable solutions which correspond to these challenges in order to achieve sustainable cities. Significantly, construction is one of the highest carbon-emitting industries, but it is essential for modern life. To date, the mainstream design approach for architecture and urban design has been the rigid and top-down masterplan. This static design approach is implemented for efficiency in this property-led society, and architectural projects see the final moment of the construction as complete. However, the persuade toward sustainable cities led to the requirement for adaptive and flexible architecture and urban design for future dynamic changes. This call for adaptive capacity underlies sustainability and resilience theory.

This study's goal is built on the assumption that the city is an organism and treats architecture and urban design as forms of integration. The Japanese Metabolism propositions are unconscious responses to architectural sustainability and include the feature of self-organization. To correspond to the cross-scale system and organic city assumption, the concept of Japanese Metabolism and self-organization was chosen as the fundament to this research. The goal of the study is to develop a self-organization design structure for urban and architecture design based on a review of theories and cases. Buildings and cities can evolve depending on user lifestyles and needs. The alternative offered by this study aims to respond to the vulnerable environment and space requirements of the future.

Keywords: resilience, adaptive cycle, self-organization, stigmergy, architecture, Japanese Metabolism, sustainability, dynamic

Content

Chapter 1 Intro

As societies continue their fast-paced development, more than half of the population live in cities (Ritchie & Roser, 2018). According to UN-Habitat, urbanization will increase in the world over the next decade, from 56.2 per cent in 2020 to 60.4 per cent by 2030 (Knudsen et al., 2020). The 2019 United Nations Environment Programme report shows that 11% of excess carbon dioxide in the atmosphere results from manufacturing materials and products such as steel, cement, and glass (IEA, 2019). Carbon emissions from the building sector have also continued to rise by nearly 1% per year since 2010 (IEA, 2019). Societies face more issues than in the past, ranging from climate change to pandemics.

1-1 Introduction

In the century of urbanization (AlWaer & Illsley, 2017), humans confront more severe surroundings and complex social issues in dense urban areas, ranging from aging society to economic inequality (Knudsen et al., 2020). In addition, after industrialization and World War II, architectural design mainly remained property-led and focused on efficiency based on material performance and standardized design. These urban planning and building design approaches no longer provide resilient and sustainable strategies for rapidly changing environments and relative social issues (AlWaer & Illsley, 2017). In light of climate change and the diverse social background of users, the living place must incorporate flexible designs to respond to different circumstances.

Cities are complex systems that must incorporate continually changing and dynamic institutions. The systems contain dynamic cross-scale interactions among different components and never stop encountering evolution-decay processes (Eken & Atun, 2019). The mainstream urbanistic and architectural design approach centers around a centralized structure with a strategic vision following a masterplan (Giddings & Hopwood, 2018). However, in the last four decades, some have criticized this approach for being an inflexible and static framework which cannot meet the dynamic environment, nor achieve sustainability (AlWaer & Illsley, 2017). Although miscellaneous theoretical proposals for improving the masterplan have been put forth since the 1960s, these manners are still insufficient, limited, and lack a connection between the urban fabric and architecture (AlWaer & Illsley, 2017; Eken & Atun, 2019). To achieve the goal of a sustainable city, the stakeholders in the domain should rethink the design approach, including the architectural design and the inputs in the design structure. This means, the design approach of urban planning and architecture should be discussed based on the assumption that the two ought to be seen as integrated.

The pertinent research questions are:
When cities/architectures are seen as a biological system, what is the design structure?
How does the self-organization mechanism operate in urban and architectural design?
What are the time-scales among different units in urban and architectural design?

Urban planning and architectural design are not friendly, accessible domains for the general public. They require professional discipline and training (Bullivant, 2012; Giddings & Hopwood, 2018). As the rigid and top-down design method and power structure, this study questions whether masterplan is the adequate answer for architecture and urban design for the complex urban fabric. In addition, the historical Japanese Metabolism movement provided visionary thinking for dynamic adaptability to architecture and urban design but failed due to the insufficient and unrealistic proposals. However, they left many seminal proposals for self-organized design forms and architectural sustainability. Hence, this thesis aims to explore a dynamic design framework of self-organization through the examples of Japanese Metabolism and built on the design structure of masterplan.

1-2 Background

In May 1960, the World Design Conference was held in Tokyo with the theme of "*City Plan and the Future Architecture.*" Approximately 250 international architects and designers attended the meeting, including a cluster of stellar architects, such as *Louis I. Kahn*, *Peter Smithson*, and *Paul Rudolph* (Lin, 2010). Among these intellectuals, a group named "*Metabolists*" presented a manifesto with the notion that the city should be capable of continuous growth, renewal and even decay (Koolhaas & Obrist, 2011). Today the demolishing of *Nakagin* Capsule Tower, a centerpiece concept of Japanese Metabolism, reprises the idea that architecture and the city were like living organisms and operating through principles of metabolism. Although several reasons led to its failure, including unmovable and oversized units, the idea is still a metaphor for the possibility of sustainable architectural.

As cities become complex systems and encapsulate social-environment issues, a new topology of sustainable architecture design is required for the current society. *Eken* and *Atun* (2019) defined the integrated connection of self-organization and resilience theory as an adaptive system. They chose Japanese Metabolism as the basis of the discussing the integration of urban plan and architectural design. The ultimate goal of the study was to combine resilience theory and a self-organizing system through the cross-scale interactions between architecture and the city. *Eken* and *Atun* (2019) divided the study into three parts: descriptive theoretical research, historical research, and explanatory theory. In the theoretical section, they summarized several theories underpinning resilience and self-organization in urban design and identified features of the framework.

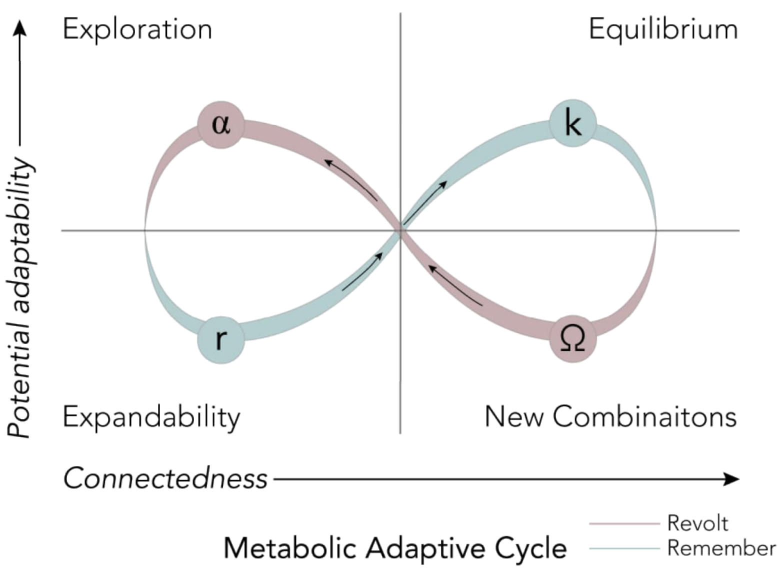


Figure 1. Metaphoric elucidation of the metabolic adaptive cycle.

1. The theory of resilience and self-organization have been integrated as keywords when researching cities as socio-ecological systems.
2. The adaptive capacity of resilience is a critical driver for self-organization.
3. The resilience feature relates to the ability to self-organize within the cross-scale system.
4. Elaboration and innovation at the local scale are essential elements for urban transition.

They further explored the past visions of Japanese Metabolism and the resilience adaptive cycle model for developing a theoretical framework that relates resilience and the self-organizing system jointly at the city scale. Japanese Metabolism was seen as the initial creation of self-organization and resilience on a cross-scale between architecture and urban design. As such, they reviewed it as fundamental to the discussion. Based on the above knowledge, they established a framework of urban self-organization on integration between architecture and urban design.

The study revealed adaptive genetic capacity as a critical feature of the self-organizing city. The proposal of the self-organizing resilient city provides a metabolic adaptive cycle for the theoretical framework. The model is built on the resilience adaptive cycle and can be divided into fore-loop (*revolt*) and back-loop (*remember*), which foster the cross-scale innovations and maintain the system. The city model considers architecture as the fundamental component in urban planning, which accomplishes the system of the small-scale invention (architecture) and large-scale maintenance (urban design). Although the study clearly defines the theoretical framework of the self-organizing resilient city, the system's practical mechanism remains abstract. As a result, this thesis aims to extend *Eken* and *Atun* (2019) research on the self-organization design framework for architecture and urban design with a more definite structure and practical process, including a further understanding of self-organization and its features of architecture and urban design.

	Revolt	**Remember**
Scale	Small	Large
Speed	Fast	Slow
Force	Progressive -innovative and positive to test and experience new ways to allow change	Conservative -does not allow the system to accumulate a new stability and certainty
Function	Internal organization	Accumulated memory
Property	New opportunities to increase the system capability for adaptation	Investigate a long-term resilience

Table 1. Revolt and remember cross-scale interactions.

1-3 Objective

This paper will discuss a more practical aspect of the self-organizing resilient city based on the research of *Eken* and *Atun* (2019). The aim is to find out the features and principles of self-organization for architecture design and connect them with the urban fabric. The study will conceptualize self-organization as a design framework for an integrated approach between architecture and urban planning.

Chapter 2 Literature Review

Resilience and Self-organization

Eken and *Atun*'s (2019) study shows the potential flexibility of resilience and self-organizing that first explained species' adaptability in ecology in the 1970s. Resilience focuses on the dynamic relationship between transformability and stability. The adaptive cycle model provides a framework for including innovation and the boundary of a cross-scale system that features related to self-organization. For a comprehensive understanding, here will further understand the principles of resilience, the adaptive cycle, and the self-organization mechanism.

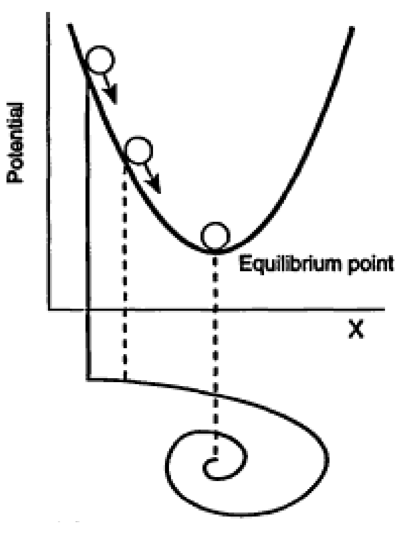


Figure 2. Engineering resilience

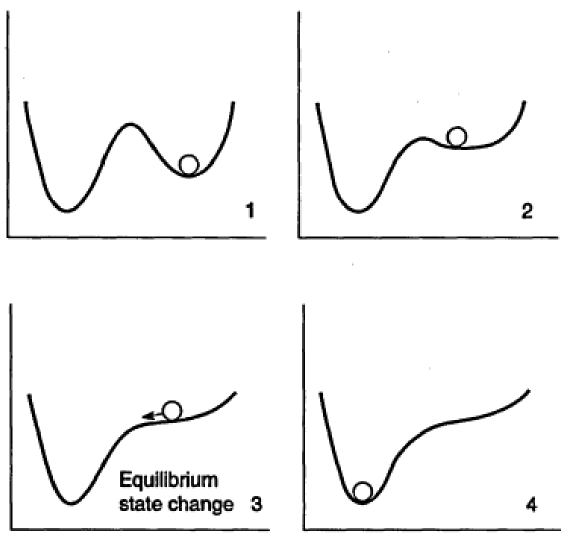


Figure 3. Biolodical resilience

2-1 Resilience: Engineering, Ecological, and Social Resilience

With a deepening understanding of biological and environmental science, the environment and biota have been shown to mutually interact and transform each other. With the increasing human impact on the global environment, people are more aware of the host of these impacts and have a growing concern about the ecological implications of designs (C.S. Holling, 1996). Designers are reconsidering the relationship between environmental sustainability and artificial creations.

In the late 20th century, *Holling* (1996) pointed out the features of ecosystem structures and identified two different forms of resilience within a system (AlWaer & Illsley, 2017; C. S. Holling, 1996; C. s Holling & Gunderson, 2002). One is engineering resilience, which focuses on efficiency and predictability. This resilience emphasizes control. It concentrates on stability near an equilibrium constancy and system design with a single operative unit. The other is ecological resilience, focusing on persistence and unpredictability. The conditions of the system are away from any equilibrium stability and are constantly transforming. The study shows biological resilience plays a vital role in the design of an ecosystem, in which the relationship between development and environment is seen in the interplay between stability and instability. When a system encounters changes, these two resilience mechanisms react differently. Engineering resilience emphasizes the efficiency of function; it responds rapidly and bounces back to its original state. This reaction quickly leads to the system being dependent and myopic. The efficient control and effective management of resources result in the system becoming more vulnerable and less resilient or adaptive to dynamic changes. By comparison, ecological resilience supports robustness in system behavior through the feature of diversity. The diversity can be explained as each unit operating on its own, but with overlapping ranges, which provide a buffer zone for adapting variables within the system. In addition, it allows the system to accept external variables, which the internal interactions will reconcile. This dynamic structure builds into continuous probing and corrective action mechanisms, making design sustainability more realistic.

Different methods and domains define and explain the resilience notion in considerable variation in literature (Eken, 2019). However, the similarity in their explanation is the ability to adapt to coping with change. Three resilience are identified in the interdisciplinary development, including engineering, ecological and socio-ecological resilience (Eken, 2019). In the concept, ecological refers to all life in the biosphere. The social aspect of resilience refers to the human dimension in society, including economic, political, and cultural (Folke et al., 2016). However, when cities act as complex organic systems that simultaneously contain a natural mechanism and social structure, social-ecological resilience plays a leading role in the operation.

2-2 Adaptive Cycle: Buffer Disturbance and Create Novelty

Holling and *Gunderson* (2002) continued the above theory and proposed a comprehensive model called "*Panarchy*," which further explains the adaptive cycle in nature, culture, and change in the future (C. s Holling & Gunderson, 2002). To them the adaptive cycle is the adaptive capacity of a complex system, which can be understood as a loop going through four phases and responding to external changes. This loop model can be divided into two stages: two-dimension and three-dimension.

The four steps of the adaptive cycle are sequentially: exploitation(r), conservation (k), release (Ω), and reorganization (α) (Eken & Atun, 2019; C. s Holling & Gunderson, 2002). The time in the loop flows unevenly, as the time between exploitation and conservation is slowest, while the others flow rapidly. The system operates in a periodic cycle starting from rule establishing, growing, and accumulating to instability and collapse, rebuilding and novel invention through the instability among units within the system. The two-dimension adaptive model is the periodic loop with a relationship between potential (for change) and connectedness (internal connection). As the individual bond decreases, the entity's mutation and innovation happen more frequently within the interactions. This mutation enhances the system's flexibility for generating new solutions for adapting to unpredictable change.

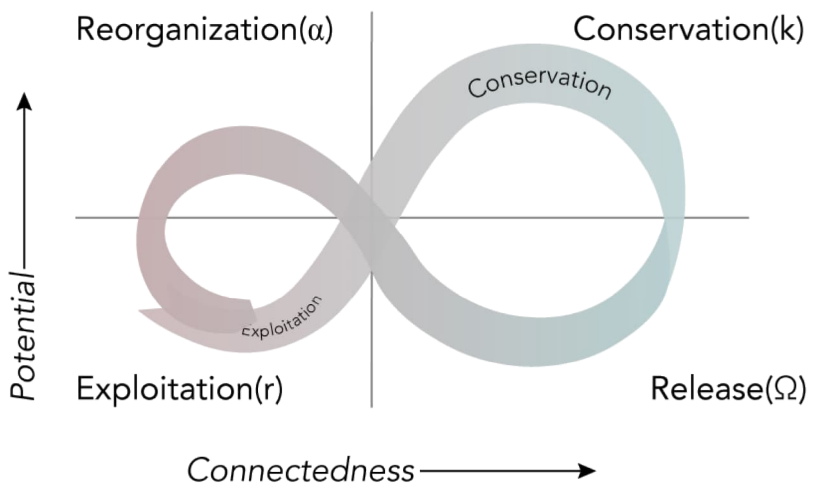


Figure 4. Two-dimension adaptive cycle

When the adaptive cycle applies in the three-dimension model, the added axis of resilience anchors the quality and quantity of the whole system. Under the condition of the reorganization phase, the system is in a broadly stable domain, but with weak regulation and connection between elements. It is an ideal experiment state. Successful results will grow and accumulate, and feedback will be returned if one fails (C. s Holling & Gunderson, 2002).

In the 1970s, another term used for resilience in the adaptive capacity of the ecosystem was self-organization. This is an adaptive mechanism via internal cross-scale interactions for external changes (Eken & Atun, 2019; Narahara, 2010). Over the years, many planners have applied the method to urban design but rarely involve the architectural design of the system as an integration (Christensen, 2014; Giddings & Hopwood, 2018; Heylighen, 2016; Narahara, 2010).

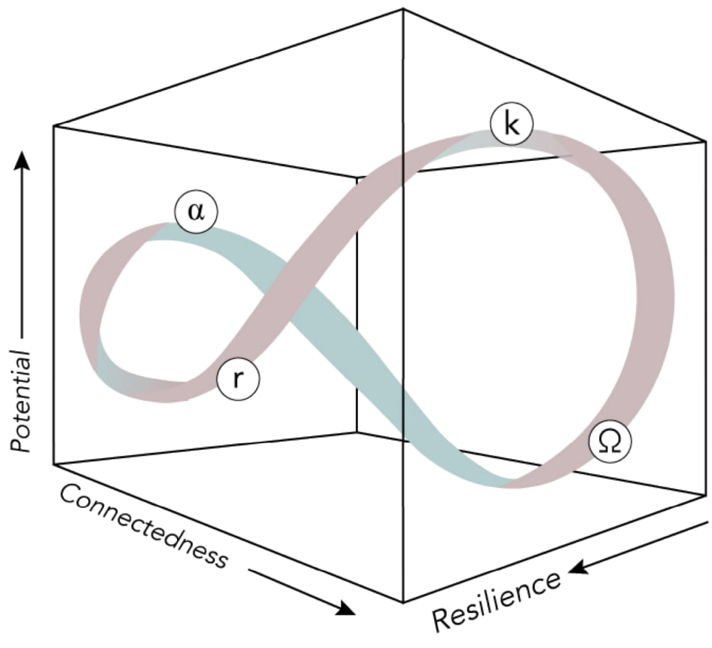


Figure 5. Three-dimension adaptive cycle

2-3 What Is Self-organization?

Self-organization is a pattern-formation process that interacts internally from the initial individuals/units, and further accumulates across different scales and influences the whole system (Camazine et al., 2001). This phenomenon occurs in various domains, including physis, chemistry, computer science, and more. It can also be commonly observed in biological systems (Heylighen, 1989; Narahara, 2010), such as the cell dividing in a human body and social behavior in insects (wasps and termites). According to *Camazine et al.* (2001), self-organization refers to a process of complex structure and patterns at the global level produced by a multiplicity of simple interactions by numerous uncomplicated components at local levels. It is also defined as a spontaneous process of an organization without being steered by external influences. Patterns of the system are composed of individual operations and interactions, which accumulated in an ordered arrangement of units in space or time. The pattern of internal interactions is also an emergent property of the system. It is a process of interacting components, not the simple superposition of actions from single members. This characteristic deals well with complex issues and adapts to unforeseen problems.

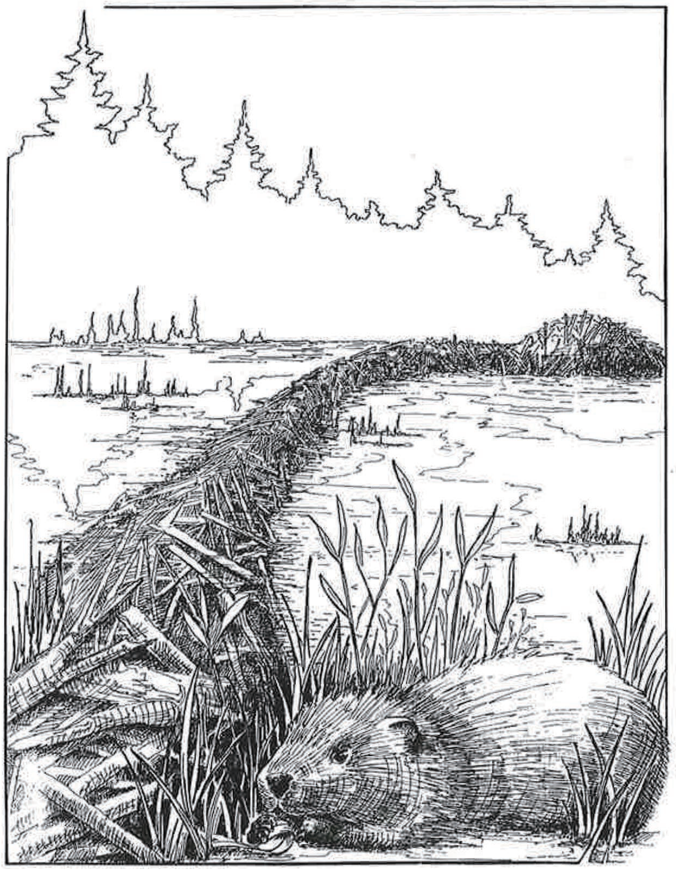


Figure 6. Beaver building behavior

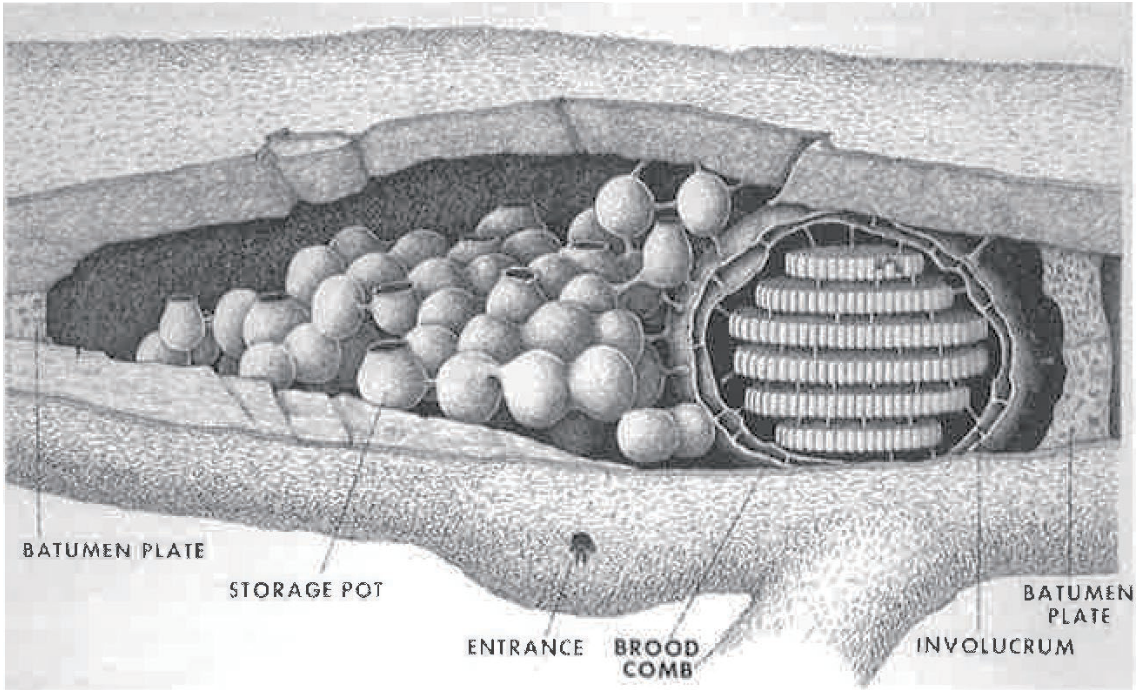


Figure 7. *Social-insect nests*

There are some examples of animal behavior in the biological systems to clearly explain the logic of self-organization (Camazine et al., 2001; Narahara, 2010). Beavers do not need a blueprint or construction plan to guide their build. Biologists speculate that the building behavior of beavers is intrinsic and genetic. Beavers would be triggered by the surrounding habitat and act in response to that input. Thus, "*rules/ patterns*" have been programmed in beavers, and cues from its habitat also trigger the construction actions, allowing them to build without an overall scheme. The construction processes by humans are centralized and scheduled. There is little space for adjustment during construction and after. Architects and developers dominate the design and configuration first, and the later construction team will follow the blueprint and plan. This approach does not tolerate later adjustment and change.

In contrast, wasps or termites utilize collective construction to establish their nest as an example of self-organization (Camazine et al., 2001; Isaeva, 2012; Narahara, 2010). The individual wasp or termite perceives the changed condition of the external environment, such as the change of temperature or humidity. This perception would trigger different reactions, and they would adjust their behaviors to find a more suitable nest and move the larvas to a more stable and secured place. However, there are potential patterns behind the motivation these individuals in the group do not lose control (Isaeva, 2012). As a result, logical rules or patterns have to be implicitly established before the operation of self-organization. Due to the flexibility of self-organization, the system does not need to be perfect as patterns can improve themselves during the procedure.

