[Re]Scaling Urbanism

FOSTERING LOW-TECH, DIGITALLY FABRICATED, AND TRANSIENT STRUCTURES THROUGH INNOVATION IN LOCAL RENEWABLE MATERIAL

A DARCH PROJECT SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI'I AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Dedication

To my grandparents, Pete and Peggy Valenti, and Lord William and Charlene Jurado. You have always been my inspiration on my voyage through time.

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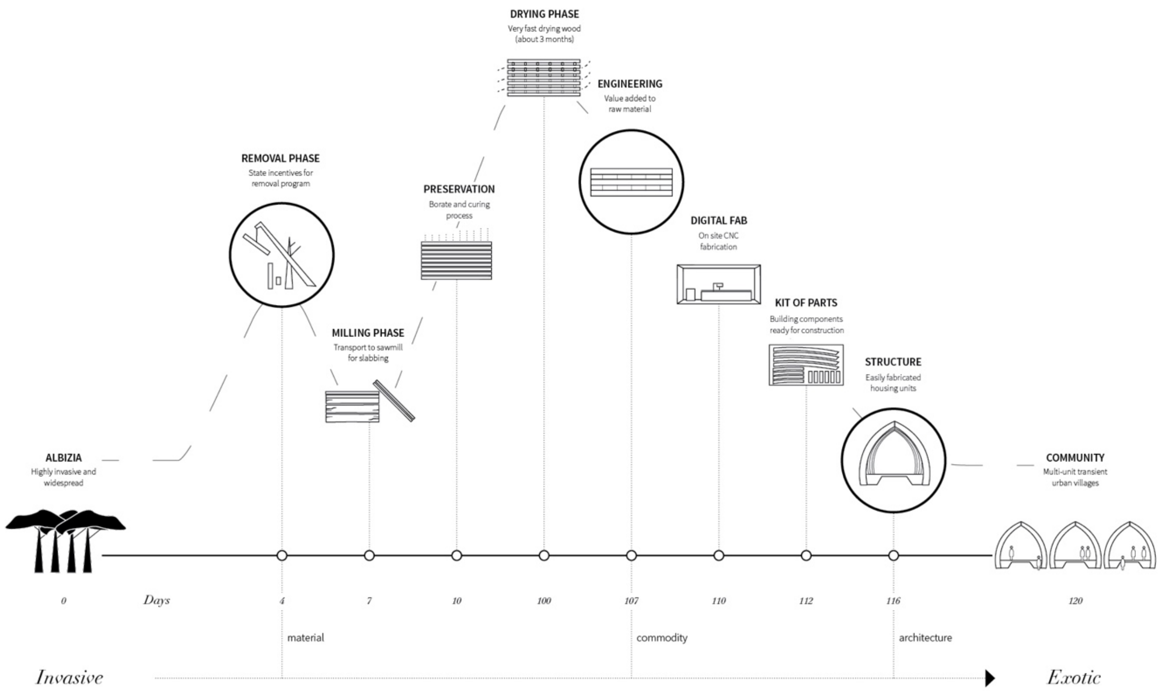
Abstract

This dissertation presumes that innovation in design and sustainable building practices can alleviate environmental and socio-economic issues within cities. Exploration of small-scale design and intelligent systems reveals a connection between local resources and new technologies that advance yesterday's way of building. The study focuses on the challenges of a vulnerable island community, addressing Hawaii's major housing crisis and the effects of impending climate change. Isolation and a global market has encouraged dependency on imports and deterred the state from achieving sustainability.

At the intersection of localized materials and global technologies, this project argues a simple and practical solution. Through a series of case study investigations and applied research on innovative design strategies, it establishes the framework for an alternative building model of less permanent and more process-based structures. *Rescaling Urbanism* reveals the potential for a system that can challenge the existing methods of Hawaii's building industry. The project embraces the use of local material with new technologies in digital fabrication to create a streamlined approach for building sustainably in Hawaii.

To compliment new statewide green initiatives, we must learn to embrace the use of vernacular materials, renewable energies, and closed-loop systems. Hawaii's surplus of invasive tree species bears the potential for local renewable building materials. This study examines the use of lumber from the highly invasive albizia tree as a building

material through application of wood engineering. By reconceptualizing the tree from invasive to useful, a problem becomes a viable solution to Hawaii’s housing deficit and outsourced building industry.



This project integrates the design and construction process by proposing a structure that is composed almost entirely of albizia and digitally fabricated from computer numerically control, or CNC routing. Engineered wood is a resource-light material that supports rapid on-site construction. CNC routing is being increasingly utilized with engineered wood to streamline the entire building process. Merging these two principles enables fabrication of sustainably sourced, high-precision, and easy to assemble building components. The outcome reveals a process that can radically lessen the threshold of scale, cost, and construction time.

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Project Statement

The urban community of Hawaii is undoubtedly among the most unique. On a tropical island with a growing population, Honolulu makes for a desirable place to work and live. However, this secluded life in paradise is not without a cost. Now more than ever, the island is facing a series of compounding issues from houselessness and affordability to oil dependency and coastal vulnerability. While these issues can fall independent of each other, a common thread becomes evident when linked to the built environment and the way we live.

This project aims to collectively explore and analyze Honolulu's tree of interwoven challenges and propose a new system of design for transient and adaptive urban living. Merging advances in technology with the tools of an architect and the craft of a designer, this approach will reach beyond existing typologies to re-envision the way we design and construct buildings.

'Design small, think big' is the fundamental tactic for the project. This approach aims to alleviate growing community needs and public anxiety in the built environment by designing smarter, environmentally mindful, and more humanistic architecture for urban living. Innovative design through digital fabrication, low-impact materials, and renewable energy will be applied. This means prioritizing our local resources to integrate an intelligent, adaptive, and resilient approach that puts our community and the planet at the heart of design.

Project Process

D.Arch I

D.Arch II

Two Parallel Tracks

1) Research

- Problem
- Material
- Case studies
- Field work
- Site mapping
- Analysis
- Application

2) Design

- Approach
- Parameters
- Concept
- Site
- Schematic
- Structure
- Systems

3) Build

- Material development
- Physical model
- Full scale mock-up

Conclusion

Part 1 | Applied Research & Analysis

1. Introduction: Hawaii's Urban Challenges

The urban context of contemporary Hawaii exists not from well thought out planning and design, rather layered decades of architectural experimentation and misconception of public interest. Honolulu falls short of a definitive architectural character. It is a mixed plate of a tropical urban port city and development boom during the Brutalist and Postmodernist movements. The result is an architectural tragedy of heavy concrete structures at dehumanized scales. Buildings leached with AC units on façades make up much of the urban fabric of Honolulu today. Architecture that once was acclimated to Hawaii's natural environment was lost in a wave of artificialized modern society, remarkably symbolic of the island's urban identity and delicate history of territorial overthrows and government strongholds.

In more recent years, Honolulu has started a new wave of development. Waikiki to Kakaako is undergoing a major revitalization phase, making way for a fresh collection of shopping centers, tower apartments, and buildings. Cranes scatter the skyline, with road closures and detours on nearly every block. Yet the island's underlying issues of affordability, carbon dependency, and coastal vulnerability remain neglected. As the city evolves, uncertainties of political, economic, and environmental conditions continue to unfold. As for now, Oahu's urban environment progresses, but its underlying challenges remain.

Current major development projects are at the focus of Honolulu's attention, leaving outlying communities hushed with a few new bike lanes and crosswalks. Yet focus ignores the realities of a population vulnerable to economic and environmental instability. Hawaii's housing crisis is among the worst in the nation, seen vividly through the lens of low-income communities. The unfortunately large pool of houselessness is growing and a real solution is yet to be defined.

Meanwhile, climate change amplifies natural disasters and rising tides, making coastal vulnerability a statewide threat. While these issues are pushed aside for more development, the 'Band-Aid' approach will gradually peel off. The inflated housing market will struggle to support those in need, while displaced families and environmental refugees continue to add weight on the scale.

New buildings will replace the old and vacant lots will eventually extrude into towers. While such big developments symbolize growth and progression, the underlying concern is defined by a question of whether this progression is responding to critical urban issues and will support the needs of a vulnerable community and imbalanced economy.

1.1 An Import Dependent Island Environment

At the center of the Pacific Ocean, the Hawaiian archipelago is the most isolated landmass on earth. While this gives the islands charm and a unique identity, it also makes them heavily import dependent. Before contact, native Hawaiians were self-sufficient and independent of outside resources. Although there were times of struggle and famine, native Hawaiians survived solely off of the land with vernacular materials and sustainable means.

Figure 1.1 Shipping port of Honolulu

Today, with over 1.4 million residents and 8 million visitors annually, Hawaii maintains a high demand for food, fuel, and energy.[1] Contrary to the native ways of self-sustained life, the islands are now almost entirely dependent on imports for survival. Food and oil are among the highest of Hawaii's imported goods. Nearly 90% of the food consumed is imported, weighing in at 6 million pounds a day. If imports ceased, it is estimated that the

[1] Todd Woody, "Food Independence Could Be a Matter of Survival for the U.S.'s Most Isolated State," Takepart, June 29, 2015, accessed October 9, 2015, http://www.takepart.com/article/2015/06/29/hawaii-local-food

population would last approximately one week on available supplies.[2] According to state figures, oil generates 71% of the island's electricity and also fuels ground transportation, commercial aviation, marine transport, and military use.[3] This puts Hawaii in a dangerous bind with the unpredictable swings of oil cost and availability.

Fortunately, Hawaii is now setting high targets for achieving clean energy in the coming years. As an ideal place for harvesting nearly all renewable energies, new state bills are in place, with the backing of current Governor David Ige, to make Hawaii state the first in the nation to achieve 100% renewable energy by 2045.[4] This change could not come any sooner, as fears loom around an uncertain future due to global climate change. With a clear vision of the years ahead, Hawaii is gearing up for big changes in the post-carbon era.

1.2 [House]lessness in Honolulu

While imports and energy needs are among Hawaii's leading challenges, houselessness is another burden that weighs heavily on the population. With the greater Honolulu area as

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[2] Ibid

[3] Hawaii State Energy Office, "Hawaii Energy Facts & Figures," November 2014, accessed October 28, 2015, http://energy.hawaii.gov/wp-content/uploads/2014/11/HSEO_FF_Nov2014.pdf

[4] Governor.hawaii.gov, "Press Release: Governor Ige Signs Bill Setting 100 Percent Renewable Energy Goal in Power Sector," June 8, 2015, accessed November 5, 2015, http://governor.hawaii.gov/newsroom/press-release-governor-ige-signs-bill-setting-100-percent-renewable-energy-goal-in-power-sector/

the most desirable place to work and live, it is no surprise that it tops the nation's housing crisis. It is a problem widely criticized, yet lacks tangible solutions. As a statewide struggle saturated by affordability, the unbalanced ratio of income and housing costs lay burdened on local residents. Families are often pressured to relocate while some are driven to the streets. An affordability crisis is flooding the state and the impact is compounded by an array of underutilized spaces, vacant parcels, and parking lots scattered across the urban fabric.

Affordability

The problem of affordability has been increasingly impacting Hawaii in recent years. According to the U.S. Department of Housing and Urban Development, Honolulu rents have more than doubled in just 10 years, from an average of $904 in 2004 to $1820 in 2014.[5] Additionally, home prices have reached all-time highs, with Honolulu currently among the most expensive housing markets in the nation. As the problem worsens, so does the likelihood of resolving it. While state legislature continues to address the need for affordable housing, there are currently few known plans for such developments. The table on the following page reveals that the current number of state-assisted housing units falls well below units needed.

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[5] Anita Hofschneider, "Just How Bad is Honolulu's Housing Crisis?" October 23, 2014, accessed November 5, 2015, http://www.civilbeat.com/2014/10/just-how-bad-is-honolulus-housing-crisis/

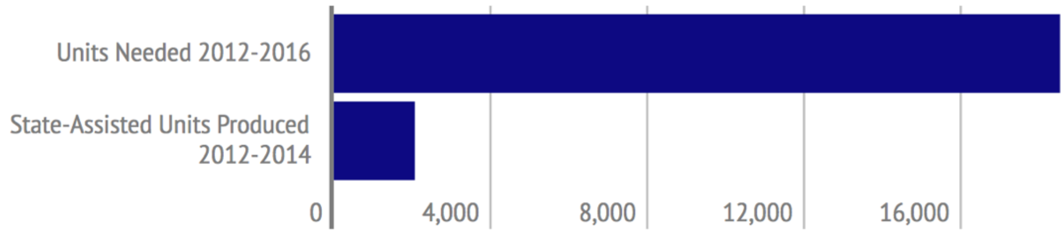

Table 1.1 Honolulu low-income housing: units needed to units provided

Although Hawaii's median household income levels are nearly 27% higher than the national median, the median of owner-occupied housing units is 181% higher than the nation's average.[6] Thus, heavily offsetting residents' qualification for government-assisted housing opportunities and further diminishing affordable housing options through supplemental income. A 2011 study found that 70% of Hawaii's housing demands are from low-income residents, indicating that the vast majority of local residents are, in fact, houseless.[7]

Affordability is often directly tied to political, social, and economic drivers. It is a challenge developers, state legislators, and designers alike regularly try to avoid. This study addresses the challenge head on and approaches it on a humanistic and incremental scale. Rather than top-down tactics, it will investigate an approach that works from the bottom up by merging short-term solutions with locally sourced materials, innovative design technologies, and streamlined construction techniques.

[6] Jennifer Nishio, "Redefining Hawaii Urban Housing and Affordability Through Adaptive Reuse, Prefabrication, Lifecycle Building and Flexible Design" (DArch diss., University of Hawaii at Manoa, 2012) 4.

[7] SMS Research & Marketing Services, Inc., "Hawaii Housing Planning Study, 2011," November, 2011, accessed November 6, 2015, http://files.hawaii.gov/dbedt/hhfdc/resources/HHPS2011%20study.pdf

Homelessness and Immigrant Families

Homelessness has undeniably become Hawaii's most critical contemporary issue. In the midst of an economic crisis, the state is facing its biggest challenges yet. Hawaii's Governor has recently declared a state of emergency on homelessness with the severity reflected by the nearly 5,000 homeless on Oahu alone. Shown in Table 1.2, a study conducted by the City of Honolulu reveals that the problem is progressively increasing.[8]

	Sheltered		Unsheltered		Oahu Total
	#	%	#	%	#
2015	2,964	60%	1,939	40%	4,903
2014	3,079	65%	1,633	35%	4,712
2013	3,091	68%	1,465	32%	4,556
2012	3,035	70%	1,318	30%	4,353
2011	2,912	69%	1,322	31%	4,234
2010	2,797	67%	1,374	33%	4,171
2009	2,445	67%	1,193	33%	3,638

Table 1.2 Oahu homeless summary 2009-2015

While some may choice homelessness, many Hawaii families are on the street largely due to affordability issues. Encampments are growing in central neighborhoods throughout Honolulu. They can be seen clustered along streets from Kakaako to Kapalama. When assessing the demographics, Pacific Island decedents are among the vast majority of in these areas.[9] It is partly due to an increasing number of Micronesian and other Pacific Islanders immigrating to Hawaii. They often move in search of new economic

[8] City & County of Honolulu, "Homeless Point-in-Time Count 2015," April, 2015, accessed November 6, 2015, http://humanservices.hawaii.gov/bessd/files/2012/12/PIT-Oahu-2015-PIT-Report-Rev-4.18.15.pdf, 7.
[9] Chad Blair, "An Untold Story of American Immigration," Civil Beat, October, 2014, accessed November 14, 2015, http://www.civilbeat.com/2015/10/an-untold-story-of-american-immigration/

opportunities, better healthcare, and education for their children.[10] Provided by the UH Manoa Department of Urban and Regional Planning, Figure 1.2 shows a breakdown of the ethnic composition of two major homeless neighborhoods in Honolulu.

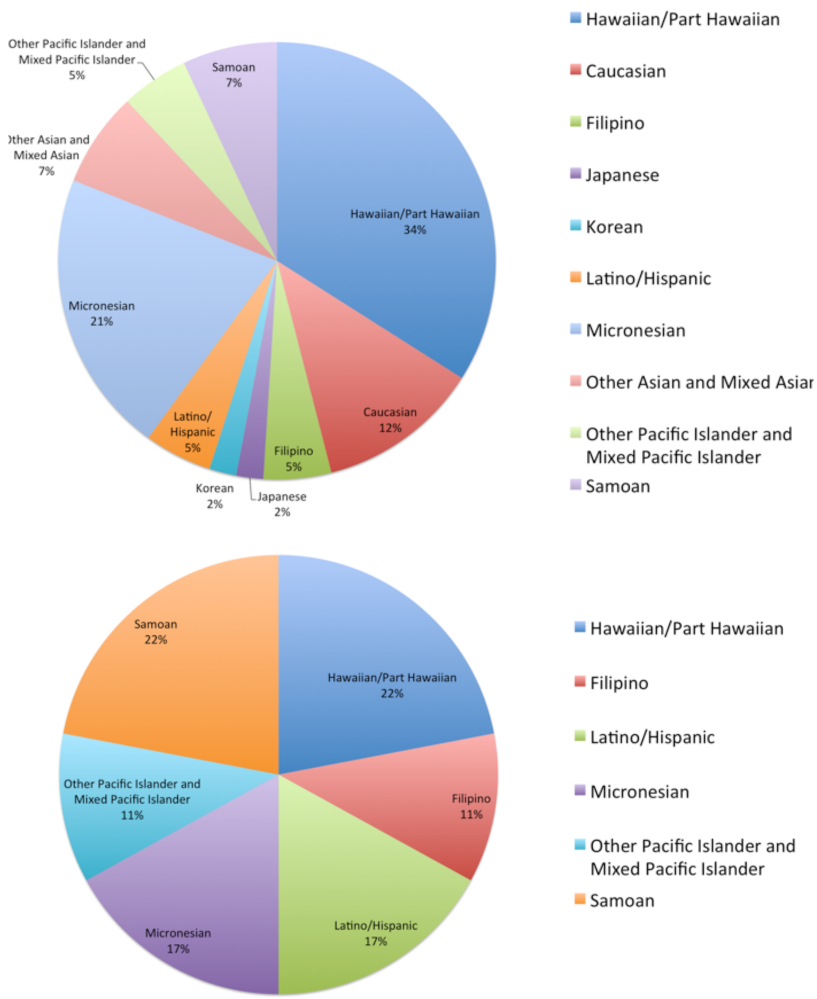

Figure 1.2 Ethnic composition of Kakaako [above] & Kapalama [below] homeless 2015

To add to the issue, data-backed predictions are forecasting a significant influx of immigrant families over the coming decades. Along with economic motivation, saltwater

[10] Ibid

inundation from climate change and other implications of sea level rise exacerbate the need to relocate. Impacts are now being realized, as populations are forced off their land and out of their homes. With the Compact of Free Association (COFA), Micronesia and other Pacific Island nations have rights to move and work freely in the United States.[11] Better infrastructure, a similar island culture, and more opportunities for work makes Honolulu a top choice for relocation.

Underutilized Urban Space

On the western outskirts of Honolulu, between downtown and the airport, industrial warehouses, undeveloped land plots, and empty parking lots scatter the urban fabric. Shifting east of downtown, a revival plan for Kakaako has brought a transformation of what was once similar to the more industrial Honolulu area. Recent years have shown a spike in development, with loads of funding invested in Kakaako, Ala Moana, and Waikiki. While these neighborhoods continue to see growth and change, outlying districts await revitalization.

As the construction of the rail makes its way to the city center from West Oahu, Transit Oriented Development (TOD) is planning for community-focused improvements. Meanwhile, fenced plots of land and empty parking lots remain abandoned and unused. Areas like Kapalama and Kalihi remain underdeveloped in a predominantly industrial

[11] Ibid

setting. With the demographics of these areas weighted heavily toward the low-income bracket, it is home to many Pacific Island immigrant families. TOD proposals claim to have a revival plan in sight, but as of 2016 a vast array of urban spaces will remain underutilized.

1.3 Disaster Preparedness and Sea Level Rise

Vulnerability

Set atop a volcanic hotspot in the Pacific Ocean, Hawaii is a particularly vulnerable island population. It is susceptible to various natural disasters including earthquakes, tsunamis, hurricanes, and flooding, which could occur unexpectedly and without warning. Fortunately, Hawaii has initiatives in place for natural disaster that consist primarily of educational programs and emergency preparedness organizations. The National Domestic Preparedness Training Center or NDPTC at the University of Hawaii is teamed up with FEMA and other external partners to develop a safer response system for Hawaii.[12] These groups are currently working to improve the strategic framework for Hawaii's disaster preparedness.

[12] NDPTC, "Strategic Planning Framework," September, 2010, accessed November 17, 2015, https://ndptc.hawaii.edu/media/files/NDPTC_Framework_2010-09-30.pdf, 12.

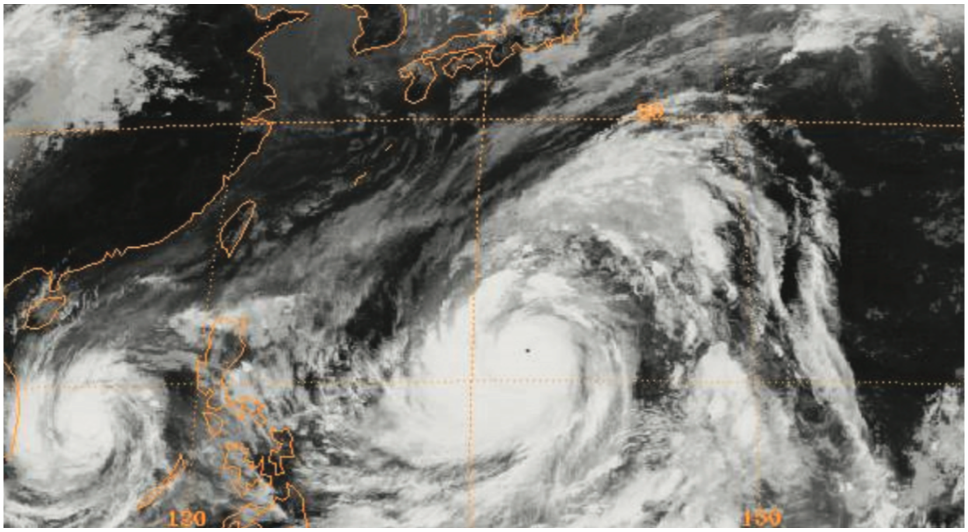

Figure 1.3   Satellite image of hurricanes in the Pacific Ocean (NOAA)

Post-Disaster Resilience

If a disaster were to strike Hawaii, the state capital would be the most vulnerable region. While Oahu is home to the majority of Hawaii's residents, much of its infrastructure is susceptible to disaster and flooding. Although a handful of buildings in the Honolulu area are able to double as shelters in emergency situations, the infrastructure would likely fall short of providing sufficient post-disaster housing. Immediate safety would be the priority, yet the days and months to follow would lack temporary housing and infrastructure solutions.

The built environment should be adaptive and responsive to approaching challenges. In planning for resilience, it is imperative to support designs that are adaptive to progressive change and unanticipated events. The former responds to issues such as sea level rise and economic instability, while the latter supports preparedness for unpredictable natural disasters. Resilience for progressive change embraces the impacts, assuming they will last, and responds accordingly. Alternatively, resilience planning for disasters generally assumes the impact is temporary and expects a return to normalcy.

Sea Level Rise Implications

As a low-lying coastal city, Honolulu will soon be faced with challenges of sea level inundation. Global warming impacts climate change and accelerates sea level rise. Such behavior has a range of adverse affects that pose a major threat to coastal areas around the world. Scientific findings predict Hawaii and other Pacific islands may be among the most impacted regions in the coming years. According to a report by Dr. Chip Fletcher at the University of Hawaii at Manoa (UHM), the past century has revealed an average of 0.6 inches of sea level rise per decade in Hawaii.[13] This rate may not seem significant in the short-term, yet long-term data indicates profound implications. By mid-century sea levels may rise one foot and up to 3 feet by 2090.[14]

Table 1 – Schedule of sea-level rise 2011 to 2100		
	Worst case	Best Case
1 ft	2040	2050
2 ft	2050	2070
3 ft	2070	2090

Table 1.3 Projected global mean SLR: best and worst case scenarios

[13] Chip Fletcher, "Hawaii's Changing Climate," Briefing Sheet, 2010, accessed November 22, 2015, http://www.soest.hawaii.edu/coasts/publications/ClimateBrief_low.pdf, 4.
[14] Chip Fletcher, SOEST, "Sea Level Rise Hawaii: Hawaii's Changing Climate," accessed November 22, 2015, http://www.soest.hawaii.edu/coasts/sealevel/index.html.

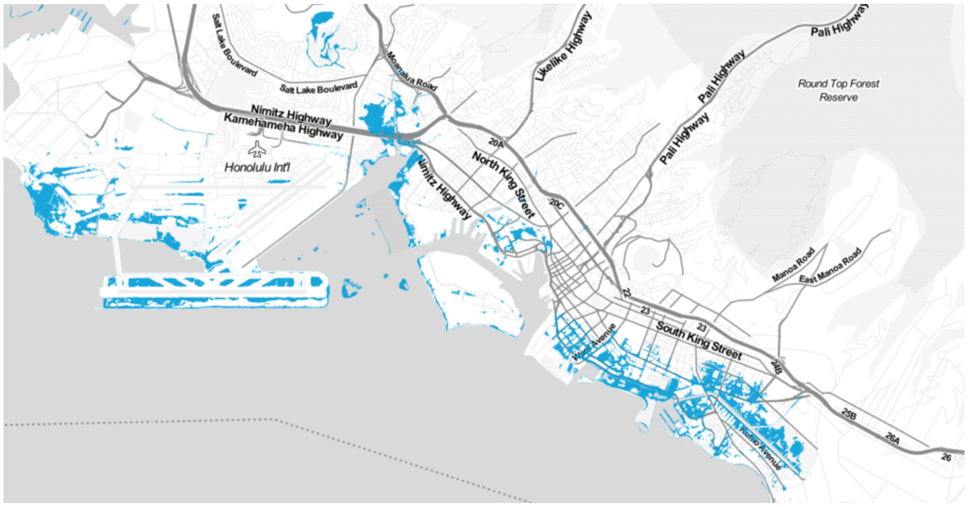

Figure 1.4 Honolulu SLR scenario at 1-m (3+ ft) rise

It is now more necessary than ever to address how the current infrastructure and upcoming building developments will respond to such issues as sea level inundation, flooding vulnerability, and natural disasters. It is not a matter of if, but when Hawaii will be faced with these challenges and how we will mitigate the impact. In contemporary society knowledge is abundant and predictions backed by science, thus we have no excuse for unpreparedness. Now is the time for Hawaii to shift its focus towards building for a resilient future.

1.4 Anticipated Futures

Buildings have always been shaped by the environment and inhabitant behavior. Until recently, human and environmental behaviors were relatively consistent. Buildings were designed on the assumption that change was gradual and society was predictable.

Modern society has evolved to a point where change is rapid and difficult to forecast. Succeeding the Industrial Revolution, the new world of advanced technologies and scientific breakthroughs still greatly relies on fossil fuels and unsustainable practices. Climate change and environmental degradation continue to accelerate. With emerging impacts, mankind must adapt to its own creations. As we shift into a post carbon era, the world is shadowed by a time of uncertainty with growing concerns for energy, extreme weather events, warming temperatures, and rising tides.

Alternative Futures and Projected Trends

An article by Jim Dator, professor and specialist in Futures Studies at UHM, discusses the importance for application of projected futures in design. His paper, "Alternative Futures of the Architectural Profession," argues that architects are a critical factor in productively shaping our society. Now more than ever, architects and planners must design for the present while remaining adaptable to anticipated futures.

As we enter a future of uncertainty, a new set of challenges emerges. Dator argues that "we must reflect, plan, design, and build on the basis of a 'preferred future' that has been determined only after we have undertaken a careful consideration of the challenges and opportunities before us based on our engagement with specific examples of each of the four generic alternative futures."[15]

The four alternative futures titled *Grow, Collapse, Discipline,* and *Transform*, were defined from a well developed set of determinants and drivers of social and environmental change.[16] They are based on a coherent understanding of past and present driving forces for how society and the environment are adapting and evolving. Each scenario is influenced by various forces including energy, technology, economy, and governance. The composition of forces for an alternative future qualitatively underlines their differences and defines the implications of each. This process is exemplified in Table 1.4 from a matrix created for a "UH Manoa Campus 2060" futures study.

Futures:	*Grow*	*Collapse*	*Discipline*	*Transform*
Forces:				
Population	Increasing	Declining	Diminished	Posthuman
Energy	Sufficient	Scarce	Limited	Abundant
Economics	Dominant	Survival	Regulated	Trivial
Environment	Conquered	Overshot	Sustainable	Artificial
Culture	Dynamic	Stable	Focused	Complex
Technology	Accelerating	Stable	Restricted	Transformative
Governance	Corporate	Local	Strict	Direct

Table 1.4 Four generic futures and their values based on seven driving forces

[15] Jim Dator, "Alternative Futures of the Architectural Profession," in Mitra Kanaani, ed., *Handbook for Architecture Design and Practice: Established and Emerging Trends*, Routledge Press, 2015, 551.
[16] Ibid

In considering futures, it is important to identify and project trends of the past and present that have shaped the given environment. This identification process includes,[17]

- Historical driving forces
- Factors of past and present driving forces
- Identification of "emerging issues"
- Identification of plausible trajectories for emerging issues
- Weaving of information from past, present and futures
- Not relying entirely on projections or trends

Arriving at a Clear Vision for Hawaii's Future

By acknowledging the current and future challenges Hawaii faces, we can begin to define the projected values of various driving forces. These forces of past, present, and future, make up the many factors that influence the social stabilities and changes of Hawaii's unique environment. In accordance with the four generic futures as defined in Dator's work, I have highlighted three that predominantly relate to the research of this project (Table 1.5).

[17] Ibid

Futures:	*Grow*	*Collapse*	*Discipline*	*Transform*
Forces:				
Population	Increasing	Declining	Diminished	Posthuman
Energy	Sufficient	Scarce	Limited	Abundant
Economics	Dominant	Survival	Regulated	Trivial
Environment	Conquered	Overshot	Sustainable	Artificial
Culture	Dynamic	Stable	Focused	Complex
Technology	Accelerating	Stable	Restricted	Transformative
Governance	Corporate	Local	Strict	Direct

Table 1.5 Three of the related generic futures based on values

The *Grow* alternative, highlighted above in orange, would be more or less a scenario of continued success. The best example of this would be present day Singapore–a thriving island community that has grown into a global economic hub and highly developed society. However, based on the related issues discussed earlier in this chapter, both *Collapse* and *Discipline* define two possible scenarios for Hawaii. These two are highlighted together in red, as they are seen as the most co-related of the four.

Hawaii is currently lacking security in food, energy, economic, and environmental sustainability. As a result, initiatives are being introduced that promote a shift towards a self-sufficient and sustainable island community. These trends run parallel to the values found in the *Discipline* scenario. Moreover, Hawaii is particularly vulnerable to unanticipated events that may affect imports and the safety of the population. If Hawaii were to experience a disaster situation, *Collapse* would be most in line with the projected future.

Regardless of the actual outcome, understanding potential impacts of alternative futures and implementing them into our built environment framework is instrumental in designing for a better tomorrow. There is no better time to start thinking transformatively and intuitively, not only to improve current conditions, but also to adhere to the growing agenda in architecture for resilient and sustainable design.

1.5 In Conclusion

To arrive at an optimized vision for Hawaii's urban community, we must begin raising questions that foster productive change. The questions noted below are intended to be the concluding remarks of this chapter and will be answered in the subsequent chapters. Thus, the research and design carried out in this project aims to foster an alternative solution to the urban challenges addressed in this paper. One that looks beyond the existing building systems and responds to Hawaii's economic instabilities, import dependency, and communities struggling with housing affordability. The questions are as follows:

> How can we implement a framework that allows for cost-efficient, holistic, innovative, self-sustaining, and dynamically integrated structures? How can the buildings we shape today begin to re-shape themselves in response to environmental change and human needs of future generations? How will future buildings address Hawaii's key issues relating to its high-carbon footprint, import dependency, houselessness, and

vulnerability to natural disasters and rising sea levels? Is there an alternative approach that could stimulate Hawaii to evolve and progress into a more adaptive and socio-economically sustainable island state?

2. Adopting a Hybrid Solution for Hawaii

As discussed in Chapter 1, the urban context of Hawaii cultivates various current and emerging challenges that the city must learn to address. To construct an improved future for all, we must learn to design alternative methods for resolving the social, economic, and environmental issues at hand. Through referencing case studies and theories on relevant challenges faced in other communities, we can begin to construct a patchwork of solutions unique to the local issues in Hawaii. By question the effectiveness of our current paradigm, we can begin to look broader and discover novel solutions to the barriers that lie ahead.

This project aims to raise questions on the issues of houselessness, climate change, and architectural resilience in Hawaii, to establish an alternative approach and viable solution. A set of criteria will be defined on the basis of transformative thinking for a new design approach that challenges the absence of current solutions and the uncertainties of *permanent* new developments. Contrary to current top-down protocols of high-end towers and unsustainable urban planning, an alternative small-scale, decentralized, and agile approach will be implemented that prioritizes community interests and explores unforeseen opportunities through such trends as *tactical* and *temporary urbanism*.

The resulting opportunities should embrace Hawaii's potential for use of vernacular materials, renewable energies, closed-loop systems, and innovative technologies. Based on these, the research ahead will integrate carefully selected precedents as influential material to define an appropriate building model for the previously addressed issues. It will aim to establish a framework for innovative design in livability, construction, and environmentally-responsive off-grid structures.

2.1 Thinking Small

A Low-Cost, Small-Scale Approach

Tactical urbanism is an urban movement that has recently been gaining recognition around the world. It has received much attention for its low-cost, short-term, and scalable approach to improving urban communities. The overarching goal pursues equity within communities, initiating reclamation, redesign and reprogramming of underutilized spaces. The values of tactical urbanism are defined within the citizen-led movements that quickly and effectively bring creative, small-scale solutions to urban neighborhoods. Resulting success stories have often led to broader social impacts. It provides a means of market analysis, data collection, and regulation-bypassing for developers, governments, and entrepreneurs to gain the support and better serve their communities.[18]

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[18] Mike Lydon and Anthony Garcia, Tactical Urbanism: Short-term Action for Long-term Change, 2015, 3.

Figure 2.1 Tactical urbanism allows for activation from all angles

Recently, urban planners Mike Lydon and Anthony Garcia published a book called, *Tactical Urbanism: Short-term Action for Long-term Change*. The book sheds light on the new urban movement, illustrating how tactical urbanism shifts away from the generic one-size-fits-all approach to city planning large developments. It rejects the assumption that any challenging forces affecting cities can be conquered by designing large and permanent structures. Tactical urbanism takes a holistic approach that "embraces the dynamism of cities" and integrates "intentional and flexible responses."[19] The concept

[19] Ibid

illuminates the need for more dynamic and elastic communities while encouraging a versatile model that embraces inevitable change and adapts with future generations.

Case Study #1 | Double Happiness: An Installation by Architect Didier Faustino

SHENZHEN–HONG KONG

A symbol of the potential for reactivating ubiquitous urban infrastructures, the converted billboard was displayed at the Shenzhen-Hong Kong Bi-City Biennial of Urbanism and Architecture as a statement for community empowerment. It signifies the enabling of urban inhabitants towards reclamation of public space through small, but effective interventions.

Tactical Urbanism in Honolulu

Honolulu is currently getting a taste of grassroots urban renewal movements such as tactical urbanism. Prior to the latest developments of the recently popularized Kakaako district, the neighborhood had a distinct character of gritty body shops and industrial warehouses. As a foreseen opportunity by big name developers, it has quickly transformed into a vibrant and trendy art district with a fresh brand and colorful charm. Local artisans, graffiti artists, and designers were recruited to brighten the dark alleys and renovate the once run-down streets into an urban hotspot.

While the transformation has offered measurable results to Kakaako's value, it must be noted that the intentions behind this revival were not in line per se, with the values of tactical urbanism. The Kakaako redevelopment plan was, in all transparency, a profit-driven approach mainly targeting large-scale development projects. Tactical urbanism proves to be much more along the lines of citizen-led and community-centered movements that demonstrate small-scale and flexible responses. That said, the Kakaako revitalization project is best described as a top-down, money-driven approach with fragments of tactical urbanism.

However, other initiatives in Honolulu are more aligned with tactical urbanism. Food trucks, pop-up shops, farmer's markets, new bike lanes, and other citizen-driven actions are becoming an integral part of Honolulu's community. Underutilized spaces are finding a new purpose as vendors continue to transform them into popular community events.

The food truck movement in particular, has proven quite successful in utilizing vacant lots and empty surface parking as valuable spaces. Increasingly popular events such as “Eat the Street” and “Makers & Tasters” have even turned into more permanent engagements.

Case Study #2 | Makers & Tasters: Outdoor Food Truck Venue and Bar

KAKAAKO–HONOLULU, HAWAII

BEFORE (ABOVE) AND AFTER (BELOW)

A once abandoned lot awaiting a many-year delay for redevelopment, has recently transformed into a citizen-led food truck market platform named Makers & Tasters. This not-so-temporary venue has taken an otherwise unused harbor-front site and allowed for an interim community-profiting, social space.

