ABSTRACT

Title of Thesis:	HERE TO STAY: THE DISASTER, DISPLACEMENT AND BIOMIMETIC RESPONSE
	Dan Lorenzana, Master of Architecture 2020
Thesis Directed By:	Assistant Professor Ming Hu, School of Architecture, Planning and Preservation.

Natural disaster can be felt all around the globe especially in the Philippines where millions of people have been displaced without any shelter. With the average of 20 typhoons hitting Philippines each year. People are still living in unsafe structures that affects the day to day of their livelihoods during and after natural disaster. According to Internal Displacement, earthquakes, floods and violence have driven millions away from their homes in 2018 alone. This acceleration in displacement can be felt in cities with growing slums and outdated infrastructure. This thesis will investigate a new integrated urban and building design typology for climate adaptation that uses and integrates Biomimicry as a design technique. This exploration hopes to use as a establish design criteria in the Philippines where typhoon is very prominent.

HERE TO STAY: THE DISASTER, DISPLACEMENT AND THE BIOMIMETIC RESPONSE

by

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Assistant Professor Ming Hu, Chair

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Preface

Born and raised in the Philippines, I have grown to love and respect the landscape of nature when I was a kid. I have gone back to Philippines recently after 13 years, I realize that it is much more crowded and more polluted than I remember along with its poor infrastructure and architecture. Climate Change is affecting the country on a large scale and it made me realize that it will not stop until we need to find a way to become more resilient and more environmentally conscious. This project is about engaging in nature's way, as understood on the level of both process and product leading to potential change the way society cultivate food, produce materials, harness energy and heal ourselves.

Dedication

To my parents for supporting me throughout this path

To my Great Grandfather; Napoleon Aguilar

A Father figure to my Mother, Thank you for taking care and helping us get out of hardship

In memory, July 31, 2019

Acknowledgements

For their valuable mentorship, debate, and discussion:

Ming Hu

Karl Dupuy

Alick Dearie

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Chapter 1: The Disaster

Typhoon

A typhoon is defined as an organizing system of clouds and thunderstorms that generates over tropical region of ocean basins that has a closed level circulations. Typically tropical cyclones rotate in a counterclockwise pattern in the Northern Hemisphere and clockwise in Southern Hemisphere.

The typhoon is typically form in the upper North West latitude of 5 ° and 30° away from the equator. Sometimes the wind at the *troposphere* change and steer the cyclone toward either the north or northwest of the North Hemisphere or towards in the south and southwest of the Southern hemisphere.[1] Typhoons often formed seasonally between May to December in the Northwest Pacific and May to October in the South China *Figure 1.1*.

A tropical cyclone tends to be a non-frontal system that is categorized by a low pressure center with a spiral rain bands and strong winds, they are usually originates from the tropical and subtropical ocean and then rotates clockwise due to the southern hemisphere and counterclockwise in the southern hemisphere. They usually powered by the heat when it is exposed by the moist air and water vapor that contains condenses or so it's called the "warm core" storm system. In order to maintain these characteristic the tropical cyclone can't be more than 27 degrees Celsius. Though the cyclones, hurricanes and typhoons can be predicted

[1] Qian, Weihong, Haoyuan Liang, and Xiaolong Shan. 2014. Typhoon Turning Atlas. Singapore: World Scientific.

in several days in advance, they can still be very extensive and very destructive that will usually more destructive than floods. The element of a cyclone is a vast whirl of aerial currents that is surrounded by the calm space called the vortex or some others refer it as the center of the storm. It is very important that the two center of typhoons is distinguished into two classes. The center of the point itself is the region of which system of winds are revolving and the biometrical center of the cyclone into a modern dynamic meteorology while the former center is generally spoken as the vortex since the direction of the winds tends to point out its bearing and baric gradients.

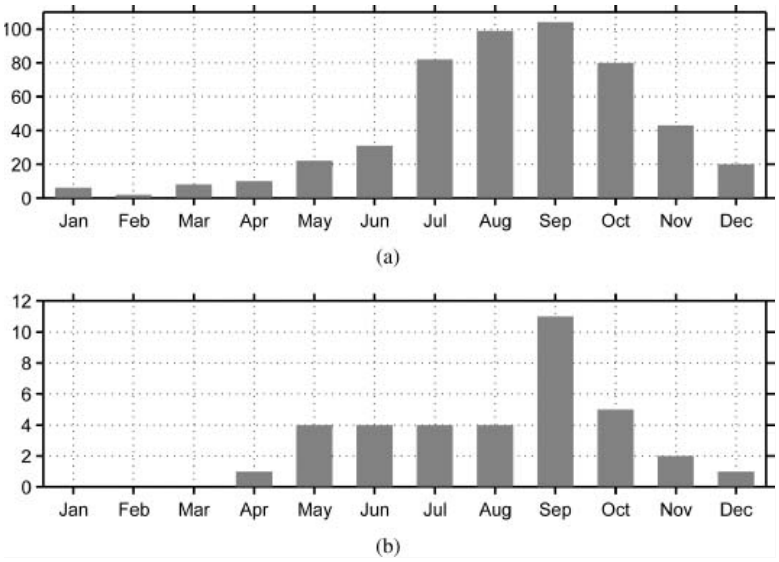

Figure 1.1. The monthly number of TYs generated in (a) the NW Pacific and (b) the SCS in the period of 1979–2011. (Source: Typhoon Turning Atlas, Author Qian, Weihong, Liang, Haoyuan, Shan, Xiaolong, 2014)

A Typhoon usually came from a Tropical disturbance when it is supported by the favorable conditions, this includes a warm sea temperature, a high tropospheric humidity, weak vertical shear of the winds and as well as a low atmospheric static stability and

favorable patterns of atmospheric circulations. After the creation of a Typhoon it moves westward along with the steering flows associated with the subtropical. In the Figure 1.2 shows the lines of positions where a typhoon formed from the initial disturbance and to where its highest peaked and to where it's dissipated. During the month of September, if the intensity peaked in the South China Sea or near the Philippines, the typhoon usually continued to more northwestwards and made a

Landfall along the coast of China and Vietnam. But if the intensity peaked in the East of 103 degree, it tends to turn northwestward in the east seas of Taiwan and the Philippines, the Typhoon will head toward Japan. The track and the forecast is the two key elements during the Typhoons life time especially when it hits the offshore regions. The motion and intensity are influenced by many factors. Figure 1.2 shows the statistical characteristics of the Typhoon track and positions. Most typhoon follow the large scale steering flows associated with the subtropical high and moved northwestwards of the North West Pacific and then move northwards or northeastwards. [2]

[2] Qian, Weihong, Haoyuan Liang, and Xiaolong Shan. 2014. Typhoon Turning Atlas. Singapore: World Scientific.

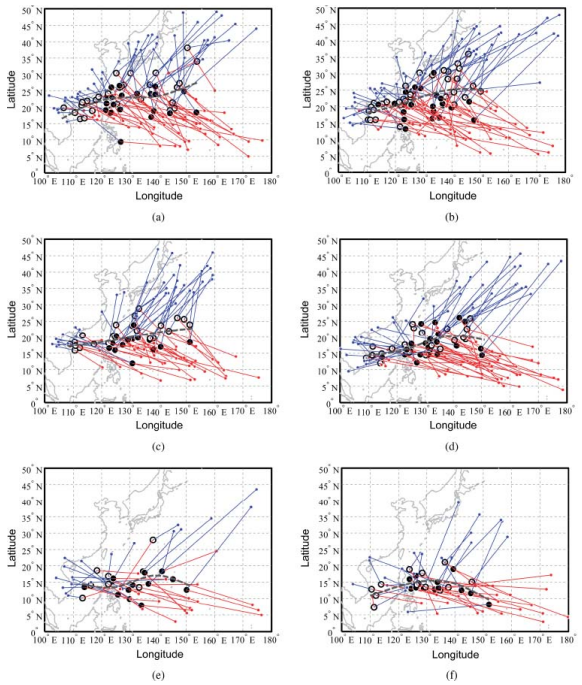

Figure 1.2 1 - Initial positions of TB (small red dots), positions of peak intensity (STs are denoted by large black dots and generic TYs are denoted by open dots), and dissipating positions (small blue dots). Black dashed lines are the cubic splines fitting the posit

Classifications and Life history of Tropical Cyclone

Classifications of Tropical Cyclone:

- **Tropical Disturbance** is organized convection with the size of 100 to 300 miles in diameter that originates in the tropics with a non-frontal migratory character and has at least maintain its identity in 24 hours.
- **Tropical Depression** hit its maximized sustained winds of 38 miles per hour or less.
- **Tropical Storm** is range between the sustained winds of 39 to 73 miles per hour
- **Typhoon and Hurricane** is a tropical cyclone with a maximum sustained of 74 miles per hour. Both terms are used based on the oceanic region, the “typhoon” are used in Northwest Pacific Ocean and the “hurricane” is used in the Atlantic oceans. Similar

storms that occurs in the Indian Oceans and South Pacific Oceans are called the "tropical oceans".

- **Super Typhoon and Major Hurricane** hits the maximum sustained winds of 148 mile per hour and or higher.[3]

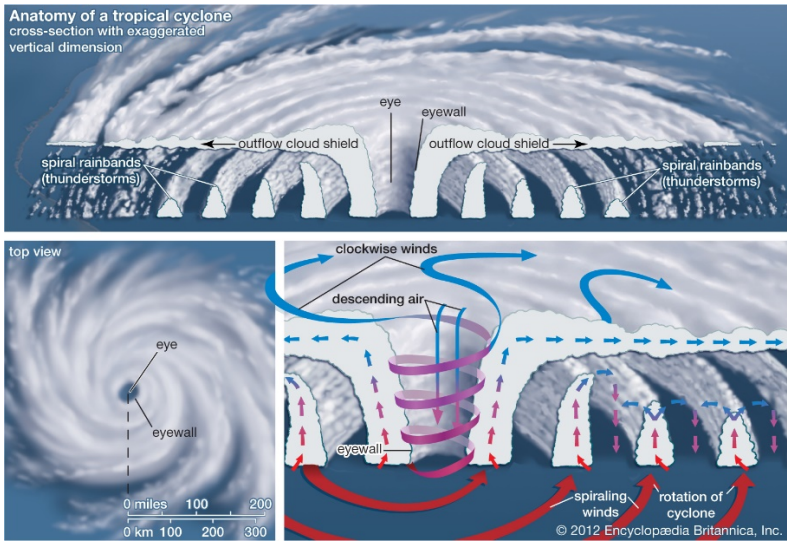

Figure 1.3 - Anatomy of Tropical Cyclone (Source: Britannica 2019)

Life history of a Tropical Cyclone:

The cyclones undergoes a constant metamorphosis from the beginning to the end cycle of the life. Usually they are last for about six days right before they enter a land or before they reach the subtropical latitudes. It is hard to predict the severity and sheer size of the cyclone, however some can detect the weather only a few hours or perhaps a day or two. There four stages of the life history of the cyclones:

- Formative Stages: The initial stage when the tropical cyclone form in waves and in line of pre-existing disturbance and wins that usually remains below the typhoon force.

