The Future is flexible

Practices of flexible architecture from the post-war period as influences on future developments in architecture

Joshi Sumeet
Architectural History Thesis
TU Delft 2023

Delft University of Technology
The Faculty of Architecture
Julianalaan 134
2628 BL Delft
The Netherlands

MSc3 Architecture:
Architectural History Thesis (AR2A011)

Document type:
Research paper

Year:
2023

Tutor:
Marcel Teunissen

Author:
Sumeet Joshi
5823498

Contents

Acknowledgement 4

Abstract 5

Introduction 6
- Flexibility in architecture

Chapter 1: Design for Resilience 9
- The primary stage (Better Shelter, Ikea)
- The secondary stage (The Liina transitional shelter, Aalto University)
- The third Stage (Container Temporary Housing, Ongawa)

Chapter 2: Metabolism Movement 17
- The Capsule house 'K,' Tokyo
- The Nagakin Capsule tower, Tokyo

Chapter 3: Digitising Design 23
- Diogene (Renzo Piano / Vitra)
- Technological Changes

Conclusion 28

Bibliography 30

Acknowledgement

I would like to express my utmost gratitude to my professor, Marcel Teunissen, for their invaluable guidance and support throughout the course of this project. Their expert advice, insightful feedback, and encouragement have been instrumental in shaping my understanding of the topic and achieving the objectives of this work.

I would also like to extend my sincere thanks to the Delft University of Technology for providing me with the necessary resources and opportunities to carry out this project. The library infrastructure, the vast collection of books, and the online portal provided by the faculty of architecture have been immensely helpful in accessing relevant literature, research papers, and articles. The academic environment and diverse community of scholars at the university have been crucial in shaping my growth and learning as a student.

I would also like to acknowledge the authors of numerous research papers, architectural works, and books that have contributed to the structure of my thesis and helped in defining the research findings.

Finally, I would like to extend my heartfelt appreciation to my family and friends, who have been a constant source of motivation and support throughout my academic journey. Their unwavering encouragement has been invaluable.

Once again, I express my sincere gratitude to all those who have contributed to the successful completion of my thesis. I hope that this thesis will contribute to the research and understanding of flexible architecture, and will provide a framework for further exploration of this topic.

Abstract

As technology advances and materials evolve, architects and designers have access to innovative tools such as digital fabrication, robotic production, CNC milling, and artificial intelligence. These tools have made them more resourceful and precise in their work, allowing them to constantly exceed the potentials and find solutions to future challenges. With the integration of technology and design, architecture is progressing to be extremely flexible to respond to the circularity movement driving the construction industry. While these technologies empower them, it is fair to say that the role of an architect in the future may be uncertain. It would not be surprising if a person received a notification saying, 'your house has been delivered!' The thesis explores the post war period when the architecture started becoming flexible, modular, and prompt reflecting on the circumstances. It specifically examines how these practices are shaping the present and the potential impact they may have on the future of architecture, including the possibility of architecture without architects.

Keywords: *flexible architecture, emergency architecture, metabolism movement, digitising architecture*

Introduction

Today, the world is more connected than ever before. We see globalisation in different sectors, connected technology, order trades in goods and services, cultures, and construction. With it, an extensive network of export infrastructure is developed, which makes it flexible for us to wear clothes that are manufactured in a different continent, to eat a fresh fruit that is grown in a different country or to order a furniture which can be assembled & dissembled in any place. Certainly, there have been significant developments in the field of architecture where flexibility is driving the way architcture is practiced. For example, modular houses are now being digitally produced as a solution to the growing housing crisis (such created by The New Makers). Additionally, emergency architecture that can be easily transported and assembled (such as the flatpack shelters designed by the Better Shelter & IKEA) is becoming more prevalent. As practitioners, these advancements can be both intriguing and intimidating, and it is important for architects to define their role in the new era. Although the future of architects may be ambiguous due to advancement in digital production and technology, the world has always been a part of this transition.

Around 1870's, the American timber merchants exported portable buildings as a kit of parts around the world, called as the Aladdin house, made of timber with uncomplicated joineries that could be assembled upon delivery[1]. Back then, these designs were based on flexibility, easy assembly and were economical and presented glimpses of the construction practises in near future. In 1970, in order to protect an ancient Egyptian archaeological site from the impact of the Aswan High dam construction, the Temple of Debod was relocated from Aswan, Egypt, to Madrid[2]. The temple was carefully dismantled stone by stone, transported to its new location, and reassembled with the same orientation as it had in Egypt. The relocation was made possible by the temple's vernacular construction, that allowed for flexibility when needed.

In the book 'Architecture without Architects,' Bernard Rudofsky argues that the true nature of architecture is not found in the work of professional architects, but in the spontaneous and anonymous creations of ordinary people[3]. He contends that vernacular architecture is often overlooked, yet it represents important aspect of human creativity and ingenuity. Before the industrialisation, we built flexible and temporary structures using vernacular methods. Today we live in a house made of concrete and steel, but tomorrow it may change. Over the last decades, the architecture discipline is constantly evolving and is extremely adaptive to new methods of building. The building industry is making a transition from linear economy into circular economy, which considers resources in a continuously cyclical way. Its principles like design for disassembly, adaptability, reuse and recycle of materials, thereby reducing the carbon footprint, addresses the urgent needs of a city. In a way, the new regulations encourage us to circle back to creating structures that are both fixed and flexible, perpetual yet temporary, and can be easily assembled on-site and disassembled for repurposing after use. The narrative brings me to the research question, **to what extent can the flexibility in future architecture be influenced by past and present practices?**

[1] Cody, J. W. (2005). Exporting American Architecture 1870-2000. Routledge.

[2] Rob. (2017, May 03). Roamin' the empire.

[3] Rudofsky, B. (1987). Architecture without architects: a short introduction to non-pedigreed architecture. UNM Press.

Flexibility in architecture

Flexibility in architecture is an abstract concept that cannot be quantified, but rather evaluated in terms of its quality. It refers to the ability of a design to promptly adapt to various circumstances and changes. A structure's ability to modify its form, spatial layout, and generate different atmospheres and experiences reflects its flexibility. In terms of space planning, flexibility manifests as multifunctionality, where the use of space is never limited to a specific activity but rather continuously evolves over time. The most adaptable spaces are often the in-between spaces, such as central squares on market days, where the activities taking place constantly change, and the objects facilitating these activities are also flexible in structure. Flexibility in architecture is not solely driven by desire and possibilities but can also stem from economic and necessary considerations. For example, a small room in a densely populated area can create flexibility and multifunctionality in its use. Achieving flexibility in architecture is a challenging aspect of design, but once attained, it can open up a multitude of possibilities.

Historical circumstances and movements are testaments to flexible architecture that have provided precedents for designing in the future. The first chapter discusses how the emergency of World War II gave rise to ideas that were extremely flexible. The second chapter highlights the metabolism movement, which inspired the world with its theories in flexible architecture, and the final chapter will explore the integration of technology and design that brings flexiblilty in architecture. The aim of these chapters together is to examine the role of historical and present practices in determining the threshold of flexibility in future architecture.

This research narrows its focus to the scale of a dwelling within the broad spectrum of architecture. By examining various architectural circumstances and movements in the post war period, which emphasised the creation of portable yet dynamic dwellings, the study aims to apply this parameter to gain insights into the development of flexible architecture. The research will be based on a thorough review of books, articles, and research papers.

Figure 1: Caravans as a home during the WW2 (source: caravanclub.co.uk)

Chapter 1

Design for Resilience

Mobile homes, also known as trailers, became a popular choice for American families traveling across states, spurred by the realization that people were spending more time in their cars commuting to work. Leveraging this situation, the automobile industry began redesigning vehicle cabins for luxury, allowing for customization and replacement of parts over time. It led to the American impulse to travel the nation by automobiles, leading to the creation of trailers (mobile homes), which allowed completed freedom to travel at convenience compared to the trains & living in a hotel (which were located only in downtown). The significant increase in the use mobile homes, modulated the urban strategies of the American cities, leading to the creation of trailer parks, equipped with public facilities and necessary infrastructure for the ones' parking their mobile home over night[4]. However, the stock market crash of 1929 left people jobless and homeless. As a result, the great depression caused a necessity to find affordable places to stay, and mobile homes became a housing source. People soon realised that what was intended to be a temporary housing option could become a permanent one.

