Sustainable and Flexible?

On tensions and alignments in architectural theory and terminology

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SYNOPSIS //

This paper seeks to analyse the terms sustainability and flexibility in architecture and attempts to examine their relationship. The following draws attention to the current inaccuracy of the terms and discusses its results in the practice of architecture. It explores the multifarious meaning of the two terms flexibility and sustainability in architecture and questions how much our current building system is based on sustainable outcomes, rather than sustainable designs.

Furthermore, this essay intends to criticise today's persistent ideologies of permanence and monumentality in architecture, by highlighting the negative ecological impacts of building inflexibly. It will begin with a brief history of building ideologies, its effects in modern architecture and urban landscapes, and the long term ecological results. The chapters that follow will explore how far we can rely on the terms sustainability and flexibility acting as a solution to waste production and to what extent examples of such architecture fail to live up to the initial meanings of both terms. This will be done by analysing five examples, each representative of a different way of approaching modular architecture.

Finally, this paper suggests causes and solutions to the lack of efficiency in sustainable building and concludes with a quest for qualifications that allow for more reliable, long-term sustainable designs.

Last week, on the 16th of March, Anne Lacaton and Jean Philippe Vassal won the 2021 Pritzker Prize, one of the most important architectural awards. This is a milestone in our society's understanding of sustainable architecture. The French architect-duo are known for their uncommon approach to sustainable building. Instead of rebuilding and demolishing pre-existing structures, they alter these in a minimalistic fashion, which enhances the building's performance immeasurably. Lacaton and Vassal introduced a new way of thinking about flexibility and sustainability in existing spaces. Their ideology and building style reiterates the value of buildings, old or new, with a simple yet innovative approach of "never demolish, never replace".[1] One reason why Lacaton and Vassal's work is so fascinating is that they massively increase the lifetime of a building through simple renovations. With their designs, they immensely reduce waste production of demolished buildings and show the beauty in architecture that can otherwise be seen as out-dated. The two architects question the way we most commonly view buildings and reinvent our perception of permanence in architecture.

There is an ever-growing need to find more sustainable ways of building, and Lacaton and Vassal's approach of valuing existing structures is a flexible response that inspires us to build in a more resourceful manner. Parallel to the desire to build with more ecological awareness, the last decades have provided significant technological advancements that have resulted in the continuous reinvention and innovation of our urban environments. Today trends and constantly changing lifestyles reshape our societies, and cities are forced to adapt. The way LacatonVassal approaches this issue of adaptation offers a sustainable solution to an increasingly alarming problem.

Whilst the architects' work is a very valuable contribution to the concept of sustainability, the question I raise is, why do we not build architecture that is more flexible from the beginning? And with sustainability being such a strong focus point in discussions on architecture, why are we ignoring the steadily decreasing life cycle of buildings?

Flexibility in architecture is a concept that responds to these questions. This idea is practised by numerous architects and allows for adaptability and changing functions of buildings. I first came across the notion of *sustainability through adaptability* in cities and architecture in the book "The Flexible City – Sustainable Solutions for a Europe in Transition". The authors Tom Bergevoet and

[1] "Anne Lacaton and Jean Philippe Vassal win the Pritzker Architecture Prize". *Pritzkerprize.Com*, 2021, https://www.pritzkerprize.com/media-news. [21.03.2021]

Maarten van Tujil explore the changing environments surrounding us. They argue that the time of growth and expansion in European cities is mostly over, leaving architects, urban planners and designers the responsibility to efficiently restructure and maintain the existing environment. This process is the same with buildings. When building new constructions we have to design them with a more sustainable intention than we do currently. We know now that architecture must anticipate change and be able to adapt to it:

> There is a need for an approach that can cope with unpredictability but the existing instruments are very much geared to long-term objectives. There is a crisis in the system. European towns and cities have become inflexible.[2]

Flexibility in cities and buildings can be achieved in numerous ways and it is important to differentiate between different types of flexibility. Whilst researching this subject, I conducted a set of interviews with the author and architect Tom Bergevoet, which inspired me and shaped my understanding of the matter. This thesis will analyse how far buildings we call sustainable and flexible truly fulfil their purpose and succeed in creating durable architecture. By creating an understanding of the background, reasons for and effects of unsustainable building and waste production, I will question the efficiency of permanent architecture. This requires a brief definition and analysis of each term and their relationship to one another. I will continue with a case study of four different sustainable and flexible examples in architecture, each representing one aspect of the numerous flexible buildings that have been built in the last decades. Finally, this essay concludes with a collection of requirements that shape the relationship between sustainability and flexibility.

2 Bergevoet, Tom & Marten van Tujil, The flexible City- Sustainable Solutions for a Europe in Transition, (nai010 publishers, Netherlands 2016) p.33

CHAPTER 1 //

Patterns in Modern Architecture

1.1 Issues with Permanence

What are our current architectural ideologies and how far do they meet our needs?

In western cultures, the concept of permanence and monumentality in architecture has always been the foundation of our cities and buildings. Nobody wants to live in a building that doesn't seem stable and solid. Nor do architects want to be remembered by a short-lived building. We take pride in the cultural history of our cities that are present through their architecture, and the older a building becomes, the more value it holds. Our society is used to admiring architecture that is massive and enduring. Nearly all recent and current designs are intended to be enduring and everlasting.

Up until today, most buildings are built solely with the consideration of their functions throughout their "lifetime", never with the thought of its deterioration. Historically, this is a natural process. Pre-industrialisation, the construction of buildings was significantly more difficult and hence, buildings were unquestionably designed to last, designed for stability and durability, and to demonstrate humankind's quest for immortality.[3] It can be traced back to the foundation of ancient architecture, when looking at the remains of buildings such as the Pantheon in Rome, Italy or the Temple of Apollo in Corinth, Greece. These two buildings are archetypes of the architectural ideology of an entire era, based on the materiality, density and weight of the building, they were created to last. In the context of the pre-industrial era, this desire for permanence resonates since manufacturing, back then, was one of the few ways to leave a mark of one' existence.[4]

In today's cultures, the intent and needs of architecture have transformed, but its implementation has remained stagnant. After industrialisation, when standard housing aimed to improve general living standards and new technology allowed for faster and cheaper construction, new building possibilities arose. Architects such as Le Corbusier, Walter Gropius and Mies Van der Rohe, saw this as an opportunity to design architecture intended to improve living standards. Their movement requested cleaner, more linear and minimalist buildings. They designed buildings that can be easily fabricated and multiplied, an idea that changed the way we have built ever since. What acted as a

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[3] Armada, Jacqueline, *Sustainable Ephemeral: Temporary Spaces with Lasting Impact*. (Syracuse University Honors Program Capstone Projects, 2012) p. 8

[4] Ibid.

groundbreaking architectural innovation has turned into bland uniform structures that lack ambition, are indifferent to space, immune to local culture, nature and materials.[5]

We have continued to build with the same tools we used to make buildings permanent and monumental. This was never the intention of the International Style Movement, nor that of industrialisation, it was merely a byproduct. Modern industries are still manufacturing under a method that was "developed when humans had a very different sense of the world", where the qualities and finite of nature and resources seemed "immeasurably vast".[6]