[3] "About Tropical Cyclones." PAGASA. Department of Science and Technology.

- Immature Stage: This stage cause the typhoon to deepen until the lowest central pressure and the maximum wind intensity are reach. The intensification does not usually happen since it has been known to die down even though the wind has attained the typhoon force.
- Mature Stage: The stage of maturity of the cyclone where the area of the circulation expands and the pressure no longer falls and no increase of maximum speed as it can be observed that can last for weeks.
- Decaying stage: dissipating stage where the area of pressure rises and the area affected diminish in size due to friction and the lack of moisture over the continent or where the colder and drier air enters through the dying cyclone.

Typhoon Haiyan to Philippines

The impact of the Typhoon Haiyan (Yolanda) struck the central Philippines on November 8 of 2013; Haiyan was one of the strongest typhoons to ever strike the land record of Philippines. In over just 16 hours, the cyclone was classified as a "Super Typhoon" with the force of Equivalent of a Category 5 hurricane. It sustained for over 195 miles per hour at its peak and weakened over 155 miles per hour with the wind gust op to 235 miles per hour and the clouds covered two-thirds of the country that swept directly through six provinces of central Philippines.[4]

[4] "Resolving Post-Disaster Displacement:" Insights from the Philippines after Typhoon Haiyan
(Yolanda). International Organization for Migration (IOM), 2015.

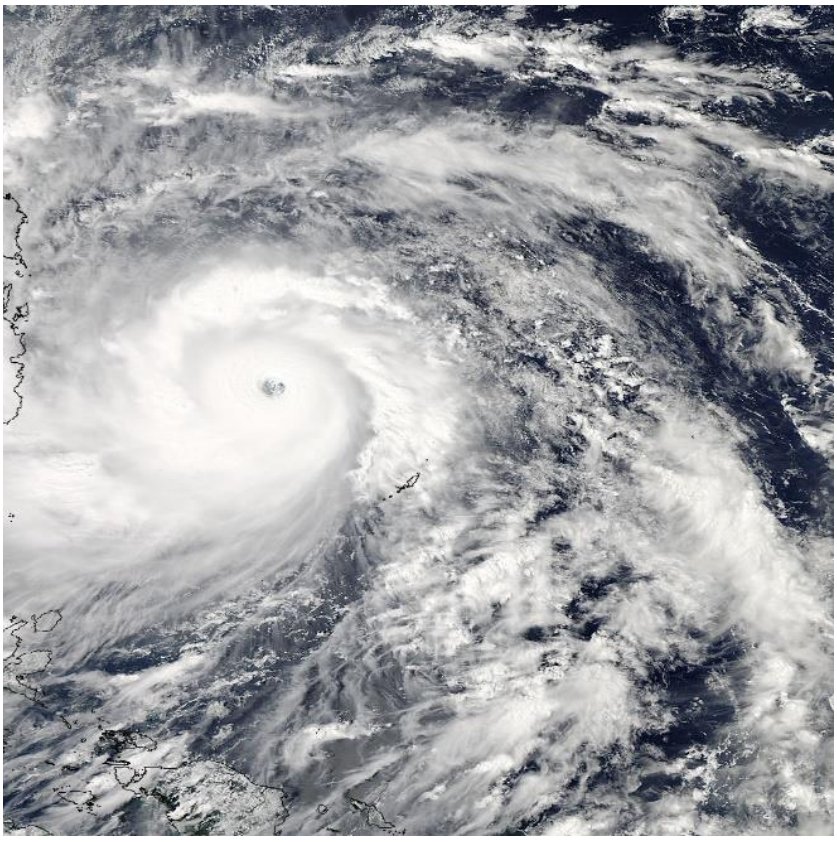

Figure 1.4 - Typhoon Haiyan as It Approached the Philippines Coast November 7, 2013

The super typhoon quickly created a crisis throughout the country and affected over 10% of the nation's population of 105 million people. Even though several had fled their homes in advance as the arrival of Typhoon Haiyan. The hardest hit areas were particularly in the coastal communities like Leyte province and the southern region of Eastern Samar. The Typhoon knocked over many power and communications and water supplies throughout the sites and provinces. The city of Tacloban was one of the hardest hit places in particular were the scene is mostly concentrated destruction and death. Thousands of Tacloban residents reportedly drowned in a "2 story high" storm surge that includes people seeking safety in a sports stadium that served as evacuation shelters and many others were killed by the flying debris.

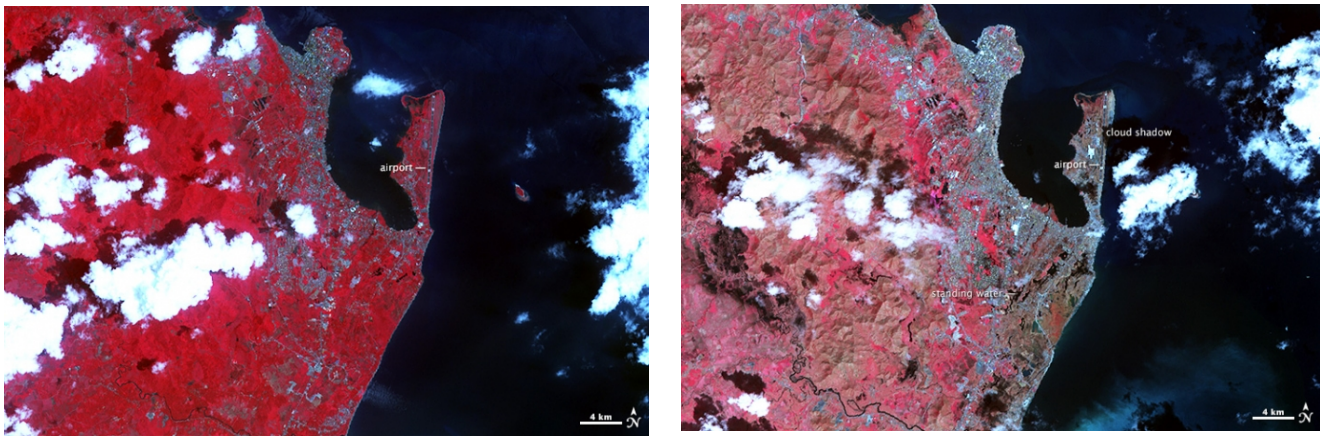

Figure 1.5 - Before and after satellite images of destruction of Typhoon Haiyan at Tacloban, Leyte. "Plant-covered land is red; urban areas are white and silver; bare ground is tan; and water and shadows are black" (Source: NASA)

Much humanitarian relief was heavily delayed due to the significant obstacles made such as the lack of transportation, limited telecommunications systems, damaged infrastructures and the disrupted government services. Despite its physical and logistics challenges, many reliefs' activities reached most of the worst stricken areas within two weeks of the storm. After two and a half month after the super typhoon struck the Philippines, the United Nations agencies reported that over 14.1 million people had been affected and over 1.4 million has been displaced. The estimation of number killed had risen to 6,201 and more than 1,785 people are missing. The number of injuries is unknown. In addition of the demographic statistics, it was estimated that 1.1 million houses had been damaged or destroyed; between two thirds and 90 percent of structures were destroyed including medical facilities, and lastly over 5.6 million people are in need of required food assistance. [5]

[5] "Resolving Post-Disaster Displacement:" Insights from the Philippines after Typhoon Haiyan
(Yolanda). International Organization for Migration (IOM), 2015.

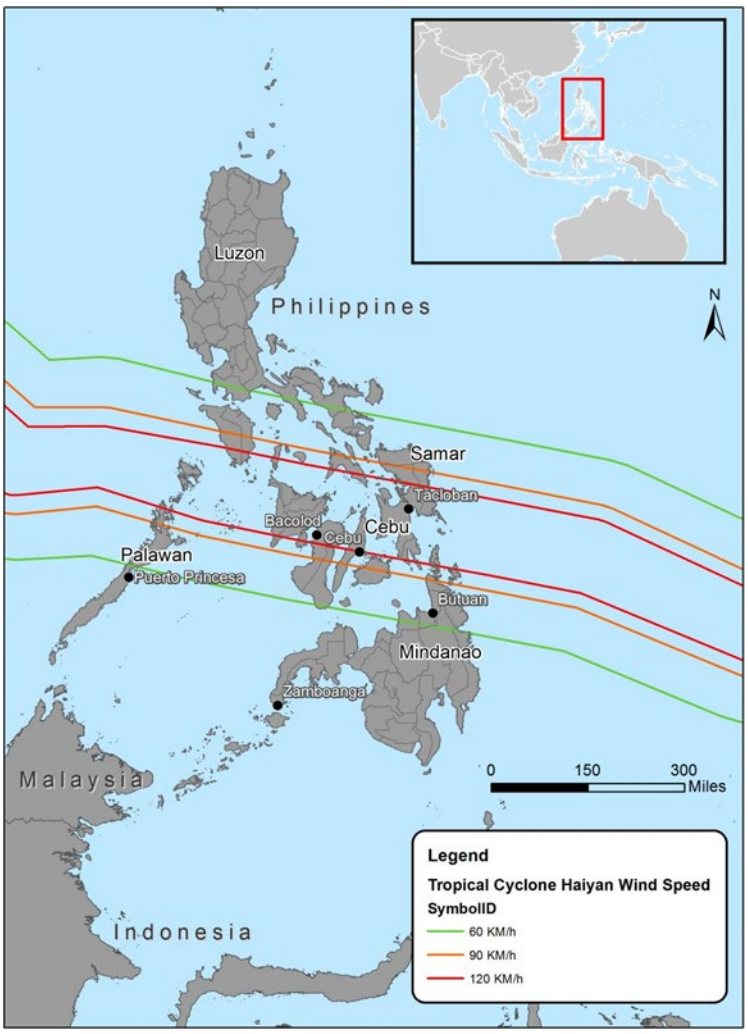

Figure 1.6 - Haiyan Wind Speeds (Source: Graphic created by CRS. Boundaries and cities generated by Hannah Fischer using data from Department of State, the National Oceanic and Atmospheric Agency, and Esri (all 2013).)

With the steady population increases in the disaster prone areas with the combination of geography consist of islands and poor infrastructure, the Philippines is extremely vulnerable to humanitarian crises. It is estimated at the average of 20 major storms hit the country directly every year. Other than Typhoon Haiyan, in 2012, Typhoon Bopha (Pablo) struck the southern region of Mindanao islands, leaving over 2,000 people dead or missing. The Island of Bohol just had an earthquake of 7.1 magnitude in October 2013 which displaced 350,000

people; many whom resisted going to shelters as Typhoon Haiyan approached as they feared it might collapse in an aftershock.

