ABSTRACT

Title of Thesis:	CHANGE IS COMING: PRE-ADAPTABILITY FOR A RESILIENT CITY
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Since its inception, the Earth has been a living and evolving planet. Phenomena such as tectonic plates shifting and changes in the atmosphere have caused our ecosystems to change and evolve by natural events. Humans have been part of this ecosystem for the past 2.1 million years but have only stopped their nomadic way of life and built village settlements 10,000 years ago. Civilizations have faced many natural and human-made disasters forcing them to renovate, rebuild, or relocate. However, the frequency of these disasters through climate change will exacerbate these transformations. For many cities around the world where landscapes are being permanently affected by climate-induced landscape change, the built environment has the responsibility to adapt. How can architecture allow for change over time? When we know that intermittent floods are becoming more detrimental, how must we build our cities to prepare for living with water?

CHANGE IS COMING: PRE-ADAPTABILITY FOR A RESILIENT CITY

by

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Dedication

I dedicate this thesis to my family and friends who have supported me throughout the years. I would also like to specifically dedicate this to my mother, Dr. Gohar Farahani, for all of her encouragement and my father, Hamid Omidvar, for his mentorship and introducing me to architecture in the first place. I wouldn't be as passionate about bettering the world without you two.

Acknowledgements

I would like to acknowledge and pay respects to the Indigenous people and their elders and ancestors of these lands and recognize the long history violence, displacement, and loss of land at the hands of European colonists. This thesis was written on the land of the Manahoac and Piscataway peoples, my education provided on the land of the Piscataway peoples, and the design of this thesis on the land of the Anacostan peoples, past and present. Long before the cities of today were built, the Indigenous peoples on what is now known to be the United States of America stewarded and the lands they rightfully lived and worked on from time immemorial. May we learn and continue to honor and celebrate their practices which have shown to create a more harmonious relationship with the land which we design and build on and look towards avenues to repatriate this land which must heal from its painful history.

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List of Abbreviations

ARP	Adaptive Reuse Potential
GGE/GHG	Greenhouse gas emissions/ Greenhouse Gas
IECC	International Environmental Conservation Code
IEQ	Indoor Environmental Quality
IPCC	Intergovernmental Panel for Climate Change
SLR	Sea-level Rise
WHO	World Health Organization
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGBC	U.S. Green Building Council

Chapter 1: Introduction

"*It is not the most intellectual of the species that survives; it is not the strongest that survives; but the species that survives is the one that is able best to adapt and adjust to the changing environment in which it finds itself." – Leon C. Megginson*[1]

Conversations and general awareness surrounding climate change began about thirty decades ago. Most of that time was spent utilizing scientific evidence to prove that it even existed. However, it is clear to most people today that the increased frequency and impact of disaster events are directly linked to the climate and the change in these weather conditions across Earth's biomes. These natural disasters have been ravaging parts of the world and leaving many vulnerable. More human and animal lives will be destroyed as humanity continues to move at a slow pace to lower carbon emissions, reduce waste streams, and to preserve and remediate our remaining natural environments.

According to the Sendai Framework from 2015, "700 thousand people have lost their lives, over 1.4 million have been injured and approximately 23 million have been made homeless as the result of disasters."[2] Also, "between 2007 and 2012, 144 million people were displaced by disasters."[3] Since this report, many more lives have been and will continue to be affected as measures are not taken to the extent that is necessary to reduce climate change effects. As Figure 1.1 illustrates, issues branch

[1] Leon C. Megginson, "Lessons from Europe for American Business" (Southwestern Social Science Quarterly, 1963).
[2] The United Nations Office for Disaster Risk Reduction, *Sendai Framework for Disaster Risk Reduction 2015-2030* (Sendai, Japan, 2015).
[3] Ibid.

into all areas of human life, including climate-related health issues, food scarcity, and impacts on mental health. [4]

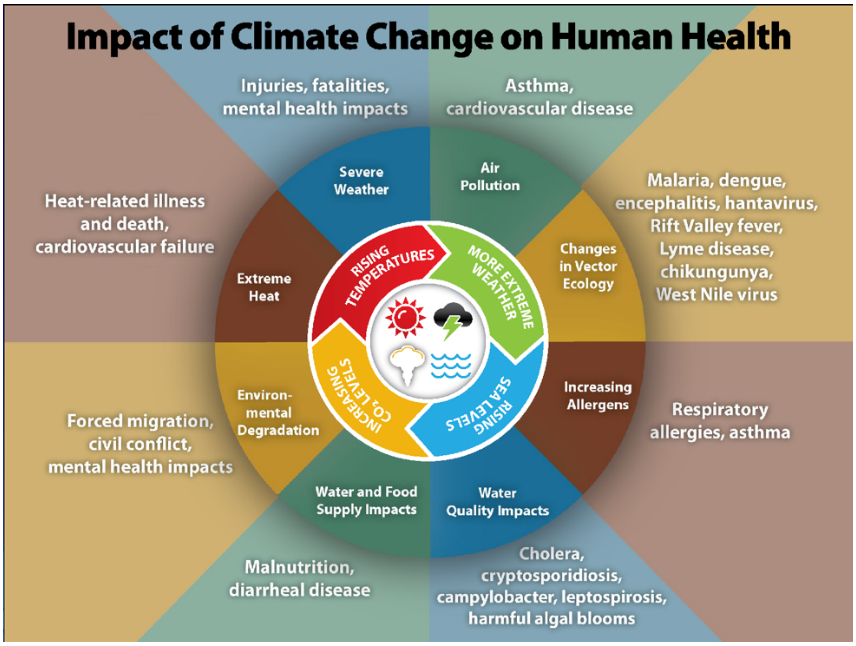

Figure 1 Impacts of Climate Change on Human Health (Source: National Center for Environmental Health)[5]

There are especially vulnerable groups related to age, socioeconomic status, race, and health conditions, which increase their risk compared to the general population. When disaster or infrastructure failure hits these regions, they can have multi-level stresses that can lead to loss of life. As these communities fall into the cycle of recovery and disaster, they will spend billions of dollars, and in the process, contract long-term physical and mental health challenges which lower quality of life. These issues further put a strain on resources and keep communities perpetually susceptible to future risks.

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[4] National Center for Environmental Health, "Climate Change : Health Impacts and Policy Challenges," *Analysis*, last modified 2019, accessed May 12, 2020, https://www.cdc.gov/climateandhealth/effects/default.htm.
[5] Ibid.

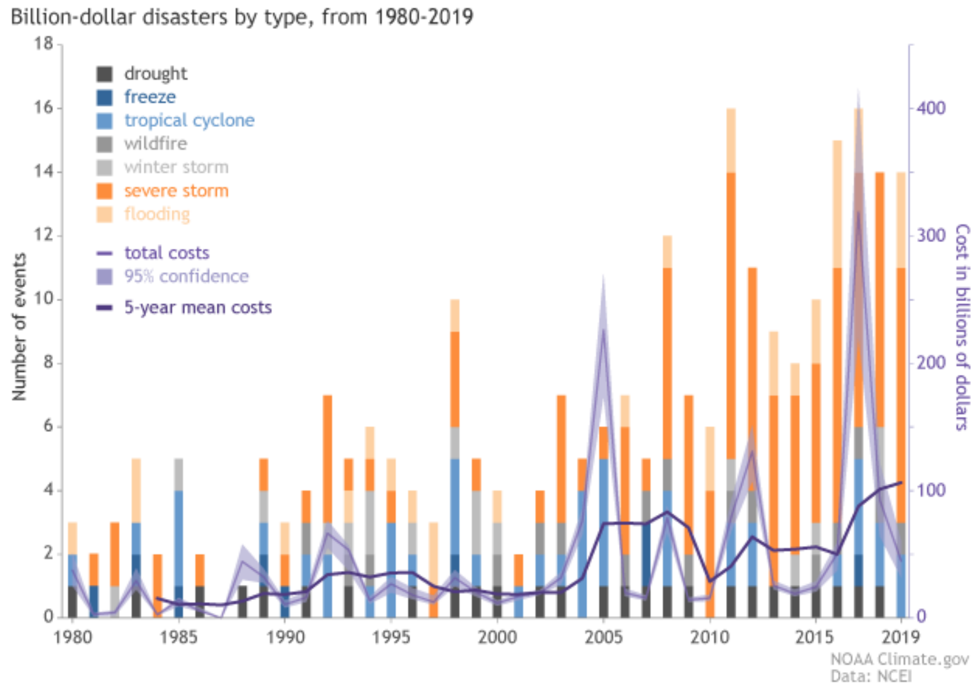

Figure 2 Billion-dollar disasters trends from 1980 to 2019 (Source: Adam B Smith) [6]

Billion-dollar events to affect the U.S. from 1980 to 2019 (CPI-Adjusted)

DISASTER TYPE	NUMBER OF EVENTS	PERCENT FREQUENCY	CPI-ADJUSTED LOSSES *(BILLIONS OF DOLLARS)*	PERCENT OF TOTAL LOSSES	AVERAGE EVENT COST *(BILLIONS OF DOLLARS)*	DEATHS
Drought	26	10.1%	$249.7 CI	14.2%	$9.6	2,993[†]
Flooding	32	12.4%	$146.5[§] CI	8.3%[§]	$4.6[§]	555
Freeze	9	3.5%	$30.5 CI	1.7%	$3.4	162
Severe Storm	113	43.8%	$247.8 CI	14.1%	$2.2	1,642
Tropical Cyclone	44	17.1%	$945.9 CI	53.9%	$21.5	6,502
Wildfire	17	6.6%	$84.9 CI	4.8%	$5.0	347
Winter Storm	17	6.6%	$49.3 CI	2.8%	$2.9	1,048
All Disasters	**258**	**100.0%**	**$1,754.6** CI	**100.0%**	**$6.8**	**13,249**

[†]Deaths associated with drought are the result of heat waves. (Not all droughts are accompanied by extreme heat waves.)
[§]Flooding statistics do not include inland flood damage caused by tropical cyclone events.
The confidence interval (CI) probabilities (75%, 90% and 95%) represent the uncertainty associated with the disaster cost estimates. Monte Carlo simulations were used to produce upper and lower bounds at these confidence levels (Smith and Matthews, 2015).

Table 1 Billion-dollar disaster types and events to affect the U.S. from 1980 to 2019 (Source: Adam B. Smith)[7]

[6] Adam B. Smith, "2010-2019: A Landmark Decade of U.S. Billion-Dollar Weather and Climate Disasters," *NOAA Climate.gov* (2020): 1–15, https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate.
[7] Ibid.

Over the past 40 years, the economic impact of floods and other disasters has increased, and a large portion of recovery costs have been spent on the recovery of the built environment (Figure 2 and Table 1).[8] While the value of many disaster events are less than a billion dollars, the number of billion-dollar disasters are rising. The continued urbanization of coastal areas and the increased frequency of heavy precipitation events with traditional construction methods will not mitigate any risk. Projections show that "rebuilding stronger, faster, and more inclusively – could generate major benefits, totaling U.S. $173 billion per year or 31 percent of current wellbeing losses due to natural disasters."[9]

Most large metropolitan cities on the East Coast of the United States were established long before the Industrial Revolution and have mostly built critical infrastructure soon after the Federal-Aid Highway Act of 1956 was passed. Importantly, these cities have aging assets that have become highly vulnerable to weather-events and are experiencing higher levels of failure.[10] When urban runoff overwhelms old stormwater management systems, cities become more susceptible to floods and impact buildings and their users. Additionally, many traditional building materials are more vulnerable to water infiltration and decay, such as brick and wood frame construction. When structures in high-risk areas face recurring floods, the material decays at a faster rate.

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[8] Ibid.

[9] Stephane Hallegatte, Jun Rentschler, and Brian Walsh, *Building Back Better: Achieving Resilience through Stronger, Faster, and More Inclusive Post-Disaster Reconstruction* (Washington, D.C., 2018).

[10] A. K. Parlikad and M. Jafari, "Challenges in Infrastructure Asset Management," *IFAC-PapersOnLine* 49, no. 28 (2016): 185–190, http://dx.doi.org/10.1016/j.ifacol.2016.11.032.

This thesis explores how building design can implement adaptability measures from the inception of the project to extend its life and conserve materials, thus producing a highly resilient structure. As a result, the author coins the term “Pre-Adaptability” which is characteristic of a structure that is capable of being adjusted over time to various environmental and societal changes to minimize its ecological and economic impact while maximizing its lifespan. While adaptive reuse can adopt adaptable ideas, the concept of pre-adaptability is distinct as it is proactive and not reactive. This concept requires reconciliation between a building’s context and the challenges that come with the passing of time. Additionally, this thesis accepts that the built environment must evolve and thus requires the removal of building stock. Through pre-adaptability, the salvage and disassembly of a building are similarly crucial in efforts addressing the high embodied energy of most structures.

Architecture has had the distinct responsibility of providing health, safety, and welfare to the public. Through pre-adaptable building design, this promise can be further confirmed from the building’s first construction to its last reconstruction. Urban and natural landscapes worldwide are changing due to climate change. The cultural fatigue of the construction industry to respond to natural forces will cause much more harm than investing in evolving their practice. Continuing with the standard practice of today ensures that the current and future building stock of our cities will fail. Fortunately, many of the ingredients of adaptability already exist in sustainable and resilient design and can be reimagined in this framework.

Chapter 2: Water in Cities

Cities have been constructed near water since village settlements were established thousands of years ago. Alluvial planes were preferred locations for settlements creating trade ports that became a generator of urban form. Additionally, the placement of a city near these fertile valleys brought fruitful agricultural sites in their immediate vicinity. However, these cities came with their own risks. Weather and climate patterns were not well understood, and nature would bring damage through flooding. Religions and rituals developed around protecting these sites from Mother Nature's hand and learned to rebuild and plan for these events over time.

As the sea-levels rise and heavy precipitation events bring more water to more cities, it is becoming increasingly difficult to prevent large-scale damage at the hands of climate change. Human ingenuity has developed many methods of mitigation, but none will prevent the inevitable. These changes affect the urban environment as much as agricultural sites. Architects and other built environment professionals have a distinct opportunity to improve flood-risk management in cities to protect billions of people living in risk areas. Importantly, the ecology and microecosystems of these regions are linked to the survival of all.

Coastal Cities

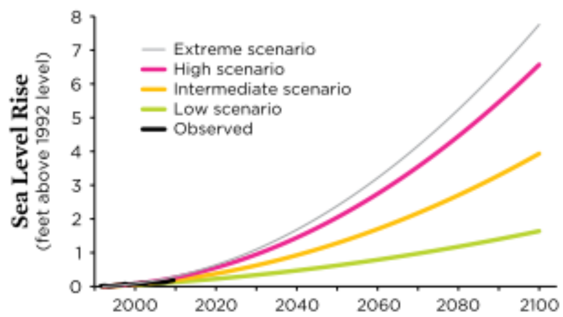

Figure 3 Expected 21st Century Sea Level Rise (Source: Union of Concerned Scientists)[11]

Sea level rise is due to factors such as melting glaciers and ice sheets and the thermal expansion of seawaters from warming.[12] It is expected that up to 6.6 feet of global sea-level rise will occur by 2100 (Figure 3).[13] The U.N. estimates that 600 million people are living in coastal areas, which are less than 10 meters above sea level, and up to 2.4 billion within 60 miles of a coast.[14] These trends affect all levels of society, and the most apparent will be the physical environment. When the tangible framework of human society falls apart, many adverse effects will occur, specifically displacement.

The most vulnerable regions to sea-level rise are coastal cities. Even so, there has been a continued attraction to seaside property in the United States. Currently, developers generally ignore information about the level of risks in these regions and

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[11] Union of Concerned Scientists, "Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate" (2018): 1–28, http://www.zillow.com/ztrax.
[12] Rebecca Lindsey and Rick Lumpkin, "In Some Ocean Basins , Sea Level Rise Has Been as Much as 6-8 Inches (15-20 Centimeters) since the Start of the Satellite Record" (2020): 1–9.
[13] Union of Concerned Scientists, "Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate."
[14] The Ocean Conference, "Fact Sheet: People and Ocean," *Ocean Fact Sheet* 102, no. 4 (2017): 24–25, http://www.tandfonline.com/doi/abs/10.1080/14639947.2011.564813%0Ahttp://dx.doi.org/10.1080/15426432.2015.1080605%0Ahttps://doi.org/10.1080/15426432.2015.1080605%0Ahttp://heinonline.org/HOL/Page?handle=hein.journals/abaj102&div=144&start_page=26&collectio.

are not incentivized to change their standard of practice due to the absence of resilient policies. Current estimates indicate that there are 280,000 people currently living in homes that are part of chronically inundated regions, consisting of 26 flood events or more per year, reflecting about 154,000 properties and $63 billion in property value.[15] These numbers are expected to climb over time. Other factors, such as infrastructure, airports, public buildings, and other elements of a city, add a $1.75 trillion valuation to at-risk coastal areas.

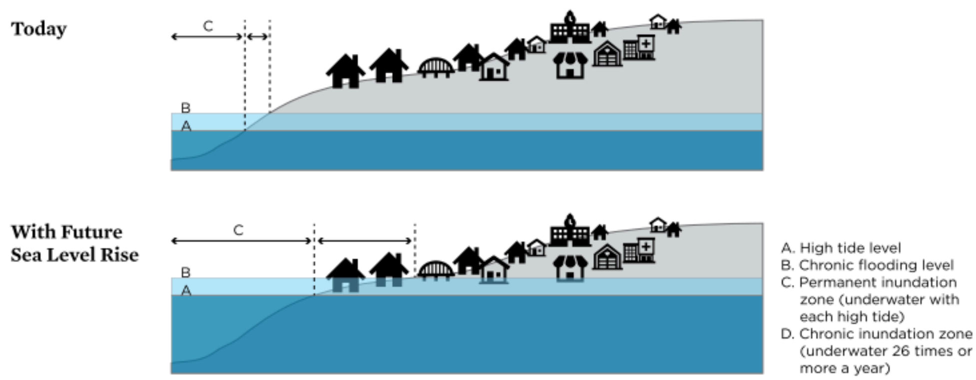

Figure 4 Sea Level Rise and Tide Trends in Coastal Cities (Source: Union of Concerned Scientists)[16]

Many of these cities, such as Ocean City, New Jersey, have received resources to rebuild after flooding and other disasters, but mostly in the same place. Adaptation of buildings in risk zones can only go so far to bring people back into viable long-term living. The Union of Concerned Scientists expects that "By 2045—near the end of the lifetime of a 30-year home mortgage issued today—sea levels are projected to rise such that nearly 311,000 of today's residential properties, currently home to more

[15] Union of Concerned Scientists, "Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate."
[16] Ibid.

than half a million people, would be at risk of flooding chronically, representing a doubling of at-risk homes in the 15 years between 2030 and 2045."[17]

Policymakers at all levels are allowing for development in risk zones with the knowledge that those areas have a high likelihood of increased flooding. One-third of coastal states found inside the United States ten-percent flood-risk zones outpace development outside of these areas.[18] Preparation for the retreat from these inundated areas is essential and will require abandonment or demolition of those structures. The event horizon is approaching, and the adaptation of existing buildings in these regions are not viable.

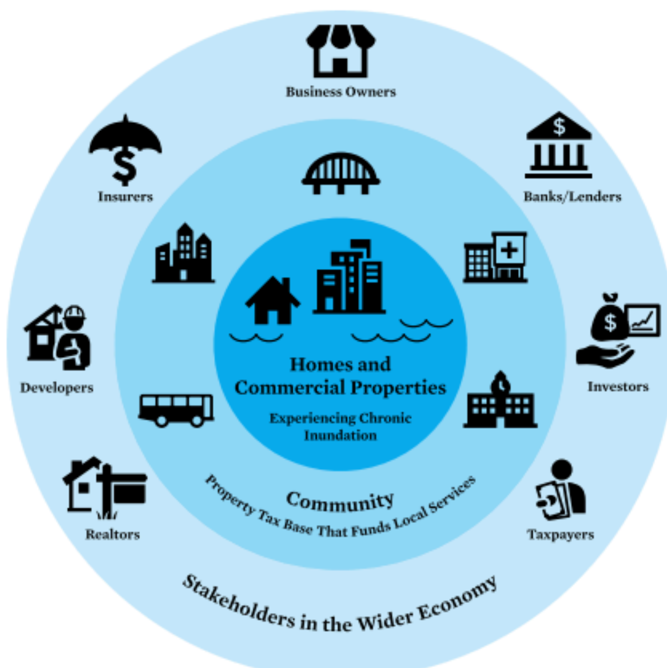

Figure 5 The Potential Economic Reverberations of Chronically Inundated Properties (Source: Union of Concerned Scientists)[19]

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[17] Ibid.
[18] Climate Central, "Ocean at the Door: New Homes and the Rising Sea," *Climate Central Brief* (2019), https://www.climatecentral.org/news/ocean-at-the-door-new-homes-in-harms-way-zillow-analysis-21953.
[19] Union of Concerned Scientists, "Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate."

