Eco social Resilience:

Adaptable Architecture Designed to be Reduced, Reused, and Recycled.

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Eco-social Resilience: Adaptable Architecture Designed to be Reduced, Reused, and Recycled.

Alexander Hollander

0.0 ABSTRACT

Historically and currently, buildings are demolished with little to no consideration of life cycles and the waste they produce. Consequently, housing shortage problems are rising and creating unavoidable issues like the demand in resources and built environments. Many architects and engineers have used prefabrication and modular systems in architectural projects as solutions and to demonstrate best practices. However, there is still an absence of architects failing to design for the life cycle, and deconstruction of buildings. This thesis investigation explores how one can design adaptive structures to revert from a linear economy approach, to a circular economy approach within architecture?

To answer this question, this thesis will investigate the use of prefabrication, modular construction, and adaptive housing designs, to address the increasing demands for multi-use, and re-usable structures, and ultimately achieve a circular economy within architecture. The investigation utilizes Building Information Modeling (BIM) and Life Cycle Analysis (LCA), to prove whether architectural components can achieve a circular economy. The prototype aims to illustrate adaptation over time and increased life span, by reusing and down cycling material, as well as building upon existing conditions. Ultimately, a circular economy within architecture is accomplished by avoiding demolition and construction waste, and contributing less to CO2 emissions.

0.1 RESEARCH QUESTION

How can one design adaptive structures to revert from a linear economy approach, to a circular economy approach?

CHAPTER 1

1.0 INTRODUCTION

Eco-social resilience at its core is about challenging and rethinking the way we design, use, and reuse resources, with the ultimate goal to eliminate the concept of waste within the building industry. Through this concept, an architectural thesis investigation was developed that aims to reduce waste within building construction and deconstruction, and ultimately creating an adaptive building concept that can support a circular economy.

Thesis: If prefabricated modular construction embraced adaptive housing designs, then it would help lead the way from a linear to a circular economy approach within architecture.

Prefabrication: A construction technique where elements are prefabricated within an enclosed factory space and later are assembled on a site.

Modular Construction: A construction technique of using three dimensional volumetric modules.

CLT Mass Timber: Cross laminated mass timber is a wood panel made from gluing together layers of solid lumber.

Adaptive Housing: Houses and apartments considered collectively that have the ability to change over time and evolve to future programmatic needs.

Circular Economy: A model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. The ultimate goal is to tackle global challenges like climate change, biodiversity loss, waste and pollution.

1.1 CIRCULAR ECONOMY

Circular economy is commonly defined by a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. The ultimate goal is to tackle global challenges like climate change, biodiversity loss, waste and pollution. *Cradle to Cradle*, William McDonough and Michael Braungart is an important resource in the movement toward the circular economy, providing insightful awareness in our wasteful ways that produce goods and dispose of them, and casts an ideal model of production and consumption called Cradle to Cradle (McDonough, 2009). They argue that the manufacturing model today is one that is of a Cradle to Grave philosophy. Meaning, this mindset has existed since the industrial revolution, and casts off 90 percent of the materials it uses as waste.

The philosophical idea of Cradle to Cradle argues: “Why not take nature itself as our model? A tree produces thousands of blossoms in order to create another tree, yet we do not consider its abundance wasteful but safe, beautiful, and highly effective: hence “waste equals food” is the first principle the book sets forth. Products might be designed

so that, after their useful life, they provide nourishment for something new-either as biological nutrients" that safely re-enter the environment or as "technical nutrients" that circulate within closed loop industrial cycles, without being "downcycled" into low-grade uses (as most recyclables now are)." (McDonough, 2009). In summary, this means that adaptive house and architecture that aims to accomplish a circular economy, the architectural components must be able to be downcycled in a technical or biological cycle, see **Figure 1**.

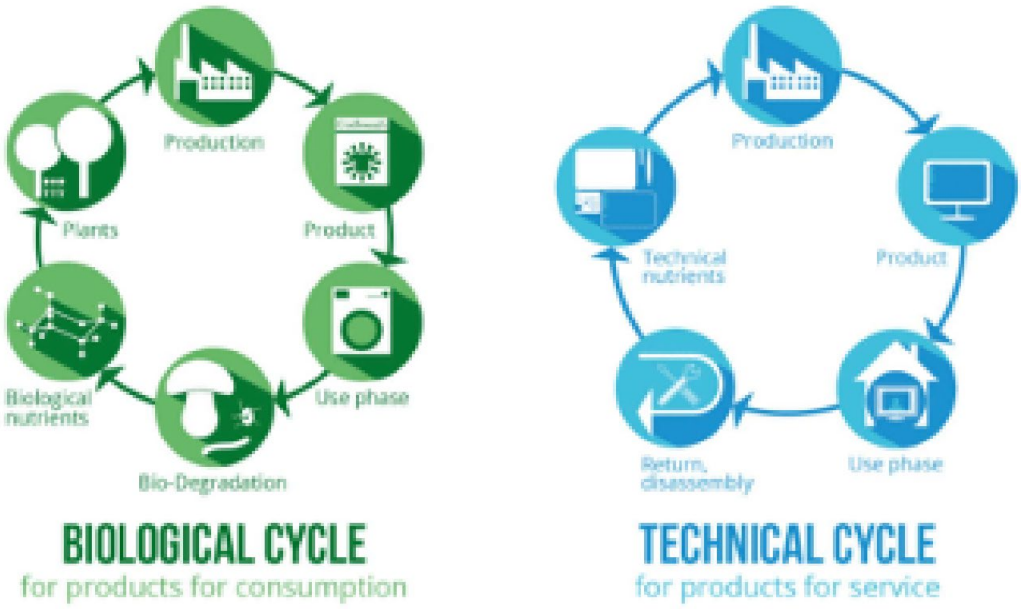

Figure 1: Explanation of products being recycled through Biological and Technical cycles (McDonough, 2009).

1.2 ADAPTIVE HOUSING

Traditionally, a majority of structures have been designed for demolition, with seemingly little to no consideration of the waste it produces. Consequently, these structures find themselves living the remainder of their lives in a landfill due to this wasteful construction method, resulting in contribution to CO2 emission levels. To flip this narrative, the necessity to design and build adaptive structures is more crucial than ever. More specifically, the design for adaptive housing can act as a solution to begin reducing these levels, and extend the life cycle and repurpose of the structures, see **Figure 3**. Adaptive housing design can be defined as houses and apartments, considered collectively, that are designed to have the ability to change over time. Stewart Brand is famously known for bringing this idea to the forefront and advocating for the longevity of structures to support generations of communities, stating: “A buildings foundation and frame should be capable of living 300 years.” (Brand, 2012).

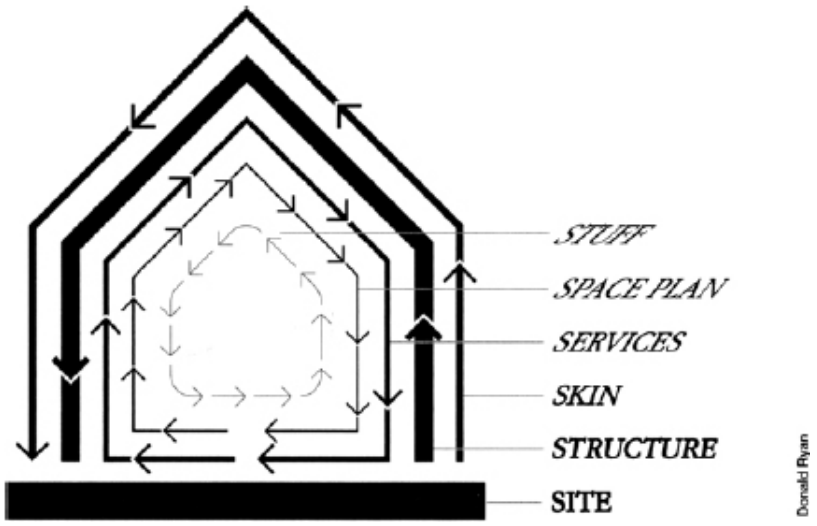

Figure 3: Stewart Brand’s visualization of an adaptable housing model (Brand, 2012).