Around the same time, the devastation of World War 2 left a profound impact on housing worldwide. Cities and towns were decimated, and millions of people were displaced. In the aftermath of the war, there was a desperate need for emergency housing for those who had lost their homes and mobile homes could have become an intuitive solution. But, during the war, the US government urgently needed emergency base housing for recruited servicemembers. To address this need, they purchased around 500,000 trailers units from the American citizens, which served as a temporary housing for the military. After the war, these mobile homes were transported to colleges across the country to provide free education and shelter for the servicemen[5]. The architecture of mobile homes typically featured a rectangular or box shape with a slight pitch in the roof, and they were often made from lightweight materials such as aluminium or plywood. These homes were often small, with necessary amenities and limited living space. While the architecture of mobile homes may not have been as elaborate or stylish as traditional homes, it served an important purpose in providing affordable and flexible housing option. The fucntion of mobile homes changed and adapted to the needs of time, putting forth the concept of a circularity. It created a notion of moveable architecture, which seems like an extension of humans whose characteristict is defined as always moving and not static.

The impact of the war on British civilians was far-reaching, resulting in abandoned houses, a shortage of housing, and an increase in demand for affordability, which necessitated temporary solutions. The initial approach of the British government was to make quick, short-term repairs to existing properties and construct factory-built temporary housing bungalows, commonly referred to as 'prefabs.' The advantages of prefabricated housing included rapid construction, with a time frame of less than a week for on-site erection. The New Towns Act of 1946 aimed to address the overcrowding in city centres by constructing new towns with a range of housing types. Pre-cast reinforced concrete (PRC) homes were one such solution, made from concrete panels and steel frames and requiring less skilled labour. PRC homes could be assembled quickly and were expected to last for at least 60 years, longer than other temporary housing options[6].

Despite the government's temporary housing efforts, many people on council housing waiting lists sought their own housing solutions. Caravans emerged as a popular choice for temporary housing *(see figure 1)* due to their suitability

[4] Black, Brian. 2023. "Trailer Parks." St. James Encyclopedia of Popular Culture (Encyclopedia.com)

[5] Rolfe, Frank. 2017. "The history of mobile home parks." Mobile home park mastery. 2. Mobile Home University. Mastery Podcast, 14 August.

[6] Science Media Museum. 2021. "Post-war homelessness: Makeshift homes between 1945 and the early 1950s." What is the Daily Herald Archive?

and ease of use. Around 1930's several families had access to caravans with an enthusiasm to travel for holidays in the trailer. On the onset of the war, air raids devastating the capital and the start of Blitz completely changed the use of caravan. People moved their belongings into trailers, allowing them the freedom to relocate to safer environments. Living in trailers gave them the ability to be on the move. In emergency situations, finding shelter becomes a top priority for individuals. It is fascinating to see the intuitive solutions people adapt during challenging times. Regardless of being intended as a short-term solution, caravans were often used as permanent housing due to the extended waiting times for more suitable accommodations post war.

Today, the world is again facing emergency situations, our cities are in crisis due to war and natural disasters. These calamities have left homes devastated, families displaced, and in search of new safe environments that can adapt to their needs. The design of these environments will shape their lives for at least a year or more. While mobile homes were once considered emergency solutions, design capabilities have improved significantly since then. This raises the question of whether we now have access to time-efficient solutions that can be deployed within minutes of an emergency. Furthermore, we must consider whether these solutions are designed to serve a purpose beyond providing temporary shelter. The challenges of the time required a shift in traditional approaches to architecture and shelter design, leading to the emergence of flexibility in resilience architecture.

Design has a transformative potential as it filters through every aspect of our lives. In this context, architecture is regarded as a social agent that tackles pressing issues, uplifts communities, and plays a critical role in time of crisis. Emergency architecture, in particular, demands innovation as it needs to be prompt, versatile, and responsive to the needs of displaced communities. Francesca Coloni, who serves as the chief of the technical support section of the UNHCR's Division of Resilience and Solutions, stated in an interview that it is important to ensure that any measures taken provide refuges with a sense of stability, safety, and dignity, despite being in unfamiliar surroundings[7].As crisis occurs unexpectedly, the immediate response is often a temporary disposition and termed as the primary stage. The transformation of these primary responses into a more permanent ones marks the secondary stage, while the creation of permanent housing for the displaced communities is considered as the third stage. We will study each of these responses to better understand the flexibility and adaptability of these structures.

The primary stage (Better Shelter, Ikea)

The immediate response to crisis often involves the deployment of flimsy, tent-like structures. In the case of earthquake disasters of 2023 in Turkey and Syria, relief camps are erected with minimal infrastructure and services. It is disheartening to see that these shelters, constructed from polyester, resemble detention centres or slums rather than providing a sense of comfort and security. To help address these issues, the big furniture giant Ikea partnered with UNHRC to initiate the Better Shelter project, a humanitarian social enterprise, in developing an emergency shelter that can fit inside two boxes. Leveraging its expertise in compacting complex furniture into small, self-assembly packages, Ikea developed a durable flat-pack shelter that can be easily assembled using a standard hex key. The flat-pack shelter includes picture-based instructions and can be put together by four people in just four hours[8].

The shelter spans with an area of seventeen square meters and is constructed of insulated polypropylene panels that clip on to the light steel frames which are anchored to the ground *(see figure 2)*. The walls are developed using the polypropylene panels as it can resist stabbing, which can be crucial and life-saving feature given that these shelters are often located in areas where violence, particularly gender-based violence, is prevalent. Installing solar panels on the roof of a shelter provide up to four hours of electricity, which can be crucial for charging mobile phones and staying connected with family. Additionally, designing the shelter to include small windows and ventilation louvers made of heat-resistant polymer plastic, increases its effectiveness in case of a fire. The Better Shelter becomes the most considered solution as it can be assembled by the locals without any prior set of skills.

Typically, camps set up as an immediate response to a crisis end up becoming more permanent settlements. The Zaatari refugee settlement in Jordan is an example of this, having started as a camp in 2012 in response to the Syrian war and gradually evolving into a long settlement over time. Refugees often reside in these camps for several years until they find a permanent place to live[9]. During this time, they acquire certain skills through workshops set up by UNHCR, and with the help of the government, they eventually build a solid house in place of the tents (which is the secondary stage of the response). As a result, the design of the initial response shelter becomes crucial since tents with canvas, ropes, and poles, are not weather protective and generally lasts for only about couple of months. A Better Shelter is priced double the cost of a typical emergency tent. However, it offers more benefits such as security, insulation, and durability, and has a lifespan of at least three years[10]. The frame of the Better Shelter can still be repurposed and covered with locally available materials like mud bricks or corrugated iron even after the plastic panels start to degrade, making it adaptable to the needs of its users and the environment.

Figure 2: Better Shelters at a transit camp on the Greek island of Lesbos in 2015. (photograph: Better Shelter)

[7] Coloni, Francesca. 2022. "Refugee Crisis." Chap. 5.7 in Design Emergency: Building a better future, by Alice Rawsthorn and Paola Antonelli, p.g 172. Phaidon.

[8] Wainwright, Oliver. 2017. "Why Ikea's flatpack refugee shelter won design of the year." The Guardian.

[9] Carlisle, Lilly. 2022. "Jordan's Za'atari refugee camp: 10 facts at 10 years." UNHCR.

[10] Ibid Wainwright, Oliver. 2017.

Figure 3: Liina Transitonal Shelter set up process (soucrce: ArchDaily)

The secondary stage (The Liina transitional shelter, Aalto University)

The Liina transitional shelter is a temporary structure built with wood-based materials for emergency situations. A time efficient solution created by the students at Aalto University's International Wood Program in 2012, the shelter can be rapidly and effectively deployed when necessary. The transitional shelter uses a flatpack system composed of prefabricated timber panels. These panels are easy to fabricate and can be produced anywhere worldwide. Additionally, all the components required to construct two shelters can fit inside a standard international shipping container[11]. The shelter serves as a secondary response after a crisis and is designed to be assembled by two adults using common non-electric tools and a cartoon diagram within six hours *(see figure 3)*.