However, as climate scientists predict new shorelines, zoning policy and development can prepare to accept displacement of those exiting coastal properties over time. If left to last-minute interventions, the cost of life and physical assets will affect more than the 9% of the U.S. economy linked to coastal properties, impact every aspect of society, and disproportionately affect marginalized communities.[20] This issue will make ripples in the built environment and economy if left to hopeful interventions with little to no acceptance of the future state of our landscapes (Figure 5).[21]

River Cities

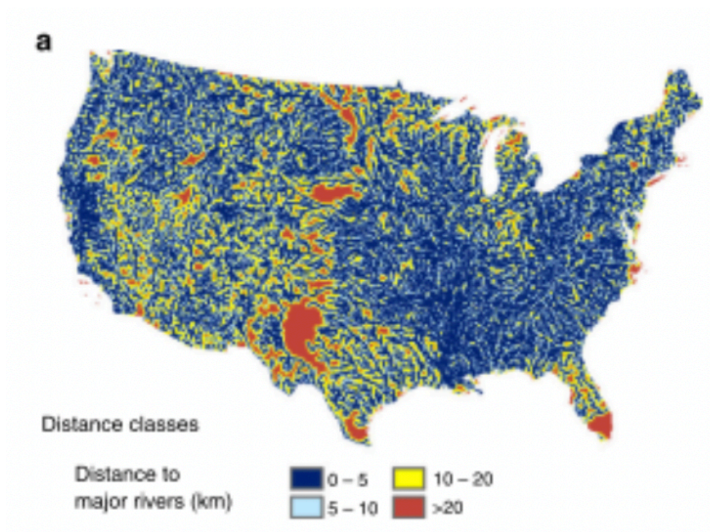

Figure 6 Distance of cities to river systems (Source: Yu Fang)[22]

Rivers are one of the most attractive locations for humans to settle near, mainly for access to freshwater for domestic and agricultural purposes. Population

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[20] Climate Central, "Ocean at the Door: New Homes and the Rising Sea."
[21] Union of Concerned Scientists, "Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate."
[22] Yu Fang and James W. Jawitz, "The Evolution of Human Population Distance to Water in the USA from 1790 to 2010," *Nature Communications* 10, no. 1 (2019): 1–8, http://dx.doi.org/10.1038/s41467-019-08366-z.

density has positive correlation to aquifers with high recharge rates because freshwater is essential to the survival of any city. Historically, the transport of materials was also easier for the trade of many types of materials for industry.[23] The proximity of city settlements to a river in many regions of the United States has remained consistent from 1790 to 2010, supporting its importance of this city typology (Figure 6).[24]

Similar to coastal cities, riverine cities have faced the effects of climate change. There has been an apparent increase in annual precipitation and river-flow in the Midwest and Northeastern regions of the United States.[25] The frequency and intensity of precipitation events are increasing in these regions as well, which puts an extra load on rivers, causing the overflow of its banks. Oversaturation of soil, lower rates of evapotranspiration of plants and trees due to rainfall, and higher rates of runoff due to impervious surfaces, cause more frequent flooding along riverine cities. These floods lead to property damage and even displacement in more extreme cases. Two of the most common types of flooding are fluvial (from an increased rate of runoff from a river catchment) and pluvial (precipitation intensity and duration that exceeds the infiltration, interception, and evaporation capacity") flooding. Flooding of this type is partially caused by poor drainage in urban environments and development in floodplains.[26]

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[23] Ibid.
[24] Ibid.
[25] A. Georgakakos et al., "NCA 2014: Chapter 3: Water Resources," *Climate Change Impacts in the United States: The Third National Climate Assessment* (2014): 69–112, http://admin.globalchange.gov/sites/globalchange/files/Ch_0a_FrontMatter_ThirdNCA_GovtReviewDraft_Nov_22_2013_clean.pdf.
[26] Andras Szöllösi-Nagy and Chris Zevenbergen, *Urban Flood Management*, *Urban Flood Management*, 2018.

The cost of riverine flooding thankfully does not tend to have high death rates, but it is worth paying attention to the loss of any life. Additionally, the economic impact of these floods is dramatic. In March 2019, flooding along the Missouri River caused three deaths and $10.7 billion in losses across six states, becoming the costliest inland flood in U.S. history. In the same month and through July 2019, the Mississippi River and parts of the Southern Plains flooded cities and farmland, causing a total of $6.2 billion in damages and the death of four people.[27] These impacts highlight the importance of zoning and the transformation of cities to adapt to a new normal. If left unchecked, these events will continue to ravage economies and livelihoods in riverine cities.

[27] Smith, "2010-2019: A Landmark Decade of U.S. Billion-Dollar Weather and Climate Disasters."

Chapter 3: Adaptability

The adaptability of buildings in an ever-evolving world will be an essential practice for the survival of cities and humanity. Natural landscapes and urban environments are changing through planned and forced scenarios and will require reconciliation of what has been and what can be. Allowing for future users and designers to work with as many choices as possible within existing buildings can enable communities to recover faster after significant weather events. There are many barriers to adaptability in the standard design and construction practices of today. Not all buildings are built equally for reuse in the future and planning of the different building elements is just as vital.

Adaptability Framework

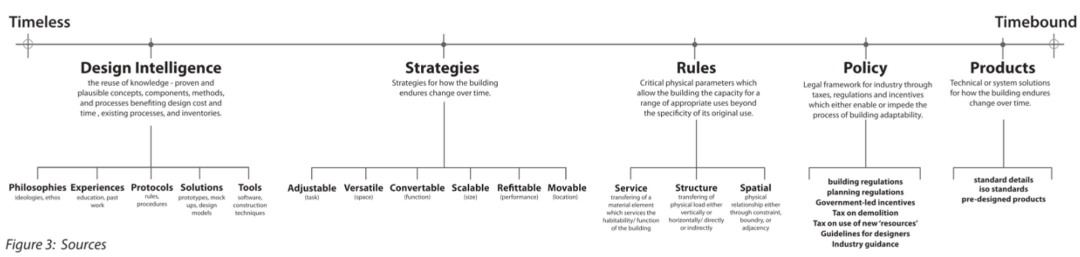

Figure 7 Different aspects of adaptability over different timescales (Source: Schmidt et al.)[28]

The term adaptability, as defined by Schmidt et al., is "the capacity to change the building's built-environment in order to respond to and fit to the evolving demands of its users/environment maximizing value through its lifecycle." The framework for adaptability must include time as a component through which design

[28] Robert Schmidt et al., "Adaptable Futures : A 21st Century Challenge," *Adaptable Futures*, no. October (2009): 5–9, http://adaptablefutures.com/wp-content/uploads/2011/11/Schmidt-et-al.-2009b.pdf.

intelligence, strategies, rules and policy, and products are developed. All of the concepts related to adaptability become part of a sizeable holistic approach to incremental change (Figure 7).[29] With every aspect of adaptable design, there are various approaches with their associated benefits and limitations. The changes required of a building includes task, space, components, function, size, and in certain instances, location.[30]

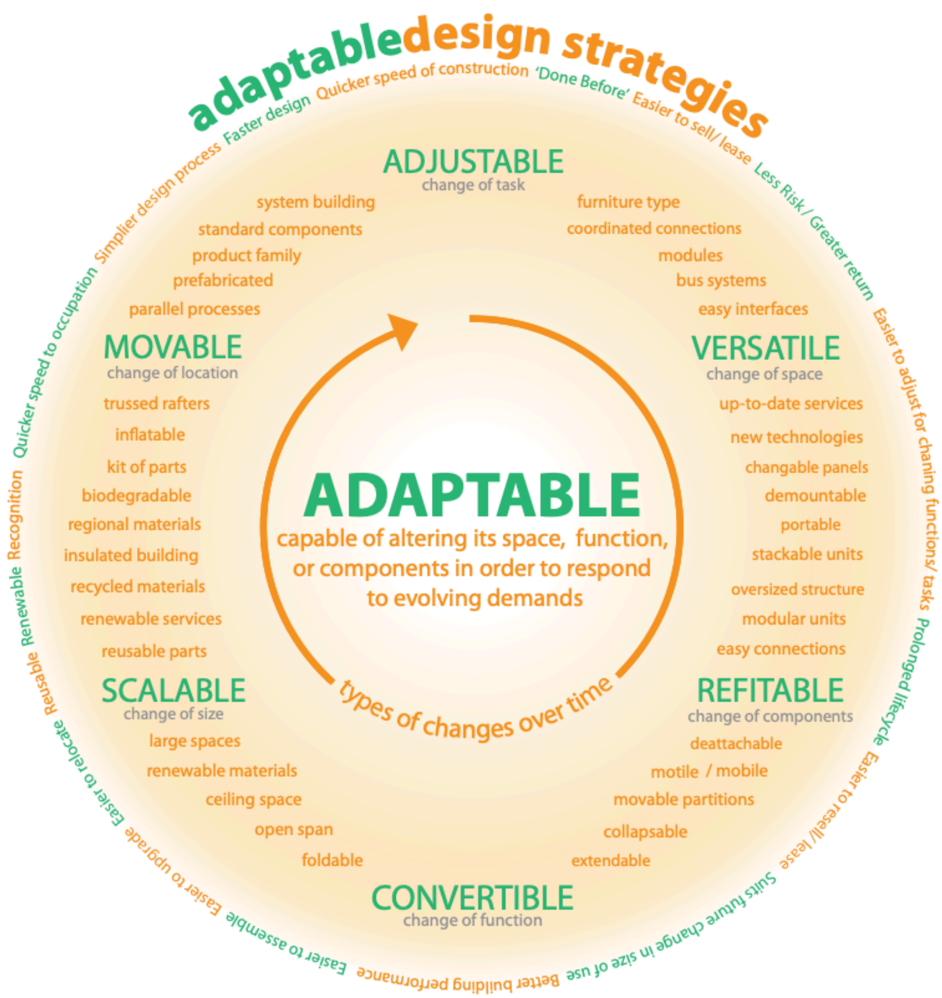

Figure 8 Adaptable Design Strategies (Source: Adaptable Futures)[31]

[29] Ibid.
[30] Ibid.
[31] Ibid.

The implementation of adaptable design requires collaboration and cooperation amongst stakeholders. Through various levels of specificity and frame cycles, buildings can apply lessons from their immediate context and overall paradigms to implement their best practices towards a longer lifespan and mitigation of obsolesces. Additionally, the frequency of potential change and its magnitude must be considered. Building components that will be regarded as adaptable will be best utilized when permutation studies and functional audits are implemented within the development of its initial design. Preemptive planning at this scale is currently not addressed in existing building practice, but it can also be applied after construction.

<u>*Adaptive Reuse Models*</u>

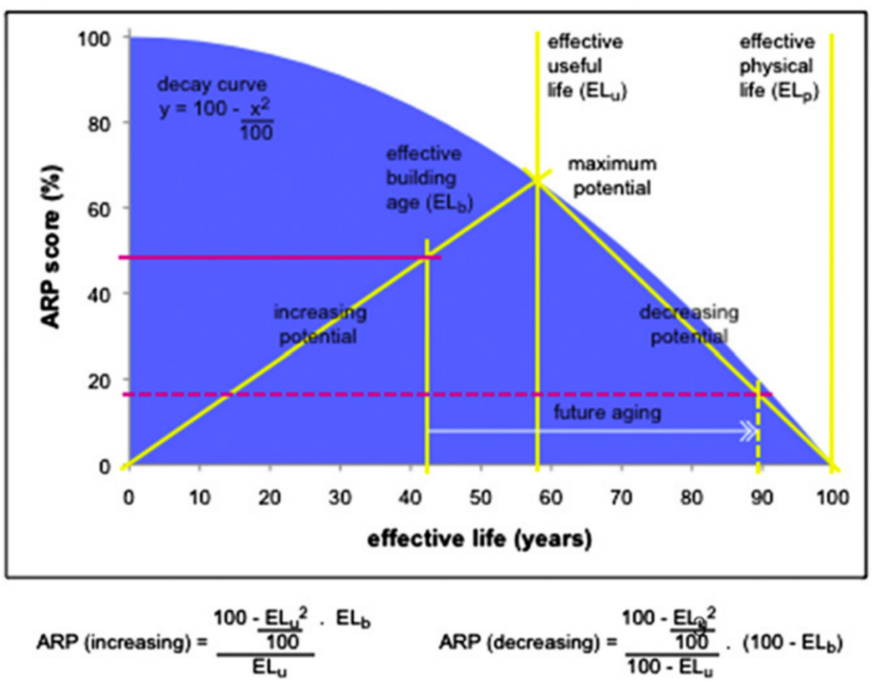

Figure 9 The Adaptive Reuse Potential Model based on Hong Kong Case Study (Source: Sheila Conejos)[32]

[32] Sheila Conejos, Craig Langston, and Jim Smith, "AdaptSTAR Model: A Climate-Friendly Strategy to Promote Built Environment Sustainability," *Habitat International* 37 (2013): 95–103, http://dx.doi.org/10.1016/j.habitatint.2011.12.003.

There are different measurements that designers can review to establish if a building is worth reusing or demolishing to address the issues of adaptability. Some of these methods include the Adaptive Reuse Potential (A.R.P.) Model and the adaptSTAR rating tool. Both are capable of considering all criteria involved in an adaptive reuse project and can give a score which can be used as a diagnostic for the building's general potential to be transformed. By using these tools at the beginning of the design process, buildings stand a better chance at success.

A.R.P. has been used to find the general trend in the effectiveness of the structure that can be mapped across its lifetime (Figure 9). This model is mainly a function of the building's physical life and obsolescence "so that the right timing for intervention can be applied."[33] Obsolescence is determined by physical, economic, functional, technological, social, legal, or political reasons.[34] Each of these factors has different criteria that identify if a building has surpassed the threshold. The higher the A.R.P. score, the better its potential to be successfully reused. This system can be applied across building typologies and regional contexts.

While A.R.P. is an important piece of the puzzle, some are developing rating systems like the adaptSTAR Model that considers more criteria, as shown in Figure 10.[35] This weighted system gives a clearer idea of the needs of the project and also

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[33] Sheila Conejos, Craig Langston, and Jim Smith, "Designing for Future Building: Adaptive Reuse as a Strategy for Carbon Neutral Cities," *The International Journal of Climate Change: Impacts and Responses* 3, no. 2 (2012): 33–52.
[34] S Conejos and C Langston, "Designing for Future Building Adaptive Reuse Using AdaptSTAR," *Proceedings of the First International Conference on Sustainable Urbanization (Icsu 2010)* (2010): 474–483.
[35] Sheila Conejos, Craig Langston, and Jim Smith, "Designing for Better Building Adaptability: A Comparison of AdaptSTAR and ARP Models," *Habitat International* 41 (2014): 85–91, http://dx.doi.org/10.1016/j.habitatint.2013.07.002.

highlights deficiencies. The method is based on the responses of 93 architects. The top three weighted criteria were physical, and the fourth most weighted criteria were aesthetics and townscape. However, the most significant consensus was on the importance of building maintainability at 80.75% of respondents.[36] By using these two systems, designers can better prepare their buildings for adaptive reuse and subsequent transformations.

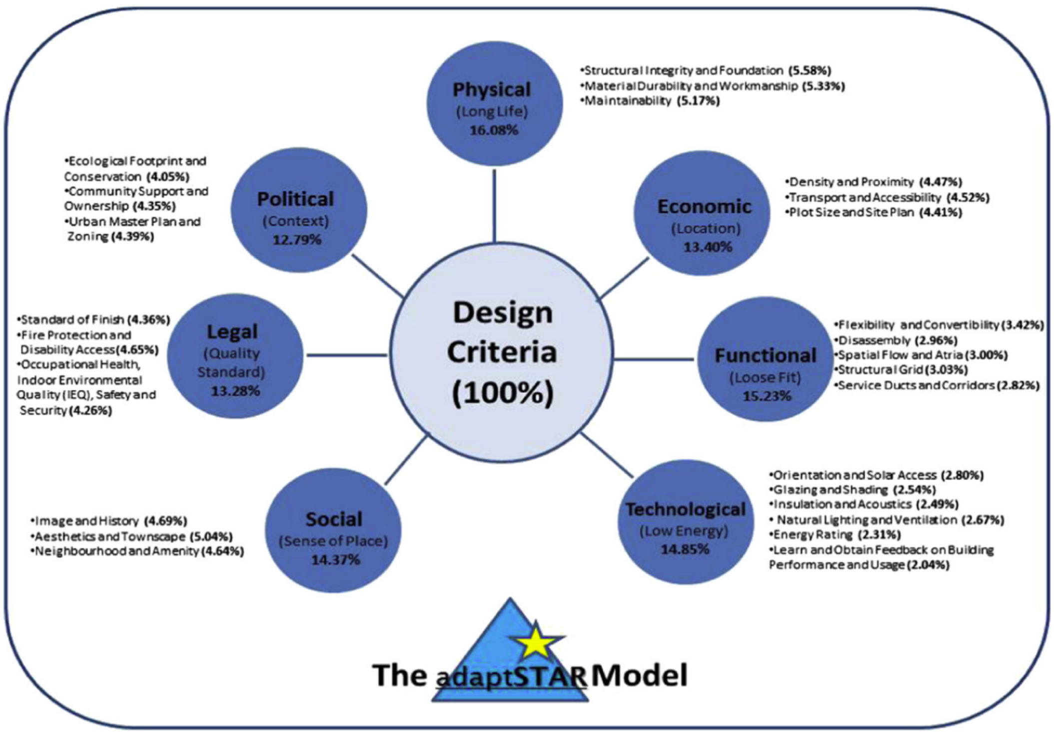

Figure 10 The adaptSTAR Model (Source: Sheila Conejos)[37]

More attention needs to be applied to the criteria listed in the adaptSTAR Model at the onset of a new building project to improve its adaptability. It may seem premature to focus on the potential of future reuse in a new building design, but this may cause one of the most significant positive impacts on the collective efforts of the

[36] Ibid.
[37] Ibid.

industry on climate change. When buildings are designed with the tools of adaptive reuse from the onset, we can extend the effective useful life of the building, causing a domino effect of benefits to our environment, economy, and society. By introducing pre-adaptability to a building, we are creating genuinely resilient structures.

Historic Adaptive Reuse

The culture of adaptive reuse can be seen in many historic cities around the world. Before the Modern Era, this method was overwhelmingly used due to the practicality of rebuilding. The labor and human cost of this were too great to deconstruct, therefore creating a culture of reuse. It was not always possible to source materials and transport them, especially when there were already buildings available to either reuse or salvage. However, this common practice was not coined as "adaptive reuse" until the early sixteenth century.[38]

Many early Classical Era European buildings were deemed "sacrosanct," especially religious structures, and generally, it was not realistic to reconstruct any building from a blank slate.[39] Therefore, the culture of reusing the existing fabric was maintained, allowing for many ancient cities to sustain their image. As architectural styles were designed and constructed, later buildings were in many ways basing their ideas off of existing fabric, reinforcing Edmond Bacon's "principle of the second man."[40] However, more prominent was Martin Trachtenberg's theory that architecture in many ways is meant to be open and unplanned, and that the last

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[38] Philip Jacks, "Restauratio and Reuse: The Afterlife of Roman Ruins," *Places* 20, no. 1 (2008): 10–20.
[39] Frank Peter Jager et al., *Old & New: Design Manual for Revitalizing Existing Buildings*, ed. Berit Liedtke and Andrea Wiegelmann (Basel, Switzerland: Birkhauser GmbH, 2010).
[40] E Bacon, *Design of Cities*, *Princeton University Press* (Penguin Books, 1965).

architect is the most relevant because their design is for that present moment.[41] As soon as the building form must change, the new form becomes its own articulation.

In many ways, the practice of reusing buildings permitted ancient societies to have a relatively stable urban language, allowing the establishment of richer cultures and traditions. The reputation of cities such as Rome generated a craze during the Romantic Era of the eighteenth century, where Dylan Thuras says people were "certainly enamored with ruin. They saw them in a kind of architectural morality, a *memento mori* for civilization."[42] While these cities died, they left behind an intangible quality in the ruins of their once well-occupied structures. Even those obsolete buildings found new meaning.

These ideas were not commonly seen in the Far East, where ideologies promoted the practice of renewal, not reuse. This practice extended out to replacing an entire structure with new materials. For example, in the Shinto religion, which follows Buddhism in many aspects, focuses on maintaining pristine and straightforward structures.[43] The process of *shikinen sengu*, or rebuilding and refurbishing, is conducted every twenty years at the main Jingu shrine in the Mie Prefecture of Japan.[44] Many other parts of Asia also practice these types of rituals but also has applied to the general culture of construction and demolition in Asian countries.[45] These trends appear to be changing as more advocates attempt to not only

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[41] Marvin Trachtenberg, "Building-in-Time: From Giotto to Alberti and Modern Oblivion" (2010).
[42] Dan Barasch, *Ruin and Redemption in Architecture* (New York, NY: Phaidon Press Ltd., 2019).
[43] Mark Cartwright, "Shinto Architecture," last modified 2017, accessed March 27, 2020, https://www.ancient.eu/Shinto_Architecture/.
[44] Jingu Administration Office, "Rituals and Ceremonies," last modified 2015, accessed March 27, 2020, https://www.isejingu.or.jp/en/ritual/index.html.
[45] Keefe Hien Yau Ch'ng, "The Beneficial Past: Promoting Adaptive Reuse as a Beneficial Design Method for East and South-East Asia," no. December (2010).

preserve heritage buildings.[46] There is a growing body of regulation and preservation efforts that are working towards creating a culture of conservation and adaptive reuse.[47]

The Modernist movement, including the likes of Le Corbusier and Frank Lloyd Wright, posed a threat to the culture of adaptation with their hopes of a cultural revolution.[48] The push for a new world, which is defined by Functionalism, claimed that retaining old buildings would create a practice of fetishism towards architecture. While this debate continued, they were able to make a considerable impact on what was considered to be the “mausolea of a dead culture.”[49] Though many of the projects of that school of thought failed, a significant amount of them have found themselves on the list of places that are being adaptively reused today.