This idea has been wrestled over time by many architects and designers, with some of the most notable contributions by Le Corbusier and Walter Gropius. In the early 1900's, Le Corbusier was responsible for developing the idea called "The Bottle Rack Principle", where a basic underlying structure was designed to allow for the removal and insertion of interchangeable components to suit a particular need at a specific time, see **Figure 4**. In the same time period, Walter Gropius was developing the "Design for an Assembly of Mass-Produced Components." (Gropius, 1924). Through this design philosophy, Gropius advocated for the integration of industrial principles in the architecture industry. He studied this principle by exploring it in two different ways: design for a flexible construction kit and producing through assembly line production facilities, see **Figure 5**. Even though these ideas were presented over a hundred years ago, today they still haven't been widely adopted by building industries worldwide. The reason why these ideas have not been widely adopted may be because of social trends or economic viability. Now, with the necessity for the reduction in construction waste and flexibility of housing, these principles are more relevant than ever. With recent advancement in BIM technology, supply chain management, and construction technology, these ideas are worth revisiting to help the field of architecture operate within a circular economy.

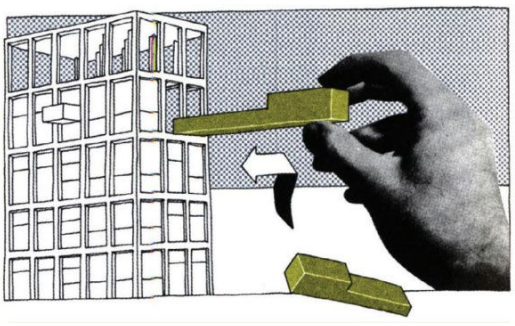

Figure 4: Le Corbusier's "Bottles and Bottle-rack" principle (Corbusier, 1935)

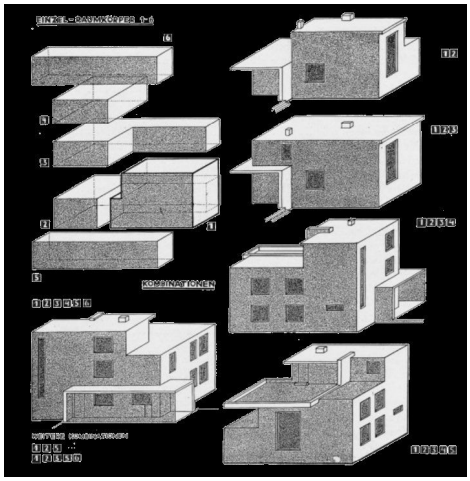

Figure 5: Walter Gropius' design as an assemblage of mass-produced components (Gropius, 1924)

1.3 PREFABRICATION

One factor that can lead the way to achieve a circular economy within architecture, is to take initiative in the pre-design phases of the process and prefabricate as many components as possible. Prefabrication is a construction technique where sections of the building are prefabricated within an enclosed factory space and later are assembled on site quickly or easily, see **Figure 6**. Where prefabrication does its heavy lifting is in the factory. By designing and constructing building components within a controlled environment, the waste that is produced can be controlled and recycled at a much higher rate. One might ask, why isn't prefabrication used more within architecture, if it's that great? One of the major limiting factors of prefabrication in the building industry is that it takes away jobs from local economies and there is a serious investment needed to afford a large factory space. Author of refabricating ARCHITECTURE, Stephan

Kieran advocates for the rethinking of our building processes by stating: “Compared to the automotive world, building contractors, as well as architects, and product engineers, are still in the nineteenth century. Buildings continue to be assembled largely piece by piece in the field, in much the same way that the car was put together before the advent of mass production.” (Kieran, 2004) This call for a revolutionary initiative to prefabricate architectural components, is long overdue, and is critical to achieving a circular economy approach within architecture. Architects and the building industry should adapt to prefabricated construction of components, like the automobile industry in order to add more value to the designer and the quality of the craft they produce, and ultimately control the level of construction waste produced from this process.

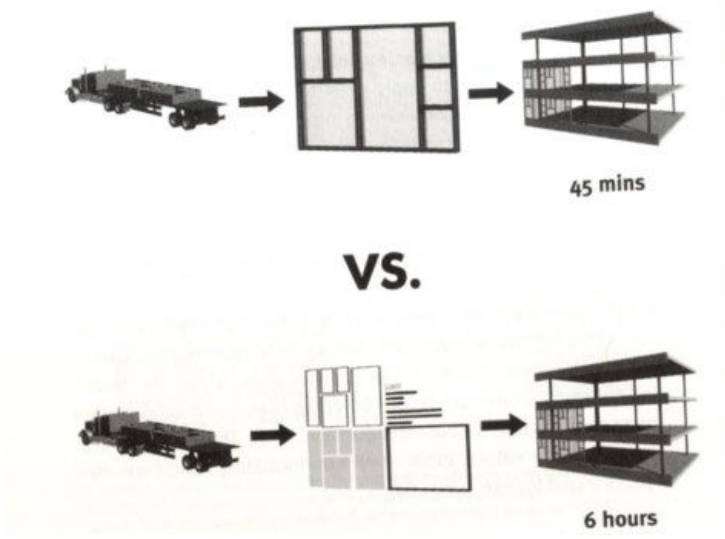

Figure 6: Stephan Kieran’s example of the prefabricated components time it takes to install, compared to traditional methods (Kieran, 2004)

1.4 MODULAR CONSTRUCTION

Modular construction is a construction technique where components of the building are used as three-dimensional volumetric modules. Modular construction has been a common construction technique to expedite and simplify the construction process, see **Figure 7**. This method has been widely used in the architecture industry combined with prefabrication to make assembly and installation on difficult sites up to 30-50% faster than traditional approaches. With increasing population growth, the demand for quickly assembled construction is becoming more and more relevant. In an interview with Portuguese architecture firm, SUMMARY, they state: “… because we are witnessing exponential demographic growth today, particularly in urban areas, which is developing at a speed and scale unprecedented in human history. This issue forces us to find faster and more effective construction solutions to respond to the growing demand for buildings.” (SUMMARY, 2022).

The American Institute of Architects recently released a practice guide to layout best practices within the field of architecture in terms of modular construction. AIA claims that although there are major time and cost savings associated with modular construction, the need for predesign and planning is paramount for ensuring success. They state: “If affordability and controlled cost is of primary concern on a project, modular construction can be used to achieve it, but it will require greater intention in design and thorough planning.” (Wilson, 2019). By conducting the majority of the design and construction in the predesign and planning phases within a controlled environment and in three

dimensional volumetric forms, the ability to create adaptive housing and tap into a circular economy becomes more of a reality.