Figure 1.7 - Typhoon Visual Size Comparison showing the largest to the average typhoon diameter compared to Philippines and United States (Source: Author)

The Philippines is prone to tropical cyclones due to its geographical location, the cyclones form very slowly towards the west of the Pacific Ocean threatening the country every year with an average speed of 19 kilometers an hour. Anything that forms in the South China Sea move generally toward northward or northeast which still get affected by the Philippines. The tropical cyclones usually produce heavy rains and flooding in the region and strong winds cause heavy casualty to the human population and destruction to crops and properties, thus making it important to have mass amount of knowledge on such phenomena

for beneficial and adaptive research. . Philippines is more vulnerable than United states because of the size of the country as the Typhoon will keep on feeding on the Pacific Ocean rather than dying off like hurricanes in the United states where it dissipates when it starts to enter through the Country. Referencing to the historic typhoons and hurricanes on Figure 1.7, The graphic compares how big the Typhoon Yolanda is with United States and the Philippines, with the destructive force of Hurricane Katrina on the east coast, one can wonder what the result of damages if it were to hits Philippines.[6]

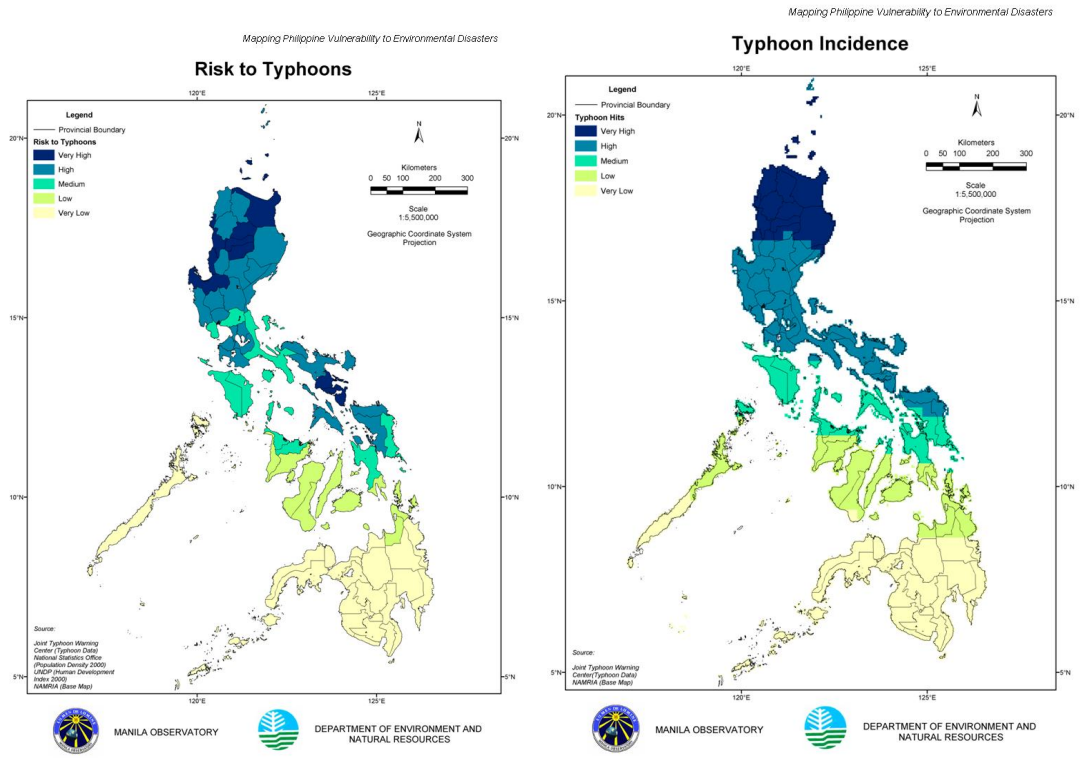

Figure 1.8 - Mapping Philippine Vulnerability to Environmental Disasters (Source: Manila Observatory)

[6] "About Tropical Cyclones." PAGASA. Department of Science and Technology.

Chapter 2: The Biomimetic Response

Biomimicry

The Biomimicry Institute defined Biomimicry as "an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies"[7]. The main core idea of biomimicry is that the nature has already solved the problems that humans have been struggling with. Many species of animals and plants have adapted for years without any technological help as they are the consummate engineers. The term biomimicry was popularized by Janine Benyus when she released her book "Biomimicry: Innovation Inspired by Nature" in 1997. Since then the concept has been widespread heavily that demonstrated the direct application of ecological concepts to the production of objects and structures. According to Benyu's book, Biomimicry is the "conscious imitation of nature's genius" suggesting that energy and materials usage have been developed by nature over almost 4 billion years using trial and error. With the use of biomimicry, it can promote the creativity used of strong, tough and intelligent materials from local natural materials with no waste.

[7] "The Biomimicry Institute – Inspiring Sustainable Innovation." Biomimicry Institute

Figure 2.0 - "The countries, communities, and companies that most closely [and] consciously mirror Mother Nature ... are the ones that are going to thrive in what I call the Age of Accelerations. I'm a big believer in biomimicry." (Sources: Biomimicry Institute)

Benyus characterize that biomimicry is innovation inspired by nature. Men and women have been exploring nature's masterpieces like photosynthesis, self-assembly, natural selection ecosystem etc. and then copying the designs and manufacturing on our own process to solve our problem[8]. Our society have been accustomed to controlling and improving nature, unlike the industrial revolution; taking the Biomimicry revolution route will introduce a new era based on what humans can extract but to learn from mother nature. Doing the nature's way can lead to potential change the way society cultivate food, produce materials, harness energy and heal ourselves

[8] Benyus, Janine M. Biomimicry : Innovation Inspired by Nature

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Figure 2.1 - Conceptual foundations of modern agriculture by using natural prairies as a model: they have been demonstrating that using deep-rooted plants which survive year-to-year (perennials) in agricultural systems which mimic stable natural ecosystems (Source: Biomimicry Institute)

In an ideal Biomimetic world, Humans would manufacture the way other animals and plants do, for example using sun and simple compounds to produce biodegradable fibers, ceramics, plastics and chemicals. Our farms would be modeled in prairies that would have a self-fertilizing and pest-resistant. Finding a new drug, would require to consult with animals and insects that have use plants for thousands of years to keep themselves healthy and nourished.[9] The more our world express and functions like the natural biosphere, the more were are likely to be accepted on this home that is ours but not ours alone. Benyus believes that human faces a dilemma not because the answer exist but just simply have not been looking at the right places.

[9] Benyus, Janine M. Biomimicry : Innovation Inspired by Nature

Benyus created the 10 lessons for companies that are based on the emulation of nature to be made for human design principles.[10]

1. Use waste as a resource
2. Diversify and cooperate to fully use the habitat
3. Gather and use energy efficiently
4. Optimize rather than maximize
5. Use materials sparingly
6. Don't foul the nest
7. Don't draw down resources
8. Remain in the balance with the biosphere
9. Run on information
10. Shop locally (Source: Biomimicry: Innovation Inspired by Nature, 1997)

The Four Steps of Biomimetic Future

Janine Benyus created a four steps to a biomimetic future, this list includes the following: Quieting, Listening, Echoing and Stewarding.[11]

Quieting – *Immerse Ourselves in Nature*

A solitary monk named Thomas Berry stated that our relationship with Nature have been autistic for centuries and that society wrapped tightly on our own version of knowledge. We first get to experience nature in our childhood stage that we must no longer taken it for

[10] Kibert, Charles J.. Sustainable Construction : Green Building Design and Delivery
[11] Benyus, Janine M. Biomimicry : Innovation Inspired by Nature

granted. Bringing back to the nature to childhood is a job for the parent and teacher, as an adult; we need to put down our books about nature and actually get out and experience the weather phenomenon to fully experience that environment. The literal immersion in nature prepares us for the figurative immersion, were we take our human bodies and realize that there is no barrier separating us from the natural world. We must remember that we are not alone in this world and we must remember how it feels to have equal standing in the world.

Listening – ***Interview the flora and fauna for our own planet.***

One of the ways to bring ourselves with the nature is to get to know these species as best as we can and discover the talent and survival web of things. The observation with life will allow us to become an "innovation matchmaker" matching the nature's design and processes to the needs of engineers who design the shape and flow of our products and materials.

Echoing – ***Encouraging Biologist and Engineers to collaborate using nature as a model and measure.***

The only way to ensure that the nature's design will be integrated is to put biologist and engineers to be on the same working field. It will take a lot of educating in the estuary where a place of two or more disciplines flow together to make a fertile ideabed. The engineers and biologist should take courses in one another's field in order to understand each other's goals and visions on a personal basis. To increase the interactions of the basis, schools and universities should create an interdisciplinary departments that flows the right way from biology to engineering. The biologist and engineers must collaborate and create a new device

or a system and use what we are learning about nature's survival principles for viability whether or not the new solutions would promote life in a properly scale economy or technology.

Stewarding – *Preserving life's diversity and knowledge*

The word *Restraint* is not a popular notion in a society that is addicted to growing the economy but at this point of history it will be one of the most powerful practices that the society needs to adopt in order to preserve the life's diversity and knowledge. If the current rate of the deforestation continues, only ten percent of the original tropical forest will cover what is left by mid-century with only fifty percent of its biodiversity. Native people to this response is to set aside a sacred site – a valley that would not be touched, hunted, a stream that would not be fished and groves of tress that would never be cut. These sites turned out to be an everlasting conservation legacies that has been passed down from generations to generations. The cultures that depends on hunting and gathering tend to have a set of codes behavior that honors both the product and resources, for example a sustainable harvesting tools like a Siene sewn purposely wide to let the smaller fish go through or a beaver trap that is design only to capture large animals.

Nature has been produce a wide range of complex materials that is way more functional than any human-made materials. Many good examples like the Abalone's shell is twice as tough as high-tech ceramics, silk form silkworm are five times stronger than steel and mussel adhesive that works underwater. The power of Biomimicry provides us the appreciation of elegant design of nature and instruct us on how to design systems that are materials and energy conserving that uses renewable energy. Biomimicry has more value as a

teacher than as a provider of information about the composition and structure of materials, and this should be part of the toolbox of ecological design. For the designers, architects, engineers and innovators the question often bring up " what would nature do here" ; there's no new idea but a wide range of ideas that have been evolved in context and tested for million years.[12]

The Three Levels of Biomimicry

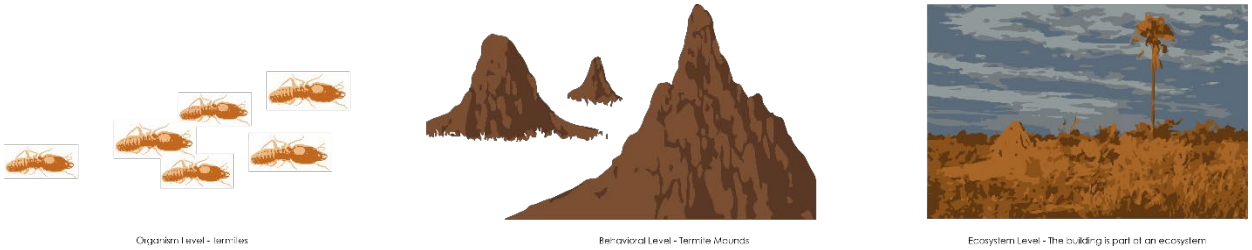


Figure 2.2 - Three levels of biomimicry example (Source: Author)

To learn deeper about Biomimetic system, we must engage in an ongoing conversation with organism and mimic what we learn into three stages of Biomimicry.[13]

Organism Level

The first level of Biomimicry is the mimicking of **natural form.** For billions of years many animals and plant species have withstood and adapted to changes over time. In this level for example, the hook and barbules of an owl's feather can be mimic by recreating a fabric that can open anywhere along its surface and even mimic the frayed edges that silent the owl's flight during the hunt. The disadvantage of mimicking an organism is that without

[12] The Biomimicry Institute – Inspiring Sustainable Innovation.
[13] Nkandu, Mwila Isabel, and Halil Zafer Alibaba. "Biomimicry as an Alternative Approach to Sustainability."

the interaction and contribution in an ecosystem at a larger context, it will produce a design that is below average in terms of the impact that will have on the environment.