Today, while climate change has proven us wrong, we have not modified our practice to the insight that our building ideals are outdated. The consequences of this inertia to take international action unfold in numerous ways, the most pressing being ecological violence. We now have more tools to create structures that can adapt better to our temporary needs. We live in a world that changes more rapidly, one that does not necessitate the permanence of new buildings. This topic is explored in "The Flexible City- Sustainable Solutions for a Europe in Transition" with the words: "In the current system for spatial development, it seems as if everything is built to last forever. The strong focus on one long-term objective removes time from the equation."[7] Dutch architects Tom Bergevoet and Martin van Tujil imply that buildings built with materials and structure set out for durability do not consider the temporal implications of the site and construction. This means that we have proceeded to build in a style that is not suitable for its function in relation to its time of existence. This is often referred to as the "life expectancy" of buildings. Researchers in the field of architecture's life-cycle analysis (LCA) address the correlation between the durability of the building and its actual existence before demolition. It was found that on average, 50% of the causes for demolition are due to obsolescence.[8] While architects continue to build with everlasting materials, monumentality in todays architecture is flawed, as modern buildings are only expected to last longer than 80 years and are averaging between 50-60 years. This is very surprising in light of current sustainability discussions as on average, "a building lifespan of 80 years reduces environmental impact by 29%, 100 years by 38%, and 120 years by 44%, all in relation to a lifespan of 50 years."[9]

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[5] Michael Braungart and William McDonough, *Cradle To Cradle*, 1st ed. (USA: Macmillan, 2003). p.28

[6] McDonough and Braungard, *Cradle to Cradle*, p.30.

[7] Bergevoet & van Tujil, *The flexible City- Sustainable Solutions for a Europe in Transition*, p.35

[8] Asko Sarja, Predictive And Optimised Life Cycle Management (Hoboken: Taylor & Francis Ltd., 2006), p.14.

[9] Rob Marsh, "Building Lifespan: Effect On The Environmental Impact Of Building Components In A Danish Perspective", *Architectural Engineering And Design Management*, 13.2 (2016), 80-100

1.2 Issues with Planning

What determines obsolete architecture and how is it reinforced in shrinking cities?

While it is not necessary, nor possible in our current society, to stop building completely, we have come to a point where our pace of creation and our way of managing the building industry has become unsustainable. The most impactful ecological issues with our building system are based on poor planning, outdated ideologies and lack of farsightedness. Shrinking cities are an embodiment of these issues.

The process of shrinking cities, such as Glasgow (UK), Detroit (US) or Leipzig (Germany), has become increasingly common in western countries over the last 50 years and has even become a "fairly normal pathway for urban development".[10] It has been found that between 1990 and 2000, more than one in four cities around the world are suffering from decline and have been declared shrinking cities. This process is particularly visible in Northern American and European cities. Currently, approximately 40% of all European cities are decreasing in population.[11]

In western countries, urban decline is most commonly found in cities that rapidly densified within a short period due to an increase in job availability. The geographic, demographic, political and social issues that occur in shrinking cities, is commonly encapsulated in the process of deindustrialisation. Cities that suffered from deindustrialisation after the 1980s, usually experience economic deterioration, unemployment and social recession- all symptoms of a structural crisis.[12] Once a city suffers under population decline, it is followed by a lack of income availability for the preservation of urban infrastructures, such as housing, school, essential stores and leisure facilities. The author Matthias Bernt describes this process as follows: "As a result, these infrastructures become under-utilised and under-maintained, and often have to be abandoned. Local living conditions then deteriorate, and population loss spurs additional decline".[13] This chain of events, that has occurred in many western cities, leads to an extreme rise in vacancy and the eventual demolition of buildings.

Instead of renovating and "saving" deteriorating buildings, however, they are commonly demolished. It would make sense for shrinking cities to try to maintain what is left of them after the population loss, instead of giving in to the insatiable desire to build more. However, demolishing

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[10] Matthias Bernt, "Partnerships For Demolition: The Governance Of Urban Renewal In East Germany's Shrinking Cities", *International Journal Of Urban And Regional Research*, 33.3 (2009), p.754

[11] Ibid, p.755

[12] Ibid, p.158

[13] Ibid, p.755

vacant buildings seems necessary to the extent that it might enhance a city's appearance and give it a new atmosphere through new design ideas. Although this surely has its benefits, it seems contradictory how much is being demolished and how much rebuilt in the case of increasing vacancy. The city is going in a loop of stagnation. Cities are built fast and cheap the moment they start growing and are demolished equally as fast once they shrink again. After large parts of a city are demolished, small areas are revitalised with new buildings. The environmental implications of this circular development are detrimental, especially considering the scale of this transition applied to cities all across Europe and North America (to be further discussed in chapter 1.3).

This is a phenomenon that we are familiar with from past experiences. After pioneering research from Hall and Hay on the regularity of urban growth and decline, they have already predicted in 1990 "The Earth As Transformed By Human Action", that urban populations tend to circulate on a time scale of about 55 years.[14] Furthermore, at a different point in the same book, the researcher on urban populations Thomas Whitmore argues that even this short rotation is underestimated.[15] He expects a much greater frequency of fluctuation with much greater impacts.[16]

Yet we still act indifferently in the face of this recurring pattern. The outcome is a gratuitous cycle of waste production. The scientist and urban researcher Martinez-Fernandez argues, that it is "worthwhile revisiting this assumption, so as to envisage urban shrinkage as a durable, structural component of urban development".[17] She acknowledges the repetitive features of shrinking cities and appeals to architects and city planners to review and learn from previous cities' growth and decline.

Returning to the issues of permanence in architecture, the aspect that is so problematic in this development is that these buildings were and are still built with non-renewable and high waste materials. Buildings that are now demolished were built with materials that could have had a significantly longer lifespan. As these cities were built without predicting an imminent decline, the reusability or recyclability of the demolished buildings is low. Therefore, as we continue to build with materials and structures that are still based on monumentality and permanence, waste production is immense. Shrinking cities show how unreliable our assessment of successful

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[14] Hall and Hay citied in B. L. Turner, *The Earth As Transformed By Human Action,* (The Professional Geographer, 40.3 1988), p. 340-341.

[15] Whitmore citied in B. L. Turner, *The Earth As Transformed By Human Action,* (The Professional Geographer, 40.3 1988), p. 340-341.

[16] Whitmore cited in Sean Burkholder, *The New Ecology Of Vacancy: Rethinking Land Use In Shrinking Cities* (Molecular Diversity Preservation International, 2012). *p*. 1156

[17] Cristina Martinez-Fernandez and Naoko Kubo, *Demographic Change And Local Development* (Paris: OECD Publishing, 2012)

architecture is and that it can be very wasteful to build such inflexible buildings. We build without regard to whether or not the building will be needed in its present location. The sheer amount of how much we can build is so ecologically harmful that building with the knowledge of impending obsolescence is unacceptable. Our modern tools have become too powerful to remain without consequences if we do not recognise that the easier building becomes, the more careful we have to be with it. The next chapter focuses on the ecological aftermath of the rapid turnover of the materials we use in the construction of cities.

1.3 Issues with Waste

What are the ecological effects of unanticipated demolitions of buildings?