Small-Scale Tactics for Empowering Communities

Seeded within the tactical urbanism objectives, communities can be placed at the heart of design. Citizens become empowered and encouraged to move forward on issues that would otherwise lie static. By utilizing the effectiveness of smaller-scale, flexible and integrated design, tactical urbanism proves that big change can come from small actions. With a growing recognition of the newly coined term, cities around the world are embracing the potential of tactical urbanism.

The design small movement is not just embraced by tactical urbanism. In the last few years, scaling down has continued to build momentum. One major contributor is the *tiny house* movement, which encourages people to simplify their lifestyles and rethink priorities. Tiny home enthusiasts argue that vanity has masked affordability with excess, and the solution is to scale down to less cost-intensive living conditions. Doing so would allow for more affordable and economical housing while reducing the building industry's carbon footprint. Since tiny houses are typically less than 400 square feet,[20] the possibility of designing and building one's own home is also an attractive feature.

Another emerging trend that is promoting both small-scale integration and community empowerment comes from a fresh perspective of young designers. These design pioneers are offering an alternative architectural typology through innovation in digital technology and scale. Architect and founder of WikiHouse, Alastair Parvin, has set out to

[20] Tiny House Community, "Tiny House FAQs: What is a Tiny House?" 2015, accessed December 15, 2015, http://tinyhousecommunity.com/faq.htm#what

make architecture accessible to the other 99 percent of populations that are most often ignored. In his TED Talk, "Architecture for the People by the People," Parvin argues that rather than limiting the design of our built environment to large corporations and developers who build cities on our behalf, we should empower the ones who are living in it.[21]

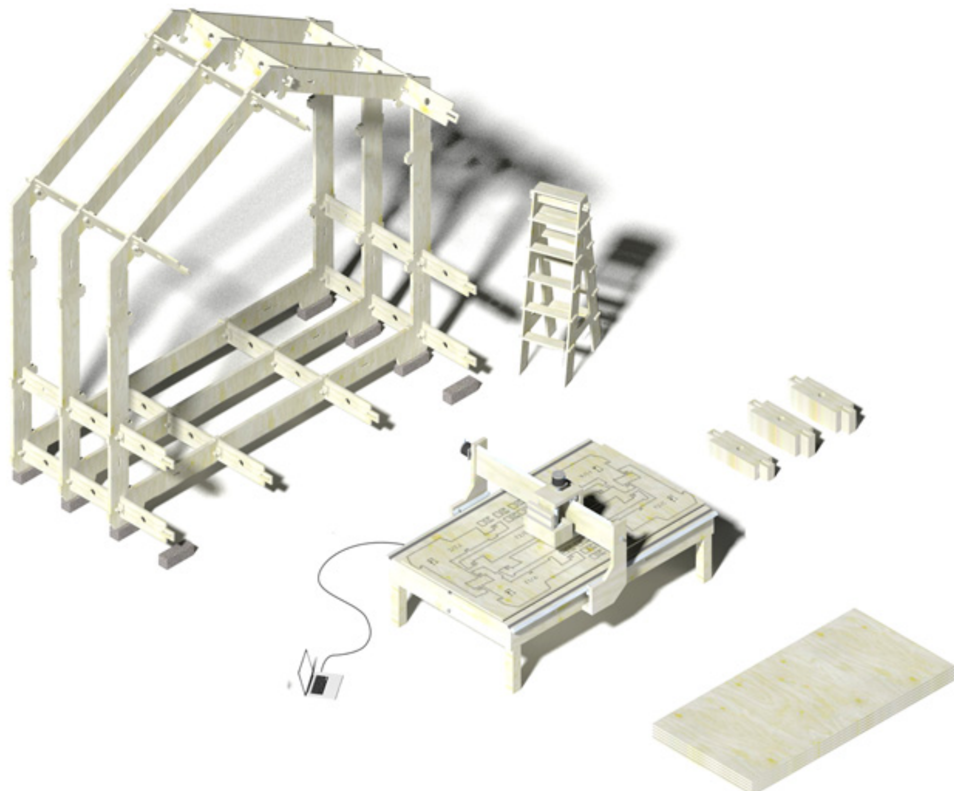
Alastair's theory rejects the one-size-fits-all approach of single monolithic projects and neighborhood developments that often discard affordability, livability, and ecological urbanism. Such developments are no longer working to resolve the health, sustainability, and climate change issues that are affecting our cities. Instead, we must begin to design with, not for, and through a system that provides the tools and infrastructure for architecture's social economy.

WikiHouse is proposing is an open-source building solution by utilizing the Internet, digital technologies, and resource-light materials. The new platform allows nearly anyone to upload, download, and build affordable housing through software and hardware freely shared on the Internet. Design is streamlined with technology to unlock the means of production for easier citizen-led developments all shared under a Creative Commons license. Using computer numerical control (CNC) routing and sustainable building materials such as plywood, anyone with access to a 3D machine can print out a simplified kit of building parts and press-fit them together.

[21] Alastair Parvin, "Architecture for the People by the People," TED Talks, 2013, accessed December 4, 2015.

Case Study #3 | WikiHouse: Open-Source Building System

London, United Kingdom



The WikiHouse platform can "radically lower the thresholds of cost, time, and scale" to resolve major structure and infrastructure problems like "off-grid energy, off-grid sanitation, low-cost, open-source, high performance solutions."[22] In just a few short years, the WikiHouse Project has expanded to a number of chapters around the world–each helping to resolve various community based issues.

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[22] Ibid

2.2 Building Smarter

The Rise of Digital Fabrication

With emerging technologies, design and construction are shifting towards digitally assisted processes. More so now than ever, the ways in which architecture is constructed is rapidly expanding alongside computer programs and digital machinery. Programs for 3D modeling and photorealistic rendering offer rapid design development and precise displays. We can design something entirely digital and in the same day fabricate it at full-scale with a 3D printer or a computer numerically controlled (CNC) machine. This production process is called digital fabrication.

In the book, *Digital Fabrications: Architectural and Material Techniques*, Lisa Iwamoto describes it as having "spurred a design revolution, yielding a wealth of architectural invention and innovation."[23] Digital fabrication offers a do-it-yourself approach to architecture, giving designers freedom for pioneering new techniques and methods with minimal human error, rapid production and highly efficient construction. The small scale production processes, generally linked to the size of the fabrication machines, put digital fabrication within reach of both professionals and students.

Digital fabrication technologies are now integrated into schools of architecture across the globe as an integral part of the design process. The School of Architecture at UH Manoa

[23] Lisa Iwamoto, Digital fabrications: architectural and material techniques. Princeton Architectural Press, 2013.

offers a number of courses on the digital tools and technologies relating specifically to digital fabrication. It provides student access to laser cutters, 3D printers, and a large CNC machine. Students at nearly any established school depend on these tools for designing and fabricating project models, furniture, building parts and full-scale mock ups. As these technologies mature, the tools become cheaper and more readily accessible.

On the professional side, digital fabrication is also becoming more commonly integrated into practices. Firms are willing to invest in the latest technologies to effectively compete. While computers are used in nearly every step of the design and construction process, digital fabrication becomes the bridge for turning digital data into reality. The computer delivers the data to the machine, be it a CNC or 3D printer, and the machine creates the parts.

CNC Routing as a Contemporary Approach to Modular

Also known as computer-aided manufacturing (CAM), digital fabrication, in simplest terms, uses either an additive or subtractive manufacturing process. 3D printing adds material and is typically limited to just a few material options. CNC routing on the other hand, uses a subtractive process and can work with nearly any material. CNC machines are also faster, flexible in function, and increasingly common in building fabrication. As a viable approach with feasibility and material access in Hawaii, CNC technology is emphasized in this section.

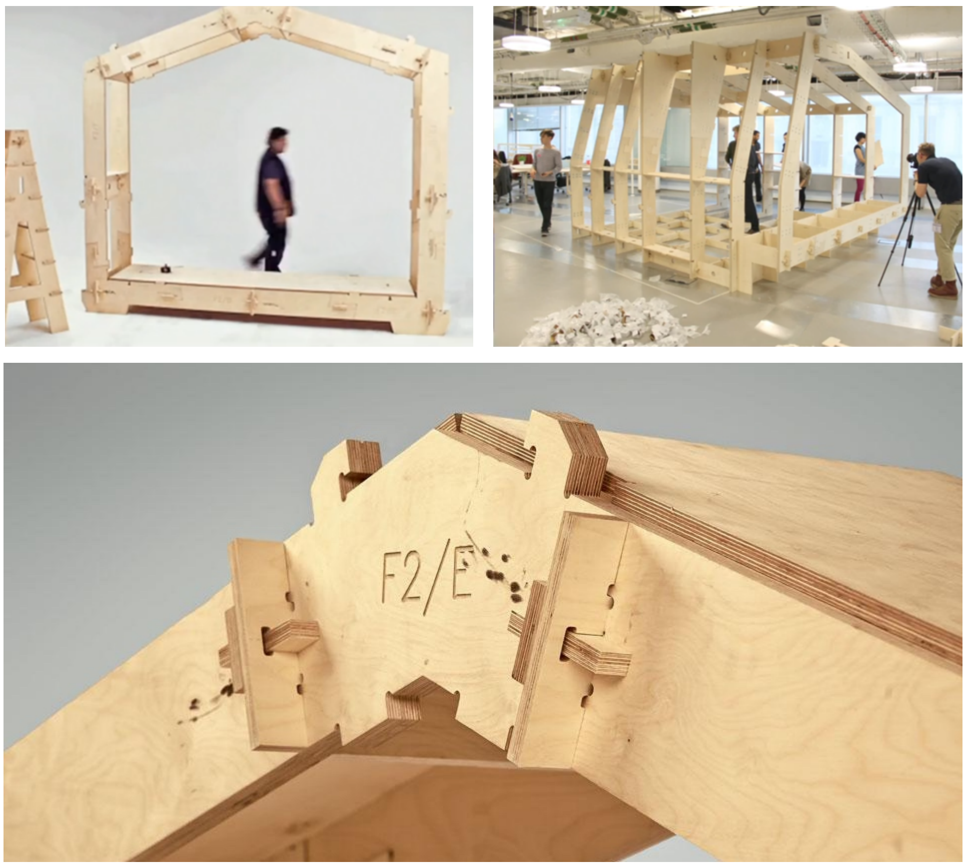
There has been an increase in interest for using CNC technology in the building design and fabrication process. The outcome allows for building components to be easily printed, essentially streamlining the process of fabricating construction materials. As discussed previously in this chapter with WikiHouse, innovative uses of CNC milling can offer many benefits including low-costs, high output efficiency, renewable materials, and rapid construction.

In the process of CNC fabricating a structure, a design is generated and then decomposed into a series of parts. These parts are then manufactured by a computer controlled machine and organized into an assembly kit. Parts can be etched and labeled according to their placement to simplify construction and various methods can be used in the joinery of components. Some methods have completely eliminated the need for power tools, screws, nails, and glue by designing the joints with interlocking wedge and peg connections.

CNC milling has revolutionized the way buildings can be constructed and assembled. It allows the user to print out buildings parts from a set of cutting files. These parts are printed with high precision and accuracy, typically on engineered material like plywood. Once the parts are fabricated, the energy source for construction is entirely human powered. Similar to an Ikea furniture set, assembly is simplified with basic, non-power tools like rubber mallets. Depending on the size and complexity of a structure, it can be built by as few as two people with no construction experience, in a matter of hours.[24]

Case Study #4 | WikiHouse: Various Prototype Skeletal Frames

London, United Kingdom



PROTOTYPING CONSTRUCTION (ABOVE) AND JOINERY DETAIL (BELOW)

WikiHouse claims the principles are in the details, but are simple at that. Following basic guidelines like never design a piece that can't be lifted, and design pieces that can't be put in the other way, ensure a fool-proof and safe building process. The press-fit parts offer a quick and easy approach for assembly and disassembly.

[24] Alastair Parvin, "Architecture for the People by the People," TED Talks, 2013, accessed December 4, 2015

While groups like WikiHouse are primarily using this process to fabricate skeletal framed structures, others have taken CNC fabrication into designing the entire building, inside and out. A team of Swedish architects at the firm Tengbom collaborated with Lund University to design an innovative student housing unit that is fabricated entirely with CNC routing. Along with finding efficient solutions in affordability, construction, and ecological impact, the project intelligently maintains livability and functionality in a truly compact space.

Case Study #5 | Tengbom Architects: 10 Smart Sqm Student Unit

Virserum and Lund, Sweden

The 10 sqm unit is sourced with local renewable materials and utilizes CNC technology to allow for flexible and environmentally friendly manufacturing. Assembly is also accelerated with minimal building parts for ease of on site construction. Counters, stairs, and shelving are all CNC routed while the doors, windows, and tables are milled and fitted as pop-out modules.

Design-Build in Situ

With new advances in digital fabrication, designers can focus locally, share ideas globally, and adapt the design based on economic and environmental context. This process has unlocked the potential to evolve beyond traditional modular and factory fabricated buildings. Facit Homes, a design company that is unveiling this potential, uses digital fabrication in an intelligent new way. They call it the *D-Process*, where digital fabrication becomes integrated into traditional on site building techniques. Thus, allowing control over the entire design and construction process to ensure quality, performance, and a high level of detail. Facit Homes is architecture, design, manufacturing, and environmental engineering all in one.

Case Study #6 | Facit Homes: The D-Process

London, United Kingdom

Facit Homes has redefined the meaning of design-build. By bringing raw building materials and digital fabrication directly to the site, a more integrated and streamlined process is created. Each project is constructed using an on site fabrication lab that houses all the necessary tools–including a CNC router.

2.3 Innovating a Low-Impact Material

Alternative Building Materials

Low-impact building materials have become an important driver of the sustainability movement. Materials are among the most impactful factors in terms of resource depletion and high energy demands. As a result of energy intensive manufacturing, transportation, and recycling processes, materials like steel, glass, and concrete are the highest of contributors to environmental degradation and climate change. Still, these materials dominate the building market as the most commonly used in construction worldwide.

Since the green architecture movement, there has been a surge of experimentation and application of low-impact materials in finding alternative, eco-friendly building solutions. Designers and engineers have been teaming up to innovate new products like Ecovative's mushroom insulation material and NewspaperWood's re-engineered wood from recycled newspaper. The proven successes of such products have revealed that confining the building industry to traditional materials limits the design potential and deters from significant energy, waste, and cost reductions.

A temporary pavilion at the 2015 IDEAS CITY Festival in New York, impressively used various low-impact materials, while maintaining a low budget. The ETH Zurich Pavilion was entirely of recycled materials. The arched roof was constructed from an engineered paper material called NakedBoard, made from recycled beverage cartons. A basic pressure-treated process under high temperatures eliminates the need for glue, chemicals, or water.[25] The roof structure is supported by staggered wood pallets, stacked to desired heights. The result is an impressive structure entirely of alternative materials.

Case Study #7 | Low-Impact Materials: New Alternatives for Design

New York City | *The Netherlands*

ECOVATIVE MUSHROOM MATERIAL (ABOVE LEFT); NEWSPAPER WOOD (ABOVE RIGHT); REWALL NAKEDBOARD (BELOW LEFT AND RIGHT)

Various low-impact material applications can offer impressive results in design. A 10,000 brick installation, designed by the firm The Living, for the 2014 MoMA PS1 used Ecovative mushroom material for its structure (above left). NewspaperWood has elegantly designed a way to upcycle old newspaper back into a unique wood product (above right). The ETH Zurich Pavilion utilized ReWall's NakedBoard beverage carton product to design an amazing event space in a very fitting urban setting (below left and right).

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[25] John Hill, "Building with Waste," May 2015, accessed January 18, 2016, http://www.world-architects.com/architecture-news/products/Building_with_Waste_2923

Shifting Back to Wood: Emerging Technologies

Over the past century, inner city developments have grown into high density structures rising many stories tall. The era of dynamic buildings and skyscrapers would place wood third in line behind steel and reinforced concrete materials. The once most desired building material, had quickly become questionable for its durability and vulnerability to the elements of time and nature. However, in recent years, wood is seeing new light. With changing technologies and the demand for green initiatives, the building industry is realizing the potential for wood as a leading low-impact and high-quality building material. While wood has always been renewable, recent sustainable forestry initiatives are helping to safeguard it to become the most environmentally friendly and carbon neutral resource.

Advancements in technologies, like wood engineering, have put timber at the forefront of creating highly sustainable and versatile materials. In raw form, wood has variable quality and limited strength. However, the benefits become tenfold once engineering techniques are applied. Engineered wood, or composite wood, is a manufacturing process that relies on binding or fixating layers of solid wood, veneers, chips or fibers.[26] There is a range of engineered products on the market today, offering a variety of applications from light interior uses to high-strength structural materials. These products include more commonly known structural materials like glulam, plywood, oriented strand board (OSB),

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[26] Remi Network, "The Benefits of Engineered Wood," January, 2014, accessed January 22, 2016, https://www.reminetwork.com/articles/the-benefits-of-engineered-wood/

and have more recently expanded with new material innovations like cross laminated timber (CLT).

CLT, still new to the U.S., has been gaining attention in other countries like Europe and Canada.[27] The engineering process is similar to plywood, where panels are cross-laminated in layers of transverse and longitudinal planks.[28] The result is a building material that is proving to outperform steel and concrete in numerous ways. Associate professor of wood science at Oregon State University (OSU) argues "not since the development of plywood has a material innovation so thoroughly changed the construction process."[29] OSU is very involved in forestry of the Pacific Northwest and has been actively researching and working with engineered materials like CLT.

Institutions and industries across North America are now investing in what is believed to be a revolutionary new building system. A key benefit of engineered wood like CLT is that it is made with lower grade materials that would otherwise have variable quality and little structural value. OSU has been testing hybrid poplar, a low-density tree species heavily cultivated in the Pacific Northwest for pulp and paper during the late 20th century.[30] Recent studies have shown potential for structural use through CLT application. With value-added engineering, hybrid poplar may offer a much more useful purpose.

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[27] M.H., "Barking Up the Right Tree," The Economist, April, 2014, accessed February 1, 2016, http://www.economist.com/blogs/babbage/2014/04/wooden-skyscrapers
[28] Arijit Sinha, et al. "Cross Laminated Timber Panels Using Hybrid Poplar," accessed February 2, 2016, http://www.swst.org/meetings/AM14/pdfs/presentations/kutnar%20pdf.pdf
[29] Nick Houtman, "OSU Advantage: Wood Panel Promise," May, 2015, accesses February 2, 2016, http://oregonstate.edu/terra/2015/05/osu-advantage-wood-panel-promise/
[30] Brian Stanton, et al. "Hybrid Poplar in the Pacific Northwest," in *Journal of Forestry*, June, 2002. 3.

The University of Utah has also been researching and testing a particular kind of low-value wood for its engineering potential. Over the past two decades, a mass pine beetle outbreak has infested North America's timberlands, leaving a large amount of pine forests destroyed. Millions of acres of ponderosa and lodgepole pine have been killed off, giving the over-abundant dead lumber its unique name, *beetle kill pine*. [31] The University of Oregon has taken it as an opportunity to turn the otherwise low-value material into a value added product like CLT. They have alternatively innovated a new hybrid CLT panel called *interlocking* cross laminated timber (ICLT).

Case Study #8 | ICLT: Engineered Beetle Kill Pine

Salt Lake City, Utah

Beetle kill pine is considered a lower grade lumber due to its inherent properties. As previous uses were primarily for fuel, the low-value application made the removal and transportation unfeasible. ICLT however, gives new purpose to what was an otherwise wasted material. The technique eliminates the need for glues and fasteners by fusing layers with tongue and groove joints.[32] This unique application allows for standard mills and timber fabricators to produce ICLT without the need for additional heavy machinery.

[31] ITAC, "Making the Most from Beetle Infestation," accessed February 7, 2016, http://itac.utah.edu/ICLT.html

[32] Ibid

[**Albizia**] **Falcataria Moluccana: Hawaii's Notorious Invasive Tree**

Albizia, scientifically named *Falcataria moluccana*, is a highly invasive tree species that has been widely spread throughout the tropics. Indigenous to Indonesia and Papua New Guinea, it was heavily exploited as a plantation tree for its rapid growth for shade and ornamental purposes.[33] It was introduced to Hawaii as a result of mass deforestation on the islands in the early 1900's. Brought in primarily for reforestation purposes by Joseph Rock, 138,000 trees were planted between 1910 and 1960.[34] Albizia has since become widespread and naturalized across the Hawaiian Islands.

In Hawaii, along with many other tropical regions, albizia is rated as a high risk species that threatens biodiversity and human safety. Due to its rapid growth rate, the tree spreads uncontrollably and can alter ecosystems through nitrogen fixation and intensive shading.[35] Additionally, large limbs cantilever several meters away from the core, making albizia prone to breakage. There have been numerous cases of severe damage to roadways, power lines and communities, particularly during heavy storms.

While various tropical regions have found a number of uses for albizia, reports have shown that Hawaii primarily has used it for corestock veneer, pallets, furniture parts, and other lightweight products. The wood is low-density, light in color, and at about 24

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[33] Nick Pasiecznik, Datasheet on Falcataria Moluccana (Batai Wood), July, 2009, accessed January 17, 2016, http://www.cabi.org/isc/datasheet/38847
[34] Ibid
[35] Ibid

pounds/ft^3 it is slightly lighter in weight than ponderosa pine.[36] Albizia also has an equivalent strength to ponderosa, which is relatively high for its properties.[37] Existing research shows the species to have a specific gravity of approximately 0.33 in Hawaii, but slightly varies depending on the age of the tree.[38] With comparable characteristics to the earlier cases of hybrid poplar and ponderosa pine, albizia could arguably have potential to offer a market for locally-sourced engineered building materials in Hawaii.

Case Study #9 | Albizia Removal Project: UH Manoa Lyon Arboretum

Oahu, Hawaii

In the distance, albizia trees rise above the palms as a crane prepares for the last removal phase at Lyon Arboretum in Manoa Valley. A project costing the university over a million dollars to remove 23 mature albizia, had no plans but to dispose of the massive timber logs on site. This is just one of many occurrences across the islands, where albizia is cut down and disposed without any intention for reuse.

[36] B. Francis Kukachka. "Properties of Imported Tropical Woods," U.S. Department of Agriculture, Madison, Wis. 1970, 3.
[37] Elbert L. Little Jr. and Roger G. Skolmen, "Common Forest Trees of Hawaii: Molucca Albizia" College of Tropical Agriculture and Human Resources, UH. Reprint, 2003, 1.
[38] Ibid

Albizia	Potential	Value Added
'Invasive'	New Building Materials	'Exotic'
Suppressive	Engineered Wood	Renewable Resource
Hazardous	CNC Structures	Locally Sustainable
Disaster Prone	Boost in Economy	Low-Cost
High in Numbers	New Industry for Hawaii	Reduce Import Dependency

A MAJOR PROBLEM → A LOCAL SOLUTION

Table 2.1 Albizia potential for local solutions

A Niche Market for Engineered Wood

Given the right approach, a major problem can give rise to a new opportunity. Through the surplus of Hawaii's invasive tree species, there is a potential niche market for local, low-impact, and renewable building materials. While a number of invasives could likely be utilized in this market, the highly invasive albizia is a particularly viable species. While currently of little value in Hawaii due to its low density and mediocre strength, there is potential for albizia to be a high-quality building material through application of wood engineering. Just as hybrid poplar and ponderosa pine have recently proven successful in their testing for value added wood products like CLT, albizia could similarly offer a surplus for local wood-engineered material. Figure 2.2 illustrates some of the key economic, community, and environmental benefits that could emerge with a market for value added albizia wood in Hawaii.

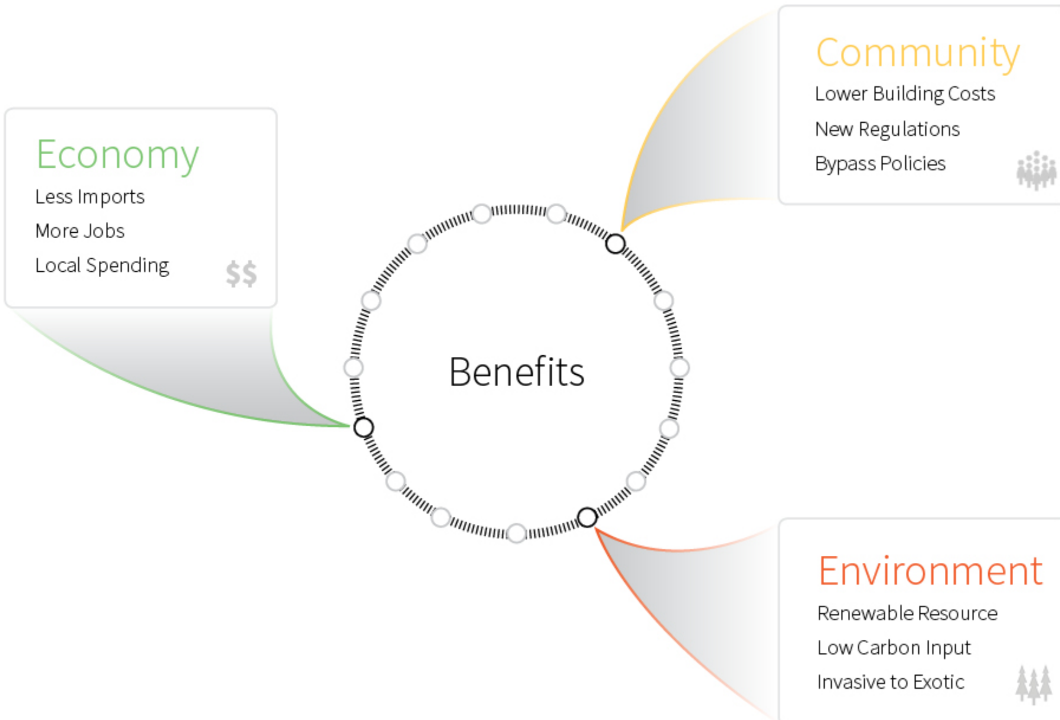

Figure 2.2 Key benefits for converting albizia into a local building material

If albizia in Hawaii was proven a viable engineered wood product, it could help to resolve sustainability issues both locally and globally. Locally, it would open a market for renewable building materials through invasive tree species, subsidizing a significant percentage of construction imports. This would be beneficial to Hawaii's economy, community, and environment by providing local jobs and creating a low-cost, high-quality, and renewable building material. What has long been a problematic species in Hawaii can be transformed into a lucrative, local solution by converting the tree from invasive to useful.

2.4 The Resilience Continuum: From Sustainability to Adaptability

Rethinking the Sustainable City

"As an architect you design for the present, with an awareness of the past, for a future which is essentially unknown."[39]

– My Green Agenda for Architecture, Sir Norman Foster

In the emerging 21st century, we are witnessing the desire of cities to return back to more simple systems, where human scale is prioritized over massive structures and walkable communities replace vehicle-dominated streets. Modern society is realizing that gridlocked traffic and inefficient housing do not make for better living. People are willing to trade in these former marvels for healthier, safer, and more sustainable lifestyles. But what makes a community truly sustainable today or even years from now?

The concept of sustainability is evolving. Science and technology have taken sustainable design to unforeseen heights with high-tech buildings and bioclimatic systems. In light of the increasing consequences of climate change, a new form of sustainability has been gaining attention; *resilience*. Resilient design is complex and multifaceted. It emphasizes the ability to adapt and survive with flexible, locally responsive solutions. It embraces the realities of future socio-economic instabilities, climate change, and energy scarcity, to prioritize more self-sufficient and tolerant communities.

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[39] Norman Foster, "My Green Agenda for Architecture," TED Talks, March 2008, accessed January 27, 2016

Figure 2.3 Aftermath of Superstorm Sandy hitting New Jersey

Resilient design has grown out of the umbrella term of sustainability. With the rising implications of climate change, simply building ‘green’ will no longer suffice. Some of the most recognized building performance rating systems are now acknowledging and supporting resilient design strategies. The U.S. Green Building Council’s LEED Steering Committee recently adopted three new pilot credits to encourage resilience in design. According to Alex Wilson at the Resilient Design Institute, they have been spearheading the approval of the credits since early 2013.[40] The new credits are a big step in promoting designers and engineers to integrate climate and energy resilient planning for safer and more responsive future developments.

[40] Alex Wilson,” LEED Pilot Credits on Resilient Design Adopted!” November, 2015, accessed on December 14, 2015, http://www.resilientdesign.org/leed-pilot-credits-on-resilient-design-adopted/

Designing for Adaptability

"There was a time, not too long ago in evolutionary terms, when our existence was based on our capacity for movement and adaptability; indeed it is to this that we owe our survival as a species."[41]

– Flexible: Architecture that Responds to Change, Robert Kronenburg

Over the centuries, we can see the evolution of architecture in the built environments we have shaped. As a reflection of its creators, architecture is fitting to the time it is conceived. It caters to the present needs, technologies, social form, and economic support. It is built to fit a given environment and serve a specific purpose. However, with today's social dynamism and environmental uncertainties, architecture now faces the challenges of extreme weather and a program that will likely change throughout its building life cycle.

As time ensures that everything stays in motion, nature will always promise uncertainty. And as society continues to evolve, the rate of change becomes increasingly unpredictable. The impact of human progression is inevitable and the ever-changing environment is transparent in its forces. Consequently, the rate in which humans must adapt is accelerating, and as our counterpart, architecture must expedite adaptation as well.

[41] Robert Kronenburg, *Flexible: Architecture that Responds to Change.* London: Laurence King, 2007, 10.

Craig Applegath, founding Principal of Dialog Design Firm and resilientcity.org, argues that resilient design requires a shift in our contemporary paradigm. He believes sustainability through resilience means built environments must be able to adapt to increasing environmental stresses and impacts of unpredictable climate change and economic downfalls.[42] He started the open-source network, resilientcity.org to raise awareness and promote a more efficient framework for increasing the capacity of resilience in communities. Applegath established the organization as a resource for shared knowledge and guidelines to promote diversity in infrastructures and systems, and cultivate a shift toward individualizing components to allow cities a higher capacity for adaptation.

Impermanence: Coming Full Circle with Tactical Urbanism

Adaptability and impermanence are interrelated when applied to resilient design. If a structure is designed to last just long enough to sustain its initial purpose, then whatever follows can be better fitted to its environment. According to the Center for Resilience at Ohio State University, "resilience is the capacity of a system to survive, adapt, and grow in the face of unforeseen changes, even catastrophic incidents."[43] Buildings that are inherently 'permanent' often lack this capacity. Yet, these are the majority of structures

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[42] Craig Applegath, "Resilience," ResilientCity.org, accessed January 12, 2016, http://www.resilientcity.org/index.cfm?pagepath=Resilience&id=11449

[43] Center for Resilience, "Risk Management and Sustainability," Ohio State University, accessed January 30, 2016, http://resilience.osu.edu/CFR-site/concepts.htm

that surround us today. And while they may be built to last, they fail to adapt to the unpredictable swings of climate change and an evolving society.

As time brings new generations, architecture becomes unfitting to the changing needs and conditions of the future. In the past, city-making was an all-in-one attempt towards the utopian dream. On the assumption that change was gradual, buildings were designed for permanence without comprehension of how they will adapt. Today we are left with the task of shaping society around the built environment, when it should be just the opposite.

The once prevailing approach to creating utopian cities through long-term tactics and strategic masterplans is now accompanied by an instrument of transient and time-limited urban interventions.[44] Impermanence is adaptive in nature, allowing for diversification of human and built systems. Robert Kronenburg, an architect, professor, and strong advocate of the temporary movement, argues that temporality "adapts to unpredictable demands, provides more for less, and encourages innovation."[45] Through his many books and panel talks, he encourages designers, architects, and other building industry affiliates to rethink the value of temporary and transportable.

City planning and urban development has always struggled to keep up with an evolving society. Mike Lydon, coauthor of *Tactical Urbanism,* argues that shorter-term, smaller-

[44] Peter Bishop and Lesley Williams, *The Temporary City,* London: Routledge, 2012
[45] Allison Arieff, "It's Time to Rethink 'Temporary'," The New York Times, December 19, 2011, accessed February 2, 2016, http://opinionator.blogs.nytimes.com/2011/12/19/its-time-to-rethink-temporary/?_r=1

scale tactics are the missing link to achieving the resiliency, responsiveness, and adaptability of future cities.[46] He sees these temporary interventions, which he calls tactical urbanism, as a way of integrating quick short-term doing, experimentation, and community activation with the already existing urban infrastructure and slow but steady city planning.

Temporary architecture can be engaged at all different scales and various functions. From urban installations to rebuilding neighborhoods, it is an approach that feeds growth instead of slowing it. It gets communities involved and embraces integration as opposed to segregation. It jumpstarts the transition of once vacant lots into vibrant and trendy districts. We have seen its success across the nation. From Oahu's own Kakaako to the busy streets of Manhattan, tactical or temporary urbanism is happening.

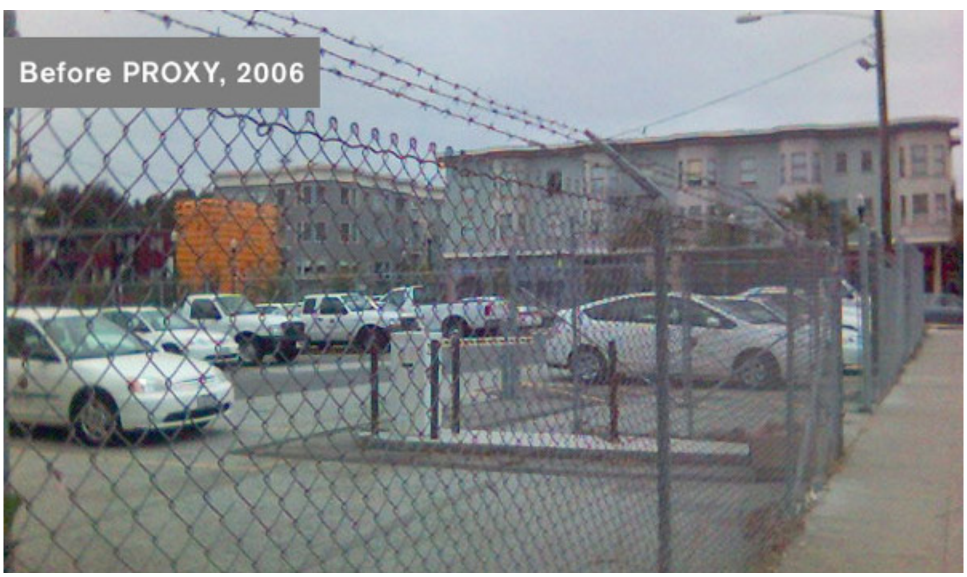
Figure 2.4/5   Kakaako wall art (left) and Manhattan tactical placemaking (right)

[46] Ibid

About halfway between Hawaii and New York, the city of San Francisco has revealed an exceptional case. The Proxy Project, by California design firm Envelope A+D, is a temporary two-block district that gave life to small businesses and cultural spaces on city-owned vacant lots. The makeshift project utilized a series of abandoned sites that would have remain undeveloped for several years following the economic downturn.[47] The design, composed of artful shipping containers, contends that the otherwise leftover lots be utilized for transient inhabitation of community uses and economic activation. With affordable housing promised for the sites future, Proxy has seeded new life to a neighborhood that now brims with vibrant and lively spaces.

Case Study #10 | Proxy: Envelope Architecture + Design

San Francisco, California



VACANT LOT BEFORE PROXY PROJECT

[47] http://www.envelopead.com/proj_octaviakl.html

SAME BLOCK AFTER PROXY PROJECT INJECTED

As an investigation of impermanence, Proxy is comprised of pop-up style retail shops, restaurants, art galleries, gardens and other community functions. The design, with temporary in mind, set out to revitalize the vacant lots through an interjection of short-term, easily constructed (and deconstructed) structures. A play on lightweight materials through frame, fabric, mesh, wall, and volume exposes the inherently adaptive systems of a portable community.[48] True to its resilience objectives, Proxy demonstrates closed-loop systems through its simple but effective infrastructure, including on site rainwater harvesting and photovoltaic power generation. It is a living example of what can grow from small-scale, short-term actions.

[48] Ibid

In Conclusion

Architecture has developed with a narrow lens for permanent structures. Iconic buildings have become contemporary aspirations for achieving monumental status. While there will always be a place for permanence, the opposite end of the spectrum is gaining momentum. Communities are becoming increasingly drawn to small-scale, short-term tactics with a new interest for impermanence. From food trucks to pop-up retail shops and tiny portable houses, the value of small-scale, temporary urbanism is evolving into an architectural revolution.

Cities are realizing the potential of dynamic spontaneity through transient, smaller-scale architecture. It is a growing continuum of design for the people by the people, to rethink temporary and bring back social phenomena like community living and collaborative consumption. It is a radical, contemporary approach to nomadic village life, where shared gardens, outdoor markets, and barter and trade are desired over gated communities and indoor shopping malls.[49] It represents a big shift for architecture. Buildings that inspire to impermanence, give architects and designers the advantage of keeping cities current and implementing new systems and technologies as they evolve.