Figure 2.3 - This building takes inspiration from the Venus Flower Basket Sponge. This sponge sits in an underwater environment with strong water currents and its lattice-like exoskeleton and round shape help disperse those stresses in various direction

Behavioral Level

The second level of mimicking is natural process, it defines as how things is being made. The behavioral level is based on organism that have learnt how to operate within the capacity of the environment condition and within the limit of the material and energy availability. The organism faces the same problem condition as humans do, therefore it needs to solve similar issues that humans face today.

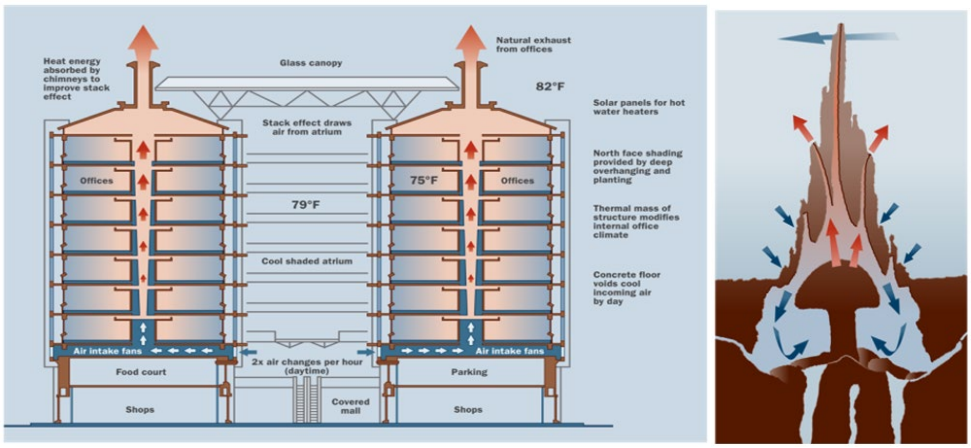


Figure 2.4 - Indigenous Zimbabwean masonry and the self-cooling mounds of African termites inspired the East gate center design (Author: Nkandu, Mwila Isabel, and Halil Zafer Alibaba)

Ecosystem Level

The advantage of mimicking at the level of ecosystem is that it can be used I conjunction with Organism and Behavioral level. Which makes it the most important advantage when approaching to biomimetic design that leaves a positive effects on overall environmental design. This level is looked at how biomimicry fits into the sustainable design practices at a macro scale. Using the biomimicry at this level presents a suitable solution to the current sustainability without affecting the environment negatively. But in order to execute at a macro scale it will require a multiple of disciplines such as biologist, ecologist and designers who will establish a relationship between the organism and systems in nature in order for them to take on ethical decisions for the built environment. There are numerous approaches to sustainable design in architecture but very few have been proven effective at such large scale as there is rapidly growing demand for an effective ecological design without

compromising the needs of the society. Once the system is implemented and imitated well, it could prove a huge advantageous in the field of architecture and human life as a whole. [14]

Level of biomimicry		Examples: A building that mimics termites.
Organism Level (mimicry of a specific organism)	Form	The building looks like a termite.
	Material	The building is made from the same material as a termite; a material that mimics termite exoskeleton/skin for example.
	Construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	Process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	Function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
Behaviour level (Mimicry of how an organism behaves or relates to its larger context)	Form	The building looks like it was made by a termite; a replica of a termite mound for example.
	Material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	Construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain time for example.
	Process	The building works in the same way as a termite would build in; piling earth in certain places at certain times for example.
	Function	The building functions in the same way that it would if made my termites; internal conditions are regulated to be optimal and thermally stable for example. It may also function in the same that a termite mound does in a larger context,
Eco-system level (Mimicry of an eco-system)	Form	The building looks an ecosystem (a termite would live in)
	Material	The building is made from the same kind of material that (a termite) ecosystem in made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
	Construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example
	Process	The building works in the same way as a (termite) ecosystem; it captured and converts energy from the sun, and stores water for example.
	Function	The building is able to function in the same way that a (termite)ecosystem would and forms part of a complex system by utilising the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc in a similar way to an ecosystem for example

Figure 2.5 - Level of Biomimicry (Source: Nkandu, Mwila Isabel, and Halil Zafer Alibaba)

[14] Nkandu, Mwila Isabel, and Halil Zafer Alibaba. "Biomimicry as an Alternative Approach to Sustainability."

Biomimicry in Architecture

Architects have looked at nature for inspiration for building forms and approaches to design, the intention of this study is to use nature as a "sourcebook" that is distinct from the majority of architectural references to the built environment. With the increasing amount of carbon in the atmosphere and climate change, this is a good opportunity to explore effectiveness of the response that natural organism have evolved.

Figure 2.6 - A rendering of HOK's Safe Harbor orphanage that will be built in 2013. The architects drew inspiration from nature in the design of the building. "The trees store water during the rainy season and shed their leaves during the dry season. Coastal mangrov

From an architectural perspective, there are two other terms similar to Biomimicry that are worth clarifying: Bio-utilization and Biophilia. The Bio-utilization defines as the direct use of nature for its beneficial purposes, ie. the use of planting that surrounds the building to produce an evaporative cooling. While Biophilia design incorporates natural materials, light, vegetation and nature views into the built environment. Some scientist and engineer's use the

term Biomimetic rather than Biomimicry due to intentions of developing a sustainable solutions. Architects have been using nature as a source of unconventional forms and its symbolic associations. As to date, biomimicry has only been applied to building design to a limited extent and has only developed rapidly in other fields such as industrial design and medicine.

Architects are continually looking for a new and innovative ways to create a beautiful and livable space that are environmentally responsible and resilient. Therefore the best way to do it is by implementing biomimicry as part of the design technique. There are many reasons why applying Biomimicry to built environment project is extremely valuable. It provides the opportunity to learn about life's water and material use strategies and broadens the design solution space to bring new solutions to the table. It accomplish multiple needs with one simple nature, In nature there are no single purpose tools, for example a tree provides shade with their leaves, generate energy and its bark uses as a protecting and cooling for the moving water beneath the surface. Imagine building surfaces that could do the same system that can accomplish a multiple functional design instead of one purpose. By constructing buildings and landscapes to perform the same service with natural ecosystem, we can create a built environment that "fits" in and actually contributing to the ecosystems that we inhabit and truly emulating the place. [15] The life on earth is an epitome of resilience, its adapting and changing itself for billion years to fit its context. By looking towards how nature resilience on its system, we can create human built system that are inherently resilient to disturbance and even during the unexpected.

15

"The Biomimicry Institute – Inspiring Sustainable Innovation."

Chapter 3: Vernacular Architecure

Filipino Architecture

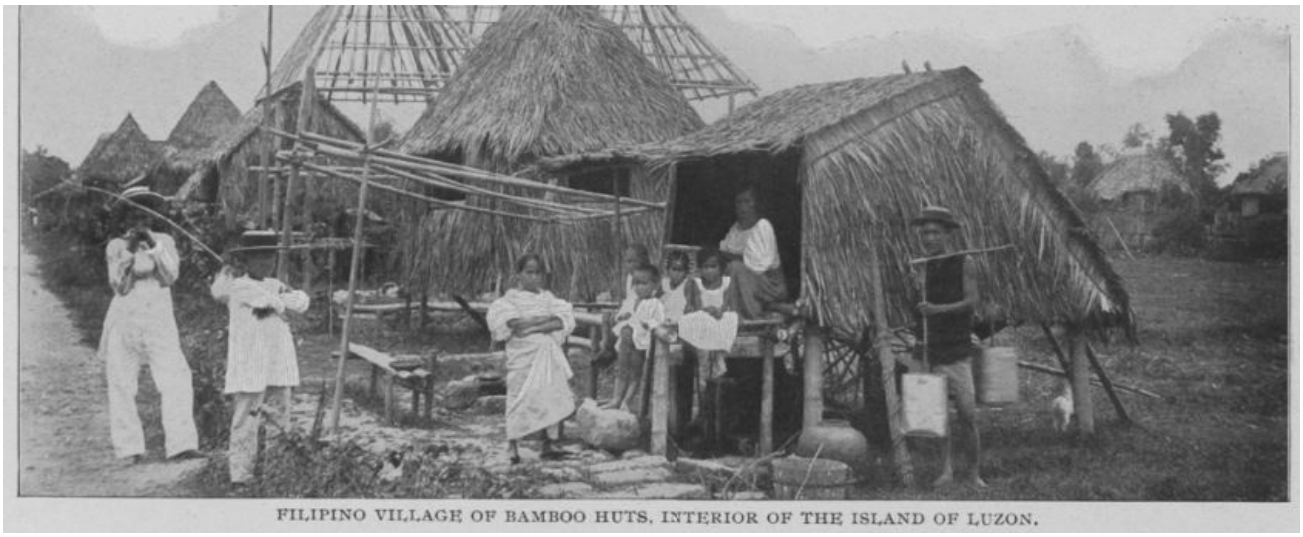


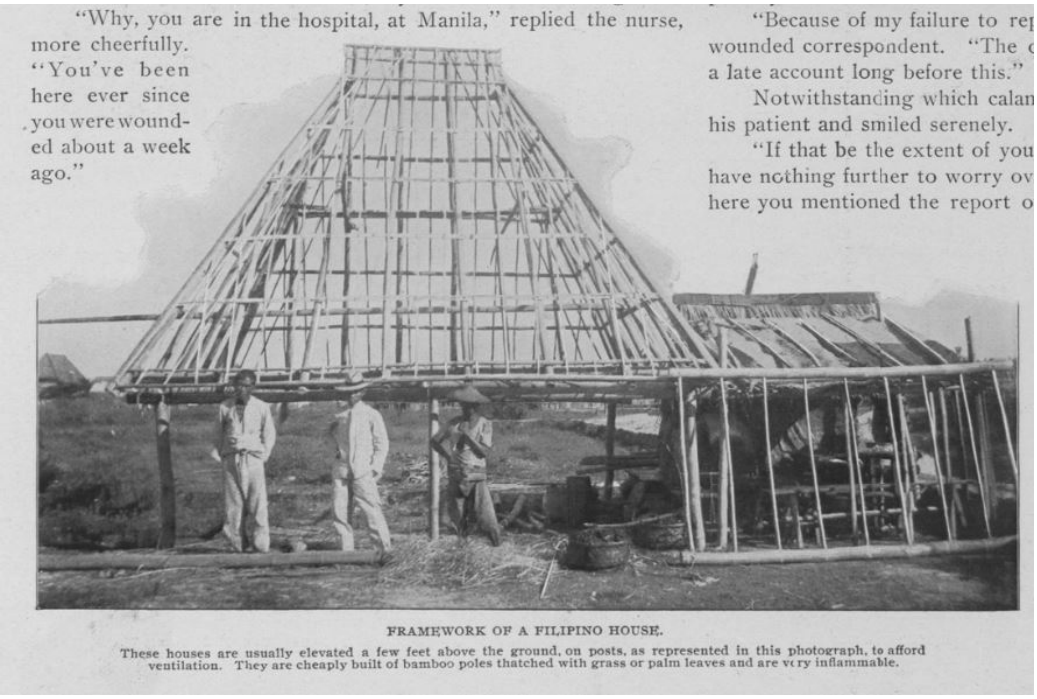
Figure 3.0 - Filipino village in Luzon with Bamboo Huts (Source: Artstor)