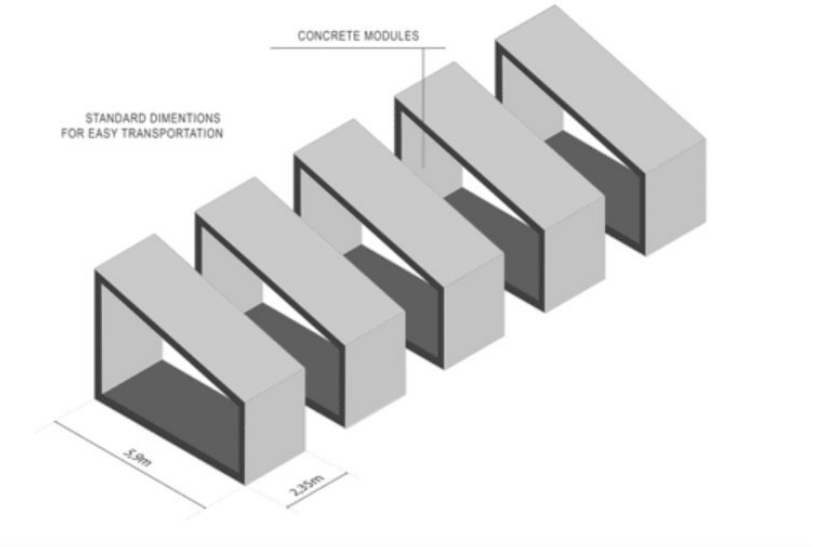

Figure 7: SUMMARY architecture studio's take on precast concrete modular construction (SUMMARY, 2022)

CHAPTER 2

2.0 SPECULATIONS

To push these ideas and evidences found within the initial research further, speculative thoughts and ideas are combined with the knowledge learned to fully realize the potential of them aligned with today's modern technology.

2.1 MANUFACTURING CIRCULARITY

"re-fabricating ARCHITECTURE"

“Compared to the automotive world, building contractors, as well as architects and product engineers, are still in the nineteenth century. Buildings continue to be assembled largely piece by piece in the field, in much the same way that car was put together before the advent of mass production.” (Kieran, 2004)

"Tesla-fy the Architecture Industry"

Architects and the building industry should adapt to prefabricated construction of components, like the automobile industry in order to add more value to the designer and the quality of the craft they produce. Prefabrication facilities should operate in a circular manner to recycle components through biological or technological cycles, see **Figure 8**.

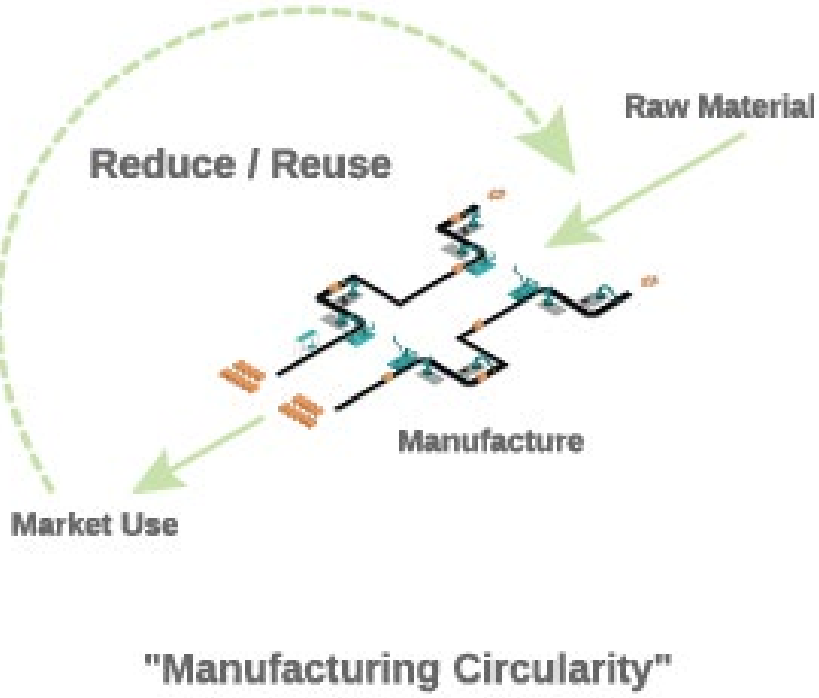

Figure 8: Manufacturing Circularity

2.2 APARTMENT VENDING

"Bottle Rack Principle"

A basic underlying structure allows for the removal and insertion of interchangeable components to suit a particular need at a specific time (Corbusier, 1935), **see Figure 4.**

"Carvana Effect"

By having a basic underlying structure, allows modules to be placed in whenever change is need or wanted. By adopting an operational strategy like the company Carvana, modular housing units could be purchased through an "apartment vending machine.", see **Figure 9**.

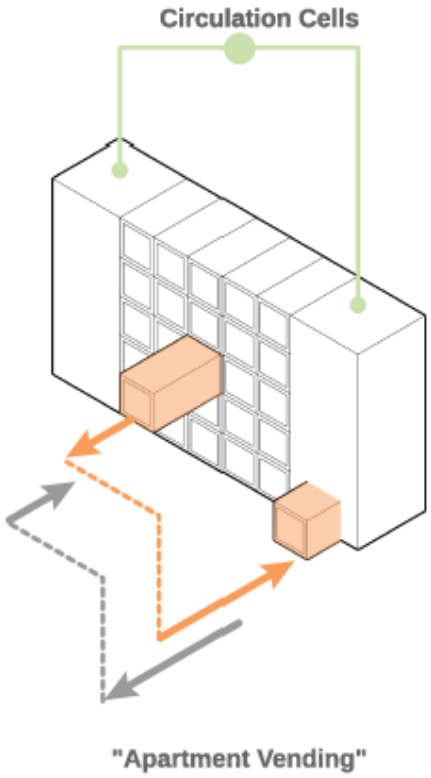

Figure 9: Apartment Vending

2.3 NESTED ADAPTABILITY

"Built for Change"

After reviewing Chapter 12: Built for Change of How Buildings Learn, the ad-vocation for adaptable design is echoed through the call on reducing the solid waste burden of demolished buildings, and promoting the longevity of structures to support generations of communities.

"Nesting Doll-itecture"

Since structure and foundations are the most resilient proponents to building construction, why not design them to expand and contract to adapt to needed program space? By following the method of nested dolls, buildings can be designed in a way to allow for expansion and contraction, see **Figure 10**.

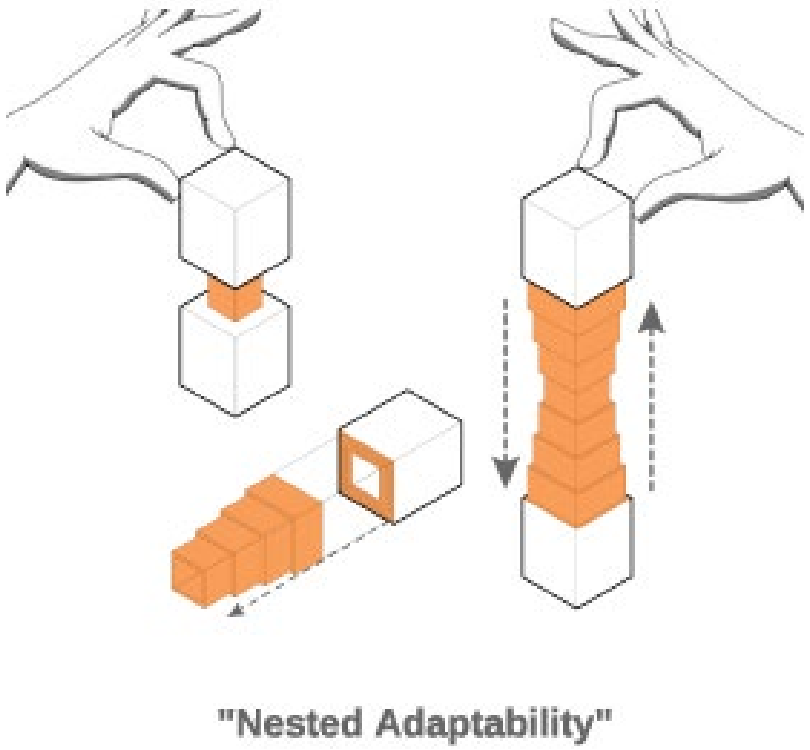

Figure 10: Nested adaptability

2.4 EVER-CHANGING HOUSING LANDSCAPE

"Mountain Dwellings"

In Denmark, BIG architecture firm developed an innovative social housing cluster that takes the idea of modular construction to new heights, called mountain dwellings. The

mountain dwellings program is 2/3's and 1/3 housing, see **Figure 11**. What if the parking area became the base upon which to place terraced housing, like a concrete hillside covered by a thin layer of housing, cascading from the 11th floor to the street edge.