The trial and error approach that has accompanied and influenced our developments within cities so many times throughout history has found itself facing a dead end. We can no longer sustain any form of wasteful architecture, especially not on the worldwide scale in which we practice it now. Sustainable construction of buildings has been a centre of discussion about architecture and design for many years now, yet, the immense impact and consequences of our way of building are not addressed with the urgency and acuteness that the topic requires. The example of shrinking cities shows us the lack of attention towards the irresponsible consumption of resources and the production of waste.

According to the European Environment Agency, it is estimated that Europe produces over 250 million tonnes of municipal waste and over 850 million of industrial waste each year.[18] The waste production of individual countries and the causes and outcomes of landfill production, marked that, even though household waste is an important and wide-spread topic in the media, construction and demolition of buildings are by far the main cause of landfill and waste. While western countries are fighting for sustainability and reduction of waste, the construction sector in the European Union is still the highest producer of waste, with 35%, compared to other economic activities worldwide.[19]

This occurs not only on a planning basis but is a trend that permeates the entire industry. Currently, our building system is not set out to avoid construction waste (CW). The focus is on fast and cheap production, increasing CW due to ordering cheap and low-quality materials, design flaws, and inefficient handling of materials at the site.[20] It is estimated that CW produced at a typical

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[18] Osmani, "Current And Emerging Construction Waste Management Status, Trends And Approaches", in *Waste A Handboook For Management* (Academic Press, 2019). p. 371

[19] Ibid. p. 368

[20] Ibid.

construction site ends up being 4%-30% of the total weight of the building materials delivered to the site. Damage, loss and over-ordering of materials are key symptoms of economically profitable but irresponsible building styles.

While especially in big cities the impacts remain barely visible, the rest of the world suffers immensely from this misuse of resources. One key example that I will highlight at this point due to the extent of its use is concrete. This resource has become the primary building material worldwide. With the exception of water, it is the most widely used substance in the world. Concrete is all around us. It is in nearly every residential building, in every street, bridge, every industrial building, in schools, the healthcare system, dams, motorways and in all other transport systems. Even though concrete does not harm the environment directly it is the main contributor to landfill and is not easily recycled, especially not into its original components. Concrete use is responsible for 10% of worldwide industrial water use and is very high in CO2 production, due to the scale on which it is used.

Apart from landfill and the water consumption of concrete, an even more dramatic reason to start building more sustainably and resourcefully is sand. Concrete is made primarily out of coarse and fine aggregates (sand). Sand is not a sustainable material. Sand is, like wood, oil and many other substances, a natural resource that can be exhausted. More so, we have already reached a point in sand consumption where the resources on land can not withstand our demands, leading construction companies to extract sand from the ocean. The consequences of this invasion into nature are not only ecologically harmful, whereby hundreds of marine ecosystems get destroyed, but also results in sociopolitical and economic issues. When sand is extracted from the ocean, in order to level out the “vacuum” that was created sand from islands fill in the lost space. Globally between 75 and 90 % of all beaches are on some sort of retreat.[21] In locations of severe extraction of sand from the ocean, the outcome was the disappearance of entire islands. To this day 25 island have vanished in Indonesia because this country sold their sand to Singapore.[22] All the natural organisms living on these islands with them.
Besides this environmental catastrophe, there are very negative political effects as well. Illegal sand importation has become a massive problem, affecting countries borders, the environment and thousands of lives worldwide. This is an example of only one of the overused resource. Similar occurrences are visible in wood, steel and many other building-material industries.

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[21] Griggs cited in *Sand: Die neue Umweltzeitbombe,* Arte Deutschland, 2013. https://www.youtube.com/watch?v=T801BaCGJlk [Accessed 23 March 2021]

[22] *Sand: Die neue Umweltzeitbombe,* Arte Deutschland, 2013. [Accessed 23 March 2021]

Thus, the consequences of “unplanned” and unstructured, wasteful building has extreme effects across worldwide ecological, economical and political sectors. In his book, “Building the Ecological City”, the author Rodney White, explains that, “because governments cannot anticipate future needs and resources it must create conditions that allow society, as a whole, the flexibility to adapt to new circumstances.”[23] His words summarise the notion that flexibility in cities, societies and buildings is a key element to successfully progress in sustainable cities. Currently, however, we build and plan cities without considering the ecological price of the resources we use. Robert Kronenburg, a pioneering researcher in the field of sustainable and adaptive architecture argues that, in order to design buildings that can respond to a new environment and to stop the immense production of waste, we need “architecture that adapts rather than stagnates; responds to change rather than rejects it; is motive rather than static”.[24] We have not yet exhausted our resources fully, however, we have not adopted a universal change in environmental consciousness which becomes increasingly relevant by the day. Capitalist expansions in this field must decrease immensely to avoid facing even more severe ecological consequences.

In essence, the effects of short-term planning and wasteful building are detrimental to our environment. To design buildings that reduce waste and adapt to future needs, as Kronenburg suggests, one must first look at the relationship between sustainability and architecture. In order to proceed to examine sustainable solutions, the next chapter will reinforce and define the terms *sustainability* and *flexibility* independently and will look at the initial meanings of each term, in order to then analyse the issues and inconsistencies in their use.

[23] Rodney R White, *Building The Ecological City* (Cambridge: Woodhead, 2002) p.16.

[24] Robert Kronenburg, *Flexible Architecture: The Cultural Impact Of Responsive Building*, (Open House International, 30.2 2005) p.1.

CHAPTER 2 //

On Relations between Sustainability and Flexibility

2.1 Misuse of the term Sustainability

What is the original idea of sustainability? And what systems are in place to support the idea?

Sustainability in architecture is not necessarily sustainable. Not in the manner we define it currently. There is an issue with the way we perceive the concept of sustainability, otherwise we would not face the ecological issues of such vast waste production. Even though sustainable architecture has become the basis for designing countless products, buildings, and cities, our current definition of it is not truly effective. The importance of building sustainably in the first place, is highlighted in this quote by Rodney R. White:

> Human-environment interactions are complex, but the key principle is terribly clear: humans- like all other species- must learn to live within the biological realities of the planet. We can run, we can shut our eyes, but we cannot hide.[25]

With dramatically decreasing building resources, it is the responsibility of designers, architects and urban planners to address the problem and find solutions. The foundation of the concept of *sustainability* evolved along with the environmental movement of the 1960s and 1970s. Environmental consciousness has become omnipresent in all of our decisions and actions; today it is a highly important part of our existence on earth.

Before exploring the topic further, it has to be stated that the definition of sustainability in architecture is part of a wide subject of themes, too broad and interdisciplinary to summarise in this format of writing. It is impossible to do the extent of the subject justice here, so the following synopsis acts only to paint a picture of the term's most broad use today.

In "Understanding Sustainable Architecture" the term is described as "a revised conceptualisation of architecture in response to a myriad of contemporary concerns about the effects of human activity"[26] and comprises a vast amount of attempts to find solutions to the irreversible, ecologically harmful effects of building. The "Dictionary of Architectural and building Technology" summarises the terms as follows:

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[25] White, *Building the Ecological City,* p.16.