"Architecture must be true to itself, its land and its people - Francisco T Manosa"

The history and culture of the Philippines are reflected in Architecture heritage, dwellings, institutions and Religious structures. Architecture in the Philippines today is a result of growth with the absorption of varied influences and turning it into an Architectural melting pot with uniquely Filipino with a tinge of occidental.[16] Developed by the neighboring Malay people, then continuing to the Spanish colonial period, the American common wealth period and then modern contemporary times. A well-known Filipino Architect, Leandro Locsin said Philippines is an elusive thing, while its heavily design with modern technology, there is still a residue of foreign influences left in the Philippines for centuries: early Malay

[16] "Filipino Architecture." United Architects of the Philippines

culture, Hindu culture and 300 years of Spanish colonization, 50 years of American rule, Arab and Chinese influences from trade and commerce resulting a hybrid. Philippine Architecture landscape also contains a contrast of small traditional huts built of wood, bamboo, nipa, grass and other native materials, massive Spanish colonial churches, convents and fortifications with baroque style. And finally integrating todays contemporary mundane concrete structures.



FRAMEWORK OF A FILIPINO HOUSE.

These houses are usually elevated a few feet above the ground, on posts, as represented in this photograph, to afford ventilation. They are cheaply built of bamboo poles thatched with grass or palm leaves and are very inflammable.

Figure 3.1 - Framework of a Filipino House (Source: Artstor)

Bahay Kubo is a typical traditional house found most in lowlands, originally built as a one room dwelling. The construction for these rural native huts has change little for centuries, that are designed by vary region with a common features including a steep roof over a living area that are raised in stilts above the ground or over shallow water. Floors may be split of bamboo to allow dirt and food scraps fall through to pigs and poultry. The Space beneath the hut is also use as a storage or workshop, however it also functions as a ventilation as it allows air to circulate and also use as a safe guard against flooding, snakes and insects. As families

become more modernize, they start to replace thatch roof with galvanized iron which last longer but makes the house hotter and more aesthetically more mundane. Tribal architecture is greatly influences in climate and environment; usually in Low land areas Bahay Kubo is ventilated on all sides, bontoc, fayu; ifugao, bale: kalinga, binayon; kankanay, binangiyan and other typology are usually an insulated dwelling. The Maranao Torogan is design for royalty with ornamentation and elaborate details. [17]

During 19th century, wealthy Filipino built houses with solid stone foundations and overhanging wooden upper story with balustrades and kapis shell and a tilted roof. Rizal houses in Calamba, Laguna and the Luna in Badoc Illocos Norte are also a good examples. Vigan Illocos Sur as well as Taal in Batangas still have the remaining surviving Spanish quarters. The Ivatan's Rakuh is built solidly on all sides made of a meter thick rubble work with thick thatch roof.

PECULIARLY CONSTRUCTED FILIPINO HOUSE.
The roof is thatched with grasses of different colors, and the sides of the house are composed of sliding panels made of oyster shells, which admit the light and temper the heat. The floors and solid portions of the sides are mahogany.

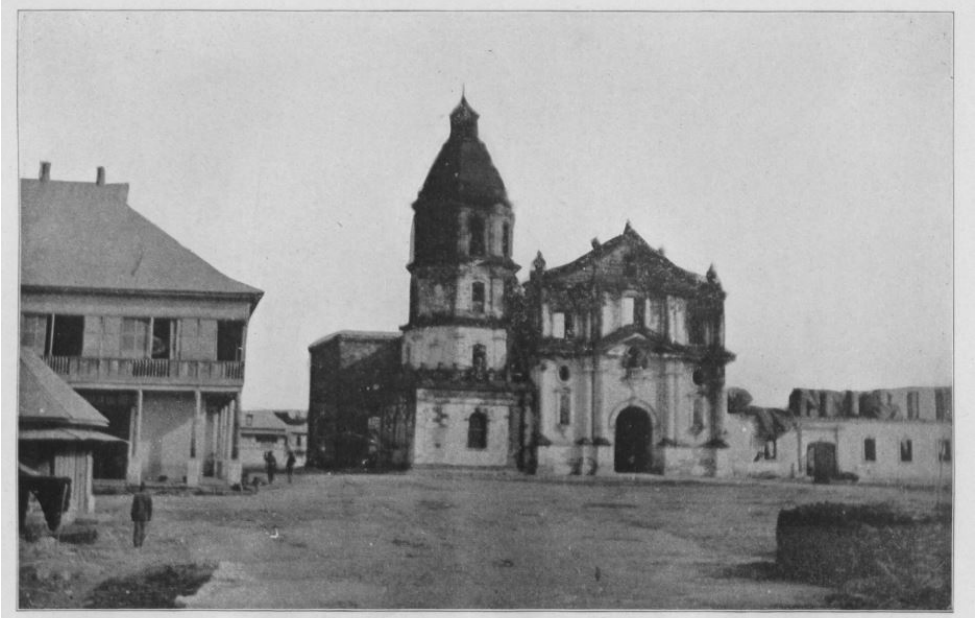
Figure 3.2 - Bahay na Bato (Source: Artstor)

[17] "Filipino Architecture." United Architects of the Philippines

The arrival of Spaniards in 1571 introduce Antillian Architecture, these European architecture transposed Acapulco, Mexico into uniquely Filipino style. The style traces back from Antilles in central America rather than Spain. Christianization of the islands was also introduced resulting in establishing religious structures, Philippine colonial churches are unique. Some of them are best preserved in Illocos Regions, as well as those in province of Laguna and Batangas, Visayan islands of Panay, Cebu and Bohol. The task was then taken over by Filipino and Chinese master-builders. These builders also left a culture stamp in the decorative motifs like tropical vegetation by Filipinos, and lions and dragons by Chinese. The Spanish culture also brought military architecture as seen in fortifications they built in archipelago like the Intramuros in Manila to protect the Spanish city from outside attackers. Bahay na Bato developed only during the latter part of the Spanish period and evolved from a typical Filipino noble house. Bahay na Bato is a derivations of traditional Bahay kubo. Bahay na Bato uses the same principle of ventilation and elevated apartments as that of its predecessor

Figure 3.3 - Typical Civic building influenced by American Architecture (Source: Artstor)

The Philippine revolution lead in 1887 led to declaration of independence from Spain. Superseded by transfer of power from Spain to the United states was part of resettlement entered by the Spain after Spanish American war. Arriving in 1898, The Americans came with a new breed of Architectural structures. The major contributions of the architectural influences were civic government buildings all the way to municipal level. These structures are heavily resembled Greek and Roman temples complete with porticoes and pediments. After second world war, modern era emerged using the simple straight lines of the international modern style as a chief mode of expression and then the Filipino style found its way back to traditional motifs and became popular forms to be copied and modernized.



CATHEDRAL AND CONVENT OF SAN FERNANDO, PROVINCE OF PAMPANGA, PHILIPPINES, BURNED DURING FILIPINO INSURRECTION

Figure 3.4 - Spaniard Influence Church (Source: Artstor)

<u>*Bahay Kubo*</u>

The vernacular architecture of the Philippines has a general acceptances that the *bahay kubo* and *bahay na bato* are the two characteristics of what a traditional Philippines dwellings would look like. The word *bahay kubo* ("cube house" derived from the Spanish word "cubo") is an indigenous dwelling that was used relative all over the Philippines before the Spanish colonial period; now it is commonly found in rural areas of the Philippines. As the name suggest, the hut is constructed traditionally in a square or rectangular form and made with a light weight material like bamboo that are typically raised on stilts. Its roof are made of nipa palm tree and cogon grass. [18]

[18] "Lean Interpretations from Philippine Vernacular Architecture." Lean Urbanism

Figure 3.5 - The bahay kubo is the traditional/ pre-colonial Filipino dwelling from which may be derived Lean housing principles. (Source: Jonathan S. Igharas via Flickr)

The construction of *bahay kubo* uses a traditional post and lintel construction framing that utilize the abundant and local materials like grass, palm leaves, timber and bamboo. With its simple construction, the dwelling promoted a lot of functions that people needed like natural ventilations and a fast and economic constructions. These dwellings are generally ranges from 320 to 550 square feet of single large spaces that can be used as a living room, dining room and bedroom. The only thing that is enclosed and private are called the “celda”, this room is provided and only used for intimate functions like washing, changing and securing valuables. The stilts of the dwelling functions to avoid the damp earth and for worse, floods and to prevent insects and animals from entering the house. The space underneath of

the *bahay kubo* is called “Silong” (“basement” in English) a space from which mainly use a storage for farming and fishing tools.[19]

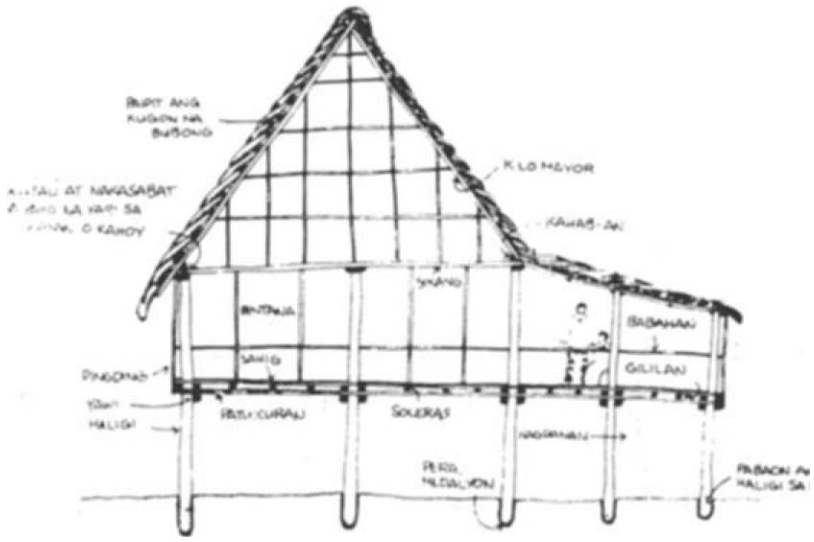


Figure 3.6 - A sketch of Bahay Kubo (nipa hut). (Source: Gavieta, Rommel)

The key to the Philippine architecture is transparency. The transparency design factor revolves around the cultural and environmental considerations. Human social interactions are heavily emphasized with large open floorplan and design of the dwelling. The vernacular is also seen as a climatic design approach into the hot and tropical environment. The materials permeability is the result of light materials.