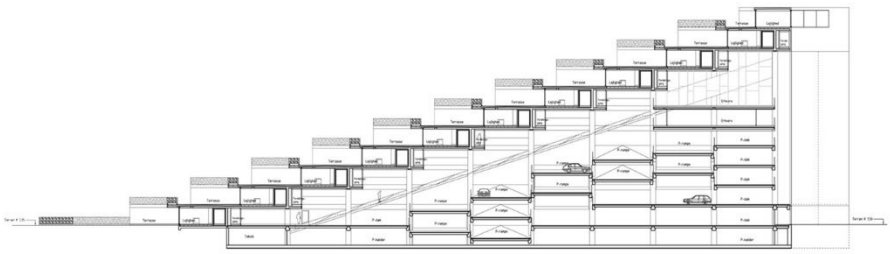

Figure 11: Section of BIG's mountain dwellings project (BIG, 2009)

"Avalanche Effect"

By treating the housing cluster like the face of a mountain, dwellings can simply erode away, creating space for a new dwelling. This would allow for adaptability and circularity to work harmonies just like nature, see **Figure 12**.

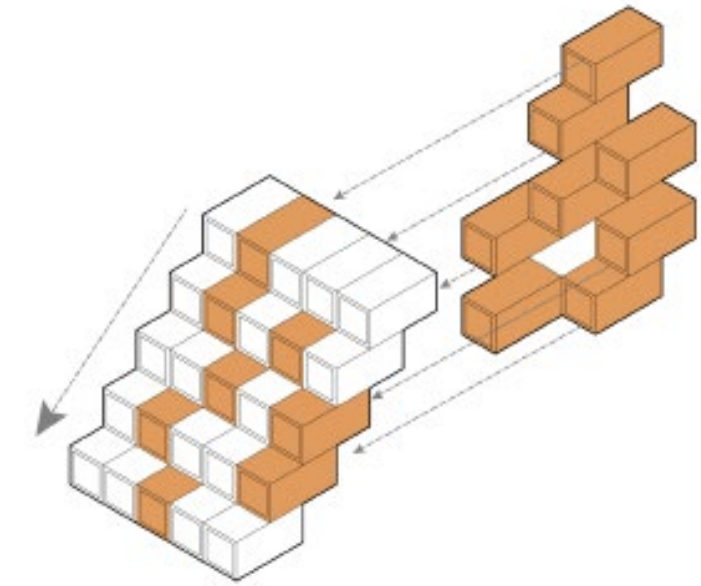

Figure 12: Ever-changing Housing Landscape

2.5 RECYCLABLE MODULAR COMPONENTS

"Design for an Assembly of Mass-Produced Components"

Walter Gropius, the founder of the Bauhaus, advocated for the integration of industrial principles in the architecture industry. Gropius explored this principle in two different ways: 1. Designing for a flexible construction kit and 2. Producing through assembly line production facilities, see **Figure 5** (Gropius, 1924).

"Lego Principle"

As Walter Gropius advocated for the design for an assembly of mass-produced components, the theory stops there and doesn't take into consideration of de-mount-ability and re-use. By applying the "Lego Principle" mass produced components can be designed with de-mount-ability for infinite configurations and reuse. When the components have lived out their life cycle, the manufacture facility can take them back for recycling or reuse, see **Figure 13**.

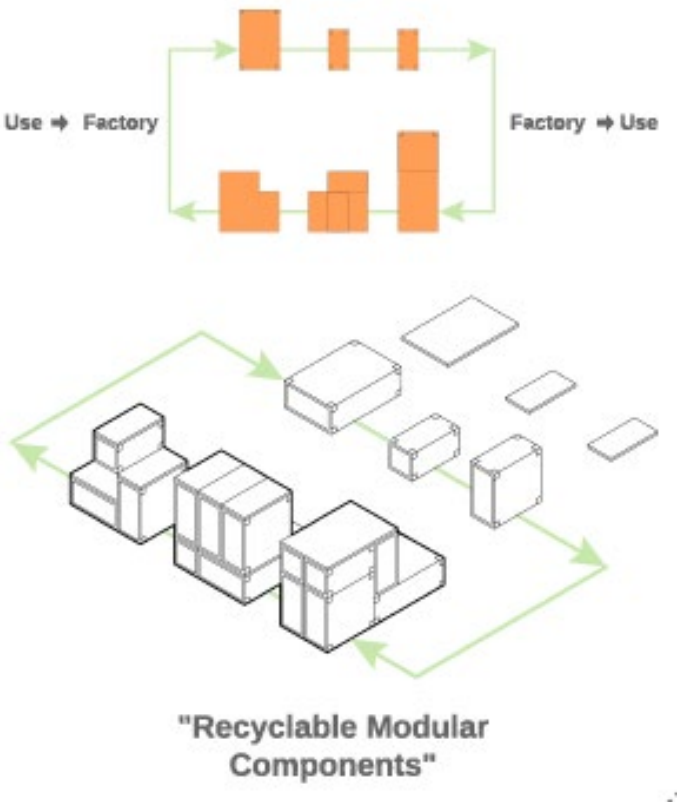

Figure 13: Recyclable modular components

2.6 DE-MOUNTABLE HOUSING

"Urban Village"

The Urban Village Project aims to allow for cheaper homes to enter the market, make it easier to live sustainably and affordably, and ensure more fulfilling ways of living together (EFFEKT, 2015). One of the ways in which Space 10 accomplishes this is with local mass timber. Space 10 envisions a more fulfilling way to live together by prioritizing livability, sustainability and affordability.

"Adaptable CLT"

Components in building construction are always built to stay put, resulting in negative environmental impacts and difficulty renovating. If CLT mass timber was design to support housing and to be disassembled in the future, then it could be recycled and reused while sequestering carbon, see **Figure 14**.

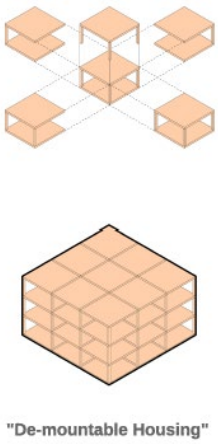

Figure 14: De-mountable Housing

2.7 LEASABLE COMPONENTS

"Circular House"

Designed to be a scale able building solution, the Circular House's goal is to build the world's first social housing units built entirely according to circular principals, where 90% of all material can be reused at a high value (Jensen, Kasper Guldager, and Sommer, 2016). This means the home construction can be disassembled and the elements recycled without significant loss of value, see **Figure 15**.

Figure 15: Circular House by 3XN (Jensen, Kasper Guldager, and Sommer, 2016)

"Lease-able Components"

Since the automotive industry is doing it, why not the architecture industry? By designing building components with a circular frame of mind, said components could be leased out to buildings for temporary use. This would open the door for a more controlled process of material circularity and design, see **Figure 16**.