2-4 How Do Self-organization Work?

The self-organizing system, as a decentralized problem-solving system (Camazine et al., 2001; Narahara, 2010), operates by interactions of similar units or events in a hierarchical system. It is a multiple-level, nonlinear, and circular system that establishes its rules and interaction patterns during the stigmergic activity process. Stigmergy can be defined as "*a mechanism of indirect coordination, through the environment, between individuals or actions*" (Heylighen, 2016, p.4). Its adaptive capacity results from the adaptive cycle, which operates through repetitive growth-collapse-growth phases to adapt to external variations (Eken & Atun, 2019). With constant experimentation and amendment, the structure will be more flexible and dynamic for future growth.

Simultaneously, the multiple-level operation pattern enhances the resilience of the interactions within the self-organizing system (Heylighen, 1989). From the horizontal level, interactions of the system are composed of numerous individual components that are independent and similar, but functional interaction. The performance between individual interactions relies on two main mechanisms: *feedback* and *information* (Camazine et al., 2001). On the other hand, the exchanges also cross scales, where each interaction would trigger the next round of activity. The balance of the vertical interactions is maintained by two forces within the system, *revolt* and *remember* (Eken & Atun, 2019). The following paragraphs will explain the rules in detail with examples.

1. Stigmergy: the fundamental mechanism of Self-organizing system

Self-organization is generally operated through communication or interaction among individuals or agents within a system (Dipple et al., 2014; Heylighen, 2016). During the Stigmergy process, individuals do not need to communicate directly, but share a small amount of information to allow group decision-making. (Heylighen, 2016; Olsen, 2019). It is a coordination mechanism that ensures individuals accomplish parallel tasks and subsequent actions/reactions are executed. The concept of Stigmergy was first proposed by French entomologist *Pierre-Paul Grassé* in 1959 (Dipple et al., 2014; Heylighen, 2016; Theraulaz & Bonabeau, 1999), resulting from the behavior of social insects and the mechanisms underlying the emergence of collective intelligence. Later research showed that Stigmergy is a prime example of a system being able to tackle complex problems via spontaneous ordering of swarm intelligence and can be applied to different realms.

From the perspective of human collaboration, *Wikipedia* is an excellent prototype for explaining Stigmergy (Heylighen, 2016; Olsen, 2019, 2019). The Wikipedia system allows users to edit the content and compose an online encyclopedia built on the users' spontaneous improvement and expansion of content. User action is stimulated by previous content that automatically updates based on the other users' insights. Each author does not communicate with other users, but only reacts to the existing content on the website. The *Wikipedia* system provides simple rules for positive expansion and utilization, such as searching, browsing, and editing. On the contrary, the system also employs negative management rules like reporting mistakes and regulation teams to manage controversial issues.

Stigmergy is a mediated mechanism of coordination between individual interactions, and this process acts in a loop. An individual's trace of reaction is left on the environment, which will evoke the implementation of subsequent responses. When the environment reaches a certain threshold, the system will follow the rules and trigger the following action. A simple instance is a heater in a Finnish student dormitory. The heater follows a condition that when the temperature reaches 15-17 degrees, the heater will automatically turn on. This reaction is similarly reflected in chemical reactions. The related products and results will be active when necessary conditions and resources are satisfied. For instance, when two chemical elements meet within a specific medium or surrounding, they react and produce products and effects.

Figure 8. *Wikipedia icon*

2. Horizontal Level: Positive and Negative Feedback

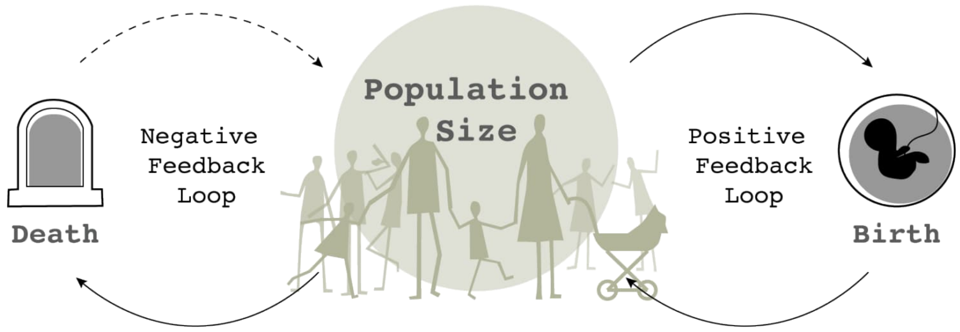


Figure 9. Positive and negative feedback

The first mechanism is positive and negative feedback, which maintains and balances the stability and innovation of the system. The growing and expanding structure of a self-organizing system mainly relies on positive feedback. Simultaneously, it generally promotes changes within the system. On the contrary, negative feedback acts as a control mechanism that helps limit excessive expansion and consumption, reminding the system of potential disturbances.

A good example here to explain the positive and negative feedback in the system is population growth (Camazine et al., 2001). The incremental growth of the human population in the previous centuries demonstrated the influences of positive feedback — health improved, and mortality declined in the system. The positive loop elicited an initial change in a system and strengthened the direction of the original deviation. However, the negative feedback will ultimately stabilize population growth — decreasing fertility rates often arise when the amplified population impacts the living environment. Metabolist *Kisho Kurokawa* also shared a similar idea in Metabolism in Architecture. The increasing number of migrants moving from the countryside to the urban area resulted in significant changes to the city (Kurokawa, 1977). Consequently, the living environment deteriorated, leading to a shortage of dwellings and a lack of jobs. This negative feedback of population growth will eventually control the expansion of the city and the environmental capacity will limit the development of a city, leading to a natural balance of population flow.

3. Vertical Level: Revolt and Remember

Two forces balance the mode of the hierarchical interactions within the self-organizing system: *stable revolt* and *conservative remember* (Eken & Atun, 2019). These two forces perform at different levels of time and scale within the system. The revolt force is the interplay at the smaller and faster level in the same way individual units adapt to transition and change. It is local scale, but progressive, which arouses innovative and positive changes. The remember force is the situation at a more prolonged, slow timeframe that establishes the boundary and acts as a conservative force within the system. This force ensures the system will not run out of control and further collapse. These two forces compose the adaptive cycle, which is foundational to the complexity of the cross-scale relationships. The circular and recursive operation coalesces as a closed loop system and ultimately become stable.

The city is a complex system where development includes urban planning at the global scale and architectural design at the local scale. Urban planning in the city is sizeable scale planning and takes more time to adopt changes and new developments. It plays a conservative remember force in the city system. Meanwhile, the architecture construction as the revolt force brings innovation, fewer time scales, and relatively diminutive scale renovations. The overall evolution of city entails a long period of renovations and improvements and will not collapse because of the balance maintained by change and maintenance.

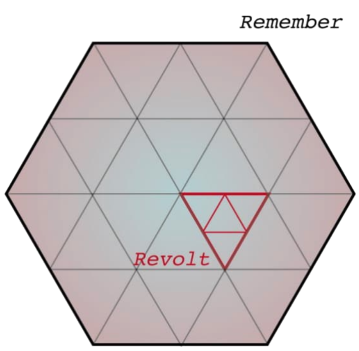


Figure 1o. Revolt and remember

4. Communication between Interactions

The structure of self-organizing system stems from the multiple interactions among its individuals within the organization (Camazine et al., 2001; Narahara, 2010; Olsen, 2019). The operation of the interactions in the system is built on information collected and transferred between individual units and then used to program subsequent actions. From biological research, the information is transferred by two methods, signals and cues (Camazine et al., 2001). The signal is a specific method by which individuals communicate through a unique channel or substance, such as ants communicating the location of food with nest peers. They convey the information via using their antennae to sense pheromones and chemicals. Cues, in contrast, are more subtle and show themselves incidentally in the environment. For instance, deer learn information of other deer and determine their next action through cues (Camazine et al., 2001). When a deer brushes against a tree, it emanates a distinct smell, which will act as a cue to inform about its sex, social status, and physical condition. Subsequent deer will use this cue to decide whether to avoid or engage in contact.

Another approach towards understanding the abstract interaction of stigmergy is put forward in research by *Megan Olsen* (Olsen, 2019), who used the predator-prey model to provide a more detailed explanation of indirect communication. In the study, emotions are used as a tool to indirectly communicate messages between hierarchical species and the same species in the swarm intelligence of the dynamic population model (Doyle & Kalish, 2004). The hierarchical units can be divided into predators, prey, and food in the model. In addition, six different emotions, including happiness, sadness, fear, and anger, flow between predators and prey and in turn affect their reactions (Olsen, 2019). Predators and prey transfer the information as signals through the emotional flow between conspecific individuals when they hunt or are hunted. Nearby species can react (join in the hunt or run away from danger) after receiving the emotion-based signals (Camazine et al., 2001). In the end, the population among the three units will reach a balance through the self-organizing process. *Olsen* offers an easy model to understand the indirect interaction method and its hierarchical relations.

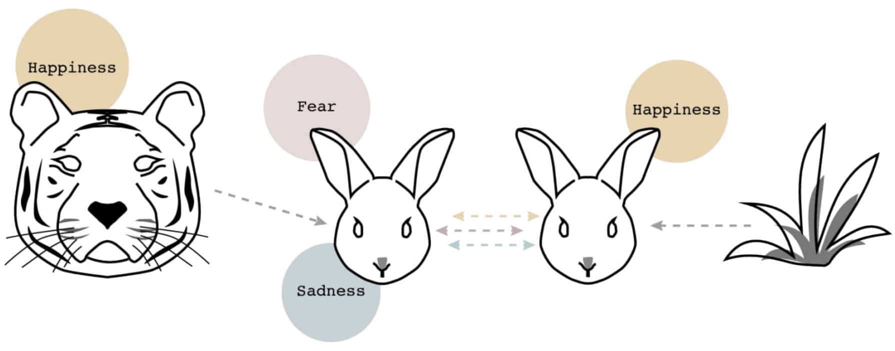


Figure 11. Emotional flow between species

In sum, self-organizing system functions through continual dynamic interactions to respond to external changes and vulnerable environments to achieve flexibility and stability. The local scale components can gather external input and information, and the partial exchanges adapt and rapidly respond to the constantly changing environment. In addition, the unsatisfactory performance of lower-level units does not materially affect the entirety, which means there is resilience against mistakes. From the aspect of construction and architectural design, a self-organizing approach shows more resilience and sustainability compared with masterplan construction methods.

Chapter 3 Methodology

The paper strives to provide an alternative design approach for dealing with the complexity of architectural and urbanistic projects. Based on *Eken* and *Atun* (2019) study, the research aims to conceptualize the dynamic design method among users, architecture, and urban planning established on a self-organizing mechanism. From the biological viewpoint, it will review the design structure of urban planning and architectural design and how it adapts to timeless, dynamic, and unpredictable changes. The research structure has three main parts: literature review, case study, and explanatory design. This research will explore the possible and adaptable solutions in which space depends on a dynamic environment and social changes.

3-1 Conceptual Research

This study aims to conceptualize a design framework of self-organization architecture by integrating users, architecture, and cities. It employs a systematic methodology and explanatory research (Shields & Rangarajan, 2013; Strauss & Corbin, 1994) to lay out the theoretical foundation of the said design framework. Research materials include published books, articles, research works and conference papers, both academic and non-academic ones. In the previous chapter, this thesis examined the theory of self-organization and resilience, as a survey of several scholars' work on the such subject. This integrative review method acts as a junction to merge two themes of preliminary research (Torraco, 2005; Snyder, 2019). By employing the research method, this thesis identified the definition of resilience, the principles of adaptive cycle, as well as the features of self-organization, providing a theoretical reference for the case studies and design framework in the following chapters.

Self-organization	
Individual unit	The basic component of the system.
Adaptability	A framework of adaptive change that has generality.
Operation pattern	The rules of indirect communication and coordination in which individuals modify the environment to pass infor-mation to their peers.
Growth Strategy	The dynamic development process.
Solution for decay	The mechanism for the metabolism of defective parts.
Collective swarm	The collective behavior that can maneuver quickly in a coordinated manner.

Table 2. Principle of Seld-organization keywords.

The main body of this thesis includes case studies of Japanese Metabolism in the 1960s, an architectural movement that displays several sustainable characteristics that correspond to the idea of self-organization. Numerous candidate projects were reviewed and evaluated by criteria based on six self-organization principles including individual unit, adaptability, operation pattern, growth strategy, solution for decay, and hierarchy (see Table 2). The selection process also took into consideration the accessibility to each project's English and Mandarin research materials because it is incredibly time consuming to translate resources written in other languages into English. Although it has been six decades since the emergence of Japanese Metabolism, this study mainly selected research materials published in the last ten years for their contemporary relevance. Metabolists created numerous works and various proposals; thus, the choice of cases will focus on the famous projects between the 1960s and 1970s, which most contain the features of metabolism and self-organizing. As a result, two Kiyonori Kikutake's projects, Sky House and Ocean City, were selected because they highly meet the selection criteria (see Table 3). The latter one is particularly worth studying because it is the only candidate that shows a great hierarchical potential within architecture and urban design.

After thoroughly analyzing the selected cases, this study moves on to juxtapose the idea of self-organization and resilience with the characteristics shown in Japanese Metabolist projects to identify Japanese Metabolism's shortcomings in overcoming the socio-environmental challenges posed by future urban development. A major difference between the idea of self-organization and Japanese Metabolism is the latter's masterplan approach, in which rigid structure declines its flexibility and adaptability. Drawing upon this comparison, this study incorporates learned insights into the proposed self-organization design framework. It is a framework that pinpoints design principles and operation systems of sustainable self-organization architecture which can be easily adapted to diverse environments and fulfills different architecture and urban design needs in the future.

Project	Architect	Year	Individual unit	Adaptability	Operation pattern	Growth Strategy	Solution for decay	hierarchy	Data collection	Actual building or Proposal
Shizuoka Press and Broadcasting Tower	Kenzo Tange	1967	●	●		●			●	A
Agricultural City	Kisho Kurokawa	1960	●	●	●	●			●	P
Nakagin Capsule Tower	Kisho Kurokawa	1970 -1972	●	●	●	●	●		●	A
Capsule House K	Kisho Kurokawa	1974	●						●	A
Sky House	Kiyonori Kikutake	1958	●	●	●	●			●	A
Tree-shaped Community	Kiyonori Kikutake	1966	●						●	P
Ocean Urbanism	Kiyonori Kikutake	1956 -1975	●	●	●	●	●	●	●	P
The city in the air	Arata Isozaki	1960	●	●	●	●			●	P
Oita Prefectural Library	Arata Isozaki	1962 -1966							●	A
Hillside Terrace	Fumihiko Maki	1969 -1992		●	●	●			●	A

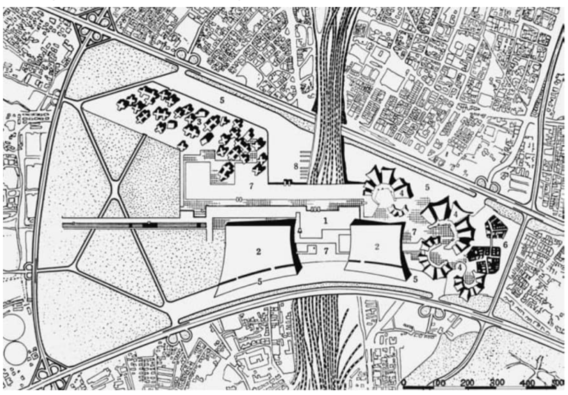
Table 3. Case selection analysis.

Chapter 4 Case Study

Japanese Metabolism 1960s

Japanese Metabolism demonstrates many elements and mechanisms of self-organization through its concepts and proposals from Metabolists. Here will look into the background and the notion of Japanese Metabolism and analyze their projects as a case study, which aims to conceptualize the self-organization architecture and highlight its features.

Figure 12. Tange Lab
Figure 13. Marine City model
Figure 14. Masato Otaka and Fumihiko Maki, Shinjuku Station Project, 1960.



4-1 Japanese Metabolism

Japanese Metabolism is a modern architectural movement originating from Japan, which was led by Kenzo Tange and a group of Japanese young architects (Jodidio, 2021; Koolhaas & Obrist, 2011; Lin, 2010; Schalk, 2014). The movement is intimate with the background of Japanese society after World War II. It includes various architects and their diverse works bases on a wide range of related concepts following a core theory. The group named themselves "Metabolism", a word from Japanese (shinchin taisha) meaning a biological process of the cell for material and energy exchange. It is akin to "*out with the old, in with the new* (Lin, 2010, p.22)."

Japanese Metabolism is a post-war movement for proposing the megastructure and repeatable modular residential units in future cities (Koolhaas & Obrist, 2011; Lin, 2010). The intellectuals desired to solve some social issues by their proposals, such as housing the rising urban population and lack of public infrastructure. They responded to the Japanese post-war dilemma and rebuilt their scorched society via creating architectural projects, proposals, and arts (Fumio et al., 2013; Koolhaas & Obrist, 2011). Japanese Metabolism emphasizes the concept that spaces grow like the organic process of growth and decomposition of life. When it reflects on architecture and the future city, the framework allows any modification to be attached, expanded, or removed depending on users' needs (Eken & Atun, 2019). This group of architect desires to build a techno-utopia of megastructures under the metabolism framework to co-live with an untainted nature. At the 1960 World Design Conference, this group of architects and designers elaborated their vision of the future city and published a manifesto, *Metabolism: The Proposals for New Urbanism*. The manifesto announces their three main objects: metabolic cycle, artificial land, and megastructure (Lin, 2010; Matsui, 2012). The publication includes the proposal of *Kiyonori Kikutake*'s "*Ocean City*," *Kisho Kurokawa*'s "*Space City*," *Masato Otaka* and *Fumihiko Maki* wrote "*Towards the Group Form*," and others' essays (Koolhaas & Obrist, 2011; Lin, 2010).

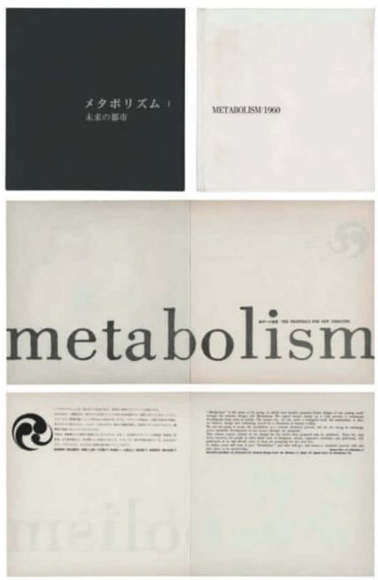


Figure 15. Metabolism: The Proposals for New Urbanism

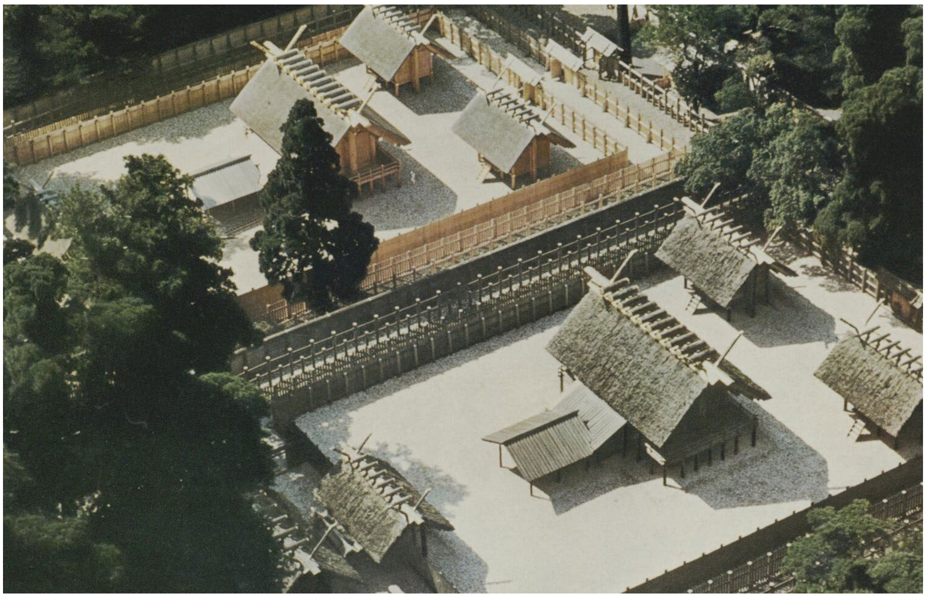
4-2 Cultural Inheritance

Figure 16. 1945 Hiroshima after atom bomb

The movement developed based on the consciousness of Japanese culture and the post-war environment (Fumio et al., 2013; Koolhaas & Obrist, 2011). The Metabolists were directly and indirectly influenced by the post-war background that colored their personal experience. *Kisho Kurokawa* witnessed the overnight bombing of *Nagoya* in the US air raid of 1945 (Kurokawa, 1977). Those 1.5 million people and a 230-year history in the city disappeared in one day. It led to *Kurokawa* thinking architecture and cities would vanish one day. Shortly after, at the age of 16, *Kenji Ekuan* visited Hiroshima soon after the atomic bombing. He felt "the call of all things manmade" (Koolhaas & Obrist, 2011) and began to conceptualize the tenuous relationship between people and objects. For *Kiyonori Kikutake*, this period was one of loss. The land reforms after World War II led to the loss of *Kikutake*'s family landholdings (Kikutake, 1958; Koolhaas & Obrist, 2011). These living experiences and dilemmas of the postwar period prompted the architects to rethink the existence and future development of architecture. In addition, the traditional Japanese belief of impermanence and rebirth was reflected in their work and concepts (Fumio et al., 2013; Kurokawa, 1977). In an interview between the Metabolists and *Rem Koolhaas* and other writings, these beliefs lay at the core of the *Ise* Shrine and *Katura* Detached Palace (Koolhaas & Obrist, 2011).

After World War II, the debate among Japanese architects focused on the pull between a modern aesthetic and historical identity (Kikutake, 1958; Lin, 2010). During the allied occupation of the country (1945-52), Japan was forced to implement a series of reforms, including a new constitution and land reform. These reforms immensely re-shaped political, economic, and cultural aspects of Japan (Koolhaas & Obrist, 2011). For instance, the political system became democratic, reducing the emperor to a ceremonial status and giving women the right to vote. At the same time, the land reform affected tenant farmers, reducing their number from 46 to 10 percent (Ohno, 2017). In addition, the allies believed that Japanese Shintoism was a fundamental cause of the wartime ultra-nationalism that was felt throughout the country (Sand, 2015). As a result, the allies forced Japan to enact legislation separating Shinto from the state in 1945 (Lin, 2010). These reforms brought out the issue of national identity, and the controversy between tradition and modernization and particularly were seen in discussions among Japanese architectural intellectuals (Lin, 2010; Schalk, 2014).

A decade later, the Metabolists came to see extending tradition as a means of innovation (Fumio et al., 2013; Kurokawa, 1977). They believed that there was no conflict between tradition and modernism (Koolhaas & Obrist, 2011). For instance, the concept of Metabolism and extension in architecture was already demonstrated in the traditional architecture of *Katura* Detached Palace and *Ise* Shrine. The *Katura* Detached Palace is a metabolic example in traditional Japanese architecture, which was extended twice over 150 years into an asymmetrical plan (Koolhaas & Obrist, 2011; Schalk, 2014). The *Ise* Shrine is the holiest and most important site of traditional religious *Shinto* in Japan. Throughout its history, it has been rebuilt every twenty years (Lin, 2010; Sand, 2015). Metabolists *Noboru Kawazoe* and *Kenzo Tange* admired its cyclical renewal and wrote a book *Ise: Prototype of Japanese*. The shrine represents two beliefs of *Shinto*: (1) The impermanence of nature, which entails the death and renewal of all things. (2) Inheritance, the building of knowledge and techniques from one generation to the next. Although the components are replaced in the Japanese concept, the *Ise* Shrine remains in its original state because the same spirit (Louw, 2017; Sand, 2015). As *Kisho Kurokawa* explained, *Ise* Shrine represents the philosophy of impermanence rather than a method or ideology (Kurokawa, 1977). In *A Defense of Culture*, novelist *Yukio Mishima* writes: "*The newly built shrine is always the original, which hands over its life as the original to the new as soon as it is built*" (Koolhaas & Obrist, 2011; Lin, 2010). Metabolism is not only a biological process of the anabolic and catabolic but also can be seen as a spiritual one found in Japanese tradition. One achievement of Japanese Metabolism is the fusion of the traditional cultural spirit and the scientifically developed mechanisms of architecture, which maintains local cultural resilience and develops a future vision of buildings.