The interior of the shelter spans eighteen square meters, meeting the accepted standard of 3.5 square meters per refugee for housing. It includes two semi-private sleeping spaces, a galley kitchen, and a dual-purpose area for eating, living, and working. A loft situated above the sleeping areas provides extra storage and sleeping space. Additionally, there is a covered exterior space of seven square meters that serves multiple purposes for the inhabitants throughout their stay. The Liina concept utilizes prefabricated sandwich panels that can be easily transported and assembled and can be flat packed into a small space. The panels are 600 mm in width, which is half the dimension of a standard plywood sheet.

This design reduces waste and allows for convenient transportation by a single adult. The sandwich panels are joined together through repeated wooden-dowelled joints and tightened with nylon straps, known as "Liina" in Finnish, which are commonly used for cargo transportation. With the use of these straps, the joints become airtight without requiring metal fasteners or electric-powered tools on-site. The frames are then tilted up, stacked one-by-one linearly, and secured with three straps. A tent-like canopy is placed over the building to provide protection against water and UV damage[12].

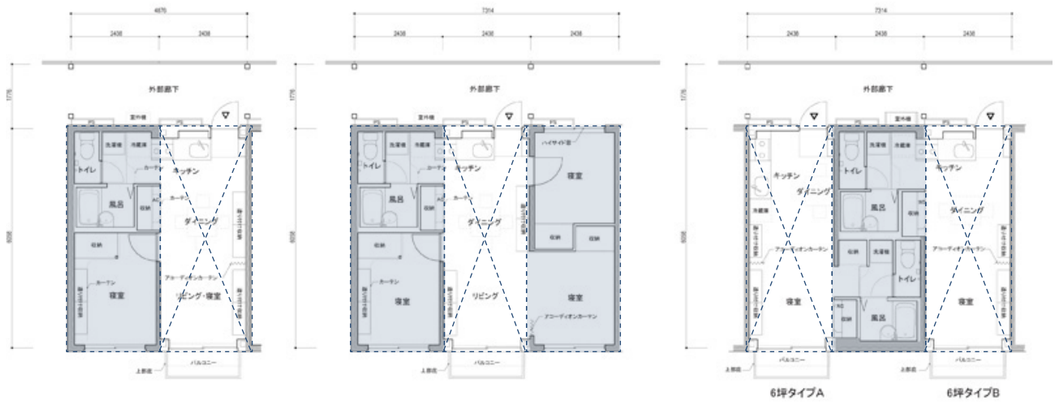
The modularity of the design allows for the addition or subtraction of frames to adjust the size of the shelter to meet the needs of its inhabitants. The shelter is designed to offer varying degrees of privacy and separate areas for daytime and night-time activities. The wood-fibre insulation provides a sustainable solution while also allowing for heat insulation in cold climate. The involvement of refugees in the construction process provides an opportunity to enhance their skillsets while allowing them to curate their own spaces giving them a sense of ownership. The shelter can accommodate a family of five for up to five years during the post disaster reconstruction phase and later the shelter can be upgraded, relocated, resold, or recycled as needed.

Liina is specifically designed to cater to the climate of the Ararat region in Turkey, which is known for its continental climate and frequent displacement of people due to natural calamities such as earthquakes and drought, as well as political unrest. Nevertheless, the adaptable design of Liina makes it suitable for a wide range of cultural and environmental contexts

[11] Wood Solutions. 2021. Inspiring Case Studies using Timber: Liina Transitional Shelter. Accessed Feb 12, 2023.

[12] Archdaily 2011. Liina Transitional Shelter / Aalto University Wood Program. 11 Oct. Accessed April 2, 2023.

(photography: Hiroyuki Hirai)



Option 1 Option 2 Option 3

Figure 4: Different module sizes developed with chequered stacking system

The third Stage (Container Temporary Housing, Ongawa)

In March 2011, a 9.0 magnitude earthquake known as The Great East Japan earthquake struck the country, resulting in a 30 m high tsunami that left widespread devastation. The VAN played a crucial role in constructing paper partitions for over 1800 units (2m x 2m) at more than fifty evacuation sites. The extent of the damage was so severe that the government sought solutions for providing temporary housing for large numbers of people as part of their post-disaster response. Pritzker architect Shigeru Ban and the Volunteer's Architect Network proposed a multi-story temporary housing solution that utilized repurposed shipping containers. The containers are stacked in a chequered pattern to achieve a three-story structure, the system creates bright common spaces in between two containers and private spaces within each container. The system allows for flexibility in creating modules of varied sizes, depending on the needs of the family *(see figure 4)*.

The design requires for a space of approximately eleven meters to be secured between buildings due to multiple floors. This space is utilized as a parking lot or a community facility to fulfil the needs of the town, such as a meeting place, a market for daily shopping and various classrooms. The proposal not only intended to enhance the indoor environment but also the surrounding area to encourage community formation[13] . The use of containers was intended to create a quick adaptable system to build temporary housing, but they are also envisioned as permanent housing eventually, setting a precedent for a tertiary response to emergency situations. The provision of a safe and secure living space is just as important as providing a sense of stability and reassurance for families displaced by emergency situations. These families come from diverse backgrounds and have faced numerous challenges, which is why the communal spaces at Ongawa are designed to restore their sense of dignity.

The container housing at Ongawa represents a third-stage response to emergency situations, providing a permanent shelter and a new opportunity for people to start afresh. The use of containers brings flexibility in design and ease in construction, and the modularity of the units also provide the possibility to move the housing if necessary. The containers are made of sturdy metal and designed to withstand natural forces. The use of contianers in this design provides a sense of assurance for the displaced families and siginifies that the choice of building material while responding with a third stage design is crucial.

It is worth noting that Shigeru Ban and the Voluntary Architects Network team have played a vital role in assisting the government during emergency situations. They developed a simple interlocking system of paper tube partitions which is still the preferred solution for an immediate response. The paper tubes are lightweight, easily available, and can be assembled quickly to create a modular and scalable system that can house large numbers of refugees under one roof. Recently, Shigeru Ban & the VAN team has been working on a Paper Log house prototype for communities affected by the Syria-Turkey earthquake. The prototype uses paper tubes as a structural frame, plywood for walls, and rests on a foundation made up of plastic crates filled with debris, making it a sturdy and effective primary response to emergency situations.

[13] SBA. 2011. Container Temporary Housing- Ongawa, Miyagi. http://www.shigerubanarchitects.com/works/2011_onagawa-container-temporary-housing/index.html.