Benefits and Challenges of Adaptability

Currently, in the U.S., Conejos 2014 states, “that for every four commercial buildings constructed, one is demolished and for every six houses built, one is demolished.”[50] Additionally, approximately 1.7% of the existing building stock is either renovated or newly built, 0.6% was demolished in 2010.[51] The process of creating through adaptive reuse requires a lengthy decision-making process that can

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[46] Esther H.K. Yung and Edwin H.W. Chan, “Implementation Challenges to the Adaptive Reuse of Heritage Buildings: Towards the Goals of Sustainable, Low Carbon Cities,” *Habitat International* 36, no. 3 (2012): 352–361, http://dx.doi.org/10.1016/j.habitatint.2011.11.001.
[47] Bangkok UNESCO, *Protocols for Best Conservation Protocols*, 2009, https://unesdoc.unesco.org/ark:/48223/pf0000182617.
[48] Kenneth Powell, *Architecture Reborn: Converting Old Buildings for New Uses* (Rizzoli, 1999).
[49] Ibid.
[50] Conejos, Langston, and Smith, “Designing for Better Building Adaptability: A Comparison of AdaptSTAR and ARP Models.”
[51] Ibid.

be both subjective and objective. There are many reasons why a building is reused or demolished, from its physical integrity to its social impact on the community.[52]

When looking at these different factors, one of the most well understood is the renovation cost to economic return generated by a building's new use. [53] Considering the financial return on investment of the new use of a building can be difficult to imagine when the upfront cost is more expensive than a new build. There is still a debate within the field about whether adaptive reuse is more expensive on average compared to new buildings. However, both are true and are dependent on the condition of the existing structure and the new program requirements, among other issues.

Many of the benefits of adaptive reuse are non-tangible and create a deeper connection between the users of a city and its population. It has been found in the conservation community that when the building fabric is conserved, communities are more likely to preserve their heritage and cultures.[54] In cities such as Hong Kong, there have been many discussions around the importance of the reuse of heritage buildings. Still, they warn of a loss of the "spirit of place" which occurs when the authenticity of a site is lost and the new use is so vastly different from the initial occupation of the building.[55] John Ruskin stated, "that spirit which is given only by the hand and eye of the workman, can never be recalled. Another spirit may be given, and it is then a new building; but the spirit of the dead workman cannot be summoned

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[52] Yung and Chan, "Implementation Challenges to the Adaptive Reuse of Heritage Buildings: Towards the Goals of Sustainable, Low Carbon Cities."
[53] Ibid.
[54] UNESCO, *Protocols for Best Conservation Protocols*.
[55] Ibid.

up, and commanded to direct other hands, and thoughts."[56] In other words, once a building's use is changed, it is no longer the same building, and any attempts to restore it to its original condition are hopeless.

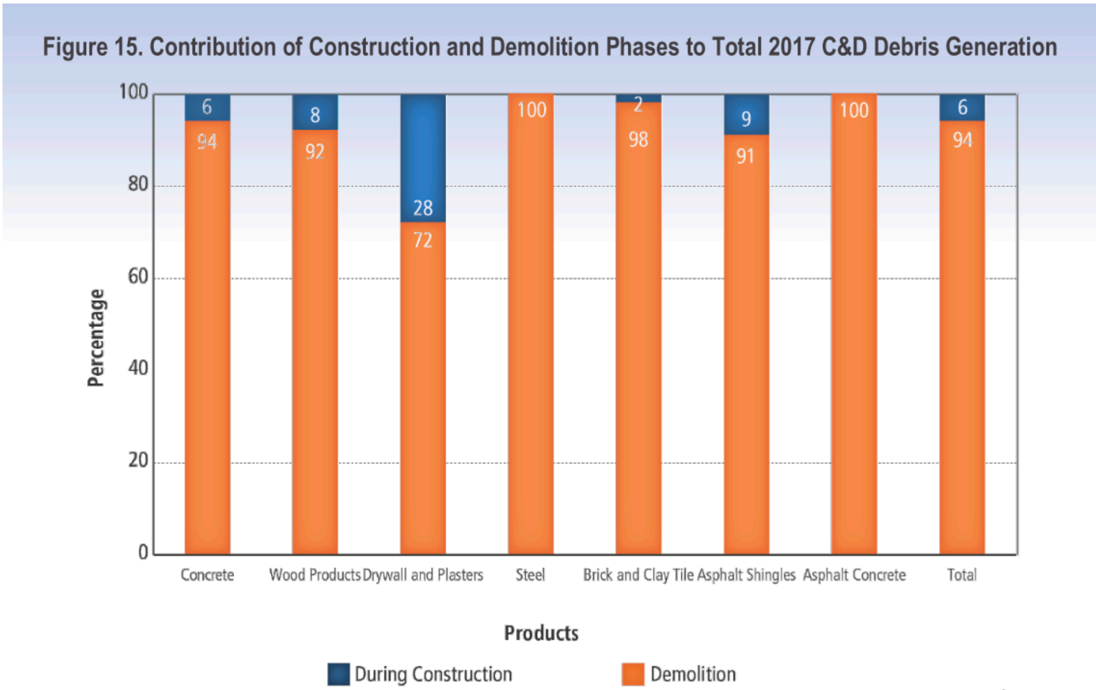

Figure 11 Contribution of Construction and Demolition Phases to Total 2017 C&D Debris Generation (Source: E.P.A. 2017)[57]

Commonly, adaptive reuse is applauded for its sustainability benefits. These range from preserving the embodied energy of the building, saving the extraction of new construction material, all of which lowers greenhouse gas emissions (G.G.E.). The existing building stock is the best place to find opportunities to reduce the construction industry's tremendous impact on its energy and carbon footprint. It is

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[56] Fred Scott, *On Altering Architecture*, *On Altering Architecture* (Taylor & Francis, 2007).
[57] EPA, "Advancing Sustainable Materials Management: Facts and Figures Report," *United States Environmental Protection Agency*, no. November (2019), https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management%0Ahttps://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures-report.

difficult to deny that when half of the 136 million tons of building construction waste generated per year is from demolition, that there is not a considerable opening to keep raw materials in the ground and preserve the environment (Figure 11).[58,59] During the adaptive reuse process, the energy efficiency and Indoor Environmental Quality (I.E.Q.) of a building can also be improved, especially in older, poorly insulated structures. [60] However, these opportunities can be missed and require closer attention during a project's redesign to maximize its potential.

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[58] Noorzalifah Mohamed and Kartina Alauddin, "The Criteria for Decision Making in Adaptive Reuse Towards Sustainable Development," *MATEC Web of Conferences* 66 (2016).
[59] EPA, "Advancing Sustainable Materials Management: Facts and Figures Report."
[60] Conejos, Langston, and Smith, "Designing for Future Building: Adaptive Reuse as a Strategy for Carbon Neutral Cities."

Chapter 4: Adaptive Strategies for Today

It is difficult to anticipate the future of our urban and natural environments, but architecture many times brings the future into the present. The adaptability of buildings for potential reuse is imperative in an age of climate change, where landscapes and weather patterns change rapidly, and human life with it. The effects of climate change are already present, with increased flooding in many cities around the world, and many more oppressive heat days, buildings must be able to adapt at two timescales. Over time, unforeseeable changes to the way our cities function will inevitably require changes to buildings both through materiality, structure, and program. However, in the short-term, there are still many strategies that can be used to protect the built environment from many upward trends in our climate.

Climate-Responsive Systems

Daily lives and the built environment that support them are feeling the effects of climate change, and it is no longer a forthcoming phenomenon. Historically, ideas, technology, and natural phenomenon were changing at a much slower pace than today. Utilizing flexible climate-responsive strategies now is essential. These approaches create comfortable indoor environments for users, but also improve the building's energy efficiency and effectiveness. Depending on the climate, different methods must be used. In this thesis, there will be a focus on a mixed-humidity climate that experiences an increased frequency of hot and summer days over 95ºF and heavy precipitation events. While many of the methods mentioned are already well understood and implemented, they are typically not used comprehensively to generate resilience as is needed.

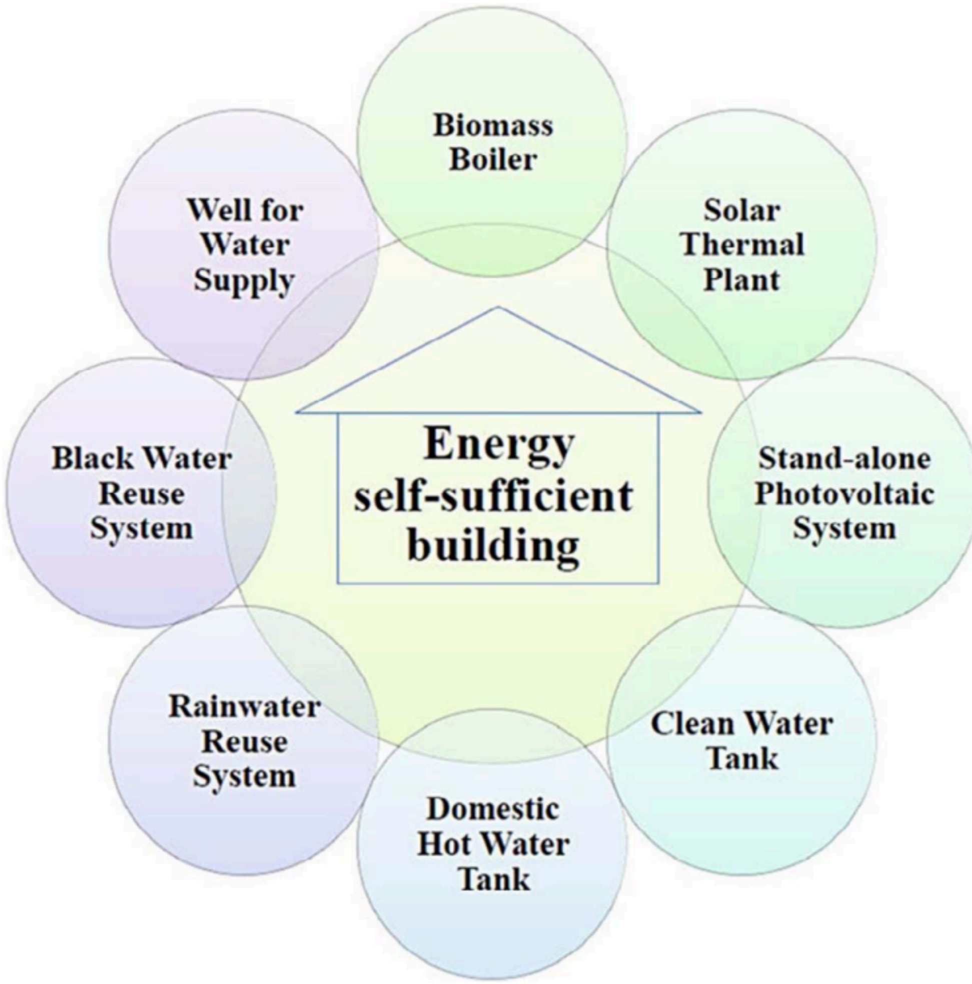

Figure 12 Aspects of an energy self-sufficient building (source: de Rubeis)[61]

Heat and flooding can have harmful effects on urban infrastructure and, in turn, create instability in energy distribution to buildings. Energy self-sufficient buildings stand a better chance of protecting its users during blackout events as many of the cascading effects of power outages are reduced. Organizations such as the

[61] Tullio de Rubeis et al., "Is a Self-Sufficient Building Energy Efficient? Lesson Learned from a Case Study in Mediterranean Climate," *Applied Energy* 218, no. September 2017 (2018): 131–145, https://doi.org/10.1016/j.apenergy.2018.02.166.

Living Building Challenge focus on self-sufficiency as an integral part of resilience in the face of climate change and minimizing further impacts on the environment.[62] Some energy harvesting methods can include solar and wind power generation. Moreover, redundancy in energy systems is equally as important. When there are power outages that shut down neighborhoods, it is increasingly important to stay cool. By providing back-up systems in a building, its users are protected from the issues that cause strain on city infrastructure. As infrastructure assets age and cannot be maintained at the rate required to keep them running, climate change will exacerbate these risks.

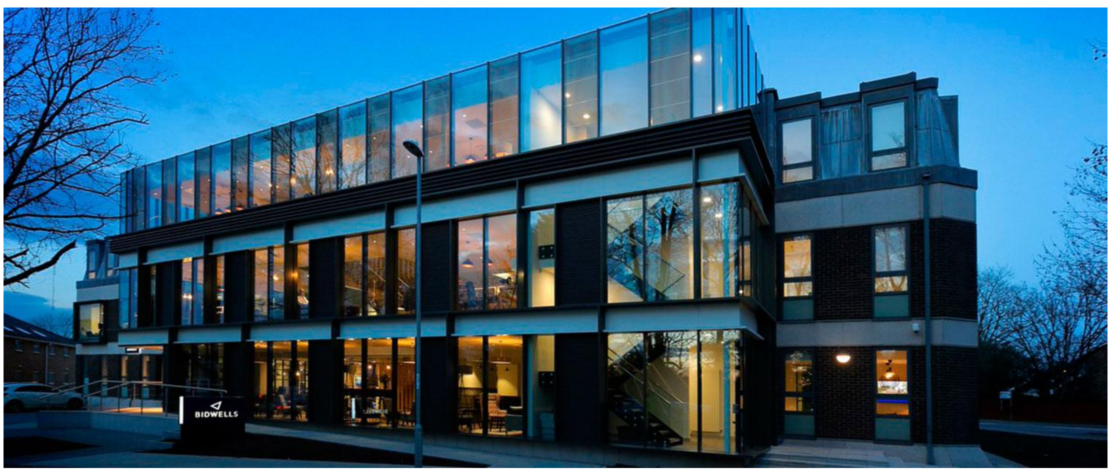

Figure 13 Photovoltaic Curtain Wall System on Bidwell Office (Source: Onyx Solar Group L.L.C.)[63]

The integration of these energy systems into a building is well understood through photovoltaics, utilized at a high capacity in the existing building stock. Newer systems, in development, incorporate solar harvesting in curtain wall systems opening up roofs for flexibility in utilization for other important elements of a flexible

[62] Driss Benhaddou, "Living Building," no. June (2017): 182–188.
[63] Onyx Solar Group LLC, "Photovoltaic Curtain Wall at Bidwells," accessed May 17, 2020, https://www.onyxsolar.com/cambridge-bidwells-house.

building. In some instances, the duplicitous use of components of a building provides more adaptability and responsiveness.

Figure 14 Bee colonies are highly cooperative and yield optimal energy use (Source: Piscisgate)[64]

Additionally, the general connection of different systems within a building can adapt to one another by taking solutions from the natural environment. The term Biomimicry is the use of functions and systems in nature to inform design solutions. The social structure of eusocial species is simultaneously about the individual and the whole. Specifically, in bees, when the colony needs to decide on a new site to nest or where to pollinate. What makes bee colonies unique is dividing labor efficiently while maintaining a singular movement forward, and they can take their local interactions and self-organize as a whole. This idea is referred to as "swarm theory," in which a large group of individuals can effectively communicate and respond to

[64] Piscisgate, "The Honeybee Worker Perform Different Jobs in the Colonies Depending on Their Age," 2015, https://upload.wikimedia.org/wikipedia/commons/8/87/Honeybee_worker_15.jpg.

changes quickly.[65] By taking individual messages and scaling up to the whole group, inclusive decisions can be made, and the system is continuously "online." These colony-scale interactions allow for efficient problem solving that benefits all.

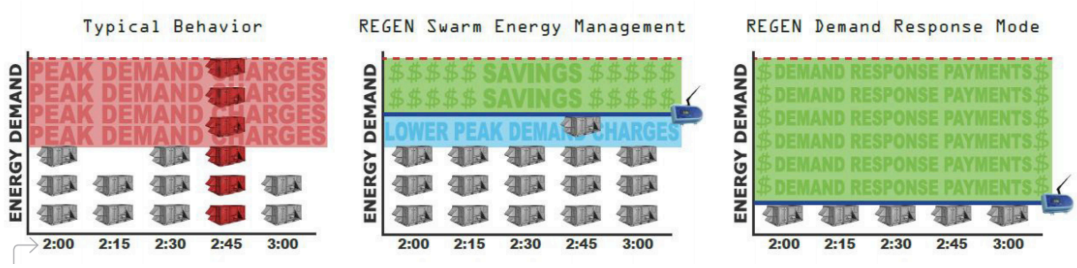

Figure 15 The modes of power management to minimize peaks and consumption (Source: Mark Kerbel et al.)[66]

This communication system can be highly lucrative in building systems and used in two ways: (1) there can be communication between elements within a building (2) buildings themselves can interact with one another as a city system. Within a building, the idea of swarm communication can allow for each room or unit to connect with one another. This system is already commercially available and use wireless controllers to "establish a mesh wireless network among power-consuming appliances, enabling them to communicate among themselves autonomously," saving during peak energy demand.[67] Most importantly, shown in Figure 15, during overload of the electrical grid, typically systems are shut off, and when brought online again, the result is an energy spike. Instead, the Encycle team created a feedback system that gradually reduces or increases the amount of energy supplied.[68] Their technology looks explicitly at the ways eusocial species communicate to develop their algorithms

[65] Mark Kerbel, Tom McKeag, and McKeag Hoeller, "The Power of Ants and Bees," *Zygote Quarterly* (2012): 73–85.
[66] Ibid.
[67] AskNature, "Groove Gather Water."
[68] Kerbel, McKeag, and Hoeller, "The Power of Ants and Bees."

allowing for significant energy savings within a building, claiming users can save up to one-third of their energy bill.[69]

These systems and strategies benefit buildings today. More importantly, implementation from the beginning of its existence allows for a longer lifespan and viability as the context around it changes. When structures that do not adopt climate-resilient strategies continue to bounce back from disasters and other events with more difficulty, resilient designs will be able to stand up to the challenge with more success. Many buildings around the world have been able to remain standing in the face of a changing world and they were not necessarily designed with high levels of technology. Incorporating a balance of modern ideas with ancient building practices that have passed through the experiment of building over millennia, can work together to preserve a building's integrity for longer than it would have under current standard practices.

Figure 16 Natural Ventilation through the seasons (Source: Author)

Older passive design strategies used in historic buildings are more likely to be successful. Climate responsive architecture is another critical tool to lower the energy load of a building and provide thermal comfort to occupants. By using natural

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[69] Encycle, "Swarm Logic | Energy Cost Savings."

ventilation and thick mass insulation with high R-values, it is possible to design buildings that can keep the warmth in during the winter and keep it out in the summer. This protection is dependent on the specific insulation material and can provide a level of humidity control. When mechanical systems in the building fail, the base design of the building is still able to provide a level of comfort until recovery is realized. The benefits of these strategies result in a low impact building, which can adapt to different weather events and disasters with less difficulty than a typical building constructed today.

Materials such as bamboo insulation can be used within the walls of the building to significantly increase its R-value while having a relatively low embodied energy. Compared to other traditional materials, bamboo is highly favorable in terms of economic and environmental costs.[70] In terms of performance, certain bamboo insulation materials have similar properties to other types of rigid insulation. Still, the material can be reused and repurposed when it is needed to be disposed of.[71] Bamboo's structural integrity over time degrades when exposed to water and is not considered water-resistant. However, it is overall much more sustainable than traditional insulation products.

Water-Responsive Systems

Water self-sufficiency is an additional consideration in a short-term adaptable design, as flooding and increased heat becomes a more significant issue and will

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[70] P. van der Lugt, A. A.J.F. van den Dobbelsteen, and J. J.A. Janssen, "An Environmental, Economic and Practical Assessment of Bamboo as a Building Material for Supporting Structures," *Construction and Building Materials* 20, no. 9 (2006): 648–656.

[71] Jose Bonivento and Gabriel Vieira, "Thermal Performance of Bamboo as a Multilayer Insulation Wall," no. April (2017).

overwhelm stormwater systems in cities. Many of our urban natural landscapes require human assistance to thrive through irrigation methods and general maintenance. By taking advantage of water harvesting systems on a building's scale, the resilience of a city improves drastically.[72] In aging cities, this is especially true as it alleviates the strain placed on their aging infrastructure regularly, but also during disaster events. The systems in place can also cause issues in providing enough safe drinking water to communities. Water insecure areas benefit the most from this system that allows for dramatic improvements from a public health standpoint to the quality of life of the users.