<u>*Bahay na Bato*</u>

The Spanish Colonial descendant, *bahay na bato* (stone house) is a translation and a mixture of the *bahay kubo* and Spanish architecture. The structure is designed into more permanent construction materials and techniques with the use stones and masonry. While is

[19] “Lean Interpretations from Philippine Vernacular Architecture.” Lean Urbanism

transformed from its indigenous dwelling design, it still keeps the same characteristics from bahay kubo, the *silong* in fact is still incorporated however it is enclosed by the masonry, transforming it into *zaguan*, a Spanish term that is associated with passageway leading to the front door to a patio or courtyard. While the characteristics of the bahay kubo remained the same in the simple floorplan, the use of light second floor and raised house.

Figure 3.7 - The bahay na bato, which emerged during the Spanish colonial period, was built of stone and wood, combining Filipino, Spanish and Chinese elements. (Source: dbgg1979 via Flickr)

The zaguan also remained to be a storage for the housing as well as a carriage parking or sometimes used as a small business use. The bahay na bato also may incorporate a courtyard and patio as an addition for private area for family gatherings and allowing more light and ventilation in the area. The bahay na bato is structured by the stone masonry on the ground floor and wooden structure on the second floor, these stone walls are non-load bearing walls that alleviates damages in event of earthquakes. The traditional Philippine houses uses large window openings that takes up a large amount of proportion that sometimes takes up 50 percent of the walls surface area. With the use of light materials and non-load bearing walls, it

is possible for the house to have a large window openings to maximizes daylighting and cross ventilation. [20]

Figure 3.8 At Casa Manila, a restored bahay na bato in Intramuros, the zaguan leads into a courtyard that provides light and ventilation to the rooms framing it. Meanwhile, the ground floor spaces have been occupied by small-scale com¬mercial uses. (Source: Duany Plater-Zyberk & Company)

The window system contains multiple components that has a layer of sliding panels fitted with a translucent windowpane made out of oyster shell called “capiz” and the second layer on top is a operable wooden louvers. The capiz panels are recessed into the walls to allow maximum ventilation while the louvers deflect the harsh light during summer. During an inclement weather the capiz panels are completely cover the window but still letting the sun light go through due to its translucent property. The transom vents above the windows

[20] “Lean Interpretations from Philippine Vernacular Architecture.” Lean Urbanism

still allows some natural ventilation even if the windows are fully shut. And lastly that *voladas* which are small perimeter passages and allows air to circulate and cool the house down during dry seasons. Although the stone house is simple in construction, it has a very comprehensive system that allows full control the amount of light and air entering the house.

With the non-loadbearing wall ground floor, it has its parallel in the post-hurricane Katrina stilted house that has a collapsible ground floor and as more super storm emerges, the bahay na bato maybe a good foundation lesson that can maintain urbanism which habitable spaces are raised above ground floor. Sustainability in built environment is gaining popularity all over the world with high energy and maintenance cost concerns, the vernacular lighting and ventilation can be a more sustainable alternative that mitigates reliance on more expensive and complicated systems

The roof and the eaves is one of the most important element of Philippine vernacular architecture. The traditional Philippine dwellings has a steep slope for capturing and storing rainwater. Not only does it captures rainwater but it allows the hot air move upwards to the top of the roof and move away from the living area. The deep overhangs blocks any incoming harsh sunlight and rain from the window and vented soffits assist the hot air escape and moderating temperature inside of the rood structure and the living space.

Figure 3.9 - Vented soffits can be ornamental as well as functional. (Source: Senen M. A. Antonio)

Chapter 4: Resilient Species - Considerations for Biomimicry

Functions of buttress roots

Many characteristics of a tree species of tropical rainforest are the root buttresses; these buttresses are a triangular flanges that joins the roots and the lower trunk of the tree, many of biologist are intrigue of the design for generations and have proposed many theories of what those buttresses functioned. Many thought that the buttresses serves to prevent the vines from climbing up to the trees but later was discredited by Boom and Mori in 1982. But overall the general consensus as the name suggested, the main mechanical role is to help and provide stability to prevent the trees from toppling over.

It has been said that trees with well-developed roots rarely produced buttresses and the development of the system is also correlated with tree height. The Buttresses is also correlated with soil textures and depth as it tends to grow more in the weaker silty soils and in shallow waterlogged soils. There is also a correlation with wind direction, although the buttresses are oriented randomly, the buttresses on the side where it faces the most prevailing wind tend to extend further from the trunk. The anchorage of the buttresses strength trees are almost double that of un-buttresses trees. Hendwood a Biologist in 1973 suggested that buttresses act as a tensile elements that increases the anchorage provided by the lateral roots of where the windward side of the tree trunk by lengthening the moment arm about which they act. The buttresses trees also possess a sinker roots that branches from the laterals along the trunk that penetrate down the subsoil. The roots are part of the anchorage system that resist downward and upward forces. Being vertically oriented, the roots are ideally placed to

resist both forces; Meanwhile the buttresses prevents the roots from splitting their length or snapping by bracing the roots to the trunk creating a smooth transition between the tension and compression of the sinkers.

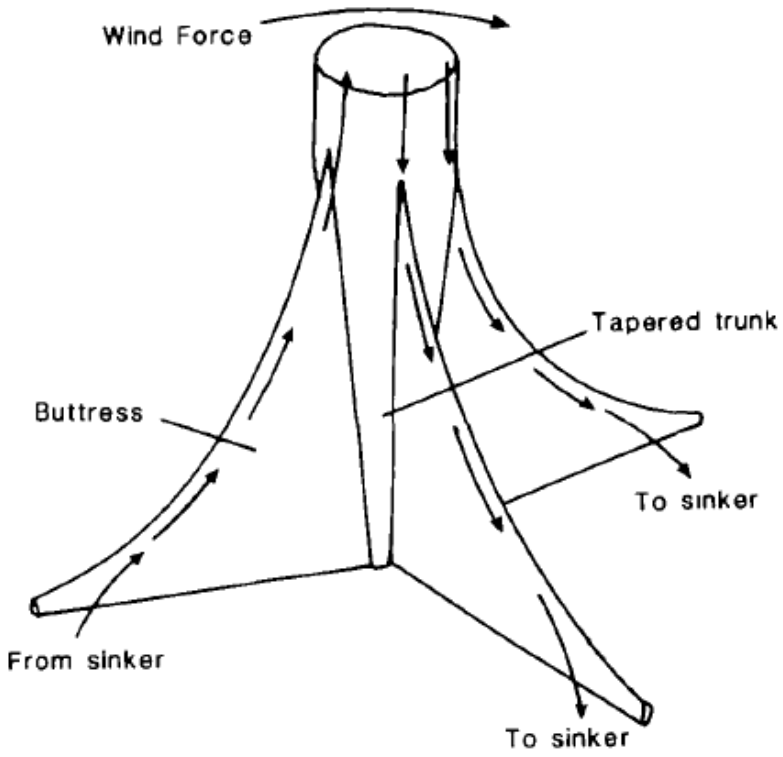


Figure 2.0 - Mattheck's model for the function of buttresses If a tree is pushed over by the wind the bending force is transmitted smoothly to lateral sinker roots by the buttresses. Windward sinkers resist upward forces, the buttresses being put into tension, while the leeward sinkers resist downward forces, the buttresses being put into compression (Source: M.J. Crook1, A.R. Ennos and J.R. Banks)

The tropical trees possessed sinker roots that branched from the ends of the buttresses. The anchorage strength of the buttresses trees is almost double that of un-buttresses ones and the maximum moments are generated at lower angles. the results suggested that buttresses acts in both tensions and compressions that make a much larger contribution in anchorage than the thin laterals of buttresses trees.

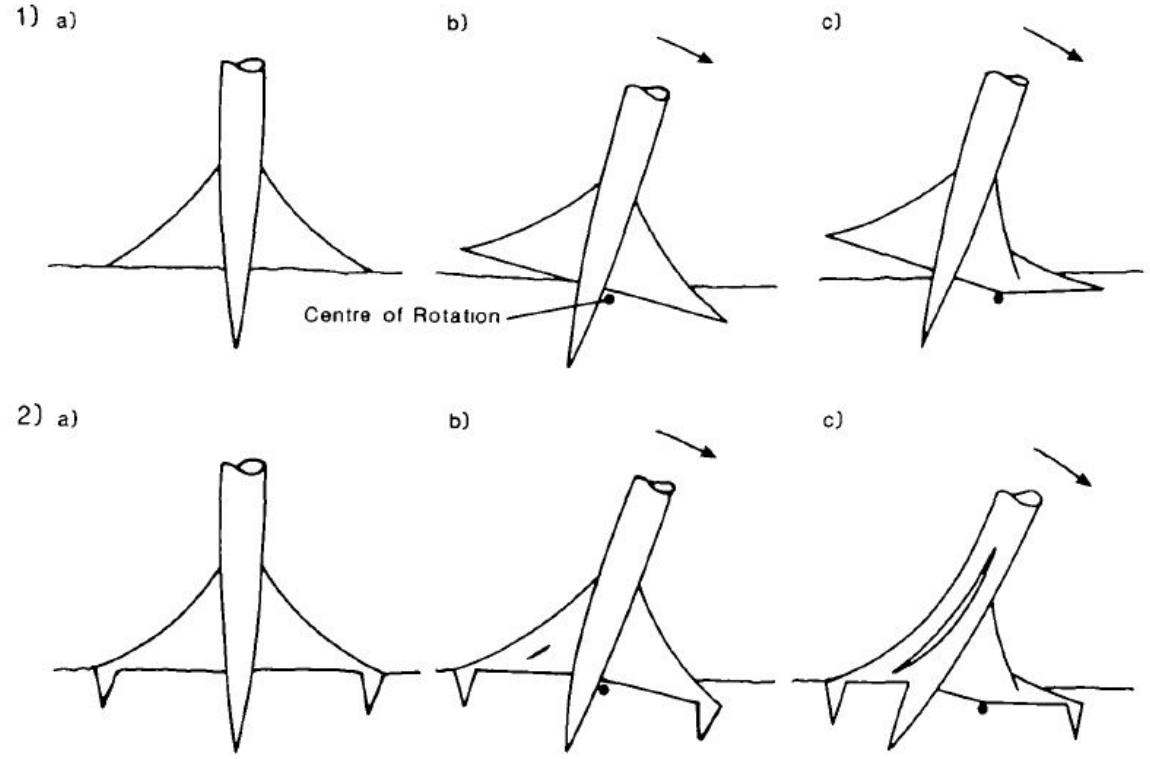


Figure 4.1 - Trunk and root movements during anchorage failure of buttressed and non-buttressed trees, (la) Buttressed tree without sinker roots (2a) buttressed tree with sinker roots. (Source: M.J. Crook1, A.R. Ennos and J.R. Banks)