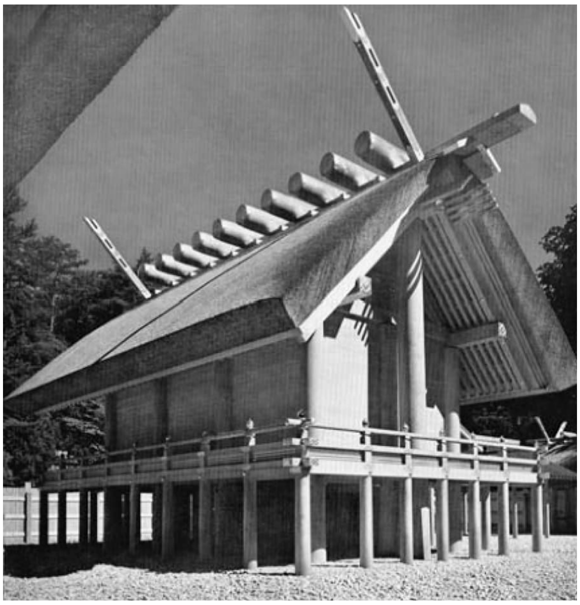


Figure 17. *Two adjacent sites for periodic rebuilding of the shrine*
Figure 18. *Ise Shrine*
Figure 19. *Katsura Imperial Villa, Kyoto,17th century*

4-3 Real Outcome

The features and principles of Japanese Metabolism are similar to the characteristics of self-organizing architecture. For a more detailed understanding, this research will focus on the products (realized cases and concept proposals) of *Kiyonori Kikutake*, who provided diverse metabolic practices and influenced later Japanese architects. In addition, the analysis of the cases uncovers the patterns, rules, and necessary elements of the self-organizing system.

1. Kiyonori Kikutake and Sky House (Move-net)

In the 2005 interview with *Rem Koolhaas, Kiyonori Kikutake* mentioned his architectural proposals are a kind of protest against land reform (Koolhaas & Obrist, 2011). He always strived to create new land for living on the sea or in the air. Man-made land can develop infinite possibilities for expansion into new topographies. The concept of "*Artificial Land*" was later widely used in Metabolic proposals.

His first masterpiece was the *Sky House*, which was his response to flexible and metabolic housing and a monument of his architecture. In 1958, *Kikutake* was acclaimed domestically and internationally for the design of a 10-square-meter own house. The house can be divided into the main, middle, and ground levels. The main structure is reinforced concrete columns located on the central axis of four sides which support a hyperbolic paraboloid concrete roof and combine with the suspended 6.6 meters and waffle-shaped platform as the main level (Lin, 2010; Schalk, 2014). The top-level between the roof and platform is the main living space, keeping a central open space with moveable supply units on the side.

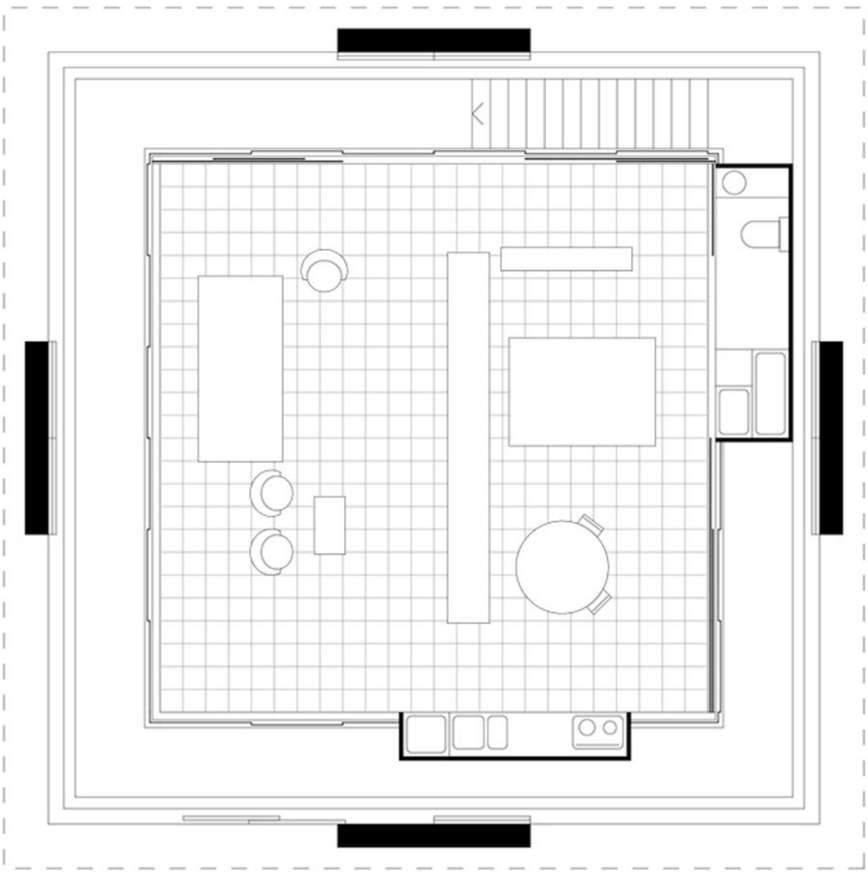


Figure 20. Floor plan of Sky House, Kiyonori Kikutake,1958

Figure 21. Waffle-shaped structure with Move-net, Kiyonori Kikutake,1958

Kikutake also designed a continuous balcony that surrounds the central open space. The balcony speaks to a Japanese-style veranda floor—*Engawa*, a traditional semi-outdoor balcony in Japan (Neustupny, 2017). The traditional engawa sits outside the sliding *Shoji* screens—translucent folding screen door, but inside the *Amado*—storm shutters that can be adjusted depending on the weather. In addition, *engawa* is a traditional method of insulation to protect interior space against low temperature in winter but allows airflow and sunlight in the summertime. *Kikutake* utilized these traditional elements in the modern concrete dwelling. The house not only allows a maximum amount of light, airflow and view, but also protects the family from earthquakes, flooding, noise and pollutions (Raffaele Pernice, 2018).

The new generation Japanese architect *Sou Fujimoto* points out that the concept of personal space came from the West (Sou Fujimoto, 2017). There is no importation of partition walls in traditional Japanese architecture. Instead, they utilize sliding *shoji* screens to divide or extend spaces. This architectural feature is also from the childhood memory of *Kikutake*, "*Our rooms were all divided with sliding doors*" (Koolhaas & Obrist, 2011). The traditional spaces can be versatile, and residents are connected by invisible links - sounds, sights, and feelings. In the *Sky House*, *engawa* and *shoji* act as thermal protection and sight screens for interior space, where users can adjust these components depending on their needs. This component application can be seen in the Gepparo Teahouse at *Katsura* Detached Palace in Kyoto (Neustupny, 2017).

Figure 22. The engawa of Sky House

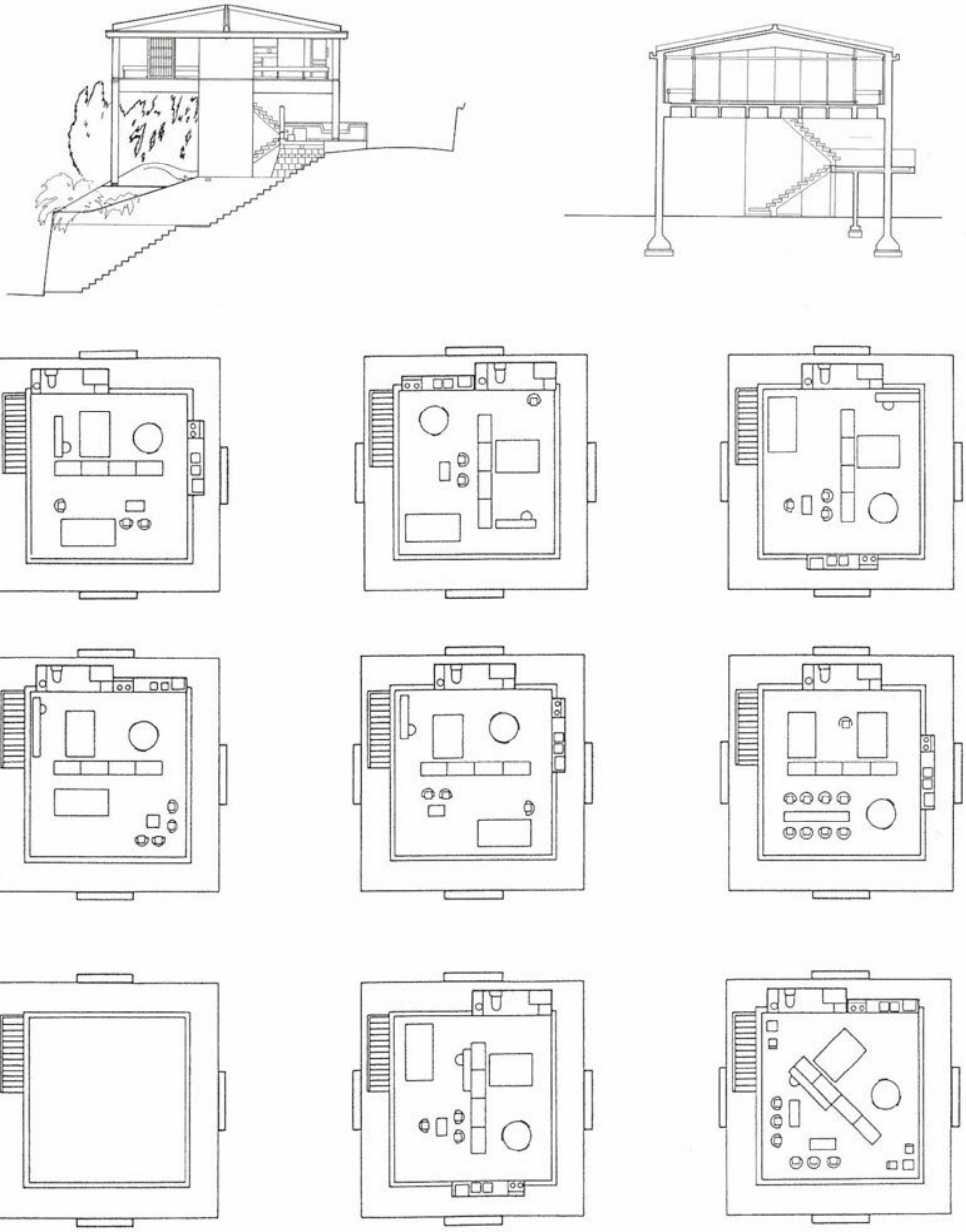
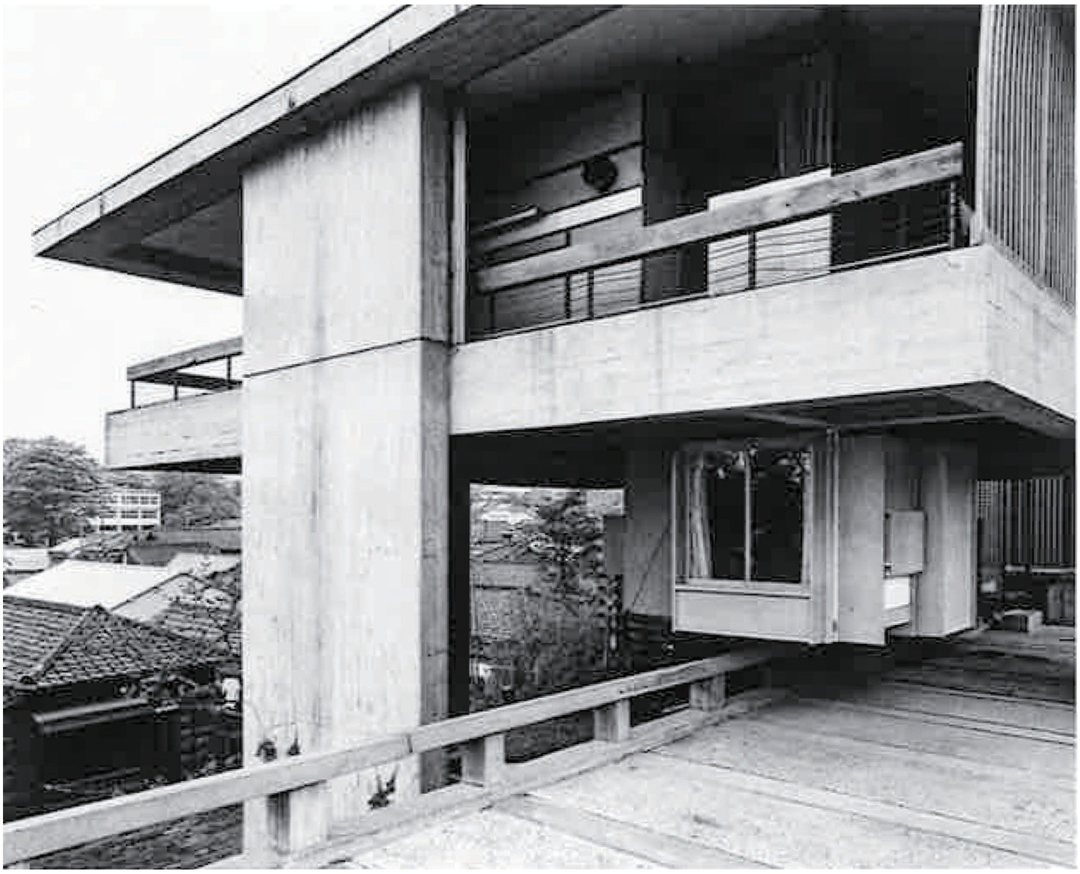
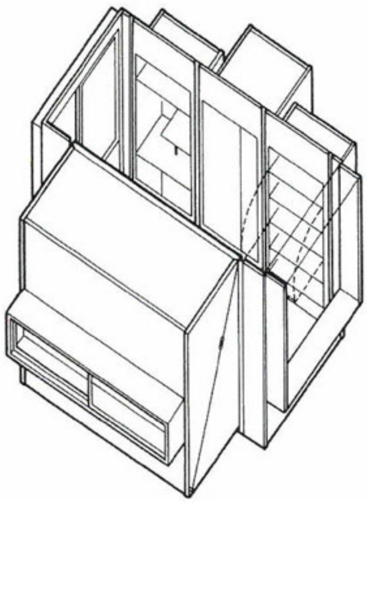


Figure 23. Layout transformation of Sky House, Kiyonori Kikutake,1958

Sky House underwent expansion and transformation seven times to accommodate different lifestyles and needs (Koolhaas & Obrist, 2011). The house originally was designed by *Kikytake* and his wife *Norie* for their two-people lifestyle. At first, the couple lived in an open square room on the upper level and utilized the furniture units to divide the space. The design included a yard on the ground level. In 1962, as the family expanded, *Kikutake* extended the middle level for his children, adding the level under the suspension waffle-shaped platform (Lin, 2010). The ability to attach extra units under the slab meant this structural system enhanced the expandability of the house. These small units, which *Kikutake* called "*Move-net*", are accessed by small holes and ladders on the floor.





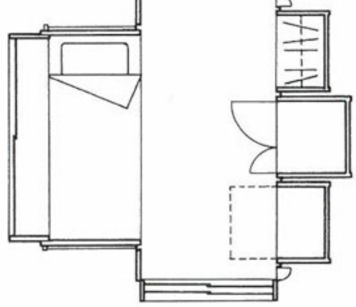


Figure 24. East view with Move-net, Kiyonori Kikutake,1958

Figure 25. Plan of Move-net: kid room, Kiyonori Kikutake,1958

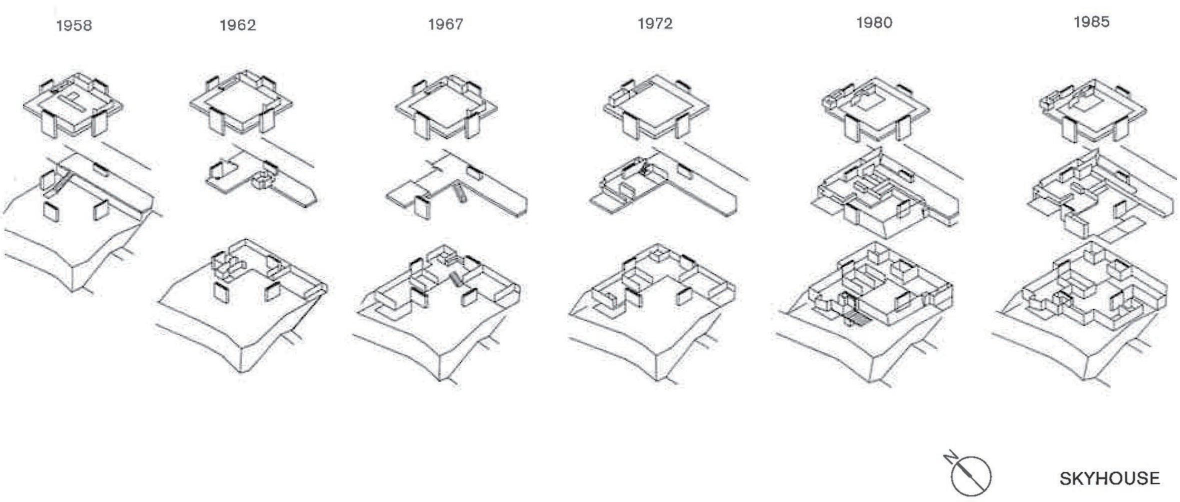


Figure 26. *Expansions of Sky House, Kiyonori Kikutake,1958*

The top layout leaves the kitchen unit and bathroom unit on the edge, because plumbing compartments are contained on the two sides of piers (Schalk, 2014). Thus, the system of structure and plumbing enhances the flexibility of the interior layout and allows for later changes. In all the different plans, the kitchen and bathroom units are still located on the axis of the reinforced columns and shaft, which can be easily adopted the adjustments of the layout. Also, both functional units remain moveable and both can be replaced and updated as technology advances. In this period, Kikutake also ran his architectural office on the ground level. In 1977, the middle level and the ground level was drastically renovated to satisfy different needs. The office was removed from the ground floor and family living spaces including a kitchen, bedroom, and sunroom were added. Moreover, the entrance and driveway were moved to the middle level (Kikutake, 1958). After 8 years, the ground level was completely occupied by living space with private rooms. The move-net units were also completely removed as the children married and left home. The system of *Sky House* created flexibility of expansion and interchangeability. It remained resilient to adapt to the changing needs and lifestyles over different periods.

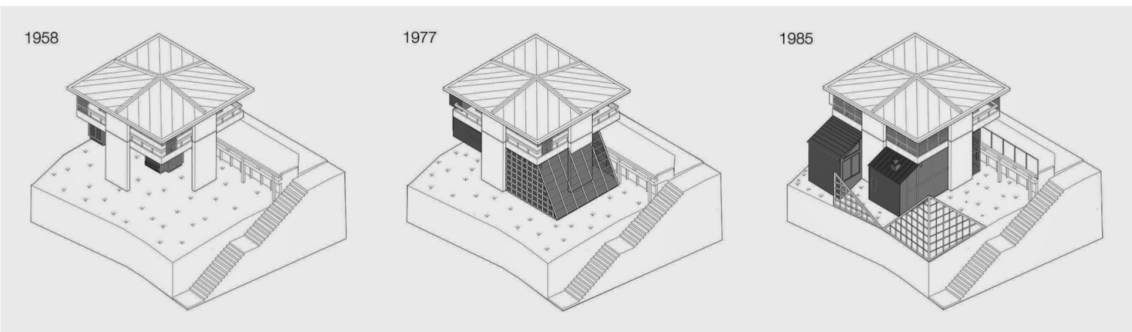


Figure 27. *Evolution of the Sky House, Kiyonori Kikutake,1958*

The principal concept of *Sky House* is that this renewability and extension of residential buildings ought to be a solution for sustainable architecture. The project aims to satisfy the needs of users in different stages of their lives. The seven transformations followed the same framework, the main concrete structure of the Sky House, but met the spatial requirement through attaching units and expansion. This solution which does not require rebuilding new buildings meets the additional demands and lessens the financial burden on owners. This concept also was implemented at the *Villa Verde Housing*, which *Alejandro Aravena* designed, in which owners could extend new rooms from an open frame. However, *Sky House* provides more resilience for the later expansion. The multiple reserved pipelines, modular sanitary equipment and kitchen all enhance the flexibility of the configuration. Users are not limited to the spatial layout set up by designers or developers and can be involved in designing their own living space

Figure 28. Villa Verde Housing, Alejandro Aravena, 2010

2. Kiyonori Kikutake and Ocean Urbanism (Self-organization)

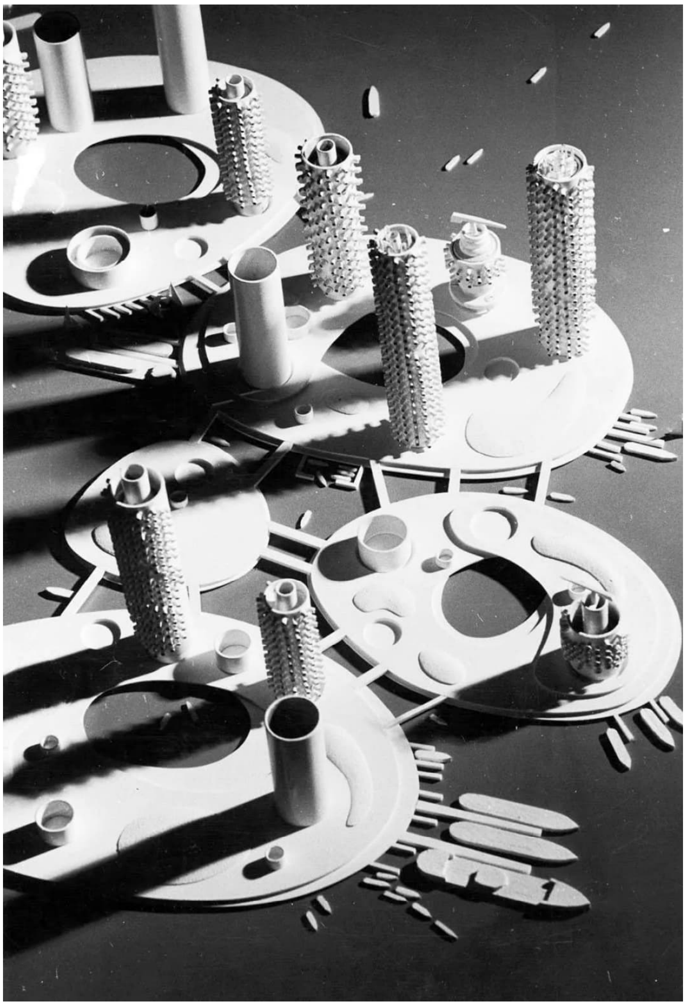
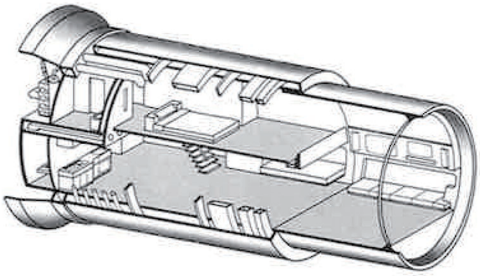


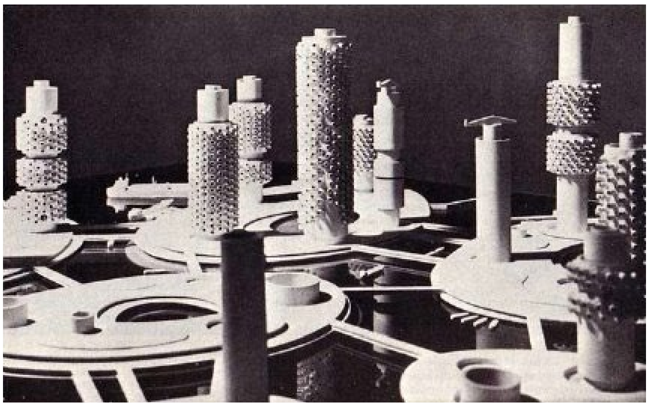
Figure 29. Marine City model, Kiyonori Kikutake,1962-63

Another project of *Kiyonori Kikutake* is the proposal of "*Ocean City*," brought profound implications. It is the first part of *Metabolism: The Proposals for New Urbanism*. "*Ocean City*" is composed of three main projects: "*Tower-shaped Community*," "*Marine City*," and "*Ocean City Unabara*" (Lin, 2010). In 1959, "*Tower-shaped Community*" was the first metabolic project (Koolhaas & Obrist, 2011). It initially developed the combination of urban infrastructure and dwelling in the vertical axis, and "*Marine City*" was the second proposal, which was an architectural illusion of floating and moveable cities on the sea. "*Ocean City Unabara*" was the last, and incorporated a mixture of the above projects (Kikutake, 1958; Koolhaas & Obrist, 2011; Nyilas, 2016).