With increasing advancements in technology, even sustainable buildings are becoming obsolete. In a matter of years, their program, function, and performance is quickly

[49] Allison Arieff. "Its Time to Rethink 'Temporary." The New York Times. December 19, 2011. Accessed on January 14, 2016. http://opinionator.blogs.nytimes.com/2011/12/19/its-time-to-rethink-temporary/?_r=0

outdated. New building materials are introduced everyday and the building technology sector is rapidly growing. Dynamic structures will outperform the static when the inevitable changes of climate and human needs are applied. If we can learn to experiment with design through the lenses of tactical urbanism, impermanence, and resilience, architecture can overcome boundaries that would otherwise be out of reach. Without the burden of permanence, cities could implement solutions faster. Architects, builders, city makers, and even communities can encourage the innovation where experimental endeavors may openly solve seemingly unsolvable urban problems of today, tomorrow, and beyond.

Part 2 | Predesign & Design

3. Defining the Framework

3.1 Project Intent

There is no single solution to any complex urban problem. Each challenge has variables and every response should be tailored to its environment. In Part 1, we studied a number of interrelated challenges Hawaii is facing in its built environment. This research was accompanied by a range of precedents, all of which were carefully selected in fostering the framework of a hybrid solution. Part 2 aims to respond holistically and intuitively based on applied research and analysis, taking inspiration from each precedent and coalescing it into a formal design approach. With small-scale, low-tech, adaptive and transient strategies, an untraditional approach can be applied.

Through a clear definition of design principles and parameters, this project aims to create an integrated strategy that embodies small, feasible, affordable, and innovative solutions. It moves beyond basic sustainability measures, towards an incremental approach of short-term actions that respond to future uncertainties. Transformative yet simple, it explores alternatives to the existing unsustainable and uneconomical systems in Hawaii. As an import-dependent and increasingly vulnerable urban island community, this design project proposes a viable solution that can considerably lessen the growing impacts of Hawaii's environmental and economic insecurities.

3.2 Objectives and Approach

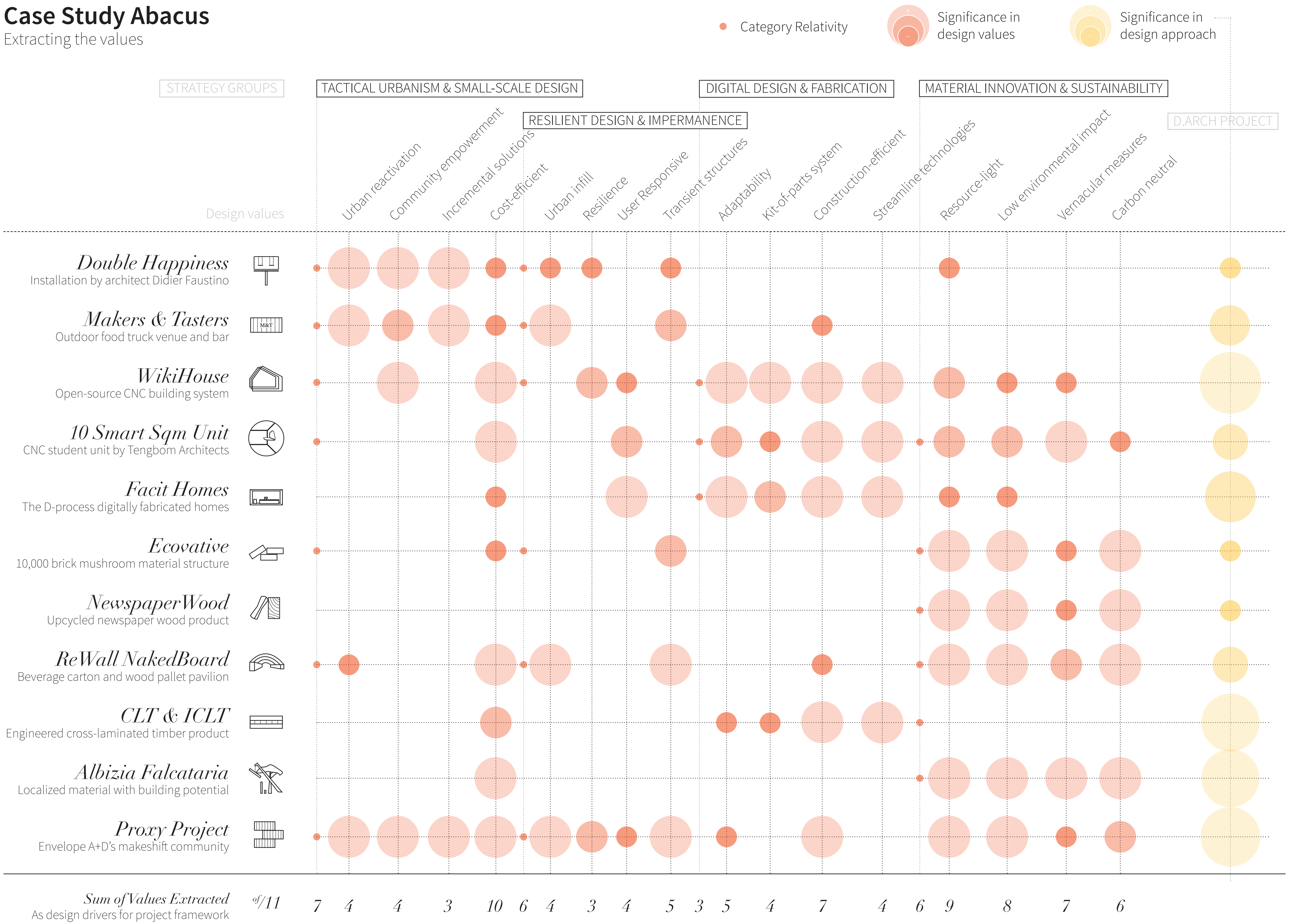
Extracting Design Values

The research and case studies in the earlier chapters have provided the basic foundation in defining the framework for this design project. While much is intuitively integrated into the design strategy, a graphical translation of each case study's inherent values provides a clearer concept of the design objectives. Through process of deduction, the combined research and case studies explored in Part 1 have been organized into a conceptual abacus or matrix diagram. The diagram helps to categorize the key design ideas within each case study and decipher their inherent values relative to the design approach for this project.

The abacus diagram quantifies the design values of each case study as an abstract representation of their significance. With the extracted design values, each facet of design stimulus can become evident as it is integrated into the framework of a hybrid building model. However, it is important to note that it is not just these case studies that drive the formation of the framework. They are only a selection of exceptional examples that help to define the key values of the design approach and strategies addressed. Through the process of deduction, each strategy offers a contributing factor based on relevance to the design problem. Following the abacus diagram on the next page, the Goals and Objectives section will supplement the graphic with a brief explanation of the key influences from Chapter 2.

Case Study Abacus

Extracting the values



Goals and Objectives

The design objectives are centered on the four key strategy groups highlighted in the abacus diagram: tactical urbanism and small-scale design, resilient design and impermanence, digital design and fabrication, and material innovation and sustainability. Within each of these is a range of interrelated design values that have been extracted through the continuum of case studies. While many of the values run parallel in their similarities, the preceding diagram has aided in defining their most significant facets for the design project.

This dissertation aims to integrate the values from the design strategies and case studies to form a framework for a new building system that responds to Hawaii's urban challenges via focusing on critical urban issues such as houselessness, extreme environmental conditions, and growing future uncertainties. The end goal is to achieve an adaptive system of more process-based structures that are less finished, yet more functional.

With an incremental approach to solving urban issues that currently remain unresolved, the project investigates the potential of small-scale and short-term solutions. It seeks to inject sustainable, cost-competitive, and easily deployable structures into the urban fabric by utilizing innovative technologies and resource-light materials. At the same time, the project envisions the integration of a low-tech, off-grid, sustainable, and centralized infrastructure system in anticipation of near-future events.

Acknowledging the realities of inevitable change and future implications, the design objectives aim to engage with the urban and environmental context through a network of transient, small-scale, easily adaptable, and replaceable systems. Its success is centered on the innate qualities of impermanence and basic life necessities. It challenges the notion of permanence as an idea masked by vanity and illuminates the potential of simple, transient, and holistic design solutions.

Design Approach

With a clear vision of objectives, the research can begin to evolve into a formal design approach. The project aims to establish an alternative building system that goes beyond the existing traditional methods. It integrates smart and innovative strategies through high-tech application and low-tech design. The high-tech application utilizes digital fabrication through CNC technology to allow both the designer and user flexibility throughout the design and construction process. The low-tech design will respect small-scale, low-cost, and impermanent strategies. By intersecting these we can coalesce a design approach that responds to the radical urban challenges of Hawaii’s built environment with adaptive and transformative measures.

The approach for this project takes the *design-build* concept and integrates the *fabrication* component. Like Facit Home’s D-Process, it brings the ‘fab lab’ to the site for a streamlined fabrication and construction process. With an intelligent building design, nearly all building components can be CNC fabricated and easily constructed on site. The process would require only simple man-powered tools for construction. As a simplified kit-of-parts, building components are to be designed with this in mind. Every piece will be small enough to lift and embedded with unique building information for fast and simple construction. The structure will rely on press-fit joinery techniques to minimize additional support material.

Given the process of CNC fabricating the building components, engineered wood is the most viable material for use. Thus, the project will explore a local, low-impact material, Hawaii's invasive albizia tree, and utilize it through wood engineering technologies. Integrating engineering methods like CLT, albizia may prove to have a significant purpose for Hawaii's local building industry. This project will study engineered hybrid albizia panels to serve as the cut sheets for the CNC milling of building components.

The resulting approach offers a building system that radically reduces the threshold of time, cost, and scale by eliminating traditional, energy-intensive construction methods. At the same time, it removes the burden of imported materials for a contemporary approach to the traditional vernacular. It will argue the low-valued, invasive albizia has merit for becoming a cost-competitive and easily accessible local building material. Designed with an ethic of global and local sustainability, the project will strive for complete authenticity.

A Responsive Building System

With a streamlined construction strategy and a cost competitive material, the smart building system offers a contemporary approach to affordable and easily deployed structures. Adaptive in its nature, each design can quickly respond to current and future scenarios including issues of houselessness to unforeseen natural disasters. Embracing impermanence, an ephemeral lifetime will allow for designs to evolve with changing community needs and rapid technological advancements. New resources can modify and replace the old, while the rooted concept of resource-light materials, intelligent design, and joinery systems will remain timeless as the essence of the system.

As a responsive building system, it can adapt to scenarios of different regions, environments, cultures, resources, and needs. In Hawaii, it can serve as a framework for responding to the current housing crisis, while readily available for future uncertainties of natural disasters and extreme environmental conditions. With a regionalized framework, it provides flexibility in design, decision making, and functions that are easily reconfigured through the digital fabrication process, which may be tailored to a multitude of design typologies and scenarios.

The following page illustrates a conceptual timeline of extreme scenarios in Hawaii. Some are already occurring and some with an expectancy of likelihood in the future. The left-most illustrated scenario is the present day *housing crisis,* which is currently in place. This scenario will serve as the design problem for the initial pilot design project.

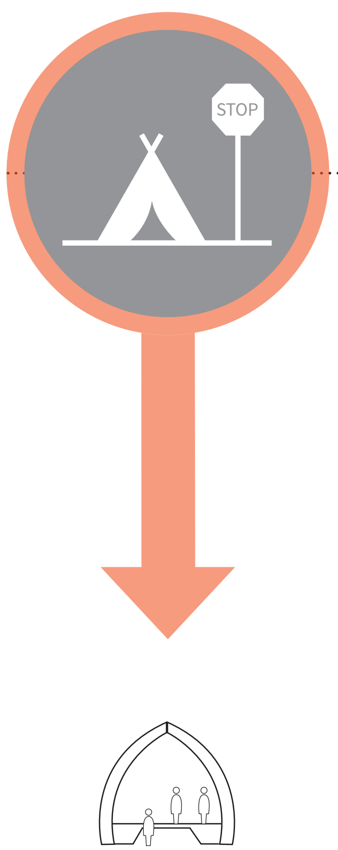
Conceptual Timeline of Scenarios

A responsive building system

Housing Crisis

2016

Present Day Honolulu



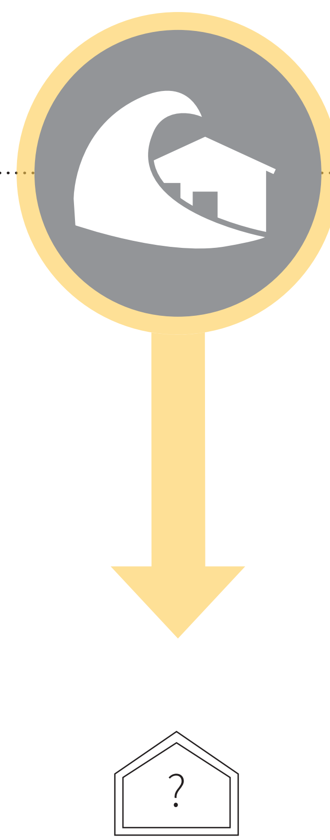
PILOT DESIGN
PROJECT

Urban infill housing project of CNC fabricated, low-cost, and easily constructed housing units made from local Albizia wood.

Natural Disaster

2036

Two Thousand Thirty-Something



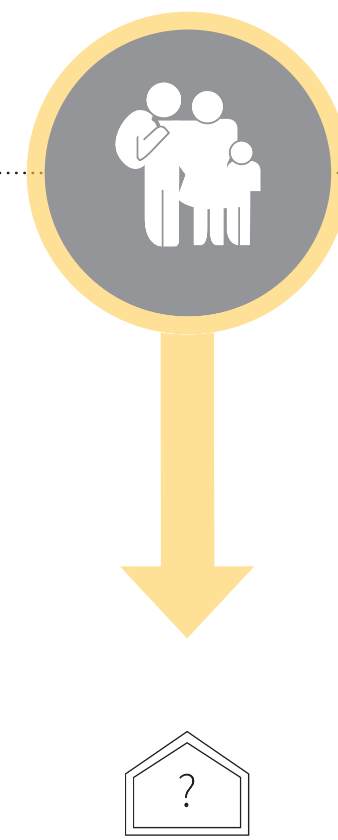
DISASTER RESPONSIVE
UNITS

Integrating readily available materials with current technologies for rapidly deployed self-sustaining relief units.

Environmental Refugees

2056

Two Thousand Fifty-Something



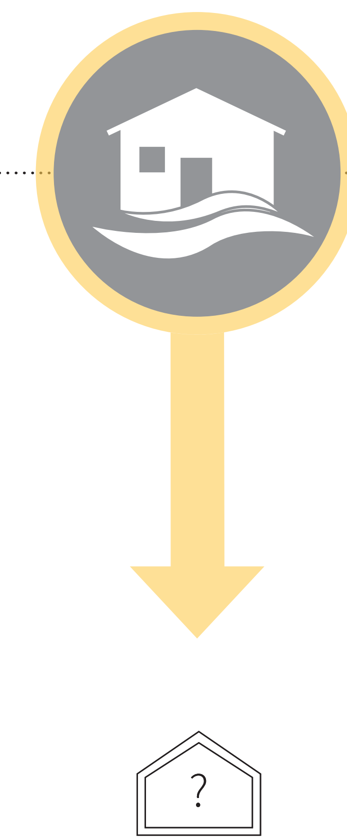
REFUGEE HOUSING
COMMUNITIES

Injecting transient unit clusters in urban leftover spaces to accommodate Pacific Islander environmental refugees.

Sea Levels Up 2ft

2076

Two Thousand Seventy-Something



RESILIENT ELEVATED
STRUCTURES

Designing flood resistant structures to house evacuated populations and withstand sea water surges.

The timeline begins at the contemporary issue of houselessness and stretches into some of the prospective future challenges that may significantly impact Hawaii's community. The colored arrows lead to a flexible design response of the proposed building system. Aside from the 2016 scenario happening now, each future scenario is a theoretical assumption based on probable events. Essentially, the building system framework provides a quick and feasible solution that can be easily adapted and deployed. As this is a mere conceptualization of future scenarios, the actual design response of each system is unknown. However, with the housing crisis as Hawaii's most relevant issue today, this dissertation will propose a design solution based on this scenario as the initial pilot project.

3.3 Piloting the Initial Project

Design Problem

While it is not feasible to attempt a design solution for each urban issue and future scenario addressed in this dissertation, we will investigate a contemporary design problem as the initial pilot project. Given the severity of the current challenges we are facing with houselessness in Honolulu, this has become the basis for the design problem of the initial pilot project.

The pilot design project will foster the new building system as an alternative approach to resolving local contemporary issues through design. Piloting it towards a tangible issue can serve as a test run in revealing its potential for success or failure. The system will strategize around smart growth, where instead of driving segregation to the outskirts of town, it will reintegrate affordable living into the city. And as a buffer against the ongoing impacts of gentrification in Honolulu, it will encourage communities to realize that change can be positive.

With a growing awareness of value in smaller urban communities, the project will center its concept around a small-scale, community-focused design approach. It will investigate an urban injection of *small transient villages* that can occupy ubiquitous vacant lots. Instead of allowing undeveloped and vacant urban spaces to lie untouched until development, the project contends to make use of what is readily available. It proposes a system of short-term solutions to balance out the problem of displacement and unavailable housing for low-income communities.

The following page illustrates the proposed system injected throughout Honolulu as small transient villages for mitigating the increasing housing deficiency. It proposes that any existing vacant or undeveloped lots are the gaps in the urban fabric that can be temporarily filled with transient structures. The illustration conceptualizes that as time progresses, the pressure of houselessness will continue to escalate. However, with an injection of placeholder communities on vacant land that would otherwise sit unused, this pressure can be reduced in small but measurable increments.

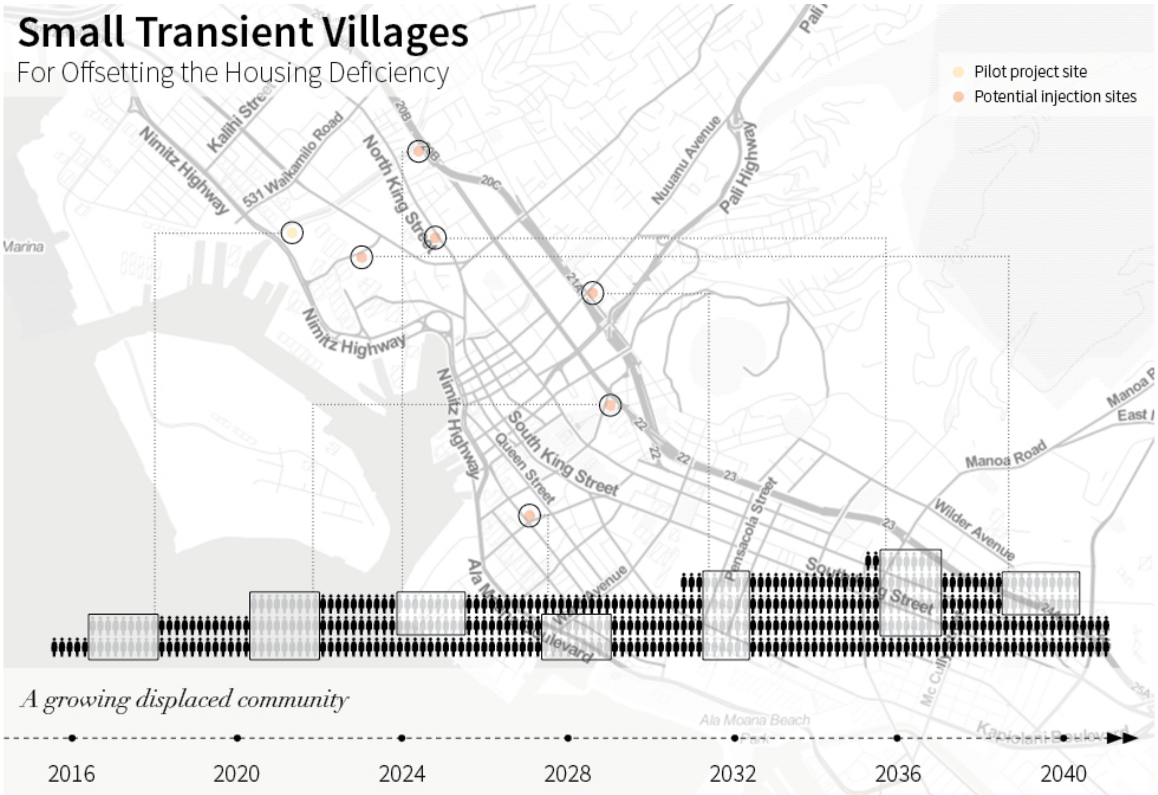


Figure 3.1 Mitigating the housing deficiency in Honolulu

A State Endorsed Venture

Architecture and design in Hawaii is currently not accessible to those below the upper-middle class. Ironically these are the ones who need it most with rising homeless and immigrant populations alongside sea levels and climate change. The public housing sector is in dire need of a supply for more affordable units statewide. The few options that are available are either beyond capacity or in poor condition. When the numbers are showing a significant increase in houselessness and the low-income housing capacity is falling severely short of the population demand, it is clear something is failing.

It should be noted that the proposed solution for this project is not be a direct response to the 'homeless problem' per se, but rather serves in offsetting the housing deficiency problem through prevention. It would provide an incremental housing approach to offset a growing number of inhabitants who are on the verge of losing their homes. With the surge of housing costs in Honolulu, local residents are becoming increasingly vulnerable this, particularly the lower-income populations. According to Hawaii's state homeless coordinator, Scott Morishige, "25 percent [of Hawaii's homeless] are homeless primarily due to economic factors."[50] As this percentage continues to rise, prevention through injecting incremental, transient housing may provide a tangible solution.

The state is currently in search of any viable approaches for combating houselessness. Governor David Ige has just pushed for a $5 million grant to Aloha United Way as an incentive to keeping 1,300 families from becoming homeless.[51] As a state endorsed venture, the funding for this project could be expedited through similar government grants. Focusing towards underprivileged groups, the pilot program would accommodate low-moderate income families and individual inhabitants with unstable incomes.

Envisioned with a flexible lifespan of five to ten years, the injected village-like communities can be easily constructed and deconstructed. They can fill in underutilized lots as they are available. And when the lots are ready for a new use, the entire system

[50] Dan Nakaso, "State to Give $5M in Relief to United Way," Honolulu Star Advertiser, February 5, 2016.
[51] Ibid

can be disassembled in a matter of days. Moving away from existing traditional affordable housing, which is currently inadequate in capacity and livability, the transient infill communities will act as a transformative housing solution. While sustaining the underlying cost-efficiency factor, the design will be an extension of user personalities, lifestyles, and cultural patterns to offer affordable urban units that provide a fresh take on vernacular and compliment Hawaii's tropical environment.

Integrating Locally Sourced Albizia

The concept of a state endorsed project becomes especially appealing when integrating the invasive albizia tree. As the proposed primary building material for this project, albizia is locally available at a very low cost. With little current value in Hawaii, nearly every tree removed is disposed. However, using albizia as a locally sourced material could give new life to this waste wood and open a new market for local building materials. The State of Hawaii currently has big incentives for removing large quantities of albizia, while at the same time is struggling to combat a severe housing crisis. This project argues that the former issue could serve in supplying materials for the latter. Intersecting these would result in a synergistic effect, where two major statewide needs could be filled with one endeavor.

Given Hawaii's limited resources, locally sourcing materials for buildings is a common hurdle. Nearly all building materials, from structure to finishes, are outsourced and imported. The proposed building system offers a viable alternative to this issue. It will aim to eliminate nearly all traditional building materials by designing with a simple material palette. Albizia wood, being the primary material, will be used in the design process for nearly all building components. Through wood engineering, digital fabrication and an intelligent design, it can perform as the main structural material. Additionally, it can be used for interior finishes, flooring, furnishing, doors and louvers. Minimizing use of energy and cost-intensive secondary materials like metal and glass, the design will explore sustainable alternatives like screen and fabric.

To ensure material quality and performance, the albizia will need a basic wood treatment processes to increase protection from natural elements. This includes common insecticide and fungicide treatments like borate, as well as fire retardant and waterproofing. Many of the disadvantages of a low-density wood material are compensated when utilizing wood engineering technologies. In its raw form, albizia proves to be a susceptible material. However, once engineered into a wood laminate and properly treated, its properties become reformed.

Studies have shown that cross laminated timber significantly reduces susceptibility to degradation. Its thick cross-section lamination provides fire and weathering resistance that would not normally exist in the wood's natural state.[52] CLT can also help to resist warping caused by shrinkage and swelling due to moisture changes. The advantages of

[52] WoodWorks, "CLT Solid Advantages," 2012, accessed February 3, 2016, http://www.woodworks.org/resources/solid-advantages/

engineered lumber integrated with wood preservation measures can offer a sound and reliable solution to using an otherwise highly susceptible building material.

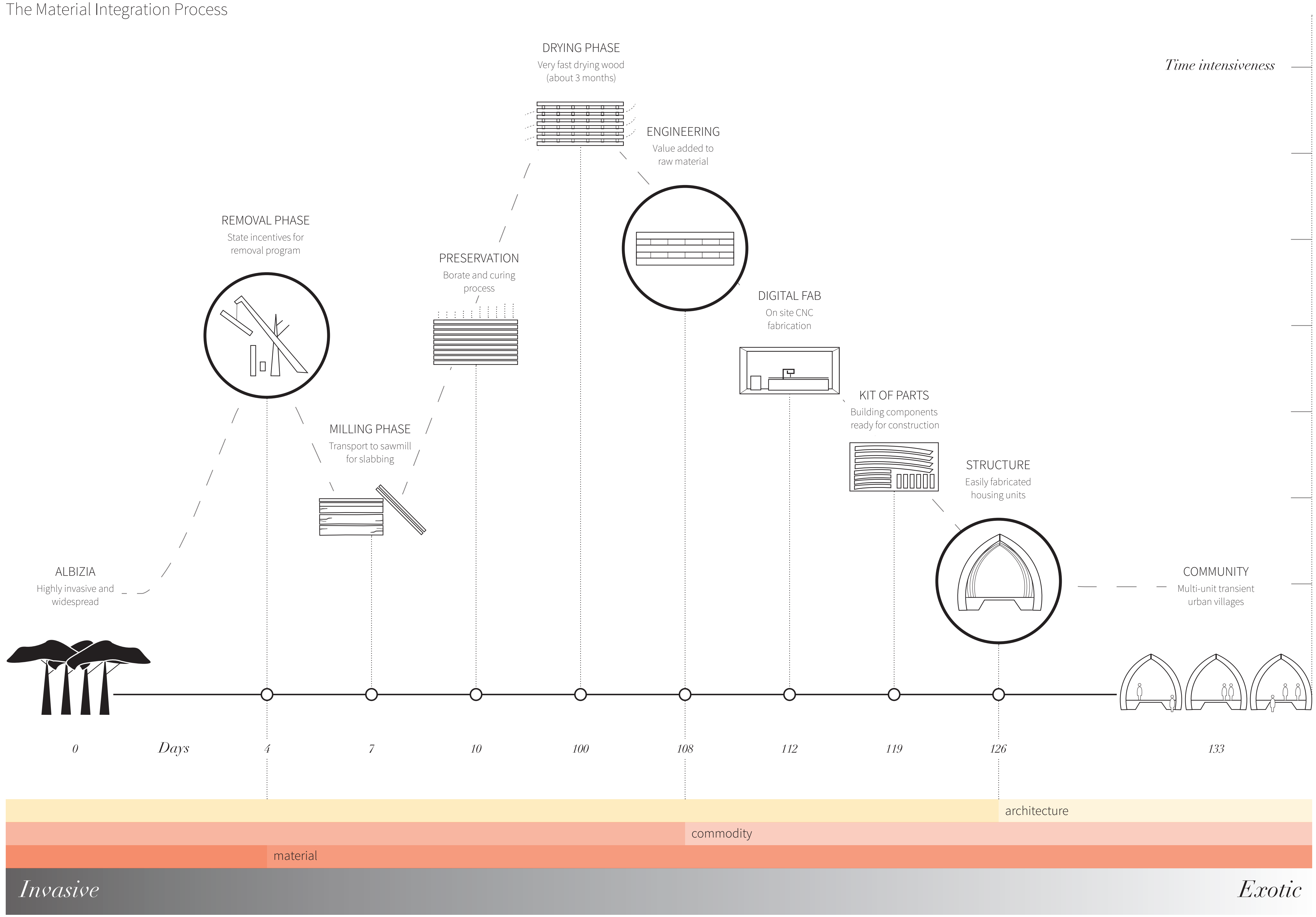
Figure 3.2 CLT testing for fire resistance

Working with the material will be critical in deducing design decisions. The overall building form and structural components will be developed on the basis of engineered albizia as the primary material. The design of non-structural components will also integrate the use of albizia, in either raw or engineered form. For example, flooring will likely use non-engineered albizia, while stairs may require an engineered material.

If we were to lay out the entire material integration process of albizia into the project framework, we could decompose it into a basic series of phases. The illustration on the following page shows a step-by-step diagram of the fundamental process for taking the albizia tree from an invasive problem and integrating it into an exotic solution.

From Tree to Community

The Material Integration Process



In simple terms, the invasive albizia would transform from an unwanted tree to a rapidly-fabricated building system. At this intersection, the underlying concept of this design project becomes clear. Using creative thinking with problem solving skills, we can arrive at a simple, yet compelling solution to many of the current and coming challenges of Hawaii's built environment. The albizia tree is transformed from an unwanted material to a commodity through treatment and engineering. It is then utilized in through digital fabrication and turned into housing communities in just months. Through this system, a derelict material is given a new life. It becomes the gift to a community in need and the soul of a new typology of tropical urban structures for a locally fabricated solution to housing.

Concluding with Design Value Scales

Based on the framework outlined in the above sections, this chapter will conclude with a list of value scales. Each value is shifted towards the fitting parameter on the continuum that will drive the design process. These values are emphasized as the framework for the proposed building system and the design drivers of the housing units for the pilot project. Chapter 4 will integrate the highlighted values in defining the criteria for site selection. Additionally, as Chapter 5 is the design proposal for the pilot project, it will embody each of the values from the following set of sliding scales.

Design Value Scales

Functional Drivers

Construction

Kit of parts — Modular

Deconstruction

Disassembly — Decay

Impermanence

1 year — 10 years

Life Cycle

Recyclable — Landfill

Component Durability

Replaceable — Robust

Flood Resilience

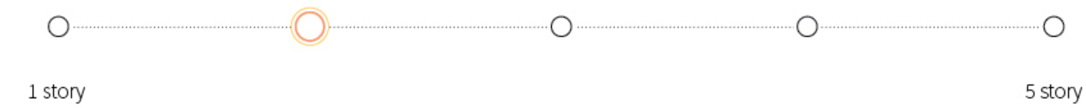
Elevated — Floating

Adaptability

Traditional — Digital Fab.

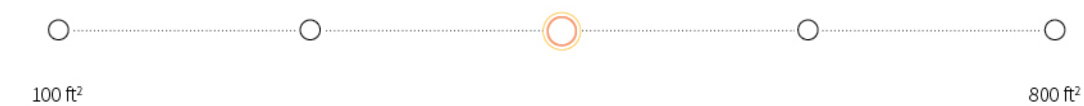
Design Value Scales
Form Finding Drivers

Building Intensity



Village Community

Small-Scale Units



Low-Cost Units

Material Source

Dominant Materials

Subordinate Materials

Design Value Scales

User Influences

Design Value Scales
Bioclimatic Influences

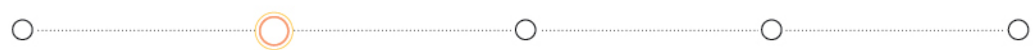
Tropical Climate

Cool & Windy | Hot & Humid

Rainfall Patterns

Always Raining | Never Raining

Wind Patterns



Strong Trades | No Wind

Solar Patterns

Always Sunny | Always Cloudy

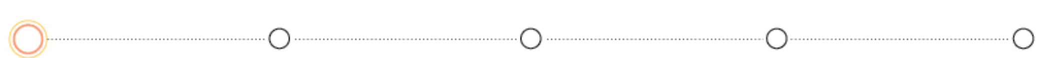
Clean Energy Potential

Low | High

Passive Design Potential

Low | High

Ventilation



Aerated | Sealed

The scales range from basic design principles established in this chapter to specific value strategies for influencing the function and form of the design. Functional drivers address the construction process, lifespan, resilience, and adaptability of design. These drivers significantly influence a more process-based, transient, yet resilient approach. Form finding drivers focus towards an affordable, small-scale, and humanistic design. Digital fabrication and albizia as a primary material will encourage the creation of a unique identity. Acknowledging the cultural and social demographics of anticipated users will ensure a design that is appropriate and desirable for low-income communities. Passive design strategies and bioclimatic influences are essential in creating a sustainable, low-footprint building. These drivers aim to influence a design that corresponds with Hawaii's warm tropical climate.

The value scales will reflect in the design proposal in Chapter 5. Before starting the design, a viable pilot site must be selected. Chapter 4 will comb through the urban fabric of Honolulu to find potential leftover sites for a small transient village. Once the site is defined and given proper analysis, the design project will follow.

4. Urban Site Mapping and Analysis

4.1 Identifying Potential Sites in Honolulu

Honolulu is the urban epicenter of Hawaii. Therefore, exploration of potential sites will focus on this area. This chapter will filter through neighborhoods and leftover sites to narrow the selection to one that accommodates the initial pilot project. With a clearly defined set of criteria, the project can reveal the opportunities that lie within the urban fabric. Analyzing urban development trends and anticipated growth can deduce a site that supports the underlying concept of injecting small transient urban villages.

This chapter will assess the approaching climax of a recent wave of big development. While like all trends, this wave will reach a peak and begin to slow down. However, the eventual arrival of the new rail system promises potential for continued urban growth. These development trends are important influences in the selection of potential sites. Such trends relate to critical factors like variable land values and upcoming development projects in the area.

Kakaako is the latest wave of development, where all but a few vacant lots are fenced off or already under construction. While gentrification seems to have already hit Kakaako, many other outlying Honolulu neighborhoods are unlikely to see such developed for years. These areas will be explored in search of potential sites that work with the proposed building system.

Figure 4.1 Multiple Kakaako sites under development

Areas such as Kalihi and Kapalama show a high potential for transient urban injections. These areas have significantly less development happening than the more central neighborhoods. As compared to other parts of Honolulu, there are currently many underutilized lots and leftover sites. These types of areas will be the focus of the investigation of sites. A site that is fitting to the initial pilot project should work spatially, conditionally, and demographically with the proposed program and potential users. It should foster an environment that embraces the spirit of a transient urban community and compliments the concept of a lightly integrated design.

Site Criteria

While the proposed building framework is intended to easily plug-in to vacant lots and undeveloped urban spaces, it should be based on some basic underlying conditions and principles. This chapter analyzes the existing urban fabric to define the criteria for where the initial pilot project should launch. Careful site selection for the project is critical in the outcome of the proposed system. In the design process, understanding the site is the foremost important factor in initiating the design. Without a site, any design would deem haphazard and arbitrary. Therefore, the first step in the design process for this project is to establish a logical set of criteria for selecting the site.

Honolulu is currently in a transitional phase with numerous plans for development and transformation. The rail system is underway in West Oahu and will arrive in Honolulu in the next few years. Transit Oriented Development (TOD) has plans for major redevelopment in locations in proximity to every rail station. As many of these TOD zones fall between Honolulu Airport and Ala Moana Center, there is a lot of room for new development. Opportunity sites are frequent in these areas, with numerous empty parking lots, undervalued buildings, and vacant plots of land. Selecting the appropriate site for the pilot project will be based on the following criteria to maximize potential for transient urban infill, affordability, flexibility, and potential flood vulnerability:

1) Urban Honolulu neighborhood
2) Low-income area
3) TOD plans location (public transportation accessible)
4) Preferably state owned property
5) An opportunity site (unused parking lot or vacant land)
6) Large enough site to fit multiple units

7) Appropriate land use zone

8) Low to medium density zone

9) Flood/hurricane inundation zone

10) Sea level inundation zone

Housing Costs and Land Values

Hawaii ranks among the highest of housing costs in the nation. Being a coastal island community makes it difficult to avoid steep prices. As a very linear city squeezed between the coastline and mountain range, nearly every area in Honolulu has value. The most desirable neighborhoods generally lie near the coast, up the ridgelines, and in the more desirable valleys such as Manoa. Neighborhoods to the east of Waikiki maintain some of the highest land values, consisting mostly of middle to high-income residences. To the west of Waikiki, Ala Moana and Kakaako are also considerably high, with many newer residential towers and a desirable mix of retail, dining, and entertainment.

Internal cost influences are also driven in part by land use and neighborhood characteristics. The areas of lower value land generally lie in proximity to Interstate H-1, as well as in public housing domains like upper Palolo Valley. Keeping to the south of Interstate H-1, housing costs begin to lessen in the communities to the west of the downtown district. This decrease happens at the transition into the more industrial neighborhoods. These neighborhoods are Kapalama and Kalihi, two areas that currently offer the more affordable options for housing in Honolulu. Mixed into this industrial area are mostly mid-rise apartments occupied by lower-income residents. Figure 4.2 illustrates a heat map of the areas of higher and lower housing costs in Honolulu.