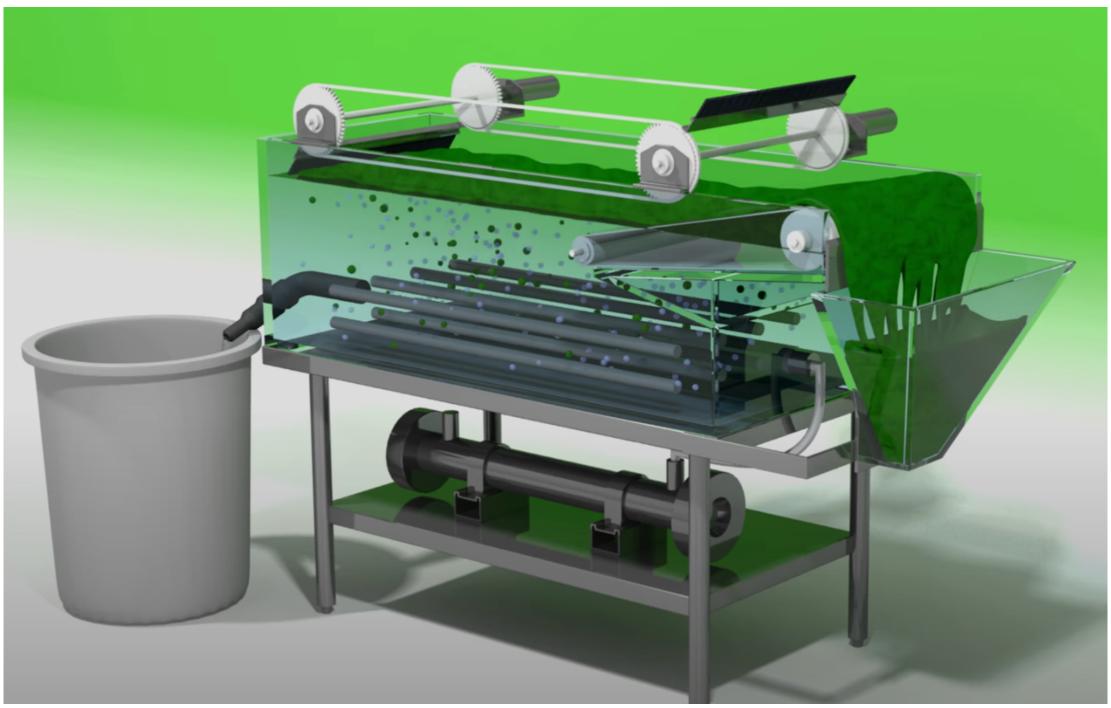

Figure 17 Image of OriginClear E.W.S. Algae System (source OriginClear)[73]

[72] Sampei Yamashita, Ryoichi Watanabe, and Yukihiro Shimatani, "Smart Adaptation Activities and Measures against Urban Flood Disasters," *Sustainable Cities and Society* 27 (2016): 175–184, http://dx.doi.org/10.1016/j.scs.2016.06.027.
[73] OriginClear, "An Animated Guide to EWS for Algae," last modified 2015, accessed April 19, 2020, https://www.youtube.com/watch?time_continue=33&v=sdERnYeb7Os&feature=emb_logo.

Water collection systems can also be connected to water treatment within the building to recycle water for the building. Operations that previously were only considered at an industrial scale are being introduced to buildings. Some systems have made their systems greener through the introduction of algae.[74] This type of system allows for the harvesting of algal biomass, while also producing water that can be used in the building and irrigation purposes. Techniques such as these provide more reliable drinking water, but also alleviate some of the water demands for the whole city.

Conventional water treatment can remove larger materials and oxidize organic waste, but treated water still contains nitrogen and phosphorous that is released back into natural bodies of water.[75] Algal filtration removes these elements from wastewater along with heavy metals and organic compounds. Importantly, this prevents eutrophication or excessive nutrients in bodies of water, which results in lower oxygen levels damaging ecosystems and further impacting human life. The potential for algal filtration within the water treatment systems in a building, can not only protect the water used for the microclimates of urban landscapes but also provide better quality water for building users. In some cases, this technology is capable of producing clean water as well.[76]

Water management systems have dated back thousands of years and can be seen in typologies such as the Roman domus. These passive systems provided many

[74] OriginClear, "EWS for Algae: A Superior Algae Harvesting Process" (2015): 1–12.
[75] N. Abdel-Raouf, A. A. Al-Homaidan, and I. B.M. Ibraheem, "Microalgae and Wastewater Treatment," *Saudi Journal of Biological Sciences* 19, no. 3 (2012): 257–275, http://dx.doi.org/10.1016/j.sjbs.2012.04.005.
[76] OriginClear, "EWS for Algae: A Superior Algae Harvesting Process."

benefits to the inner worlds of the Roman Building. During that time, streets were not typically welcoming places for people to congregate and live, as sanitation was not well understood and predominantly used for animal-drawn wagons and their waste. Most Roman homes were internally focused and implemented connections to nature and the outdoors through their courtyard systems.

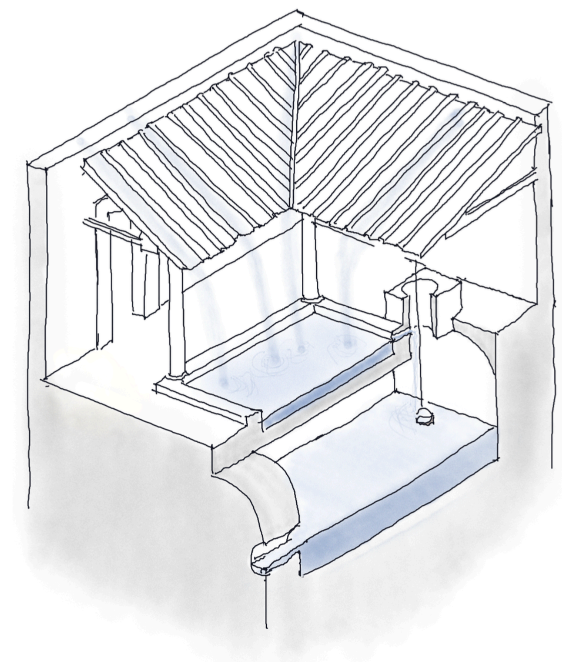

Figure 18 . Roman Impluvium Section (Source: Author)

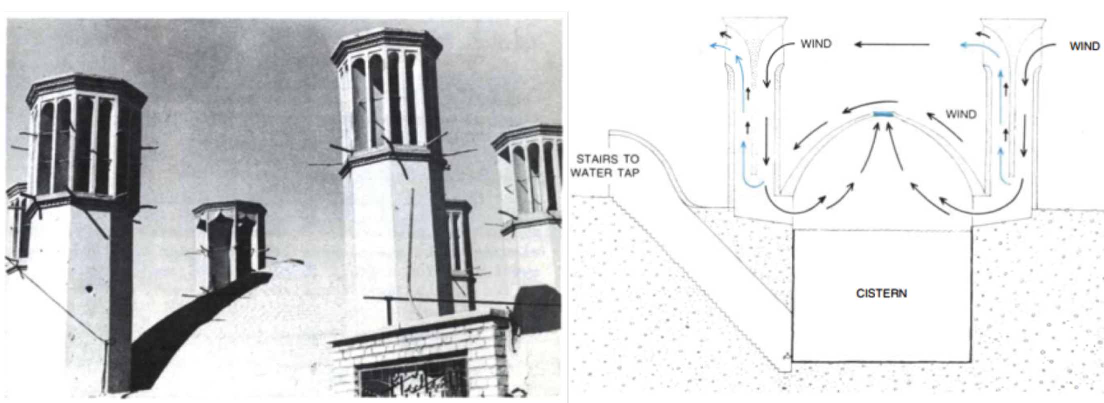

Figure 19 Cooling cisterns in Iranian Architecture (Source: Mehdi N. Bahadori)[77]

[77] Mehdi N. Bahadori, "Passive Cooling Systems in Iranian Architecture," *Scientific American* 238, no. 2 (1978): 144–154.

These design solutions also were necessary for the environmental quality of the building, such as a recessed water catchment system named the impluvium (Figure 18). They allowed for passive cooling, rainwater collection, and an aesthetic element to the building's interior architecture. A cistern sits under the visible portion of the impluvium to help alleviate the strain on the aqueducts and provide water to the home. Additionally, in ancient Persian architecture, underground water was directed to a cistern that used wind-catchers that circulated cool fresh air and acted as a well of fresh water (Figure 19). A positive side effect was also the limitation on runoff during rain events. This internal stormwater management system was designed many centuries ago; however, it can be a powerful tool towards improving urban runoff and aiding with water harvesting in areas that may deal with water insecurities.

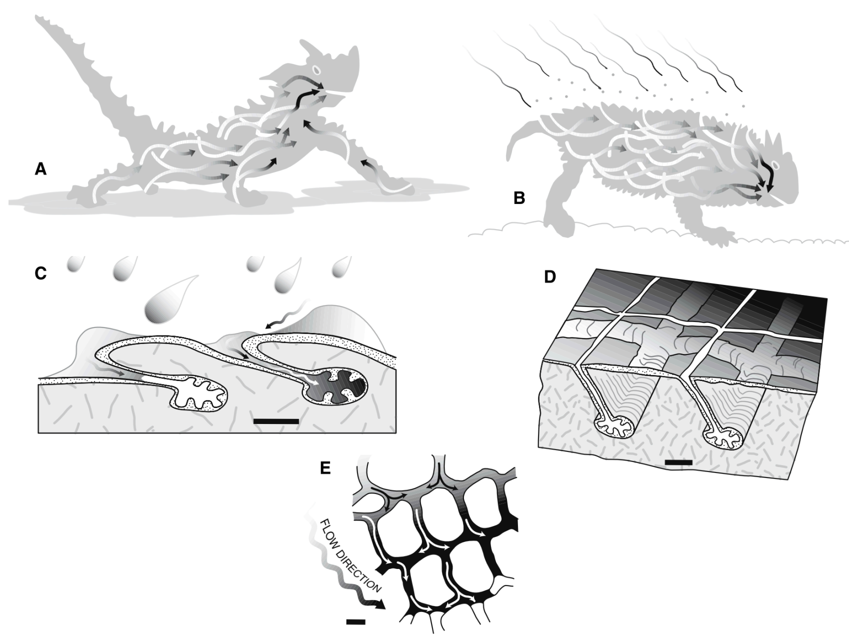

Figure 20 Schematic representations of the Moloch horridus and Phrynosoma cornutum via capillary action (Source: Sherbrooke et al.)[78]

[78] Wade C. Sherbrooke et al., "Functional Morphology of Scale Hinges Used to Transport Water: Convergent Drinking Adaptations in Desert Lizards (Moloch Horridus and Phrynosoma Cornutum)," *Zoomorphology* 126, no. 2 (2007): 89–102.

One of the most resilient animals in the world is the Thorny Devil (*Moloch horridus)*. This desert lizard collects small amounts of water in the soil and pulls it up and into its mouth to drink. This gravity-defying feat is done through capillary action, highlighted in Figure 20. Because the Thorny Devil has semi-enclosed channels that are only between five to 150 microns wide, the water pulled from the ground moves into a small enough space that its surface tension is strong enough to move up the body of the lizard.[79] Typically, the Thorny Devil will bury itself in the sand deep enough that it can pull out the smallest amounts of water. For climates that are hot and dry, these systems can be mimicked to pull water out of the ground and into buildings and other structures for future water use. This function can also allow for dew that forms in the cool, dry nights to condensate in the channels and be collected.[80] There are opportunities to implement this type of water reclamation in wetter climates within a building's façade to pull water from the ground to mitigate runoff or wick condensation from the façade to a water catchment system.

During active flooding events, in buildings which cannot build on higher ground or on raised platforms there are a few strategies that can be used to get through. In buildings, there are predominant strategies such as elevation, dry proofing, wet proofing, and flood barriers. All of these methods aim to protect the building from damage and are typically static approaches. Flood barriers can be permanent or installed when rain events are expected to occur. For example, in the Georgetown area of Washington, D.C. there are flood barriers which protect the

[79] AskNature, "Groove Gather Water."
[80] David Attenborough, *Life on Earth: A Natural History* (Little Brown & Co., 1981).

waterfront area from flooding. However, they must be manually installed with ample notice otherwise the area will flood. Most of these systems work overall, but they are not actively responsive to flooding.

Figure 21 The Shed a moveable building that allows for expanded arts programs (Source: Warren Eisenberg)[81]

Kinetic building systems can move elements of a structure to change the form and many times the function of the building. These designs range from the rotation of sunshades matched to the path of the sun, to entire building structures moving. In the former, these systems have been utilized as a benefit to the indoor environmental quality of the building but also to improve energy efficiency. Alternatively, projects such as The Shed in New York City, in Figure 21, use gantry crane technology to

[81] Warren Eisenberg, "Untitled - The Shed" (New York, NY, n.d.), https://images.pexels.com/photos/1629885/pexels-photo-1629885.jpeg?cs=srgb&dl=high-line-nyc-shed-1629885.jpg&fm=jpg.

allow for the shell of the building to glide out and create a new indoor space to maximize the adaptability of the structure.

By taking inspiration from these designs, vertical kinetic structures can provide opportunities for urban environments in high flood risk areas to provide a way for the building to be pulled up and away from water. Since the building's spaces are now out of the way, polluted water avoids infiltration and saves the users from the need to restore any internal or external damage to the building. Additionally, this strategy can be especially useful in urban environments where elevation of the ground plane would damage the street edge and remove opportunities for commercial development.

Water has been an asset and a risk for centuries. Urban environments have the capacity to use various levels of technology that are both new and ancient to handle strained water infrastructure and extreme weather events. The judicious use of both depends on site context. Still, it will improve the likelihood of survival of buildings in the future as they are faced with an increasing amount of environmental pressure. The systems and design approaches mentioned in this chapter cannot be used independently to achieve a flexible response to the environment and its users. It will take the implementation of a kit of parts to be able to show a substantial impact on a building.

Chapter 5: Adaptive Strategies for Tomorrow

There are many areas in which adaptive reuse is vital in extending the life of a building and thus being more sustainable and resilient. However, many of them are not designed with the future in mind and therefore require a large amount of energy to determine what can and cannot be preserved from its original construction. By implementing adaptive reuse strategies from the genesis of a building's design, the efficacy of the building will remain longer and allow for more flexibility in the future. As stated by Brian Rich, " The concept of future-proofing is the process of anticipating the future and developing methods of minimizing the effects of shocks and stresses of future events."[82] While the term alludes to a perfect system ready for anything, pre-adaptability is at the core of the concept. A systems approach to different industries can aide the built environment in preparing for the type of adaptability required by climate change. Pre-adaptability strategies used before a building is erected at a larger scale will give cities a better chance of survival.

[82] Brian D Rich, "The 10 Principles Of Future-Proo Fi Ng Historic Buildings : And," no. December (2013).

Modular Systems

Figure 22 Sky House by Kiyonori Kikutake (source: Yokio Futagawa and Iwan Baan)[83]

In the early 1960s, a group of young architects in Japan came together at a moment of dramatic change in their country's history to propose an idea that leaned into the philosophies of transformation and growth of a city. The appreciation of the biological process of metabolism became the term used for the group consisting of the likes of Kiyonori Kikutake, Kenzo Tange, and a handful of others. The Metabolists believed that "cities can grow and transform in a manner like the evolution and metamorphosis of an organism."[84] Through the unpredictable growth of a city, their forms were based on the flexibility of cellular organisms. Their aim at a

[83] Yokio Futagawa and Iwan Baan, "Kiyonori Kikutake, Sky House, Tokyo, Japan 1958" (Kawashima Architecture Photograph Office, 2015), https://www.flickr.com/photos/ofhouses/17212094958/.
[84] Zhongjie Lin, *Kenzo Tange and The Metabolist Movement: Urban Utopias of Modern Japan*, 2010.

utopian city was never achieved, and today it is abundantly clear that utopias come with their flaws and limitations as a whole. The central concepts, however, can still be adapted to cities today and in the future.

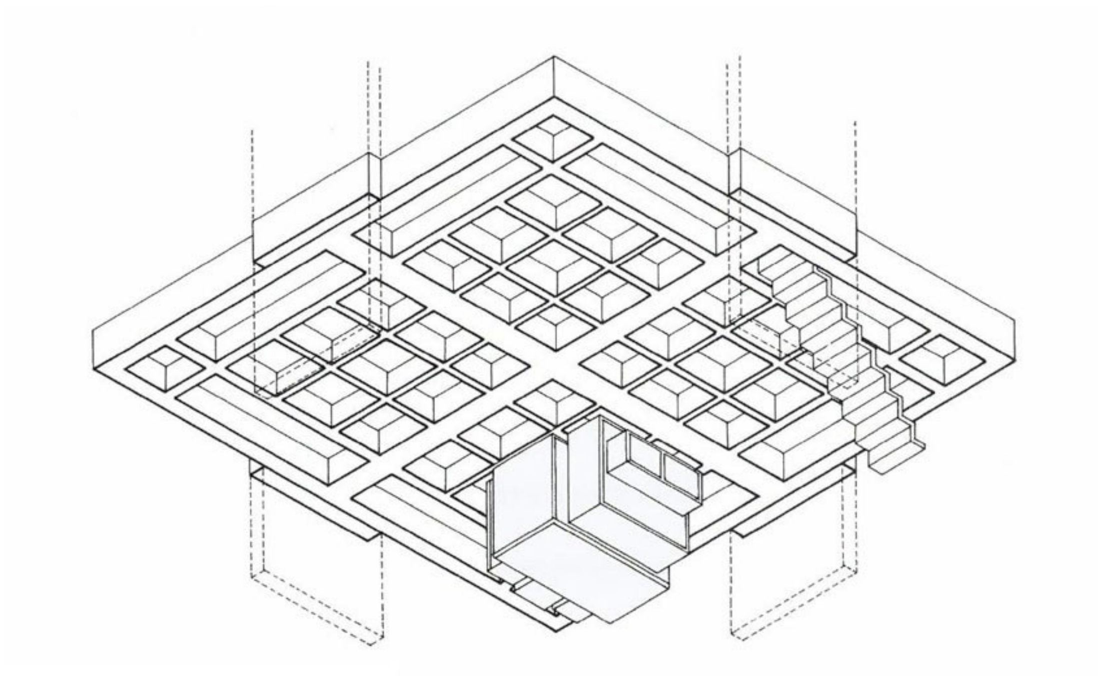

Figure 23 Sky House Moven-ettes (source: Kiyonori Kikutake Archive)[85]

Kikutake's Sky House, built in 1958 for himself in Tokyo, was one of the first Metabolist structures. The single-family house was designed to allow for maximum flexibility of interior spaces. The waffle slab beneath the elevated floor allowed for the addition of other rooms through removable "moven-ettes." In Figure 23 the kid's room is shown, which was added after the building was erected and removed once the child moved away. As new purposes emerge, and others become unneeded, the Sky House opened the door to adaptability overtime.

[85] Futagawa and Baan, "Kiyonori Kikutake, Sky House, Tokyo, Japan 1958."

Figure 24 Nagakin Tower by Kisho Kurokawa (Source: Kakidai)[86]

[86] Kakidai, "日本語: Nakagin Capsule Tower, at Shinbashi Tokyo Japan, Design by Kisho Kurokawa in 1972.," last modified 2018, accessed April 15, 2020, https://commons.wikimedia.org/wiki/File:2018_Nakagin_Capsule_Tower_03.jpg.

As the Metabolists were interested in the constant evolution of the built environment, the refusal to believe in a world of persistent change may cost more than previously imagined. The possibility to create removable pieces within a building that can be replaced and expanded upon in the future is a tool that can prepare buildings for incremental adaptation. Kisho Kurokawa's Nakagin Capsule Tower was one of the first to be designed with the ability to remove individual pods and replace them. The theory was never realized, and the building lays in disrepair today. However, designing a building with the core idea that it will inevitably change is essential to flexible design in adaptive reuse.

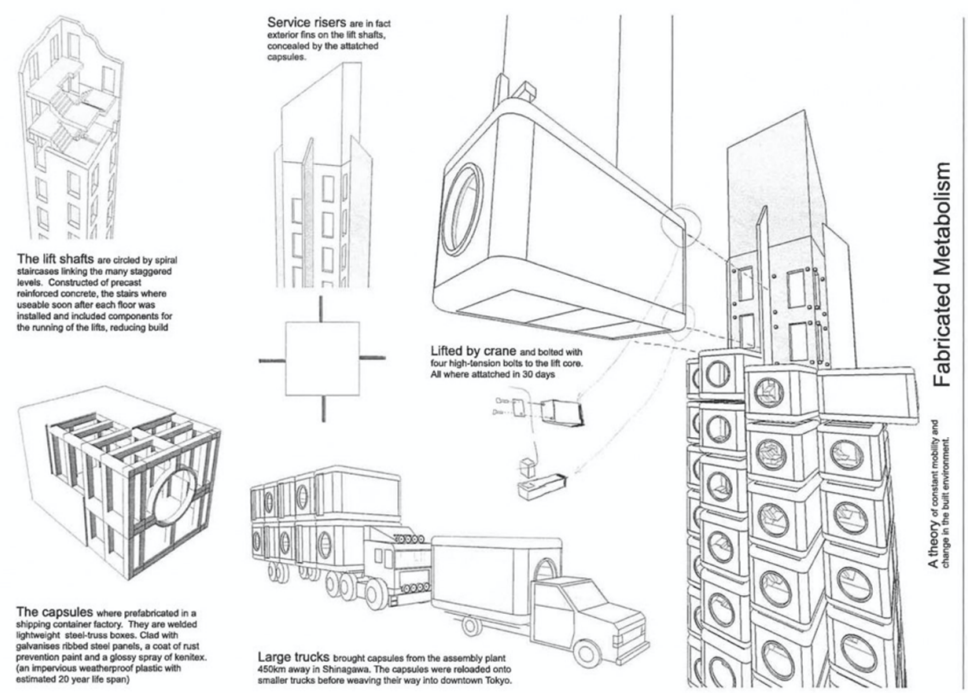

Figure 25 The installation process of pods for Nagakin Tower (Source: William Harbison)[87]

[87] William Harbison, "Nagakin Capsule Tower by Kisho Kurokawa, Located in Shimbashi, Tokyo, Japan," last modified 2011, accessed April 15, 2020, https://www.metalocus.es/en/news/nakagin-capsule-tower-tokyo-1969-72.