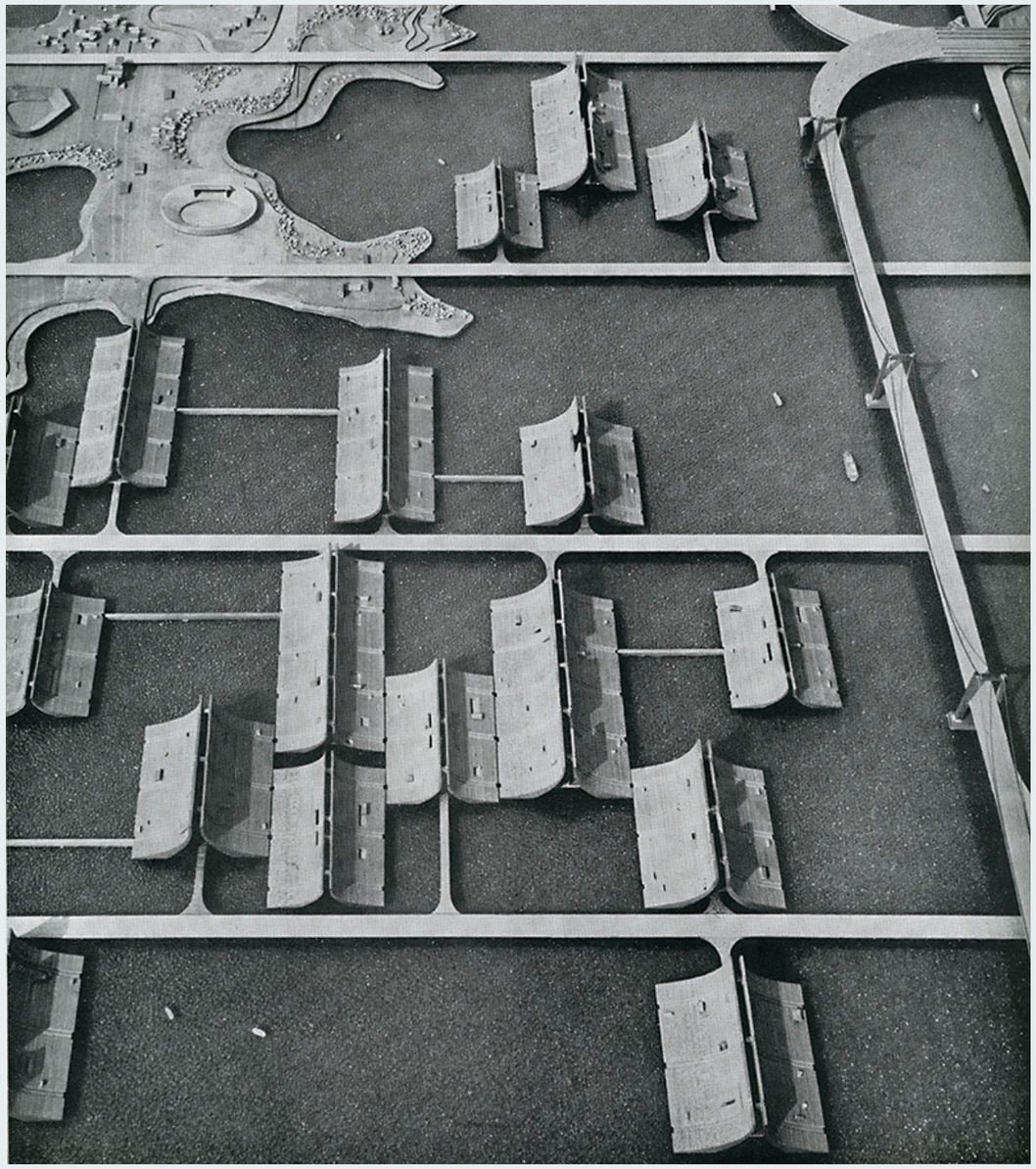


Figure 6: Plan for Tokyo Bay (source: Kenzo Tange. Casabella 258 1961, 10)

Chapter 2

Metabolism Movement

Japanese architecture has a rich and diverse history spanning over thousands of years, with influence from unique Indigenous traditions, shaping the building practices. There are many significant periods in the Japanese architecture that resulted into distinctive styles, but the most prominent development was during the Meiji Period from 1868 to1912. According to Kisho Kurokawa, the Meiji period has the first-generation of architects under which, Japan experienced rapid modernisation and westernisation, by adopting western architectural styles and techniques without any modification at all. During the Taisho period from 1912 to1926, Japan realised a successful development of industrial revolution, where the second generation of architects were influenced of contemporary European art movements such as the Art Nouveau and Vienna Secession. The third generation of architects, which includes Kenzo Tange & Kunio Maekawa, were able to respond to the changes wrought in architectural styles by adapting to the philosophy of CIAM and Le Corbusier. It was since Kenzo Tange, who set the visions for a new post-war architecture, for the first time Japanese Architecture influenced the world. The fourth generation of architects whose point of origin was the aftermath of war and destruction, believed that the introduction of Western architectural styles by previous generations of architects had cause confusion and conflict within national architecture[14]. The dissatisfaction of constant influence from western architecture and the repercussions of World War II, led to the development of the Japanese avant-garde movement "Metabolism," whose distinct ideas and concepts about flexible architecture made a huge contribution to the architectural discipline in the early 60's.

At the end of the World War 2, Japan was devasted and affected by the destruction of its infrastructure. The government wanted to be able to rebuild the nation, both economically and culturally that could accommodate the future growth. Many Japanese architects including Kenzo Tange and Kunio Maekawa, along with the fourth generation of architects including Kiyonori Kikutake, Arata Isozaki, Fumihiko Maki, Masato Otaka, Kisho Kurokawa and others participated in restructuring their ideologies for the future of the cities in Japan. At that time, Japan faced a huge challenge in densification of its capital cities like Tokyo and Osaka. The government enacted a plan to make economies in the areas of Tokaido stronger through direct public investments that led to concentration of people, functions, and activities, with a special concern of industrial system than social equality. The strict government guidelines aimed on promoting quantity over quality, which resulted in huge fragmented urban fabric filled with congestion and overpopulation. The need to provide millions of dwellings became a pressing social issue, which led to a strong demand of industrialisation of residential buildings.

The Metabolism movement was borne out of the issues of rapid urbanisation and industrialisation of Japanese cities and to propose a critical theory that is linked with the characteristics of Japanese social history and Buddhist culture. As its core, the philosophy of the Metabolism movement was to view buildings as living organisms, that could grow, change, and adapt over time. The movement was heavily influenced by the concept of metabolism in biology, which refers to the process by which living organisms convert food into energy to sustain life. The principles of architectural adaptability, replaceability, and metabolic cycles align with the doctrines of Buddhist philosophy, which emphasises the impermanence of humanity and time[15]. In architecture, metabolism movement sought to create flexible, adaptable, and expandable structures that could respond to the changing needs of the society.

[14] Kurokawa, Kisho. 1977. Metabolism in architecture. Studio Vista London. 23-27

[15] Ibid, Kurokawa, Kisho. 1977. Metabolism in architecture. 35

The movement emphasises the use of modular construction and prefabrication, which allowed buildings to be easily modified and expanded as needed. The Metabolism movement also embraced technological innovation, particularly in the use of new materials and construction techniques, as a means of shaping society and promoting social change. The movement found it necessary to blend modernity (western developments) with the heritage of Japanese traditions and to create environments that allows synchronisation of changes in a contemporary society[16].

The movement was established by architects Kiyonori Kikutake, Kisho Kurokawa, Masato Otaka, and Fumihiko Maki by proposing a manifesto ahead of the World Design Conference in Tokyo 1960. The architects advocated for an adaptable architecture & urban design strategy, which could evolve and expand by replacing its worn-out elements and by introducing new components according to the necessity of socio-economic environment. The group proposed several urban design theories, such as "Floating City -Kasugimaura" which was based on an idea of patchwork-like city, which imagined an urban fabric with random placement of city blocks, so that the city could lead its own development and growth. They aimed to create dynamic cities that could regenerate themselves over time, shedding old parts and incorporating new ones, as necessary. Kenzo Tange, regarded as the Metabolist group's mentor during that period, put forth a development plan for Tokyo that sought to tackle urban sprawl by extending the city across the bay *(see figure 6).* His plan also reflected the adaptability of the city as a process but emphasizing on the notions of mobility and urban structuring. Tange's suggestion to accommodate the expansion and revitalization of the city was significant, as numerous urban areas in the industrialized world were grappling with the challenges of urban sprawl[17].

After receiving worldwide acclaim for their avant-garde ideas, the revolutionary group felt it was necessary to gain practical understanding to be informed of possibilities and inconsistencies in their theory. It was during this time that the group realised that a prefabricated house is a technical application of metabolism theory. In the 1970s Osaka Exposition, the group had the opportunities to implement and showcase their research, where Kisho Kurokawa, designed the modular Takara Beautillion - an unfinished yet finished pavilion, expressing qualities of growth. Later, he developed 'capsules' as a flexible & contemporary element of a building design and went on to build the famous Nagakin Capsule Tower in 1972.

Declaration of capsule as an adaptive, flexible, replaceable part of the building, modernized the Metabolism movement. The capsules were designed for the homo movens (a man on the move) and can be referred to the mobile homes, which were immensely popular in America and played a significant role in combating housing shortage during the World War 2. Here, the capsule aimed to diversify the society by representing a new image of independent individual spaces of living as compared to the traditional way of a family house. With rapid urbanisation and industrialisation of Japanese cities, individuals started commuting to the city centres for work, and often finding a hotel for a temporary stay. The capsules reflect the functionality of mobile homes as temporary accommodation units placed in the city centres. The units signified highly individualist spaces assembled to create a new social character for the outsiders. The design was an attempt to adapt a new prefabrication system to rationalise and standardise the housing construction[18].