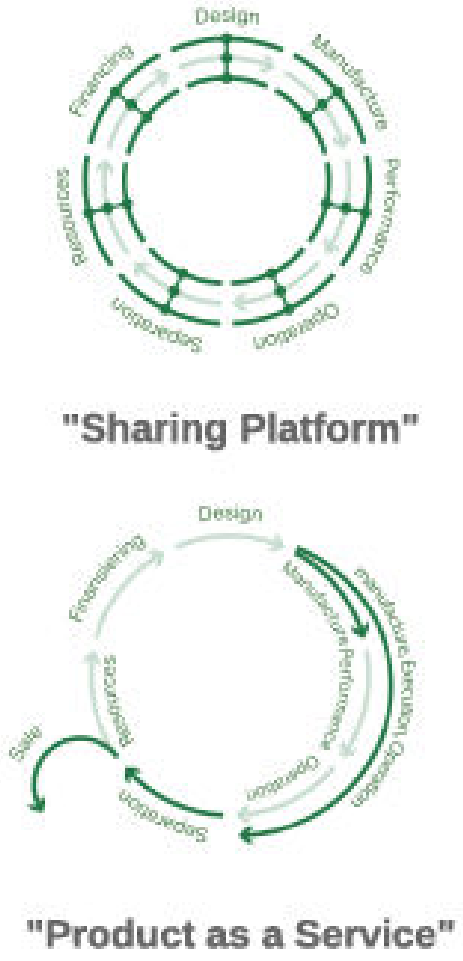

Figure 16: Lease-able architectural components (Jensen, Kasper Guldager, and Sommer, 2016)

CHAPTER 3

3.0 METHODOLOGY

Initiating this prototype concept is conducted through architectural sections to test its possibilities. Following the insights and speculations, this prototype is controlled by the site constraints and size of mixed-use developments in the area. The key aspects investigated here are the speculations and how they could be implemented.

3.1 LOCATION + SITE

To begin this investigation, a protype must be deployed to test its effectiveness. One of the main factors of this protype is the site and location. This thesis could potentially be deployed as a national and even a global deployment strategy to combat contemporary issues like rapid urbanization, climate change, and natural disaster relief. Narrowing the search through climatological factors and analyzing population trends, Denver, Colorado became a viable location to test this thesis. In the last decade, Denver has experienced large increases in population growth, and more specifically youthful generations. Consequently, Colorado is barring on a housing crisis, and due to the population growth, and an estimated 500,000 housing units need to be constructed each year for the next five years to keep with demand (Sisson, 2020). With the demand for housing in Denver at such a high rate, this design investigation will test the idea if eco-social resilience can be achieved, see **Figure 17**. This concept could Denver with

their housing issues by being able to rapidly produce sustainable housing, through prefabrication and modular construction.

Figure 17: Location of site in Denver, Colorado

3.2 COMPARITIVE STUDY

To compare the thesis with an existing structure, Star apartments by Micheal Maltzan was chosen for showcasing best practices in architecture.

Star apartment's site originally had a 1-story building, and rather than tear it down, Michael Maltzan decided to build right on top of it with five-stories of community space and apartments. The project will have 102 efficiency apartments of permanent supportive housing in the downtown core. The ground floor will be used as retail space, the first floor will be a community area with recreation and shared spaces, while the next four floors will be used for residences, see **Figure 18**.

Figure 18: Star Apartments by Michael Maltzan (Maltzan, 2015)

3.3 CONSTRUCTION METHOD

The construction process first starts out by sustainably extracting material from the environment or recycling existing structures or material. Timber is one of the only structural systems that grows from the ground and can be completely downcycled in a biological cycle and sequester carbon, making it completely circular. Once the materials are extracted, the timber would be prefabricated into modules in a localized factory. The goal of prefabricating in a localized factory has a number of benefits, one being the reduction in travel from factory to site, the second to stimulate the local economy, and third to control the waste produced from fabrication (Wilson, 2019). The next step would be to flatpack and ship to the site for assembly. Flat packing the module for

transportation allows for more efficient transporting, by shipping larger amounts of components, see **Figure 19**.