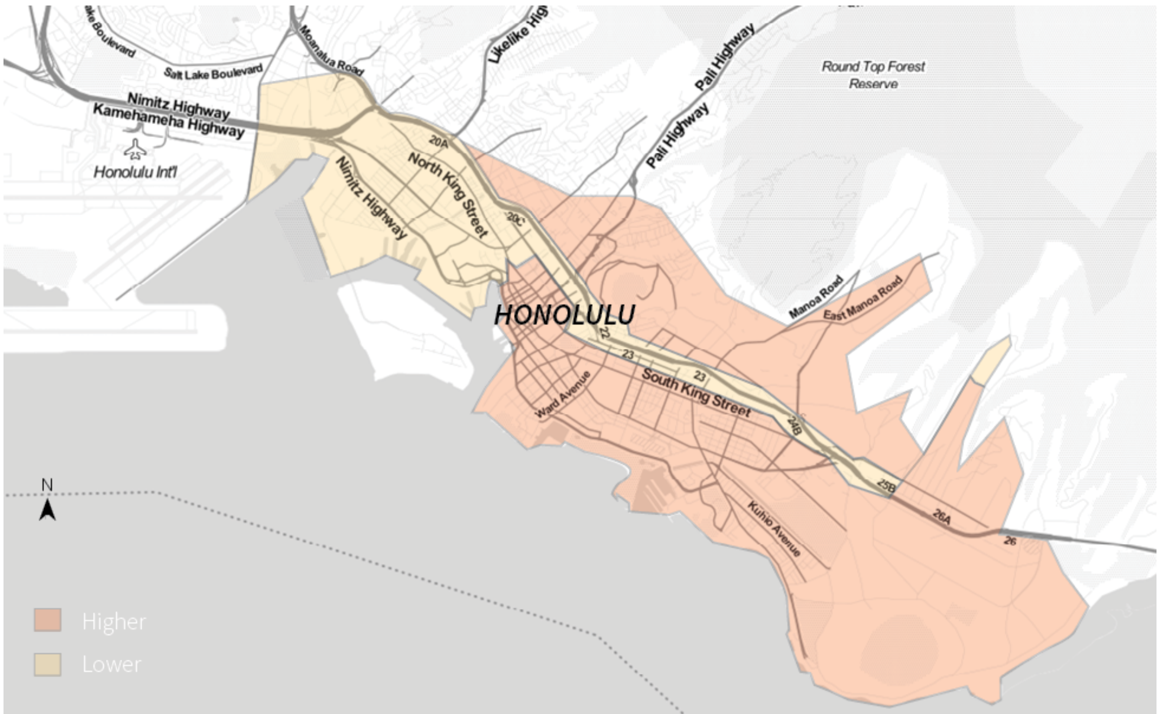


Figure 4.2 Heat map of housing costs by area

Through analysis of existing housing costs in the central Honolulu area, a logical deduction can narrow the site selection to the western region of the city. Focusing on an urban neighborhood with lower housing costs respects the first two conditions of the listed criteria for selecting a site. According to the diagram above, drawn based on Google map data,[53] lower urban housing costs lie in the Kalihi-Kapalama neighborhoods. As we continue the list of site criteria, the extent of the site selection will focus within this

[53] Google, "Heat Map of Oahu Housing Costs," accessed February 20, 2016. https://www.google.com/maps/@21.328983,-157.810468,11z?hl=en-US

area. Figure 4.3 highlights the scope of the Kalihi-Kapalama area that will be analyzed and explored with respect to the remaining criteria.

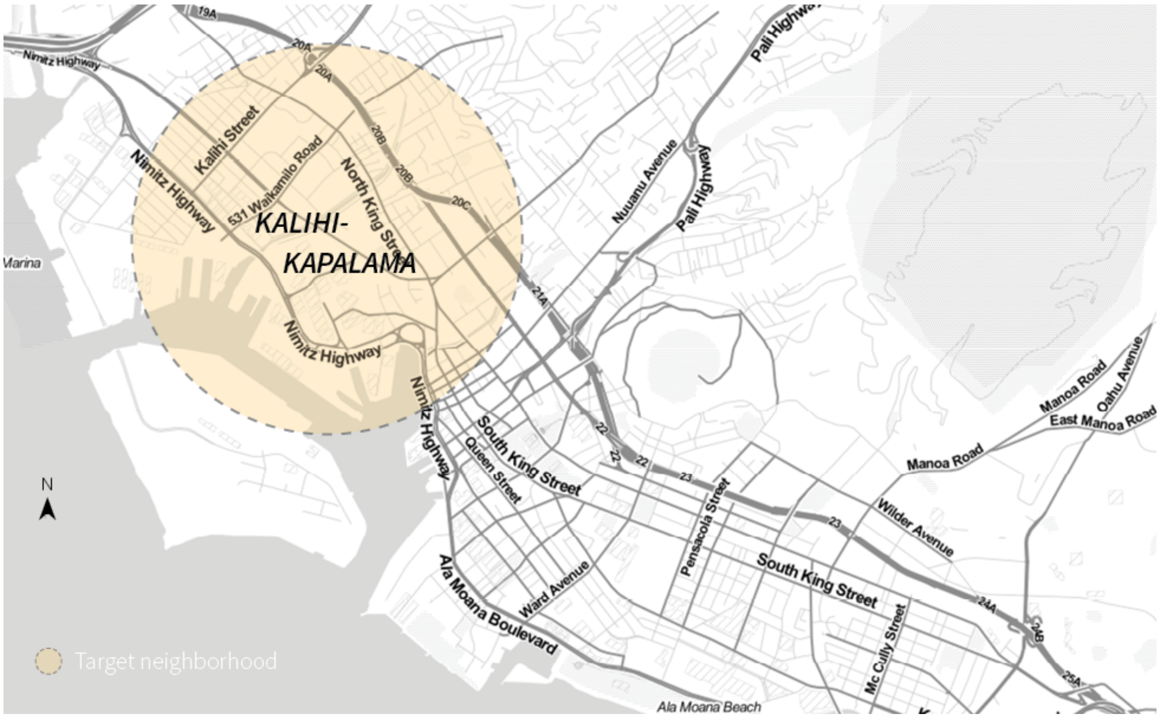


Figure 4.3 Narrowing the site mapping to Kalihi-Kapalama

Transit Oriented Development

Kalihi and Kapalama are two districts on the western end of Downtown Honolulu. Kapalama borders Downtown, while Kalihi borders Kapalama. According to City and County of Honolulu TOD plans, these neighborhoods fall in route of the new rail and are anticipating future development.[54] With this information, the third listed criteria for the site is met. As the current Kakaako development is nearing its end, we must anticipate

[54] City and County of Honolulu, "Kalihi Neighborhood TOD Plan," November, 2014, accessed December 7, 2015, http://www.honolulu.gov/tod/neighborhood-tod-plans/dpp-tod-kalihi.html

the drivers for future development trends. Therefore, having the site in radius of the TOD plans is important in relation to the context of this design project.

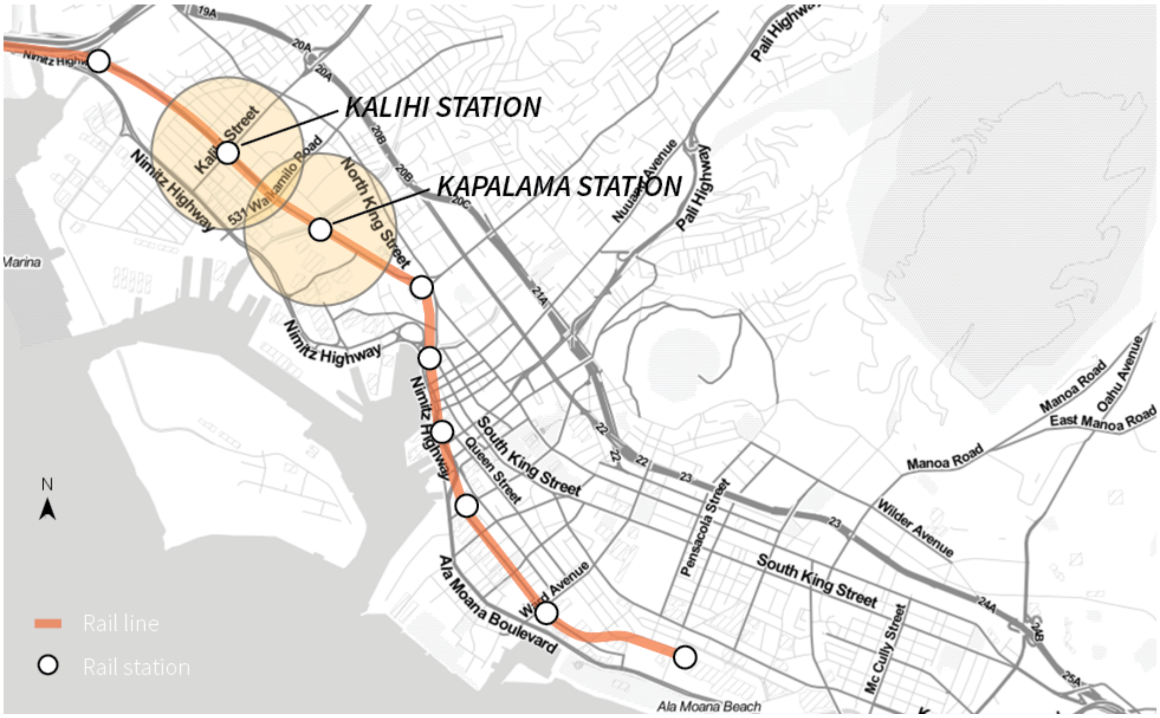


Figure 4.4 Rail stations at Kalihi and Kapalama

TOD has plans to revitalize outlying neighborhoods like Kalihi and Kapalama, promising community-focused developments over the coming years. With the rail aiming for completion in the early 2020's, a number of stations will be built from the Honolulu Airport to Ala Moana Center. These can be seen in the map above, where the orange circle around Kalihi and Kapalama stations designates the proposed radius of TOD plans.[55] TOD proclaims to initiate new development in the areas surrounding these stations, with a focus on promoting walkable and livable communities.

[55] Ibid

4.2 Opportunity Site Exploration

Narrowing the Search

At this point in the urban site mapping and analysis phase, it would require visiting the neighborhoods and exploring potential opportunity sites. Given the range of potential sites between Kapalama and Kalihi, taking to the neighborhood by vehicle has been the approach to analyzing the area. The exploration of sites included main roads and filtering into smaller neighborhoods. While there proved to be many opportune sites, the search was narrowed down to eight viable options.

Each of the eight were assessed based on if they fit the site criteria list. Of the eight potential sites, three were state-owned properties. Using a site owned by the state would arguably be the most valid for the initial pilot project. This ties into the notion of it being a state endorsed venture. Therefore, the exploration narrowed to three potential sites. One in Kalihi is on unused land and owned by Oahu Community Correctional Center. The other two are in Kapalama and property of Honolulu Community College (HCC). The eight opportunity sites are shown on the following map in Figure 4.5.

Figure 4.5 Opportunity sites in Kalihi and Kapalama

Of the three state owned sites, the Kalihi site was dismissed as it is on Correctional Center property. While there are rumors that the facility may be relocated, it would not work as of now. Therefore, the selection was narrowed down to the two Kapalama sites owned by HCC. Given the neighborhood appeal and site potential, these two proved to best fit the criteria. They can be seen on the map above as the two points along Kokea Street, on opposite sides of Dillingham Boulevard.

Land Use and FAR

Of the final two sites, singling the most applicable would depend on the remaining of the listed criteria. Both sites proved to be viable opportunities and large enough to accommodate multiple units. According to the following map from the Kalihi Neighborhood TOD Plan, both are currently in public/quasi-public zones (dark blue). The two sites are circled with their paired images to the left at no opacity, while the third site that has been dismissed is at the top with opacity.

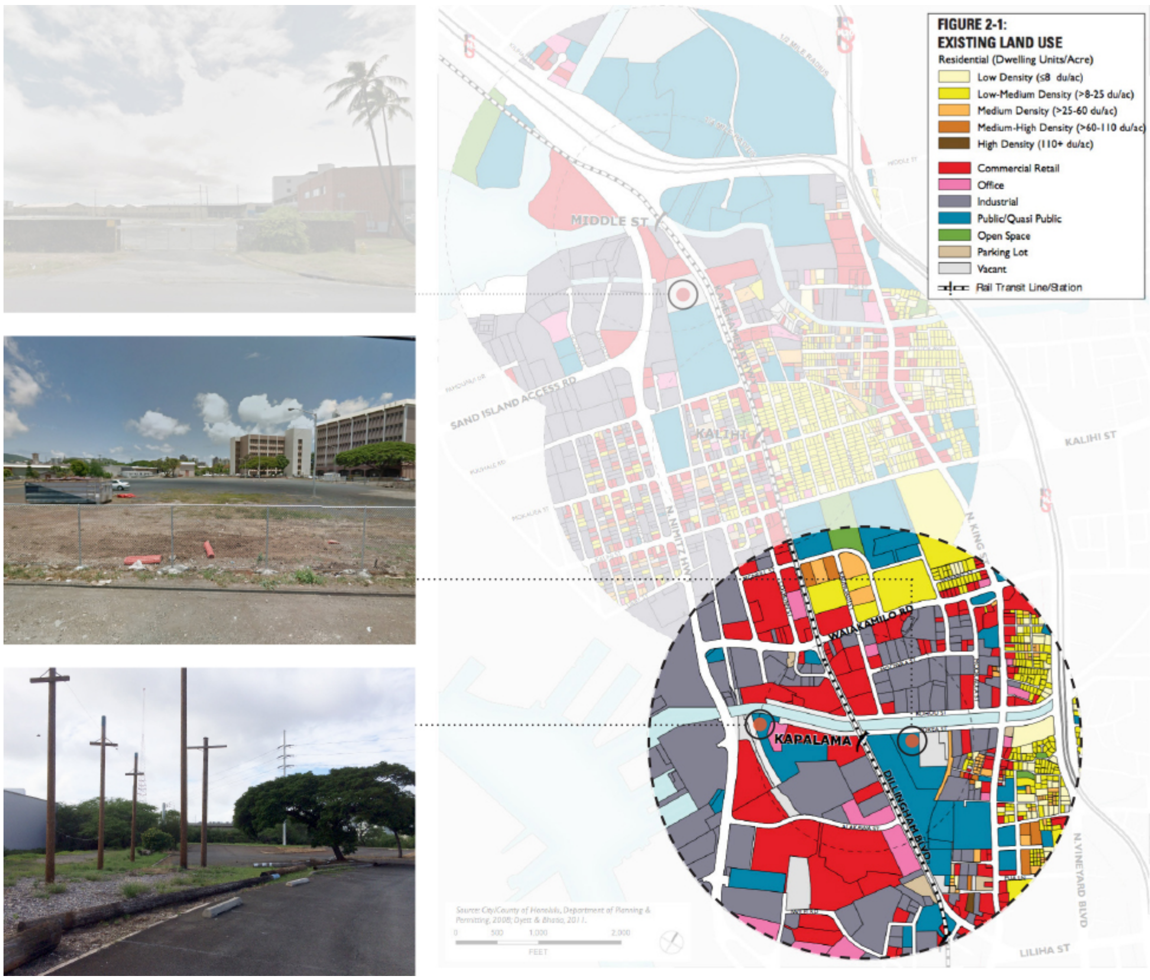


Figure 4.6 Narrowing selection to two potential sites

While the above illustrates the two potential sites over the existing land use in the Kapalama area, the TOD proposal also reveals the future land use plan and maximum building intensity (FAR). The land use plan map (Figure 4.7) shows that the two sites will remain public/quasi-public areas. The building intensity map (Figure 4.8) shows both sites in the lowest FAR zone of 0.5 to 1.9. This verifies that either site will work well for the pilot design project.

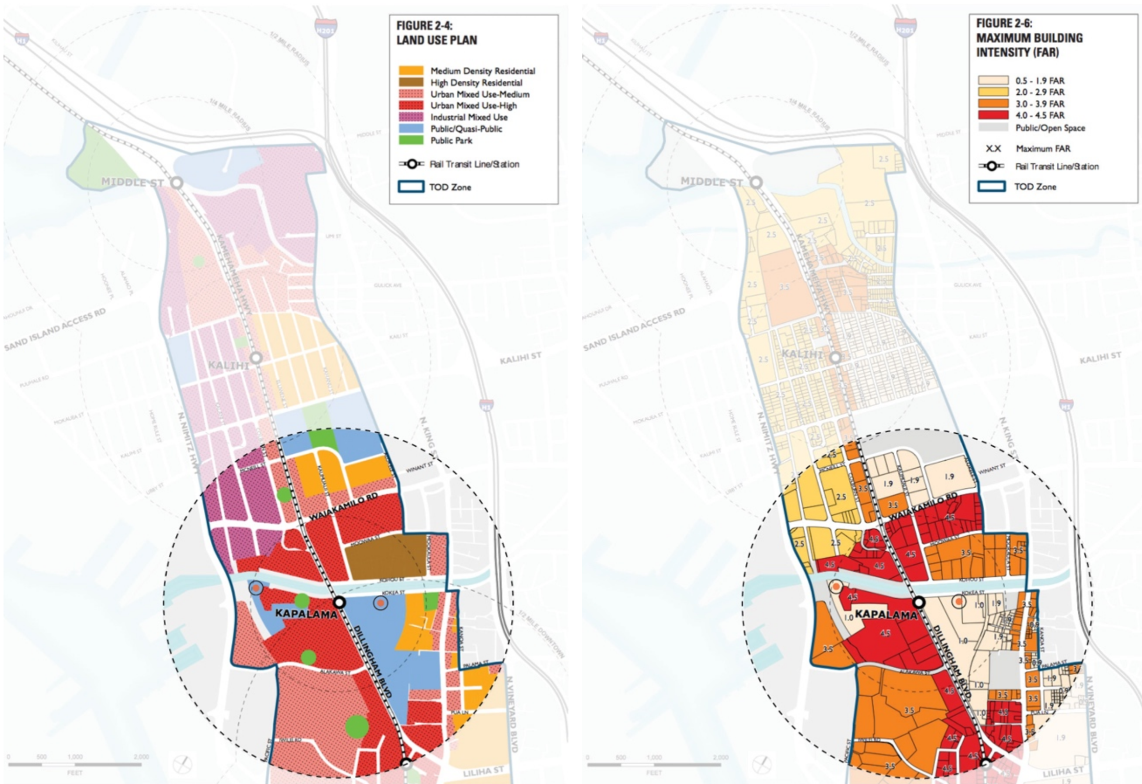


Figure 4.7/8   Land use plan (left) and FAR (right)

Analyzing the proposed TOD land use and FAR plan in relation to the existing context confirmed the validity of both sites. As both are HCC property, they fall into the public/quasi-public domain and the lowest FAR intensity. Therefore, either will fit well with the proposed project parameters. Typically, a public/quasi-public domain would be undevelopable. However, with the proposed system for this project, it compliments the idea of a state endorsed project.

Site Vulnerability

The final steps in determining the best suited site are the environmental factors. The site is intended to be in a flood/hurricane zone and sea level inundation zone, as these factors have been an integral part of the theoretical framework of the project. Analysis of the inundation risks of the area was done using PacIOOS interactive maps. The left map illustrated below reveals potential Sites 1 and 2 with hurricane inundation and the right reveals sea level rise at a 1-meter scenario. While both sites would be impacted by extreme weather conditions, Site 1 would be most affected. This is because of its proximity to the harbor and Kapalama Canal. Further examining the conditions, the sea level rise map shows that Site 1 would be the only site affected.

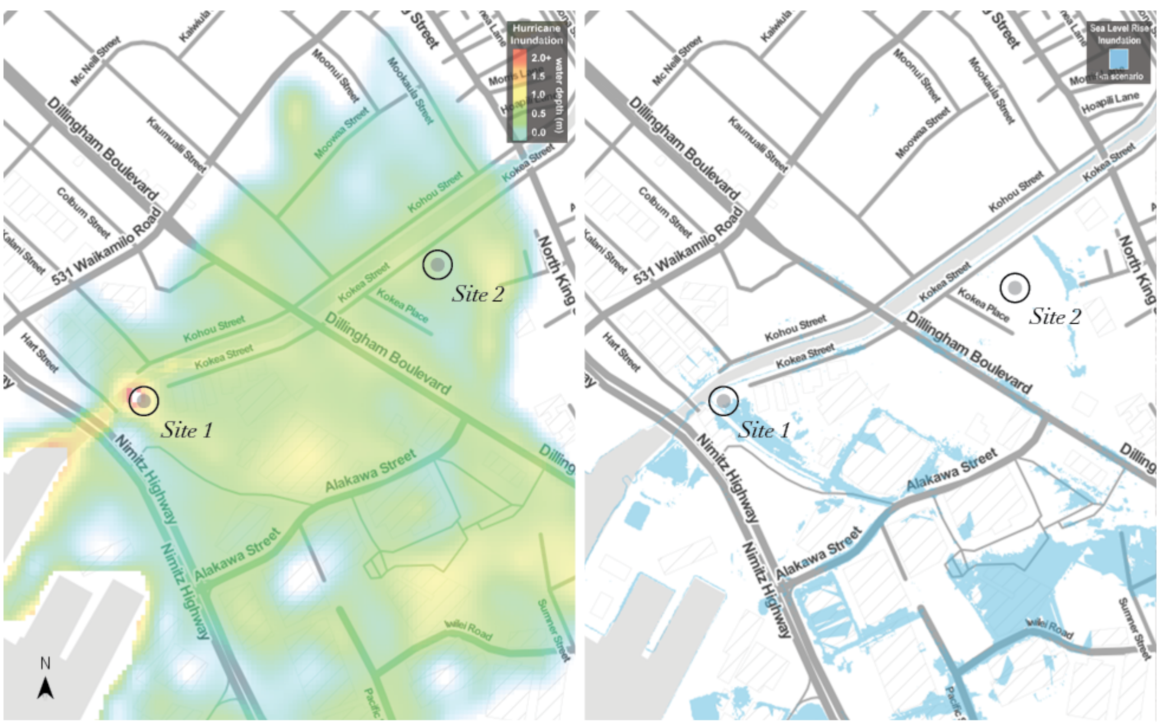


Figure 4.9/10 Flood/hurricane inundation (left) and sea level rise inundation (right)

4.3 Site Selection and Analysis

Pilot Site Selection

To encourage the dynamism and design responsiveness of the pilot project, the site that is most vulnerable to inundation has been selected. The highlighted area in the high-resolution satellite image below will be the chosen site for the design project. As listed in the image, the site contains all the necessary criteria defined in this chapter. The selected area makes up approximately 65,000 ft^2 and maintains a fairly level grade (< 5%). This makes it a very practical and potentially buildable site for the proposed design.

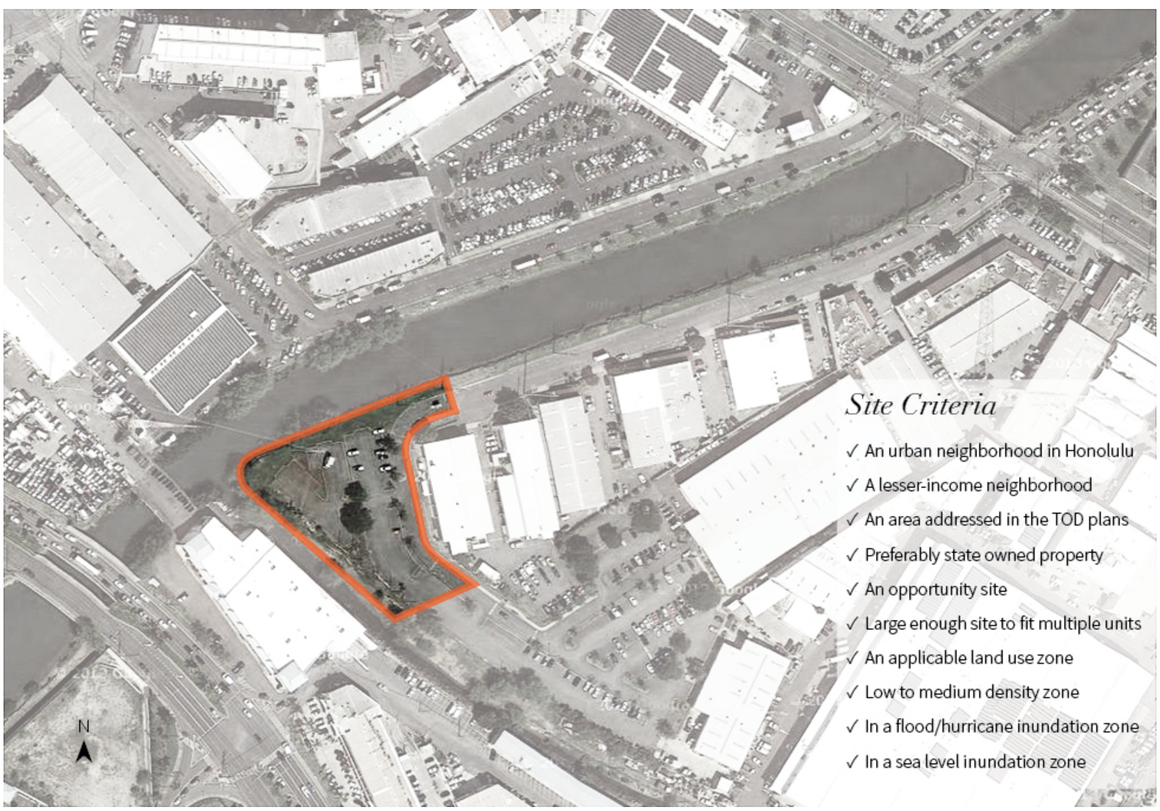


Figure 4.11 Site selection

Preliminary Analysis

The preliminary analysis of surrounding context addresses nearby highways, roads, points of access, waterways and other influential factors. It also highlights proposed TOD plans for a nearby promenade and the Kapalama rail station. These relationships are integral in setting the framework for the initial phase of design. The light green area highlights the entire 445 Kokea Street parcel owned by the University of Hawaii. The hatched darker green area highlights the proposed pilot site.

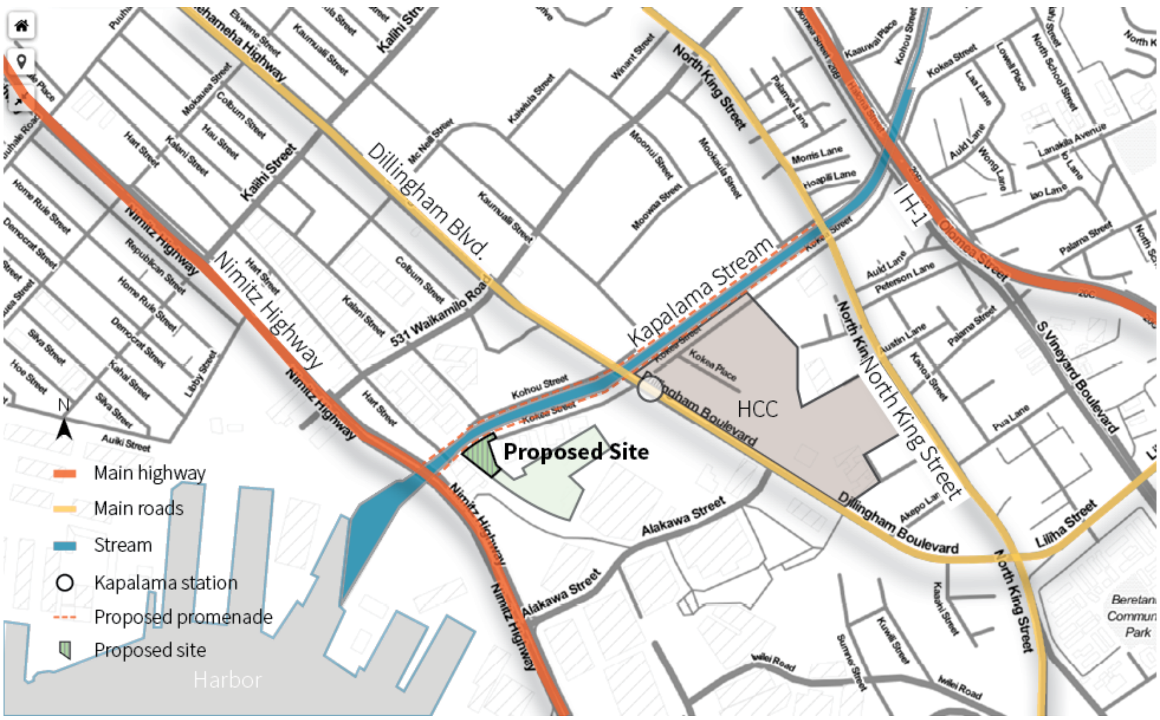


Figure 4.12 Surrounding context

The site is currently an abandoned parking lot at the end of Kokea Street in Kapalama. It is adjoined to a larger parking lot that serves a Honolulu Community College facility. The existing neighborhood has an industrial character of warehouses and mixed use shopping centers. It is in industrial-commercial mixed use IMX-1 zoning. According to the City and County of Honolulu Department of Planning and Permitting (DPP), there is no street setback or lot restriction for the site.[56] There are existing trees, abandoned telephone poles, and a power line that must be considered when designing the site.

Figure 4.13 Site context

Site Analysis

The site analysis investigates surrounding environmental and climatic conditions. This includes a fundamental analysis of sun path, prevailing winds, rainfall patterns, and existing site context. The site has a slight slope with its highest point at the northwest corner. The highest point was measured approximately 8 feet above sea level at low tide. This height slightly decreased to about 6 feet over the length of the site. A small canal

[56] Department of Planning & Permitting: Interactive GIS Web Map and Data Services, Parcels & Zoning Information, accessed Monday, December 7, 2015, http://gis.hicentral.com/FastMaps/ParcelZoning/

runs along the southwestern side of the site, while Kapalama Canal runs to the north. Existing infrastructure exists on the east end of the site.

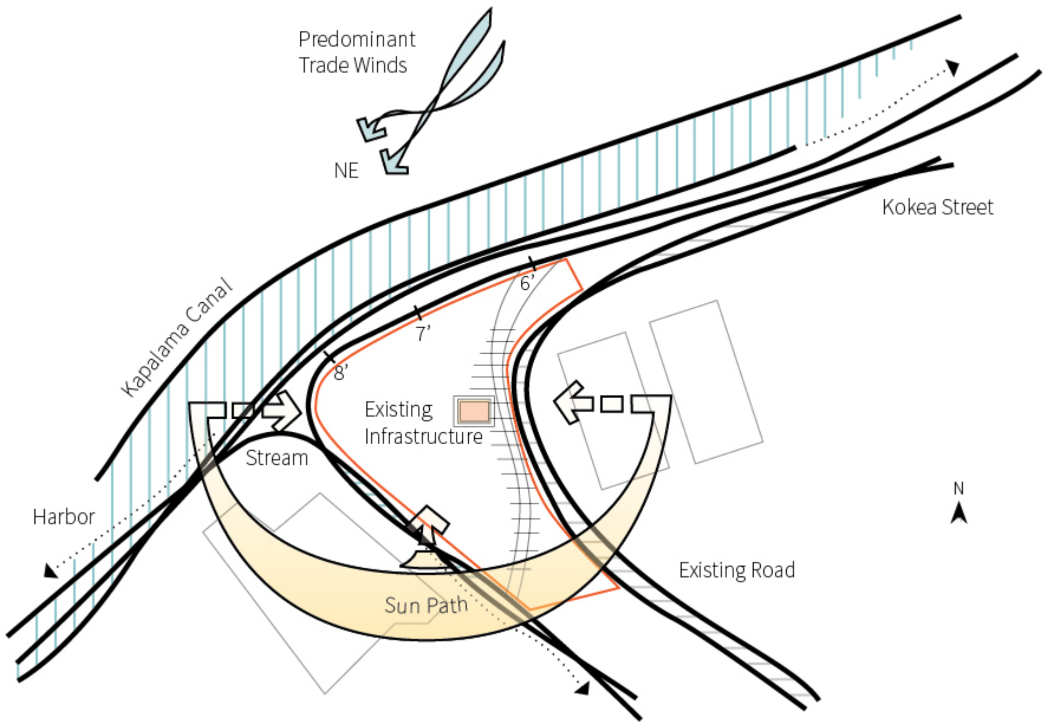


Figure 4.14 Site analysis

Analysis of surrounding context and existing site conditions are an integral part in the the design process. The site layout must work with existing trees, slope, access, and surrounding buildings. The design of the entire village system will compliment the local ecologies, while individual units will be in tune with Hawaii's tropical climate. In doing so, the design must respond to predominant winds, sun direction, and maintain an overall relationship to surrounding elements.

5. Pilot Design Project

5.1 Design Concept

Built from Nature... Inspired by Nature

As we transition into the design project, Chapter 5 begins with an introduction to the concept. The building system is centered around albizia as a local sustainable building material. In harnessing the authenticity of this, the design concept has taken its inspiration from the natural processes of the albizia tree and pod system. Figure 5.1 illustrates a dissection the *Falcataria moluccana* pod found in Hawaii. The pod functions as the casing for the seed clusters. Within the pod, the seeds are connected to a stem that is the lifeline to the tree. This integrated system has become the basis of the pilot project design concept.

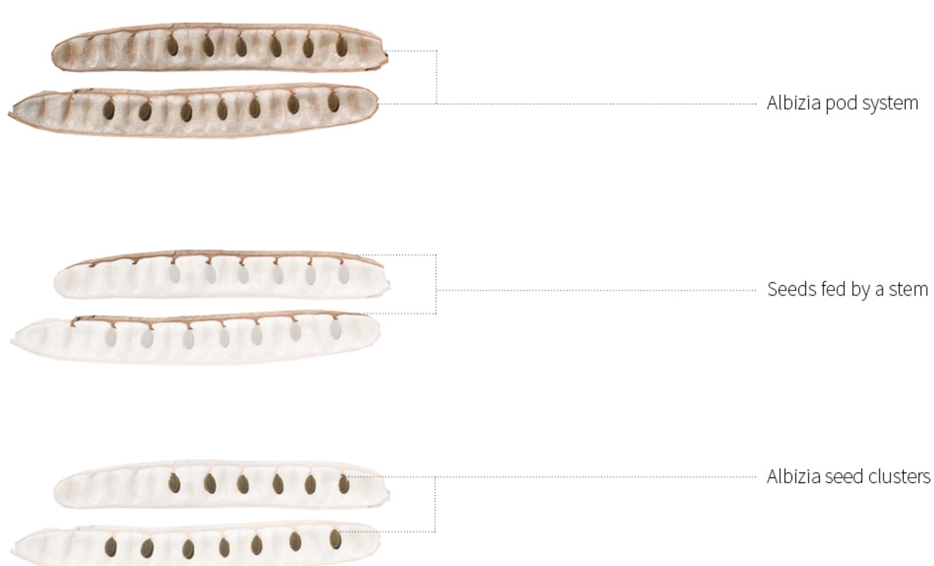


Figure 5.1 *Falcataria moluccana* pod system

The concept traces the albizia pod system from seed to tree. The soul of the tree is captured and integrated into the heart of the design. It mimics the remarkable process of photosynthesis, where a seed becomes nourished by the sun, water, and nutrients to develop into a thriving organism. It respects the balance of nature's energies and offers the potential as a self-sustaining system. Just as the tree has the capacity to create its own nutrients, grow rapidly, and reproduce, the design takes this and translates it into a biomimetic building system.

As a solution to mitigating the housing crisis, the design proposes a rapidly deployable and potentially off-grid system. It mimics the tree and its pods as a self-contained organism. The tree translates to the central hub, which has been named the infrastructural core. Like a tree, it harnesses energy from the sun and rain, while serving the more practical functions of a communal space for shared facilities. Similar to how the stem of a tree connects to its pods, a series of integrated infrastructure pathways are connected to each housing unit cluster on the site.

In studying the elements of the tree in nature, we can begin to reverse engineer its systematic process. The tree collects and manages the essential nutrient for life. This translates to the design of the infrastructural core. The lifeline is fed through the stems and into the pods, which is reflected in the integrated infrastructure pathways. The seeds are clustered within the pods, translating to the individual unit assemblies. The diagram in figure 5.2 visually simplifies the concept as a bio-inspired building system and renders it onto the project site.