Figure 3o. Tower-shaped Community unit, Kiyonori Kikutake, 1963

Figure 31. Marine City model, Kiyonori Kikutake, 1962-63





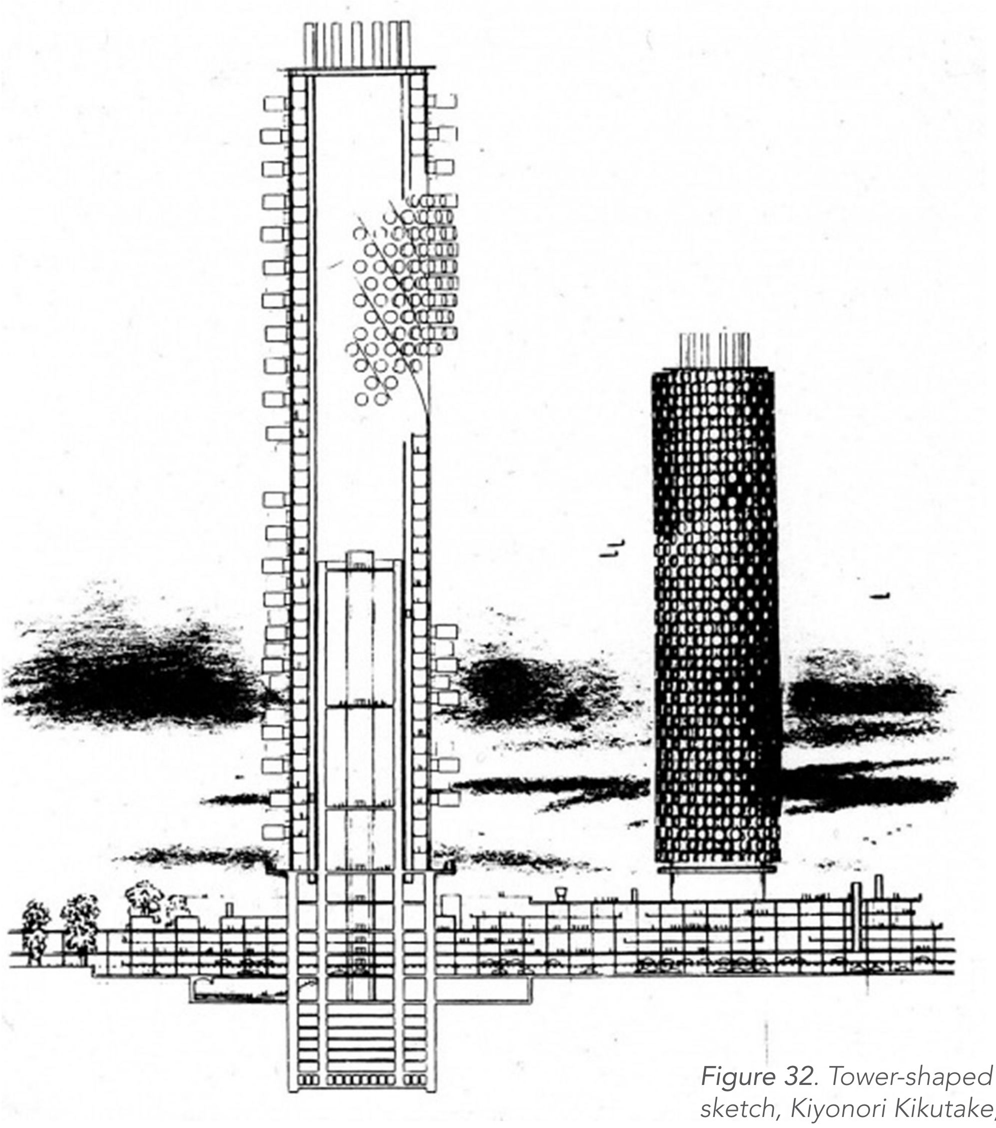


Figure 32. Tower-shaped Community sketch, Kiyonori Kikutake, 1958

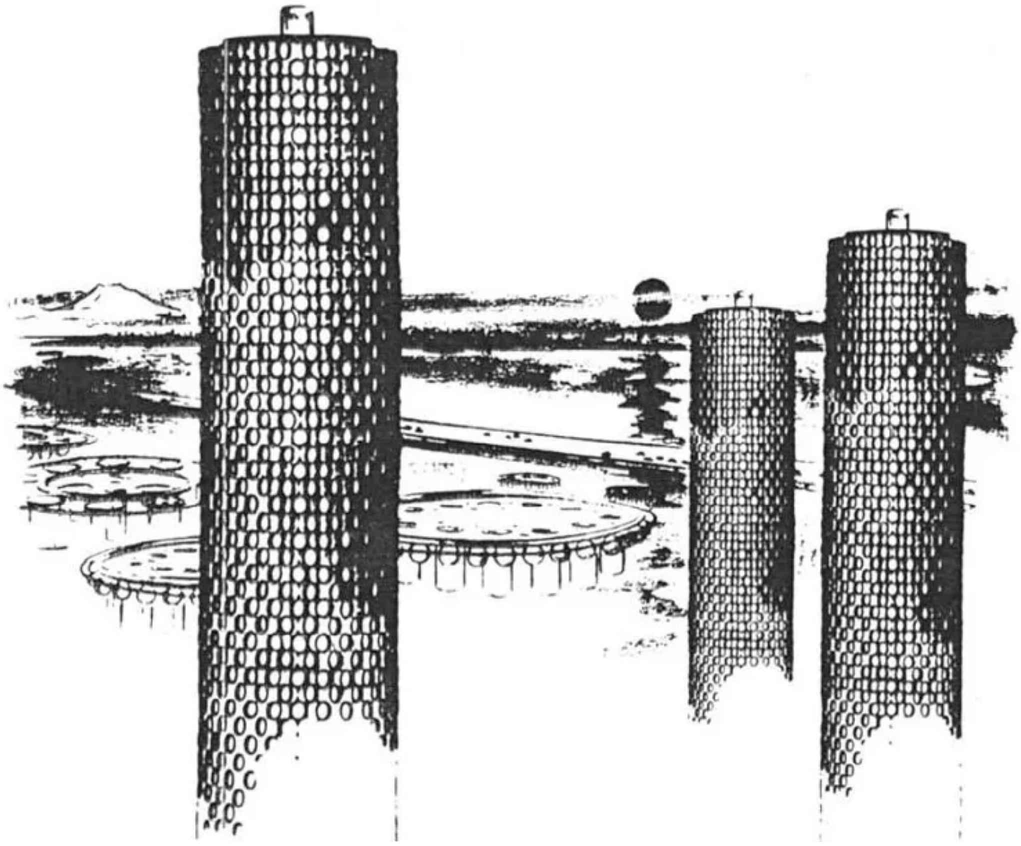


Figure 33. Tower-shaped Community sketch, Kiyonori Kikutake, 1958

Tower-shaped Community was the first proposal among the collections, which was a 300-meter skyscraper and included 1,250 living units and public infrastructures (Lin, 2010). *Kikutake* conceived this building as a vertical extension of the ground. In *Kikutake*'s conceptual framework, the concrete core for supporting units was a metaphor of land. Compared to the traditional Japanese houses that were horizontal developed (Angelidou & Yatsuka, 2012), this project responded to the crowded urban space and high land prices of 1960 Tokyo (Schalk, 2014). The integrated and individual unit was a four-member family configuration, including a kitchen, toilet, and bedrooms (Angelidou & Yatsuka, 2012; Kikutake, 1958). The living unit will be cantilevered on the central concrete cylinder core act like leaves on the trunk of a tree. In the design, these replaceable modules were programmed to be renewed every fifty years. In addition, the tower accommodated all kinds of urban public facilities, including utility pipelines and a manufacturing plant for prefabricated units (Lin, 2010). The project concentrated on creating a small-scale city in the tower buildings.

The second project in the series is *Marine City*, which aims to solve the social issues resulting from the scarcity of land and increasing population in the urban regions (Lin, 2010). The city was shaped as concentric circles and a floating artificial island, with a diameter of 4 km and an area of approximately 1,000,000 square meters (Nyilas, 2016). From the plane axis, the central core was the control facility. The residential part was the six cylindrical towers at the second cycle. The living units of the building would grow along with the core downward under the sea, which was the reversed version and application of a tower-shaped community. Twelve spherical industrial facilities were planned to be at the outer periphery of the circle, while the ground is reserved for agriculture, industrial, and entertainment use (Lin, 2010). In this project, Kikutake desired to concentrate a city within the artificial land on the sea. He called the city a unit of human society serving as the "*mother body*" of Marine Cities (Kikutake, 1959). The aim of Marine City is neither to enlarge the land nor to escape it. It was a proposal of a new style of living on the sea. *Kikutake* developed five different prototypes for the floating city that all shared modular features of self-organizing and metabolic characteristics for the lifespan of the project. The modular unit of the Marine City, airtight equilateral triangles made of concrete, would continually grow downward as the population increased. Marine City would sink into the sea and become a new habitat for marine creatures at the end of its service life (Kikutake, 1958; Lin, 2010).

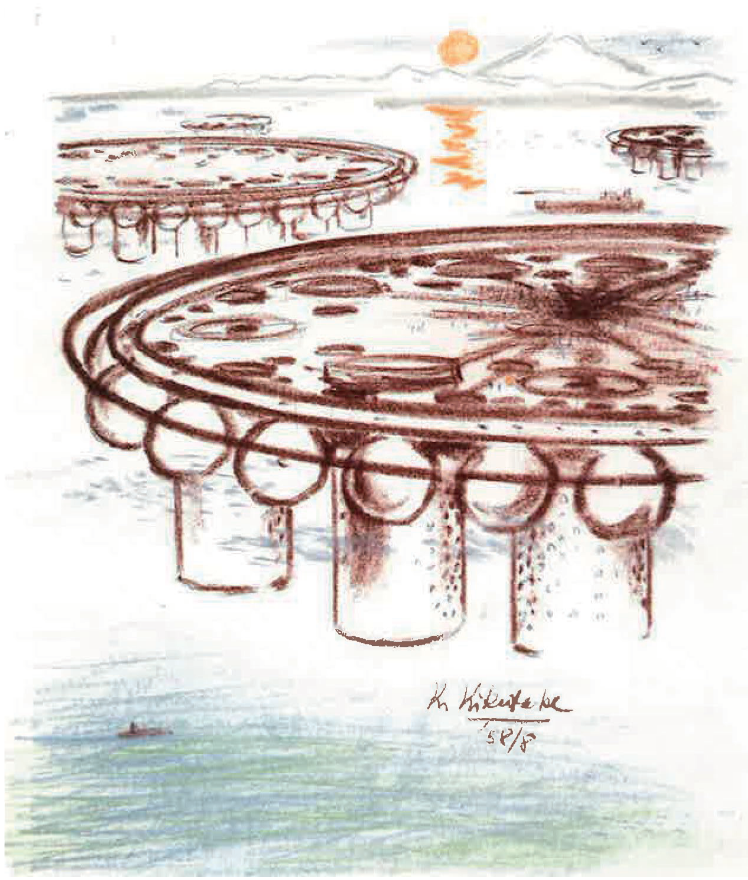
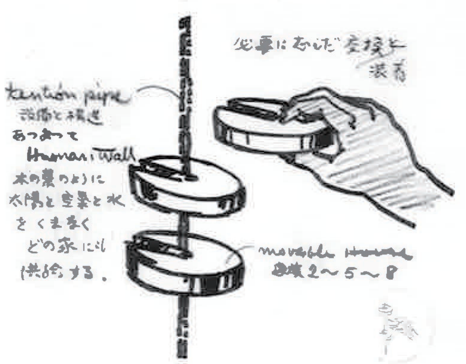
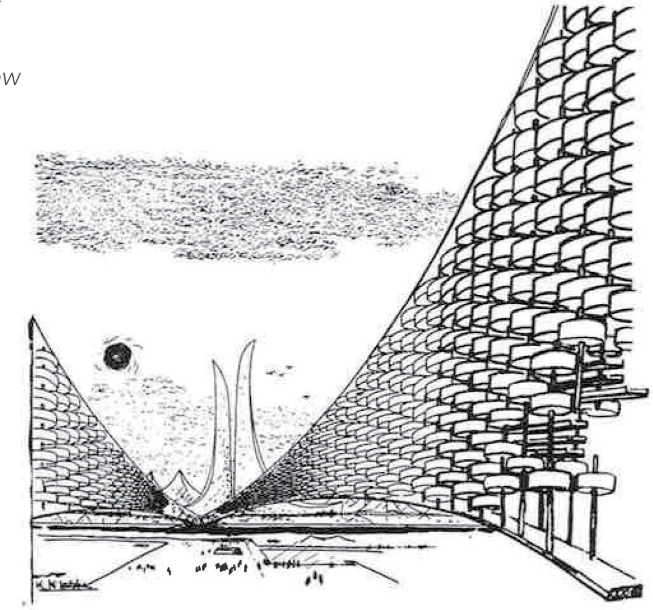


Figure 34. Marine City sketch, Kiyonori Kikutake, 1958

Figure 35. Kiyonori Kikutake's concept of movable house, Ocean City, 1960
Figure 36. Kiyonori Kikutake's general view of housing structure, Ocean City, 1960





The definitive collection of the series of proposals, *Ocean City Unabara*, was first published in Metabolism 1960 (Lin, 2010). This Unabara combined characteristics of earlier projects at a greater scale as an industrially mobile city on the sea. The city consisted of two organic-shaped rings: the inner ring was the residential area and the outer ring for industrial production (Lin, 2010; Nyilas, 2016). The building differed from the rule and form of the tower-shaped community, as it accommodated sailboat-shaped living units and was to be built on a concrete floating platform. The administrative facilities were located at the intersection of two circles. The lagoon within the inner ring is utilized as an entertainment area, while the water body between the two rings works as fish farms (Lin, 2010). *Kikutake* also considered the influence of waves on the city, thus the outer production region and the fish farms act as the buffer zone to minimize wave impact (Kikutake, 1958). In addition, the system strictly regulated the population of the city. When the number of people reached the limitation, the city would proliferate like cell division. The newly divided city would function similarly to the original one. The administrative point was the control tower, which is the nucleus of the system and the first part to be duplicated. These two nuclei gradually develop as two connected and almost mature cells or growing cities and later detach as two individual cities.

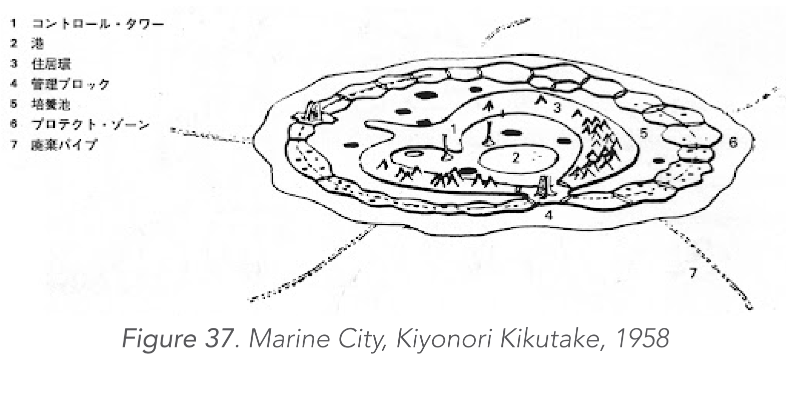


Figure 37. Marine City, Kiyonori Kikutake, 1958

The units of these three projects are the smallest cells of the dwelling system, which compose the scale of the residential block. The next scale is a city, composed of multiple residential blocks, which interact in hierarchical layers. Various systems work in parallel similar to the different organ mechanisms in the human body. This series of metabolic proposals demonstrate the cross-scale interactions and innovation from self-organizing architecture. The Tower-shaped community is the first scale level, concentrating on residential units and public facilities and creating operational rules. Marine City is the next larger scale within the series. *Kikutake* combined the reversed version of earlier community buildings with a floating city on the sea. This project contains two parallel systems: industrial and residential regions, where the designer not only extends the space and function but also increases the system's complexity. The final rung in the hierarchy is Ocean City which includes the previous operation pattern and the rule of the proliferation of the marine colony. In addition, the manufacturing factories in the projects reflect the required innovations in the self-organizing system. This hierarchical interaction is the revolt, as mentioned earlier, acting as the force of the adaptive cycle. At the same time, the limitation of the city's population can be seen as the remember force, which creates a safe boundary for the system.

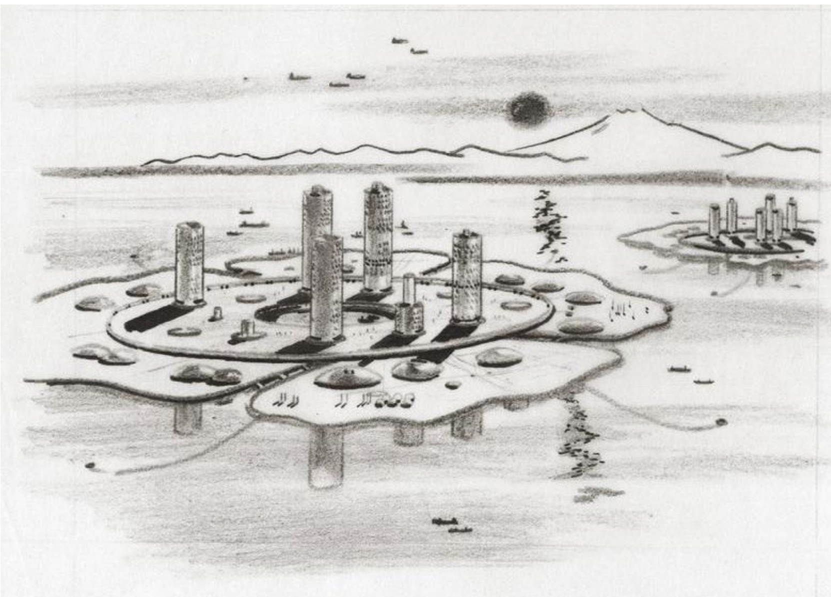


Figure 38. Marine City sketch, Kiyonori Kikutake, 1959

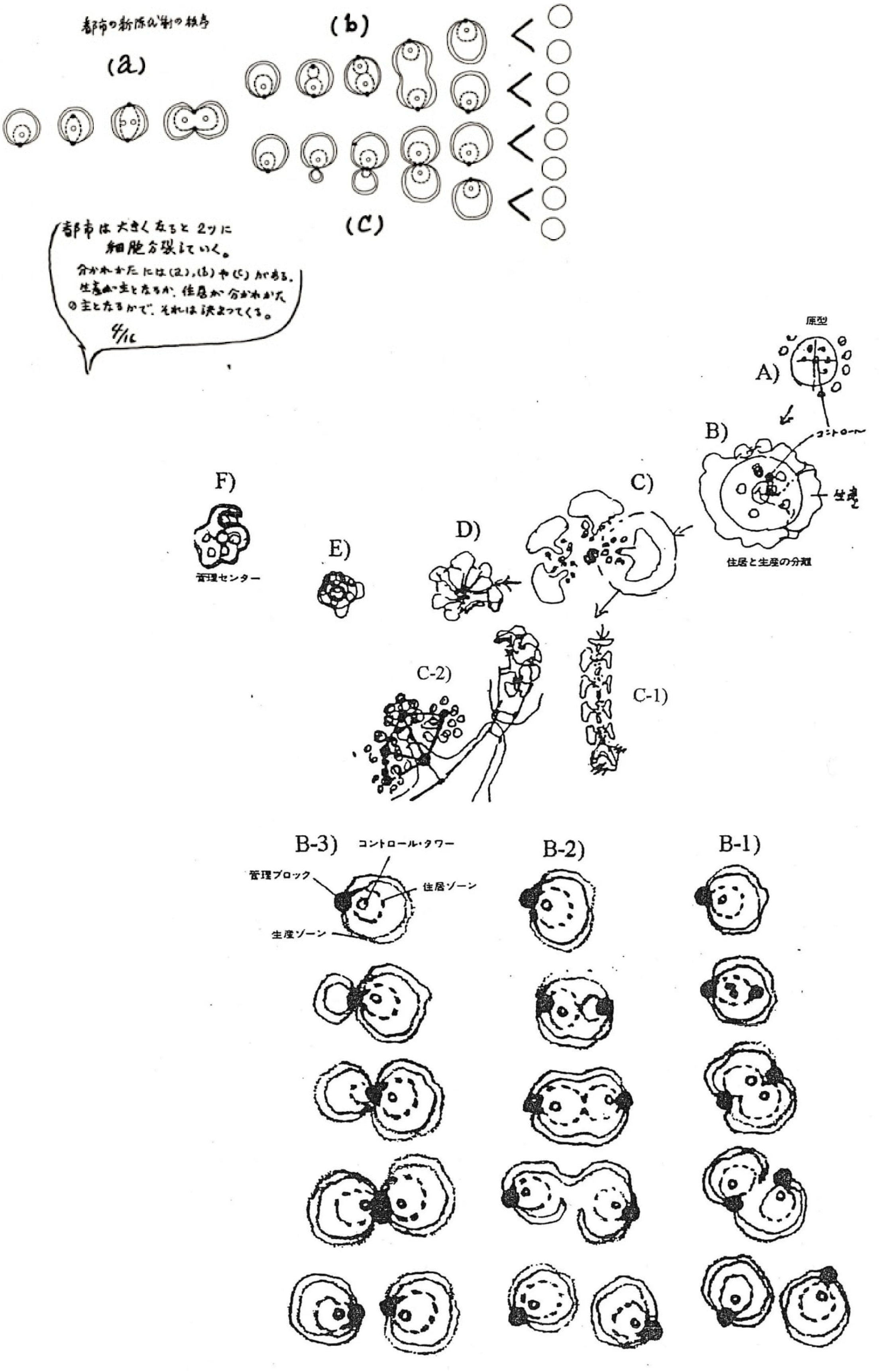


Figure 39. Kiyonori Kikutake's concept of urban metabolism, a sketch included in the Metabolist manifesto, 1960

4-4 Influences of Japanese Metabolism

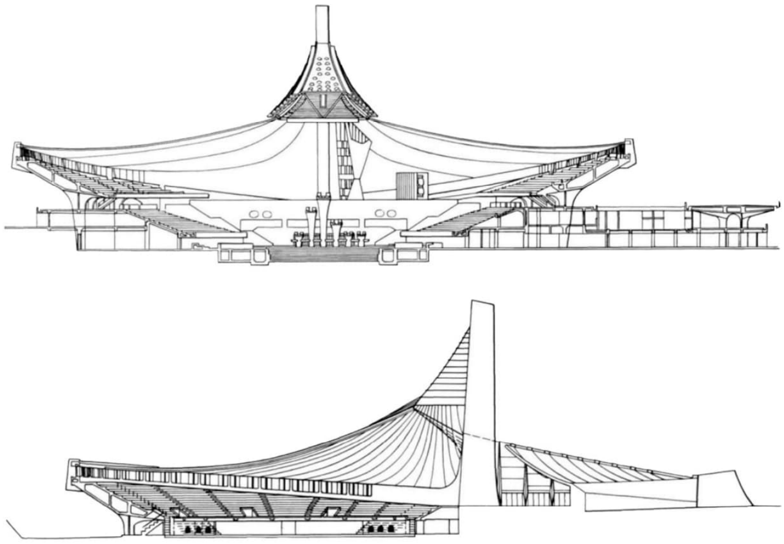


Figure 40. Yoyogi National Gymnasium, Kenzo Tange,1964.

Although most Japanese Metabolism proposals remained on paper, their theories and visions influenced the following periods significantly (Lin, 2010). In the post-war atmosphere of the society, citizens desired to be removed from the frustration after World War II and accepted Western influence and technology. Their ultimate goal was to redefine their national identity and undergo an enormous transformation to join the modern, global community. The active performance of Metabolists responded to these social desires and forged a new national identity in architecture. Proposals such as *Kikutake*'s Tower-shaped Community and Ocean City are still considered experimental, but valuable in today's society (Jodidio, 2021; Kikutake, 1958).

There was a debate among Japanese architects about the merged experiment of traditional and modern architectures in the 1955 architectural magazine—*Shinkenchiku*, edited by *Kawazoe Noboru* (Koolhaas & Obrist, 2011; Lin, 2010). This debate continued to the publishing of Metabolism 1960. These Metabolists acted as the spiritual and formal architecture bridge, connecting the past, present, and future. They merged reincarnation and impermanence ideas from Japanese traditional buildings and culture with modern architecture and future cities. Their creations lead to renewal and adaptive architectural theories. Besides extending the features of conventional buildings, Metabolists also created original structures and concepts of architecture. For instance, Yoyogi National Gymnasium, designed by *Kenzo Tange*, shows vernacular creativeness and strength equal to Western modernism (Fumio et al., 2013; Jodidio, 2021).