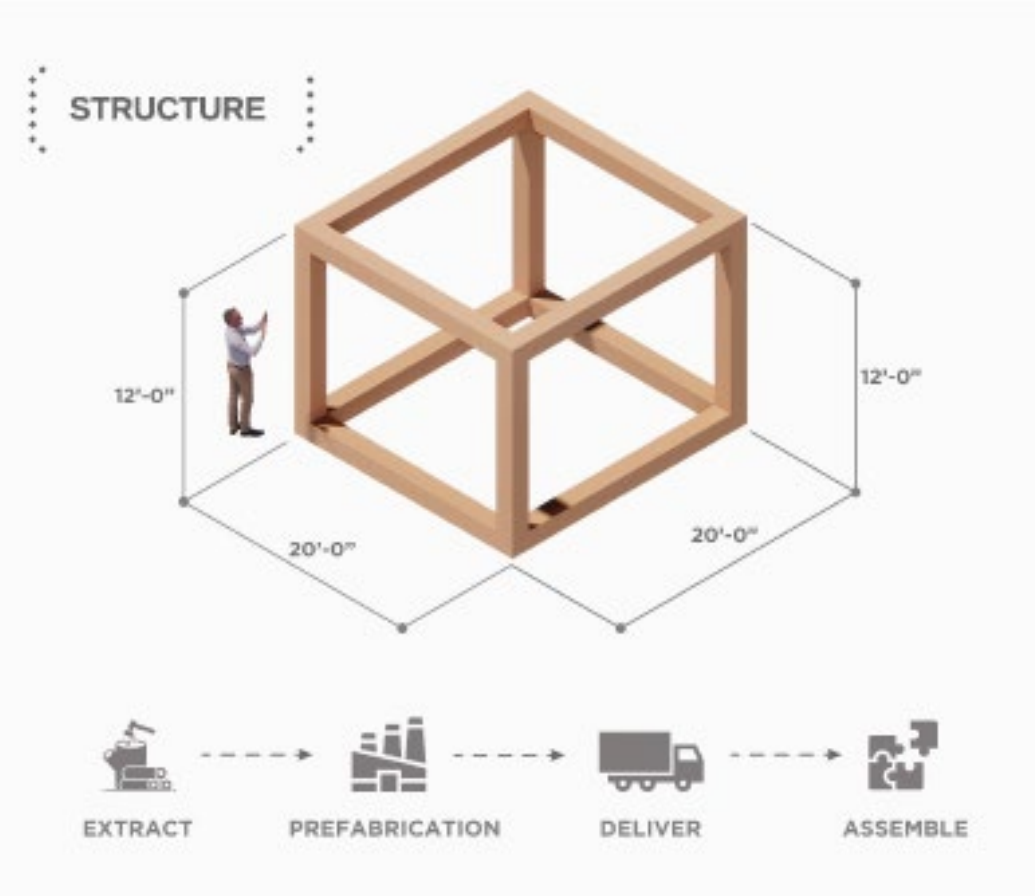

Figure 19: Construction Process

3.4 PROGRAM

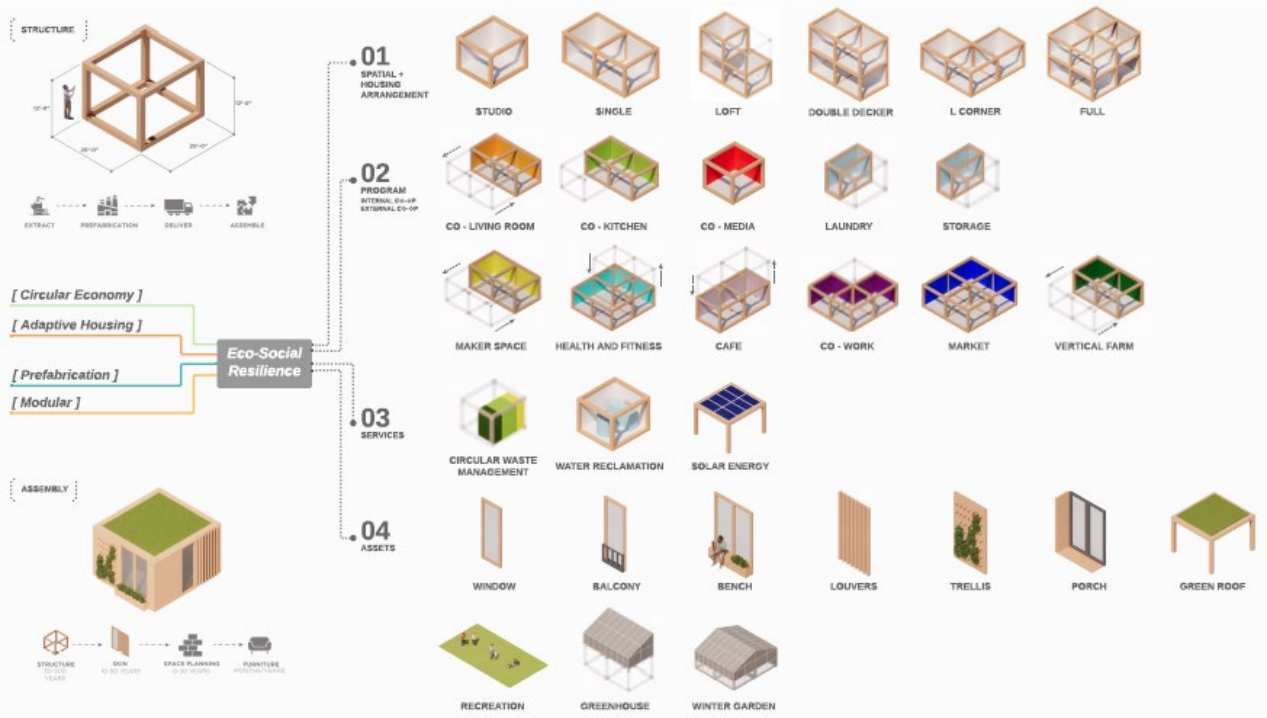

Figure 20: Program Matrix

The idea of adaptive housing could imply the adaptability to change to whatever needs possible. This is definitely a possibility, but to begin to test this investigation a program must be incorporated to display the results. For this investigation, the program to be tested will be mixed use housing with along with amenities. To achieve eco-social resilience, this step by step process was created to streamline design, offer playfulness through adding and subtracting modules, and clarity of programmatic needs, see **Figure 20**. By having the modules in standardized dimensions, one can simply pick and choose to add on whatever programmatic space needed. The standardization of module sizes allows for the tactical addition and subtraction of units with ease. To walk through the process, one would start with step 01 and choose the space arrangement. Step 02 one

would select whatever program needed. Step 03 one would select the necessary services and finally in step 04 one begins to choose your assets and utilities.

3.5 DESIGN FOR DECONSTRUCTION

Incorporating the Design for Deconstruction will play a crucial role in proving whether a circular economy or adaptive housing can be accomplished. The ultimate goal with designing the structure to be demountable will be to show how the modules can be adaptable, circulate their life cycle, and manage the down cycling of materials.

3.6 FOUNDATION AND CORE

A buildings foundation and core are among the most resilient aspects of the structure. For this prototype, helical piers with be used as the foundation to allow for adaptability and circularity, while cores will be precast concrete. The cores will be considered the most consistent element that will remain stagnant through time. Accepting standard building codes and providing accessible paths of egress is important to maintain with an adaptable housing design.

3.7 MATERIAL

The ultimate goal with material is that it is sufficient enough to perform for its function and be downcycled technically or biologically. In an effort to combat CO2 emissions, wood products could be used because they are a renewable resource and its growth takes place in photosynthesis, and not through mining or extraction. Typically, trees grow in most climates, so the ability to set up localized prefabrication sites can be achieved. Not only is wood versatile and durable, but it can also be designed in a way to be deconstructed and reused for other structures or recycled products, resulting in sequestering carbon.

3.8 LIFE CYCLE COMPARATIVE ANALYSIS

The validity of this thesis will be based on not only the design investigation, but also be completing a comparative life cycle analysis with the comparative study of Star apartments. This type of comparative analysis of life cycles will showcase the difference in construction methods over time, how this prototype can truly perform, and the live cycle of the architectural components. The circular time frame and life cycle of a module can vary drastically, depending on use, economy, downcycling, and trends. The ultimate goal of the module is last for as long as necessary until it is reused or downcycled in either a technical or biological cycle. The general time frame of a module is the structure existing anywhere from 30-300 years, the skin and envelope will be applied every 10-50 years, space planning can range from 0-30 years, and finally furniture being the most circulated component, circulating every month to a year, see **Figure 21**. When a module

or components within a module have lived out their life cycle, they will be managed and downcycled through either technical and biological cycles.

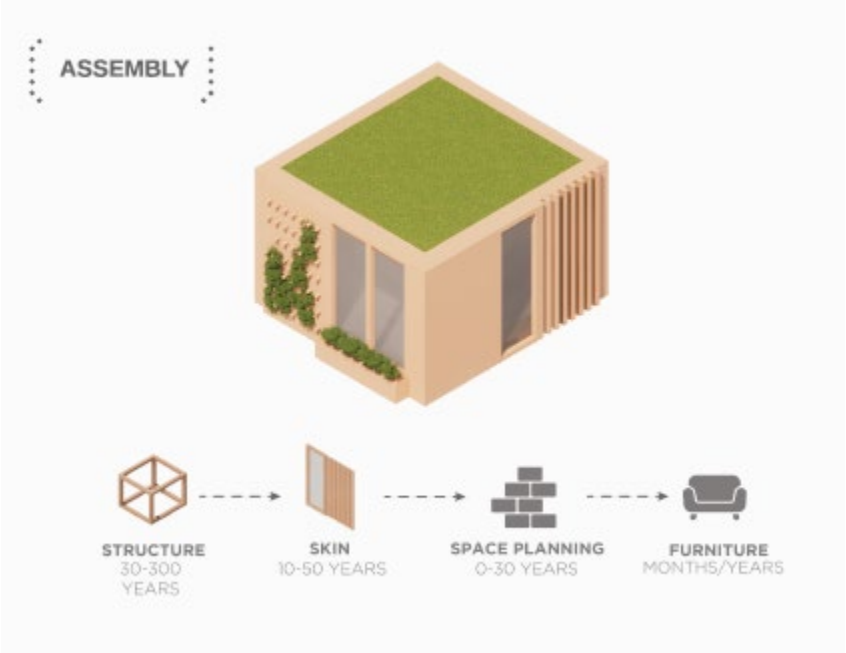

Figure 21: Assembly of module, and lifespan of components

3.9 BUILDING INFORMATION MODELING

Building Information Modeling or BIM for short, will be used to carry out the digital modeling of this prototype. BIM's ability to comprehend modeling information, allows the designer to input materials and quantities of the design into data, which can then be interpreted. This data will be used to conduct the life cycle comparison analysis and to inform design decisions and performance.

CHAPTER 4

4.0 DESIGN INVESTIGATION AND ANALYSIS

These speculative architectural sections are the groundwork to develop the design investigation further and to analyze the components, see **Figure 22**. These sections act as a springboard or a manifesto for a more realistic form of architecture to support the thesis investigation.