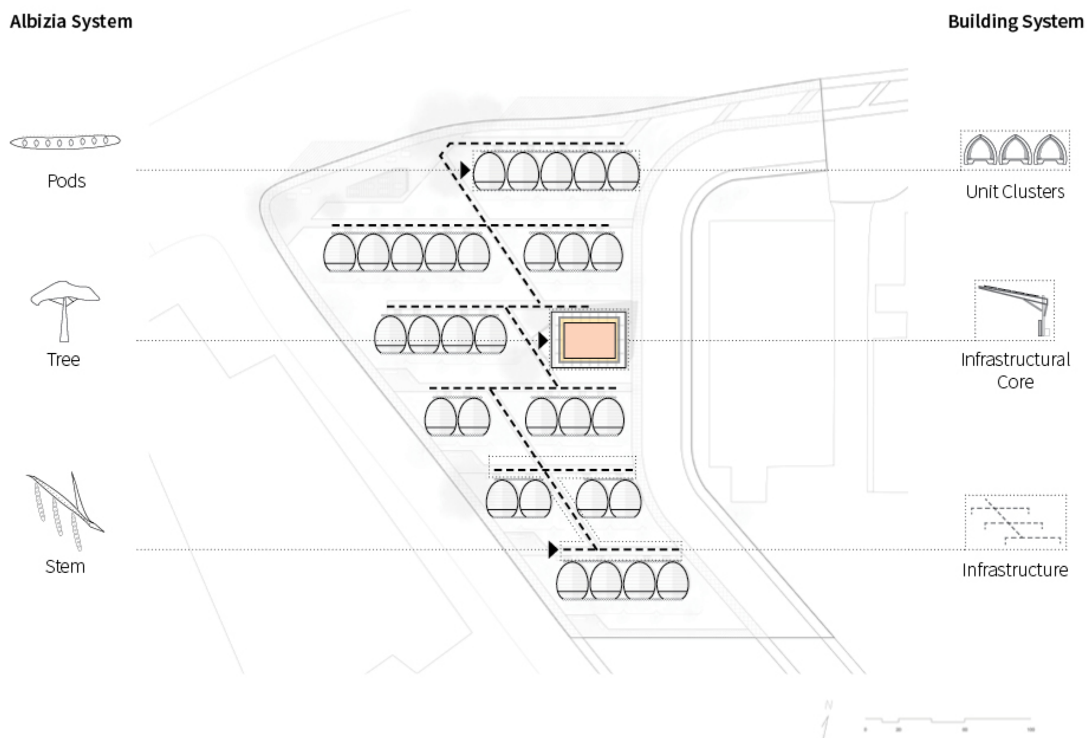


Figure 5.2 Bio-inspired building system

The concept ties to the application of an easily deployed housing community. Each layer is composed of a simple system of the basic necessities for a small transient village. The infrastructural core functions as the hub for power and water supply. The supply is fed through the infrastructure system to each of the unit clusters. Acknowledging uncertainties of future supply and demand, the building model offers flexibility in accommodating a self-sustaining system. At the same time, it can easily hook up to the existing city grid. This system will be explained in more detail later in this chapter.

The following section explores the proposed site design. It justifies the development of a site plan and defines a lightly integrated approach to the landscaping and infrastructure.

5.2 Site Design

The site plan developed from a linear layout of spatial and organizational drivers. Working concurrently with site accessibility, context, unit size, privacy and public nodes, the site plan was an ongoing process throughout the design. A logical circulation system followed suit with the linear structural system of the units and pitched angle of the westernmost site edge. A clear north to south orientation was necessary in allowing for natural ventilation and lighting to work with the bioclimatic design of the units. This was slightly offset from the true north axis for the units to correspond to surrounding building layouts.

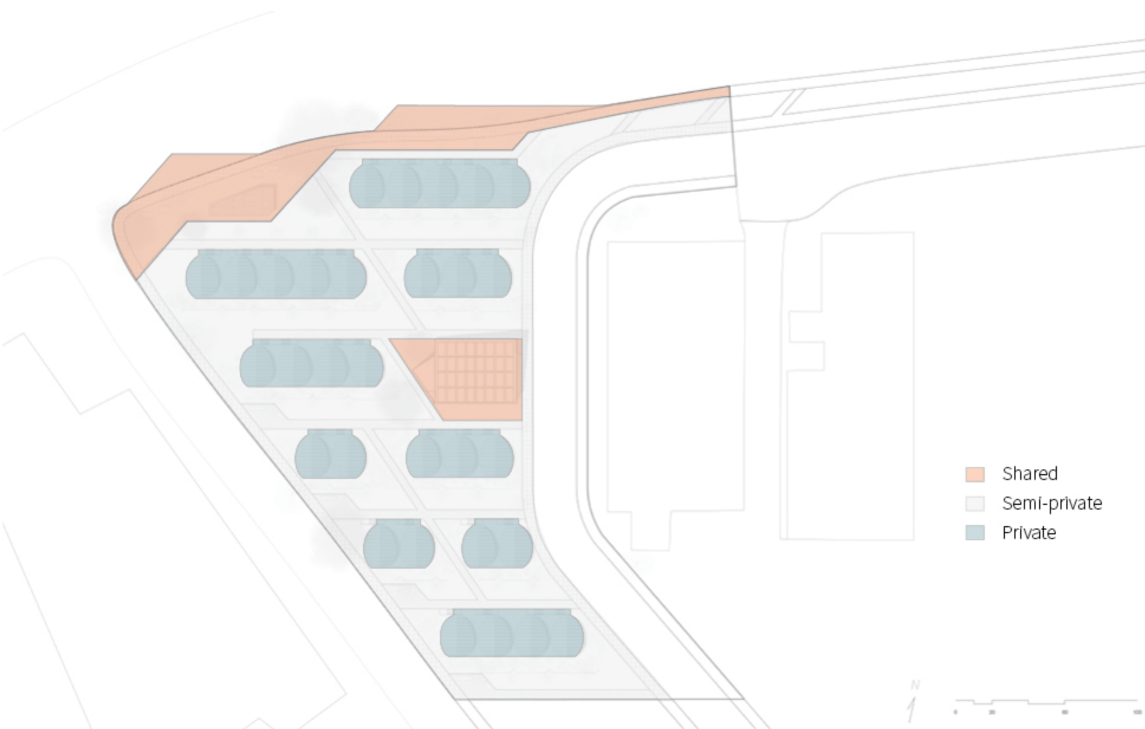
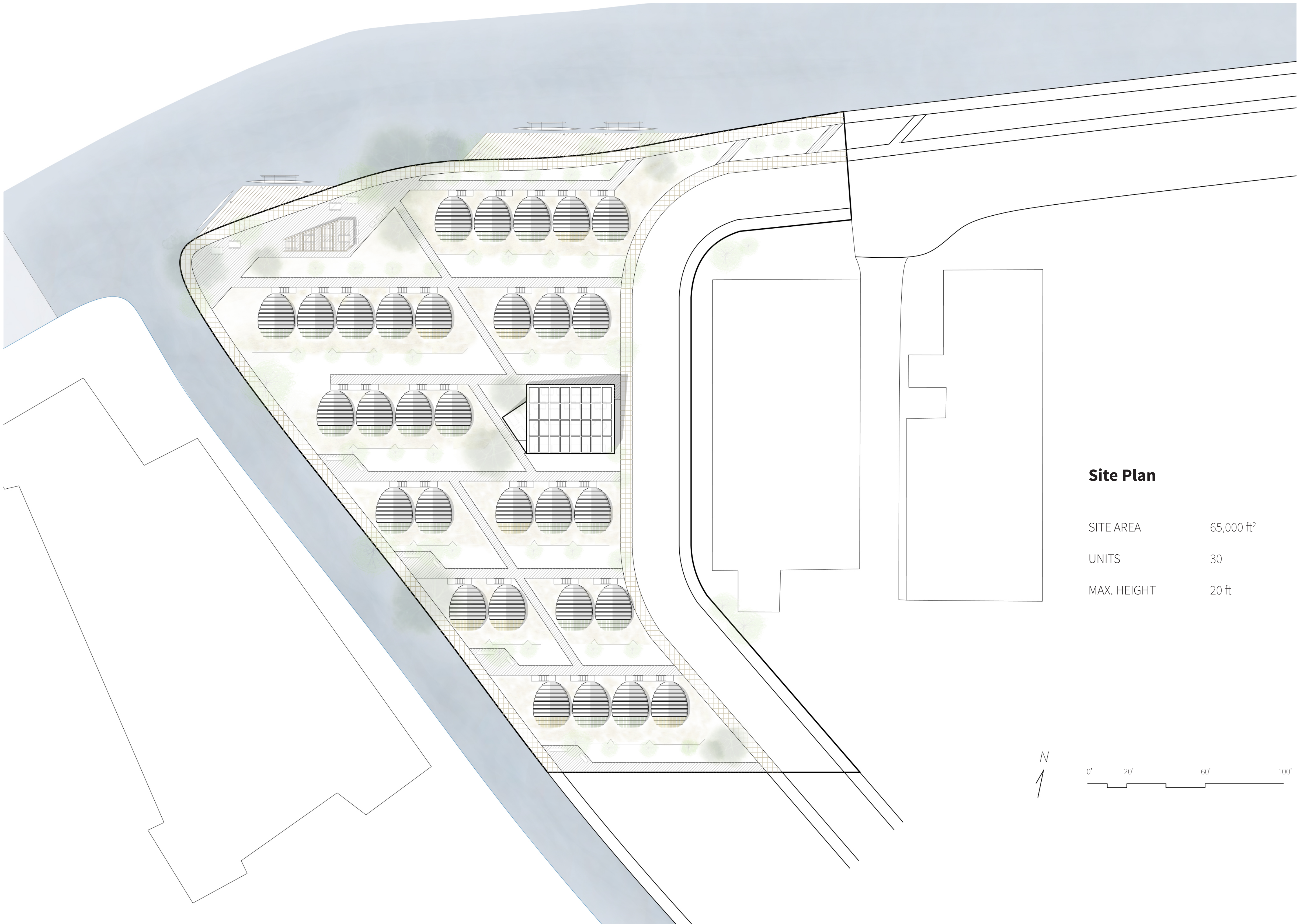


Figure 5.3 Zone distribution diagram

The site is distributed into three basic zones: shared, semi-private, and private. Shared zones are designated as community social areas for the village dwellers. The semi-private zones are areas between shared and private areas that function as garden spaces, circulation pathways and nodes. The private zones are made up of the spaces within and around the housing clusters.

The northernmost edge of the site maintains a strong connection to the Kapalama Canal. This area is complimented with a shaded pavilion, barbeques, and social seating for shared public use. The design also proposes the potential for a light integration of dry docks for water access along the canal. The second shared zone is the infrastructural core. As described in the preceding section, this central hub is the heart of the building site system. It has been rationally placed in proportion to the number of unit clusters, as it will serve as the main communal facility. The structure is oriented with a south-sloping roof to accommodate a photovoltaic array and rainwater catchment system.

The site has been organized with 30 housing units. In each housing cluster, a 2’ space is left between units for maintenance and privacy. Every row of clusters is spatially organized to allow for circulation throughout the site. The distance between rows maintains a consistent 30’ spacing, offering privacy on the north and south façade of each unit. The southern façades open to a small semi-private area of garden beds. At the threshold of these gardens are lightly planted trees and shrubs. The next page illustrates the site plan, followed by a rendered elevation of simple site modifications and landscaping between units.

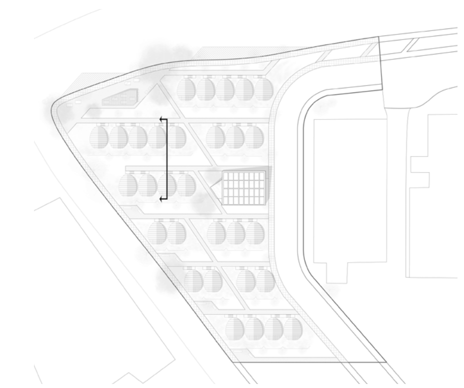


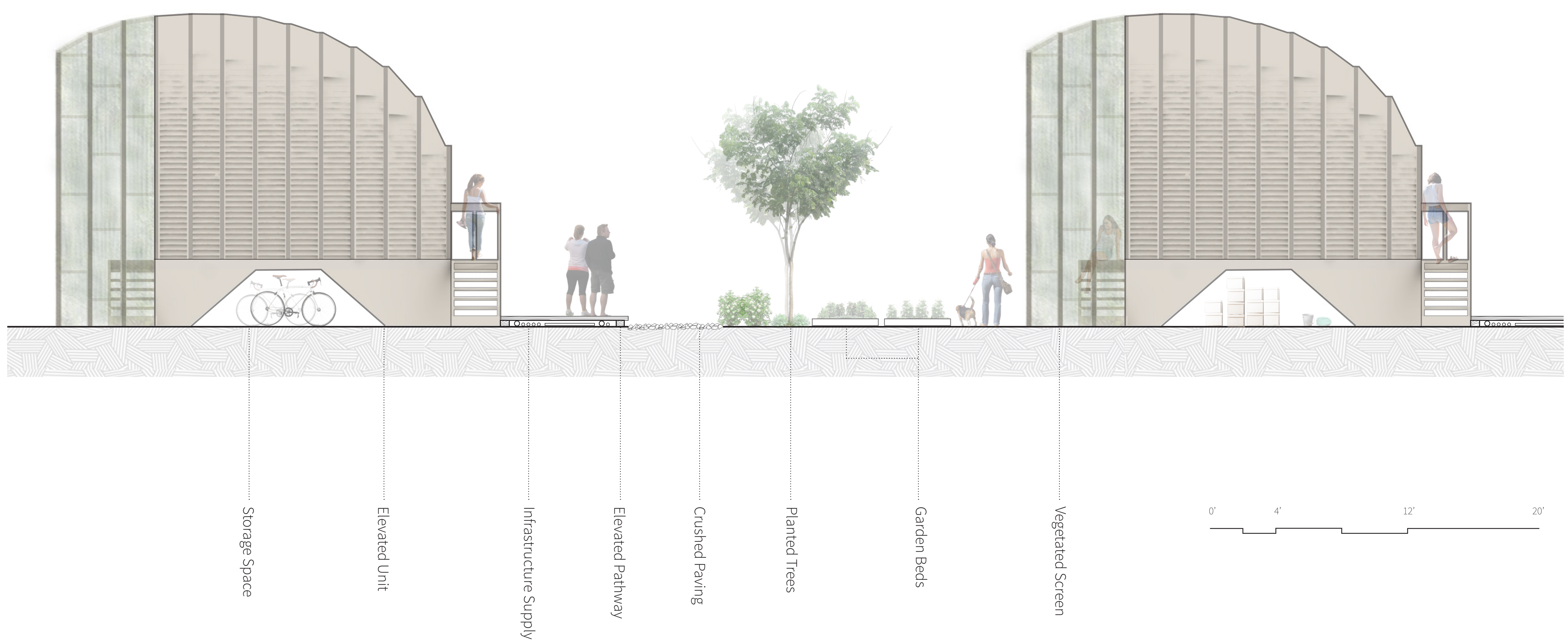
Site Plan

SITE AREA	65,000 ft^2
UNITS	30
MAX. HEIGHT	20 ft

Simple Site Modifications

Touch the earth lightly





Site landscaping demonstrates a light removal and crushing of existing surface asphalt. This provides a simple leveling solution for built areas, while creating zones for pervious paving and vegetation. Planting of small trees and raised garden beds are logically placed in relation to designated private and public zones. Main pathways to unit clusters and common areas are designed as a system of elevated wood decking. Infrastructure supply from the central hub to each unit is located beneath the decking. Figure 5.4 illustrates the elevated pathway system and its relationship to the housing unit.

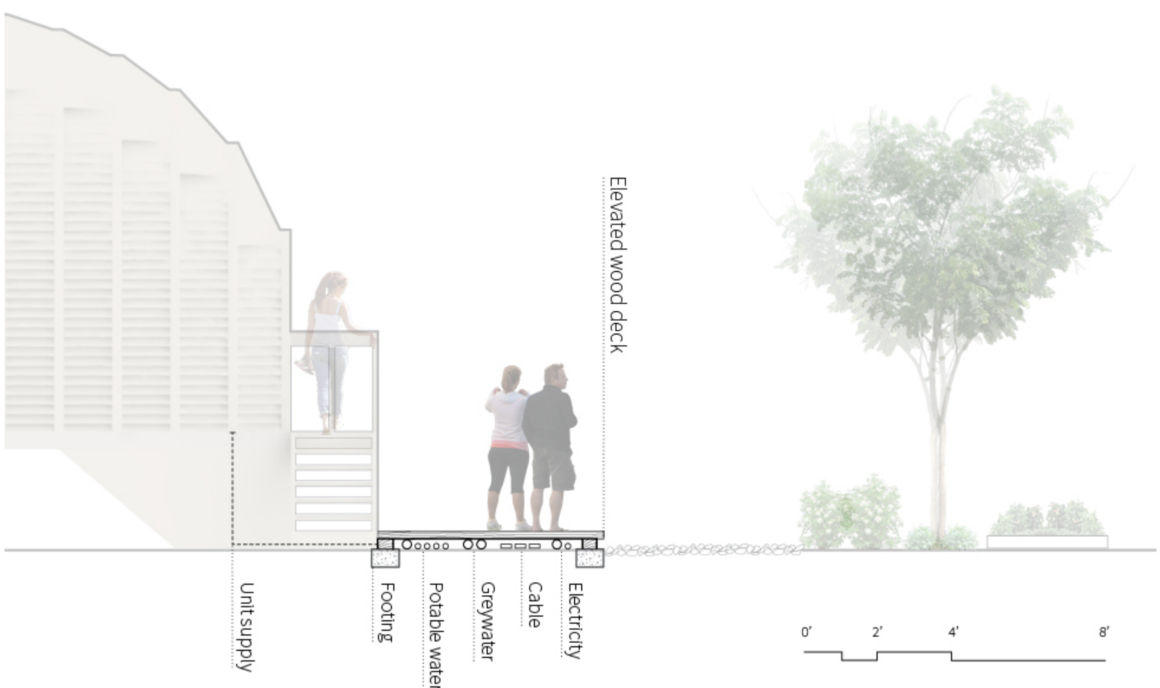


Figure 5.4   Elevated pathway system

The elevated pathway system is designed to double as the footpath circulation and infrastructure supply throughout the site. By elevating a simple deck made of albizia, we can eliminate the need for major site infrastructure modifications and unnecessary materials. Utilities for each unit can be supplied through the pathways and delivered beneath each front entry landing. The supply of utilities will be managed and distributed from the central infrastructural core.

5.3 System Phasing

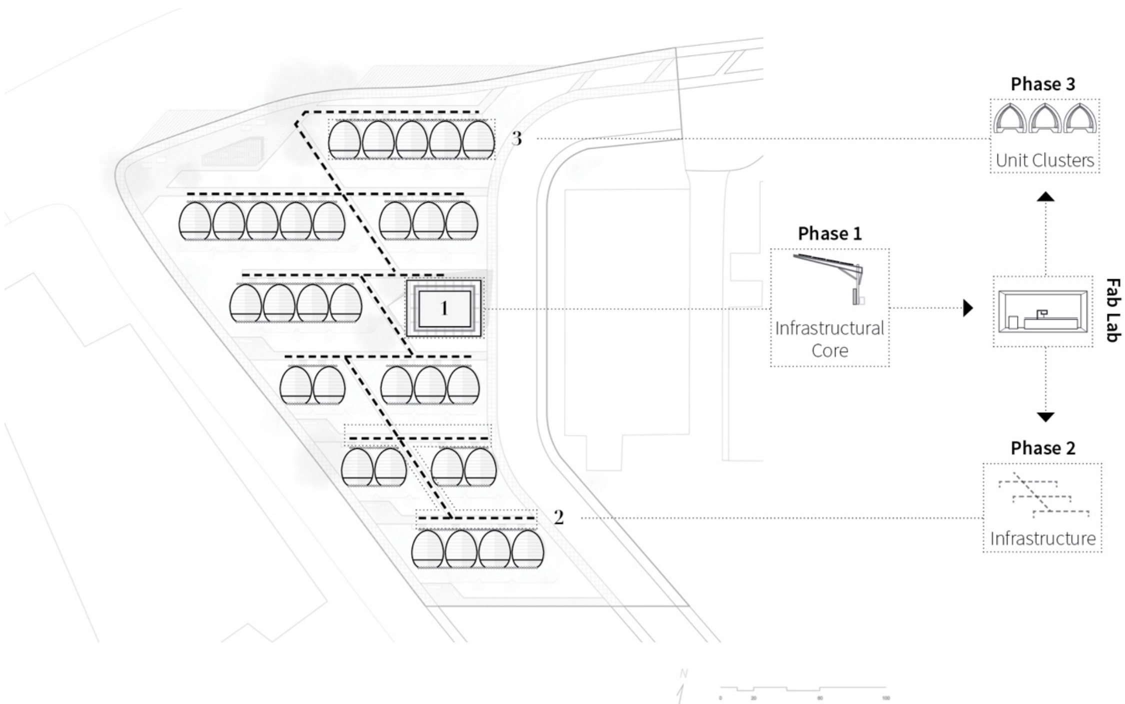


Figure 5.5 Three phases and on-site fabrication lab

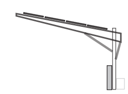
Relating back to the concept diagram as a bio-inspired system, the site can be dissected into three main phases of construction. Following a basic leveling and removal of existing asphalt, the initial phase includes building the infrastructural core and powering the fab lab. The second phase is laying out the infrastructure, elevated pathways, and basic site landscaping. The final phase is housing unit fabrication and connecting their internal systems. This phasing sequence is illustrated on the following page.

System Phasing Sequence

A three week timeline

Day

1 - 9

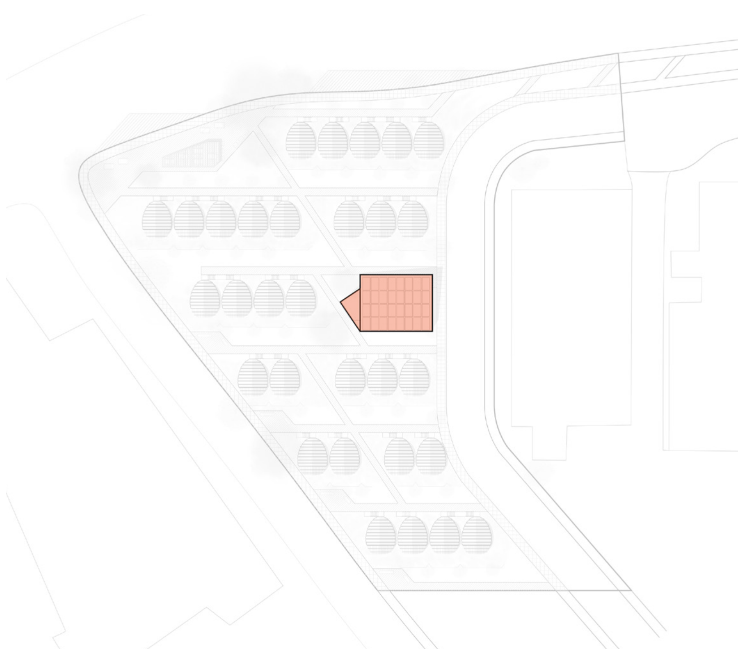


Infrastructural Core

Fab lab

Energy generation

Shared facilities



Day

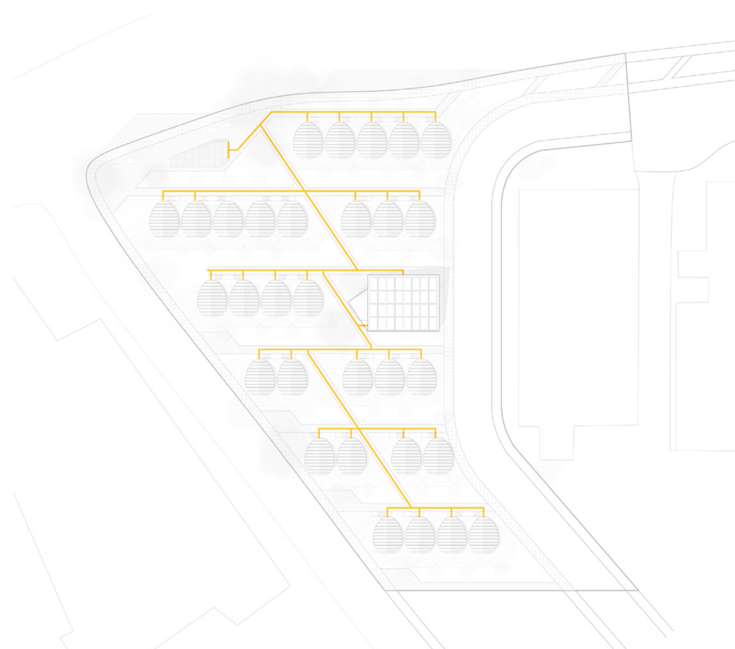
10 - 14

Infrastructure

Elevated pathways

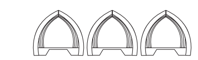
Unit utilities

Site modifications



Day

15 - 21

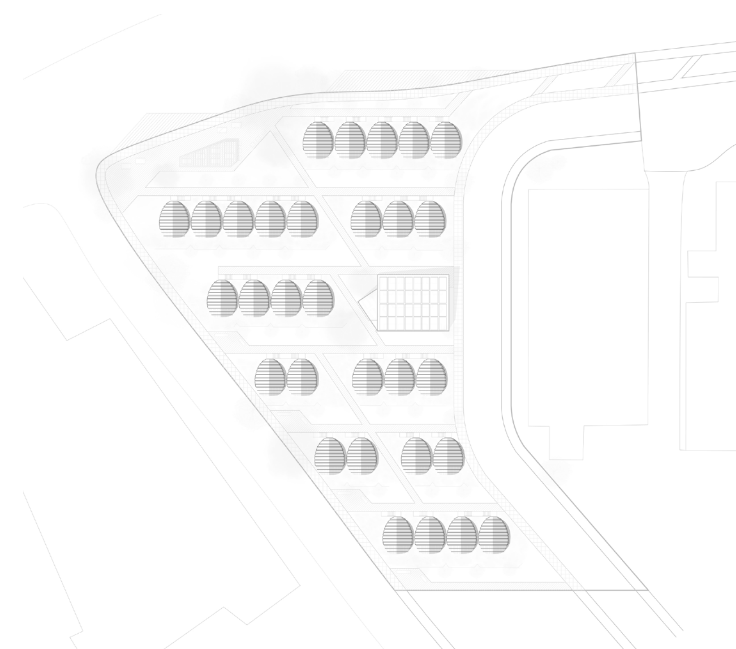


Unit Clusters

Foundations

Housing kits

Internal systems



The building components will be systematically organized into a flat pack kit-of-parts to streamline the construction process using on-site CNC fabrication. The system phasing sequence proposes a three-week timeline from constructing the infrastructural core to the final housing unit. This is an estimated timeline based on the efficiency of digitally fabricated structures and building components with embedded information.

The first phase is crucial in achieving this, as the infrastructural core will house the on-site fabrication lab. Once the building envelope is completed and connected to a power supply, the fab lab can begin production. An on-site CNC machine and sufficient building material will offer rapid fabrication of pathways, seating and shading areas, and housing units. As the fab lab generates components, the core structure can continue to finalize construction. This phase is estimated to take 9 days for completion.

The fabrication lab will simultaneously make components for the infrastructure pathways and other site features, which will initiate the second phase of construction. As the elevated pathways are laid, the integrated infrastructure can be installed beneath. This phase is estimated at five days of construction.

Once all components are fabricated for the second phase, the fab lab can transition to making the kit-of-parts for the housing units. Before installation, the housing units will require basic concrete footings. These can be installed as the unit components are fabricated. Once a unit kit is ready, it can be taken to its site and assembled. The internal unit systems such as electricity, lighting, and utilities for the bathroom and kitchenette can be installed as the structures are built.

The system phasing sequence offers a simplified framework for building an entire village of 30 housing units in just weeks. While it may appear an ambitious target, it represents the ease of assembly and transient nature of a village set within a concrete jungle. The succeeding sections will delve deeper into the design and systems of the housing units and infrastructural core.

5.4 Infrastructural core

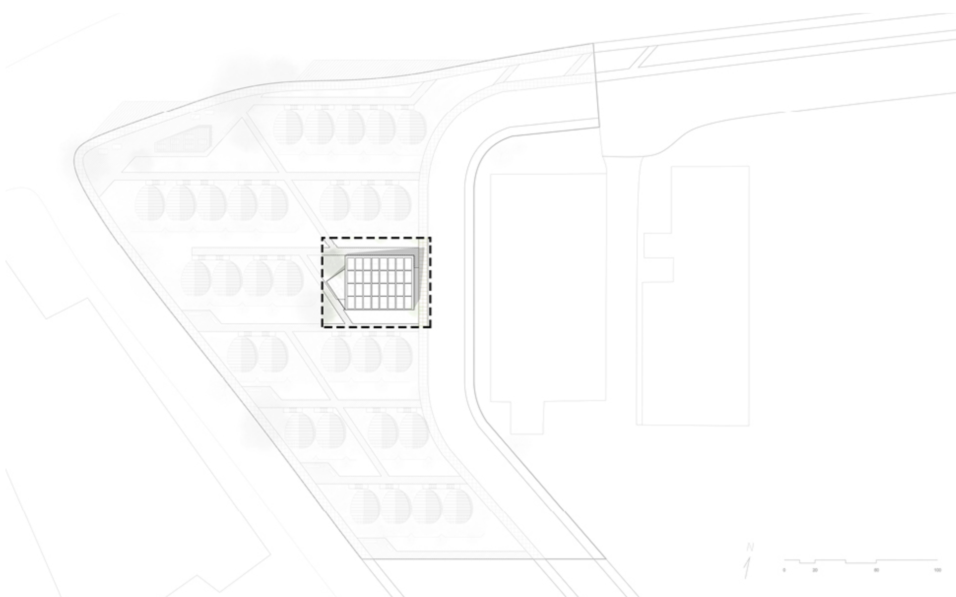


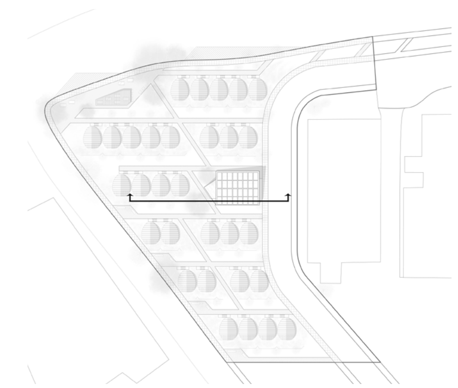
Figure 5.6 Infrastructural core in site plan

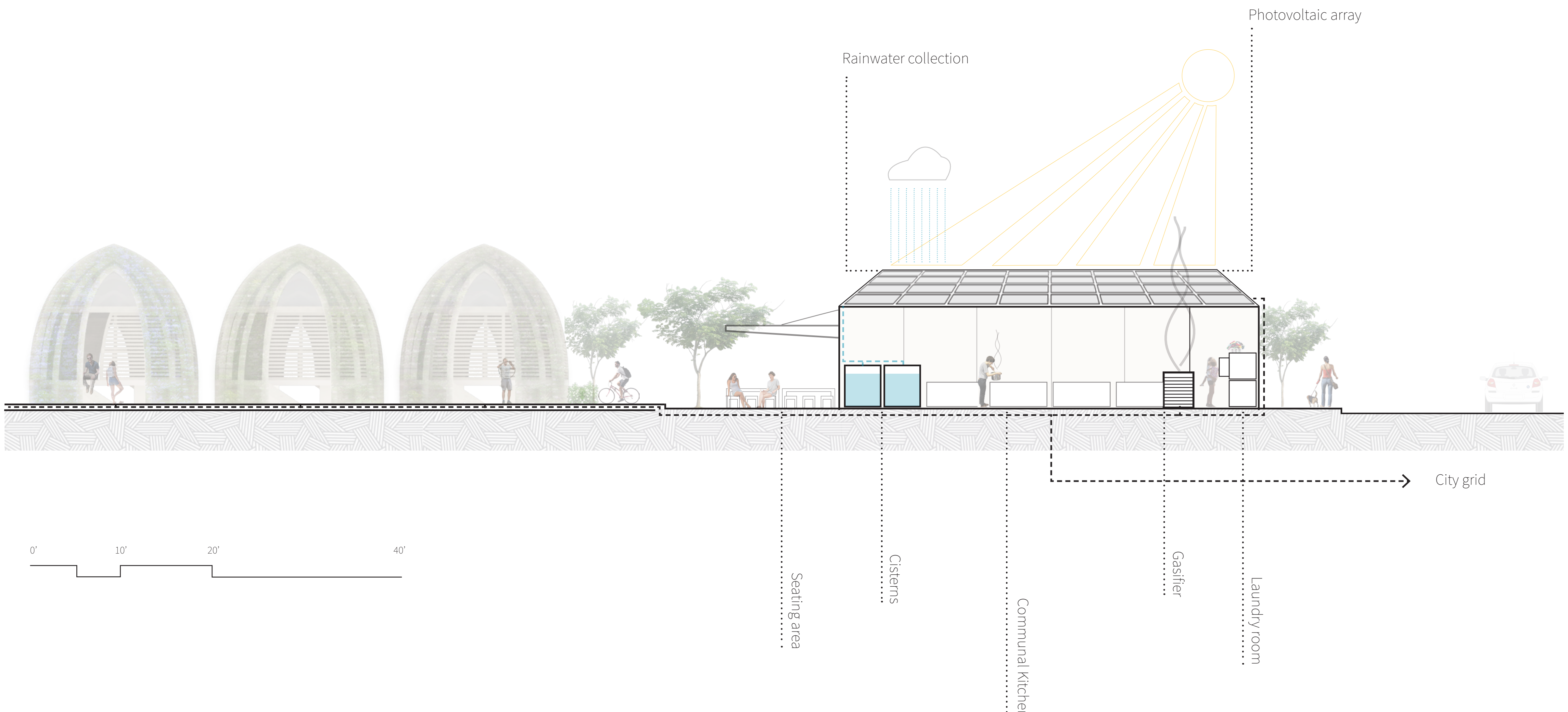
The infrastructural core is the central hub of the village. As the first phase of construction, it will house and power the on-site fabrication lab. For the duration of construction, the fab lab will serve as a placeholder for the shared kitchen and laundry facility. Once the infrastructural core structure is built, it will run until all phases are complete. Then it will be removed and replaced with furniture and appliances for the kitchen and laundry.

The structure is strategically placed near the existing city grid. It will provide the framework to function both on and off the grid. This potential will depend on state incentives, budget, and existing regulatory framework. The southern-sloped roof is angled to allow for on-site power generation through photovoltaic panels. It also functions as a rainwater harvesting system for site irrigation. Additionally, an on-site gasification system is proposed to utilize the albizia scraps from the construction process and continue use with food waste and biomass. These systems offer the potential to generate energy and collect water, while being able to connect to the city grid as necessary.

The rendered section on the following page illustrates the functions of the infrastructural core and its relationship to the housing units.