[26] T. J Williamson, Antony Radford and Helen Bennetts, *Understanding Sustainable Architecture* (Taylor & Francis, 2003) preface x

sustainable Strategies for building and living that are capable of being maintained for a long period of time so that resources are not depleted or permanently damaged.

sustainable design Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[27]

Both descriptions centre around the general meaning of sustainable building, however, the actual depth of possibilities, issues and complications of this subject are revealed more effectively by the many proposals to build more eco-friendly. The ecological factors of sustainable architecture consist of a series of solutions to make building more climate-neutral and resourceful. "Green" or "environmental" are two common descriptions of ecological designs and building solutions. According to Chansomsak and Vale, site selection, building typology, material selection, water and energy conservation, insulation, use of renewable energy, air quality, building maintenance, renovation and demolition play an important role in minimising the buildings negative impact on the environment.[28] Furthermore, there are systems in place to ensure the sustainability of a building. Organisations such as the life cycle assessment/ life cycle analysis (LCA), the environmental impact assessment (EIA) and national building evaluation systems (eg, LEED, BREAM, DGNB etc.) conduct research and assess the sustainability of buildings, yet unfortunately, even within buildings that are designed as part of environmental architecture, the goal is rarely, if ever, fully achieved. Three of the most common approaches to improve our way of building are known as reduce, reuse and recycle. The following chapter will focus primarily on the use of one of these terms, by breaking down the theory of *reuse*. This term inevitably interlinks with the concept of flexibility, based on the hypothesis that within the building sector, flexibility in architecture is the most efficient way to reduce our impact on the environment.

2.2 How Flexible became the new Sustainable

2.2.1 Reuse as a Step towards Flexibility

How is flexibility related to sustainability and why is it relevant in architectural practices?

While recycling is a very effective way to handle materials in the building sector, it is a solution to a problem that wouldn't exist if we would *reduce* or *reuse* materials. Reusing is a preventative way of

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[27] Henry J Cowan and Peter R Smith, Dictionary Of Architectural And Building Technology (New York: Spon Press, 2004) p. 301

[28] Sant Chansomsak and Brenda Vale, *Sustainable Architecture; Architecture As Sustainability*, in Proceedings Of The 2008 World Sustainable Building Conference, (2008)

handling materials. It is a solution to make recycling less necessary. To explain this simply: if we build a house so that we can take it apart and reuse the materials, we do not have to recycle it. Similarly, the concept of *reducing* is flawed, in that it tries to limit the amount we build. This is a noble goal and, like *reuse,* a preventative measure to the negative human impacts on the environment. Yet, in our current world, it remains highly unrealistic. Therefore, I have chosen to focus on *reuse*, and hence flexibility as I consider it to be the most realistic and efficient contemporary solution.

"Reuse" in architecture is the concept of the repeated adoption of material, resource or even an entire building in a different context. The effect of properly "reusing" materials, buildings and equipment, are predominantly waste reduction and preservation of resources. As mentioned earlier, we have used the technological advantages developed during the industrialisation with a misguided focus on extreme growth and capitalism. Like in most consumer-orientated industries, we prioritise products based on availability, speed and low costs. The architect Andreas Lendager agrees with this observation, arguing that:

> Unfortunately in our society, we have chosen to construct buildings where short turnaround and low upfront costs are the two most important factors. But the reality is that this approach generates way higher costs later down the line, both financial and environmental. When buildings are deconstructed, their component materials may not be at the end of their lifespan, which generates massive wasted potential.[29]

Although this process has been recognised, it is not addressed with the attention necessary to guarantee a successful sustainable culture of building and designing. Our cities inevitably change. Our buildings decay, existing spaces become obsolete and will be maintained, renovated or demolished. In the book, "Buildings must Die", by urban planner and activist Jane Jacobs and the investigator of urban-rural systems Stephen Cairns, the authors argue that "architecture can design either facing towards waste and death or looking away".[30] This is a direct appeal to architects to anticipate a building's eventual "death" and prepare and plan for it, an appeal to make our buildings reusable. This issue has been widely recognised in the west and concerns the entire infrastructure of cities and even countries. Yet, despite the flourishing attention over the last decades, it is still not the central focus of our building industry.

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[29] Lendager cited in Hannah Wood, "Recycled Buildings: How To Design For Disassembly",(Archinect, 2018) https://archinect.com/features/article/150067785/recycled-buildings-how-to-design-for-disassembly [Accessed 23 March 2021].

[30] Stephen Cairns and Jane Jacobs, *Buildings Must Die* (MIT Press, 2017). p. 228.

The strategy of "reuse" in sustainable architecture solves this negative trend. It allows us to use materials again without decreasing their initial qualities. To achieve this, a building's materials must be flexible and versatile enough, so that they can be disassembled into their original elements.

2.2.2 The history of the concept of Flexibility in Architecture

What defines flexibility and how is it used in architectural practices?

Today, *flexibility* is a popular term, used in architecture and design, as well as economics, politics and lifestyle choices. The term *flexibility* has been in English usage for many centuries, while its application in architectural terminology only surfaced around the 1950s. Walter Gropius was one of the first ones to use the term in writing in 1954 in response to architecture:"(1), [T]he architects have to conceive building not as a monument, but as a receptacle for the flow of the life which they are to serve, and (2), that his conception should be flexible enough to create a background fit to absorb the dynamic features of our modern life".[31] Gropius touched upon an idea that soon after developed into the world-wide movement of flexible architecture. His words summarise a concept that was explored amongst some of the most established architects in history. *Flexibility* became an aspect of an entirely new definition of building and structuring housing.
The Oxford English Dictionary defines flexibility as follows:

"**flexibility** (1) the ability to change to suit new conditions or situations, (2) the ability to bend easily without breaking"[32]

The term's architectural use focuses on the first definition of the word rather than the second. *Flexibility* means designing buildings that can accommodate change and are able to transform in new environments. It is an idea that serves several purposes. It offers an element of choice and personalisation, parallel to ensuring a lasting functionality of a building. Furthermore, *flexibility* allows buildings to be altered in the future; It allows for a strategic, yet raw design, for adaptability, mobility, transformation and interaction.[33]
The concept of flexibility in architecture spread rapidly. It originated during the Modernist movement, a socialist take on improving and simplifying housing to achieve a better living standard. Architects like Le Corbusier, Mies van der Rohe and Gerrit Rietveld were key figures of the

[31] Gropius quoted in Adrian Forty, *Words And Buildings* (London: Thames & Hudson, 2019) p.142

[32] Oxford English Dictionary online, [online accessed 03.01.2021]

[33] Kronenburg, *Flexible Architecture: The Cultural Impact of Responsive Building*, p.2.

movement and practised this way of designing housing very successfully.[34] Their building ideology was to create simplified dwellings, houses with clear lines, efficient use of all its properties, a feeling of simplicity, purity and openness. They believed in making housing accessible, with prefabricated designs that were devoid of unnecessary decorative ornaments. These buildings were archetypes for practicality and flexibility of the individual properties. Inspired by the Bauhaus movement of the early 1920s, the buildings were a response to political issues, like lack of housing, while simultaneously exploring the interaction between architects, artists and dwellers. The spaces were multi-functional and could respond instantly to individual needs,[35] which allowed the inhabitants to have control over the building and personalise their homes. Architects included elements such as sliding and folding interior systems and furniture to give single objects multiple functions and transform them.