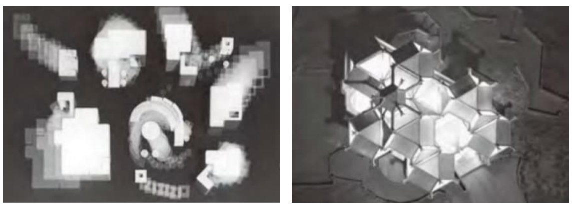


Figure 41. Fundamental research of QS72

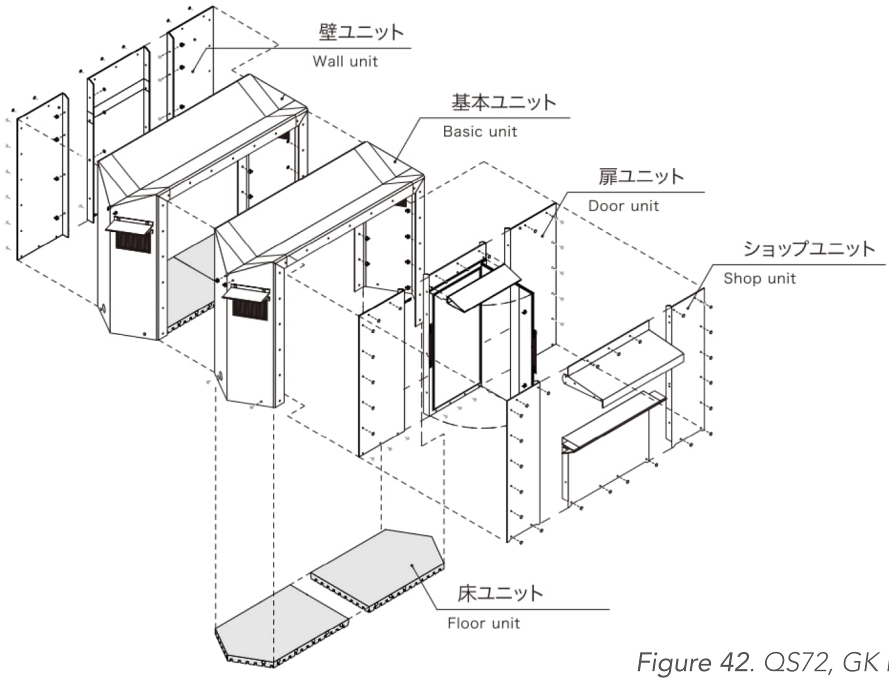


Figure 42. QS72, GK Design Group, 2008

In addition, the theories and proposals of Japanese Metabolism started from the scorched environment after the war. Metabolists sought to provide diverse solutions in response to different disasters. For instance, *Kenzo Tange*'s Skopje project was reconstructed in the regional capital of Macedonia (Koolhaas & Obrist, 2011). *Kenji Ekuan* proposed a temporary medical unit named QS72 (Quick Space 72) for refugees after the typhoon (Asada, 2011; Jodidio, 2021). These concepts and projects also inspired future reconstruction following natural disasters (Harris, 2014) like earthquakes, tsunami and the Fukushima Nuclear Accident. Japanese Metabolism provided later intellectuals a fundamental system of how architecture adapts to unpredictable changes and co-exists with nature. These proposals seem unrealistic, but they offer a different concept of collective intelligence and shared economy, which are currently being implemented in sustainability. Metabolists also started to consider the relationship between architecture and nature before they knew the concept of sustainability.

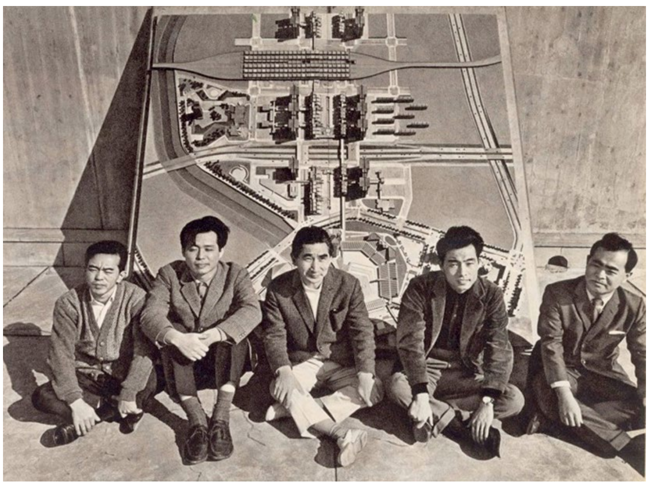


Figure 43. Skopje Project, Kenzo Tange

4-5 Comparison between Self-organizing Architecture and Metabolism 1960 for Sustainability

Sustainable architecture is an overused term, but the main issue for all practitioners is that it only employs part of the concept in applications (Schalk, 2014). Designers respond to the social, economic, and environmental crisis through their explanations of sustainable architecture, but they are still limited by realistic problems, like cost and market-orientation. In addition, recently sustainable architecture seems to be a combination of renewable technologies and architectural form (Donovan, 2020), which emphasizes energy efficiency and eco-friendly materials. However, there is little consideration for adapting to external changes in the future or looking beyond the service life of buildings. This chapter will look into the discrepancies and opportunities for sustainability between Self-organizing Architecture and Japanese Metabolism.

When Japanese Metabolism was firstly introduced at the 1960 World Design Conference in Tokyo, the concept of sustainable architecture and resilient urbanism had not widely understood in general (Schalk, 2014). At that time, the Metabolism architects were committed to solving social and environmental issues through the proposals of metabolic buildings and future cities (Fumio et al., 2013; Koolhaas & Obrist, 2011). These challenges were similar to problems contemporary societies face, including land scarcity, unequal development and pressure on congested urban areas (Lin, 2010). In contrast, Self-organizing Architecture is a systematic design manner from local to global scale of buildings (Narahara, 2010). It focuses on a practical approach to architectural design and future flexibility for adapting to changes, even if there are no specific problems to solve. However, Japanese Metabolism and self-organizing architecture share the same method of participatory design of the individuals—different power relationships in the systems.

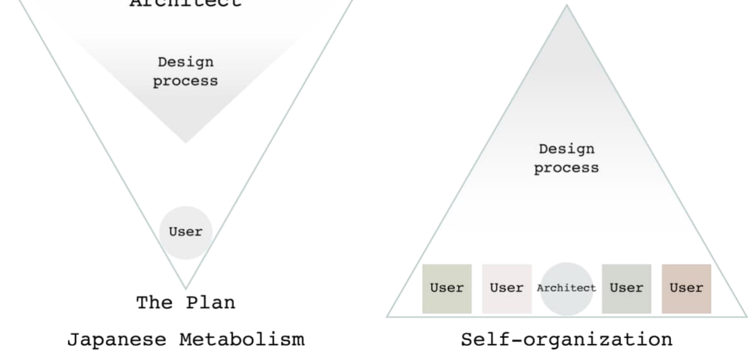


Figure 44. Power structure of Japanese Metabolism and Self-organization

From the aspect of design principle, the primary thinking of Japanese Metabolism is a perennially central structural core with organically grown individuals (Schalk, 2014), thereby reacting to the needs of users. These structural cores and individual units consist of a megastructure that operates as a metabolic cycle—units attach or detach depending on specific needs and service periods. This system reflects a flexible and resilient solution in architecture and offers re-creatable notions in construction. However, the movement fell out of favor because the super-scale megastructure was challenging to maintain and operate at the human-scale, and the applications only expanded, never shrinking or being demolished. Although the Metabolists did predict the decay of the structure core (Lin, 2010), they did not consider the practical part of future maintenance and replacement. In addition, Metabolists predicted the material decline of the buildings, but this decline could not match the rapid growth and renewability of metropolises. A good example here is the Nakagin Capsule Tower, an iconic and realized building in Japanese Metabolism designed by *Kisho Kurokawa*. It will be demolished because of the spoilage of the main structure and units and the dangerous old structure. In his original vision, units of the building could be rotated out and replaced every twenty-five to thirty-five years (Lin, 2010). Still, the complexities of ownership, physical limitation (the weight and size), and high maintenance costs were obstacles in this reconfiguration (Narahara, 2010).

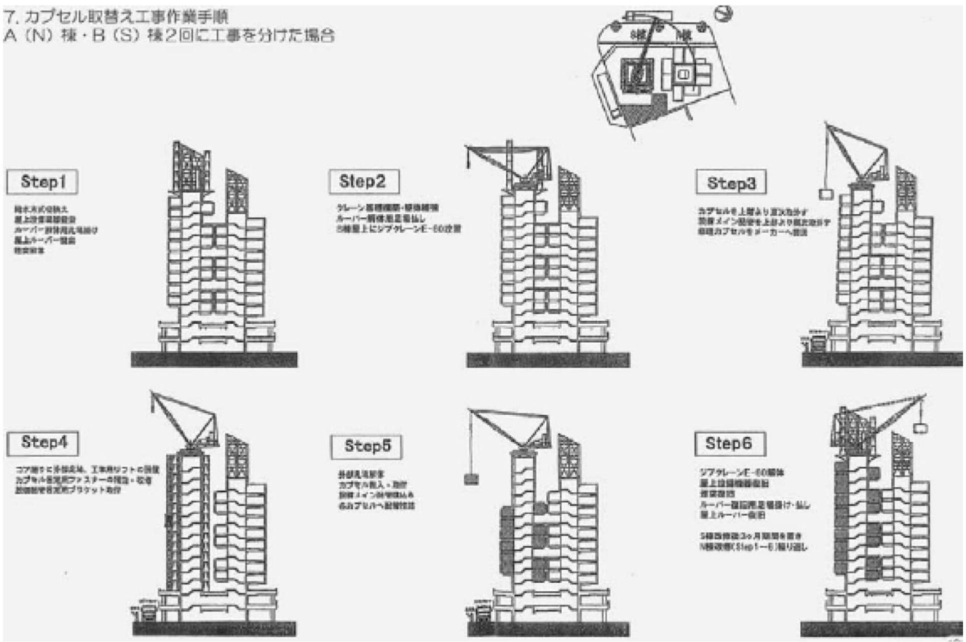


Figure 45. Nakagin Capsule Tower renovation plan, Kisho Kurokawa, 1998–2007

On the other hand, self-organized architecture is a decentralized design approach that emphasizes building the rules of the system operation and cross-scale interactions among the units. These individual units can operate independently, interact mutually, and constitute a systematic network. The basic principle constitutes two situations in the system: an adaptive cycle (Eken & Atun, 2019; C. s Holling & Gunderson, 2002), including the revolt force (internal innovations), and remember force (outer frame). This circumstance is similar to the concept which Metabolist *Kiyonori Kikutake* presented in the Tower-shaped community project. The units could be plugged in when residents increased or were replaced, like the growth of a tree (Lin, 2010). Architects provide an operating pattern of the units and a structured framework of the system. In the initial design, the method of the skyscraper community would autonomously function and grow organically. However, this 'open' system was still limited by the lack of a brain that could provide innovations into the system, upgrade the existing structure, and repair the broken parts of the system. The theory of adaptive cycle fetched up the insufficient renewable feature, which revolt force which is small and fast innovation lead to a progressive change.

Moreover, a problem both Japanese Metabolism and Sustainable architecture faced is engaging citizen participation as a part of the system. Even though the concept of Japanese Metabolism demonstrated architectural and urban resilience in that age, there was little consideration for adapting to external changes in the future or beyond the service life of buildings. In addition, although Metabolists allowed residents to develop their own houses under the metabolic framework, the power of collective design remained top-down (Lin, 2010). Compared to conservative architecture, self-organizing architecture is a bottom-up design system that allows more stakeholder involvement and more flexibility to react to exterior variations (Narahara, 2010). Meanwhile, peer-to-peer networks have become common in contemporary societies, where the community and technology can both support the participatory design.

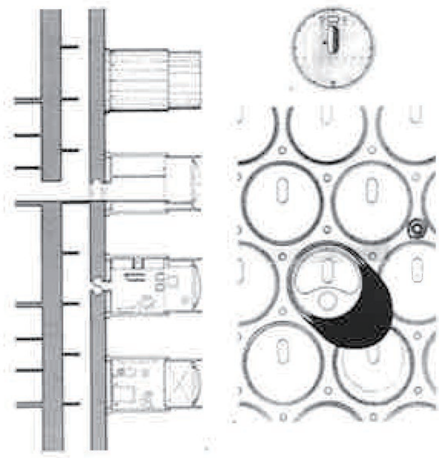


Figure 46. Elevation and section, floor plan for residential unit, Kiyonori Kikutake, 1963

In the post-war background in 1960, the citizens of Japan sought a new national identity at the controversial point of modernism and tradition (Jodidio, 2021; Schalk, 2014). Japanese Metabolism provided visions based on the vernacular form. Some Metabolists, such as *Kenzo Tange* and *Kisho Kurokawa*, also utilized the influence of media to express their visions of future cities and the concept of a more sustainable society (Koolhaas & Obrist, 2011). The diverse expressions on different media helped them gain the attention of citizens and support from authorities. The success was a composite of various factors, including the pervading low confidence of Japan as a defeated country and economic growth. Metabolists utilized media communication and established an excellent example of cultural resilience and public engagement. However, this communication stayed one-way and top-down manner. Architects and authorities were the dominators in their relationships and products. There were limited communication channels between the system keepers (design and maintenance team), users, and authority, which is why sustainable architecture mainly remained an idealistic concept but has not been comprehensively implemented. Self-organizing architecture provides a different angle to design, one of a local-to-global approach. In order to satisfy their requirements and needs, users ought to participate in discussions at the design stage and provide feedback after use.

Figure 47. The Work of Kisho Kurokawa : Capsule, metabolism, spaceframe, metamorphose

Chapter 5 Question

Is the Masterplan Problematic?

This research seeks to conceptualize a design framework of self-organization for architecture and urban design. Although the projects from Japanese Metabolism contain self-organizing characteristics, they still followed the masterplan approach, including the top-down design structure with users and an inflexible form of implementation. Thus, the step is to understand the development process and relevant issues of the mainstream design approach Masterplan through analyzing another improvement for comprehensively understanding the design structure and developing an alternative design structure based on knowledge.

5-1 Masterplan in Urbanism and Architecture

After World War II, with the high expectation from people that society would rise out of the ashes, masterplan had become one of the main tools for public sector planning. As a result, the masterplan in the 1950s was prescriptive characteristic with detail and comprehensively planning (Giddings & Hopwood, 2018). By its nature, the masterplan is a top-down blueprint that is developed by trained professionals. Through the subdivision of issues, designers repair dysfunctional parts and translate knowledge via precise and prescribed vision on an outcome last extended decades. (Bullivant, 2012; Feliciotti et al., 2015; Firley & Groen, 2014). After World War II, the decadent and barren environment provided a tabula rasa for architects and planners to develop relevant technologies and apply new concepts and design approaches (Giddings & Hopwood, 2006; Koolhaas & Obrist, 2011). In this postwar background, cities were required to be rapidly rebuilt based on cost-effective and efficient forms of renovation. As a result, specific design methods, technologies, and materials became mainstream in the era, including the masterplan approach and the prevalence of concrete for buildings (Giddings & Hopwood, 2018; Todes et al., 2010). From the aspect of the public sector, authorities needed a strategy for the instantaneous redevelopment and a means of control. Hence, the master planning method became the primary tool for the era from the 1960s (Giddings & Hopwood, 2018). The implementation of the masterplan method generally lost its appeal, but it has been resurgent since the 2000s along with the sustainable concept (Bullivant, 2012). In the present, financial-oriented market society, the masterplan is still the fundamental design approach to academic and practical architecture (Bullivant, 2012; Giddings & Hopwood, 2018; Todes et al., 2010).

Masterplans are created by specialists (Giddings & Hopwood, 2018) who have been equipped with specific knowledge and skills. They will develop a series of visual models for evaluating different scenarios with other stakeholders. Architectural or urbanistic development projects require the participation of various stakeholders, including politicians, developers, design teams, and users. Significantly, the stakeholders who control the budget reserve the greatest power in managing projects (AlWaer & Illsley, 2017; Bullivant, 2012). Compared to the bottom-up design approach, large-scale and top-down design structures are more conservative and have predictable outcomes (Eken & Atun, 2019; Giddings & Hopwood, 2018). Thus, masterplans in a less risky, visible, and understandable manner have become the mainstream for investors to visualize future projects or sites. They can make it easier to evaluate the payback period. However, masterplan leads to predetermined vision and performance based on the preference and bias of a narrow group of professionals and planners. Giddings's (2006) example shows that a Newcastle planner believes planners should trust their capacity and know they are right even when others disagree (Giddings & Hopwood, 2006). The masterplan approach was also criticized in the late 1960s for creating inhuman buildings that were disconnected from the cultural fabric and the local community. Meanwhile, the centralized method underrated the unpredictably complex dynamics after the masterplan was realized (AlWaer & Illsley, 2017; Feliciotti et al., 2015).

In the late 1970s, masterplan design was criticized for being static and inflexible (AlWaer & Illsley, 2017; Giddings & Hopwood, 2018). Although the centralized design approach demonstrates financial efficiency and generated some vivid projects, its development of any projects ceased when all subdivisions were designed. This method can be understood as a closed system focusing on solving modifications for a pre-designated period of time, rather than being flexible to deal with changes after implementation.

The rebirth of the masterplan can be traced to the late 1980s. Architects and planners tried to apply the method to a more complex built environment and combine it with sustainable concepts. In addition, the global economic crisis caused a lot of construction to be postponed. This delay created space for designers to reflect on what is an appropriate conceptual framework for the current urban and social fabric. In addition, the sustainability agenda transforms design emphasis towards the ideas of place-making, community cohesion, and quality of life. A rising consciousness of time was also highlighted in the procedure. The previous masterplan focused on the topic and circumstances in the present and depicts a future vision. However, it rarely considered the future after implementation and how to adapt to changes. Hence, time should be regarded as a vital element and forces architects to better understand it within the design structure.

The current digital society faces instantaneous and continual changes, and all industries encounter more complex situations and issues. In addition, Urbanists believe cities are dynamic and complex. These updated circumstances mean linear and stationary design structures do not correspond to the built environment. For instance, static design renders more fragile cities on an urban scale. This linear design structure cannot adapt to the continuously changing environment, nor offer answers to social and cultural questions. On the other hand, at the scale of architecture, the centralized method easily loses its connection with localism and merges into the existing urban fabric. For instance, the Taipei Performing Arts Center, designed by OMA (a highly regarded global architecture firm) is criticized for its progressive design and disconnection from the local environment and culture.

Figure 48. Taipei Performing Arts Center, OMA, 2020.

5-2 Reinforcement of Masterplan

Figure 49. Haus-Rucker-Co.
Figure 50. Japanese Metabolism in Osaka Expo, 1970.

Globalization, new forms of communication, innovation of technology, the renewing of social concepts, and the increasing value of sustainability led to an urban planning and architectural design transformation. Starting in the 1960s, designers started to question the fundamental issue of whom they were designing for and the purpose of design (Giddings & Hopwood, 2006). These questions led to the bloom of copious visions of futuristic architectural designs, leading to diverse design proposals, such as Haus-Rucker-Co and Japanese Metabolism. These projects demonstrated eclectic suggestions and tried to involve resilient consensus within the design structure and theory. In the 2000s, the growing consciousness of sustainability shifted designers and planners and reinforced the concept of resiliency within the masterplan to adapt to future issues (AlWaer & Illsley, 2017). However, today the unprecedented circumstances all societies are facing reveal more defects in this method of designing cities.

Masterplan methods remain in the center of the design world despite the above criticism. Nevertheless, the urbanistic and architectural design communities have started to transform their emphasis towards decentralized, local, and cross-tier design approaches. The updated trend has also been extended to the masterplan (Feliciotti et al., 2015; Todes et al., 2010). Thus, many experimental design projects and research center around the innovation of design approaches. To reach the goal of sustainable urban resilience, the design structure should be flexible and adaptive, satisfy engineering and biological resilience, and connect with culture and localism. *Feliciotti et al.* (2015) also noticed the insufficiency of the masterplan. They provided a proposal for reinforcement based on research and summarized the principles of socio-ecological resilience and urban design sustainability. They developed a theory of *Masterplan for Change* for and highlighted its related improvements.

1. Masterplan for Change

Masterplan for change, developed by *Ombretta Rómice, Sergio Porta, Alessandra Feliciotti*, is driven by the desire to address dynamic changes, user needs, and requirements for timeless, flexible design structures. They aimed to underline a resilient framework in conducting the conception and assessment of masterplans, meanwhile responding to the requirement for both urban sustainability and socio-ecological resilience (Feliciotti et al., 2015).

To confirm the comprehensiveness and accuracy of the principles, they compared numerous documents and pulled out key concepts from other academic and non-academic publications on urban design sustainability and socio-ecological resilience. They developed the fundamental twelve principles of Masterplan for Change built on the combination of similarities based on the two features lists. Moreover, the twelve principles are further categorized as structural characteristics and behaviors which are essential for constructing an urban, resilient system. They found that there is almost no difference between structural characteristics and behaviors of the system. Yet, they believed that only certain features could be created via design, and others are only evoked through certain elements and evolve over time. For instance, modularity (from structural features) can embed into the system through division in urban design, but self-organization (from behaviors) cannot.

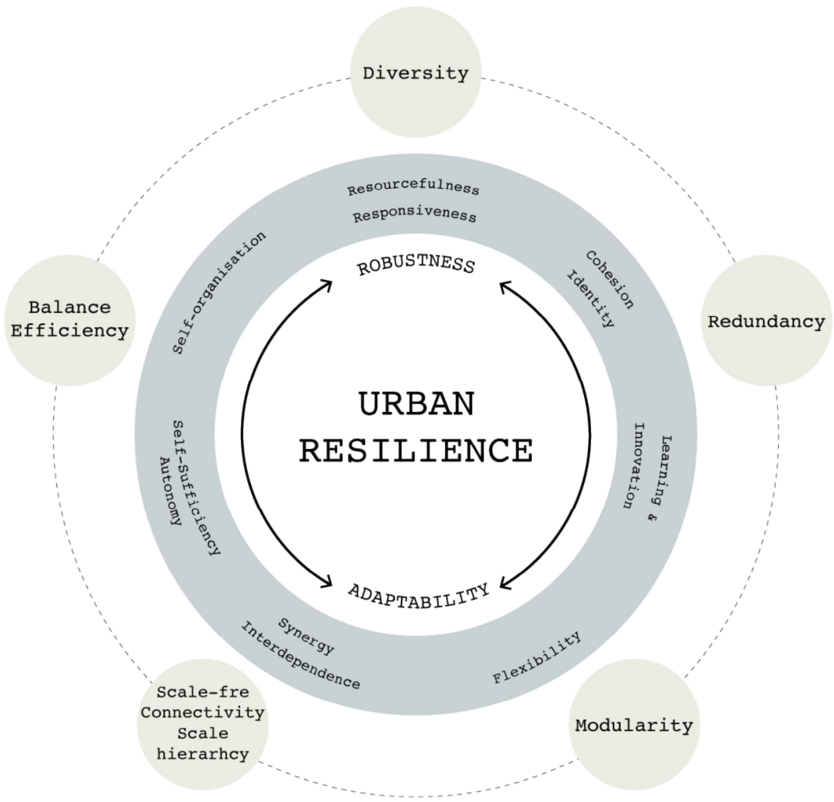


Figure 51. Urban resilience principles for Masterplan for Change.

From the nature of the design process, Masterplan for Change is a four-phased approach for production, analysis, strategy, regulatory framework, and masterplan. The reformed process looks traditional, but the authors believe the process will enable system evolution over the generations. They divide the design procedure into four operating subsystems, which constantly provide feedback during the development of projects. The most significant difference between the Masterplan for Change and the original method is the third stage - the regulatory framework. This part can be subdivided into *Foundation Masterplan* and *Local Urban Code*. Foundation Masterplan is the operative document that details strategic decisions and aims to deal with physical continuity decisions and merge them into the urban fabric. Local Urban Code (LUC) is a database of desirable design elements, which is a catalogue of the regional characteristics and a hierarchy of elements. It provides a range of local references for planners, which can easily extend the transformation along with the existing network. Masterplan with the LUC database remains an open document, which enhances the flexibility of the system for adaptive changes and simultaneously follows the "street front".

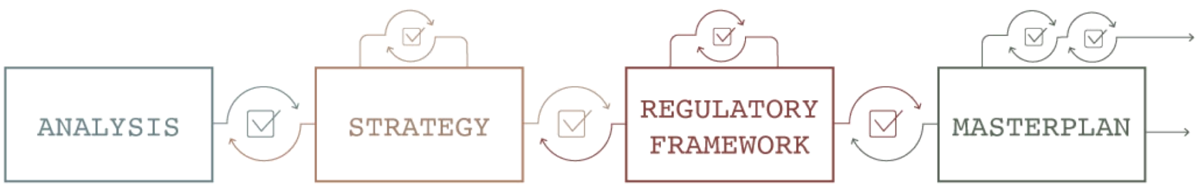


Figure 52. Masterplanning for change: flow diagram of the overall process of design.

5-3 What Is the Next

The contemporary masterplan strives to lessen its distance with human needs and more tangibly satisfy sustainability. Some architects and designers have improved on the unfriendly parts and lack of responsiveness to users of the masterplan method by implementing a human-centered design system coined by *Mike Cooley* in a 1987 publication. It aimed to tackle the relationship between people and subjects using a solution-based approach (Gill, 2016). In architectural projects and urban planning, it connects people and buildings as a community and attends to their needs, contexts, and behaviors (El Sayad et al., 2017). Human-centered architecture collects ideas and involves resident participation through discussion workshops and hand-made processes (Voegeli,2020). Although the method engaged more users in the projects, the ultimate decision remained within the hands of design teams and planners, which seems to conflict with the desire to shape the variety and consensus of the community.