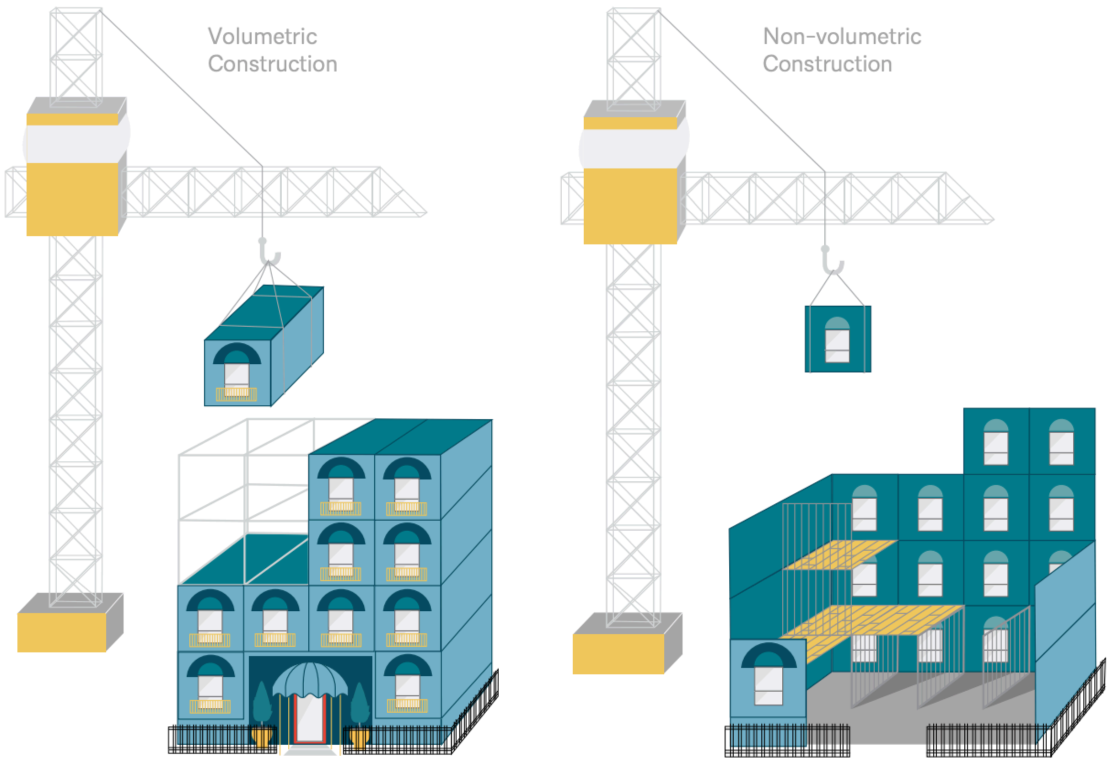

Figure 26 Volumetric and Non-Volumetric Construction (source: A.I.A.)[88]

Modular construction lends itself to the highest level of flexibility in a building's lifetime. Generally, the construction and assembly process of a modular building is achieved through prefabricated building elements that can be volumetric or non-volumetric, or a mixture of both.[89] There are many sustainable benefits to modular construction and allows for more resilient buildings. Modular building elements support adaptive reuse because its components are removable and replaceable. Over time, these elements can be reevaluated and possibly redesigned

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[88] The American Institute of Architects, "Design for Modular Construction: An Introduction for Architects" (2019): 1–41, http://content.aia.org/sites/default/files/2019-03/Materials_Practice_Guide_Modular_Construction.pdf.
[89] Ibid.

better to meet the needs of the building years later. Through this style of construction, building structures are also better customized to resist extreme weather events compared to conventional methods.[90] Additionally, modular construction benefits pre-disaster preparedness and post-disaster recovery due to its easy assembly and affordability.

Changing Face

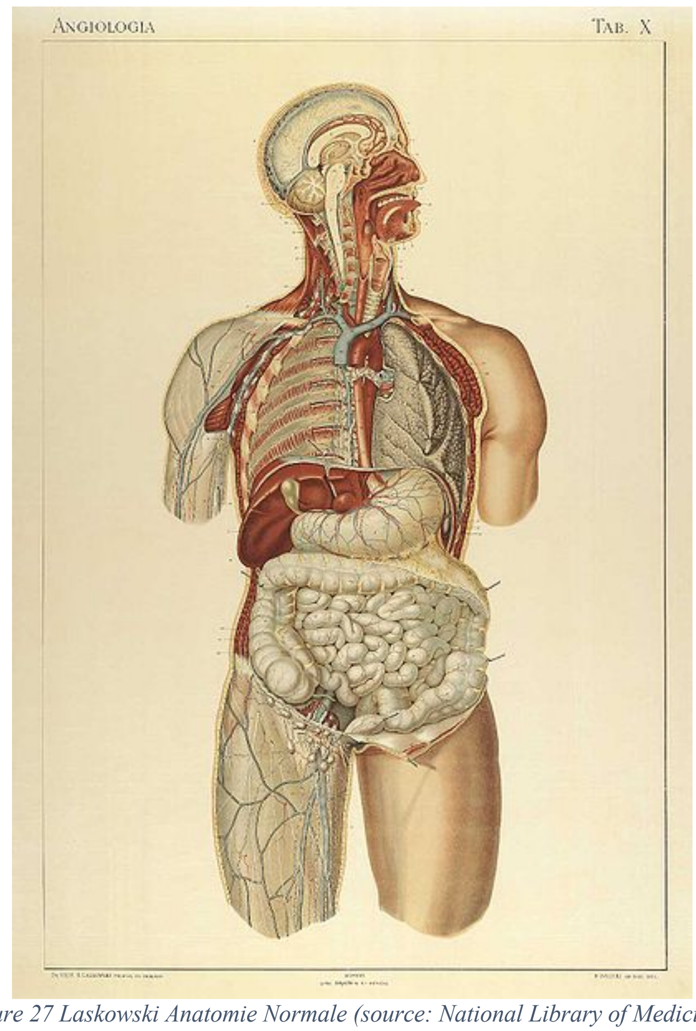

Figure 27 Laskowski Anatomie Normale (source: National Library of Medicine)[91]

[90] Andriel E Fenner et al., "A Review of Prefabrication Benefits for Sustainable and Resilient Coastal Areas," *6th International Network of Tropical Architecture Conference* (2017): 316–328.
[91] Sigismond Balicki, "Anatomic Plate from Laskowski's 'Anatomie Normale Du Corps Humain' (1894)" (National Library Medicine, 2008).

Metabolist and modular construction produce opportunities for future adaptation. However, they do not allow for the form of the building to feel connected to one uniform system. Generally, the Metabolists wanted to expose the cellular and organic form of their designs to reinforce the idea of organismal change in buildings. While modern urban cities such as New York City and Tokyo lend themselves to the modular aesthetic, this does not always generate good urban form as a scalable level. To expand upon the ideas of the Metabolists, one can imagine that some living organisms inherently are made of many elements that grow and evolve throughout their lifetime. Those pieces are held together by their skin organ and can protect key elements of the organism.

Buildings are artificial bodies in many ways and require protection similar to human skin (Figure 27). There has always been a debate on the expression of architectural ideas and structure on the façades of a building. Over time, architects have taken their stance on whether they should be exposed or not. Regardless of their expression, facades act as a layer of protection from the external environment and are the first line of defense against weather events. Therefore, the adaptability of this skin is as essential as the structures and internal systems of the building.

Figure 28 Science for Citizens Building (Source: Carlo Ratti Architects)[92]

The importance of adaptable facades is two-fold, it allows for replacement when damaged, and changes in form as the needs of a community change. The Science for Citizens Building (Figure 28) uses dry brick construction on the façade that can be disassembled and reused as necessary in the future.[93] This development is focusing on a circular economy of materials and uses. Brick materials are material resources that have a cost and embodied energy associated with them, as all materials do. By preparing the building for unpredictable change and the potential for a modification in form, there is an opportunity to reduce the need for extra materials sourcing in the future. When there is a disaster event, it allows for a more accessible pathway to the replacement of parts.

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[92] Carlo Ratti Architects, "Science for Citizens," last modified 2018, accessed April 20, 2020, https://carloratti.com/project/science-for-citizens/.
[93] Stephen Cousins, "Robots Help Build Changeable Facades," last modified 2018, accessed April 22, 2020, https://www.ribaj.com/products/robots-lay-five-million-bricks-university-of-milan-italy-technology-stephen-cousins.

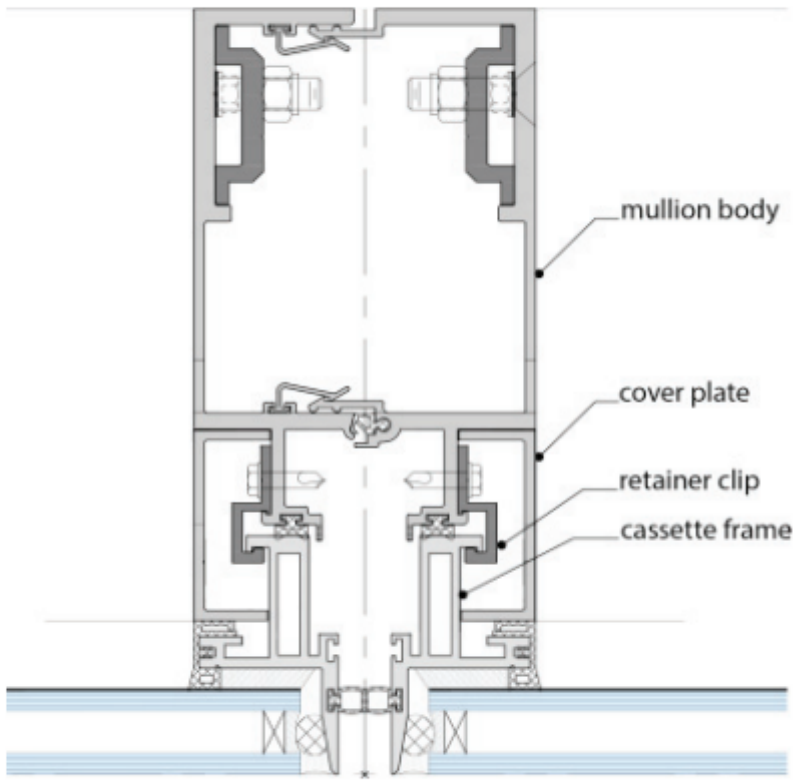

Figure 29 Section detail of vertical mullion showing the concept for a removable cassette system (Source: Enclos)[94]

The mechanism for reconfiguration and removal is a crucial element of an adaptable façade system. Intensive weather events and water damage over time will wear away or ultimately damage the building's skin. Similar to the modular components that make up the spaces internally, the façade is assembled in such a way that individual units can be removed. The size of the units can change depending on the architectural expression desired. Design studios are exploring different techniques that allows replacement of building façade systems with relative ease (Figure 29).

[94] Mic Patterson, Jeffrey Vaglio, and Douglas Noble, "Incremental Façade Retrofits: Curtainwall Technology as a Strategy to Step Existing Buildings toward Zero Net Energy," *Energy Procedia* 57 (2014): 3150–3159, http://dx.doi.org/10.1016/j.egypro.2015.06.061.

The removable cassette systems prepare buildings for the replacement of units in a curtain wall façade system. By taking advantage of unitized systems, buildings can create snap-off elements that make maintenance of the exterior of the building more economical and flexible. These strategies all work towards extending the lifespan of a building and working against its obsolescence.

While these adaptable concepts allow for the incremental change of a building, it will still require cost later in the retrofit or renovation stage. Additionally, these systems, while important to implement in the onset of a new building, are similarly able to be installed in existing buildings. By generating a kit of parts for adaptable structures, there will be more opportunities for all buildings to stand the test of time. While no building will be completely protected from nature and its damaging capabilities, pre-adaptability aims to reduce the level of damage and resource requirements during recovery.

Disassembly

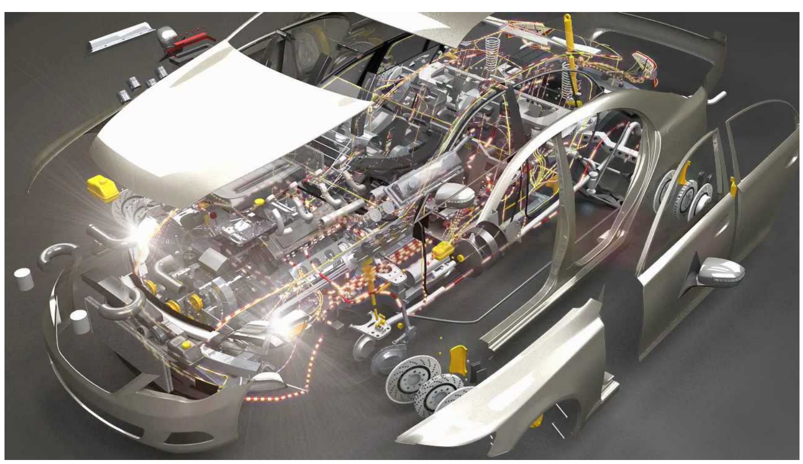

Figure 30 Car exploded view (Source:Mohvisuals)[95]

[95] Mohvisuals, *Vehicle Exploded View Animation* (Youtube, 2011), https://www.youtube.com/watch?v=_i5RkAxGiwQ.

As mentioned previously, buildings have lifespans that can be extended through pre-adaptability. The physical integrity of the building is one of the most important aspects in determining the need for demolition. Therefore, the designs of buildings can implement sequential disassembly planning, which can save time, money, and materials during the planning of the building's next use. This process assesses all of the materials and their assemblage to determine the process of dismantling using scheduling tools such as a Critical Path Method.[96] Mainly, a more user-friendly building is produced. Once a building's initial occupation is considered obsolete, there can be a faster assessment of what needs to be replaced with a better understanding of the coordination efforts required to access the target parts.

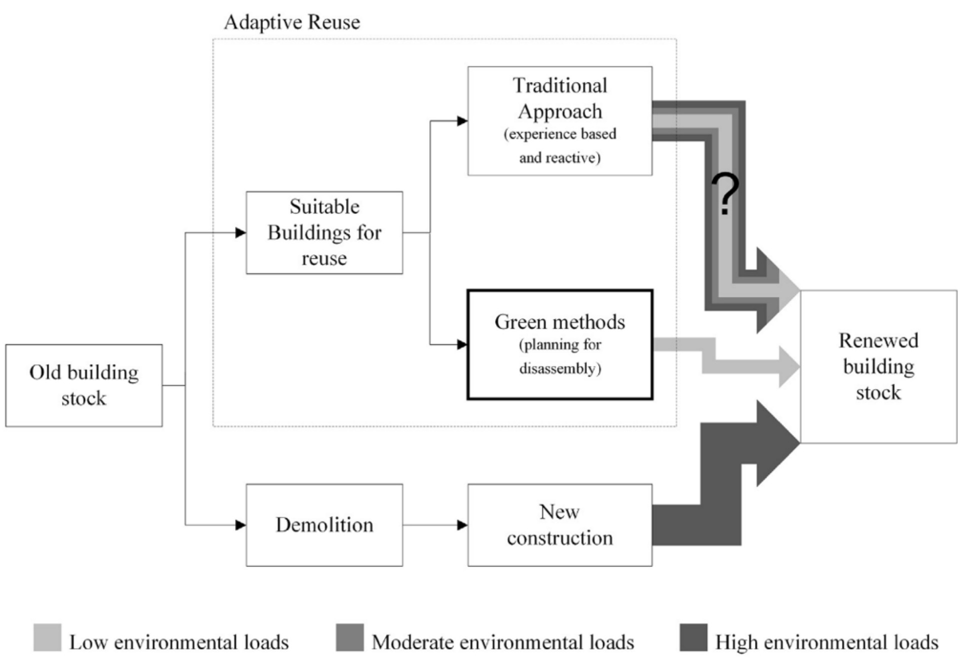

Figure 31 The role of green design methods in the reduction of environmental burdens for building stock renovation (Source: Benjamin Sanchez)[97]

[96] Benjamin Sanchez and Carl Haas, "A Novel Selective Disassembly Sequence Planning Method for Adaptive Reuse of Buildings," *Journal of Cleaner Production* 183 (2018): 998–1010, https://doi.org/10.1016/j.jclepro.2018.02.201.
[97] Ibid.

These strategies can prove useful in disaster scenarios as well. When a building is constructed with preparedness for its disassembly, then it is better equipped to be rebuilt or altered. As these tools are further developed, there are elements of a building that can be identified as areas of vulnerability that focus on as a place for adaptation in further iterations of a building's life. A building with components that are adaptable in themselves and can be easily applied to various typologies, by definition, is resilient. Over time, cities will be able to sustain elements of its fabric, while simultaneously leaving opportunities for adjustment and growth.

As climate change pulls floodplains further inland and increases additional vulnerabilities, there may be a day where the current building stock is no longer viable in certain regions. Proper disassembly not only allows for the building to be moved to safer locations when needed but also protecting the environment from the degradation of building materials into the reclaimed natural environment. When incorporated at a larger scale, cities are able better equipped to deal with changing landscapes due to climate change and the painful reality of retreat.

Chapter 6: Southwest, Washington, D.C.

The Southwest DC neighborhood in Washington, D.C. has been an area of nearly constant change since its inception. From marshlands to alley slums to urban renewal, this pocket of D.C. has seen enormous amounts of change and has required its occupants and visitors to adapt. The neighborhood has the difficult task of sitting between the substantial development of federal buildings, with public housing projects and industry. Also, it is a place of great environmental risk to sea-level rise, various types of flooding, and extreme heat. As the neighborhood looks into ways of reconciling and celebrating its history, there is notable pressure from the community to create a more functional and resilient environment for everyone.

Site History

The Powhatan Confederacy and Algonquian-speaking Anacostans originally inhabited the land which the District of Columbia sits.[98] The area was full of marshes, streams, and bluffs along the Potomac and Anacostia Rivers. A completely natural environment with a robust wildlife population, the area was a perfect location for the flourishment of life. Soon after European settlers arrived in the early 1600s and within 40 years, the indigenous people of the area were reduced to one-quarter of their initial population due to the introduction of disease and war.[99] Eventually, the land developed into an urban environment, and most of the remaining indigenous

[98] District of Columbia Office of Planning, "Ward 6 Heritage Guide" (2018).
[99] National Parks Service, "Native Peoples of Washington, DC," last modified 2018, accessed May 3, 2020, https://www.nps.gov/articles/native-peoples-of-washington-dc.htm.

tribes were forcibly removed and relocated away from their lands.

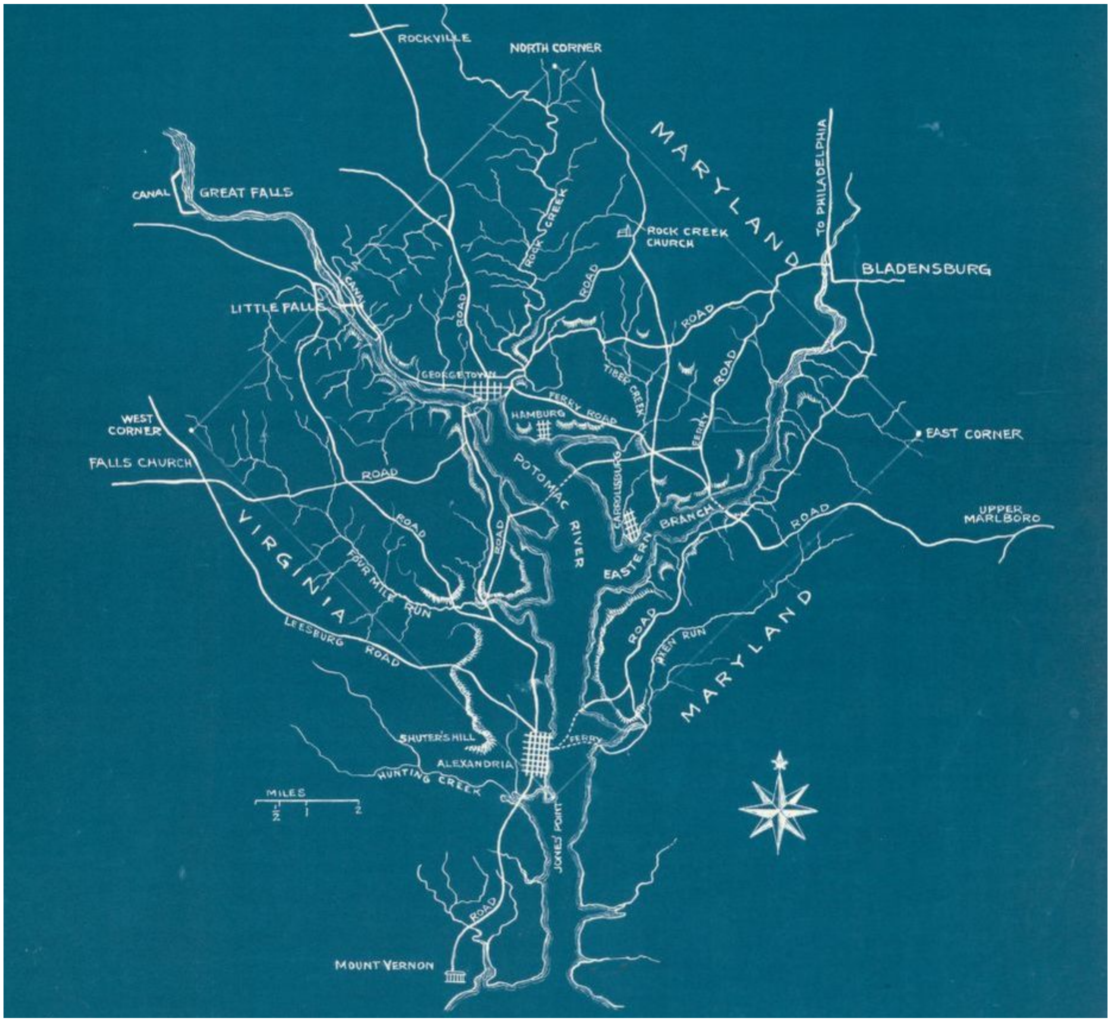

Figure 32 1791 Map of District of Columbia pre-L'Enfant Plan (Source: A.C. Harmon)[100]

At the establishment of the City of Washington in 1790, the area contained farms and plantations with enslaved black people, and a few with free people of color.[101] Soon after Andrew Ellicott and Benjamin Banneker laid the boundary stones for Washington D.C., Pierre L'Enfant was commissioned to design the city plan. The

[100] A. C. Harmon, "Map of District of Columbia, before the City Was Laid out: Showing the Main Roads Used by President Washington as Surveyed by Andrew Ellicott in -2 and Published in Paris, France, in 1815" (Washington: Retrieved from Library of Congress, 1791), https://www.loc.gov/item/88694209/.