Infrastructural Core Functions
A communal facility with off-grid potential





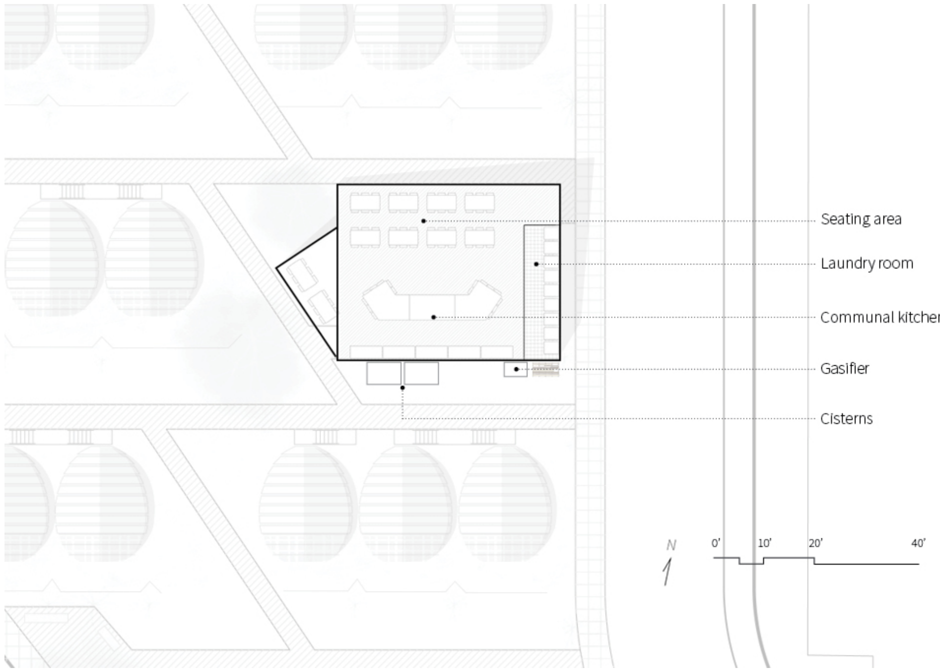


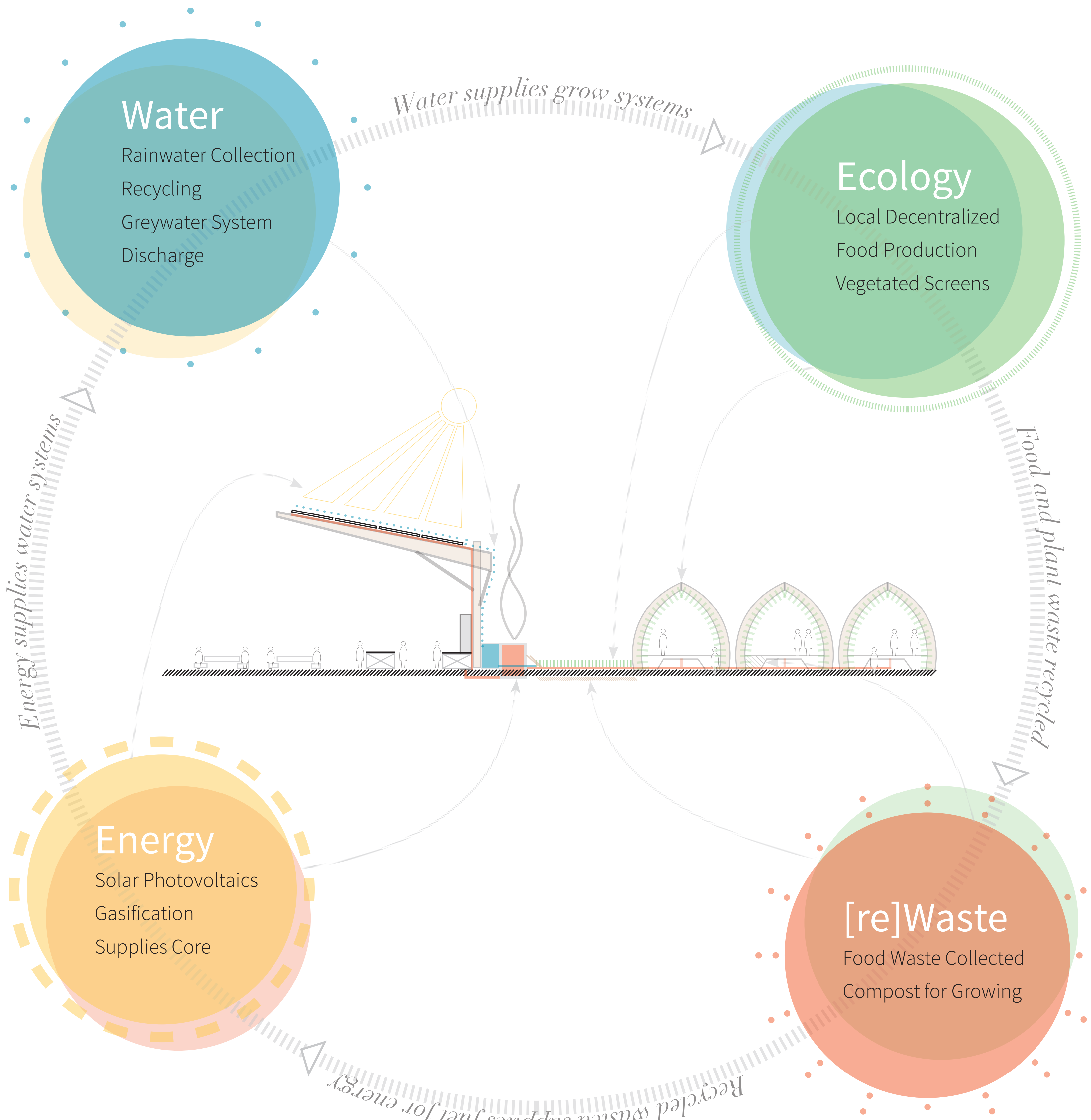
Figure 5.7 Plan view of core functions

With an area of 1,800 ft^2, the structure houses all the necessary equipment for a shared kitchen and laundry room. It is an enclosed space that will be accessible to inhabitants during regular operating hours. The kitchen supplies all the basic needs including sinks, ovens, stoves, storage, and cookware. An indoor-outdoor seating area runs along the north and west façades. Parallel to the access road, the laundry room has ample washers and dryers for the community. The structure provides ample space for residents to comfortably use and share communal space.

The following page illustrates the off-grid potential of the infrastructural core in relation to the entire village system. Four key elements coexist to create a closed loop system. Water supplies the ecology systems. Food and plant waste are recycled. The recycled waste creates fuel for energy and fertilizer, and is then fed back into the system.

Off-grid Potential

A closed loop system



5.5 Housing Units

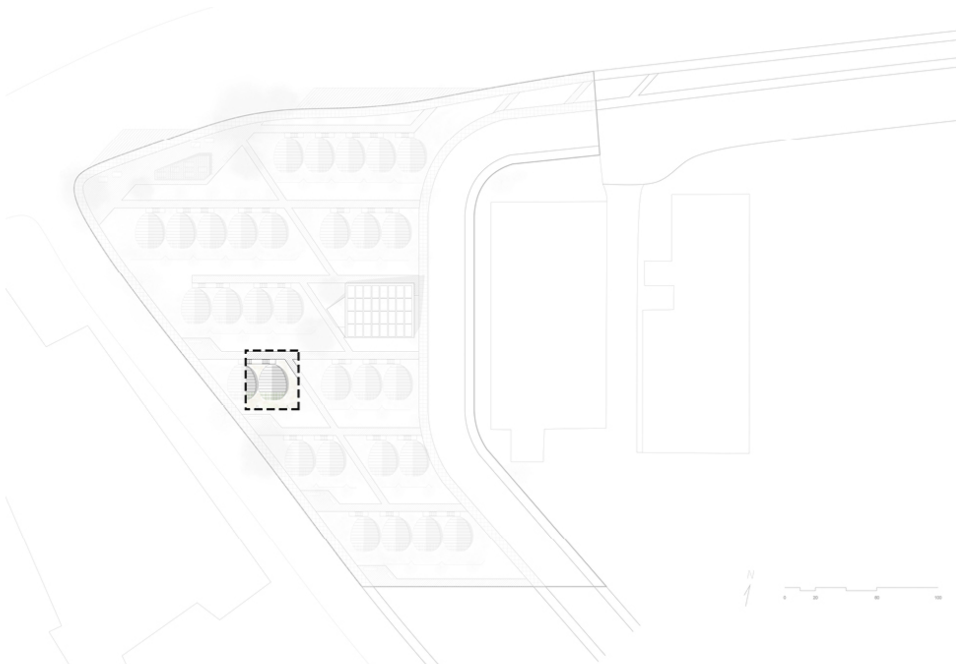


Figure 5.8 Housing unit in site plan

Unit Design

The housing units are the most important layer of the project. They are infused with a bohemian soul and a raw humanistic design. The form, scale, and structural components were developed to create a rapidly deployable and easily constructed unit. Balancing cost and livability was key in achieving a simple, affordable, and well-designed structure.

Conceived with an awareness of Hawaii's warm tropical climate, the units are tuned to the natural environment. The design reverts back to indigenous roots for achieving a low ecological footprint. It utilizes passive design strategies for inducing human comfort, while eliminating the need for a mechanical cooling system. A steep arched structure helps it deflects rainwater and diffuse heavy winds. Between a ribbed skeletal frame, a louvered skin system with protective internal screens allows for natural ventilation. The south façade is veiled with a vegetated screen to bring in natural light. The living space has an open floor plan and is elevated four feet for protection and flood resilience.

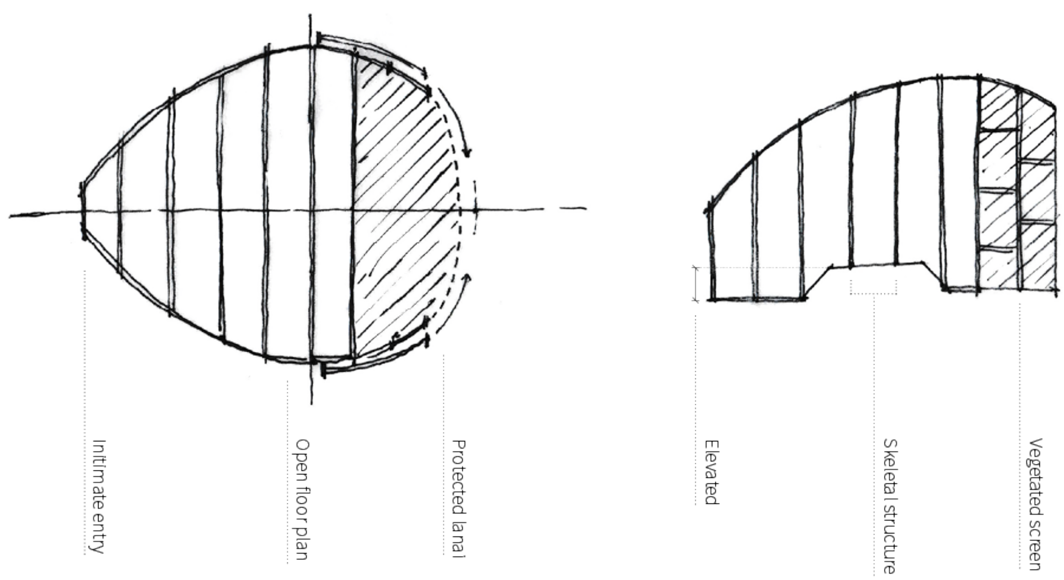


Figure 5.9   Concept sketch

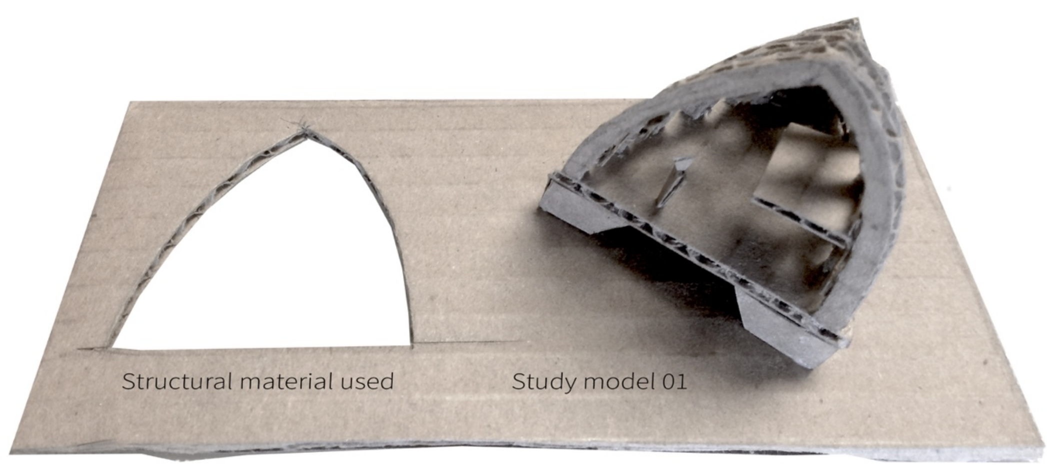


Figure 5.10   Study model

The form employs an arched structural rib system. It aims to eliminate traditional building materials with a soft palette of engineered albizia ribs and a treated albizia louver system. Press-fit joinery locks the ribs together while bracing ensures stability. The design fosters low-tech living through high-tech application. A simple rib and skin system creates a structure unique to the material it is conceived of.

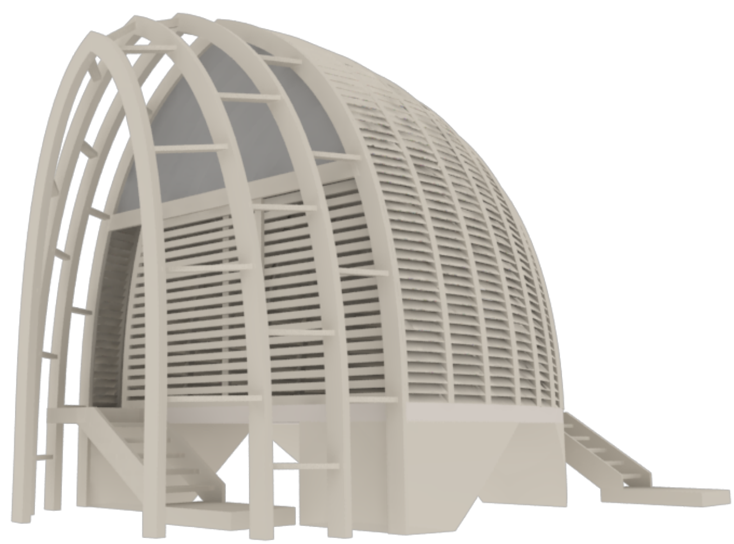


Figure 5.11 View of south entry

The units are small two story structures with an open floor plan and upper level loft. The south façade is designed with a large open screen window on the second level. Below is a slotted sliding wood door made of horizontal panels. The stairs lead to a small private terrace that is protected by the continuation of ribs. The ribs provide framing for a vegetated screen system that offers shading and diffuses natural light as it reaches the interior.

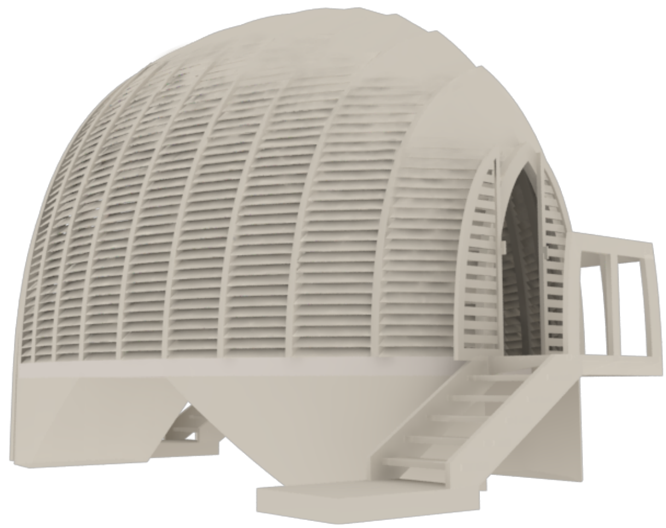


Figure 5.12 View of north entry

At the north façade is the main entrance to the units. The structural ribs narrow inward to create a more intimate front entry. The front door follows the same language as the south sliding doors. They are designed as two half-arches that slide apart to open. The north and south entries, including stairs, doors, and railings, are also made entirely of albizia.

A Bohemian Soul

Aside from the basic interior necessities, the structure is a highly customizable shell. A bohemian design approach encourages inhabitants to create their own interior space. Simple partition walls and an exposed structural system supports easy customization of open areas. The bathroom is an enclosed space with a composting toilet, shower, and sink. A small kitchenette mirrors the exterior bathroom wall. This allows for water supply to be easily distributed.

Figure 5.13 Section of unit interior

Each unit has a floor area of 270 ft^2 on the first level and 160 ft^2 on the second level, with a combined living space of 430 ft^2. The basic systems and walls for the bathroom, kitchenette, and loft are fixed, while the remaining space welcomes customization. An interior staircase near the front entrance leads up to the loft. To maximize natural light, a void near the large south window creates an opening to the space below. The remaining space on the first level provides a network of cables, hooks, and shelving to maximize customization. The rendered section in Figure 5.13 reveals the interior of a unit inhabited by a small family.

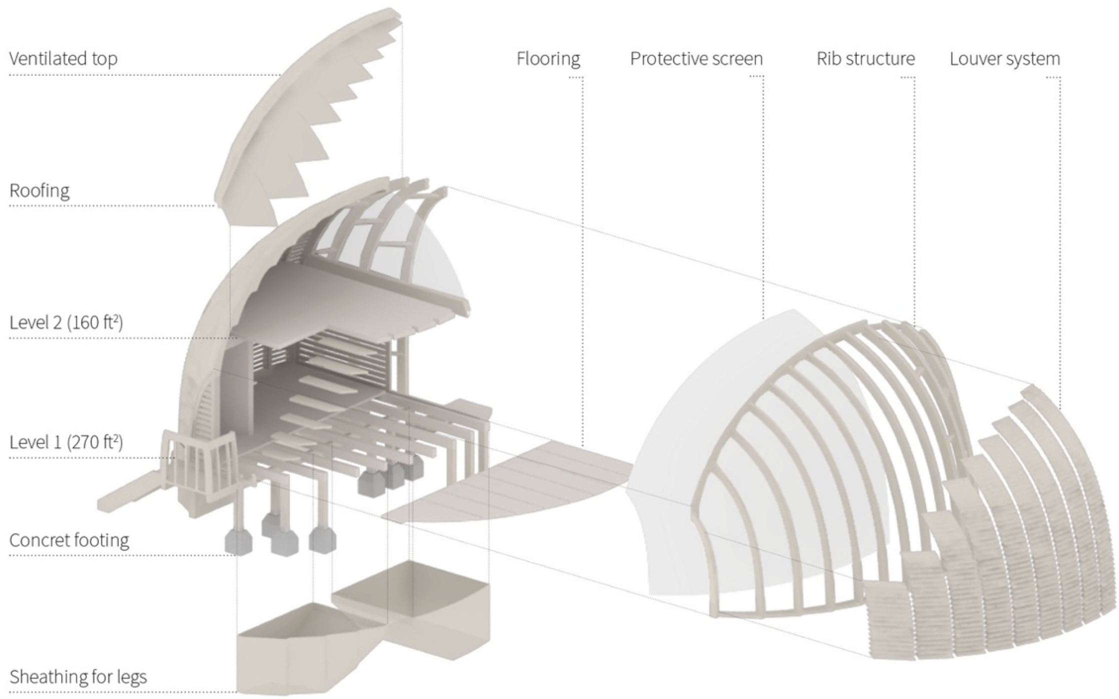


Figure 5.14 Exploded axon of unit components and interior

The structure is elevated 4 feet from ground level for protection and flood resilience. It also creates space for utilities and storage. The floor beams are held up by support columns that are placed into a concrete footing. The legs are encased in wood sheathing for an aesthetic finish. The flooring is laid with treated albizia boards that rest directly on the cross beams. Albizia louvers slide into the bays between each set of ribs to create a breathable building skin. The inside of each bay is sealed with a protective screen for repelling insects. The louvers transition into sealed roofing towards the upper arch of the bays. This provides weather protection and enhances the privacy of the second level bedroom. The spine at the apex provides bracing for the ribs and is mounted with a waterproofing membrane and a raised cap for ventilation.

A Louvered Skin System

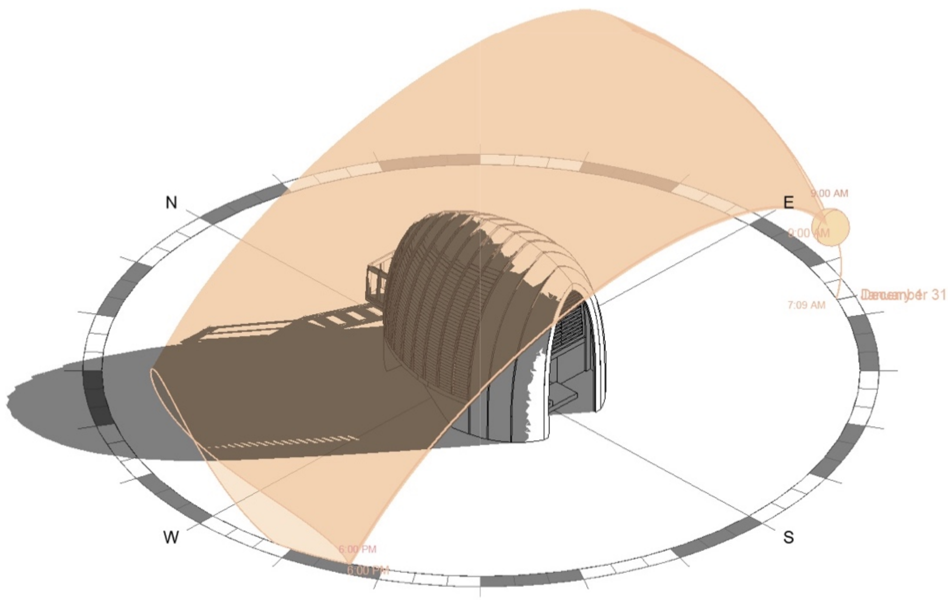


Figure 5.15   Autodesk Revit solar study for optimizing louver system

The skin design integrates a number of parameters in establishing the optimal louver angle, spacing, and depth. It considered privacy, views, ventilation, shading, and visual aesthetics to define a logical execution of design. The optimal solution was developed through a series of sun studies and 3D modeling software. A 45-degree angle and 4” louver spacing optimized the balance between outward visibility and inside privacy. It also visually reads well as a skin and transitions nicely along the curve of the ribs. This is demonstrated in the illustrations on the next page.

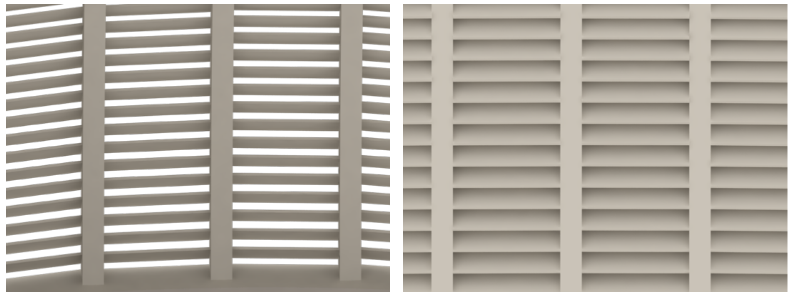


Figure 5.16/17   View from inside (left) and outside (right)

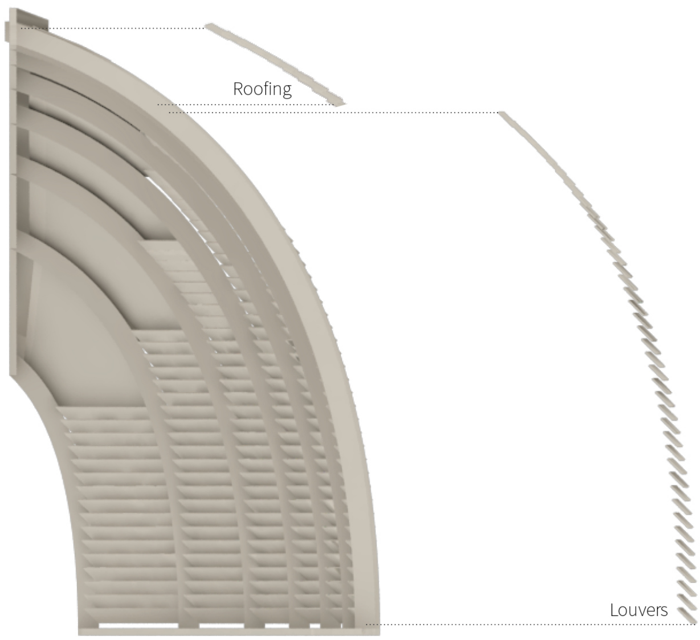


Figure 5.18   Louver to roofing transition

The louvers gradually become flush with the curve of the ribs as they ascend upward. Once they meet the 45-degree angle of the curve, they begin to overlay as roof shingles. Finding this solution was challenging as the curving ribs on both vertical and horizontal axes revealed the limitations of a flat rectangular louver. Rhinoceros 3D modeling software and Grasshopper plug-in proved useful in resolving the system. Figure 5.19 shows the digital model with the louver system in red when utilizing Grasshopper algorithm editing. Figure 5.20 is the Grasshopper script that was created to control and edit the angle, placement, and spacing of the louver system in each bay.

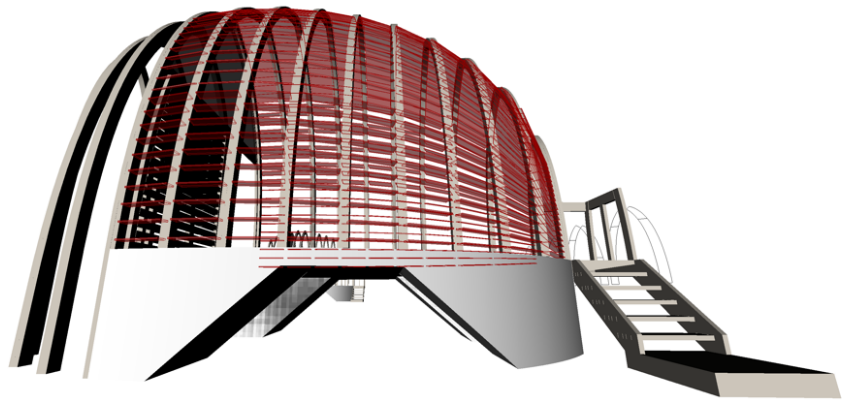


Figure 5.19 Grasshopper algorithm editing with Rhino 3D

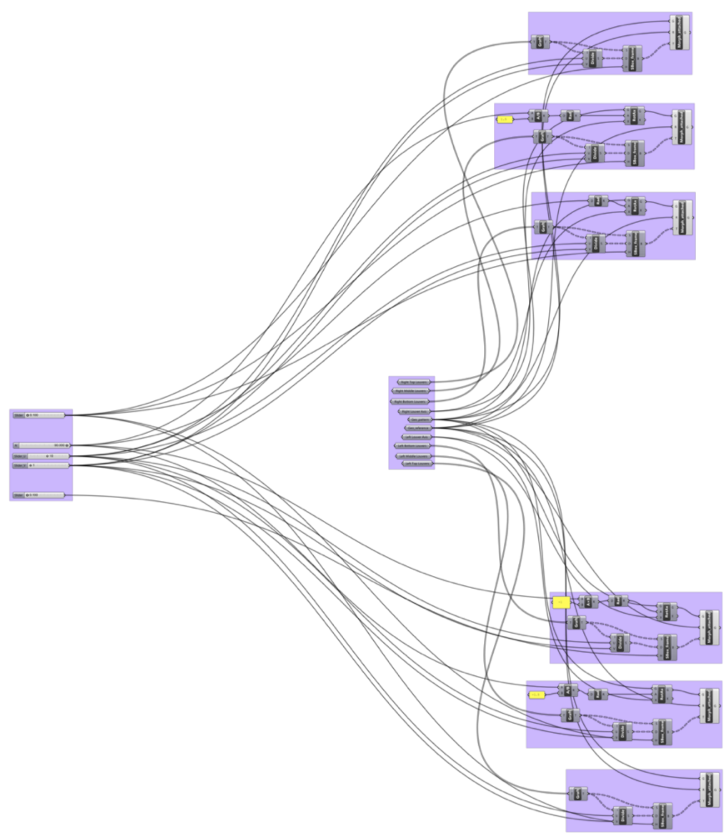


Figure 5.20 Grasshopper script used for louver system

Digital fabrication through CNC will provide precision cut components of louvers and ribs to streamline fabrication and installation. The design worked to develop a solution for keeping a consistent louver dimension within each bay. Louvers will be embedded with the information to make installation fast and easy. The ribs will be milled with a slot for each louver to slide in place. This is demonstrated in Figure 5.21 and will be tested at full-scale in Part 3.

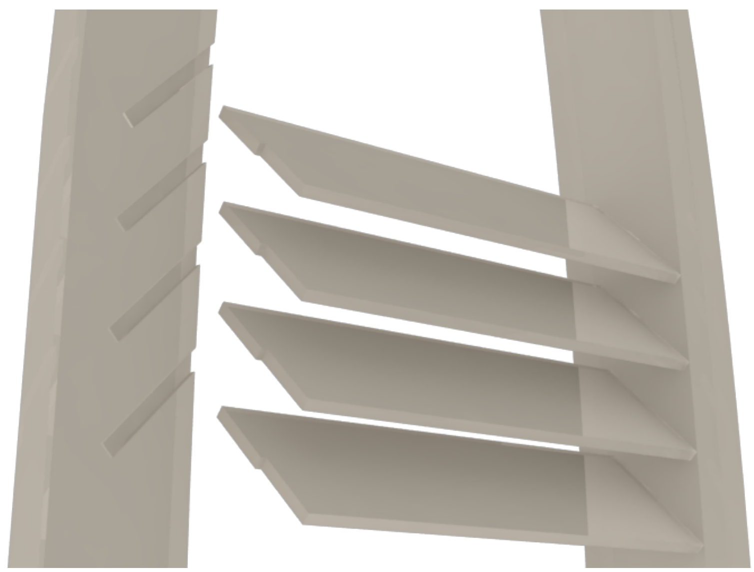


Figure 5.21 Rib and louver sliding system

Cultivating a Unique Identity

The elegant form and humanistic spirit of the housing units are complimented with an inimitable vail that wraps the south façade. Three structural ribs continue along each side to create an intimate enclosure of vegetated shading. The exposed ribs are integrated with a screen mesh system that will grow with local flora. It will serve as a green canvas for users to cultivate their own identity. A variation of local tropical vine species like lilikoi can create edible, colorful, and beautiful compositions among housing clusters.

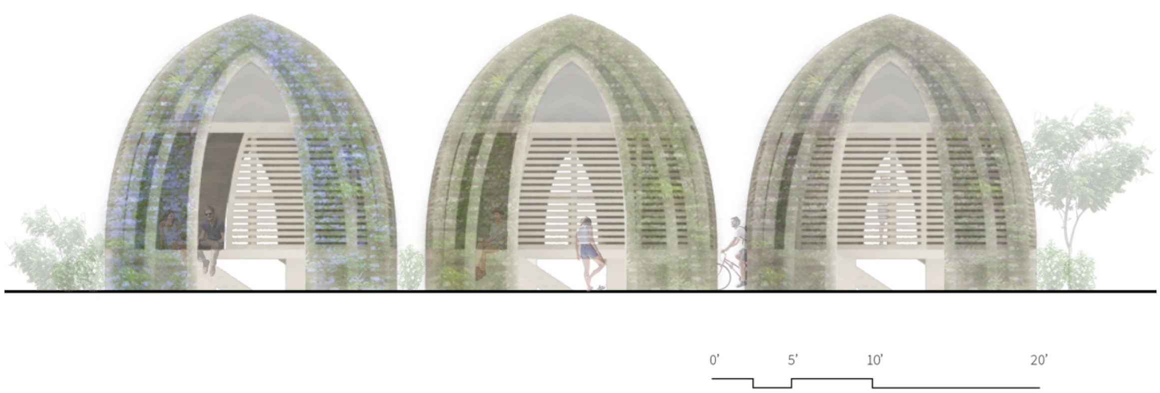


Figure 5.22   Elevation showing variation in unit identities

Chapter 5 and Part 2 conclude with the housing unit design. The next section will further investigate the unit and proposed material for testing and fabrication. Donated albizia from the University of Hawaii Lyon Arboretum will be used as the actual material in building the scaled model and testing full-scale housing unit components. Each phase of the albizia removal, milling, drying, and engineering is documented.

A full-scale mock-up of the structural rib and louver system will be built to test material engineering potential and design viability. A 1:16 scale model will also be built as the final stage prototyping. This will illuminate the advantages and unforeseen challenges of the proposed kit-of-parts building system. Discovering the pros and cons on a physical level can provide the necessary steps for further refinement of design and material engineering.

Figure 5.23 Rendering of inhabited housing clusters

Part 3 | Housing Unit Prototyping

6. Material and Unit Fabrication

Part 3 is the concluding section of project. It provides a visual documentation of the build component of the design project. It is important to note that this section could not have been possible without the generous material donation and support of the University of Hawaii's Lyon Arboretum in Manoa. The end of an albizia removal project at the arboretum was photo-documented in early November, 2015. One large log was donated to this project for testing and prototyping. The rigorous process of transforming the material from tree to structure is shown in sequential order.

The first section shows the phases of extracting the albizia and processing it for drying. The second section includes the process of engineering the wood to a CLT test panel. This panel is used in the third section for the full-scale rib and skin mock-up. The louvers use regular albizia boards. The final section demonstrates the construction of the 1:16 scale model. The model building process is documented as a time-lapse photo documentation from start to finish.

6.1 Material Extraction and Processing

The last two *Falcataria moluccana* trees out of a twenty-three tree removal phase was documented at Lyon Arboretum on November 6, 2015. One log was donated for this study and two others were saved for canoe building projects. The remaining material of the twenty-three trees was discarded. The following set of images are broken down into phases. Each phase is chronologically organized based on the material extraction and processing that occurred in this study.

Phase 1 | Albizia Tree Removal and Log Selection [November 6, 2015]

Lyon Arboretum, Manoa Valley

Figure 6.1 Crane in the distance

Figure 6.2   Imua Landscaping crew cutting albizia

Figure 6.3   Bringing the tree down

Figure 6.4   Breaking it down to logs

Figure 6.5   Transporting to disposal site

Figure 6.6 Unused material disposed on-site

Figure 6.7 Selected log for D.Arch project

Figure 6.8   Ends coated with Anchorseal green wood sealer

Phase 2 | Albizia Tree On-Site Milling

Lyon Arboretum, Manoa Valley

Figure 6.9   Day 1 [December 18, 2015] – Leveling first board

Figure 6.10 Day 1 [December 18, 2015] –Alaskan chainsaw milling

Figure 6.11 Day 2 [December 19, 2015] – Three 2” slabs milled

Figure 6.12 Day 2 [December 19, 2015] – Slabs relocated to North Shore for drying

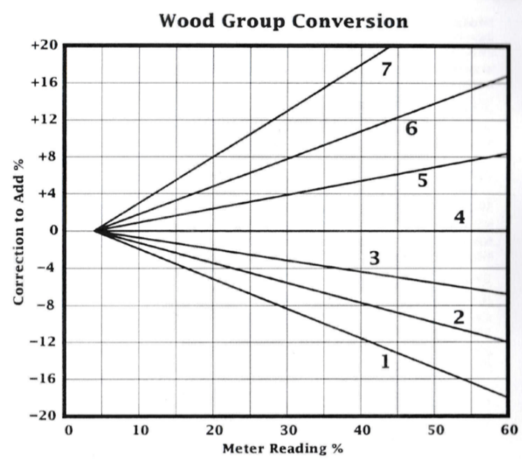
Figure 6.13 Day 3 [January 6, 2016] – Two 1.5” slabs milled

Figure 6.14 Day 4 [January 12, 2016] – Three 1.5” slabs milled

Figure 6.15 Day 4 [January 12, 2016] – Slabs relocated to SoA Shop for drying

Figure 6.16 Day 5 [January 14, 2016] – Last 1.5” slabs

Figure 6.17 Day 5 [January 14, 2016] – Ends coated with Anchorseal



WOOD SPECIES CORRECTIONS

Your meter is calibrated for the industry-standard species Douglas Fir at a temperature of 68 degrees Fahrenheit (20 degrees Celsius). For best results it is wise to correct your meter readings for other species, using the chart above. For wood at different temperatures correct the readings using the table on the opposite page.

EXAMPLE: Your sample of Western Red Cedar gives a meter reading of 15%. In the Table Of Wood Groups (later page) the listing for Western Red Cedar gives a wood group number of 3. We therefore use the line labelled "3" in the chart above. This graph shows that for a meter reading of 15%, for wood group 3, the correction to add is minus 1%, therefore the true moisture content is 14%.

EXAMPLE: Freshly-cut butternut reads 50%. In the Table Of Wood Groups butternut is listed as group 5. Therefore we use the line labelled "5", which shows that for a meter reading of 50% the correction to add is plus 7%, therefore the true moisture content is 57%.