A very celebrated example of this design style is Gerrit Rietveld's Schroder House from 1924. This building is one of the earliest examples of flexible elements in permanent architecture. The sliding wall approach of the building's interior allowed for a fluent transition between spaces, multi-use and a more liberated dwelling.[36]

Figure 1 & 2 Schroder House in Utrecht (Netherlands) by Gerrit Rietveld 1924, exterior and interior.

This aspect of interior flexibility has continued to be explored by numerous architects. A more recent example, that responds to multi-functional spaces and is even more transformable, is the Rogers House by Richard and Su Rogers. This building from 1968 can be seen as a pioneering example of transfigurative designing that is a baseline for multiple domestic spaces today. The key element in both buildings is sliding walls, which separate and open the interiors depending on the

[34] Braungard and McDonough, *Cradle to Cradle,* p.28.

[35] Larissa Acharya, *Flexible Architecture For The Dynamic Societies; Reflection On A Journey From The 20Th Century Into The Future* (Postgrad., University of Tromsø, 2013), p.19.

[36] Ibid.

residents' needs. With its simple and demountable construction, the Rogers house however is also designed in a more modular manner that allows broken elements of the building to be replaced if necessary.


Figure 3 & 4 Rogers House by Richard and Su Rogers, 1968, exterior and interior interior

The same intent for flexible architecture was practised across the world by one of the most influential modern movements. The Metabolists, a group of young Japanese architects who established in 1960, are archetypes of the modernist style and execution. They designed buildings with the idea of emulating living organisms. The term *metabolism* defines the process of maintaining living cells, a word suitable to the movement as the architects envisioned successful cities and buildings to function like living beings. They are designed to be changing constantly throughout their lifespan and develop organically. Examples of their conceptual architecture include designs that are flexible, expandable and adaptable. The most distinguished and famous building of this movement is the Nakagin Capsule Tower by Kisho Kurokawa. I will return to this building in chapter four to examine the success and failures in flexible architecture.

2.3 Limitations in Terminology: Flexibility and Sustainability as boundary objects

Where do the terms meet their boundaries? How can they be misinterpreted?

Today, we have become more accustomed to the use of *flexibility*. Flexible architecture is now more common in relation to sustainability. Attempts and prototypes of flexible structures have become regularly associated with sustainable architecture. Multi-purpose objects, demountable furniture and mobile homes are only a few examples of flexible designing. Flexibility surrounds us today in fashion, in technology, in our furniture and our everyday objects.

As much as the wide-ranged development of this design practice has its value and positive impacts in worldwide building cultures, the indefiniteness and expansiveness of the term's use are detrimental when trying to identify the degree of sustainability in flexible building structures.

There are several reasons why buildings fail to be fully sustainable. One of which could be a result of the vagueness of the definition of the term, a phenomenon that becomes visible in research and writings about the topic.

To make the concept of sustainable and flexible architecture comprehensible for us, we are compelled to break down the term and its solution into different categories. The word's popularity and steadily increasing use since its emergence in the 1960s is only due to its vague and diffuse meaning. Both terms are only in use so frequently because they are general enough to be applied to many different fields of study. This causes the terms to adopt slightly different meanings in every environment it is used in. As a result, the definition becomes more and more unclear.

Viewed from a sociological perspective, this process makes both terms *sustainability* and *flexibility* boundary objects. The "boundary object theory" was introduced by Susan Leigh Star and James R. Griesemer in 1989 and describes an object that is used differently by different bodies of people. It is an object, or in this case, a term, that "is both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites."[37] In other words, an object, like *sustainability*, is so transformable that it applies to many different themes and fields of study, yet it is homogenous enough to maintain its position and sustain its ambiguous, universalised definition. Terms like these feed on their quality of being adaptable; they rise in popularity, while simultaneously losing their definition and distinction. The boundary object effect on this scenario causes *sustainability* and *flexibility* to become shallow and obscure. Guy and Farmer support this notion with their definition of sustainable architecture in "Reinterpreting sustainable architecture". Here, the two authors describe that due to "conflicting interpretations" and the constant redefinition of the issue, the "nature of the environmental problem itself" loses its clarity and becomes inaccurate. They suggest that discussions about this topic are "shaped by different social interests" which are "based on different interpretations of the problem", eventually leading "towards a range of sustainable futures".[38] Whilst sustainable building is appreciated in any form, it can take on so many forms of *sustainability* that its true value, namely to what extent the building is minimising ecological harm to the environment, can get lost.

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[37]Susan Leigh Star and James R. *Griesemer, Institutional Ecology, 'Translations' And Boundary Objects: Amateurs And Professionals In Berkeley'S Museum Of Vertebrate Zoology 1907-39* (Social Studies of Science, 1989). p.393.

[38] Graham Farmer and Simon Guy, *Reinterpreting Sustainable Architecture* (London: Routledge, 2011), p. 148

The same has occurred with *flexibility*. *Flexibility* as a tool to build sustainably is still unsuitable to define a building as eco-friendly. We define *flexibility* ambiguously, both in the designs we create, as in the way we talk about architecture, weakening its originally very powerful and prominent meaning.

How sustainable is Flexibility?

How far do the two terms depend on one another and cause each other's successes and failures?

In architecture, the two terms *flexibility* and *sustainability are d*ependent on one another, to some extent. Sustainable architecture is never truly viable if it isn't flexible enough to adapt to changing environments, if it cannot respond to user needs, or is too monumental to be demountable after its initial use. On the other hand, possibly flexibility is only necessary due to its function in sustainable architecture. In the field of architecture, one could argue that neither concept is complete without the existence of the other.

For *sustainability* to be successful, it must be "fail-safe" to some extent, a term more commonly associated with flexible designs. In his essay "From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world" Jack F. Ahern describes this phenomenon by arguing that in urban and landscape planning, the concept of sustainability was "envisioned as a durable, stable, sometimes formulaic, fail-safe urban form or condition that - once achieved - could persist for generations"[39]. Here, the author highlights the relationship between flexibility and sustainability in urban structures. Ahern argues that "resilience demands for a new way of thinking about sustainability". He believes flexibility is a "more strategic than normative concept", as, to be effective, it must be functioning through "environmental, ecological, social and economic drivers". [40] The author continues to claim that already in its definition, flexibility is adaptable to unpredicted changing environments. Therefore flexibility is the aspect of sustainability that reacts to time. Sustainability cannot exist without the flexibility to adapt fluently to changing circumstances; a structure must be able to anticipate external developments so that it is able to react sustainably.
Hence, the concept of sustainability must be understood in relation to time. Without responding to time, and with it inevitably change, sustainability doesn't exist. Along these lines, flexibility is a necessity within sustainable designs. The circuit of designing is only truly sustainable in relation to a buildings ability to adjust with the passing of time.

At this point, another term comes into play. Having established that *sustainability* and *flexibility* are boundary objects that include a wide variety of ideas, *modularity* is a flexible concept that seems to be truly sustainable in its theory. *Modularity* stands in an equal dichotomy to *sustainability* and

[39]Jack Ahern, *From Fail-Safe To Safe-To-Fail: Sustainability And Resilience In The New Urban World*, (Landscape And Urban Planning, 100.4 2011), p.3

[40] Ibid.