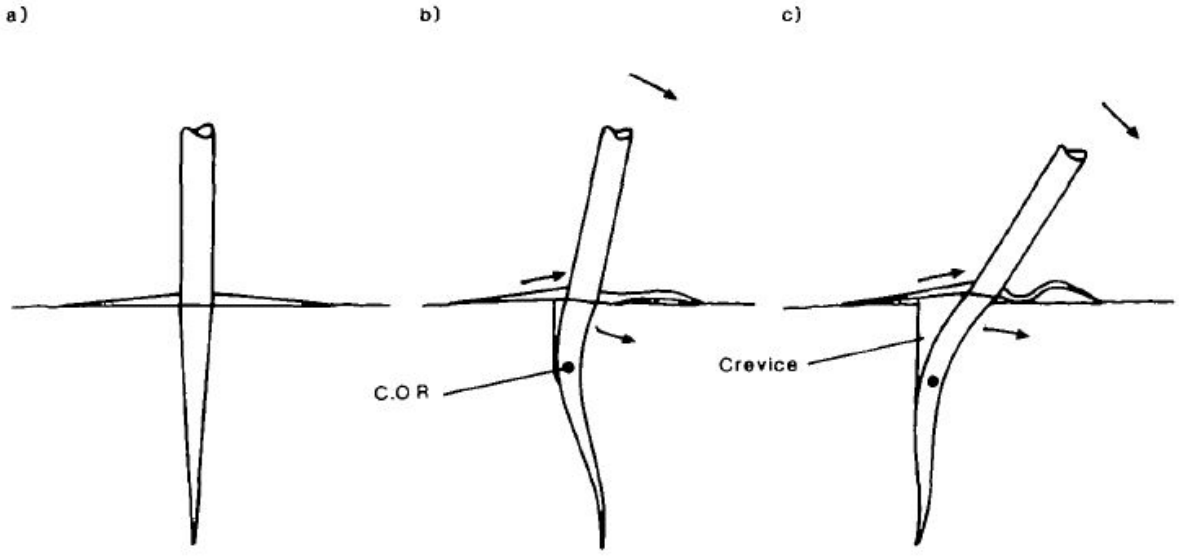


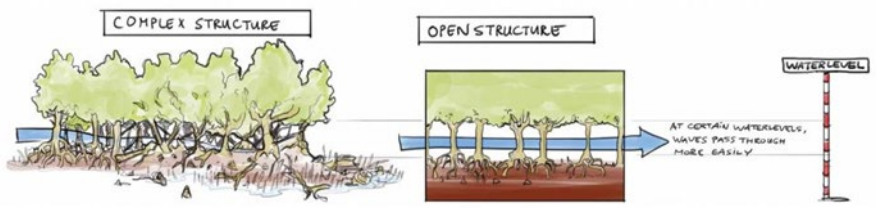
Figure 4.2 - Trunk and root movements during anchorage failure of non-buttressed trees. These root movements continue, the leeward laterals buckling, the windward laterals uprooting and the tap root pushing into the soil, increasing the size of the crevice. (Author: M.J. Crook1, A.R. Ennos and J.R. Banks)

Mangrove Species

Mangroves are a group of tropical halophytic wood plants. Mangroves forest are recognize to be the more productive forest ecosystem in the world that both links through terrestrial and marine system through intertidal zone. The species plays an important part of the ecosystem as they serve as a shelter for marine fauna and protection against from strong waves during tsunamis, storms and wind. Mangroves can substantially reduce the vulnerability of the adjacent coastal land from the inundation and erosion. The roots system is often serve to support the trees but in some species it provides an air circulation to the roots while they are submerged during the higher tidal events. The mangroves are a type of coastal wetland that are characterized by the presence of the salt adapted trees and shrubs, these forest can be recognized by the dense tangle of prop roots that make look like it appears to be standing on stilts above the water.

Figure 4.3 - Mangrove Trees (Source: USAID)

Mangroves are the most effective natural forms of coastal protection found all over the world. Its complex root system and its physical structure makes it able to absorb wave energy and reduce the wave heights from the storm surges. A study found that the wave height can be reduced by 13 to 66 percent with over 100 meter wide of mangrove belt while 50 to 100 percent will be reduce if it's over a 500 meter mangrove belt. With the same physical structure that reduce the wave energy, it is also serve to settle the sediment out of the water. With the combination of wave reduction energy and increased in the sedimentation to reduce coastal erosion can keep pace with the sea level rise through accumulation of sediment and vertical growth, providing ongoing protection during sea level rise. [21] Mangroves also reduce the wind across the water preventing the propagation or reformation of the waves. The tightly packed roots and low branches present a solid obstacle to waves thana few or no aerial roots. Debris movement can also be reduced by the mangroves with the complex of roots and branches that serves as a trap even large moving object. The dense canopies of mangroves also reduced the speed of the wind locally, preventing further development of the wind and waves behind the mangroves potentially reducing damage nearby structure. They may be damaged or torn up by the high winds and waves, it is rare for a mangrove to break or uprooted.



[21] "Mangroves." Naturally Resilient Communities

Figure 4.4 - Mangrove Systematic Structure (Source: Wetlands International and The Nature Conservancy)

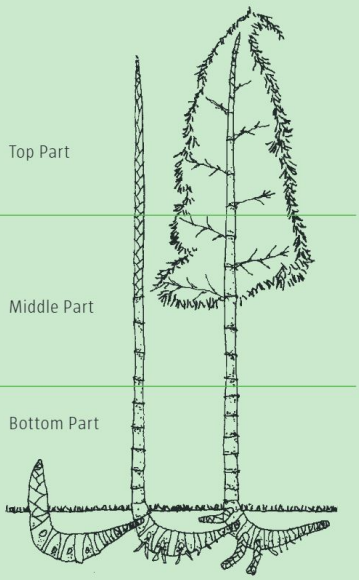
In addition to reducing the impacts of storm surges and limiting erosions, the mangrove offers wide range of benefits. Mangroves also provide habitat for animals like the fish and the bird species, giving an opportunity for a place for recreational fishing and bird watching for outdoor tourism and activities. Mangrove also play an important role in carbon sequestration and water purification, they are capable of trapping carbons in their soils creating a carbon storage than other habitats that store carbon solely in the form of biomass.

Bamboo

The word "bamboo" was introduced in 1753 by Carl von Linne. The most common mistake that people classify bamboo is that is not a tree but a grass plant like rice, corn and sugar cane. During its growth span the tissues of Bamboo's structure gets hard as wood but gets more flexible and light. Bamboos in the wild form grow all over the continents except Europe. The majority of these species are found in warm zones with humidity level forest and soils, for many reasons they are often found near water. Approximately 1,200 species exist in the world, which are 750 in Asia and 450 in America.

Figure 4.5 - Bamboo (Source: Minke, Gernot)

Bamboo plays a major in tropical landscapes. It stabilized hillsides during rains, act as a wind breaker for infrastructures and produce strong, flexible building material that strengthens houses during high winds and earthquakes. These ecosystem and structural qualities is well known in the Philippines where Typhoons and earthquakes are very common. The bamboo is an economically member of the grass family Poaceae, in the subfamily of Bambusoideae. It is commonly known as the "poor man's timber". The bamboo has been part as a construction material that used basic habitats to complex structures; it has formed a major part of elements that were essential part of the cultural development in Asia.



	USES ACCORDING TO THE PLANT SECTION		DESCRIPTION	HEIGHT	LENGTH
Leader	Returns to the earth as organic material		Apical part of the plant	20 m	1.20 – 2 m
Stick	Structural straps for roofs, and guides for transitory cultivations		Part of the stalk with the smallest section	18 m	3 m
Top					
Middle	In structures such as roof purlins, scaffolding, structural columns for greenhouses		Because of its diameter, it is the most marketable part of the upper stalk	15 m	4 m
	Elaboration of planks, slender columns and beams		Part of the stalk most used, for its diameter	11 m	8 m
Bottom	Columns in civil works, greenhouses and fences		In this part, the stalk has the greatest diameter. It is the most resistant part of the plant	3 m	3 m
Rhizome	Sculptures, furniture and children's toys		Network of underground stalks	2m	2 m
USES ACCORDING TO AGE	30 days Food	1 year Basketwork	2 years Planks, Strips, Laths	3 to 4 years Civil Structures, Floors, Laminates	

Figure 4.6 - Bamboo parts and its uses (Source: Minke, Gernot)

Bamboo is known to have a rapid growth resources that can produce much more biomass per hectare per year than eucalyptus. Although the production for bamboo biomass depends on many factors, the production of dry aerial biomass from Southern India reaches about 47 tons per hectare per year after it has been cultivated. The bamboo has a network of

roots that anchors on earth and helps to lessen the erosion during rains and storm surges. One hectare can retain over 30,000 liters of water. Not only it does water retention, it also can regulates its hydraulic flow in its stem and conserve water in the rainy season then use it later for dry season. Thanks to their leaves and stems it can assimilate Carbon Dioxide for photosynthesis and storing it in their biomass which is very important to the global climate. Due to its rapid growth rate, it can take in more CO2 than a regular tree. [22]

Pilli Nut Tree

The pili nut, also known as Canarium ovatum is part of the Burseraceae family. It is native to the Philippines and most of the tree are wild and found in the forest. The canarium spices bear nuts and are eaten like an olive. Although there known on extensive research on any aspect of culture or use. Its known that the pili nut tree is a good windbreaker because of its spreading roots and prominent buttress. [23]

Choosing the three plant species is important due its resiliency to climate change and adaptation. With the feature of its deep root system, the flexibility structure, wind resistant branches and prominent buttress roots. It will be a great important role in designing and exploration to create a typhoon resilient community

[22] Minke, Gernot. Building with Bamboo : Design and Technology of a Sustainable Architecture.
[23] Wanitprapha, Kulavit. "Pili Nut ." Economic Fact Sheet #17.