6

Wood Temperature Corrections

TEMPERATURE IN DEGREES FAHRENHEIT (ROW F) OR CELSIUS (ROW C)

MOISTURE METER READING %

C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
F	32	41	50	59	68	77	86	95	104	113	122	131	140	149	158	167	176	185	194	203	212
4	4.7	4.5	4.4	4.2	4	3.8															
5	5.9	5.7	5.5	5.2	5	4.8	4.6	4.4	4.3	4.1	3.9	3.8									
6	7.1	6.8	6.5	6.3	6	5.8	5.6	5.3	5.1	4.9	4.7	4.5	4.4	4.2	4	3.9	3.7				
7	8.3	7.9	7.6	7.3	7	6.7	6.5	6.2	6	5.7	5.5	5.3	5.1	4.9	4.7	4.5	4.3	4.2	4	3.9	
8	9.4	9.1	8.7	8.4	8	7.7	7.4	7.1	6.8	6.6	6.3	6.1	5.8	5.6	5.4	5.2	5	4.8	4.6	4.4	4.2
9	10.6	10.2	9.8	9.4	9	8.7	8.3	8	7.7	7.4	7.1	6.8	6.5	6.3	6.1	5.8	5.6	5.4	5.2	5	4.8
10	11.8	11.4	10.9	10.4	10	9.6	9.3	8.9	8.5	8.2	7.9	7.6	7.3	7	6.7	6.5	6.2	6	5.8	5.5	5.3
11	13	12.5	12	11.5	11	10.6	10.2	9.8	9.4	9	8.7	8.3	8	7.7	7.4	7.1	6.8	6.6	6.3	6.1	5.8
12	14.2	13.6	13.1	12.5	12	11.5	11.1	10.6	10.2	9.8	9.5	9.1	8.7	8.4	8.1	7.8	7.4	7.2	6.9	6.6	6.4
13	15.3	14.8	14.2	13.6	13	12.5	12	11.5	11.1	10.6	10.2	9.8	9.4	9.1	8.7	8.4	8.1	7.8	7.5	7.2	6.9
14	16.5	15.9	15.3	14.6	14	13.5	12.9	12.4	11.9	11.5	11	10.6	10.2	9.8	9.4	9	8.7	8.4	8.1	7.7	7.4
15	17.7	17	16.3	15.7	15	14.4	13.9	13.3	12.7	12.3	11.8	11.3	10.9	10.5	10.1	9.7	9.3	9	8.6	8.3	8
16	18.9	18.2	17.4	16.7	16	15.4	14.8	14.2	13.6	13.1	12.6	12.1	11.6	11.2	10.8	10.3	9.9	9.6	9.2	8.8	8.5
17	20.1	19.3	18.5	17.8	17	16.4	15.7	15.1	14.5	13.9	13.4	12.9	12.3	11.9	11.4	11	10.5	10.2	9.8	9.4	9
18	21.2	20.4	19.6	18.8	18	17.3	16.6	16	15.3	14.7	14.2	13.6	13.1	12.6	12.1	11.6	11.2	10.8	10.3	9.9	9.5
19	22.4	21.6	20.7	19.9	19	18.3	17.6	16.9	16.1	15.6	15	14.4	13.8	13.3	12.8	12.3	11.8	11.4	10.9	10.5	10.1
20	23.6	22.7	21.8	20.9	20	19.2	18.5	17.7	17	16.4	15.8	15.1	14.5	14	13.5	12.9	12.4	12	11.5	11.1	10.6
22	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	14	13	13	12	12
24	28	27	26	25	24	23	22	21	20	20	19	18	17	17	16	16	15	14	14	13	13
26	31	30	28	27	26	25	24	23	22	21	21	20	19	18	18	17	16	16	15	14	14
28	33	32	31	29	28	27	26	25	24	23	22	21	20	20	19	18	17	17	16	16	15
30	35	34	33	31	30	29	28	27	26	25	24	23	22	21	20	19	19	18	17	17	16
32	38	36	35	33	32	31	30	28	27	26	25	24	23	22	22	21	20	19	18	18	17
34	40	39	37	36	34	33	31	30	29	28	27	26	25	24	23	22	21	20	20	19	18
36	43	41	39	38	36	35	33	32	31	30	28	27	26	25	24	23	22	22	21	20	19
38	45	43	41	40	38	37	35	34	32	31	30	29	28	27	26	25	24	23	22	21	20
40	47	45	44	42	40	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21
42	50	48	46	44	42	40	39	37	36	34	33	32	31	29	28	27	26	25	24	23	22
44	52	50	48	46	44	42	41	39	37	36	35	33	32	31	30	28	27	26	25	24	23
46	54	52	50	48	46	44	43	41	39	38	36	35	33	32	31	30	29	28	26	25	24
48	57	55	52	50	48	46	44	43	41	39	38	36	35	34	32	31	30	29	28	27	25
50	59	57	55	52	50	48	46	44	43	41	39	38	36	35	34	32	31	30	29	28	27
52	61	59	57	54	52	50	48	46	44	43	41	39	38	36	35	34	32	31	30	29	28
54	64	61	59	56	54	52	50	48	46	44	43	41	39	38	36	35	34	32	31	30	29
56	66	64	61	59	56	54	52	50	48	46	44	42	41	39	38	36	35	34	32	31	30
58	68	66	63	61	58	56	54	52	49	48	46	44	42	41	39	38	36	35	33	32	31
60	71	68	65	63	60	58	56	53	51	49	47	45	44	42	40	39	37	36	35	33	32
65	77	74	71	68	65	63	60	58	55	53	51	49	47	45	44	42	40	39	37	36	34
70	83	80	76	73	70	67	65	62	60	57	55	53	51	49	47	45	43	42	40	39	37
75	89	85	82	78	75	72	69	67	64	61	59	57	54	52	50	49	47	45	43	41	40
80	94	91	87	84	80	77	74	71	68	66	63	61	58	56	54	52	50	48	46	44	42
85	100	97	93	89	85	82	79	75	72	70	67	64	62	59	57	55	53	51	49	47	45
90			98	94	90	87	83	80	77	74	71	68	65	63	61	58	56	54	52	50	48
95				99	95	91	88	84	81	78	75	72	69	66	64	61	59	57	55	53	50
100					100	96	93	89	85	82	79	76	73	70	67	65	62	60	58	55	53

CORRECTED MOISTURE CONTENT IS AT INTERSECTION OF "TEMPERATURE" COLUMN AND "MOISTURE METER READING " ROW

7

Figure 6.18 Moisture meter correction table by Electrophysics

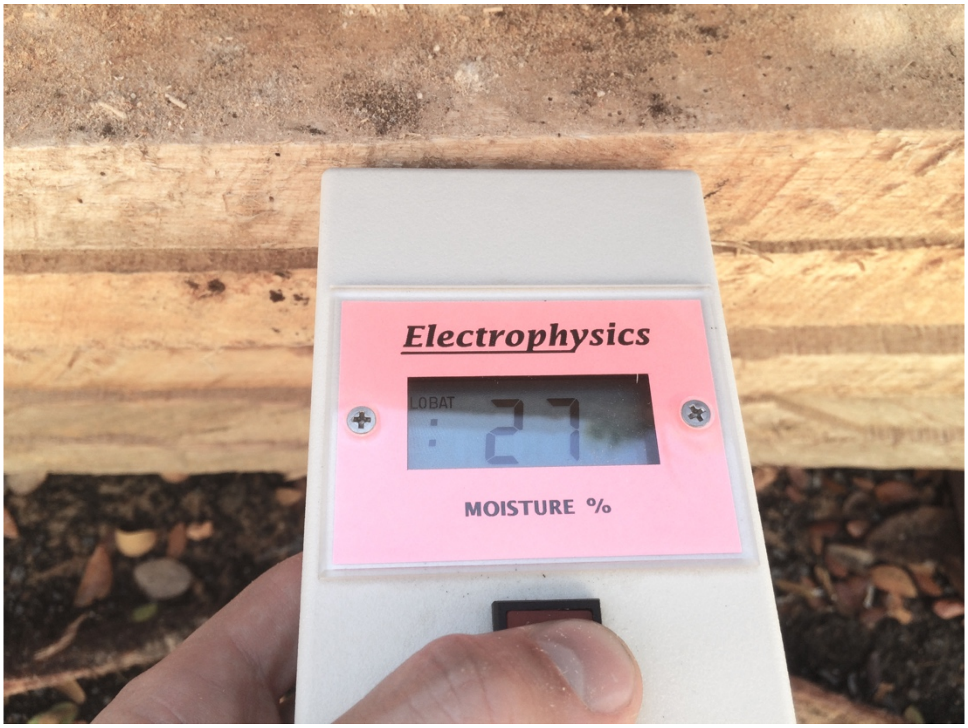


Figure 6.19   Moisture Check #1 [January 14, 2016] @ 27 + 3 = **30%**

Figure 6.20   Moisture Check #2 [February 3, 2016] @ 19 + 2 = **21%**

Figure 6.21   Tim-bor Professional preservative product [February 10, 2016]

Figure 6.22   Preservative treatment [February 10, 2016]

6.2 CLT Engineered Albizia

This section demonstrates the engineering process for turning an albizia slab into a CLT panel. The panel will be tested on the CNC router for fabricating the full-scale rib and skin detail. The entire process was executed at the UH School of Architecture Fabrication Lab. It included a series of steps in milling the material to correct board dimensions. Once the boards were ready, they were pressure-glued with clamps into three separate layers. The layers were then cross laminated into one panel and pressure-glued with a vacuum press. The following images illustrate a condensed version of the process to show a few of the essential steps.

Figure 6.23 Getting boards to correct dimensions

Figure 6.24 Running boards through joiner

Figure 6.25 Setting up boards for gluing

Figure 6.26   Gluing one panel layer with clamps

Figure 6.27   Vacuum pressure gluing CLT layers

6.3 1:1 Scale Structural Detail

The initial prototyping phase tested the CLT albizia panel on the CNC router. The panel was just large enough to fit a section of two ribs and a joint detail. The louvers were also fabricated with the CNC machine, but used regular albizia wood. The result provided tangible insight on what can be further explored for a greater precision of the building components. The line drawings below are the CAD files used for CNC fabrication. The images that follow demonstrate the CNC in action and the system put together.

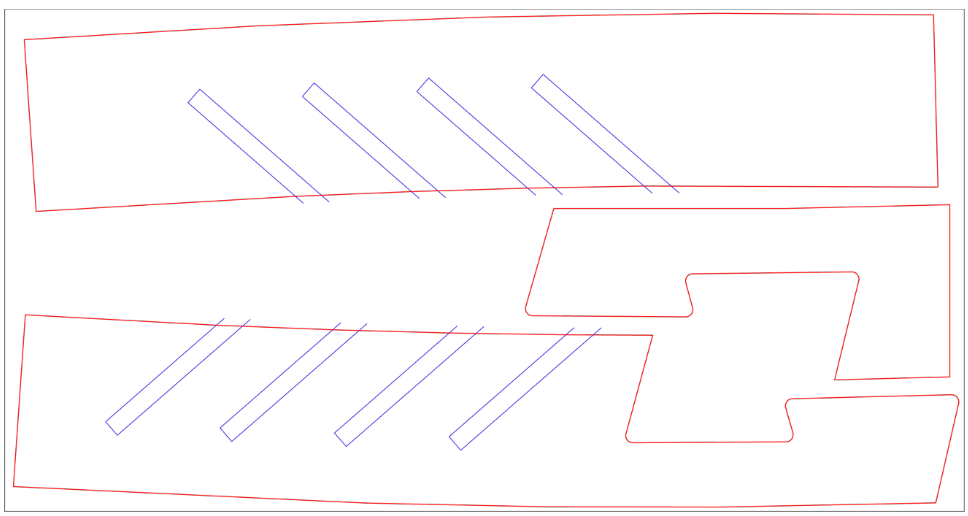


Figure 6.28 Cut sheet for rib components

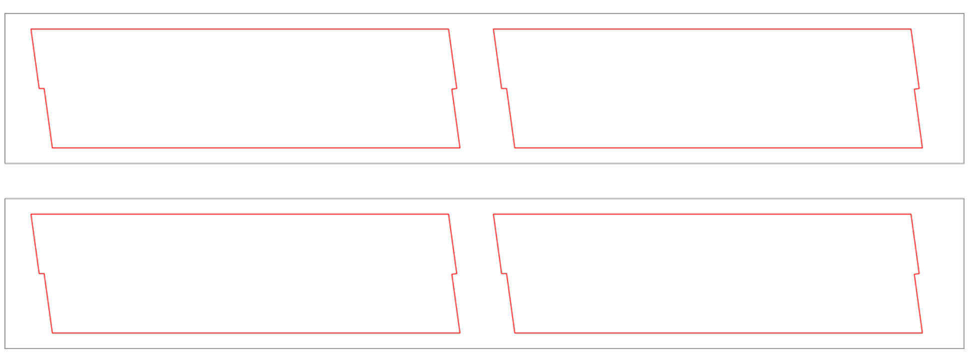


Figure 6.29 Cut sheet for louvers

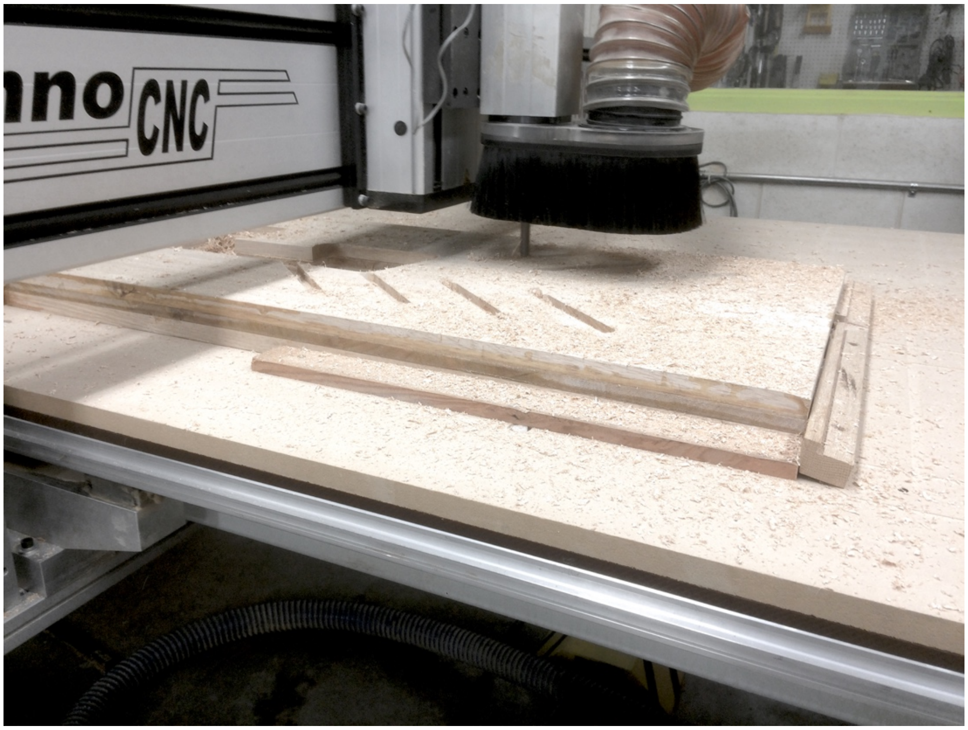


Figure 6.30   CNC milling in action

Figure 6.31   Successful rib and louver prototype

6.4 1:16 Scale Model [3/4” = 1’]

A volunteer without a background in architecture was asked to build the model. This was decided as an experiment to test the feasibility of the unit as a kit-of-parts. The results proved promising for an easy-to-assemble housing system. The 1:16 scale was large enough to explore the structural components at a basic level. The joint connections and louver system were simplified for the model scale, but closely resembled the full-scale version. Most of the model material utilized albizia and simulated the CLT panels with non-laminated material. At the 1:16 ratio, the louvers had to be 1/32” in thickness. This was unachievable with the albizia due to equipment limitations. A 1/32” veneer of white oak was used as a similar alternative.

The process was captured through a time-lapse photo documentation from start to finish. This is presented sequentially in the images below. Cut sheets were embedded with component information and an instruction manual for how the model is put together. A sample procedural diagram of the first kit-of-parts sheet is shown with its cut sheet on the following page. Each photo summarizes a phase of completion in the construction process. This follows the same process as intended for building the unit at full-scale. Under light supervision, the volunteer successfully constructed the model with minimal complications.