[101] District of Columbia Office of Planning, "Ward 6 Heritage Guide."

Baroque plan was informed by the topography in the region and generated broad radial avenues over a grid.[102] The Southwest area of the city was owned by Notley Young, the area's largest private landowner, which included the undeveloped shoreline and a plantation settlement. While the city plan was being developed, there were addition of buildings such as Wheat Row as housing for the area in hopes that it would become a significant port area for the District. This growth only lasted through the Civil War and declined soon after due to the better-located ports in Baltimore and New York.[103]

Figure 33 Wheat Row in Southwest DC. Source: Historic American Buildings Survey[104]

[102] National Parks Service, "The L'Enfant & McMillan Plans," accessed May 3, 2020, https://www.nps.gov/nr/travel/wash/lenfant.htm.
[103] QED Associates LLC et al., *Historical Context Study Southwest Washington, DC 1791-1973*, 2014.
[104] Historic American Buildings Survey, "Wheat Row, -1321 Fourth Street Southwest, Washington, District of Columbia, DC" (Washington, D.C.: Retrieved from the Library of Congress, 1933), https://www.loc.gov/item/dc0401/.

Figure 34 Wash. D.C. Alley dwelling. This photograph shows the front door of an alley dwelling. (Source: Harris & Ewing Collection)[105]

Due to the poor sanitary conditions of the neighborhood, Southwest DC became notorious for the spread of diseases and subpar conditions. The marshlands around the area became muddier with "the widespread clearing of land for agriculture, roads, buildings, and other activities stripped away protective plant covering and leveled the riverfront bluffs."[106] Much of the effluent in the District traveled down to the Southwest area and caused high rates of certain diseases. Over

[105] Harris & Ewing Photograph Collection, "Wash. D.C. Alley Dwelling. This Photograph Shows the Front Door of an Alley Dwelling. The Clutter of Filth, Debris and Tin Cans Allhave Highly Utilitarian Purposes. Many of the Houses Are without Gas, Water, or Electric Connections. 11/28/35" (Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA, 1935), https://www.loc.gov/item/2016881817/.

[106] LLC et al., *Historical Context Study Southwest Washington, DC 1791-1973*.

time, the reputation of the area pushed many blacks, immigrants, and marginal businesses to the area. Additionally, because of its disconnection from the rest of the city due to creeks and canals, it became known as The Island.[107] These areas became a place for the marginalized, as a neighborhood they could live and create a community that protected themselves from discrimination of the prosperous world.

Southwest D.C. became a hotspot for escaped slaves from the South and immigrants, building small shelters behind more significant affluent buildings, creating poorly lit alley housing, many of which housed several under one roof. This uncontrolled development supported people who served the wealthy white families of the area and allowed for living close to their employment. However, the conditions of these slums were extremely poor and became a major focus of the City Beautiful movement.[108]

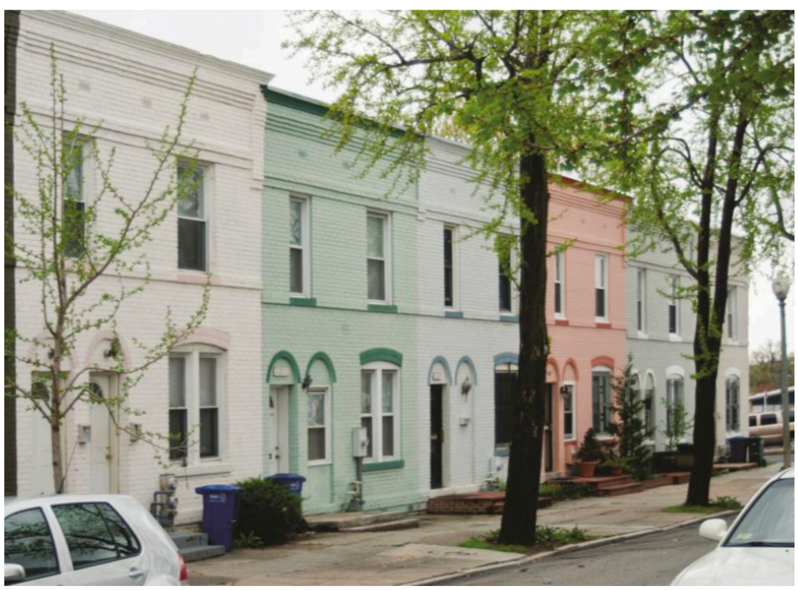

Figure 35 Sanitary Housing in Southwest (Source: Peter Sefton)[109]

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[107] District of Columbia Office of Planning, "Ward 6 Heritage Guide."
[108] LLC et al., *Historical Context Study Southwest Washington, DC 1791-1973*.
[109] Ibid.

The pressures to improve Southwest D.C. following this movement introduced Sanitary Housing in the District, which aimed at building better housing for the poor and brought a sweeping campaign to demolish the alley dwellings. While the goal of improving the welfare of those living in these new developments seen as a benefit to society, there were many underlying agendas to attempt to instill capitalistic and virtuous housing through the push for "attaining Christian virtue once situated inadequate housing" and thus be saved.[110] As this plan moved forward with the developer group Washington Sanitary Improvement Company (WSIC), their emphasis was on the importance of pulling poor African-Americans out of the alley slums, which caused disease and reduced quality of life through affordable payment options. The rent structure for the Sanitary Houses was subsidized to allow for affordable payment options, but overall put many families into a position of having to pay rent at all.

Over time, as the New Deal era, beginning in the 1930s, came with funding for housing programs, and there was yet again a push to provide housing and boost the economy and provide for the working poor during the Great Depression. The Alley Dwelling Authority (A.D.A.) and later the National Capital Housing Authority (NCHA) was established to tackle the still existing issues of the alley dwellings in the District. These areas, which had once been mixed with Irish and German Immigrants and Black Americans, mostly provided better employment options to the former group. This privilege left the black parts of the neighborhood to create their own economic and social structures that supported each other and were thriving in many

[110] Ibid.

ways. The deprived parts of Southwest D.C. dealt with high levels of crowding and illegal sources of income, which put an even larger target on their backs for the NHAC. Over the next thirty years, the organization provided its idea of proper housing for especially the working poor.[111] Eventually in Title 1 of the National Housing Act of 1949 was put into action through the support of the Supreme Court, which allowed for condemnation of buildings by the federal government if they were "deemed unsafe and uninhabitable" and would further the mission "to beautify a community for the benefit of the general public."[112]

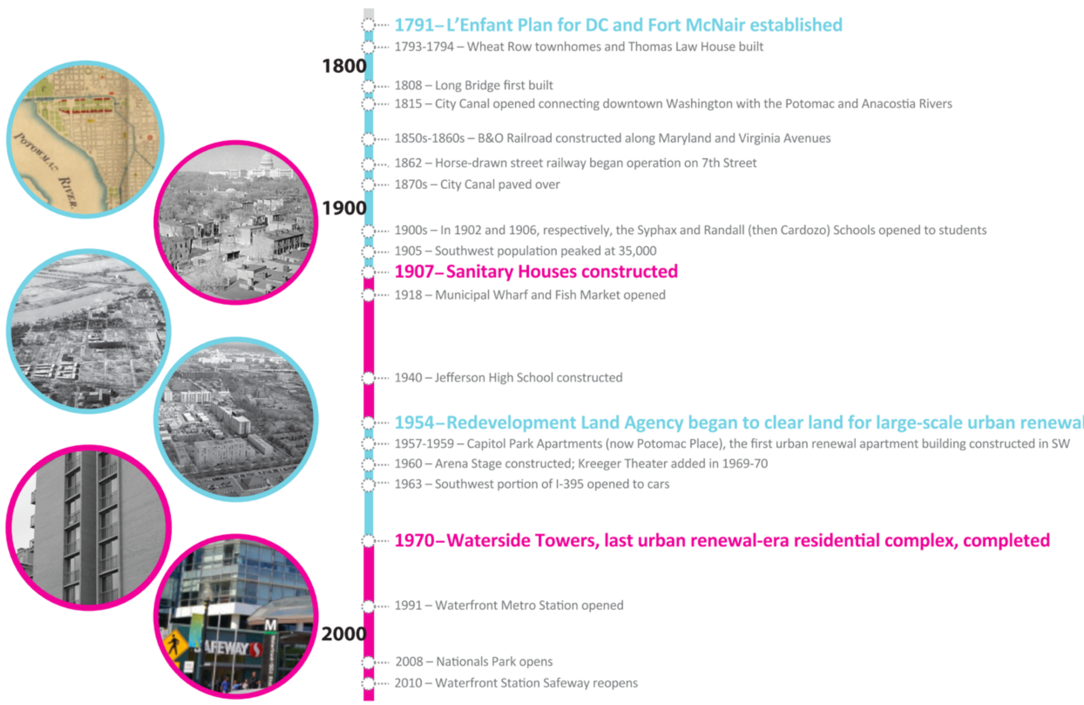

Figure 36 Historical Timeline of Southwest DC (Source: District of Columbia)[113]

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[111] Ibid.
[112] Southwest Washington, "Urban Renewal: The Story of Southwest D.C. | Whose Downtown?" (2013), https://whosedowntown.wordpress.com/urban-renewal-the-story-of-southwest-d-c/.
[113] Government of the District of Columbia, "Southwest Neighborhood Plan" (Washington, D.C., 2015).

These implementations and the complete razing of the Southwest neighborhood during this period demolished 99 percent of the building stock and displaced 4,500 Black families. When this type of displacement occurs, it is very damaging to the neighborhood and community culture and history. These types of interventions have been practiced throughout the United States since and disenfranchise original residents and cause the perpetuation of inequity.[114] Over the past three hundred years, this area of the District has undergone constant renewal and erasure. Yet, these pieces of the neighborhoods held on and have worked on making their community as strong as they can.

City Planning and Climate Preparedness

The District of Columbia, like any other region throughout the world, is required to redefine their climate risks, and through programs such as Sustainable DC have been providing findings on projected trends and how they will affect the area. This effort has also come with adaptation plans to phase in different initiatives to mitigate increased risks incrementally. These findings also look into different climate scenarios depending on the human implementation of reduced G.H.E. and pollution rates. Through these assessments, the two main risks to the District are extreme heat and flooding.

Sea level rise (S.L.R.) along the Potomac and Anacostia watersheds will face a three times increased rate in the region. The rest of the East Coast of the United

[114] Sharon E. Sutton and Susan P. Kemp, eds., *The Paradox of Urban Space*, 1st Editio. (Palgrave Macmillan, 2011).

States will also see this trend compared to the average global S.L.R.[115] These trends also play a part in the frequency of coastal storms such as hurricanes which increase the likelihood of storm surges. However, the District lies on the line between the Northeast and Southeast regions, which require development of separate estimates to that incorporate elements of both regions' trends to arrive at more accurate projections.

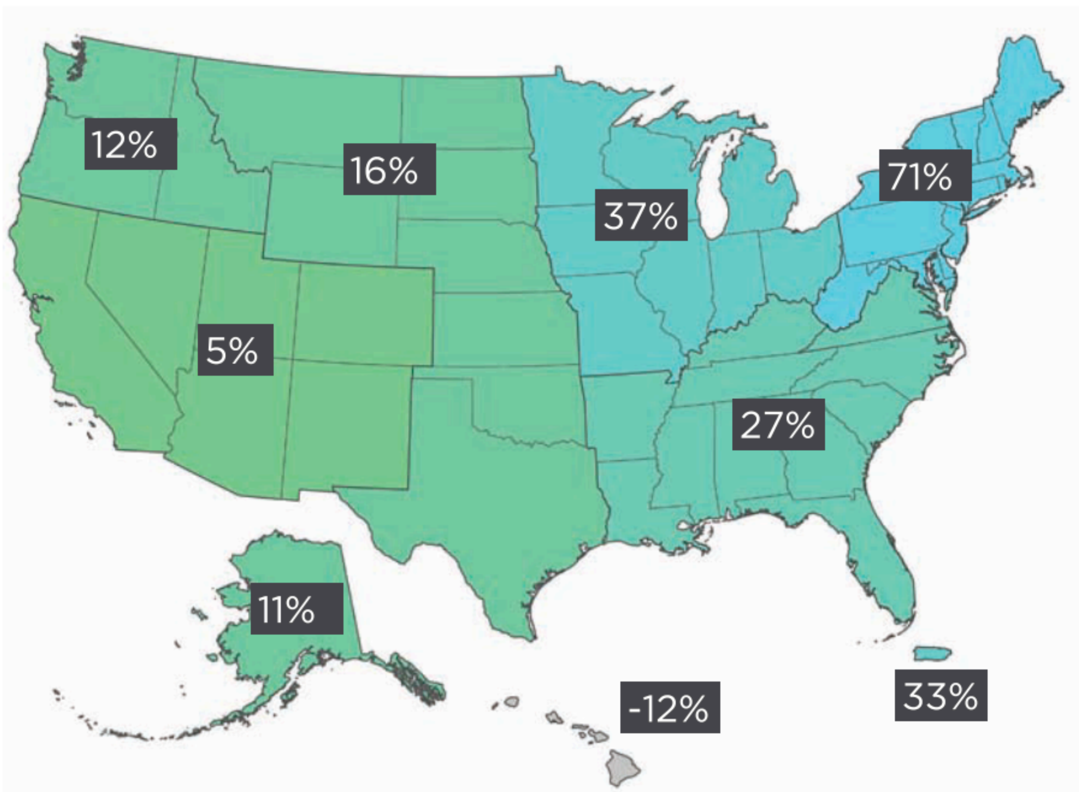

Figure 37 Changes to heavy precipitation nationally (Source: Kleinfelderl)[116]

[115] Perkins+Will et al., *Climate Projections & Scenario Development: Climate Change Adaptation Plan for the District of Columbia* (Washington, D.C., 2015).
[116] Ibid.

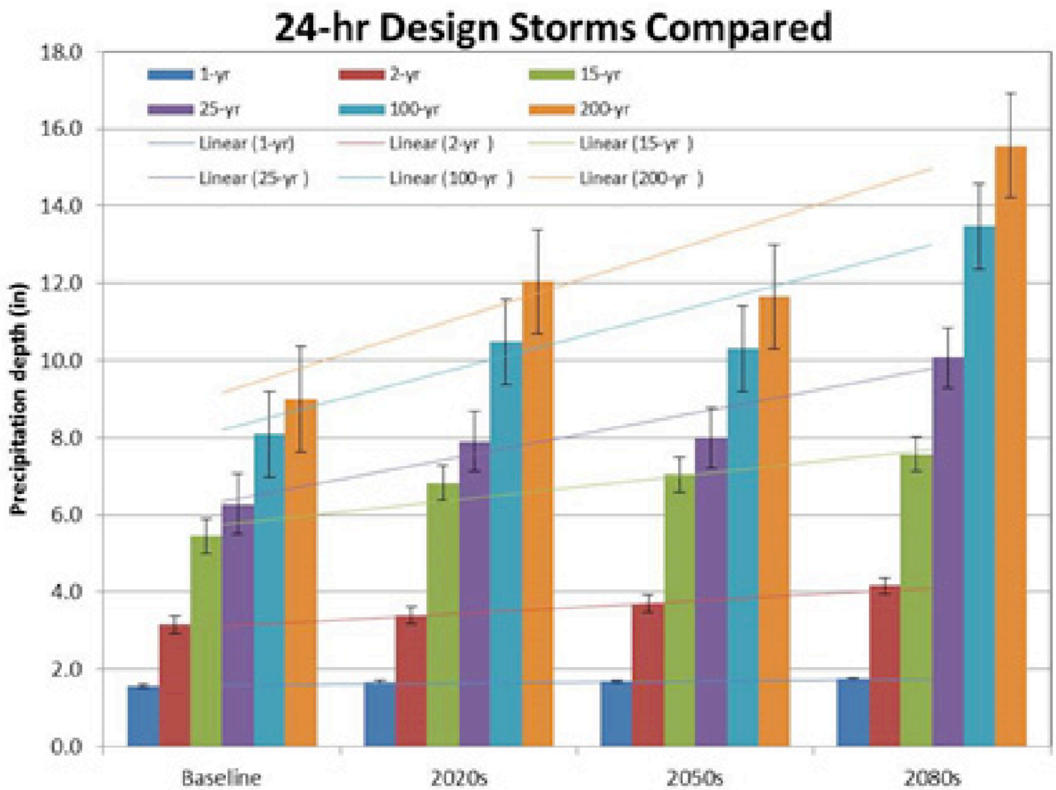

Figure 38 Projected average increase in precipitation events with more than 1" or 2" (Source: Kleinfelder)[117]

[117] Ibid.

Serial No.	Precipitation Indicator	Baseline 1981-2000	2015-2034 (2020s)	2045-2064 (2050s)	2080s
1	# of days/year with rainfall at or above 1 in	10	12 (10 – 15)	13 (11 – 18)	14 (12 – 18)
2	# of days/year with rainfall at or above 2 in	1	1.5 (1 – 2)	2 (1 – 3)	3 (2 -5)
3	1-yr 24 hr. storm (in)	1.6	1.7 (1.5 - 1.8)	1.7 (1.5 - 1.8)	2 (±<1)
4	2-yr 24 hr. storm (in)	3.2	3.4 (3.2 - 3.7)	3.7 (3.5 - 3.9)	4 (4 - 5)
5	15-yr 24 hr. storm (in)	5.5	6.8 (6.0 - 7.3)	7.1 (6.7 - 7.6)	8 (4 - 9)
6	25-yr 24 hr. storm (in)	6.3	7.9 (6.8 - 8.6)	8 (7.5 - 8.8)	10 (8 - 12)
7	100-yr 24 hr. storm (in)	8.1	10.5 (8.9 - 12.4)	10.3 (9.0 - 11.9)	14 (10 - 16)
8	200-yr 24 hr. storm (in)	9	12 (10.1 - 14.7)	11.7 (9.8 - 13.6)	16 (11 - 19)
9	2-yr 6 hr. storm (in)	2.3	2.4 (±<0.1)	2.6 (2.6 - 2.7)	3 (±<1)
10	15-yr 6 hr. storm (in)	3.6	4.6 (4.3 - 4.8)	4.7 (4.6 - 4.8)	5 (4 - 6)
11	100-yr 6 hr. storm (in)	5.1	6.7 (6.5 - 6.8)	6.5 (6.4 - 6.7)	9 (7 - 10)
12	200-yr 6 hr. storm (in)	5.6	7.5 (7.2 - 7.7)	7.2 (±<0.1)	10 (8 - 11)
13	80th Percentile storm (in)	0.8	0.9 (0.1)	0.9 (0.1)	0.95 (0.1-0.15)
14	90th Percentile storm (in)	1.14	1.24 (0.1)	1.24 – 1.34 (0.1-0.2)	1.24 – 1.39 (0.1-0.25)
15	95th Percentile storm (in)	1.5	1.6 – 1.65 (0.1-0.15)	1.6 – 1.75 (0.1-0.25)	1.75 – 1.85 (0.15-0.35)

Table 2 Projected precipitation indicators (Source: Perkins+Will et al.)[118]

Precipitation is said to pose as much of a threat to the District as sea-level rise and storm surges.[119] Storm frequency and intensity will dramatically increase in the next 60 years (Figure 38). Even within the next ten years, these trends pose the detrimental potential to the District if not addressed. These impacts will see both coastally but also with interior flooding due to the overall stormwater management of D.C., which mainly consists of a combined sewer system, overflow brings added

[118] Ibid.

[119] District of Columbia Department of Transportation, "Climate Change Adaptation Plan," *Climate Change Adaptation Plan of the U.S. Environmental Protection Agency* (2015): 1–67.

public health issues. While most of Southeast DC does not fall within the combined sewer system, it plays a role in the amount of runoff that can contribute to overflow.