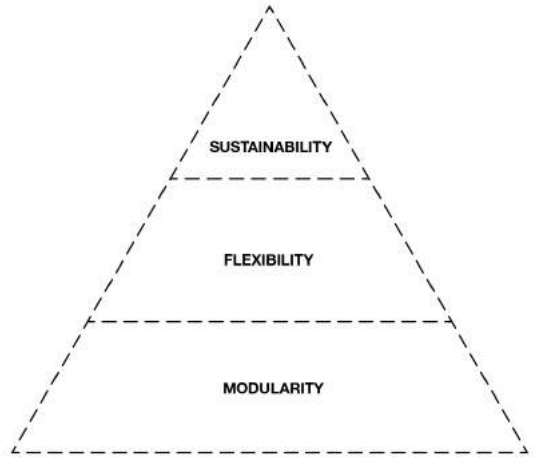

Figure 5 Hierarchical relations between Flexibility modularity and Sustainability

flexibility. Building in a modular way allows for maximum flexibility as the building can be taken apart and altered in a wider fashion. In other words, the flexible building is dependent on its modular features, as otherwise, it is not actually flexible (to be further discussed in chapter 5). To visualise this relationship, one can imagine a pyramid-like layout, where modularity is the base of flexibility; flexibility is the key to reuse and reuse is a factor allowing for sustainability.

Modularity is a key idea that enables actual change in the building typology without making a single building multifunctional.

The concept of modular, sustainable building is currently trending in the design for disassembly (DfD) movement. This theory embodies the idea of creating from the inside out, designing products and buildings almost in reverse. It is a way to design for maximum flexibility. Here, the designs start from acknowledging the finality of the product's lifetime and building it to be taken apart again in a sustainable manner. DfD is a way of building with reduced waste potential as the object can be deconstructed in a way that does not harm the materials themselves. It is one of the most contemporary ways of addressing flexible buildings but is still in its early stages of development. Numerous architects have recognised the need to build more modular constructions and have responded with architectural designs that prioritise flexibility. A question that remains is how far and for what reasons the buildings are successful in their adaptation of flexibility for sustainability?

The relationship between flexibility and sustainability shows that adaptability can act to increase sustainability in its design, not that it guarantees it. As established earlier, a major flaw of the two terms is that they are so ambiguous and adaptable that they may refer to something which is not at all ecologically sound. For example, if a building is flexible, it might still not be sustainable if it does not adapt to future needs.

A prominent example of this discrepancy in function and ideology is the previously mentioned Nakagin capsule tower in Japan. It is constructed of over 140 prefabricated cell-capsule-units that are all connected to the building's simple frame by four high tension bolts. Each capsule contains the necessities of temporary living and allows for “comfortable”, yet minimalist housing. The capsules are easily disconnected from the main frame and are exchangeable in case of dysfunction. Room was left to add capsules, according to the needs of the housing market. This building is a “prototype of sustainable architecture”[41] with a partly reusable, or at least adaptable function.

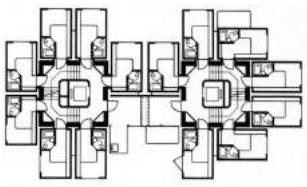

Figure 6 (left) Kurokawa, Nakagin Capsule tower, 1972 **Figure 7** (middle) Tower exterior 2017
Figure 8 (right) Nakagin Capsule tower Plan

The building, known as a milestone in sustainable and transformable design, has never delivered on its promise.[42] In reality, however futuristic and ambitious the original idea, the building was never truly flexible. Unfortunately, it is less practical than originally theorised as exchanging or moving

[41] Acharya, *Flexible Architecture for dynamic societies*, p.20.

[42] Nicolai Ouroussoff, *Future Vision Banished To The Past*, The New York Times Online, 2009 https://www.nytimes.com/2009/07/07/arts/design/07capsule.html [Accessed 23 March 2021].

the capsules is prohibitively expensive. In fact, since its first construction in 1972, the building has remained in its initial shape and none of the capsules have been restructured. Despite its symbolic importance, the Nakagin Capsule Tower might now be awaiting its demolition and replacement by a more modern and efficient building.

This extraordinary piece of architecture beautifully illustrates how fruitless *flexibility,* as a base of *sustainability*, can be. Despite the idealistic concept, the building remained inflexible in reality and thus unsustainable. The Nakagin Capsule Tower exemplifies that even with the intent of flexible and sustainable designs, the execution does not guarantee either. Using the words *flexibility* and *sustainability* about buildings like these diminish the value of the very terms.

Another architectural example that supports this line of argument from a different angle is the Hermann Miller factory in Bath, UK. At the same time as the construction of the Nakagin Capsule Tower was built, on the other side of the world, the architects Nicholas Grimshaw and Terry Farrell designed a building with a similar concept. This factory is built to be extremely flexible, both inside and out. Matching Hermann Millers products, Grimshaw describes his plans with the words "I wanted it to be a factory that could be reconfigured, changeable and adaptable".[43] Years after the construction, he says in an interview that the "building and furniture was there to support human activity", an intention that strongly resembles that of the Japanese Tower.

Although the building was not conceived with a focus on ecological sustainability, it successfully embodies flexibility. The Hermann Miller factory was built out of a complex steel frame with an interchangeable external skin. Individual insulated fibre-glass and glazing panels clad the steel structure. The interior of the factory allowed maximum flexibility, with few fixed walls elements. The building can change its entrance, its exterior appearance and allows for transformable outside seating areas.

Unlike other *flexible* buildings, this building has actually been rebuilt or transfigured five times within its use as a furniture factory. This design allowed the company to achieve a production rate that was six times higher than the initial plan for the factory until the company relocated because the factory no longer fulfilled its needs. Grimshaw architects are now renovating the building to turn it into a campus building for the Bath Spa University.

The building is a very successful example of flexible and hence durable design as it was able to adapt to new needs without necessarily creating waste. Despite this successful aspect, this building is still not fully sustainable. Firstly, the fibreglass panels need to be maintained and replaced

[43] India Block, "*The Most Destructive Thing Is To Demolish A Building" Says Nicholas Grimshaw*, (Dezeen, 2021) https://www.dezeen.com/2019/02/15/nicholas-grimshaw-interview-riba-royal-gold-medal-2019/ [Accessed 23 March 2021].

regularly, creating waste. More importantly, however, whilst this is a perfectly efficient flexible building, its interchangeable features do not allow for any sort of “trans-building” flexibility. Hence, although this structure can transform and convert itself into different shapes and functions, this ability is not projected onto any other works of architecture. If the building, for example, had to be demolished, one could not reuse the exterior panels for another project. To be fully sustainable, therefore, the panels would have to be part of a universal design that could be used in different building types. Hypothetically, a way to prevent the panels from being wasted would be to standardise panel design for exterior walls. This way, they could be used in so many different buildings that, in case of a demolition, the remaining panels could be reused in their original form in a different piece of architecture. This idea follows a sort of LEGO principle, an idea that has been revived in recent thoughts on modular building. This design is based on the issues of reusability even within flexible structures. The children's game LEGO here has quite a remarkable function, allowing to build different, yet demountable, structures from the same set of “stones”. The Hermann Miller factory does not work sustainably because it is not universal enough. Following this metaphor, one can only use the factory’s elements to build the same factory. LEGO stones are universal enough to truly transform a factory into, say a castle or a townhouse.