The conservative masterplan methods cannot satisfy the continuously changing environment due to the lack of an organic and reactive mechanism. From the historical aspect, a significant failure of planning outcomes resulted from the masterplan, but outstanding designs also sprang from it. Meanwhile, historic examples showed some cities as a combination of masterplan and self-organization, demonstrating flexibility and responsiveness to societal changes over time. Research from *Feliciotti et al.* (2015) showed that self-organization cannot emerge via design, it only is indirectly encouraged. However, the cases from the 1960s Japanese Metabolism demonstrated a concept of self-organization in architecture and urban planning (Eken & Atun, 2019). In the last decades, many studies and projects have indicated the theory's potential in urbanistic and architectural design.

Chapter 6 Design Framework

Self-organization Architecture

6-1 Design Features

From the viewpoint of Japanese Metabolism, the future city was defined in the form of multiple stabilities (Eken & Atun, 2019). Metabolists divided the city scale into architecture and urban design (Lin, 2010) and applied the metabolic cycle to design their subjects as living organisms. The built environment could be seen as the main drive for the complex system of cities, which constantly decompose and reorganize to achieve self-organization (Eken & Atun, 2019). Under the modern sustainable consciousness, the system's hierarchy should be more complicated. The hierarchical levels should be described as users, buildings, cities, and external surroundings from small to large scale. Based on this, self-organizing architecture can be summarized as encompassing five main features based on the previous chapters' review and analysis. The following will further explore each element and highlight its role in the design system.

1. Unit and individual component
2. Organic growth
3. User involvement
4. Time scale and decay
5. Social resilience of the system

1. Unit and individual component

A vital feature of self-organization is the primary cell or component (Camazine et al., 2001), which interacts within the cross-scale system. When the feature was applied to architectural design, the units elaborated on previous architectural movements and theories. Various campaigns and architects have given the cell different names, but it can be understood as capsule architecture (Šenk, 2017). Capsule architecture stemmed from these architectural movements around the 1960s and the post-industrial background (Andrzejewski, 2018; Jaillon et al., 2008). In addition, postwar technological advancement and the flourishing of prefabricated construction influenced international architects to create eclectic forms, which utilized spatial units as a space extension solution, such as Archigram and Japanese Metabolism. The replaceable and flexible nature of capsule architecture is one solution to meet the requirements of sustainable architecture provided by Japanese Metabolism. It aims to adapt to dynamic social issues and the vulnerable environment, which modern society faces.

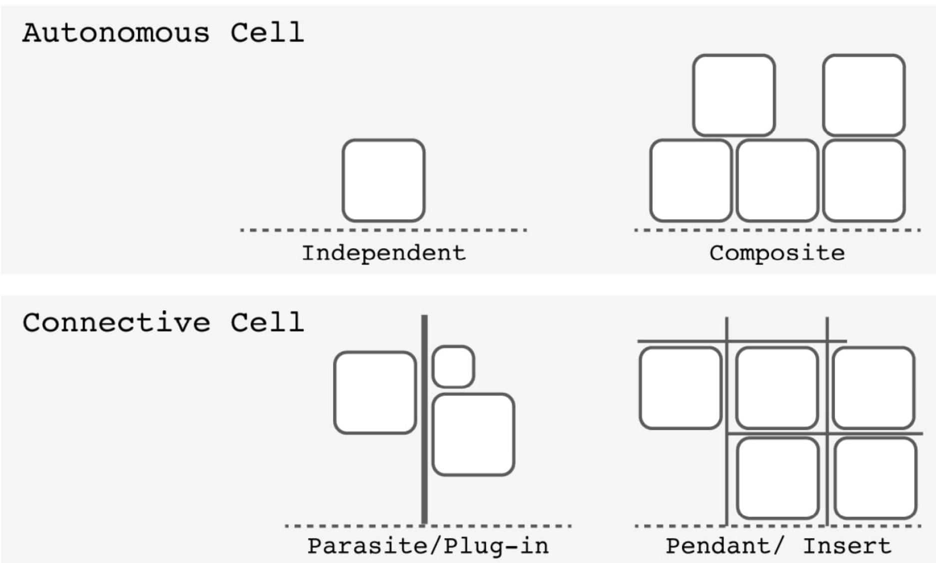


Figure 53. Taxonomy of the typology of the capsule in architecture.

There are two main typologies stemming from the development history of this architecture: *autonomous* and *connective* capsules (Šenk, 2017). The autonomous unit requires independence and self-sufficiency. It is further divided into independent and composite cells, which are differentiated by whether these components can be assembled or not. This can be understood as operating independently or being mutually combined. Independent capsules are functionally and structurally separate, possessing high mobility, autonomy, and full function. These features lead to the independent capsules frequently being utilized in polar research or living units in extreme environments. At the same time, this typology relates to the recent *Tiny-house movement*, which resulted from the issue of simple living and sustainability. Nowadays, dwellings have become a luxury and unaffordable for the general public. Through the Tiny-house movement, architects and designers have responded by creating a fully functional but minimum volume house, which satisfies all the daily needs of an individual or a family. However, a complete unit also means less resilience and difficulty in adjusting or adding to the space.

In contrast, the composite capsule maintains mobility and autonomy, but it can be aggregated as a combination or established as a community. This type is regularly implemented as an emergent shelter in natural and human disasters, providing physical and social safety. Composite capsules include an internal structure that is self-bearing and can easily be assembled with other capsules without an extra external loading structure. It leads to horizontal or vertical capsule accumulation, and further organic growth. This characteristic results from advanced prefabricated technology where capsules can be attached, disassembled, and reused.

<table>
<tr><td rowspan="2">Autonomous Cell</td><td>Independent</td><td>• Functionally and structurally separate.
• High mobility, autonomy, and full function.
• Tiny-house movement.</td></tr>
<tr><td>Composite</td><td>• Mobility and autonomy but can be established as a community.
• Without an extra external loading structure. Emergent shelter.</td></tr>
<tr><td rowspan="2">Connective Cell</td><td>Parasite</td><td>• Individual units are attached to a load-bearing core structure.
• Tower-shaped Community by Kiyonori Kikutake in Japanese Metabolism.</td></tr>
<tr><td>Insert</td><td>• Insert units based on an external loading structure.</td></tr>
</table>

Table 4. Features and categories of capsule architecture.

Another typology, the connective capsule, is a more complex system built on a medium or a core structure (Šenk, 2017). The typology includes two forms - the parasite form, where individual units are attached to a load-bearing core structure and the inserted form, which is based on an external loading structure. The connective capsule is flexible for spatial extension, repairable to aging parts, and a nonlinear system for providing more space for future modification. A typical typology is the megastructures of Tower-shaped Community by Kiyonori Kikutake in Japanese Metabolism. Nevertheless, the flexibility and replaceability rely on moveable units and a mechanism (like a crane) for adjustment. For instance, a present-day example of this can be found in the *Vertical Forest* by *Stefano Boeri Architetti* in Milan adjusts the vegetal elements through a crane in the system. Many previous cases failed and were finally demolished due to an impractical mechanism for replacement and renewal of its components. This is particularly the case with the Nakagin Capsule Tower by *Kisho Kurokawa*. Although the connective capsule is a potential solution for a more continuous and adjustable method of future construction, it still requires an operating system and practical approach for sustainability.

According to this theory exploration and case study, the capsule/unit can exist both independently and attached to other infrastructures. However, the unit must be mobile and moveable for long-term adjustment and replacement. The cross-scale system in cities can be revealed as architecture (small scale) and urban planning (large scale), and the two domains have been proved as inter-reliant (Eken & Atun, 2019). According to the hierarchical scale, the architecture unit also can be subdivided into smaller spaces, like rooms, for operation by their functions. This subdivision can focus more on user needs, satisfying their requirements, and enhancing the adaptation to new social crises.

Figure 54. Vertical Forest, Stefano Boeri Architetti, 2014

Figure 55. Tiny House.

2. Organic Growth

Organic growth in a self-organizing system states that individual units can generate interactions between units and novel configurations without requiring a blueprint (Eken & Atun, 2019; Narahara, 2010). The feature involves independence of and connection between individuals, benefiting the overall operation and flexibility of the system. This feature also responds to the bottom-up pattern exhibited by the collective intelligence of the self-organizing system (Narahara, 2010). As a critical benefit, the development of units would be adapted to the external variations through small-scale innovations.

There are many spontaneous and organic outgrowths in architecture in the current cityscape. For instance, in Taiwan, people often attach corrugated metal sheets to the roof of detached houses to capture extra space. These illegal, flexible, and non-professional spaces belong to the Urban Informality (Chiu, 2015). It is based on individual reactions to social or environmental dilemmas. The extension can be categorized as squatting, where people extend their residence based on their own needs and creativity. This self-organizing phenomenon naturally results from the scarcity of land and high house prices. However, unplanned and untrained organic spatial growth often leads to structural danger and inefficient sustainability.

Figure 56. Urban informality.
Figure 57. Kowloon Walled City.

Another example of instability of organic growth can be found in Hong Kong's *Kowloon Walled City*. Kowloon Walled City was an unsafe structure but an excellent example of the organic spatial growth based on automatic behavior by residents (Narahara, 2010). The walled city developed as Hong Kong existed in a politically turbulent time in the power struggle between China and the British. The Kowloon area, a grey area with only a few laws, was a shelter for refugees escaping the civil war and the Communist government. These political refugees developed the city using their untrained knowledge of carpentry and low-quality concrete. However, the finished space was most suitable for the residents and coped with the area's rapidly rising population. These informal constructions were implemented by citizens who were not equipped with professional training and did not consider structural logic and material safety. The above results led to the dangerous megastructure being demolished.

In this case, organic growth unfolds as a housing product where the general public can extend space through collective intelligence. However, it requires understandable rules among individual unit interactions and an easy operating system. There are three communication approaches for units to convey information: *direct, diffusion*, and *signal/cue* (Olsen, 2019). Direct communication is a linear way to contact another peer or individual, which directly transfers information. In contrast, communication in diffusion and signal/cue belongs to the form of stigmergy, which is indirect and incremental. Diffusion approach can be seen when the information diffuses outward in concentric circles and gradually decays. The final and abstract version is the signal/cue mentioned in the previous chapter. In the biology examples, different species transfer information through specific approaches, such as an ant's antennae and pheromones. These allow only the peers to comprehend and react to the messages; meanwhile, excluding other species from invading and consuming resources. When signal/cue approach is implemented in construction, the hierarchical components simultaneously operate in different levels and scales (Christensen, 2014). Hence, the method allows maximum flexibility and resilience for adapting to various future scenarios and changes.

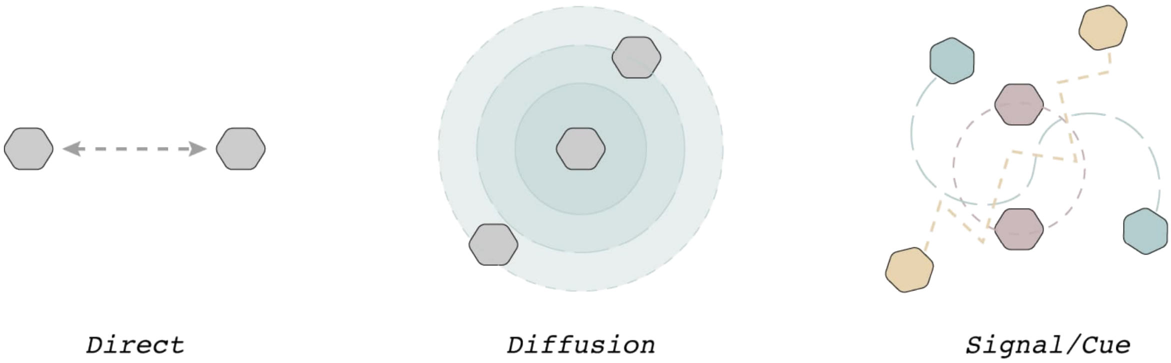


Figure 58. Communication approaches for units.

3. User Involvement

Self-organizing architecture is a system of numerous interactions between individual capsules. In the book *Metabolism in Architecture*, *Kisho Kurokawa* believes that each capsule space acts as shelter for the individual and users present their individual character through the interior of the unit (Kurokawa, 1977). The human can be seen as the soul of the capsule buildings. As a result, user participation is an integral part of the system, where networking between people is a critical operation pattern.

Architecture design has proven to belong to the domain of human-centered design (El Sayad et al., 2017). However, modern societies and businesses remain value engineering resilience, efficiency, and economic profits, leading to real estate and design methods lacking user involvement and feedback. The typical masterplan design approach is top-down, dominated by design teams, excluding user involvement. Users are usually ignored in the process due to their lack of relevant knowledge.

When it comes to multiple-level buildings, the building industry finds it particularly challenging to collect and integrate user experience and opinions because future residents are unknown and have no chance to participate in the development process. This means a universal, but empty, residential design is provided to the market. This design approach creates certain issues. For example, this spatial modification increases material and energy consumption and environmental impact. The typology of these buildings is also less resilient for future adaption. Thus, this manner cannot effectively support the sustainable transition towards a decreased ecological impact of construction and modification (Othman, 2007).

For achieving the sustainability transition in architecture design, it is essential to establish a mechanism of user participation and a feedback loop from the development process to the end-user experience (Othman, 2007; Sopjani et al., 2019). As a result, there are three approaches that motivate user involvement in the process (Sopjani et al., 2019). First of all, sharing the control of design with users. It means that architectural design is accessible to everyone, and architectural design is no longer out of reach. It will be a democratizing design process which is a belief of Japanese Metabolism (Koolhaas & Obrist, 2011; Kurokawa, 1977). Metabolists believe that people can easily enjoy design through user participation and mass production (Koolhaas & Obrist, 2011). Secondly, simplify and share the professional expertise. Through simple operation rules and limited selections, which are the principles and features of self-organizing architecture, it can be easy for the general public participates in the design discussion. Finally, users motivate changes. Users can be seen as the internal variations in the sustainability transition and self-organizing system. Individuals detect the external changes then influence the design through their adjustment in behavior and participation in the innovation process. There is an excellent example of individuals as the change agents in the biological system. Termites change their behaviors and build actions to adapt to the external environment, which helps the group survive and adapt to the changeable surroundings (Camazine et al., 2001).

User roles and innovative influence depend on the type and degree of user participation in the system (Sopjani et al., 2019; Vines et al., 2013). The first level is the standard and current implementation, listening and observing the user domain. Architects plan the design and layout through observation and investigating the general public's opinion. The overall survey results in a universal product which might be obsolete and inappropriate depending on the unilateral decisions from the design team. Moreover, architects might be focused on a specific group when determining the role of potential residents and design products will only serve a limited set of stakeholders. This means standard design fails to contribute solutions to the affordable housing issue and offers little benefit to disadvantaged people.

The next level of involvement is to ask the requirements and preferences of residents. In Taiwanese real estate design, architectural design is divided into building and interior design. The division enhances the efficiency of the developments and allows designers to focus on their specific area of expertise. Residential buildings have become factory-manufactured and economic-oriented products, which incorporate a rigid design approach and thus are less resilient for adjustment. The current industry provides only a frame for users, and occupants ask interior designers to renovate the space to satisfy their needs and preferences. However, architecture is a more complex creation incorporating scientific logic, aesthetic demonstration, and social-technical response. User preferences and individual needs should be included in the development process. As a result, co-design and co-creation with users are the inevitable next phase for future transition (Sopjani et al., 2019; Vines et al., 2013). Individual feedback and collective intelligence are valuable resources to initiate a new system and accelerate its development. Users and their diverse roles fertilize the system when technology is implemented. This growing and dynamic system also benefit the users themselves.

Figure 59,60,61. Community planning workshop in Tanzania.

4. Time scale and decay

The three-dimensional model (potential, connectedness, and resilience) of the adaptive cycle (C. s Holling & Gunderson, 2002) no longer satisfies the current social structure and environment which can be defined as dynamic, complex, and vulnerable. A fourth property, time, is required to address future, dynamic and unexpected variables. This new four-dimensional design structure must deal with complex and multiple-level urbanism and architectural design. The design approach should be considered cross-scale in space and time and able to cope with physical decay within the system (AlWaer & Illsley, 2017). There is a crucial problem with the implementation of the masterplan method, which is the ending of the project at the finish of construction (AlWaer & Illsley, 2017; Louw, 2017). To cope with the time issue, Metabolists tried to involve the time concept in their proposal. They proposed the building's metabolic cycle (Kurokawa, 1977; Nyilas, 2016), which undergoes the process of adding, combining, replacing, and removing to extend the lifespan of buildings (Lin, 2010). In the example of Nakagin Capsule Tower, the use period would last sixty years for the core structure, and the capsule would be renewed every twenty-five to thirty-five years (Kurokawa, 1977; Lin, 2010). Although the failure of the movement showed an unrealistic assumption, the lifespan of buildings in Metabolism inspires the time concept of architecture.

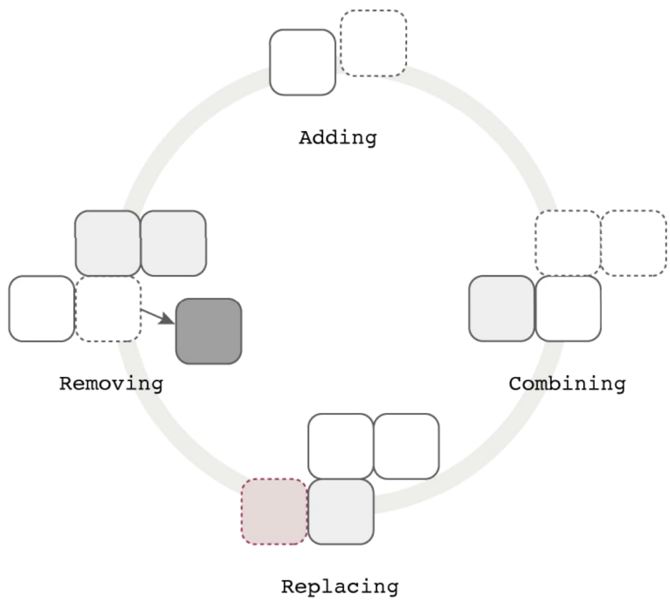


Figure 62. Metabolic cycle.

Japanese Metabolism presented time consciousness in their proposals, which was influenced by traditional culture (Neustupny, 2017). In the literature review, Metabolists showed a strong connection to the Ise Shrine, especially *Kenzo Tang*e and *Noboru Kawazoe*, who together wrote a book about the iconic structure (Koolhaas & Obrist, 2011; Louw, 2017). Every twenty-year rebuild of the Ise Shrine represents a renewal process that reflects the religious concept of ensuring the vitality of the deity by rebirth (Sabia-Tanis, 2012). According to *Shinto*, the *Kami* (gods) gradually lose their power and efficacy over an extended period; thus, they undergo resurrection to regain their strength. Another traditional Japanese concept, *Wabi-sabi*, represents a concept of time frozen in material things and the acceptance of the passing of time (Louw, 2017). Wabi-sabi objects are expressions of material with the effect of weathering and human treatment. Based on these notions, Japanese Metabolism reflects the time notion of architecture based on the cyclic concept of rebuilding and decay (Nyilas, 2016).

In essence, the metabolic architecture presented the time notion of which buildings were mutable to accommodate different functions at different periods (Kurokawa, 1977). Besides the renewal concept, the time concept of recycling and transformation are central to the metabolic proposals. In the case study of *Kiyonori Kikutake*, Move-net showed the staged utilization of a moveable kid's bedroom, which was attached and detached to the main structure according to the age of the child. The housing grew with the changing family structure. The seven transformations satisfied the different stage requirements of users through the removable unit and the flexibility of the house structure. In addition, the marine city project demonstrates the growth process of a city, which eventually turns into an underwater habitat for marine life after the lifetime of the city reaches its endpoint.

Figure 63. Wabi-sabi in Japanese Gardening.

On the one hand, the time consciousness from Japanese traditional culture and architectural metabolism can be summarized as the past, present, and future being integrated via a medium/procedure (Sabia-Tanis, 2012), I like building or knowledge. From the aspect of construction, integration of time means the mutability and flexibility of the architecture. On the other hand, the half-life of various elements within the relationship between people and the built environment is uneven. The failure of the Japanese Metabolism movement was based on their systematic underrating of the variable time decay of different stakeholders. In reality, the construction of materials, advances in technology, and information flow compose the environment of cities and architectures, which all require separate time scales and operation channels. Each element among the people-external surrounding model operates on different lifespans and experiences varying speeds of physical decay. Cities and buildings are artificial creations, and without adequate recovery capacity, the physical decay and time flows would be one-way and irreversible.

Cross-scale interaction features of self-organization make the system more accessible to include different time beats among various units. The temporal scales in the adaptive cycle model by *Holling* and *Gunderson* (2002) have shown the irregular processes of each stage for adapting to external variables. Their model reveals an adaptive process in the system when it encounters unexpected variations. In addition, *Eken* and Atun (2019) proposed the tool of the metabolic adaptive cycle to explain the rapid and *small*-scale innovations within the slowly adaptive but conservative boundary. Building on the theory, the relationship time model of people-building-cities-external surroundings could be seen as a multiple-layer concentric sphere, composed of numerous time loops on different levels but interrelated.

Furthermore, the material decay of buildings is a predictable result in the system. From this viewpoint, the degradation within the system is examined from two aspects. One is the material part, in which the spatial unit could have another purpose after the end of its initial use. Another one is the system could take the decay as an opportunity for innovation. At the reorganization stage, the replacement of new components depends on the condition at the time, which could keep the original version or require an updated one. As a result, the goal of the time model is to pull together the four stakeholders as an association group, with a variation of one part triggering the others. As it is applied, the parameters will be generated from the sectioning of the sphere model. These parameters present practical situations at the intercept time, such as user needs at the moment, requirements of building, site conditions, and social background. This timing tool enhances the flexibility and allows a more dynamic, adaptive design strategy.

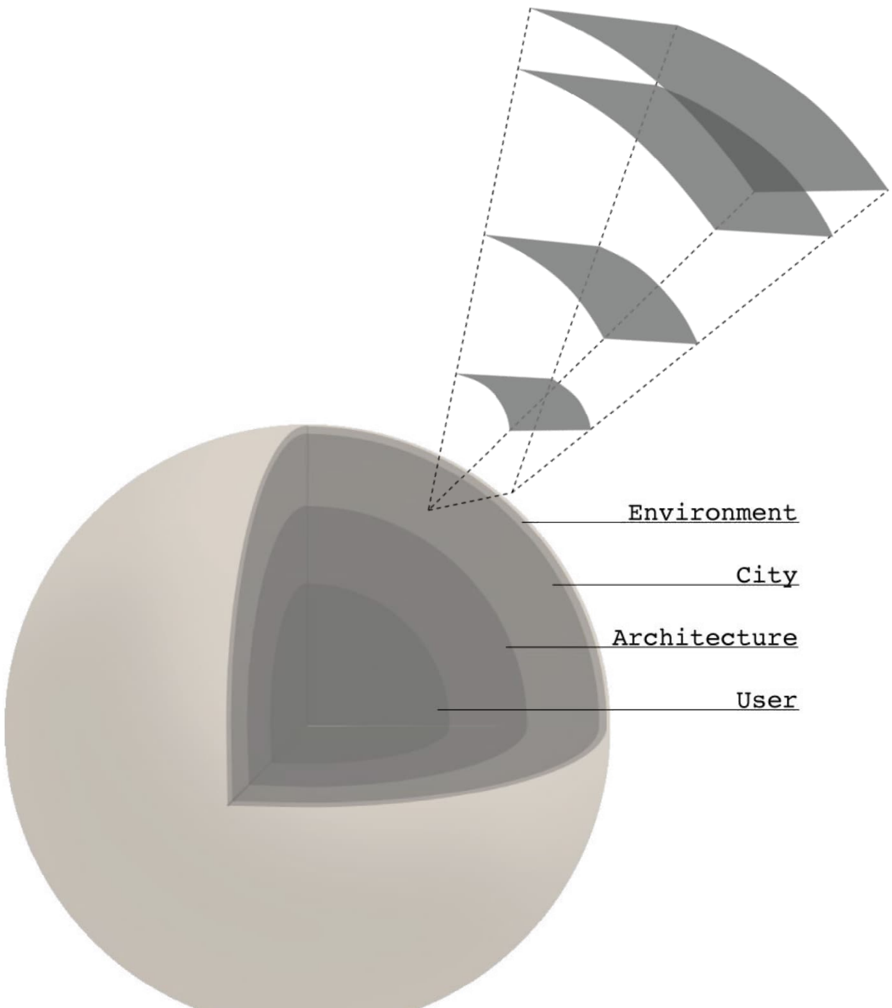


Figure 64. Time relation among user, architecture, city, and the environment.

5. Social resilience of the system

Resilience is the capacity of the system evolution along an open-ended trajectory within a stable realm, which adjusts the system to renew itself, absorb disturbances, and reorganize (AlWaer & Illsley, 2017). As humans are a part of the biosphere, maintaining ecological and social resilience is vital for sustaining the city.