[16] Pernice, Raffaele. 2018. "Metabolism reconsidered its role in the architectural context of the world." Journal of Asian Architecture and Building Engineering 357-363.

[17] Lin, Zhongjie. 2007. "Urban Structures for the expanding metropolis: Kenzo Tange's 1960 plan for Tokyo." Journal of Architectural & Planning Research (JSTOR) 24 (2): 109-24.

[18] Ibid. Kurokawa, Kisho. 1977. Metabolism in architecture. 75-85

The Capsule house 'K,' Tokyo

Completed in 1971, this house is a prime example of Kurokawa's innovative approach to architecture, which seeks to merge functionality and aesthetics to create a harmonious living space. Capsule House 'K' is a modular, prefabricated house that consists of eight interconnected capsules that are suspended from a central steel framework. The capsules are rectangular in shape and are designed to house specific functions, such as sleeping, dining, and bathing. Each capsule is connected to the central framework by steel beams, which allow the capsules to be arranged and rearranged according to the resident's needs *(see figure 7).*

The design concept behind Capsule House 'K' is rooted in the Japanese concept of "ma", which refers to the space between objects. Kurokawa sought to create a living space that would embody this concept, with each capsule representing a unique space that is interconnected to create a harmonious whole[19]. The modular design of the capsules allows for flexibility and adaptability, making it easy for residents to change the layout of their living space as needed. The house was built using prefabricated components, which were manufactured off-site and then transported to the construction site for assembly. The capsules were constructed using a steel frame, which was then covered with a durable, lightweight material that provided insulation and protection from the elements. The capsules were then suspended from a central steel framework, which was anchored to a concrete foundation. The use of prefabricated components allowed for quick and efficient assembly on site and allowed for flexibility and adaptability during construction. The modular design of the capsules also made it easy to transport and install them on site, reducing construction time and costs.

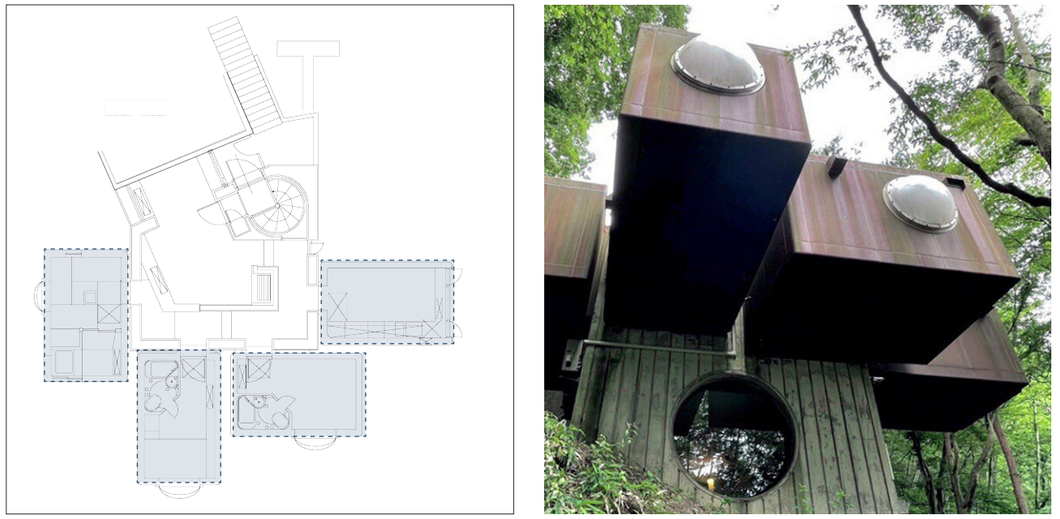


Figure 7: Plan and view of Capsule House 'K' (source: designboom)

[19] Ibid. Kurokawa, Kisho. 1977. Metabolism in architecture. 112-115

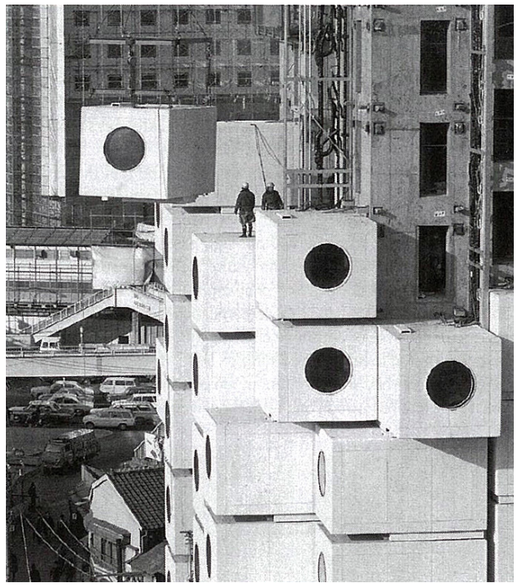


Figure 8: Nagakin Capsule Tower (source: architecturalmoleskine.blogspot.com)

The Nagakin Capsule tower, Tokyo

The Nagakin Capsule tower, completed in 1972, was intended to provide affordable single bedroom dwellings for young professionals in Tokyo, or businessmen's visiting the city for brief periods. Its modular design and prefabricated components were seen as a tactical solution to the city's housing crisis [20]. The building is composed of two towers: the main tower, which is thirteen stories tall and consists of single bed dwellings, and an annex that is eight stories tall and consists of office and commercial space. The main tower contains 140 capsule units, each measuring 2.3 x 3.8 x 2.1 meters, all prefabricated at a factory & along with its utility & interior fittings. The capsules are arranged around a central core, which contains elevators, stairs, and services, and are connected to the core by steel beams & high-tension bolts.

Additionally, each capsule was independently cantilevered from the reinforced concrete core, allowing for easy removal without any impact on the other capsules. This modular design also allowed for flexibility and adaptability, as capsules could be added or removed as needed *(see figure 8).* Construction of the tower involved two stages, on-site construction of the cores, along with required services, and factory production of capsules and assembly of the parts. The capsules were manufactured off-site and then transported to the construction site, attached to the core at the rate of five to eight capsules per day, with all work being completed within a thirty-day period.

One of the key features of the Nagakin Capsule Tower is its use of the Metabolist philosophy, which emphasized the use of technology and innovation to create flexible and adaptable structures that could respond to the changing needs of society. The capsules were designed to be easily replaced or modified, allowing for a more sustainable and long-lasting building. The building's steel structure and prefabricated components also allowed for easy maintenance and repair of the existing capsule with a possibility of ordering a new module to replace the existing one. The design of the Nagakin Capsule Tower is characterized by its modular and prefabricated construction, which allowed for quick and efficient assembly on site. This modular design also allowed for flexibility and adaptability, as capsules could be added or removed as needed. The designed conceived a dynamic arrangement where groups of capsules designated for specific functions could be connected with doors to create an apartment of ordinary size. The tower's design reflected the anticipated living conditions of a future world where global mobility would become more prevalent. The tower created a new housing system that promoted social equality by offering identical capsules to individuals, while also allowing for individual customization of the interior space.

Despite its innovative design, the Nagakin Capsule Tower faced challenges over the years, including concerns about fire safety and earthquake resistance. Although the Nakagin Capsule Tower's tiny homes were originally designed to be rotated out and replaced every 25 years, a lack of funding prevented this from being realized, resulting in the deterioration of the capsules. The tower was demolished in April 2022, and few of its capsule are preserved honouring Kurukowa's notion of 'architecture in motion[21].' Today, the structure remains an important example of the Metabolist movement and a testament for a more sustainable and adaptable urban future.

[20] Ibid. Kurokawa, Kisho. 1977. Metabolism in architecture. 105-111

[21] Crook, Lizzie. 2022. "Demolition of iconic Nakagin Capsule Tower begins in Tokyo."