Figure 22: Speculative architectural section of the thesis investigation

4.1 FOUNDATION, STRUCTURAL CORE, MODULE DESIGN AND ANALYSIS

The design investigation started by looking into three major components that combined create a form of architecture, that being the foundation ground experience, the buildings

structural core that holds the vertical circulation and systems to serve the building, and lastly the module itself, see **Figure 23.**

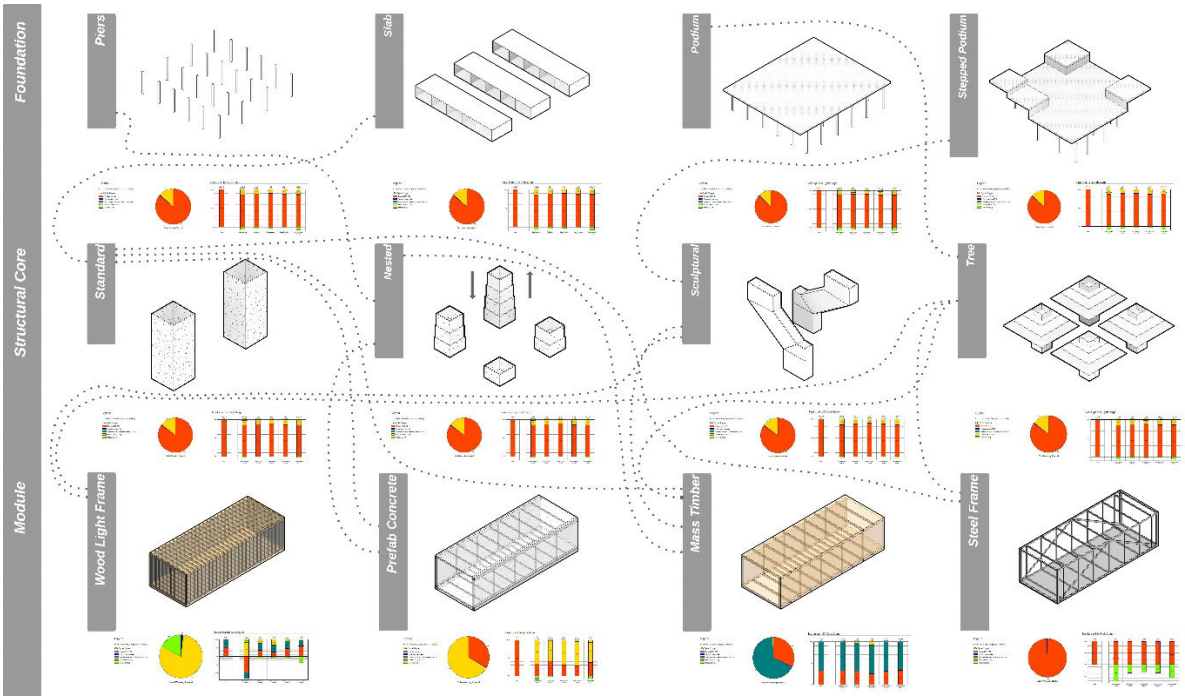

Figure 23: Foundation, Structural Core, and Module design and analysis.

For each of these aspects, the design began with the baseline comparison of star apartments. Star apartments utilized an extensive stepped podium, a sculptural structural core, and wood light frame constructed modules.

After conducting the life cycle analysis and environmental impact test, the result quickly exposed how the extensive stepped podium infrastructure and sculptural structural core had massive global warming potential, represented as red in the charts.

The design intent then was to reduce the infrastructure, by reducing the infrastructure to more basic forms of construction to improve its life cycle and global warming potential. The more the design reduced the foundational support and structural core the closer the results got to reducing the environmental impact and achieving circularity.

This was most notably found while testing the mass timber construction module where it had the lowest global warming protentional and best life cycle of material, due to it being a natural material grown from earth that sequesters carbon and can be downcycled in a biological cycle.

4.2 ITERATIVE DESIGN AND ANALYSIS

Although these components were tested independently, the next step was to see how they would all performed combined together. This design investigation was done by completing iterative design studies, by combining multiple various of the components and conducting the LCA to test the results. After combining various iterations of the components, the design, construction, and results started to show their true colors.

This first set of iterations 1-3 started showing great promise in terms of adaptability and the potential for future growth, see **Figure 24**. The number of potential apartments was 20 more than Star apartments, showing it’s able to grow beyond the comparison study. In terms of the LCA, the concrete modules and structural core began to show its negative life cycle and circularity results. As the design changes to steel, there is better results in the LCA, because of steels ability to be recycled through technical cycles.

Finally, as the design changes to the mass timber modules, the LCA is dramatically showing better results, proving that timber is the most circular material.

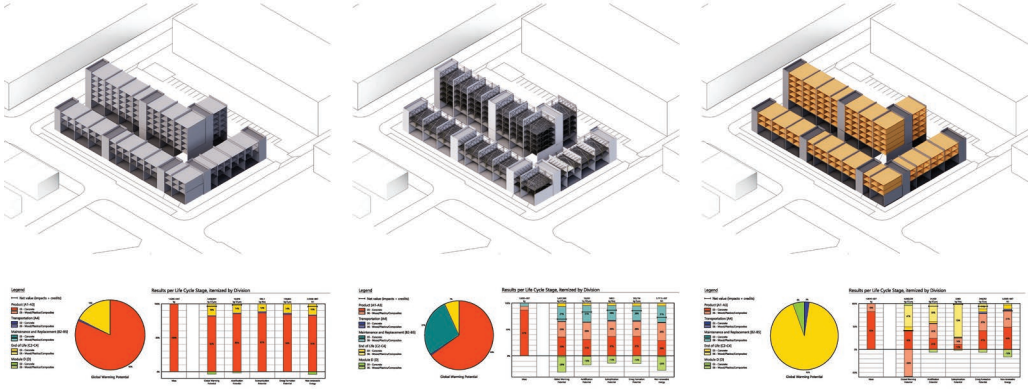

Figure 24: Design iterations 1-3

The second set of iterations 4-6 performed the worse by utilizing an extensive tree structural core and concrete podium, see **Figure 25**. Coincidentally, the mass timber modules started to show overall improvement within the results, despite utilizing an extensive infrastructure.

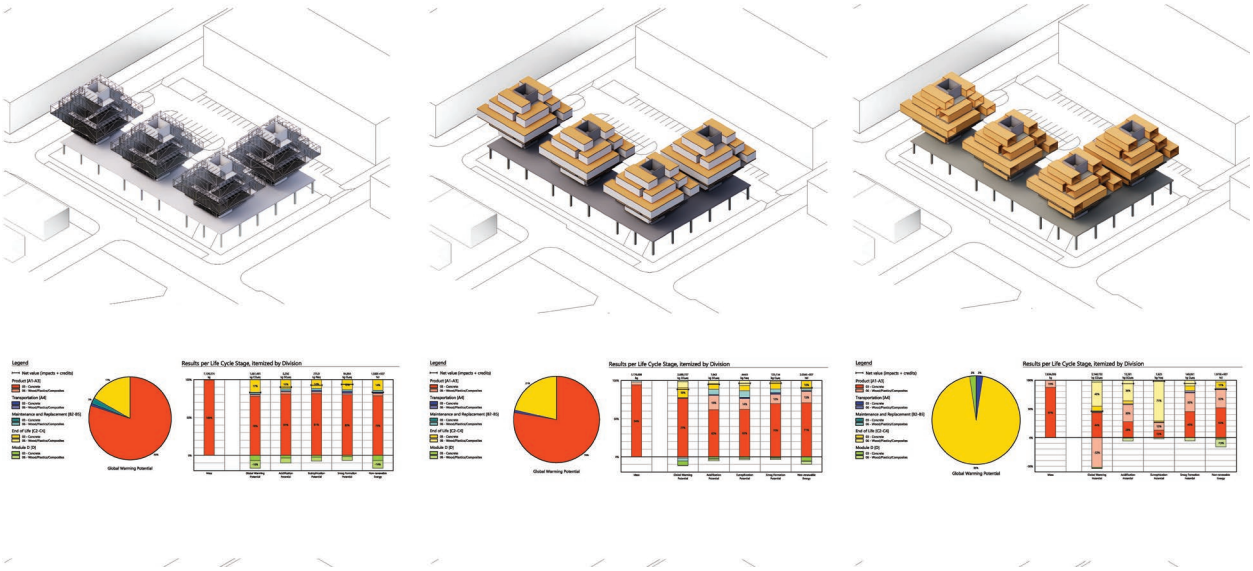

Figure 25: Design iterations 4-6

This third set of iterations 7-9 composed of the stepped podium and sculptural core like star apartments. These iterations showed a lot of promise with adaptability and growth, pushing the number of apartments from 100 to 145 units, well over-performing the comparative study. This set of iterations showed some great results, but especially with the introduction of mass timber, see **Figure 26.**