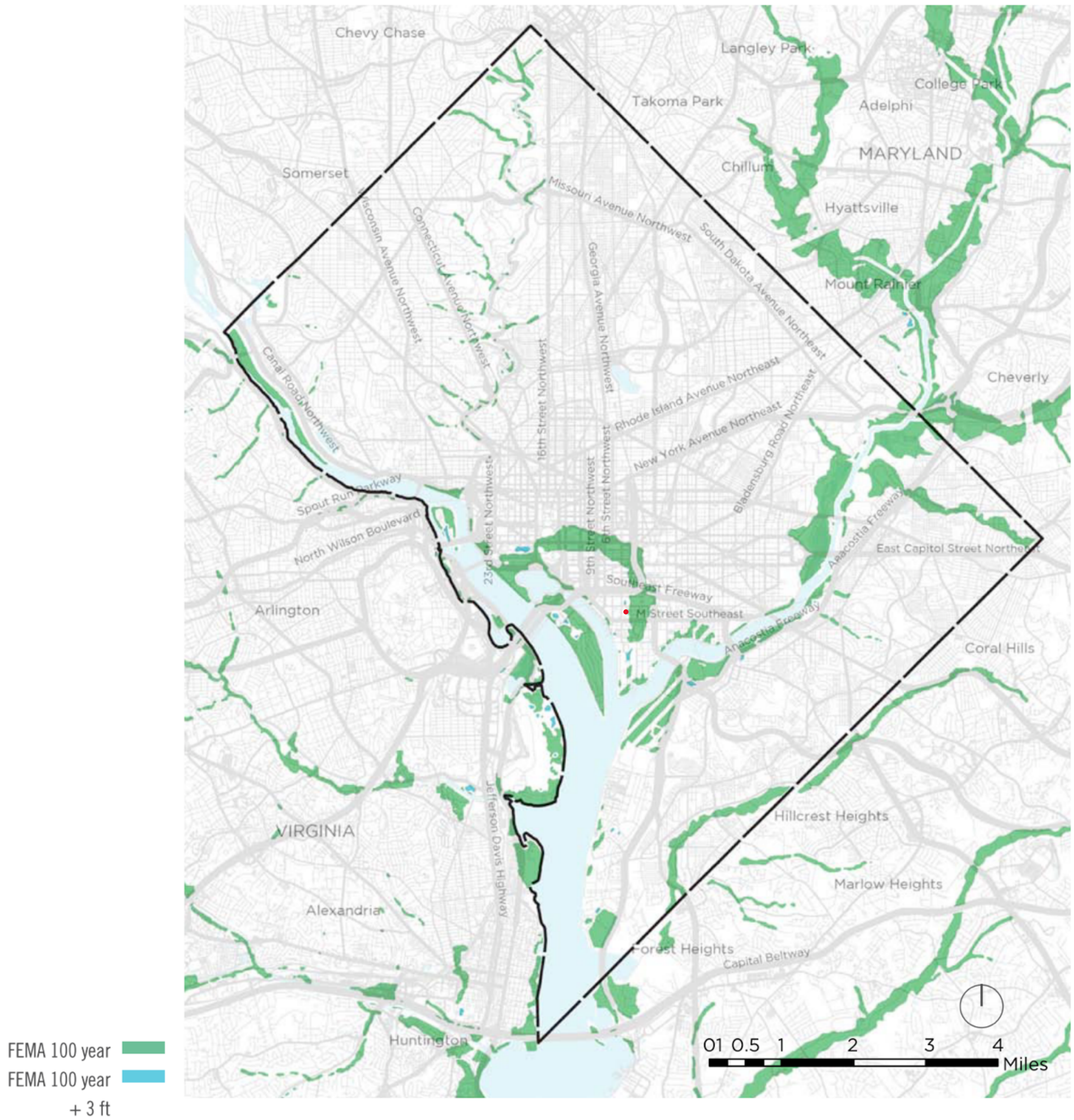

Figure 39 FEMA floodplain map 2015 (Source Perkins+Will et al.)[120]

Table 2 shows the rate of rainfall over time and the importance of planning for buildings related to stormwater management practices and other elements of design to

[120] Perkins+Will et al., *Climate Projections & Scenario Development: Climate Change Adaptation Plan for the District of Columbia*.

protect the District from damage and obsolescence. Flood risks are more significant in areas closer to water, such as Southwest DC, and its impacts have already been felt. As climate change progresses, there will need to be continued revisions to floodplain boundaries, as 100 and 500-year floodplains will change (Figure 39).

Heat is another factor that poses major threats to the District and kills more people annually than any other natural disaster in the United States.[121] While there is an expectation of higher temperatures, there will likely be more oppressive heat days with air temperatures above 95ºF. Heat index findings project that here will be 70 to 80, and 70 to 105 days above 95ºF by the 2050s and 2080s, respectively. The length of heatwaves is further exacerbated as well, in turn, negatively affecting human health and putting more strain on aging infrastructure.

Using climate trends, D.C. has implemented various plans to tackle the issues that have identified vulnerable regions and adaptation strategies to mitigate risks. As part of Climate Ready DC, the goal for the buildings and development aspect of the report is to "upgrade existing buildings and design new buildings and development projects to withstand climate change impacts" through policy actions and incentives.[122] Depending on the vulnerabilities of each focus area within the District, there will be an emphasis on different aspects of climate adaptation. Focus Area 4 is drawn around Southwest DC and consists of vulnerabilities related to emergency and

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[121] Laurence S. Kalkstein et al., "Assessing the Health Impacts of Urban Heat Island Reduction Strategies in the District of Columbia" (2013): 1–28.

[122] District of Columbia, "Climate Ready DC: The District of Columbia's Plan to Adapt to a Changing Climate" (2013), https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/CRDC-Report-FINAL-Web.pdf.

medical services, municipal resources, energy, and wastewater (Figure 40).[123] Within this area, there are many community resources that are vital to the wellbeing of the public that must be addressed in order to lower their risk.

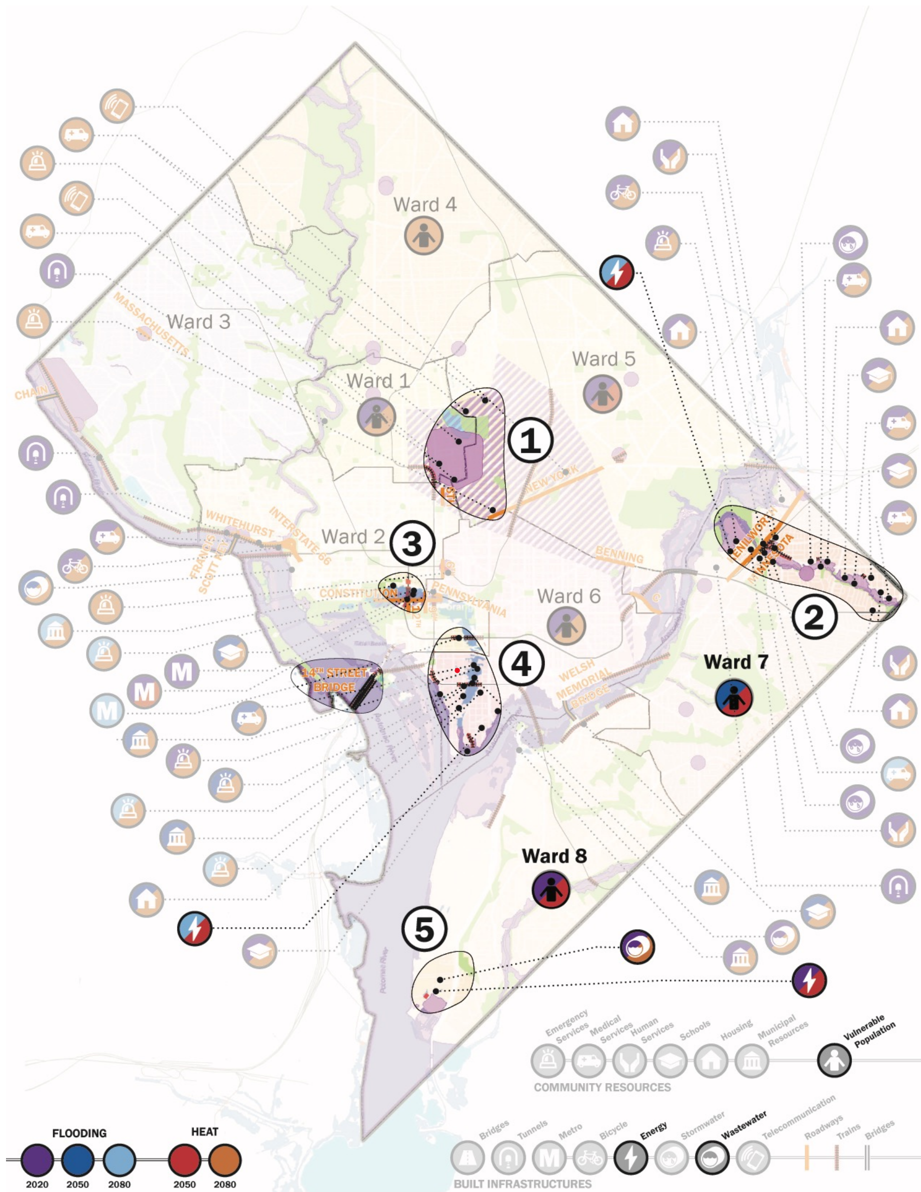

Figure 40 Vulnerability Map of Washington, D.C. (Source AREA et al.)[124]

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[123] District of Columbia Department of Transportation, "Climate Change Adaptation Plan."
[124] AREA, Perkins+Will, and Kleinfelder, *Climate Change Adaptation Plan for the District of Columbia* (Washington, D.C., 2016), https://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/AREA_Climate_Adaptation_Plan_ForScreen_2016-11-11.pdf.

New and Newer Uses

There has been a high level of development in the Southwest DC area, which has brought more attention to its needs. In 2015, the D.C. Office of Planning and Southwest Neighborhood Plan Advisory Committee developed a neighborhood plan, which laid out a community-based process for implementation. The plan's seven core concepts include visions for a model community, modernist gem, green oasis, arts and cultural destination, thriving town center, optimized district parcels, and vibrant connections. [125] D.C. is seeing a resurgence in its population and requires planning for new residents and the resources that they need.

Figure 41 Planning areas in Southwest DC Plan Source (District of Columbia Planning)[126]

[125] Government of the District of Columbia, "Southwest Neighborhood Plan."
[126] Ibid.

Figure 42 I.M. Pei's Waterfront Tower (Source: James W. Rosenthal)[127]

Part of maintaining a model neighborhood is through the maintenance of affordable and market-rate residential units, to ensure that there is a diverse community that does not push out existing residents who may be at risk of displacement. Additionally, the neighborhood aims to bring more accessibility to the site while improving the overall health of its residents through better access to healthy food access. With these new changes, the neighborhood plan highlights their pride in the Modernist architecture, built during urban renewal periods between the 1940s and 1970s. Some of these buildings include I.M. Pei's Waterfront Towers, which has

[127] James W Rosenthal, "VIEW OF TOWN CENTER, MARINA VIEW TOWERS SOUTH BUILDING (ORIGINALLY TOWN CENTER PLAZA WEST) AT 1000-1100 SIXTH STREET; TOWN CENTER PLAZA WEST WAS DESIGNED BY I.M. PEI & PARTNERS AND BUILT IN 1962 BY WEBB & KNAPP - Southwest Washington, Urban Renewal Area," (Washington, D.C.: Historic American Buildings Survey, 1962), https://www.loc.gov/resource/hhh.dc1017.photos/?sp=6.

become part of a repertoire of Modern buildings that is now part of the identity of the neighborhood. The preservation of these landmarks paired with design guidelines that inform new development responsibly to promote a variation of building heights, building frontages, and enhance green spaces around these structures.

Figure 43 Vegetation in Southwest DC (Source: District of Colombia)[128]

The green oasis of Southwest DC will consist of not only increased connection between parks through improved tree canopies but also the general improvement of sustainability measures within the neighborhood. These elements

[128] Government of the District of Columbia, "Southwest Neighborhood Plan."

will improve the well-being of its residents and provide opportunities for a healthier environment. As the area aims to implement Sustainable DC goals, the neighborhood will become a more resilient place over time. Some of these goals include elements that decrease the overall surface area of impervious surfaces to improve runoff within the region.

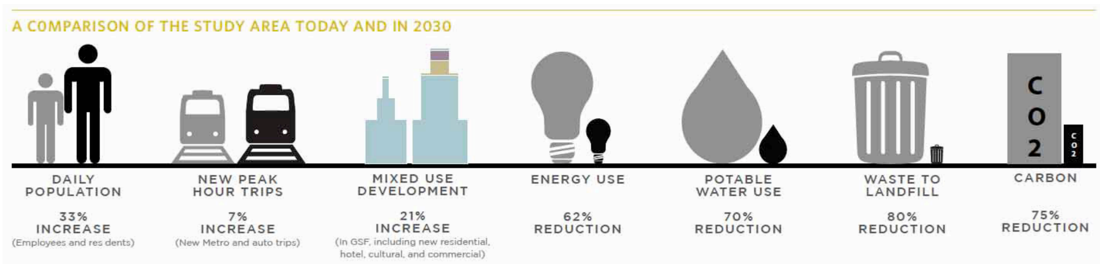

Figure 44 Projected Figures for the SW Ecodistrict. (Source: National Capital Planning Commission)[129]

In addition to these ideas, there can be many lessons taken from the Southwest Ecodistrict Vision Plan released in 2013. There is massive redevelopment of the predominantly publicly owned land within the area, which is home to many of the District's federal buildings. The SW Ecodistrict will provide many levels of sustainable solutions to boost the resiliency of the area. The environmental framework includes improvements to energy, water, and waste systems, as well as an increase in green infrastructure.[130] The neighborhood plan can participate in these goals and implementations to increase their rate of success too. Incremental changes through various scales of design solutions will be required to meet these goals, but they are achievable.

[129] National Capital Planning Commission, "The SW Ecodistrict: A Vision Plan for a More Sustainable Future," 2013.
[130] Ibid.

Figure 45 Blind Whino Church in Southwest DC, a renovated arts space (Source: Artwhino)[131]

Throughout the last several decades, the neighborhood has been home to well-known art establishments and less formal facilities. The planning committee acknowledged that "Southwest already has great cultural assets" in its institutions such as Arena Stage, The Blind Whino (Figure 42), and the future Rubell Museum at the Randall School. More emphasis on local artists and public art will garner even more attention to the area and make it an arts and cultural hub for the District. Recommendations include a "[strengthened] 'I' Street as a cultural corridor by encouraging artists to move into the neighborhood through affordable means and incubator spaces.

[131] Artwhino, "Blind Whino Church" (Washington, D.C., 2013), https://commons.wikimedia.org/wiki/File:Blindwhino.jpg.

Overall, the importance of development in the Southwest DC area is necessary as more people are moving back into the city and will not only require more housing, but general services and amenities to create a vibrant neighborhood. The community itself has already placed some building blocks. As time goes on, these areas will be required to continually reevaluate their position to adapt and grow while ensuring that its original residents are protected from gentrification. Climate challenges will test this site and will require solutions that give the built environment as many options to increase the probability of flourishing in the face of these pressures. Pre-adaptability seeks to give buildings every opportunity possible to remain viable and useful. Likewise, the expansion of adaptable buildings within Southwest DC will prepare the neighborhood from repeating its deleterious history and due to undesirable circumstances and be able to continue to build on a strong foundation of adaptation.

Chapter 7: Design Approach

Figure 46 Birds-eye view of the project. (Source: Author)

Program

Figure 47 Guiding Principles of the Southwest Neighborhood Plan (Source: Southwest Neighborhood Plan)

Applying adaptable ideas to the existing synergy of development in Southwest D.C. will provide less risk over time. There are many opportunities to take advantage of the community's drive to improve their neighborhood and bring a better environment to a fast-growing and gentrifying area. Therefore, this thesis explores pre-adaptability through a new building that provides needed spaces for today and adaptable capabilities for tomorrow. Creating a greater arts and cultural hub in Southwest D.C. is an important element of this neighborhood, which informs the programming of the building.

The community seeks to provide housing for local artists and "house arts/creative incubator uses" within the neighborhood. Cooperative housing for artists can create a community that supports and allows for the flourishing of creatives. Through this co-op program in the building will provide spaces for art studios and exhibition and a portion of housing units to create a living and working community. Retail spaces and larger urban garden spaces will provide a channel for the community to engage with the building as well and create a new center for the community. Currently, the building is situated close to the intersection of the arts corridor on I street and a newly developing retail hub on 4th street (Figure 47).

Figure 48 Site location takes advantage of I Street arts and 4th Street retail development. Blue indicates arts/cultural buildings; Red depicts retail spaces. (Source: Author)

Connectivity

The site as it currently exists, has a pathway across which allows for easier access to the library and other areas of the neighborhood when residents travel from the metro to their homes. The project maintains this connection through the courtyard of the building from the Southwest to the Northeast of the site while also providing openings on the Northwest and Southeast (Figure 48). We see the building naturally fits into the outline of the site, with openings on every corner allowing for maximum porosity throughout, encouraging foot and bicycle traffic through it. On the Northeast side of the site, artist cube fragments open up to the pre-established community and community buildings such as the church to the North and library to the East, offering a greater openness and connectivity. Additionally, the contours of the site draw water towards the dry creek bed in the Southeast green space within the courtyard. The modularity of the building, in this case, allows for freedom of form and a natural fit to the site's constraints. Additionally, the porosity of the building footprint welcomes the community into the building to benefit from the art programming provided within the building and the courtyard.

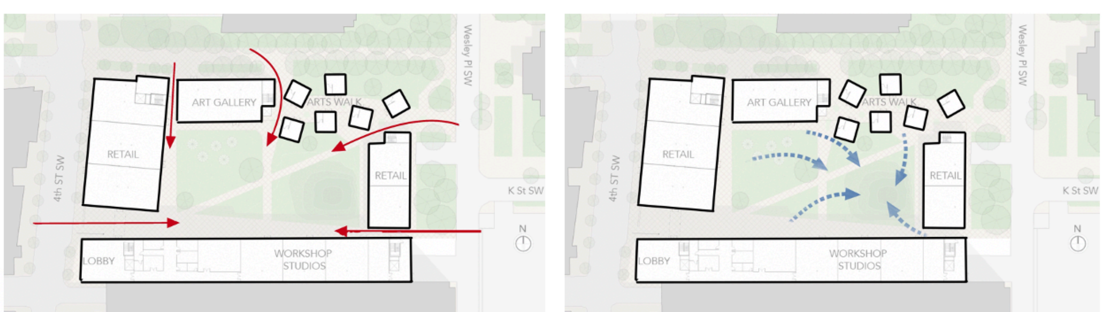

Figure 49 Left image: Connectivity on project site Right image: Hydrology diagram of the site. (Source: Author)

Adaptable Strategy

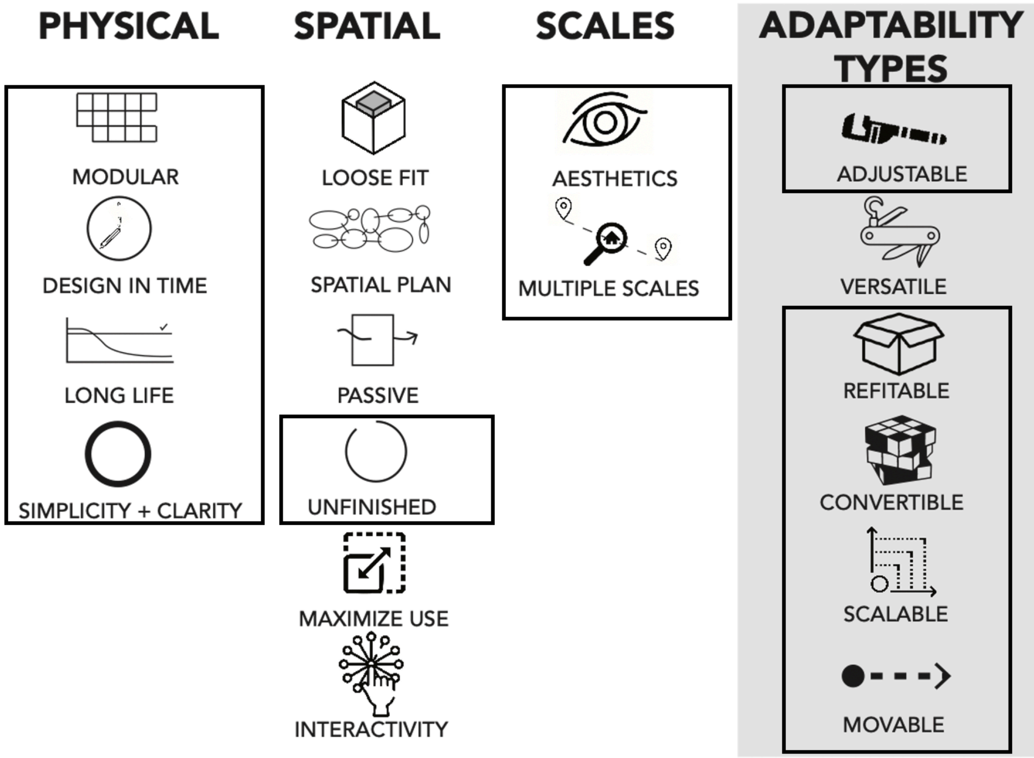

Figure 50 Pre-adaptable strategies employed in the project (Source: Author)

Many different strategies can be implemented in pre-adaptable design, many related to specific site situations. This project will incorporate a few methods which have been outlined in Figure 49, adapted from strategies discussed in Chapter 3. Considering climate projections for Washington D.C. and their flooding risk within the area the design strategy incorporates modular design as the main strategy to lengthen the building's lifespan. This building's adaptation strategies focus on long-term changes, recognizing that flooding strategies within the next few decades in Washington D.C. do not yet require major interventions (Figure 51). While the building can adapt to include more protection on a shorter timescale, those potentials can be realized and adapted to at a later time.