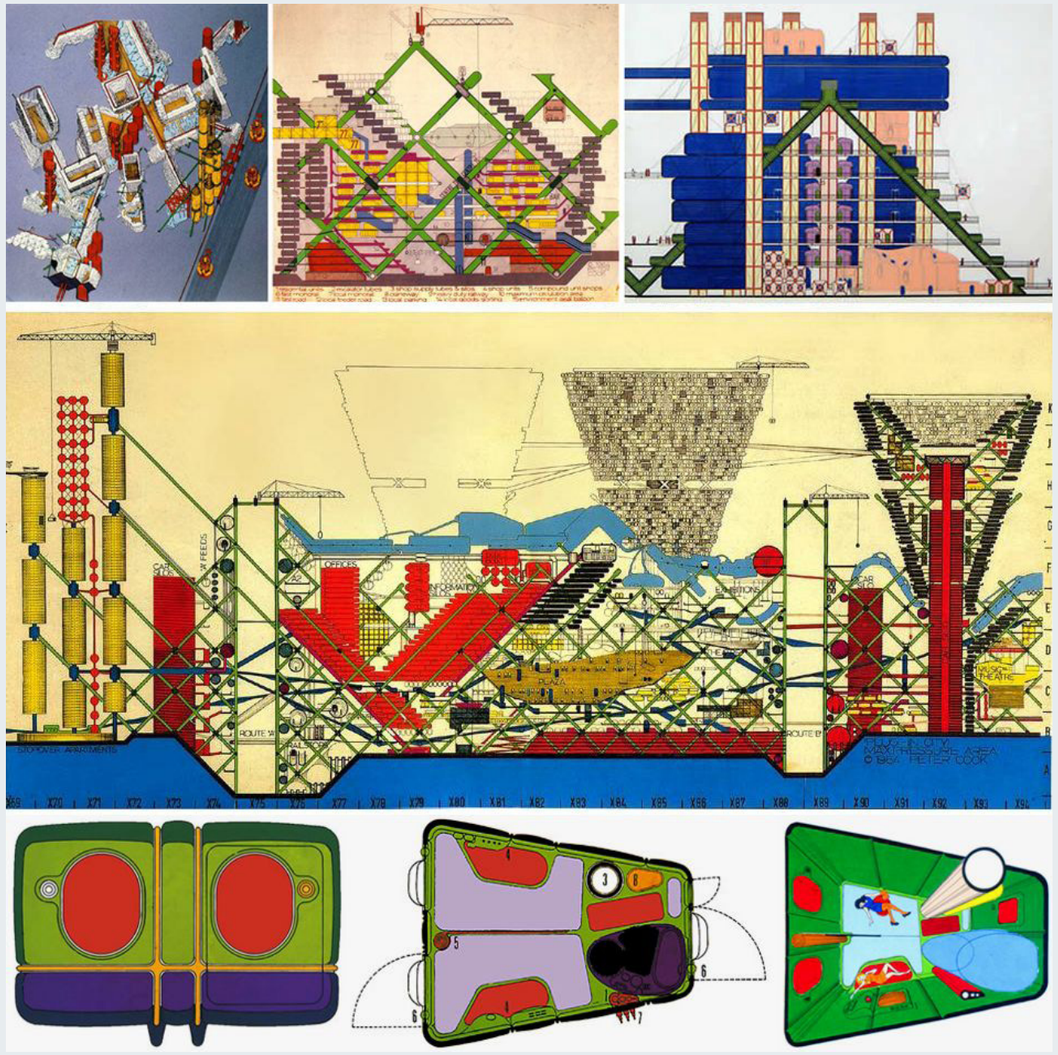


Figure 9: Plug-in City by Peter Cook, Archigram group

Chapter 3

Digitising Design

Technological advancements have revolutionized the field of architecture, transforming the way buildings are designed, constructed, and maintained. Back in 1970's, the Archigram group was a pioneer in the modernization of architecture, publishing avant-garde ideas about the function and planning of cities. Peter Cook's Plug-in City *(see figure 9)* proposed an urban experience that was less definite, but a temporary exchange between the city and people[22]. It signified that architecture necessarily need not have to be a fixed entity and can simply be an adapted or reconfigured creating an event or action in the present. However, the architectural possibilities of their visionary concepts were never fully realised due to limitations in technology at the time. Architects are now equipped with a range of innovative tools and techniques that enable them to create structures that are not only aesthetically pleasing but also efficient, sustainable, and resilient. From 3D modelling software to building information modelling (BIM), virtual and augmented reality (VR/AR) to artificial intelligence (AI), and digital fabrication to green materials, technology has brought about a new era of innovation in architecture. This has not only expanded the possibilities for architectural design but also improved the functionality, safety, and longevity of buildings.

Nowadays, many architects, building technologists, and production practices are embracing digital fabrication as a new way of construction. As countries race to achieve a circular economy, the construction industry is adaptive to these changes. Utilization of technology in construction enables the efficient use of resources, reduction of construction waste, reuse of by-production waste, and standardisation of materials circulating in the market. The approach aims to create a cyclical approach to construction where materials can be reused or recycled in a continuous loop.

Digital fabrication, which involves computer-aided design and computer-aided manufacturing, offers a chance to combine the fields of architecture, engineering, and construction into a streamlined digital process. Mass production has been a strategic force, but the concept of mass customization in building design has become possible due to the ability to produce irregular building components with the same ease and cost-effectiveness as standardized parts. This means that a CNC milling machine can produce one thousand unique objects as easily and cheaply as it can produce one thousand identical ones[23]. With technology, we can realise complex structures, which comes with complexity in assembly where traditional methods to locate building components using dimension, tapes or plum bobs can no longer be helpful and requires digitally driven technologies. Annette LeCuyer describes how Frank Gehry's Guggenheim Museum in Bilbao was constructed using digital fabrication techniques, with each structural component being bar coded and marked for precise placement based on a CATIA computer model[24]. The use of CNC milling in building processes has gained the interest of several construction firms and architects due to its ability to minimize material waste. This process can also make use of sheets and boards made from recycled materials, and designers can even reuse milling waste to create other products, promoting a cyclical approach. The residential sector is the first to witness outcomes from comprehensive research and development as cities grow more crowded, housing demand increases, and the construction industry adopts circularity principles.

The rise in interest rates on home loans and overall inflation has led people to search for housing options that are more affordable[25]. Additionally, people are increasingly interested in homes that are low-maintenance, energy-efficient, and environmentally friendly. As a result, the demand for low-cost, environmentally friendly tiny houses is

---

[22] Sadler, Simon. Archigram: architecture without architecture. Mit Press, 2005. pg16

[23] Kolarevic, Branko. 2001. "Digital fabrication: manufacturing architecture in the information age." In Proceedings of the twenty first annual conference of the Association for Computer-Aided Design in Architecture, 268-278.

[24] LeCuyer, Annettee. 1997. "Building Bilbao." Architectural Review 43-45.

[25] Data Bridge. 2022. Europe Tiny Homes Market - Industry Trends and Forecast to 2029. October.