Figure 9 (top left) Exterior of the Hermann Miller factory
Figure 10 (bottom left) Single exterior wall panels
Figure 11 (right) Panels being applied onto the exterior

Synchronicity among sustainable strategies is a different way of achieving the goal of lasting ecological building. This refers back to the coalescence of *reuse, reduce* and *recycle*. The Urban Mining and Recycling (UMAR) unit in Zurich, Switzerland exemplifies this theory. Here, the architects used flexible design strategies, therefore practising the principle of *reuse* and also worked with fully recycled materials. The composition of the UMAR housing unit is rather simple. Just like the Nakagin Capsule Tower, it is stabilised by a concrete frame with single prefabricated housing units that can be placed between the concrete layers of the frame. What sets this apart from other inefficient, flexible designs, is maximum modularity in the design and the use of 100% recycled and compostable materials. In this case, the building is especially modular through flexible interior settings and full demountability of all materials. The different building components are only assembled with dry joints that can be taken apart again after their use, unlike glue, mortar or welded metals.

In terms of its reusability, this building is thoroughly sustainable. Although the concrete base is neither reusable nor sustainable, its application is reduced to the bare minimum, to guarantee the frame's durability and lasting stability. Other than the concrete base, this is an example of a successful *circular building*. Nearly all components have reusability and recyclability that allows the building components to have a very long life cycle. Dirk E. Hebel, one of the three architects explains that "the used materials are neither consumed nor disposed of; they are merely removed from their life cycle for a certain period of time and are returned to it at a later point."[44] The building is intended to have multiple layers of reusability; firstly, the base of the building can hold any interior setup, whether it is an office, a gym, or housing, etc. Furthermore, each housing unit is transformable, allowing for different interior floor plans. Finally, the materials of the individual units can be fully disassembled and can restart another life cycle with a different purpose. Along these lines, this building exemplifies the collaboration between reusability and recyclability, resulting in a very *fail-safe* and truly ecologically flexible building.

[44] Betina Sigmund, *Wohnmodul Aus Recycling-Material,* (Detail Magazine 2018) https://www.detail.de/artikel/wohnmodul-aus-recycling-material-32134/ [Accessed 23 March 2021].

Figure 12 (top left) Prefab unit being built off-site.

Figure 13 (top right) Prefab unit active in the building

Figure 14 Unit being set into the concrete building

The People's Pavilion in Amsterdam, Netherlands, is another example of adaptable and ecologically friendly architecture. It was designed by the dutch Architects Overtreders W and Bureau SLA, to have “almost no ecological footprint” according to Peter van Assche, the founder of *Bureau SLA*. “We took the circular idea to the maximum level.”[45] Indeed, the temporary installation is constructed exclusively of “borrowed” and recycled materials. No components of the design are wasted or altered from their initial state so that all materials can be returned to their “owners” after the building is deconstructed. This is an example of a 100% circular building, in which no materials are wasted or decrease in quality through the construction.[46]

The People’s Pavilion is built without screws, nails, or wet joints, etc. All its elements are assembled with tie-down straps, tension belts and cable ties, in a fully innovative way of construction. Like most buildings, it stands on a structural base of concrete, yet, the concrete pillars, just like all wooden beams, the ground floor glazing and the glasshouse glazed roof are borrowed and will be returned instead of demolished. The only materials that were produced or altered for this building are the 100% recycled plastic tiles on the facade, made from the plastic waste of neighbouring homes. These too, are returned to the homeowners in the form of tiles after the deconstruction of the pavilion.

The significance of this building lies in its holistic approach. Without exception, every step of the building process can be universalised which makes it an entirely ecologically friendly construction. Unless we design buildings in which all materials remain in their original condition like the *People’s Pavilion*, they degrade the quality of the material; inevitably leading to an unsustainable outcome.

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[45] Amy Frearson, *People's Pavilion "Has Almost No Ecological Footprint" Say Designers*, (Dezeen, 2021) https://www.dezeen.com/2017/10/27/peoples-pavilion-dutch-design-week-low-ecological-footprint-bureau-sla-overtreders-w/ [Accessed 23 March 2021].

[46] Ibid.

Figure 15 (top left) Peoples Pavilion in Paris - exterior
Figure 16 (lower left) Building's interior joinery system
Figure 17 (lower right) Building materials disassembled

A final example that is equally flexible to the Peoples Pavilion and the UMAR housing unit is the Wooden Nursery located in the Luxembourg Gardens in Paris, designed by Djuric Tardio Architects. This building is a slightly less temporary construction than the peoples pavilion, even though it is designed for disassembly, it is a permanently finished construction. The Parisian nursery is entirely demountable and reconstructible without any waste production. The nursery will remain in the Luxembourg Gardens for two years before it is dismantled and then reassembled in a different part of Paris. As the building is constructed of single identical and interchangeable modules, it remains flexible to adapt to new sites.[47] The joinery is inspired by traditional Japanese systems that allow the reusability of the materials. What makes this building so valuable in the discussion of efficient flexible architecture, is its "normal" appearance. It is proof that we must not adapt our entire style of building to look modular and flexible, like the Peoples Pavilion in Amsterdam, but that we can

[47] Valeria Ozuna, *Modular And Nomadic Building In Paris*, (Metalocus, 2020) https://www.metalocus.es/en/news/modular-and-nomadic-building-paris-wooden-nursery-luxembourg-gardens-djuric-tardio-architectes [Accessed 23 March 2021].

design architecture that resembles our current style of building while remaining flexible and sustainable. The 48-cradle nursery is made predominantly from wood and is designed to be reconfigured into numerous different structures that allow its function to change into emergency housing, offices and more. This causes the building to be theoretically more flexible as its design might not require disassembling it into single materials for even longer.

Figure 18 (top left) Wooden Nursery by Djuric Tardio Architects in its current location in the Luxembourg Gardens, Paris
Figure 19 (top right) The construction being assembled
Figure 20 (lower left) Building's interior in use as a Nursery

These five case studies elucidate the limitations of flexible and sustainable architecture. In summary, the primary issue with the way we use flexibility in architecture for sustainability is that we do not use it in a holistic approach. The previous examples show four solutions where flexible architecture might be genuinely sustainable.

CHAPTER 5 //
Requirements for Flexibility

5.1 Designing Flexibility

What are possible solutions to ensure efficiency in flexible, and therefore sustainable designs?