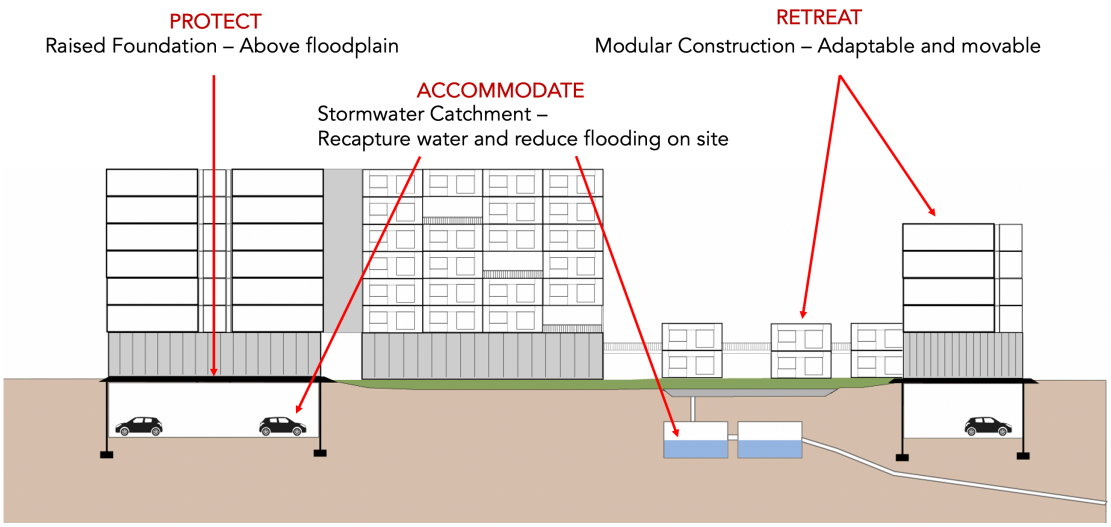

Figure 51Flooding Strategies (Source: Author)

To accommodate long-term pressures of the site to flooding, the main adaptability type that this design focuses on is movable design. By creating prefabricated modular systems that can be stacked and un-stacked, the building is given the opportunity to relocate when the risk of staying on the site becomes too great. The design includes a simple stacking structure which can connect to one another and disconnect with simple bolts. This stacking structure consists of Structural Steel cages reinforced with lightweight structural aluminum to create the modules which stack and connect to one another (Figure 52). The modules are built off-site and can be brought fully fit-out by a flat-bed truck. The dimensions of one residential module are 20’x30’ and can be combined to create multiple room residential units. Importantly, these module units stack on top of a Structural Steel platform, which is installed on-site. This will allow for a stable base that elevates the units and frees up the ground floor as needed (Figure 53). In addition to the residential module, a 20'x10' corridor module was designed to allow for removable elements within the building along the circulation path. This corridor unit accounts for systems running vertically through the building, allowing for easy connection to the walls within the residential unit and ease of access for maintenance within the corridor (Figure 54).

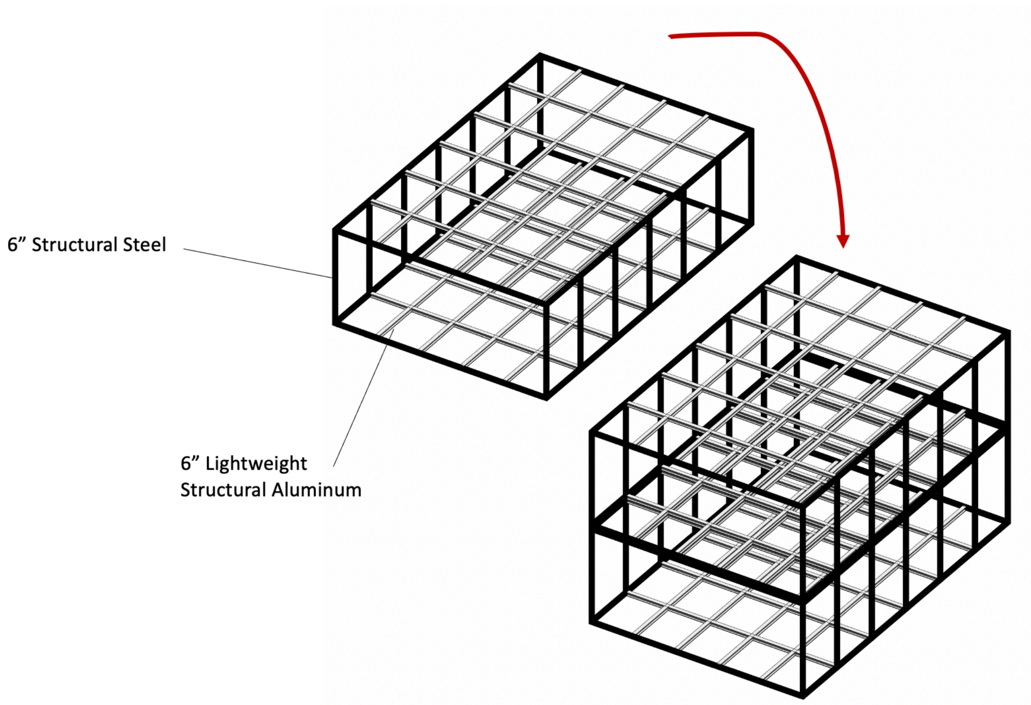

Figure 52 Structural Cage, created with Structural Steel and reinforced with Lightweight Structural Aluminum (Source: Author)

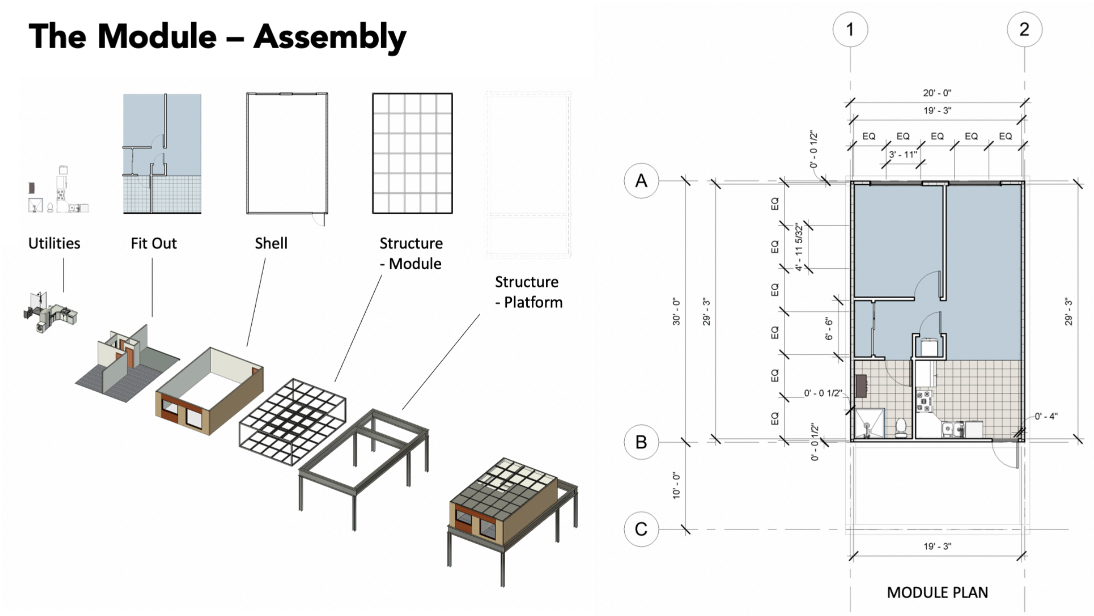

Figure 53 Left images: Diagram of the construction of a module and its placement on the base structural platform. Right image: floor plan of a typical one-bedroom residential module. (Source: Author)

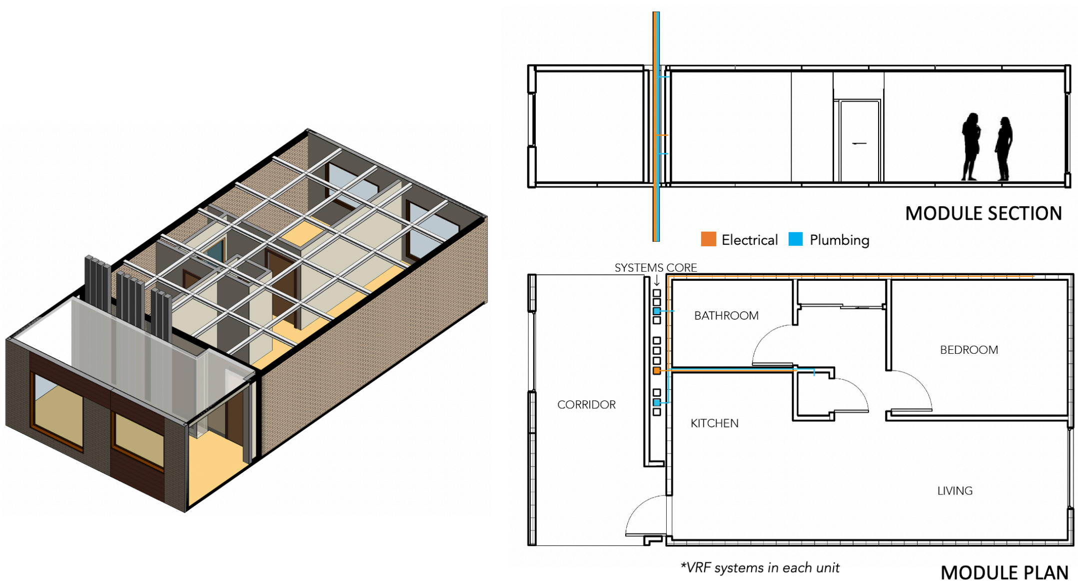

Figure 54 Left image: Axon of the corridor and residential modules with vertical systems. Right image: Plan and Section views showing systems connection into residential modules. (Source: Author)

Additionally, the module and structural cage allow for other fit-outs for different program needs. For this project residential, terrace, and art studio modules were used to accommodate the program requirements of the building. The regularity of modules can be maintained within each unit and as it stacks vertically, creates a clear diagram of systems and spaces (Figure 55) while allowing the building to form around the site's constraints (Figure 56). The simplicity of the systems and spaces of the building intentionally allows for a level of clarity, which will then permit the future designers of the building to better understand and apply adaptations as needed.

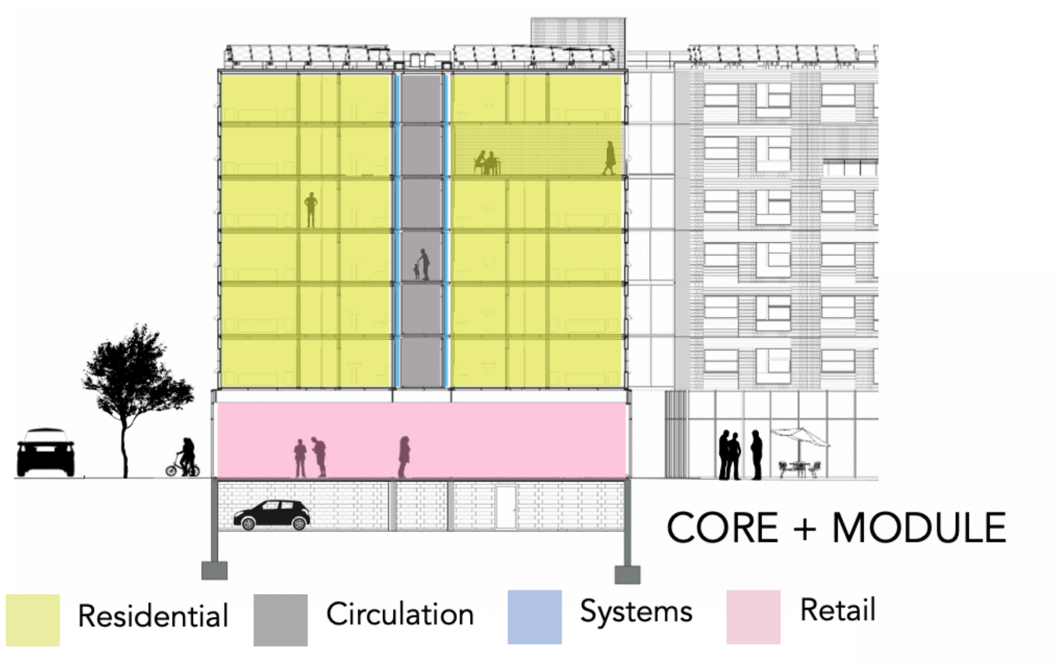

Figure 55 Diagram of systems and spaces stacking in the building. (Source: Author)

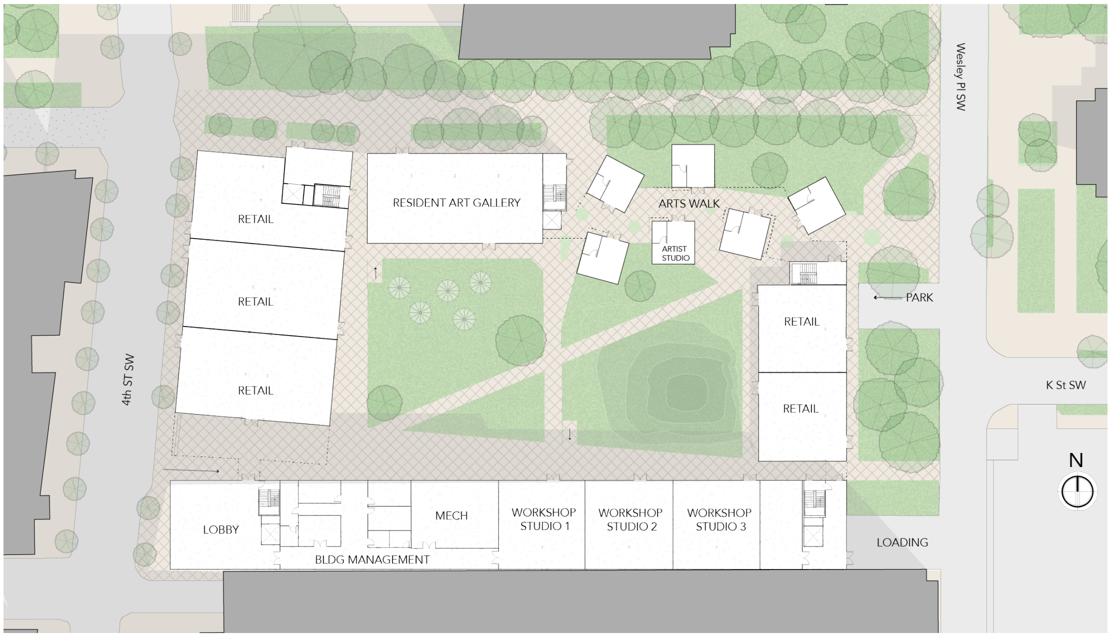

Figure 56 Ground floor plan (Source: Author)

Disassembly

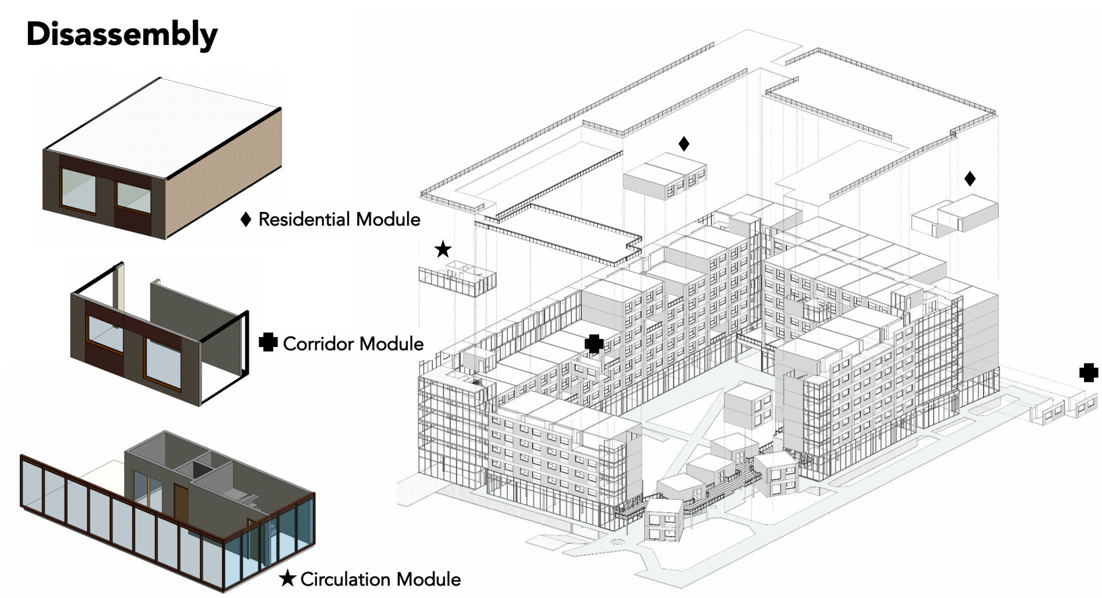

Figure 57 Disassembly Diagram. (Source: Author)

A building can be full of adaptable strategies to extend its life on its original site and maintain that it is an enjoyable and safe place to live, but ultimately with the forces of climate change, it may not matter. Climate change will fully arrive to cities such as Washington D.C., and the amount of flooding and risk will far outweigh the protection and accommodation strategies that had previously protected the building and its users. As noted in Chapter 6, Southwest D.C. will face higher flood risks and potentially be considered an area of chronic flooding by 2080. This project is uniquely equipped to recognize those vulnerabilities and respond appropriately when the time comes, giving the option for disassembly and relocation to a safer location. As the roof membranes are removed, the modules will be able to be disconnected from one another and removed via crane and driven to its new location (Figure 57), saving in material costs, embodied energy, and time.

There is a growing interest in designing buildings for disassembly, to begin to create a more circular economy of materials. This capability is not a pessimistic approach to designing, but something that allows for architecture to foster more futures for new construction when they eventually become a part of the adaptive reuse process. The acceptance and understanding that the land which a site sits on may become too dangerous for people to live on is difficult and painful. Pre-adaptable design acknowledges and prepares for these realities to give agency and opportunity for the building’s occupants to move safely and with relative ease. The new relocated building may consist of the same form, maybe new potentials are realized when it is adapted and reused; only the future can tell.

Appendices

Figure 58 View of the courtyard after flooding (Source: Author)

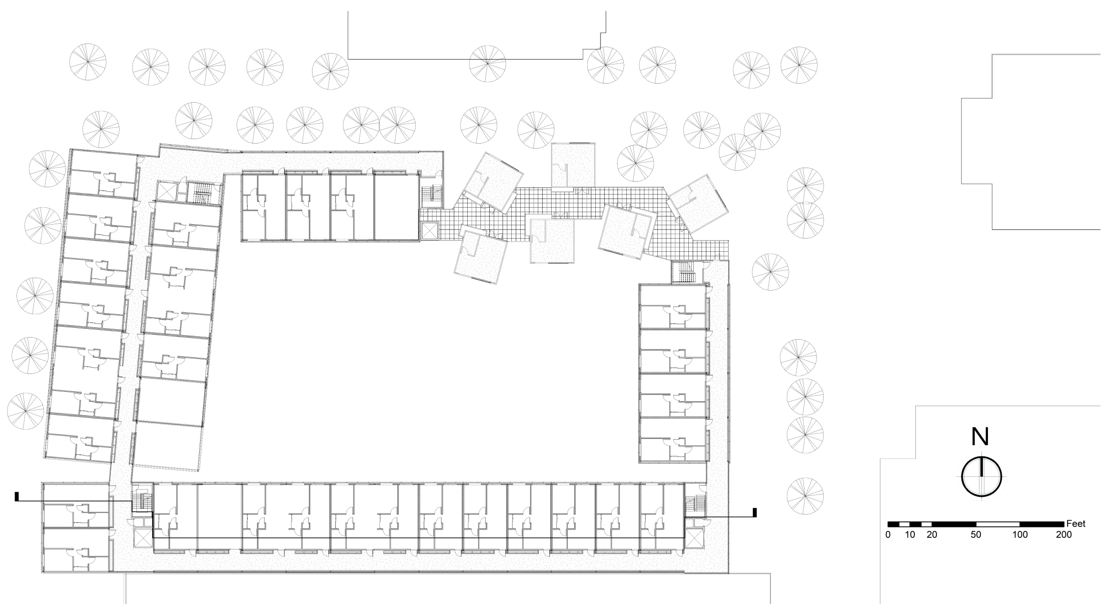

Figure 589 Second Floor Plan (Source: Author)

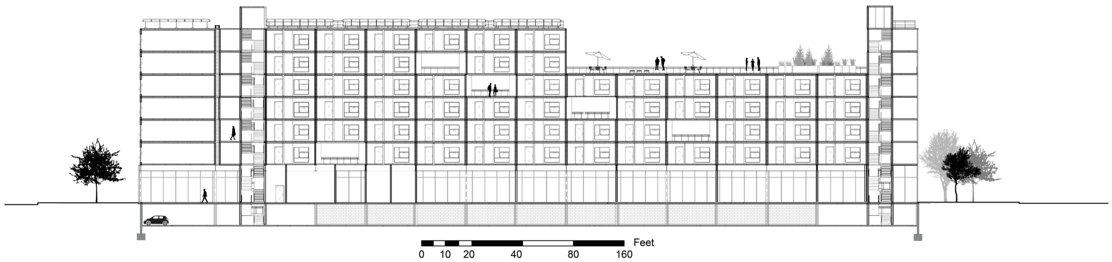

Figure 59 Longitudinal Section (Source: Author)

Figure 60 Section Perspective (Source: Author)

Figure 61 View from 4th Street SW Northwest corner (Source: Author)

Figure 62 View from Fourth Floor Terrace (Source: Author)

Figure 63 View within an artist studio (Source: Author)

Figure 64 View from Second Floor Art's Walkway (Source: Author)

Figure 65 View of building approach from 4th ST SW (Source: Author).

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