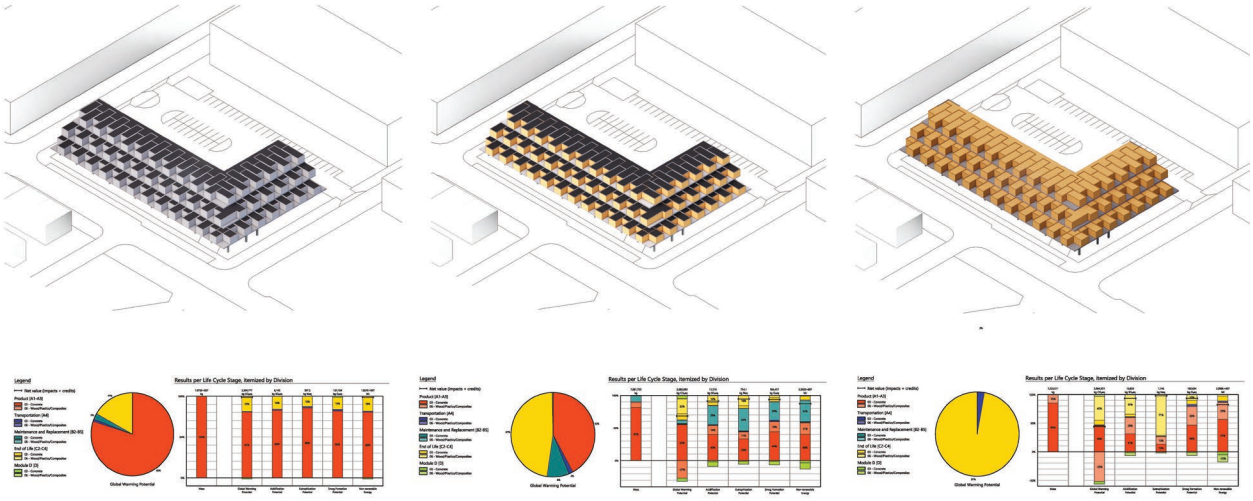

Figure 26: Design iterations 7-9

This final set of iterations 9-12 showed to be the most promising in terms of adaptability and circularity. With this design, the concept was able to into increase the number of modules by almost 75% at 172 modules, the most amount of potential growth and adaptability out of all the investigations. Again, as the mass timber modules were introduced, the better the LCA results were, see **Figure 27**.

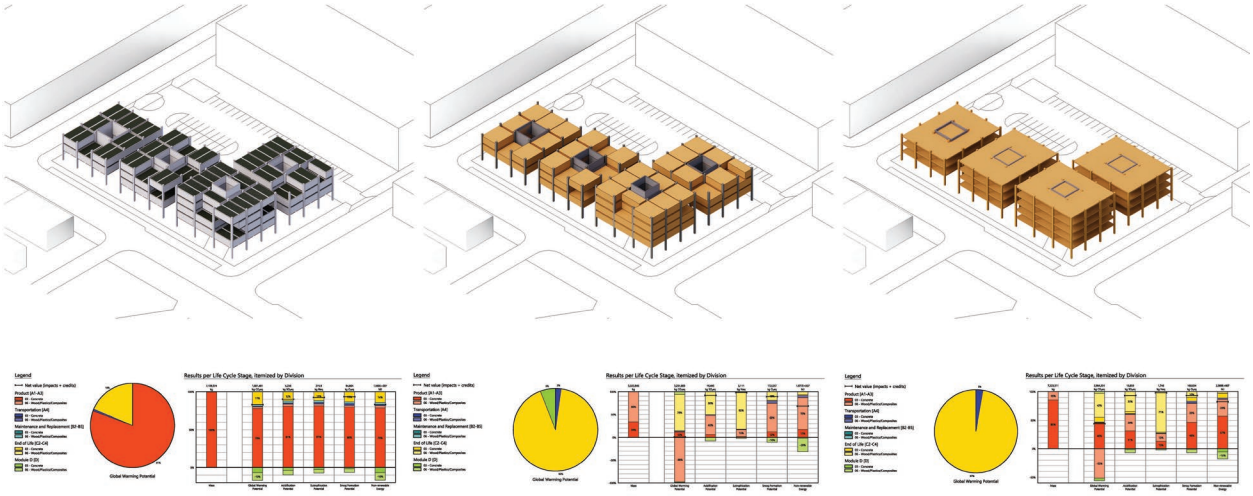

Figure 27: Design iterations 9-12

Iterations 7-9 performed the best in terms of the life cycle analysis as well, especially the last two options where the infrastructure is reduced the most and utilizes the least amount of concrete. I began to take these last two design iterations that were top performers and took them a bit farther to visualize their reality and how they could manifest the thesis. The next step was

4.3 ITERATIVE DESIGN AND ANALYSIS OUTCOMES

Iterations 11 and 12 were the obvious design iterations that showed the most relevant arguments to proving the thesis. They performed the best LCA results and adaptability, supported by prefabrication and modular construction. To further realize the conceptual thesis investigation, design iterations 11 and 12 were developed further to showcase the reality of this concept.

How this architectural proposition could be created would be by utilizing a CLT Mass timber shear wall structural core composing of the vertical circulation and MEP systems, see **Figure 28**. Following the results of the iterative design investigation, the less concrete material the better.

Figure 28: Mass timber shear wall structural core

The phase would be to install all of the supporting structure for the modules like columns, beams, and bracing, utilizing mass timber as well. This supporting structure's design intention would have de-mountable connection to allow for the disassembly in the future, see **Figure 29**.

Figure 29: Mass timber supporting structure

The next phase would be to simply insert a Mass timber module where ever it is needed, due to programmatic needs. The modules would be installed with the intention that they could be built upon and expanded, see **Figure 30.**

Figure 30: CLT Mass timber modules inserted into the supporting structure

Finally, in the last phase, the module is installed a removable façade panel can be installed to keep things weather tight, but also allow for any adaptation in the future, see **Figure 31**. Having a universal façade that is composed of timber allows the component to be universally adaptable and circular.

Figure 31: Removable façade applied

CHAPTER 5

5.0 CONCLUSION

What has been derived the most from this thesis design investigation was the value of having adaptable space to allow for growth and expansion, but also for the inclusion of mass timber for downcycling and recycling of the modules. See **Figure 32.**

Figure 32: Elevation showcasing the open adaptability for growth

Another aspect that was derived to be highly important was the design for disassembly. For architecture to achieve any realistic form of circularity, the connections must be designed in order for it to be disassembled in the future. This could possibly be one of the main reasons why architecture is demolished day after day and ending up in landfills. If the way we designed

buildings was meant to be disassembled instead of demolished, then why would there be the need to demolished and harm the environment?

To make this concept a reality and to ultimately prove this thesis, many hurdles present themselves especially the logistics. One is that prefabrication can take jobs away from local economies and construction unions. The need for the prefabrication to collaborate with the local economies and construction unions are crucial to assisting this concept, and be very difficult. Another major logistical concern is the scarcity and difficulty of utilizing mass timber. Through the design investigation, it was proven that mass timber assisted with achieving a circular economy, but mass timber can be very expensive and often times scarce to particular geographical locations. This leads to the discussion that architects and engineers could start to collaborate with material scientists to create new building materials that have similar properties to mass timber.

This thesis investigation has proven that there is the potential to achieve a circular economy approach within architecture by utilizing mass timber, modular construction, and prefabrication, but it has also proven that it's skeptical if a built structure can be 100% circular it can be very difficult to accomplish, resulting in an endless pursuit to achieve Eco-social Resilience.

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