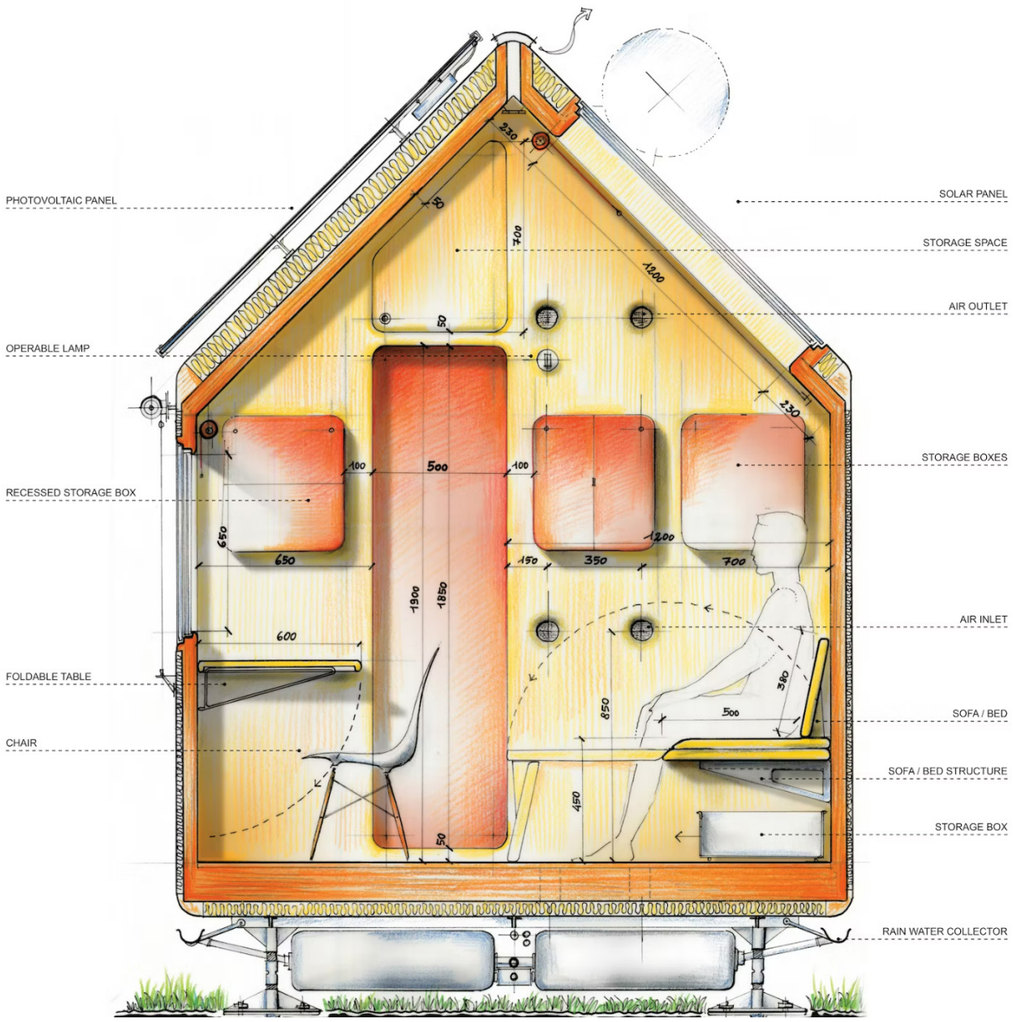


Figure 10: Diogene Cabin Sectional View (source: architizer.com)

increasing in European countries. The trend towards tiny homes is gaining popularity as it offers an innovative and cost-effective housing solution. These homes require less land and construction materials and can be maintained with basic amenities. The cost savings are significant, as heating, cooling, property taxes, and home maintenance expenses are reduced. Additionally, tiny homes consume less electricity, water, and energy compared to larger homes and has a less carbon footprint. The tiny-house movement, also known as the small-house movement, emphasizes downsizing living spaces and simplifying life by living with less resources and thus adopting a sustainable approach. Tiny homes offer the advantage of being able to connect to the electricity grid or operate as self-sufficient off-grid structures, depending on the building regulations in different countries.

Le Corbusier built the Cabanon in 1951, as a small vacation cabin for himself. The Cabanon is the result of research on the smallest possible living space and became a modern interpretation of a traditional primitive hut. It measures 3.66 x 3.66 meters and 2.66 meters high, is made entirely of wood with pine bark cladding, enclosing a rest area, a working area, a toilet area, and a washbasin[26]. Although the Cabanon was constructed with hand labour and human skills, today's technological developments allow for the prototyping of structures that were once impossible.

Diogene (Renzo Piano / Vitra)

Renzo Piano's curiosity to understand the minimum area required for a person to live in, led to the creation of Diogene - a tiny, self-contained cabin developed in collaboration with the Swiss furniture company Vitra. Inspired by the ancient Greek philosopher Diogenes of Sinope, who chose to live a simple life in a ceramic jar to critique the corrupt values of society, the cabin is a testament to the power of less[27].

Measuring just 7.5 square meters, Diogene is a model of efficiency and functionality. Despite its small size, the cabin is a complex technical structure that is designed to function autonomously in a variety of climatic conditions. Whether connected to the electricity grid or functioning off the grid, the cabin can meet all its energy needs with its solar panels and rooftop boiler. Inside, the cabin is partitioned into a multifunctional space, with a pull-out sofa and folding table on one end, and a shower, composting toilet, and kitchen on the other *(see figure 10)*. The movable and foldable furniture creates a hybridity in the use of the small space, allowing for a range of activities and uses. The exterior of the cabin is developed by joining CNC milled cross-laminated timber panels, which is then clad in brushed aluminum panels, which reflect heat and give the cabin a contemporary look. The triple-glazed windows interrupt the panels, providing natural light and a connection to the outside world[28].

Diogene is designed to be easily transported to any site location on wheels. Its multifunctional nature makes it a versatile addition to any landscape, whether used as a nature retreat, an extra office space in the front yard, a houseextension in the backyard, or even placed in groups to form an informal hostel[29]. It is an exceptional example of minimalist design, efficiency, and functionality. Renzo Piano's innovative use of space and technology has created a inspiring architectural achievement that challenges the conventional notions of housing and living in today's time.

---

[26] Foundation Le Corbusier. 2019. The architectural work of Le Corbusier, an outstanding movement to the modern movement.

[27] RPBW. 2013. Diogene. Accessed March 31, 2023.

[28] Ibid. RPBW. 2013. Diogene

[29] ArchDaily. 2013. Diogene / Renzo Piano.

Figure 10: Modular scalable system (source: urbanbeta.com)

Technological Changes

Robotic construction technology is an emerging trend in the construction industry, which aims to automate and optimize various stages of the building process, including design, fabrication, and assembly. This technology involves the use of advanced robotics, 3D printing, and artificial intelligence to reduce construction time, labour costs, and material waste while improving efficiency and precision. The integration of technology with the building industry has made it possible to advance towards a circular building economy. This circular movement not only has an impact on the building industry, but also on everyday life. Advocates of the circular economy promote downsizing as a solution to housing unaffordability and to break free from the societal pressure to constantly accumulate possessions[30]. The COVID-19 pandemic has also altered the dynamics of the system, making work from home a viable option. As a result, the trend for tiny houses and micro housing has gained momentum as people seek multifunctional spaces close to their homes. Taking advantage of this opportunity, designers and construction companies have begun to create digital productions of tiny cabins.

The New Makers Studio, a Dutch company specializing in tiny houses, places an emphasis on sustainability and innovative design solutions that incorporate digital fabrication technologies which mitigates construction waste, and uses natural building materials to reduce carbon footprint. By prefabricating the building components and using plug-and-click concept for joinery, their cabins can be produced in as little as six weeks and up to two months, depending on user customization. Once delivered to the site, assembly can be completed in just one to two days making the process fast and efficient.

Urban-Beta is a German-based company that utilizes AI-powered technology to automate the building sector. They focus is on creating scalable building systems that allow for change over time *(see Figure 11)*. The system is based on circular principles, making it highly flexible, adaptive, and reusable. The use of renewable material passports and ecological construction techniques makes it carbon negative. Moreover, the building system allows to develop projects as small as a tiny house and as large as a large apartment, which is revolutionary in its way. The need for a growing, adaptable and flexible system for the development of cities has been an important topic since the post-war era. The use of technology and flexible building approaches are contributing to the advancement of a circular building economy, which prioritizes sustainable and environmentally conscious practices in the construction industry. This is indeed changing the way we build.

[30] Doroteo, Jan. 2016. A Tiny Luxury: What are "Tiny Houses" Really Saying About Architecture? 15 July.

Conclusion

Throughout the research, we have discussed various topics related to the emergence of flexible architecture in the post-war period. We have explored various instances where flexibility in architecture has paved the way for solutions that address the growing needs of cities, whether it is a political circumstance to address urgent issues or apolitical where it adapts to changes in people's lifestyles, all based on the modern principles of sustainability and circularity. As human beings, we are constantly on the move, and we tend to favor things that can move with us, bringing flexibility to our activities. According to the laws of physics, when we are in motion, the world around us appears to be stationary. Einstein's theory of space relativity suggests that a person in uniform motion can be considered in a stationary state, while the surroundings are in motion. Through examining historical instances of people moving during times of war, we see how mobile homes provided them with a sense of stability and a stationary place amidst the chaos. It was the flexibility of the mobile home design that became an extension of people's motion, enabling them to be stationary even though they were on the move. This highlights the fact that a living space does not necessarily have to be fixed, but can also be in motion with us.