The initial issues with flexible designs are impracticality, imperfections in their ideal functions, and an insufficient prediction of future needs or challenges. In simple terms, flexible architecture must actually be *flexible* in its adaptation to future challenges and needs. When interviewing Tom Bergevoet, his response to this challenge was:

> You have to ask yourself, what is flexibility? When you come up with something that is flexible, it is something that is usable in multiple ways. There are more possibilities for problems to occur. That means that all possibilities should be evolved and incorporated into the design.[48]

This way of thinking calls for a new form of designing *flexibly*. Robert Kronenburg, a pioneering researcher in this field, supports this view as he expressed that "the idea of flexibility in architecture has changed dramatically over the last 20-30 years."[49] He predicts that flexible architecture was originally practised by untying a building's design from its function. Kronenburg sees this as a "mistake", arguing that in these kinds of designs, buildings do not fulfil their initial function well enough, instead, flexible buildings should have a single function but can change with time.[50] The Nakagin Capsule tower is an ideal example of the issues with the original idea of flexible designs. What *flexible* buildings commonly lack is that, eventually, issues arise that the architects did not anticipate. As much as we can try to foresee all challenges that a building could face, a singularly flexible design is not extensive enough to succeed in lasting sustainability and the prevention of waste production.

Kronenburg's concept of successful flexible architecture can be seen in the last three examples mentioned above. The key to this idea is again modularity. A first solution to the issue of changing needs is universalising a flexible design. As the Hermann Miller factory demonstrates, flexibility in buildings must be reusable beyond the scope of a single building. To achieve lasting sustainability through reuse in a flexible structure, the building materials must be adaptable to different designs.

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[48] Tom Bergevoet, 2020.

[49] Robert Kronenburg, *Motopia: A New Age For Modular Construction,* https://www.youtube.com/watch?v=Xgfi9gGGHos: (USC Architecture, 2011).

[50] Ibid.

In essence, it is not enough to design a building typology that can be disassembled into the same typology in a different location, it must be flexible enough to be reassembled into a new typology if necessary.

Another way to solve the negative ecological effects of insufficient flexibility is by designing in collaboration with a different sustainability strategy. If *reuse* is applied in a design that also includes the principles of *reduce* or *recycle* or both, the building stands a chance to create a circular life cycle and decrease waste production. This can be seen in the UMAR units in Zurich as well as the dutch People's Pavilion.

The final design concept that has an efficient ecological outcome is construction without altering the materials. The limitations of this process are that the materials may not be changed or reformed in any way, which takes away their purity and makes them less applicable to an entirely different design.

All three strategies can act as tools to build truly sustainable cities. Chansomsak and Vale state that: "to improve the world to be close to a sustainable condition, it is essential to focus on the overall results as well as the intention of the creation."[51] These words reflect the need to compare the intent of the design to the actual outcome and judge them by their final product. This would result in many buildings that are currently called "flexible" or "sustainable" to be reconsidered with different terms or definitions.

5.2 Interaction between Terminology and Execution

How far could the discrepancy between the theory and practice of Flexibility affect or everyday life?

Having established that the definition of flexibility is often misinterpreted, leading to an incorrect application of the concept, the next question is, where the theory of flexibility faces its boundaries. To really understand our perception of flexibility, we must again consider its origin. There are three layers to *flexibility*: the initial layer is the concept or theory. It is the idea of flexibility which is the broadest category. The second layer is elucidated by the examples of flexibility in architecture. This refers to our application of flexibility, how we turn it from theory into praxis. The third layer is how we now define flexibility according to what already exists. The definition of flexibility is shaped through architecture and designs that we have created and called *flexible*. During the interview I held with Tom Bergevoet, his response to this idea was that ultimately, designers and architects have to "come up with intelligent designs that don't need words anymore", that is what defines

[51] Chansomsak and Vale, *Sustainable Architecture; Architecture as Sustainability.* p.2296

flexibility.[52] This approach to the issue is very different from my previous understanding of the terminology of *sustainability* and *flexibility*. It navigates the complexity of the subject into a direction that is comparable with the chicken or egg dilemma. What came first: a definition that was too vague and thus allowed buildings to be called flexible, although they are not? Or was it the designs that were not flexible in the first place but came to be called that, thereby broadening the term and making it void?

Both answers to this dilemma result in the inaccuracy of the terminology and raise the question of the boundaries of the theory of flexibility. Hypothetically, the concept of flexibility is so broad that to make it comprehensible in our practice, we need to delimit it. There are many different formats of flexibility, whether it is urban flexibility, functional flexibility, material flexibility and modularity, it is all part of the same complex of theories. In this thesis I have only explored a fraction of the effects that define our understanding of flexibility. Possibly the sheer amount of different ways to interpret the theory, its execution and its terminology, might be the cause for way more choices in our designs.

For example, maybe if we would define the boundaries of the theory of flexibility more, we would be able to build more universally flexible? It could be that the reasons why so many flexible designs fail are because we expect the design to be too complex, and hence make it so. Or maybe we perceive flexibility to be something immediate, like sliding walls, instead of trusting that real flexibility needs to be about longevity? Also, the appearance of modular designs tend to be visually modular too, even though the aesthetics don't follow any function. Is this because if we did not make *flexibility* somehow tangible for us, we fear that we might miss it?

[52] Tom Bergevoet, 2020.

The way we define *sustainability* and *flexibility* in architecture has changed over the last decades. The use of the terms has increased immensely while their meaning has become diffuse. Whether the lack of efficient terminology is caused by the absence of fully *sustainable* building, designing and urban planning, or whether, in fact, the diversity of *sustainable* buildings is cause for this ambiguity remains unclear. Regardless, the outcome is the same: the terms *flexibility* and *sustainability* are used with a misguided focus on the design intent, rather than the design's effects. This inconsistency allows the terms to be applicable to numerous concepts, cities and buildings, that do not, in fact, accord with the original definition of the terms. In relation to one another *flexibility* and *sustainability* have made each other boundary objects. These terms have become inexplicit and imprecise, allowing more and more buildings to be falsely accredited and be celebrated with an almost meaningless glory. Flexibility in architecture is an element we view as luxury, while the current worsening situation should make it a necessity. There is no time and no resources to allow for false sustainability; for sustainability and flexibility that is not truly ecological in its outcomes.

In essence, it might not be necessary to create a new term, nor even to redefine either *sustainability* or *flexibility*; it is crucial, however, that we reflect on past patterns of constructing and demolishing and learn from this process. We must build more flexible buildings that allow for adaptations to a changing environment and that welcome technological, social and economic progress without instantly resulting in waste production. With the technological advancements that are available in this modernised era, our architectural ideologies should shift from a monumental and permanent base, which is in itself an outdated concept as the average building is only built to last between 50 an 80 years anyway, to one that is adaptable, mobile, creative and sustainable.

Many individual architects, like Tom Bergevoet and Martin van Tuijl, have been advocating of more flexible designs, buildings and urban planning for a long time now. Lacaton and Vassal winning the 2021 Pritzker Prize is a huge step in the right direction, by giving credit to a view on architecture that should become normality. Whether we think flexibly enough to remodel existing buildings, to prevent their demolition, or we build them with a flexible reusability from the start, both are great solutions that enhance sustainability.

We need to rethink architecture. Instead of viewing architecture as an end product, we must see it as a process from the design up to its eventual demolition. Flexibility in a building's function can increase its lifespan in this fast-paced society, but it's design must also anticipate that a building's materials can have a longer life cycle than that of its original building. Reusing materials is the most

preventative action to save resources that are running out. Buildings should be able to grow and transform with their society and cultural environment, not prevent changes and limit it in its progress. Flexible building is a solution that can change modern architecture, even more significantly than it does today. With the right designs and enough preparation, it could be a solution to our environmental crisis that can alter the history of architecture.

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