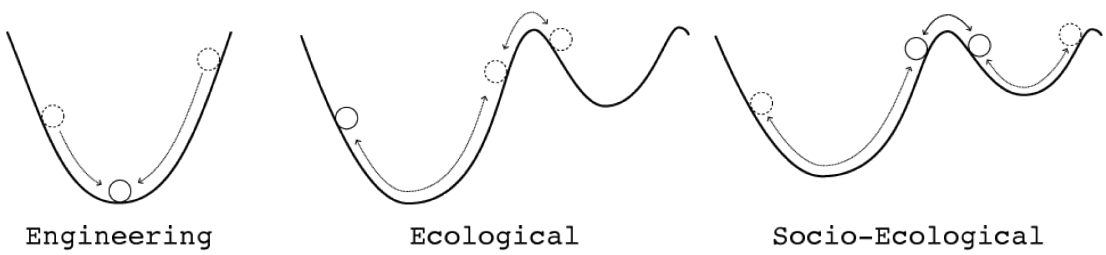


Figure 65. Engineering, Ecological, and Socio-Ecological Resilience.

In the self-organization design system, resilience plays a cohesive role to connect the features of hierarchical levels and multiple individuals. This supports linkage between these components and upholds the framework of the system. On the one hand, when architecture and urban design are applied, there should be a medium between the de-sign approach and the original urban fabric to connect the local social textures. On the other hand, according to specific case studies of urban transition (Ernstson et al., 2009), the resilience of cross-scale interactions is the crucial factor that drives transition in the system for adapting to the external environment. In addition, the study reconceptualizes cross-scale interactions as ecological and social networks. One transfers material and genetic information, and the other is a continual communication channel by society. The system cannot be sustained by only depending upon flows of material and energy, it al-so requires the flow of information and cultural resilience. The shared information channel also created the platform by which materials flow. The point echoes the mech-anism of self-organizing system, where hierarchical interactions operate and infor-mation flow between components.

Meanwhile, the research on resilience theory shows that to keep the system active and sustainable, it needs to be renewable and allow for innovation. The researchers of urban resilience theory think that innovation sits at the heart of understanding resilience and transformative capacity in a human-dominated system (Ernstson et al., 2009). This point also reflects the feature which involves innovative change but a stable frame within self-organizing system.

One distinguishing point in the resilience frame is the collaboration between soci-ety and the environment, especially from the social perspective. This feature of cultural resilience provides the potential space of increasing resilience and engages the public in the system. The increased resilience could not only lay in the material and energy di-mension, it harnesses the interaction among stakeholders adapting to unpredictable change. The cases in Japanese Metabolism show that cultural resilience helps the pro-ject be successful and the adaptive capacity more enduring (Eken & Atun, 2019). The various stakeholders also enhance the dynamic interplay with their diverse backgrounds and knowledge. It helps to steer innovation toward more sustainable solutions. This kind of city lab has been demonstrated in Urban Living Labs (Puerari et al., 2018) which are spatially embedded sites for co-creation dynamics by the local communities and pro-fessionals. This experimentation not only helps to engage users in the system and in-creases public awareness of the social issues but also could collect feedback from users as a basis of upgrading the system. In addition, when the design is applied to different regions, cultural resilience acts as the medium which enhances the connectedness with localism and merges into the urban fabric and cultural heritage.

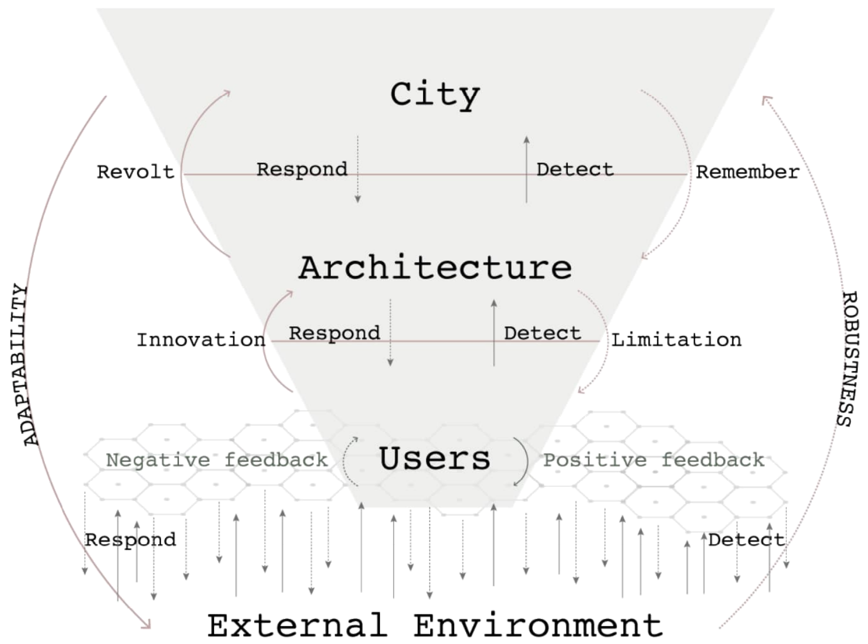


Figure 66. Individual acts as the sensor for variations within the hierarchical system.

6-2 Design Framework

The city is a complex system that includes economic, ecological, and social subsystems. As a result, the different characteristics of the complex systems enact through cross-scale interactions achieving self-organization in the urban fabric. Based on this, the built environment presents as a stratiform structure in the relations among users, architecture, and urban design. The project aims to link these three components and operate in a self-organization system. According to the above five features, the design structure of self-organization can be divided into the operating system, parameter resources, and linking medium.

Firstly, the operating system includes physical spatial units and the rules for interactions within the system. The unit is the spatial container which is in line with the setting as the fundamental component of the system. These spatial containers will organically grow based on the given rules and patterns in the method. Secondly, the diversity and flexibility of the system results from the parameters of the user and the time dimension. Besides the operation system and parameter resource, Cultural resilience is an essential medium for connecting the design framework with the urban fabric and linking exterior design with localism. It plays the glue in the structure, which operates by user involvement. In the system, users not only provide their requirements for driving the system but act as detectors by sensing changes from the external surroundings.

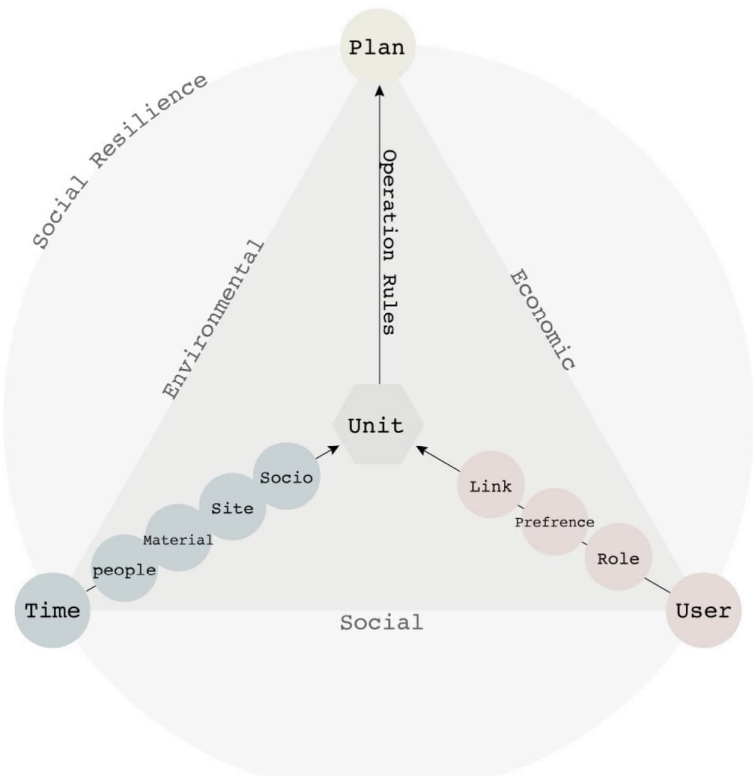


Figure 67. Design framework of self-organization architecture.

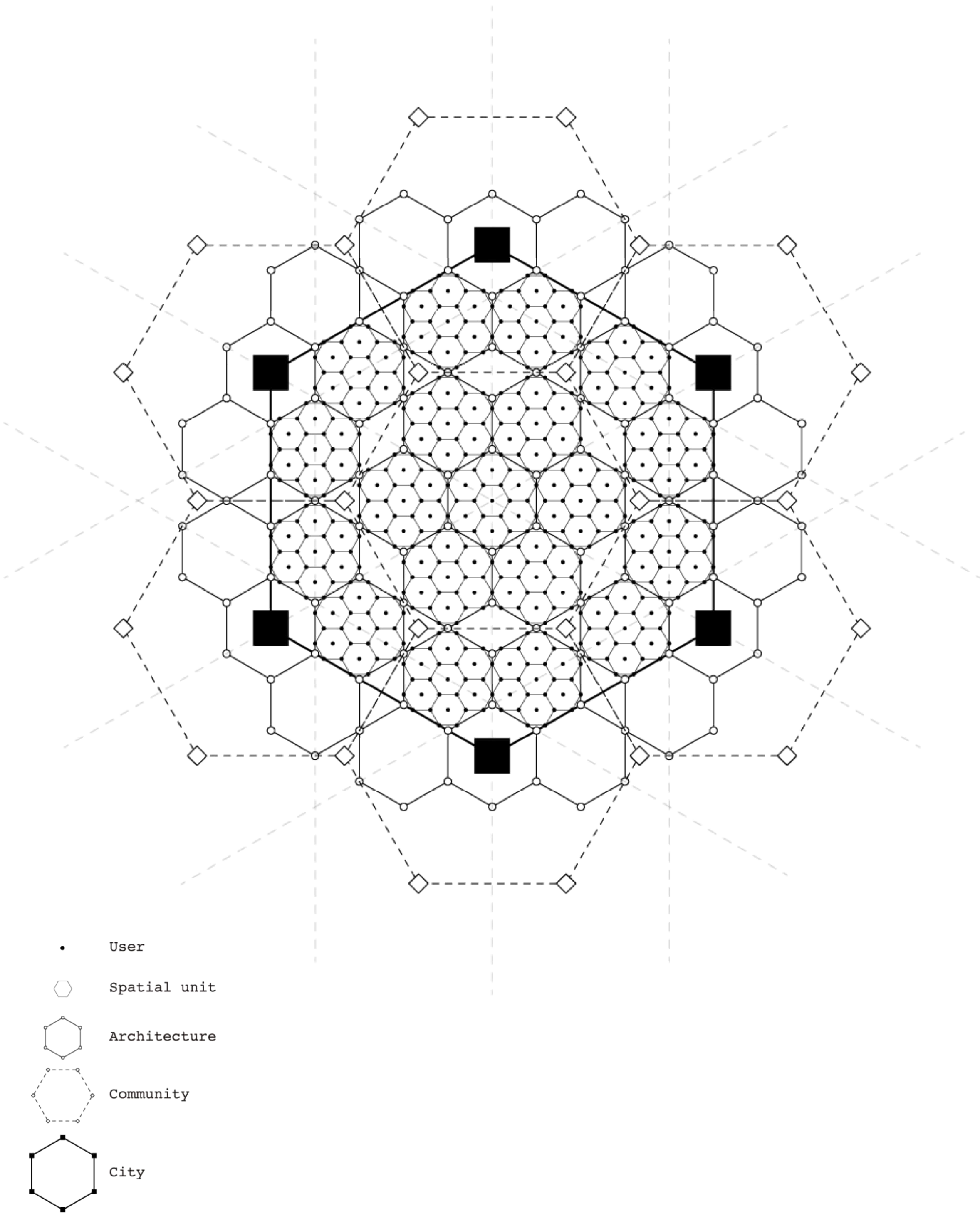


Figure 68. *Hierarchical relationship of the system.*

1. System principle

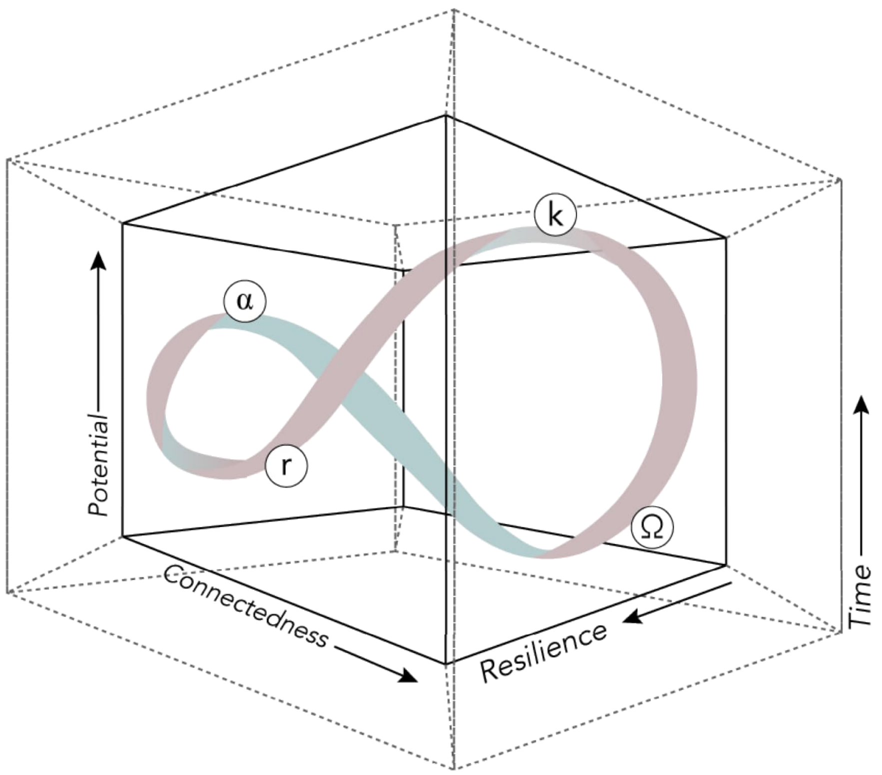


Figure 69. Four-dimension adaptive cycle.

The principle of the system is a four-dimension model, which is built on the three-dimension model of the adaptive cycle. As the fourth dimension is added to the system, architecture and urban design enhance the adaptive capacity and turn into a dynamic system for future variations. This circular process of collapse and reorganization with a time dimension comprise the dynamic loop of the system. In addition, based on the integrated relationship between architecture and urban design as described by Eken and Atun (2019), the hierarchical associations of user-environment allow a chain reaction in the design system. The mechanism is protected by the conservative boundary, which is the loading capacity of the environment. At the same time, the architectural innovations act as renewal factors of the system, which are triggered by user requirements. These small-scale innovations accumulate towards large-scale evolution on the urban level. This mechanism will help cities sustain an equilibrium between the environment, society, and economy. On the other hand, the system will not entirely collapse when an invention fails due to the protection boundary.

2. Operation system

The operation system can be further divided into the spatial unit and procedure pattern. According to analysis derived from self-organization, the fundamental unit should first be defined. Based on findings in the previous chapter, the spatial unit should be considered from the aspects of moveable scale and the physical decay of material. The redefinition of the basic unit is the priority for the system. The unit/capsule plays the role of a cell in the operation system, able to interact with other components. Based on the principles of self-organization, the pieces are diverse and operate along corresponding channels. In addition, the unit remains as part of the open system, where users can add units according to their needs. The preliminary setting of the unit is a single space that divides the room depending on its functions, such as a bedroom, kitchen, or toilet. These containers also are transformed to other purposes at the end of the initial lifecycle.

These various units operate by patterns, following the principles of stigmergy and self-organization. The rules can be defined as horizontal (positive and negative loop), vertical (revolt and remember), and interaction method (operation regulations). Compared to the communication method, the first two components are more straightforward. They can be explained as an extension or limitation based on the user requirement and system boundary. This part needs more detailed rules for interaction and operation patterns, which follow the principle of stigmergy. An initial suggestion is that the procedural pattern can generate results based on parameter resource through evaluations of the computational design tool.

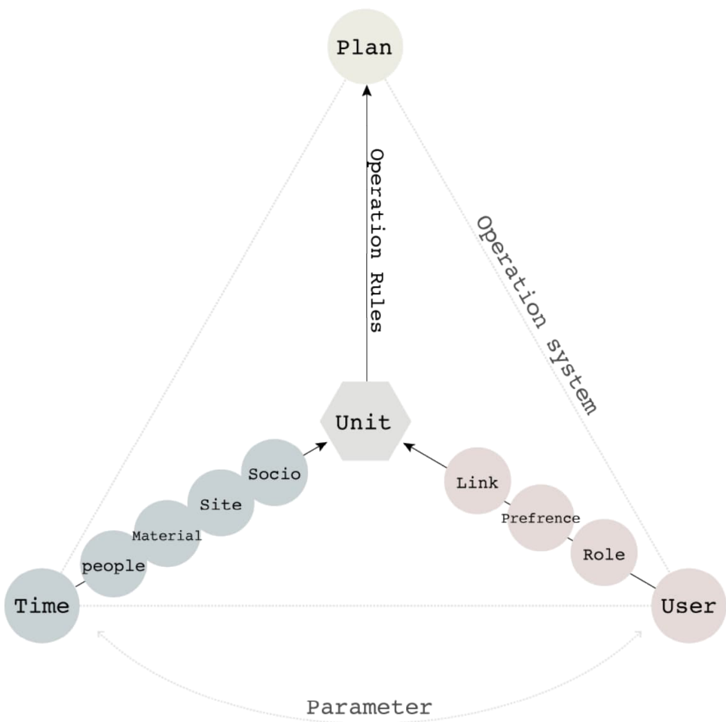


Figure 70. Structure of the operation.

3. Parameter resource

In the framework, parameter generation is the factor in which the system remains open and flexible to adapt to the built surroundings. The resource of parameters results from the user role, their relationship with others, and the section of the time model. The various personalities in the spatial units demonstrate the preference of different users. Kisho Kurokawa mentioned that although the spatial container is a prefabricated product, the user gives the soul to the space (Kurokawa, 1977). In addition, the unit is independent and belongs to an individual, but it can be combined with other users. The varying combinations lead to infinite results and possibilities. The fundamental unit changes in reaction to the requirements of residents and changes in the number of members. Furthermore, the loading capacity of the system depends on the system's limitation and physical decay of the unit, which can be seen as the boundary of the resident environment and design. As a result, the basic conditions that ought to be defined are the typology of the fundamental unit, the hierarchical relationship among units, the physical decay rate of capsules, and the system's maximum capacity.

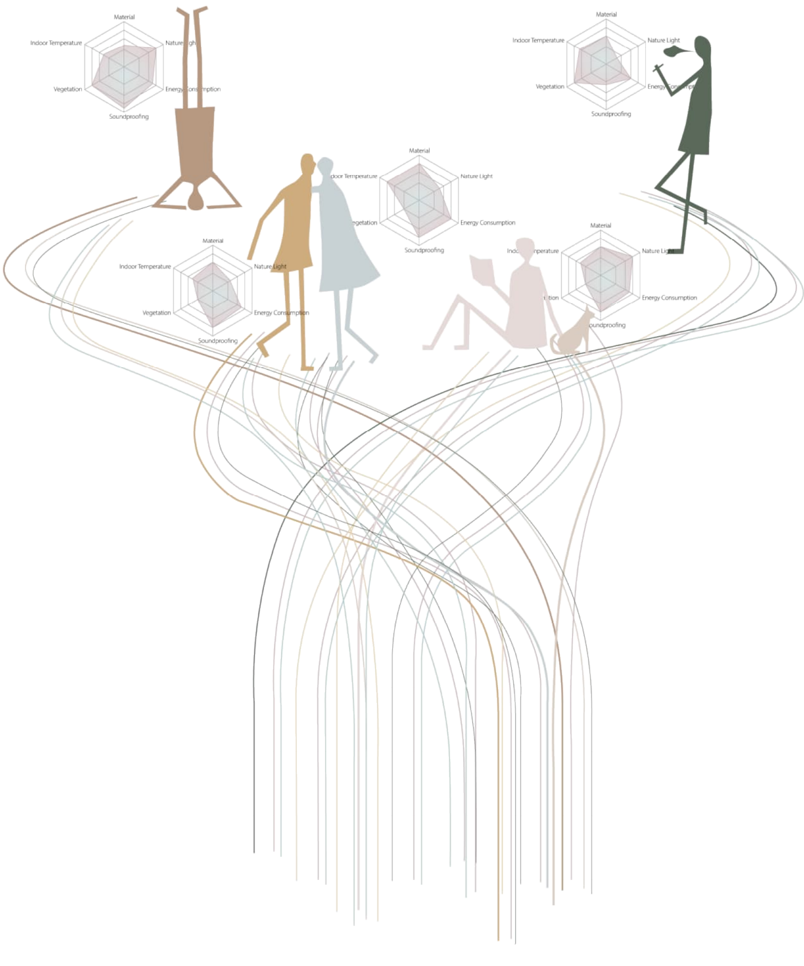


Figure 71. The Combination of user parameters generates infinite results.

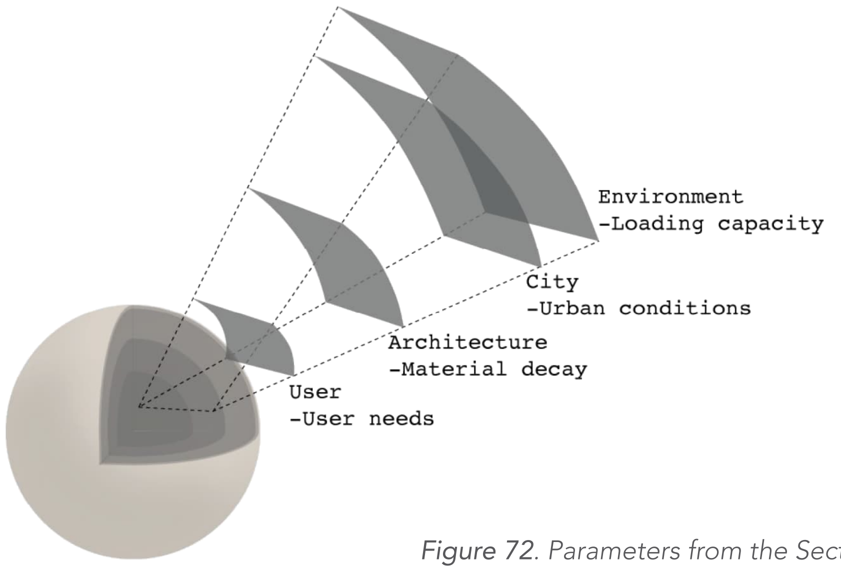


Figure 72. *Parameters from the Sections of Time Model.*

The sections from the time model provide data of the four categories for the system. The modeling stage is analogous with the analysis step of the masterplan, which usually analyzes the plot site to gather detailed information about the local fabric. However, the action is laborious and time-consuming, leading to an incomplete investigation and only a surface-level understanding. The data from sections of the time model include the user requirements, the decay rate of materials, conditions of the site area and social structure, and more. This information in the system can be transformed as parameters for the design.

The innermost layer of the sphere represents the time between people and space. Human time is linear with constant growth, but extended through the generations, which can be seen as overlapped loops. Moreover, different stages of an individual's lifespan correspond to various needs and requirements. In the next step, the time beats of cities and architecture are discussed as an integrated entity. The relationship between architecture and the city is the mutually reliant time flow based on the model of Eken and Atun (2019), which are the fast, innovative changes on the architectural scale and slow, conservative maintenance on the urban scale. The second sphere represents the time of buildings, composed of numerous individual adaptive cycles of units. The time of construction can be divided into two aspects. One is the time influenced by the user, which connects with the first layer of the model. The other is the rate of material deterioration of the physical container, which ought to be renewed at the peak of decay. The third layer, the time of cities, is formulated by undergoing multiple small collapse-reorganization processes of architectural components, while maintaining the boundary of the system. The final temporal layer is the external surrounding. With time, the change in the environment is gradual, and the transitions are too incrementally slow to notice. Time is a two-sided element that contains growth and decay. When it corresponds to the environment, it can be explained as the relative proportion between consumption and recovery. As a result, the model aims to reconcile the rate of consumption from the urban and architectural domains with the recovery of the environment.

The self-organization design framework is an extension of the Masterplan method rather than a denial of its contribution and effect. As mentioned in the masterplan chapter, many masterworks are built on the masterplan design approach, readily coping with the practical issues of buildings and meeting aesthetic requirements. For instance, several important pillars in the modern Japanese architecture community, like Andou Tadao, Toyo Ito, and SANNA, were outstanding projects following the masterplan method over the decades. The works of these architects who are influenced by Metabolism have demonstrated personal explanations of modern Japanese architecture and have been a bridge between the non-digital design age and the parametric tool. This study attempts to find a combination and transition between the two realms (masterplan and self-organization) and achieve a more flexible and sustainable design approach.

6-3 Scenario

Figure 73. The scenario of the community with the self-organization building.