Flexibility in architecture is an intriguing concept that can transform the way we perform our activities. The Japanese Metabolist group reformed the concept of flexibility in architecture by creating designs that could adapt to changes seen in people's mobility and population trends, particularly in urban areas. The design of capsules for Nagakin Tower integrated technology to prototype flexible and adaptable units. The capsules served as a functional part of the building and could be replaced or repaired when stationary in use. Although the group was ahead of its time and idealistic, they put forth revolutionary theories that greatly influenced the discipline of architecture. It is fair to say that these theories can be considered as the heralds of circularity in architecture.

Today, architects find themselves working interdisciplinary to produce designs, and this has significantly changed the traditional relationship between architecture and means of production. Digitising the production of architecture, brings new ways of construction that embrace the principles of circular economy. The discipline has the responsibility to innovate solutions that can address the densification of cities and provide accommodation for citizens. The progress made with circular building economy is significantly changing the traditional way of construction. We are encouraged to design for disassembly, build structures that can adapt, grow and be flexible in use. The tiny house movement completely changes the stationary notion of how we have always built houses. Technology brings automation in design, and automation brings flexibility in production. Such significant changes can be seen in the furniture industry, where self-assembly furniture parts are compacted into flatpack, bringing flexibility to design and its use. The furniture can be assembled, disassembled, moved, replaced, or even repaired at convenience. The construction industry is adopting similar design strategies and the concepts of flexible architecture will lead the innovation in the industry. It will help make the shift from static architecture to dynamic and growing ones.

The government, builders, and architects should be open to flexible ways of circular construction, utilizing new architectural possibilities. Circular building principles need to be adopted throughout the entire process, and it should start with redefining the notion of land. Land is scarce, and we must consider how much more we are going to build. We need to adopt a modern way of thinking, where land is no longer restricted to being a place on the ground.

With the help of technological advancements, a scalable building system can be developed that creates a bare-bone architecture, leaving the land as an empty space within the system. These vacant spaces can be utilized by individuals to plug in or plug out their houses from the building system as per their requirements. Moreover, modern methods of digitally producing a house can offer customization and flexibility in construction, making houses movable assets for people who need to relocate.

In conclusion, the research findings demonstrate that future of architecture is about flexibility and adaptability. As our cities become more densely populated and resources become scarcer, the designers need to embrace new ways of designing and constructing buildings that are sustainable, efficient, and able to adapt to changing circumstances. By adopting circular building principles and leveraging new technological advancements, we can create buildings and homes that are dynamic, flexible, and able to meet the needs of our ever-changing world. The future of architecture is about embracing flexibility and adaptability and working towards a more sustainable and resilient built environment.

Bibliography

ArchDaily. 2013. Diogene / Renzo Piano. *https://www.archdaily.com/396082/diogene-renzo-piano.*

ArchDaily. 2011. Liina Transitional Shelter / Aalto University Wood Program. 11 Oct. Accessed April 2, 2023. *https://www.archdaily.com/174909/liina-transitional-shelter-aalto-university-wood-program.*

Belogolovsky, Valdimir. 2022. Archdaily interviews. 11 10. *https://www.archdaily.com/990321/i-am-always-mindful-that-construction-is-a-sin-interview-with-vinu-daniel-of-wallmakers.*

Black, Brian. 2023. "Trailer Parks." St. James Encyclopedia of Popular Culture (Encyclopedia.com). *https://www.encyclopedia.com/media/encyclopedias-almanacs-transcripts-and-maps/trailer-parks.*

Carlisle, Lilly. 2022. "Jordan's Za'atari refugee camp: 10 facts at 10 years." UNHCR. *https://www.unhcr.org/news/stories/2022/7/62e2a95d4/jordans-zaatari-refugee-camp-10-facts-10-years.html.*

Cody, Jeffrey W. 2005. "Exporting American Architecture 1870-2000." Routledge.

Coloni, Francesca. 2022. "Refugee Crisis." Chap. 5.7 in Design Emergency: Building a better future, by Alice Rawsthorn and Paola Antonelli, p.g 172. Phaidon.

Crook, Lizzie. 2022. "Demolition of iconic Nakagin Capsule Tower begins in Tokyo." *https://www.dezeen.com/2022/04/12/nakagin-capsule-tower-demolition-begins-tokyo/.*

Data Bridge. 2022. Europe Tiny Homes Market - Industry Trends and Forecast to 2029. October. *https://www.databridgemarketresearch.com/reports/europe-tiny-homes-market#:~:text=Rising%20inflation%20leads%20to%20a%20rise%20in%20living%20costs&text=The%20growing%20interest%20in%20and,high%20home%20loan%20interest%20rates.*

Doroteo, Jan. 2016. A Tiny Luxury: What are "Tiny Houses" Really Saying About Architecture? 15 July. *https://www.archdaily.com/791333/a-tiny-luxury-what-are-tiny-houses-really-saying-about-architecture?ad_medium=gallery.*

Foundation Le Corbusier. 2019. The architectural work of Le Corbusier, an outstanding movement to the modern movement. *https://lecorbusier-worldheritage.org/en/cabanon-de-le-corbusier/.*

Kolarevic, Branko. 2001. "Digital fabrication: manufacturing architecture in the information age." In Proceedings of the twenty first annual conference of the Association for Computer-Aided Design in Architecture, 268--278.

Kurokawa, Kisho. 1977. Metabolism in architecture. Studio Vista London. pg 23-27. pg 35. pg 75-85. pg 112-115. pg 105-111

LeCuyer, Annettee. 1997. "Building Bilbao." Architectural Review 43-45.

Lin, Zhongjie. 2007. "Urban Structures for the expanding metropolis: Kenzo Tange's 1960 plan for Tokyo." Journal of Architectural & Planning Research (JSTOR) 24 (2): 109-24. Accessed March 30, 2023. *http://www.jstor.org/stable/43030795.*

Pernice, Raffaele. 2018. "Metabolism reconsidered its role in the architectural context of the world." Journal of Asian Architecture and Building Engineering 357-363. doi:*https://www.tandfonline.com/action/showCitFormats?doi=10.3130/jaabe.3.357.*

Rob. 2017. Roamin' the empire. 03 May. *http://www.roamintheempire.com/index.php/2017/05/03/temple-of-debod/#:~:text=The%20Temple%20of%20Debod%20was,the%20northwest%20area%20of%20Madrid.*

Rolfe, Frank. 2017. "The history of mobile home parks." Mobile home park mastery. 2. Mobile Home University. Mastery Podcast, 14 August. *https://www.mobilehomeuniversity.com/mhp-mastery/the-history-of-mobile-home-parks.*

RPBW. 2013. Diogene. Accessed March 31, 2023. *http://www.rpbw.com/project/diogene.*

Rudofsky, Bernard. 1987. Architecture without architects: a short introduction to non-pedigreed architecture. UNM Press. 6-10

Sadler, Simon. 2015. Archigram: architecture without architecture. Mit Press. pg16

SBA. 2011. Container Temporary Housing- Ongawa, Miyagi. h*ttp://www.shigerubanarchitects.com/works/2011_onagawa-container-temporary-housing/index.html.*

Science Media Museum. 2021. "Post-war homelessness: Makeshift homes between 1945 and the early 1950s." What is the Daily Herald Archive? *https://www.scienceandmediamuseum.org.uk/objects-and-stories/post-war-homelessness.*

Wainwright, Oliver. 2017. "Why Ikea's flatpack refugee shelter won design of the year." The Guardian. *https://www.theguardian.com/artanddesign/2017/jan/27/why-ikea-flatpack-refugee-shelter-won-design-of-the-year.*

Wood Solutions. 2021. Inspiring Case Studies using Timber: Liina Transitional Shelter. Accessed Feb 12, 2023. *https://www.woodsolutions.com.au/case-studies/liina-transitional-shelter.*

Zellner, Peter. 1999. "Hybrid space: generative form and digital architecture." Rizzoli International Publications, Inc.

Delft University of Technology
The faculty of Architecture
Architectural History Thesis
2023