Sheet #1 Cut Sheet CAD File

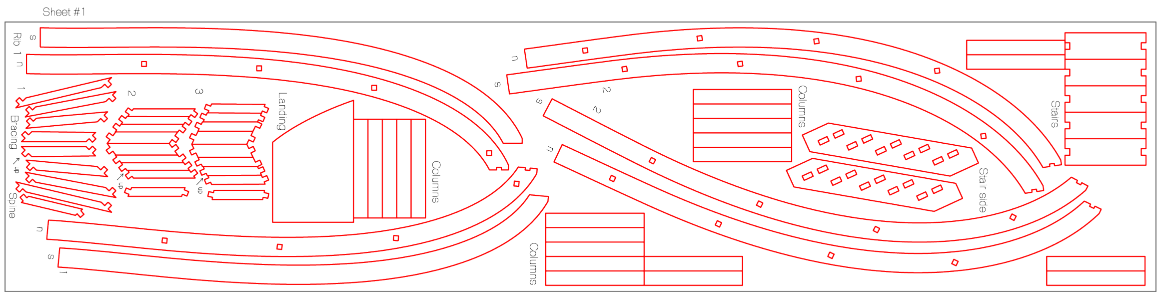


Figure 6.32 Cut sheet #1

Sheet #1 Procedural Diagram

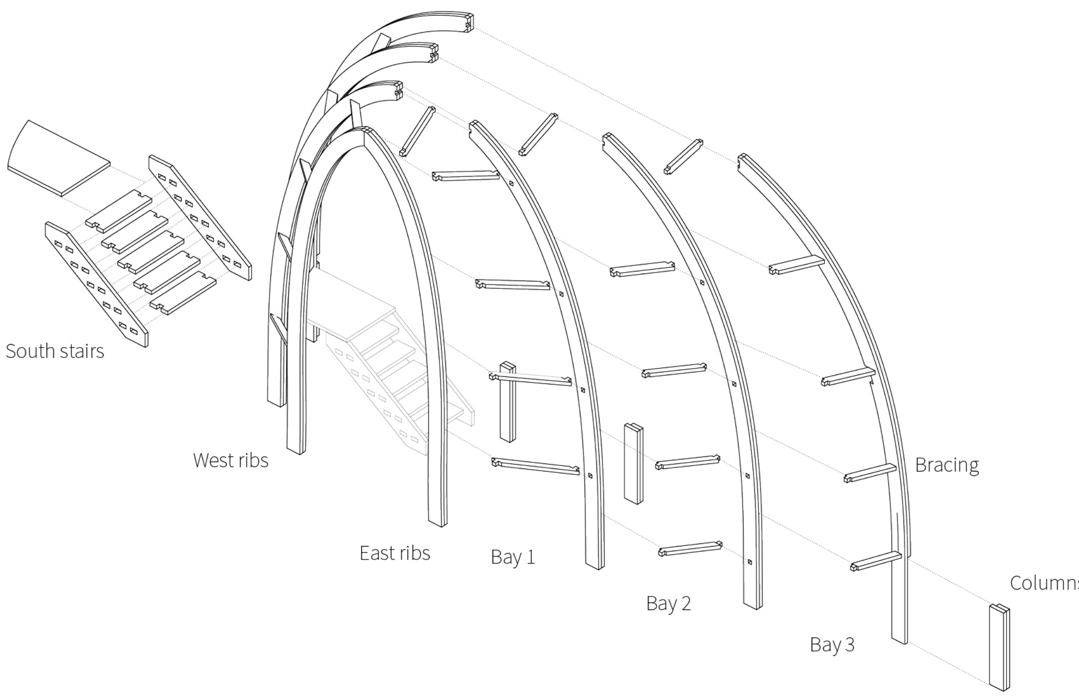


Figure 6.33 Sheet #1 instruction manual for assembly

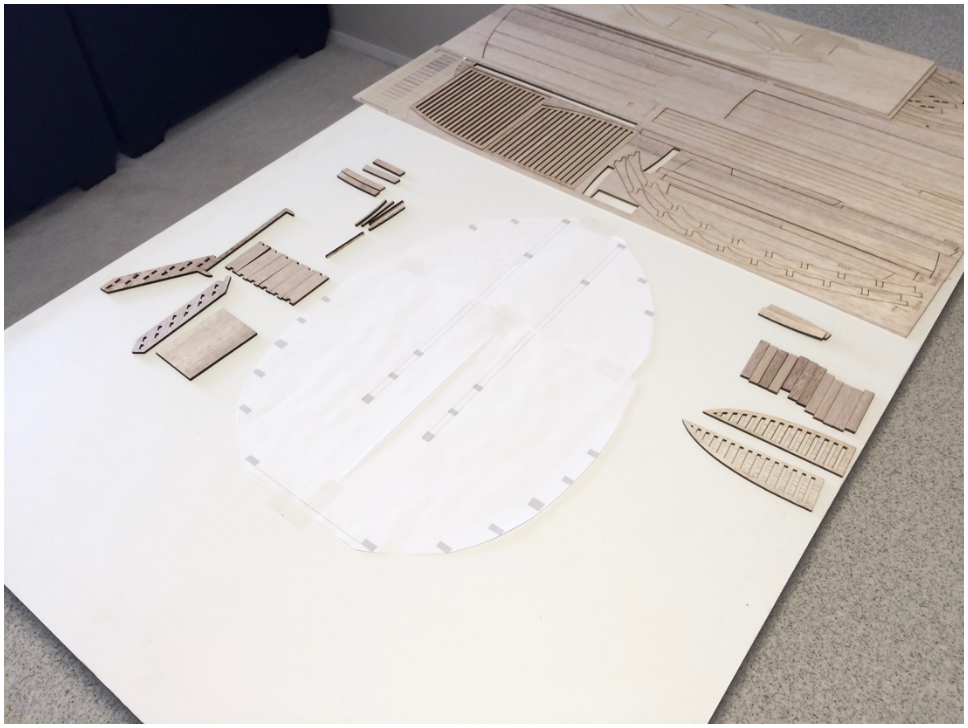


Figure 6.34 Setting up the unit layout and cut sheets

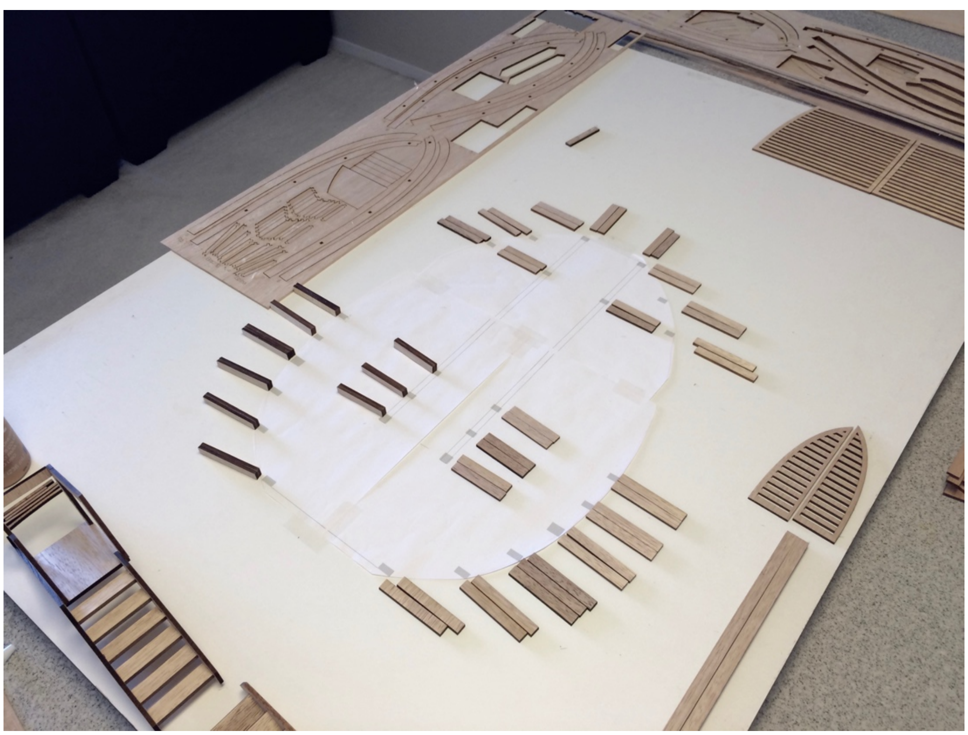


Figure 6.35 Built stairs and placing columns

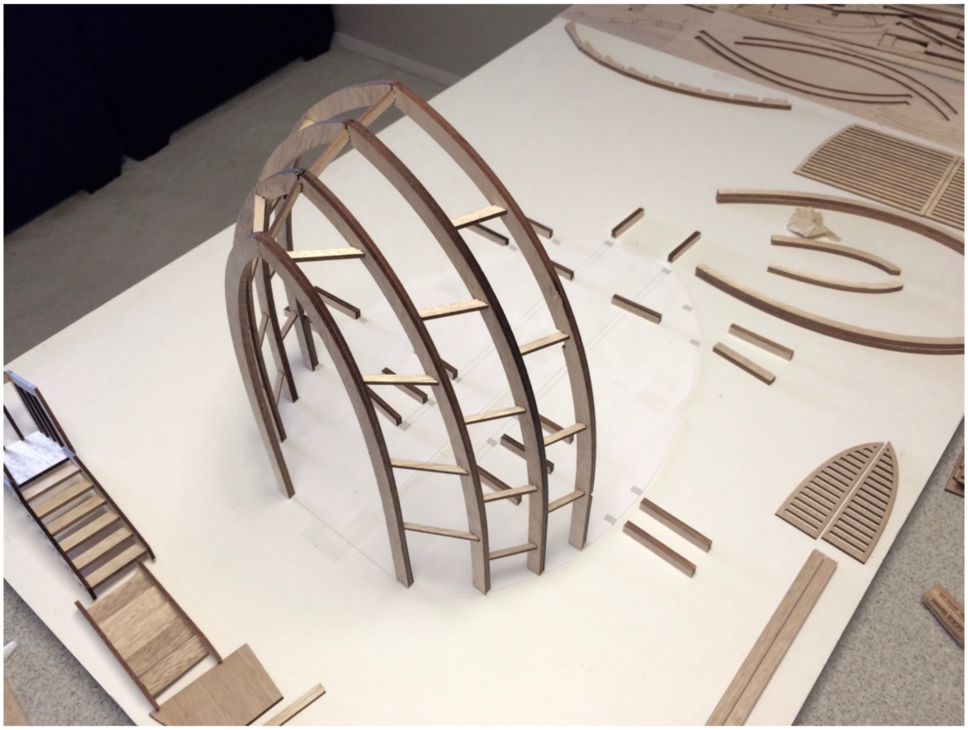


Figure 6.36 Sheet #1 complete

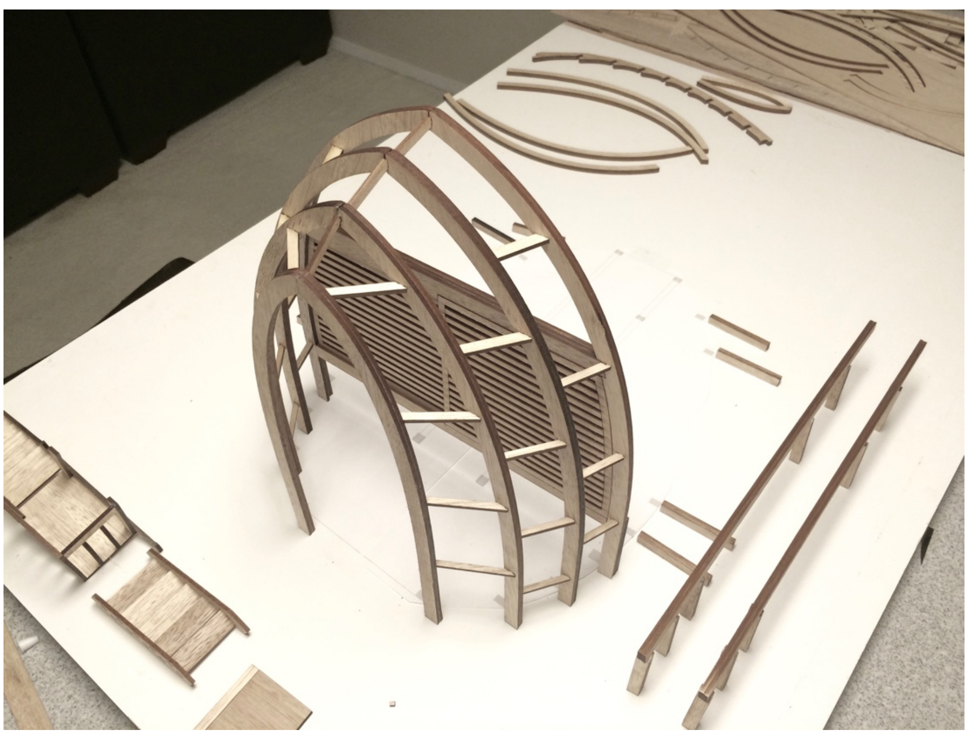


Figure 6.37 Built floor beams and sliding doors

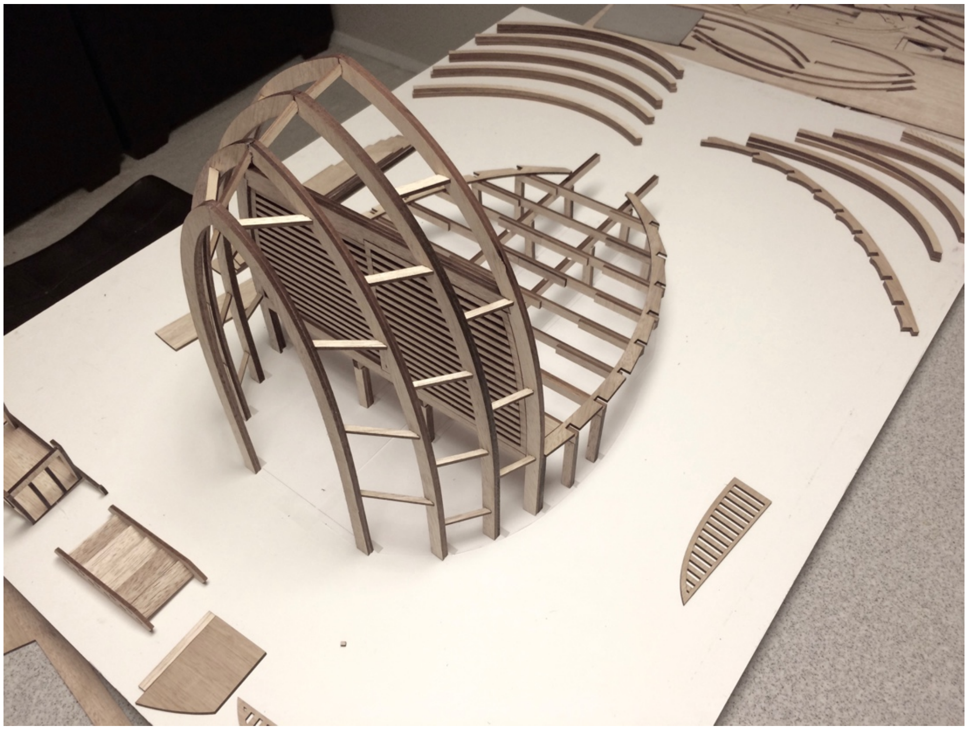


Figure 6.38 Built cross beams

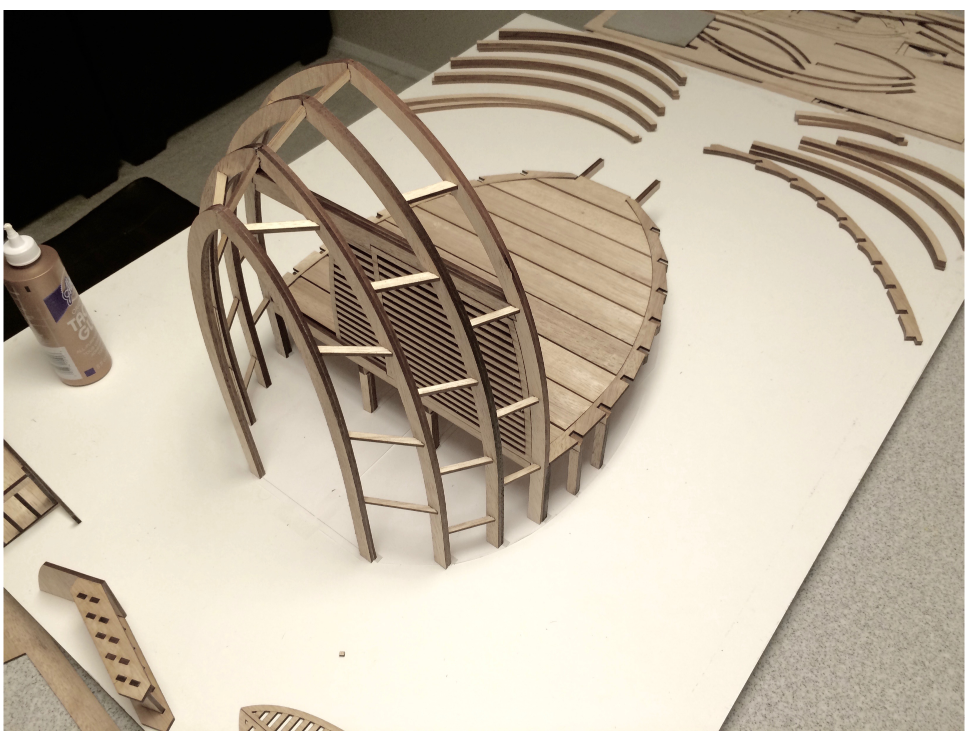


Figure 6.39 Built flooring

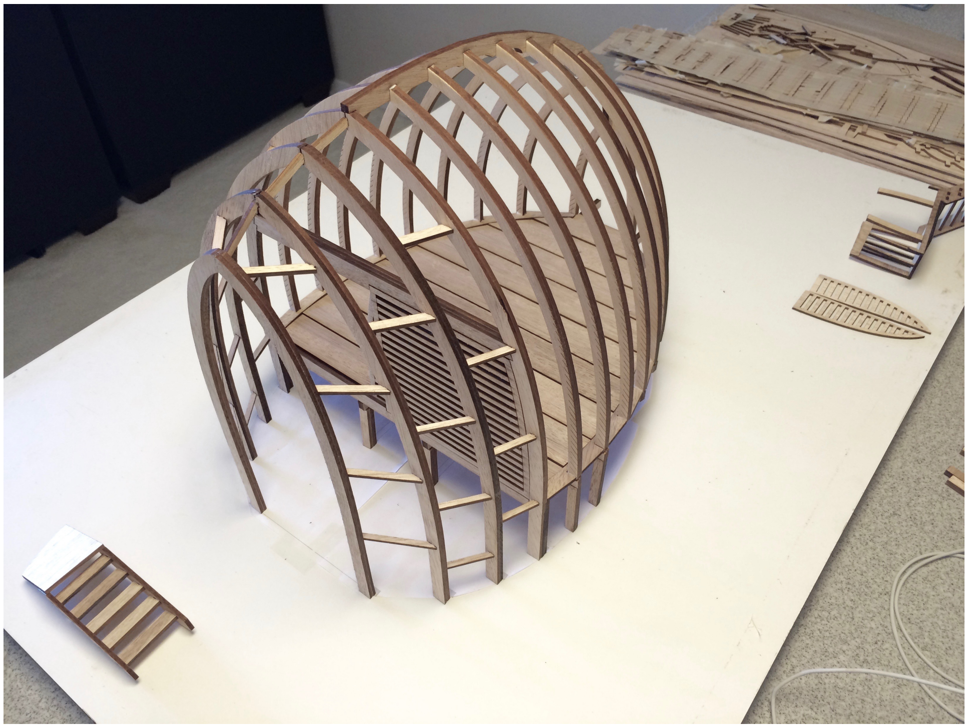


Figure 6.40 Built ribs

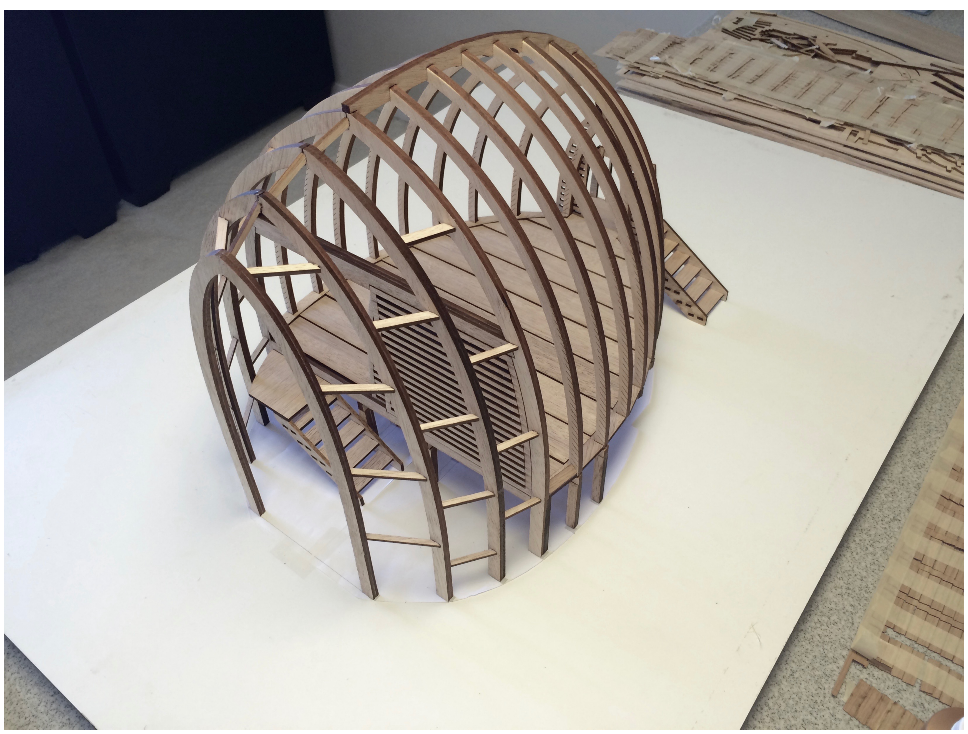


Figure 6.41 Stairs attached

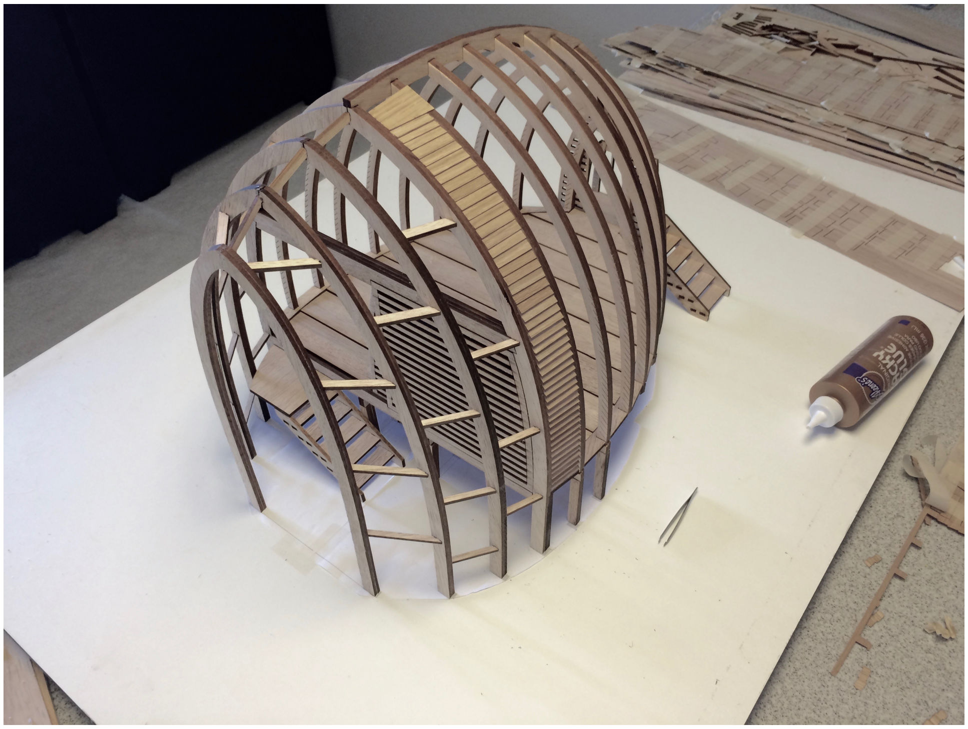


Figure 6.42   First bay of louvers and roofing built

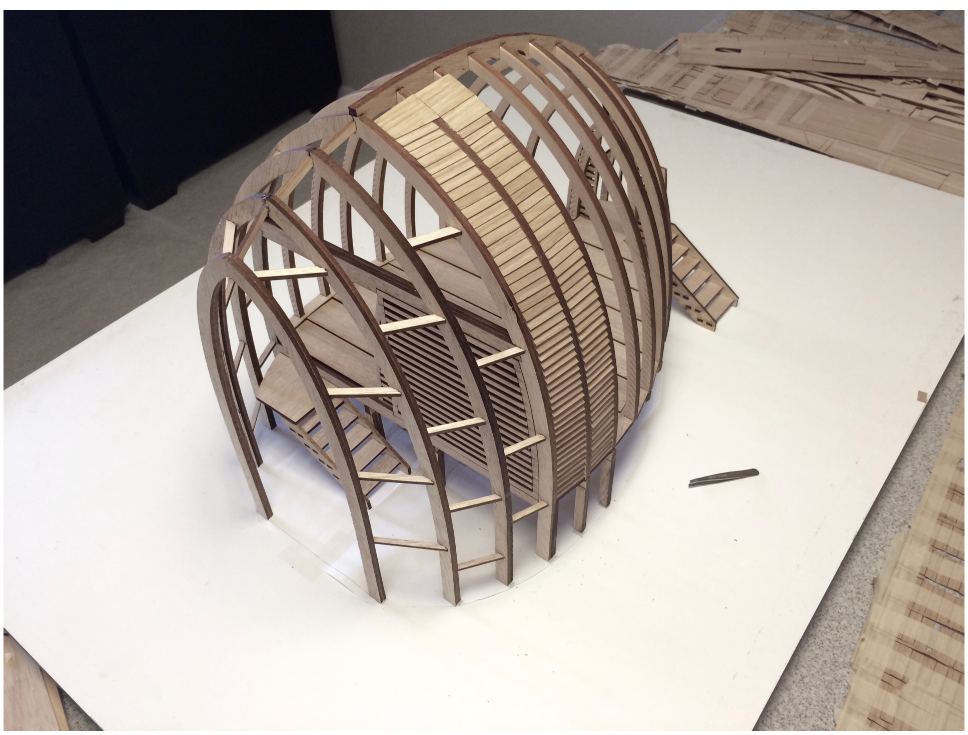


Figure 6.43   Bay two built

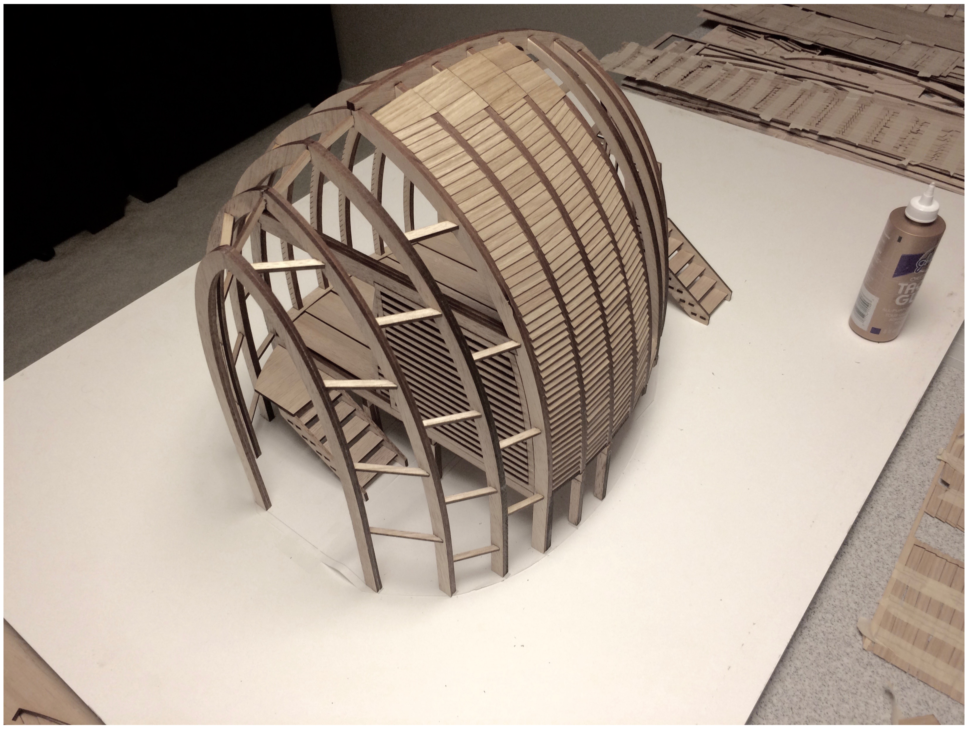


Figure 6.44   Bays three and four built

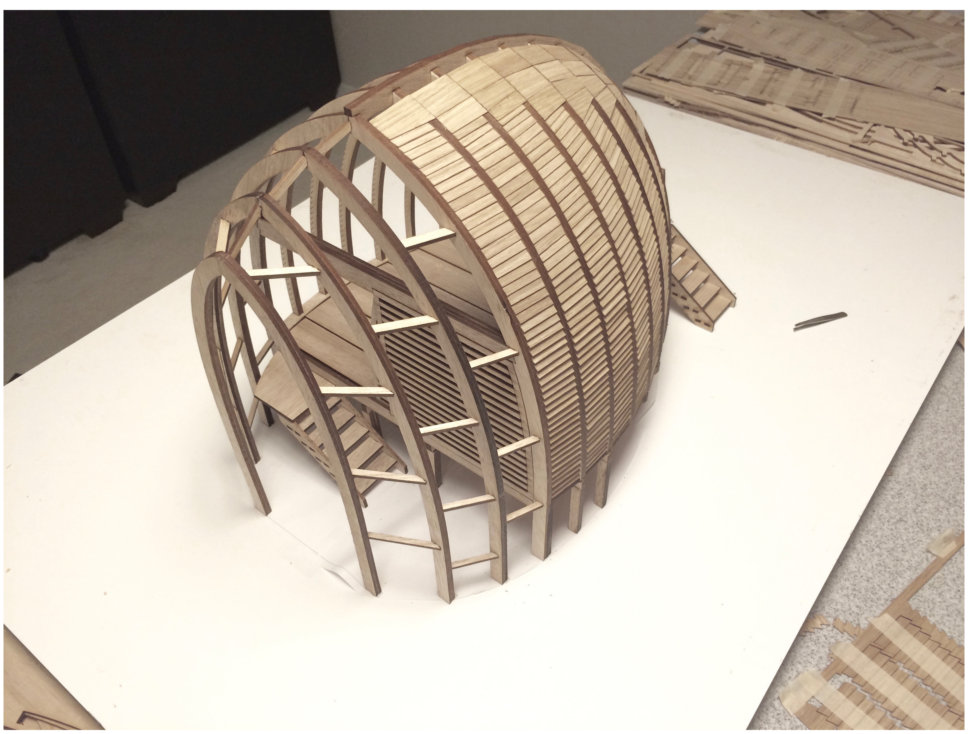


Figure 6.45   Bays five through eight built

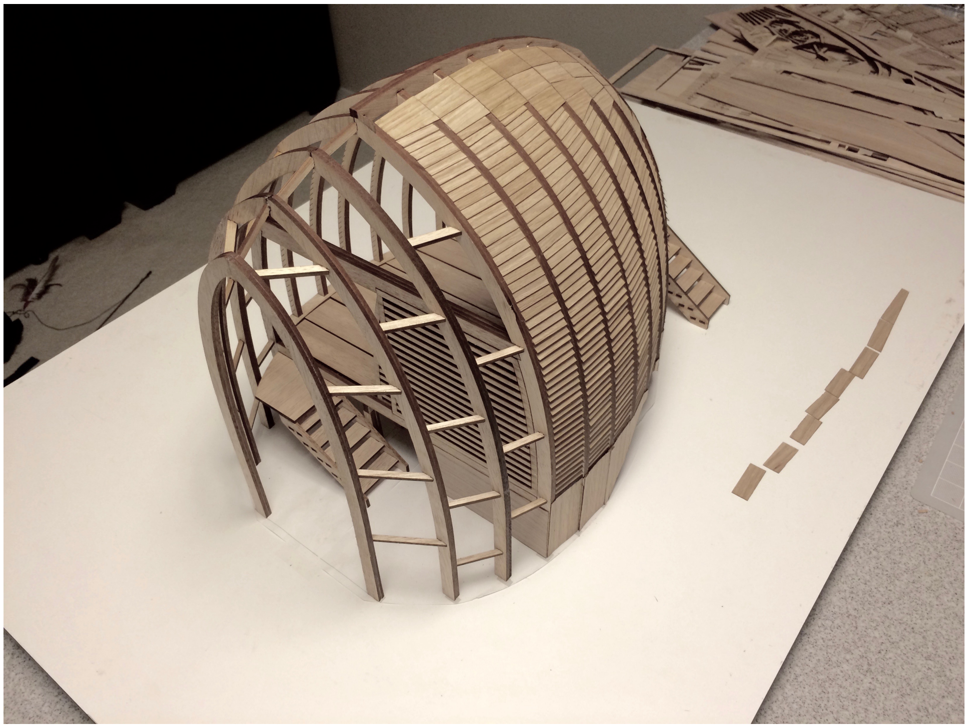


Figure 6.46   Leg coverings built

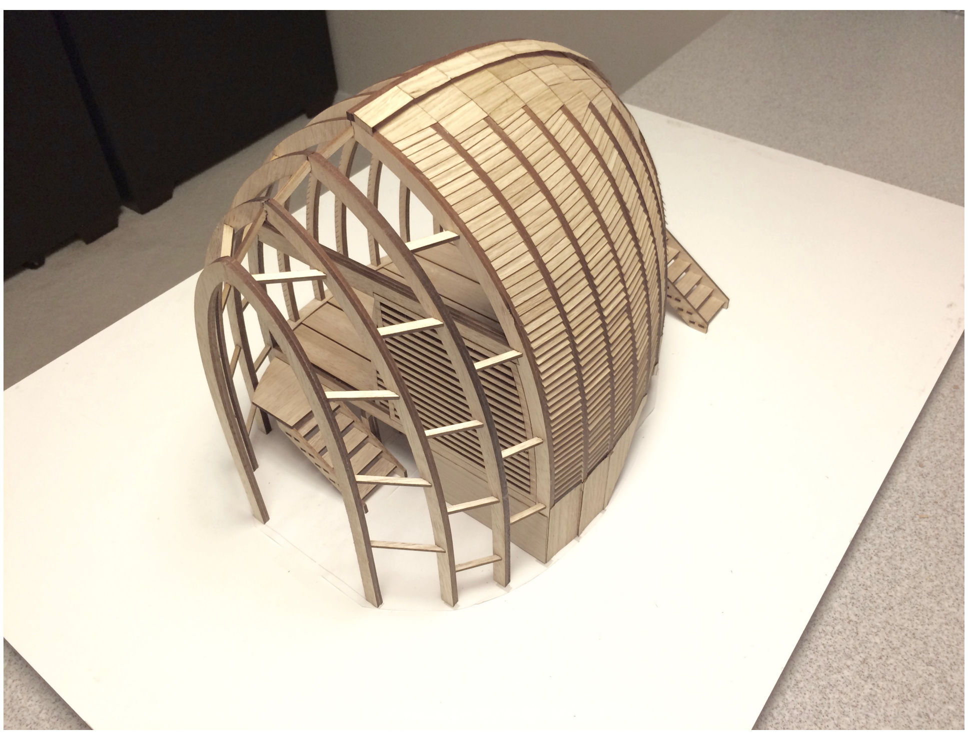


Figure 6.47   Ventilated roof cap built

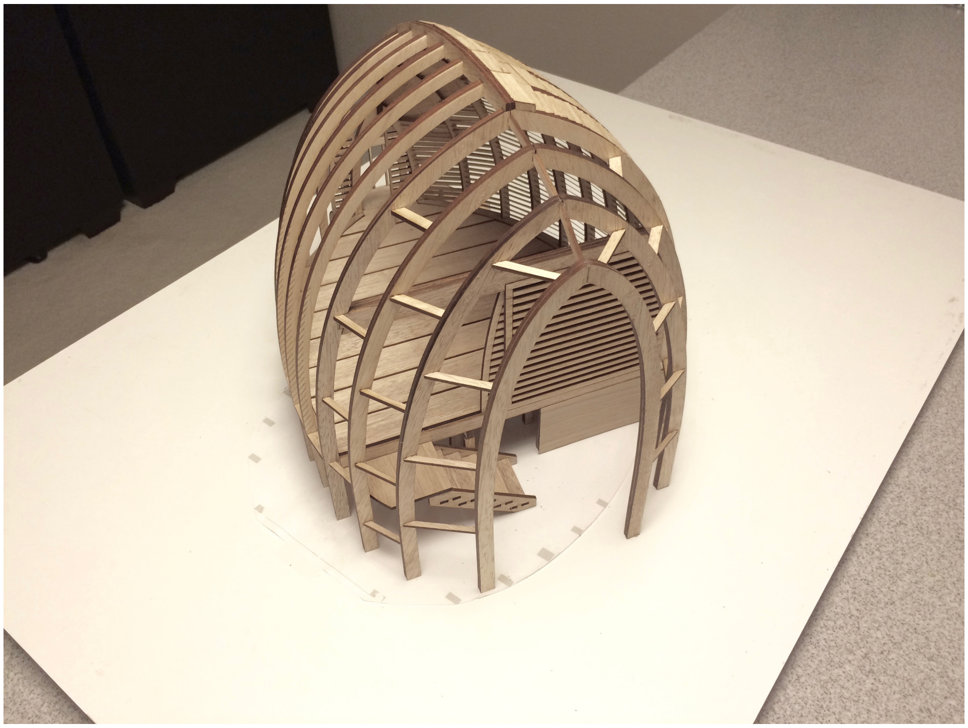


Figure 6.48   View 1 – West façade intentionally unfinished to reveal interior

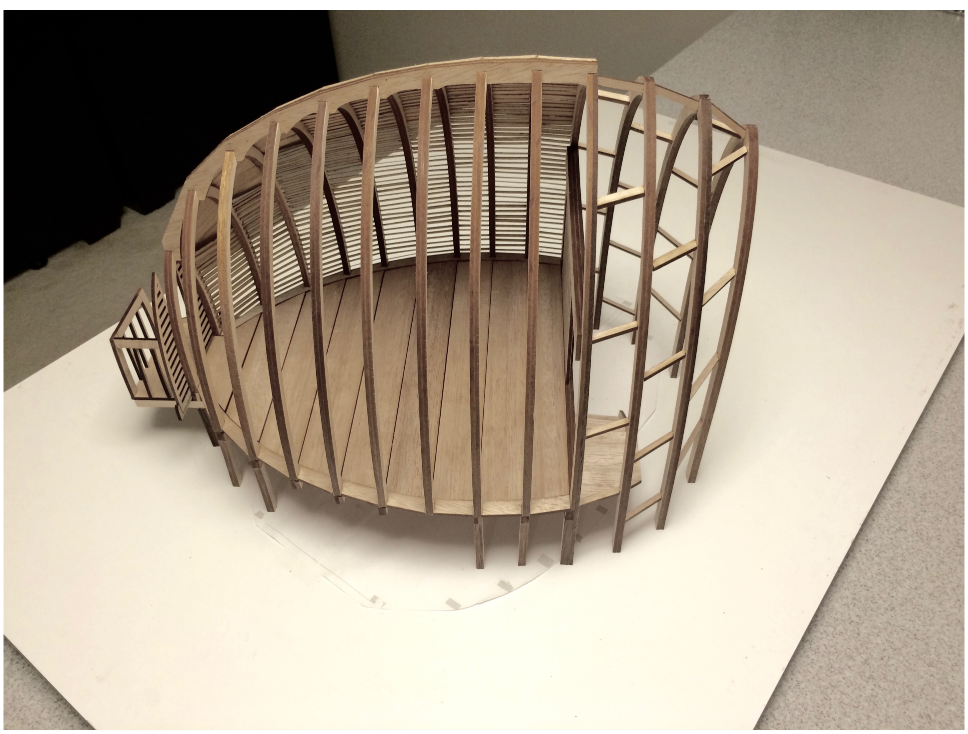


Figure 6.49   View 2 – Interior, walls and upper level will be built in next scale model

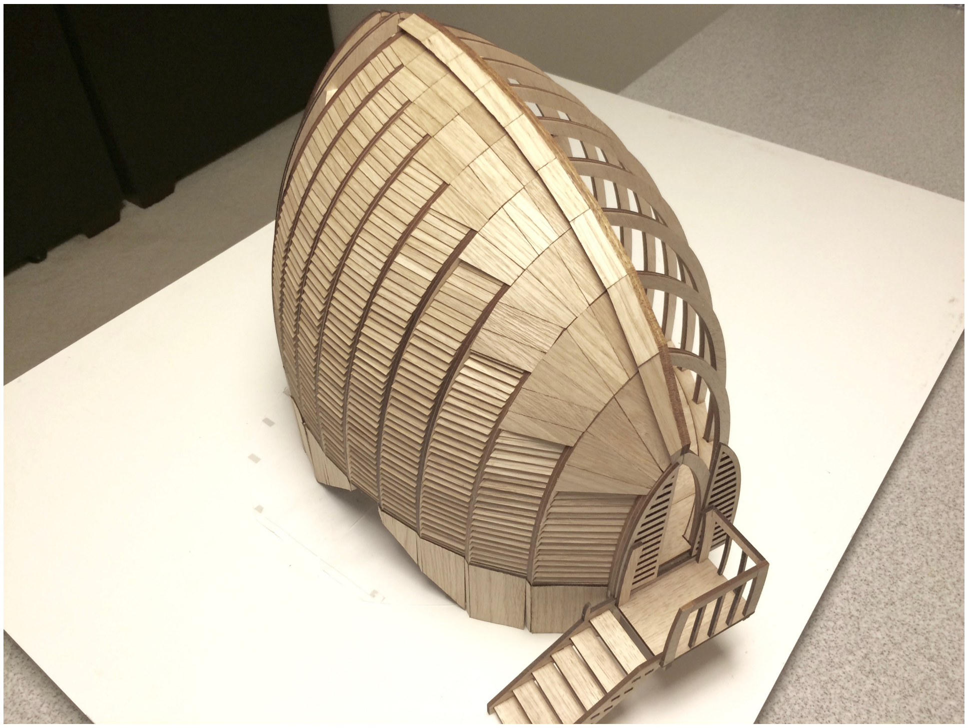


Figure 6.50 View 3 – North entry

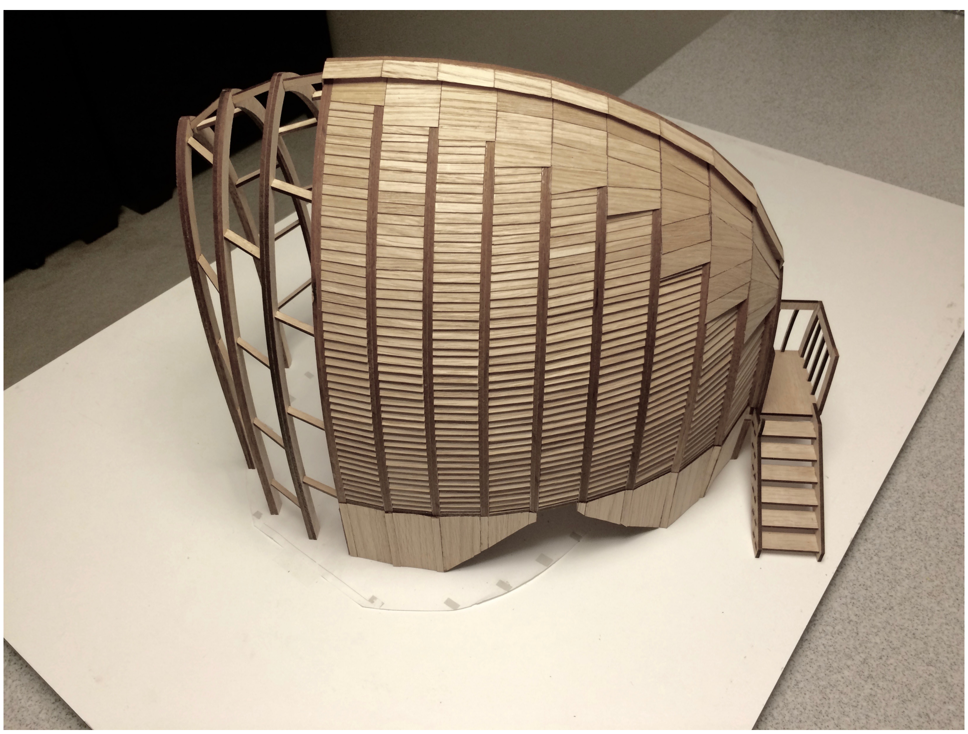


Figure 6.51 View 4 – Complete east façade

This concludes Chapter 6 and Part 3 of the study. The housing unit prototyping was an essential step of the project. It allowed the research and design idea to come to life. The use of locally-sourced albizia solidified the concept of an albizia-made structure. The tacit knowledge and experience gained from locally extracting a material at its source was as valuable as the preceding research of this study. While it was a time-intensive process, the project would not have been achievable without the tenacity and commitment to hands-on application.

7. Conclusion

Revisiting the Issue

This study set out to explore the emerging socio-economic and environmental issues within Hawaii's built environment. It has raised questions about the vulnerability of an isolated island community and argues that we must rethink the way in which we are building our cities. Honolulu and other counties across the Hawaiian Islands are facing a severe housing crisis along with the inescapable impacts of climate change. The project has stressed the interconnectedness and importance of these topics and reveals our distance from any real solution.

In response to such observations, this applied research project proposes an alternative building framework that has the capacity to achieve a more sustainable future for Hawaii and the planet. The project offers a fresh perspective on change and embraces the idea of impermanence. It argues that buildings do not have to be permanent to be impactful, material does not have to be common to be useful, and design does not have to be opulent to be valuable. The unsustainable practices of our existing systems neglect to consider these alternatives. With nearly all building materials imported and countless other inefficiencies in construction cost and time, Hawaii's current building system necessitates reformation.

The Response

As a practical solution with a simple response, *Rescaling Urbanism* fuses innovation in materials and design with smart building systems to foster a new model of locally fabricated transient village structures. It embraces Hawaii's potential for vernacular design through local renewable materials and closed-loop systems. On the basis of relevant case studies and emerging innovative technologies, it takes the statewide issue of the invasive albizia and integrates it with digital fabrication. The outcome offers an adaptive system of small-scale tactics for local and easily fabricated structures.

An injection of these structures as small, transient infill communities has proven viable through utilization of leftover or vacant urban sites. With state incentives and community support, such an approach can be achieved as a tangible solution to mitigate the housing crisis. When we synchronize the need to remove albizia with the demand for an environmentally and economically sustainable building model, we can begin to respond to Hawaii's more profound challenges.

The study concludes with a design proposal that focuses on Hawaii's underprivileged communities. Through biomimetic and bioclimatic design, the concept takes inspiration from the natural processes of the albizia tree. It fosters a new building model that can lightly integrate with the site and offer off-grid potential. It explores passive design strategies with indigenous principles to compliment Hawaii's tropical climate. Low-tech solutions with high-tech application allow for a simplified kit-of-parts of rapidly deployable transient housing. Balancing cost and livability, the structure takes a raw humanistic approach to design that allows the inhabitants to personalize their space.

Beyond the Pilot Design Project

Shifting back to the big picture, the outcome reveals a well-crafted and responsive building system that streamlines the design and construction process. It offers a flexible template that can be mobilized and adapted to available resources and community needs. As for now, it provides a framework that Hawaii can utilize to combat houselessness and unsustainable building practices. The initial pilot project proposes a small transient village on a vacant state-owned lot in Honolulu. It is just one design option that could be translated into other opportunity sites throughout the urban fabric. If the project is applied to other sites, the proposed framework encourages each deployment to manifest a unique identity that reflects its context.

The framework also offers flexibility in its application to future economic and environmental uncertainties. Digital fabrication is a rapidly evolving technology and local material availability is variable. Currently, the proposed system would utilize the surplus of albizia for an affordable, sustainable, and responsive housing solution. In the future this niche will likely change and the framework can adjust accordingly.

With proper precautions, this approach could be applied globally to other regions, climates, cultures, and resources. It could serve a multitude of scenarios from housing solutions in developing countries, to disaster response units in vulnerable areas. It would promote the sustainability of our local community with benefits at a global scale. The material component reduces pressure on rainforest deforestation and a warming global climate, while the design provides a framework for localizing economies and uplifting communities. Integrating the two provides a system of innovative thinking and smart building systems for a new model of sustainable design and construction.

UH President's Award for Green Project Implementation

Rescaling Urbanism investigates real-world issues within Hawaii's built environment. It set out to make a valuable academic contribution by reaching beyond expectations in search of a functional solution. Institutions of higher education are key to unlocking the potential within our communities. If we can instill the level of passion that we posses in our work to the network around us, we can earn the support and resources needed to bring great ideas to life.

In acknowledgement of its innovativeness and significance, *Rescaling Urbanism* was awarded the inaugural UH President's Award for Green Project Implementation during the 2016 University of Hawaii Sustainability Summit for Higher Education. The award includes $10,000 in funding for continued research and implementation of the project. The funding will be used to further develop and fabricate a full-scale prototype housing unit. The unit will be utilized for testing mechanical and structural integrity of material, while revealing efficiency measures in renewable energy, design, construction, durability, and livability. It will offer a public display of UH's role as a leader in green initiatives. The project and its results will be presented at the 2017 UH Sustainability Summit to promote more sustainable building practices in Hawaii.

Continued collaboration with Clemson University's Natural Engineering Lab and others will help to further explore the potential of the engineered albizia wood. This includes more in-depth studies on wood engineering, joinery techniques, skin design, and other technical challenges. The integrated design and digital fabrication process will be built upon with a continuation of applied research and development to maximize the potential of the proposed building system.

Final Remarks

The most valuable skill of an architectural designer is their ability to solve problems. *Rescaling Urbanism* set out to do just that. It was an investigation of real contemporary issues in our built environment. The study has explored the application of problem solving through the lens of innovation and design. It argues that we have the capacity to employ an alternative, resilient building framework that effectively responds to Hawaii's urban challenges. The outcome, if nothing more, has brought us one step closer to reaching sustainability on our island and planet.

Appendix A: Inaugural UH President's Award

For Green Project Implementation


President's Award for
Green Project Implementation
awarded to

Rescaling Urbanism

In support of applied research and design to develop
an alternative framework of building for the sustainability
of our island and our planet

March 11, 2016
Honolulu, Hawai'i

David Lassner
President, University of Hawai'i System

Figure A.1 President's Award

Figure A.2 Sustainability Summit Poster Session

Approx. 300 sq ft unit

Personal Budget	$2,000
Total Budget	$12,000
Estimated Expenses	*$11,960*
Actual Expenses To-Date	*$60*
Available Budget	$11,940

Date: 12/20/15

Materials				
Description	**Estimated Cost**	**Actual Cost**	**Difference**	**Detail**
Wood	$1,200.00		$1,200.00	est. additional materials
Anchor Seal	$40.00	$40.00	$0.00	Sealant
Glue and Additives	$300.00		$300.00	est. $30/per gallon
Borax Treatment	$420.00		$420.00	est. $70 per gallon
Roofing	$1,000.00		$1,000.00	low est. with Albizia wood
Flooring	$1,000.00		$1,000.00	low est. with Albizia wood
Doors/windows	$1,200.00		$1,200.00	est. 3 doors, 6 jalousie windows
Hardware	$250.00		$250.00	est. extra installation hardware
Waterproofing	$300.00		$300.00	est. exterior sealant
Foundation	$300.00		$300.00	est. simple blocks
Total	**$6,010.00**	**$40.00**	**$5,970.00**	

Supplies				
Description	**Estimated Cost**	**Actual Cost**	**Difference**	**Detail**
Safety Equipment	$150.00	$20.00	$130.00	Respirator, hard hat, goggles, boots
Tools and Equipment	$400.00	$0.00	$400.00	Tape, saw blades, chisels, mallot, etc.
Total	**$550.00**	**$20.00**	**$530.00**	

Process Costs				
Description	**Estimated Cost**	**Actual Cost**	**Difference**	**Detail**
Hauling Fees	$750.00	$0.00	$750.00	est. $250/per trip
Saw Mill Use	$1,400.00	$0.00	$1,400.00	est. $70/per hour (20hrs)
CNC Machine Hours	$3,000.00	$0.00	$3,000.00	est. $60/per hour (50hrs)
Total	**$5,150.00**	**$0.00**	**$5,150.00**	

Indirect Costs				
Description	**Estimated Cost**	**Actual Cost**	**Difference**	**Detail**
Misc Cost	$250.00		$250.00	Unanticipated costs
Total	**$250.00**	**$0.00**	**$250.00**	

Figure A.3 Project budget submitted with proposal

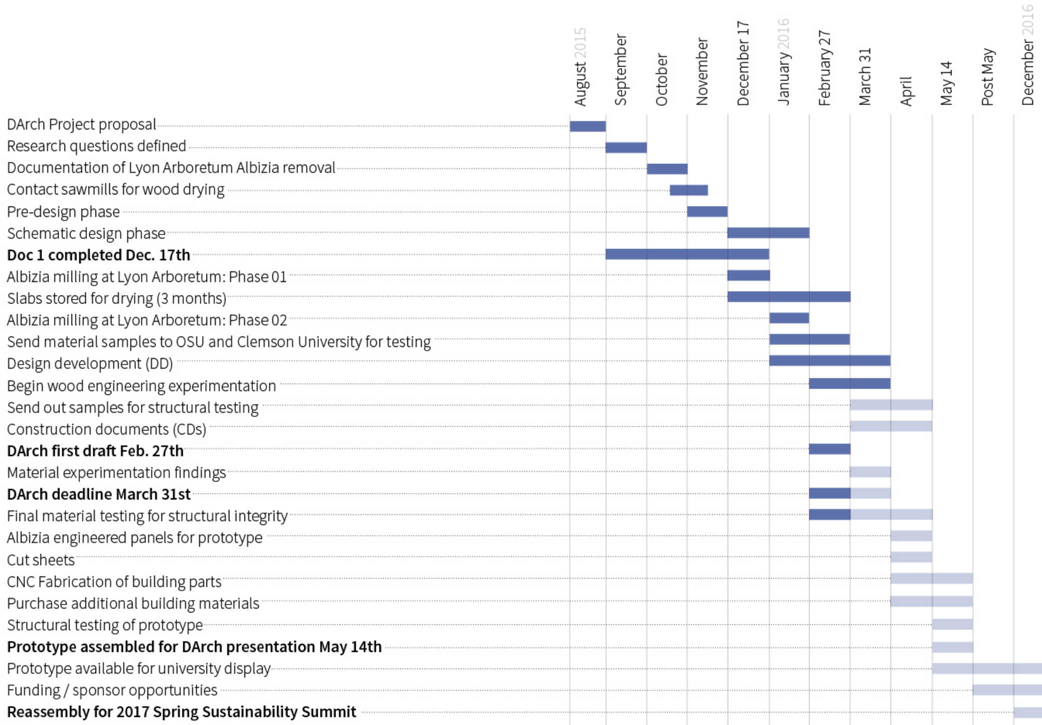
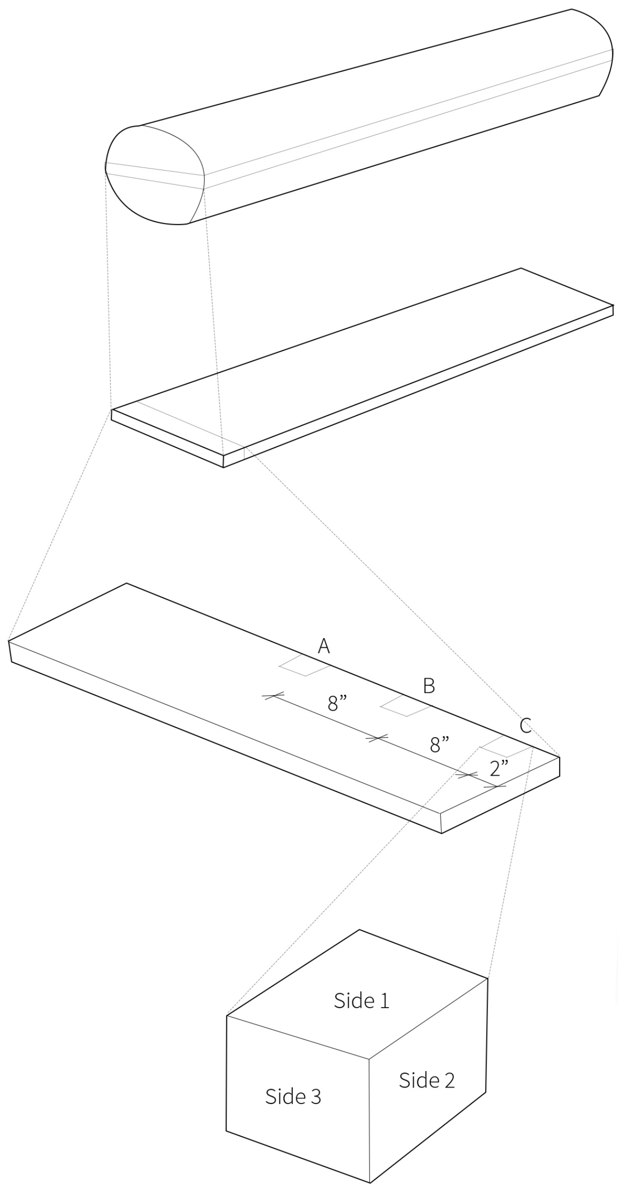


Figure A.4 Project gantt chart submitted with proposal

Appendix B: Albizia Material Testing

In Collaboration with Clemson University Natural Engineering Lab



3 Samples

A: 18” from bark
B: 10” from bark
C: 2” from bark

Orientation

Side 1: Face grain
Side 2: Edge grain
Side 3: End grain

Figure B.1 Material samples and diagram for Natural Engineering Lab

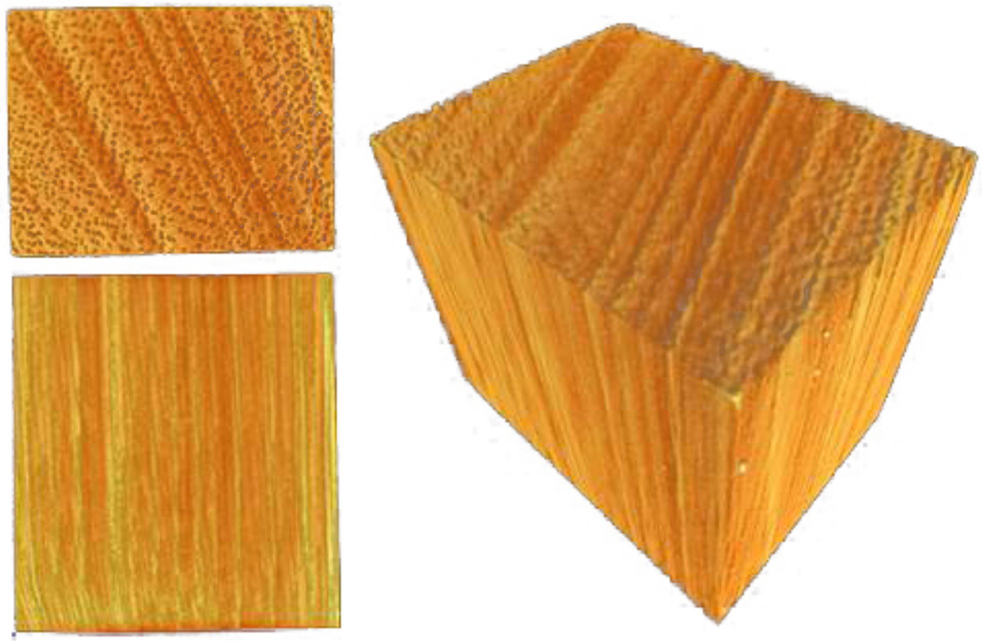


Figure B.2 CT Scan of Samples

This research on albizia material properties is still in early stages of development. Results have shown the material to be very porous and anisotropic, with well-aligned pore channels and density gradients. This is expected to be associated with the growth bands of the material. Collaboration with the Natural Engineering Lab at Clemson University is to be continued following the completion of this dissertation.

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