• *Projects could generate several simulations through the parametric tool and assume scenarios based on the above definition and rule set.*

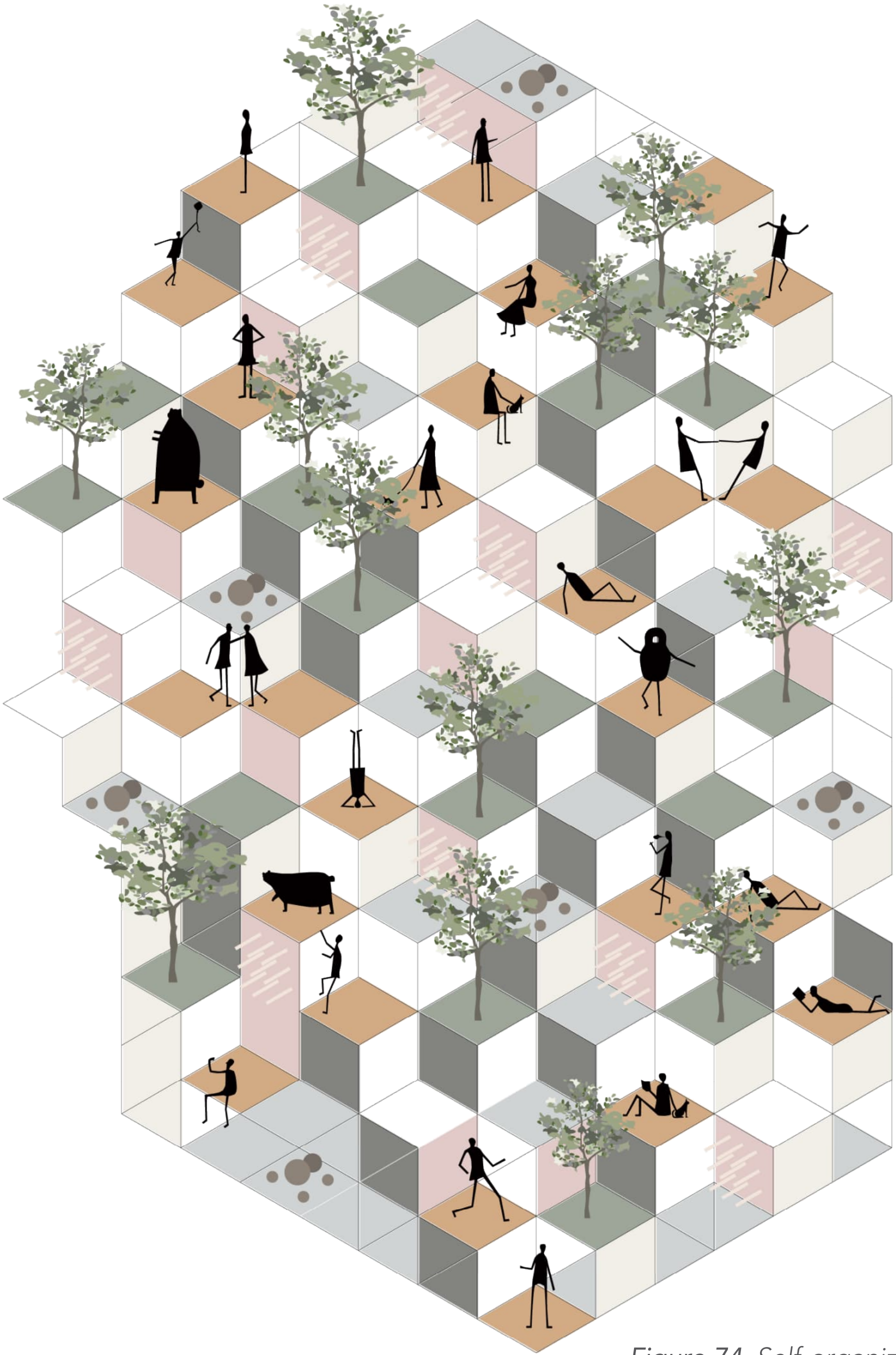


Figure 74. Self-organization architecture concept.

The system is hierarchical and reactions can be accumulated to the next level in a chain reaction fashion. The framework also links with the time mechanism and can adapt to the external variations and internal adjustments. In addition, the living containers grow with the surroundings and respond to the socio-structure with time. The framework aims to make design dynamically adapt to continual changes with no set finishing point.

Figure 75. The scenario of the room with its user.

• Users endow the rooms based on the same spatial unit with different layouts and personalities. These preferences would turn into parameters of the system and trigger reactions within the system. The room unit can exist independently or connect with other components when the users interact or the relative requirement exists.

• Users act as environmental sensors which detect changes and provide feedback to the platform. They are the bridge between the design teams and the urban fabric.

Figure 76. The scenario of the room with its user.

Figure 77. The scenario of the room.

Chapter 7 Conclusion and Future

7-1 Conclusion

Nowadays, architectural design is not only the solution and blueprint for the construction details of buildings. It has to react to more complicated social issues and achieve more sustainable development. Its top-down design approach allows little space for mistakes and mainly presents the aesthetic and consciousness of architects. In essence, architecture strives to fulfill the needs and requirements of people and provide a shelter for living, while cities create sustainable surroundings for these developments. A static and partial method no longer meets dynamic variations and a constantly changing environment. In addition, the role of the architect is a controller who selects the best solution for issues and strikes the best balance between stakeholders. However, the desire to create aesthetic projects necessitates material consumption and carbon-emissions which conflicts with the goal of sustainability. As a result, the appropriate equilibrium between desire and purpose is an obvious question for sustainable designers.

The study aims to pursue the equilibrium of unplanned planning and imperfect perfection. It revises the time sense of the ending of masterplan projects and provides a bottom-up design framework that is adaptive and responsive to the built environment. Self-organization and Japanese Metabolism share many similarities, including operation mechanisms and philosophical concepts. Self-organization is an expression of the collective swarm, where individual effects potentially influence the ultimate result. The phenomenon is also reflected in the modern political environment in which democracy in the political system could be seen as self-organization. When it links to design, design democracy means making things accessible to the public so that everyone can enjoy the products and achieve equality. *Kenji Ekuan*, an influential industrial designer in Japanese Metabolism, supported the concept and mentioned that the Japanese people and environment inspired his design.

Japanese Metabolism and self-organization indicate the imperfect and impermanent consciousness of architecture and urban design. In Japan, this concept could be traced back to Wabi-sabi, which presents the imperfection, impermanence, and incompleteness of traditional culture. It reveals the acceptance of the vulnerability of artificial things and the natural aging and weathering of materials, such as the devolution of buildings. From self-organization, the unplanned plan is a presentation of the system and pursuing the equilibrium of perfect imperfection for projects through 'nature' patterns, such as the invisible hand in the business market and sand organizing in the desert. Systems ultimately settle in a '*perfect balance*' under specific rules.

In response, this design approach aims to build a vibrant and bottom-up strategy through the features of self-organization. The bottom-up approach is closer to user needs and provides more autonomy to unskilled owners. It extends the amount of interaction between the design process and the local environment while enhancing the flexibility of buildings, even on the city scale. The design framework should allow the layering of time in the design process, which considers system decay as an opportunity to evolve and improve the entity.

7-2 What Is the Next?

This thesis is an initial step of the design framework that explores the essential mechanism of self-organization and points out its features of architectural design. There are some vital issues for completing the project that require further study.
The first is the setting of the fundamental component, including the physical (material, size, form, etc.) and the categories of needed parameters. What is more, the most complex and vital aspect is the rules for the operation that conduct the interactions between components. According to the self-organization mechanism, the rules are vertical and horizontal, and specific components have their channels for operation. The third part is the development of the user participant service, a platform for users to update their current circumstance, adjust their own space, and provide local knowledge as a design reference.

Self-organization is a method of collective intelligence. This characteristic leads to the flexibility and inclusion of the system in adapting to unpredictable changes. The resilience also maintains the equilibrium of the whole system when there are small-scale collapses. This framework aims to provide a mutualism between design and users, the environment and artificial products, and aesthetics and science.

References

AlWaer, H., & Illsley, B. (2017). Rethinking Masterplanning: Creating Quality Places. ICE Publishing. https://doi.org/10.1680/prmp.60715

Andrzejewski, E. (2018). FAST, LOW-SKILLED, AND FLEXIBLE BUILDING ASSEMBLY (NOW!): REVISITING THE JOINT-BASED UNIVERSAL BUILDING SYSTEM. The Pennsylvania State University.

Angelidou, I., & Yatsuka, H. (2012). Metabolism and After: A Correspondence With Hajime Yatsuka. 24, 33–41.

Asada, E. (2011). Overcoming contradictions—QS72 ar the disaster site. 22(2011.10), 6–8.

Bullivant, L. (2012). Masterplanning Futures (p. 313). https://doi.org/10.4324/9780203720684

Camazine, S., Deneubourg, J.-L., Franks, N. R., Sneyd, J., Theraula, G., & Bonabeau, E. (2001). Self-Organization in Biological Systems. Princeton University Press. https://doi.org/10.1515/9780691212920

Chiu, C.-S. (2015). 「朗讀違章」與「建構蘭花屋」：當代台灣違建論述之公共空間觀點與公共性詮釋 . 建築與規劃學報 , 16(1), 21–39.

Christensen, L. (2014). Practices of Stigmergy in the Building Process. Computer Supported Cooperative Work (CSCW), 23. https://doi.org/10.1007/s10606-012-9181-3

Dipple, A., Raymond, K., & Docherty, M. (2014). General Theory of Stigmergy: Modelling Stigma Semantics. Cognitive Systems Research, 31–32. https://doi.org/10.1016/j.cogsys.2014.02.002

Donovan, E. (2020). Explaining Sustainable Architecture. IOP Conference Series: Earth and Environmental Science, 588, 032086. https://doi.org/10.1088/1755-1315/588/3/032086

Doyle, M., & Kalish, M. (2004). Stigmergy: Indirect communication in multiple mobile autonomous agents. Knowledge Systems for Coalition Operation.

Eken, C. (2019). Learning from Resilience: Cities towards a Self-Organizing System. 92–103. https://doi.org/10.25034/ijcua.2018.4686

Eken, C., & Atun, R. A. (2019). The Self-Organizing City and the Architecture of Metabolism: An Architectural Critique on Urban Growth and Reorganization.

El Sayad, Z., Farghaly, T., & Hamada, S. (2017). INTEGRATING HUMAN-CENTERED DESIGN METHODS IN EARLY DESIGN STAGE: USING INTERACTIVE ARCHITECTURE AS A TOOL. Journal of Al-Azhar University Engineering Sector, 12, 947–960. https://doi.org/10.21608/auej.2017.19180

Ernstson, H., Leeuw, S. E. van der, Redman, C. L., Meffert, D. J., Davis, G., Alfsen, C., & Elmqvist, T. (2009). Urban transitions: On urban resilience and human-dominated ecosystems. AMBIO A Journal of the Human Environment. https://www.researchgate.net/publication/49667946

Feliciotti, A., Romice, O., & Porta, S. (2015). Masterplanning for Change: Lessons and directions. Book of Proceedings AESOP Prague Annual Congress 2015., 3051–3065. http://aesop2015.guarant.eu/aesop-2015-proceedings.

Firley, E., & Groen, K. (2014). The Urban Masterplanning Handbook. Wiley. https://www.perlego.com/book/1000412/the-urban-masterplanning-handbook-pdf

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. Ecology and Society, 21(3). https://doi.org/10.5751/ES-08748-210341

Fujimoto, S. (2017). 如何將最小空間發揮到最大 HOW TO TAKE MINIMAL SPACE TO THE MAX? [Audi Taiwan]. https://www.audi.com.tw/tw/web/zh/Audidestination/audidestination/HOW_TO_TAKE_SPACE_TO_THE_MAX.html

Fumio, N., Hajime, Y., Yasufumi, N., Souhei, I., Kayoko, O., Lee, A. Y. L., Seng, K., Saikaku, T., Kisho, K., Yoshikazu, N., Kiwa, M., & Yoshiyuki, Y. (2013). 代謝派未來都市：當代日本建築的源流 . 田園城市文化事業有限公司 .

Giddings, B., & Hopwood, B. (2006). From Evangelistic Bureaucrat to visionary developer: The changing character of the master plan in Britain. Planning Practice and Research, 21, 337–348. https://doi.org/10.1080/02697450601090849

Giddings, B., & Hopwood, B. (2018). A critique of Masterplanning as a technique for introducing urban design quality into British Cities. http://stuffit.org/bnb/research/regeneration/pdf/masterplan.pdf

Gill, K. (2016). Architect or Bee? Mike Cooley: The human spirit. AI & SOCIETY, 31. https://doi.org/10.1007/s00146-016-0675-2

Harris, D. (2014). Kiyonori Kikutake Capsule Living Within The Metabolist Movement 2014. Trans-national Mega Projects, Deakin University. https://doi.org/10.13140/2.1.2081.2482

Heylighen, F. (1989). Self-Organization, Emergence and the Architecture of Complexity. Proceedings of the 1st European Conference on System Science, 23-32.

Heylighen, F. (2016). Stigmergy as a universal coordination mechanism I: Definition and components. Special Issue of Cognitive Systems Research – Human-Human Stigmergy, 38, 4–13. https://doi.org/10.1016/j.cogsys.2015.12.002

Holling, C. S. (1996). Engineering Resilience versus Ecological Resilience. Peter C. Schulze. https://doi.org/10.17226/4919.

Holling, C. s, & Gunderson, L. H. (2002). Resilience and adaptive cycles. In Panarchy: Understanding Transformations in Human and Natural Systems, 25–62.

IEA. (2019). Global Status Report for Buildings and Construction 2019. United Nations Environment Programme, 2019. https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019

Isaeva, V. (2012). Self-Organization in Biological Systems. Izvestiia Akademii Nauk. Seriia Biologicheskaia / Rossiiskaia Akademiia Nauk, 39, 144–153. https://doi.org/10.1134/S1062359012020069

Jaillon, L., Poon, C. S., & Chiang, Y. (2008). Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Management (New York, N.Y.), 29, 309–320. https://doi.org/10.1016/j.wasman.2008.02.015

Jodidio, P. (2021). Contemporary Japanese Architecture. TASCHEN.

Kikutake, K. (1958). Kiyonori Kikutake: Between Land and Sea. Ken Tadashi Oshima, co-published by Harvard University Graduate School of Design.

Knudsen, C., Moreno, E., Arimah, B., Otieno, R. O., Ogunsanya, O., Arku, G., Jedwab, R., Broto, V. C., Iracheta, A., Klopp, J., Bilsky, E., Dentinho, T., Simon, D., & Leck, H. (2020). World Cities Report 2020-The Value of Sustainable Urbanization (p. English). United Nations Human Settlements Programme (UN-Habitat).

Koolhaas, R., & Obrist, H.-U. (2011). Project Japan: Metabolism Talks. Taschen.

Kurokawa, K. (1977). Metabolism in Architecture (1st Ed.). Studio Vista.

Lin, Z. (2010). Kenzo Tange and the Metabolist Movement: Urban Utopias of Modern Japan. (1st ed). Routledge.

Louw, M. (2017). The Craft of Memory and Forgetting.

Matsui, M. (2012). "Metabolism: City in the Future". Artforum International Magazine. https://www.artforum.com/print/reviews/201201/metabolism-city-in-the-future-29881

Narahara, T. (2010). Self-organizing Computation: A Framework for Generative Approaches to Architectural Design. Harvard University Graduate School of Design.

Neustupny, M. (2017). Tradition in Mid-Century Houses of Shinohara and Kikutake. SAHANZ 2017 Annual Conference Proceedings. NMBW Architecture Studio, The University of Queensland.

Nyilas, A. (2016). On the Formal Characteristics of Kiyonori Kikutake's 'Marine City' Projects Published at the Turn of the 50's and 60's. Architecture Research. https://doi.org/10.5923/j.arch.20160604.03

Ohno, K. (2017). The History of Japanese Economic Development (1st Edition). Routledge.

Olsen, M. (2019). Stigmergy for Biological Spatial Modeling (pp. 169–197). https://doi.org/10.1007/978-3-030-20309-2_8

Othman, A. (2007). Supporting End-Users Involvement in Developing Sustainable Housing Project Supporting End-Users Involvement in Developing Sustainable Housing Projects.

Puerari, E., Koning, J. I. J. C. de, Wirth, T. von, Karré, P. M., Mulder, I. J., & Loorbach, D. A. (2018). Co-Creation Dynamics in Urban Living Labs. Sustainability. https://doi.org/10.3390/su10061893

Ritchie, H., & Roser, M. (2018). Urbanization. Our World in Data. https://ourworldindata.org/urbanization

Sabia-Tanis, J. (2012). One Site, Many Dimensions: Time, Space, and Identity at the Grand Shrine at Ise. 18.

Sand, J. (2015). Japan's Monument Problem: Ise Shrine as Metaphor. http://past.oxfordjournals.org/

Schalk, M. (2014). The Architecture of Metabolism. Inventing a Culture of Resilience. https://doi.org/10.3390/arts3020279

Šenk, P. (2017). Capsules: Typology of Other Architecture. Routledge.

Sharma, K. K., & Mediratta, P. K. (2002). Importance of keywords for retrieval of relevant articles in medline search. 34, 369–371.

Shields, P., & Rangarajan, N. (2013). A Playbook for Research Methods: Integrating Conceptual Frameworks and Project Management.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Sopjani, L., Stier, J. J., Ritzén, S., Hesselgren, M., & Georén, P. (2019). Involving users and user roles in the transition to sustainable mobility systems: The case of light electric vehicle sharing in Sweden. The Roles of Users in Low-Carbon Transport Innovations: Electrified, Automated, and Shared Mobility, 71, 207–221. https://doi.org/10.1016/j.trd.2018.12.011

Strauss, A., & Corbin, J. (1994). Grounded Theory Methodology. An Overview Handbook of Qualitative Research. Handbook of Qualitative Research, 273–285.

Theraulaz, G., & Bonabeau, E. (1999). A Brief History of Stigmergy. Artificial Life, 5, 97–116. https://doi.org/10.1162/106454699568700

Todes, A., Karam, A., Klug, N., & Malaza, N. (2010). Beyond master planning? New approaches to spatial planning in Ekurhuleni, South Africa. Habitat International, 34, 414–420. https://doi.org/10.1016/j.habitatint.2009.11.012

Torraco, R. J. (2005). Writing Integrative Literature Reviews: Guidelines and Examples. Human Resource Development Review, 4(3), 356–367. https://doi.org/10.1177/1534484305278283

Vines, J., Clarke, R., Wright, P., Mccarthy, J., & Olivier, P. (2013). Configuring participation: On how we involve people in design. In Conference on Human Factors in Computing Systems—Proceedings (p. 438). https://doi.org/10.1145/2470654.2470716

Voegeli, A. (2020, September 24). Human-Centered Architecture: What Is It and How It Makes a Difference. Dormakaba. https://blog.dormakaba.com/human-centered-architecture-what-is-it-and-how-it-makes-a-difference/

List of Figures

Images are taken or illustrated by the author unless otherwise stated.

Figure 34	Marine City sketch, Kiyonori Kikutake, 1958	©Kiyonori Kikutake,1958. Between land and see, 2016, p.184
Figure 35	Kiyonori Kikutake's concept of movable house, Ocean City, 1960	©Kiyonori Kikutake,1960. Between land and see, 2016, p.189
Figure 36	Kiyonori Kikutake's general view of housing structure, Ocean City, 1960	©Kiyonori Kikutake,1960. Between land and see, 2016, p.189
Figure 37	Marine City, Kiyonori Kikutake, 1958	©Kiyonori Kikutake,1958. Marine City Megastructure / Kiyonori Kiku-take. (2020, May 8). ARCHEYES. https://archeyes.com/marine-city-megastructure-kiyonori-kikutake/
Figure 38	Marine City sketch, Kiyonori Kiku-take, 1959	Kiyonori Kikutake,1959. Between land and see, 2016, p.194
Figure 39	Kiyonori Kikutake's concept of urban metabolism, a sketch included in the Metabolist manifesto, 1960	©Kiyonori Kikutake,1960. Marine City Megastructure / Kiyonori Kiku-take. (2020, May 8). ARCHEYES. https://archeyes.com/marine-city-megastructure-kiyonori-kikutake/
Figure 40	Yoyogi National Gymnasium, Kenzo Tange,1964.	©Kenzo Tange Architects. National Gymnasium for Tokyo Olympics 1964 / Kenzo Tange. (2020, December 11). ARCHEYES. https://archeyes.com/national-gymnasium-for-tokyo-olympics-kenzo-tange/
Figure 41	Fundamental research of QS72	Asada, E. (2011). Overcoming contradictions—QS72 ar the disaster site. 22(2011.10), 6–8. p.11
Figure 42	QS72,GK design group, 2008	Ibid.
Figure 43	Skopje project, Kenzo Tange,1963	Iersel, M. V. (2020, December 11). Masterplan for the City of Skopje. Failed Architecture. https://failedarchitecture.com/masterplan-for-the-city-of-skopje-macedonia/
Figure 44	Power structure of Japanese Me-tabolism and Self-organization	
Figure 45	Nakagin Capsule Tower Renovation Plan, Kisho Kurokawa, 1998–2007	
Figure 46	Elevation and section, floor plan for residential unit, Kiyonori Kikutake, 1963	©Kiyonori Kikutake,1959. Between land and see, 2016, p.196
Figure 47	The Work of Kisho Kurokawa: Cap-sule, metabolism, spaceframe, metamorphose	Koolhaas & Obrist, 2011, p.387
Figure 48	Taipei Performing Arts Center, OMA, 2020.	©2021 Inside Outside. Taipei Performing Arts Center. (n.d.). INSIDE OUTSIDE. https://www.insideoutside.nl/Taipei-Performing-Arts-Center

Figure 49	*Haus-Rucker-Co.*	*©Haus-Rucker-co, Gerald Zugmann. Haus-Rucker-Co: Architectural Utopia Reloaded. (2014, December 30). Archdaily. https://www.archdaily.com/582842/haus-rucker-co-architectural-utopia-reloaded*
Figure 50	*Japanese Metabolism in Osaka Expo, 1970.*	*Moreno, L. (n.d.). THE METABOLISM MOVEMENT - THE PROMISED TOKYO. Sabukaru. https://sabukaru.online/articles/the-promised-tokyo*
Figure 51	*Urban resilience principles for Masterplan for Change*	*Feliciotti et al. (2015). p. 3061*
Figure 52	*Masterplanning for change: flow diagram of the overall process of design.*	*AlWaer, H., & Illsley, B. (2017). Rethinking Masterplanning: Creating Quality Places. ICE Publishing. https://doi.org/10.1680/prmp.60715. Chapter, 9. p.6*
Figure 53	*Taxonomy of the typology of the capsule in architecture*	*Šenk, P. (2017). Capsules: Typology of Other Architecture. Routledge. p.115*
Figure 54	*Vertical Forest, Stefano Boeri Architetti, 2014*	*Vertical Forest. (2014). Stefano Boeri Architetti. https://www.stefanoboeriarchitetti.net/en/project/vertical-forest/*
Figure 55	*Tiny House*	*New Frontier Design. Why the Tiny House Is Perfect for Now. (2022). BBC. https://www.bbc.com/culture/article/20211215-why-the-tiny-house-movement-is-big*
Figure 56	*Urban Informality.*	*© 2022 Initium Medi.* 台北新北向違建宣戰，拆除違章建築如何才能不變成「人口驅逐」？. *(2017). Initium Media. https://everylittled.com/article/107033*
Figure 57	*Kowloon Walled City*	*Zou, C. (Ed.). (2018). Kowloon Walled City. TNL MEDIA GROUP. https://everylittled.com/article/107033*
Figure 58	*Communication Approaches for Units*	
Figure 59	*Community Planning Workshop in Tanzania*	
Figure 60	*Ibid.*	
Figure 61	*Ibid.*	
Figure 62	*Metabolic cycle.*	
Figure 63	*Wabi-sabi in Japanese Gardening*	
Figure 64	*Time relation among user, architecture, city, and the environment.*	

Figure 65	*Engineering, Ecological, and Socio-Ecological Resilience.*	*Goosse, T., & Boelens, L. (2020). Evaluation of the Belgian FRAMES pilots AN ANALYSIS THROUGH THREE PERSPECTIVES. p. 10*
Figure 66	*Individual Acts as the Sensor for Variations within the Hierarchical System.*	
Figure 67	*Design Framework of Self-organization Architecture.*	
Figure 68	*Hierarchical Relationship of the System.*	
Figure 69	*Four-dimension Adaptive cycle.*	
Figure 70	*Structure of the Operation.*	
Figure 71	*The Combination of User Parameters Generates Infinite Results.*	
Figure 72	*Parameters from the Sections of Time Model.*	
Figure 73	*The Scenario of the Community with the Self-organization Building.*	
Figure 74	*Self-organization Architecture Concept.*	
Figure 75	*The Scenario of the Room with its User.*	
Figure 76	*The Scenario of the Room with its User.*	
Figure 77	*The Scenario of the Room.*	

Acknowledgments

This project would not have been done without the support of many people. Many thanks to:

Thesis supervisor
Mikko Jalas

Thesis advisor
Filz Günther

Language Tutor
Pablo Nicacio Monk

Thank you to my friends for providing pivotal advice, especially *Yao Chaowen*

During the thesis development, there are many non-architecture reflections on self-organization. As a Taiwanese with a controversial political status country, I appreciate the environment that made me the person I am. I believe Democracy should be implemented in diverse realms and around the world.