Chapter 5: Site

Site Selection

Criteria to Sites	Illagan City, Isabela	Tacloban City, Leyte	Legazpi City, Bicol
Typhoon Frequency	3	2	1
Typhoon Severity	2	1	3
Suitable size (Population density)	1	3	2
Displacement	1	3	2
Accessibility	2	3	1
Proximity to relief services	3	1	2
Orientation	1	3	2
Proximity to Homes of Affected people	1	3	2
Infrastructure conditions	3	1	2
Geological hazards	2	3	1
Total	19	23	18

Figure 5.0 - Site Criteria Table (Source: Author)

The site selection process for this thesis was difficult. There are three possible sites for the thesis. The first site is Illagan City, the site is part of the Isabel provinces from which the location is very susceptible to flash flood based on the region and nearby connecting river. With the repeated cyclone strikes, it is often common for people to be displaced. The site is placed in a residential area and the center of the city where nearby amenities and point of interest are close within a mile. The second potential site is Tacloban City in Leyte province; in 2013 Typhoon Haiyan was one of the strongest typhoon ever to be ever recorded. The city of Tacloban was directly hit with the wind velocity of 200 kilometers per hour. As a result the city has been reduced to rubble and over 4,000 people have died. Little over a year later,

thousands of people are still living in temporary shelter and 4 million people have remained to be displaced and still looking for a place to settle down. The last is Legazpi City, Bicol; Bicol is surrounded by natural feature that causes natural disaster, with its long coastline, volcanoes, mountains and rivers. Legazpi is extremely vulnerable in geological hazards. The process of habitable areas and following the hazards maps was required to identify where to locate the new village that can moved at least 50,000 people. The investigation over 3 potential sites, one was chose. It should be noted that the project is not site specific. With the frequency cyclone hits all over the country proves that there are numerous valid sites that can be applicable with the concept. Ultimately, the search was chosen to Tacloban City due to its recent history with the super Typhoon Yolanda (Haiyan) and its existing condition.

History

Tacloban City

Tacloban City used to be called as Kankabatok, which defined as the domain of Kabatok, Kabatok was a settler who occupied the area that we know in the present as the Downtown Tacloban. Right on the coast, the bay was named after him (Cancabato Bay). During the 1770 the arrival of missionaries, Kankabatok was proclaimed a municipality and was changed name altered to Tarakluban which means the place where the settlers used the taklub (bamboo contraption for catching crab, shrimp, and fish.) after many years it was gradually called in its present form, Tacloban. The location of its port gave an opportunity to developed into a major trading point between the province of Leyte and Samar, and was declared the capital of Leyte in 1830. And by June 20, 1952, Tacloban City became a chartered city through Republic Act that was signed by President Elpidio Quirino.

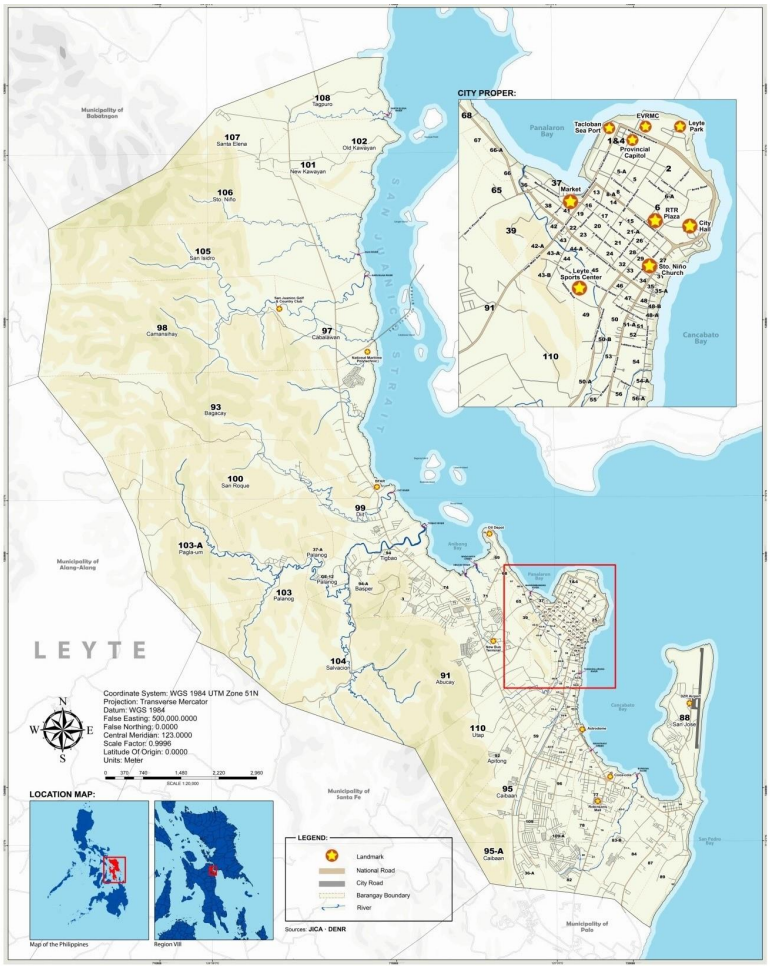


Figure 5.1 - Tacloban Barangay Map (Source: City Government of Tacloban, 2018)

Physical and Geographic Profile

Tacloban City is located in the northeastern region of Leyte which is part of the islands in the eastern Visayas. It is situated in southwest of Manila for 580 kilometers. The land is about 20,172 hectares or 201.72 square kilometers that includes the nearby small islands within the territorial border of the city.

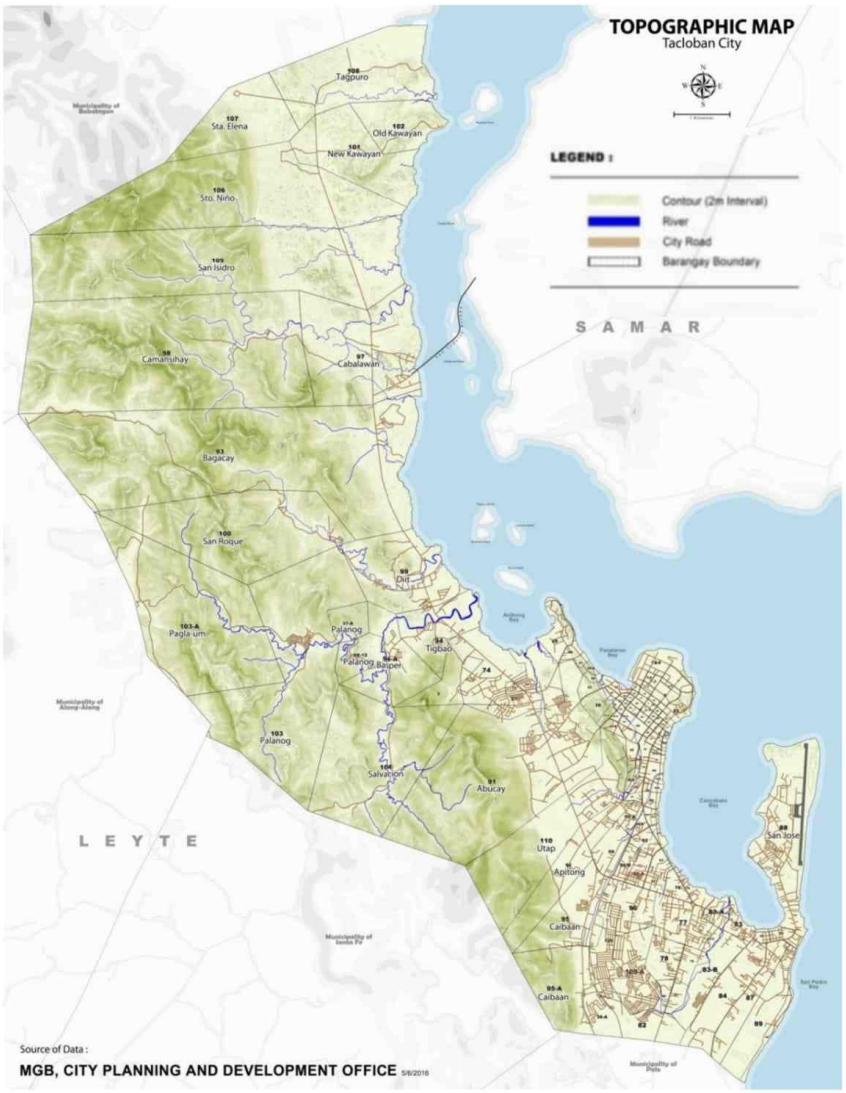


Figure 5.2 - Topographic map (Source: City Government of Tacloban, 2018)

Economic

With over 240,000 people in Tacloban City, it has a potential for it to triple in influx of residents due to the readily availability of utilities and services in the city. The demand for the multifamily and permanents housing is increasing due to its central location for business, education, health and activities. The major tourism hub in Tacloban City yielded about 44.87 of the city's economic drive and has surpassed its target in 2015 by 16.72 percent. The city has contributed the highest tourist receipts to 4.05 billion Philippine pesos. Tacloban city has

taken almost half of the regional tourist to the total regional earning generated. The city contains three of the biggest state universities in the region; the Leyte Normal University, The Eastern Visayas State, and the University of the Philippines Visayas. With the major graduates from the school gives a rich pool of young professionals that are skilled in technical and professional workers in various industries. These new young professionals are suited to the business ventures due to the familiarity of the location and culture. Waray are one of the biggest cultural group of workers in Metro Manila. In addition of education, Tacloban is also a regional healthcare hub with six major hospital, it contains Tacloban's hospital most advanced healthcare facilities and best practitioners in the region. The city has always been a regional melting pot for anyone who wishes to live, invest and or anyone who wants to pass through Tacloban City.

S.W.O.T. Analysis

Strength

Tacloban City contains undeveloped lands further away from the coastline. According to the new Lan use maps, residentials can be developed in these areas and will allow 75 percent of the population to be moved from the downtown Tacloban city. The Philippine Pan highway is located in the area allowing tourist and ease of transportation to easily access the area and travel directly to the capital of the Philippines, Manila. There is a existing river that stretches within the city that connects with the Cancabato Bay for 2.40 miles from the north of downtown Tacloban City. The Mt. Naga Naga creates a beautiful scene within the city and served as a great background scenery for the tourism.

Weakness

There is a major undeveloped land and infrastructure in the area where people are still leaving in temporary slums. The overall urban pattern is mix between urban and suburban sprawl with no system when it comes to street hierarchies. The topography varies from high to flat conditions where they are susceptible to flash floods and storm surges.

Opportunities

The mountain is a big potential geological land as it can be used as a role of water shed that can redirect rainwater to prevent flash flood. The areas can be extended and connected to the highway and create an anchor retail for tourism purposes and to extend the city's grid and residential fabric. The Cancabato bay is being used as a storm water drain through the city, by extending this and transforming it into a constructed wetland, it will help with drainage and redirecting future flood prone areas.

Threats

There is an existing flood hazard areas within the site as it contains flat topography and susceptible in water table. Other than that no other hazard in the areas.

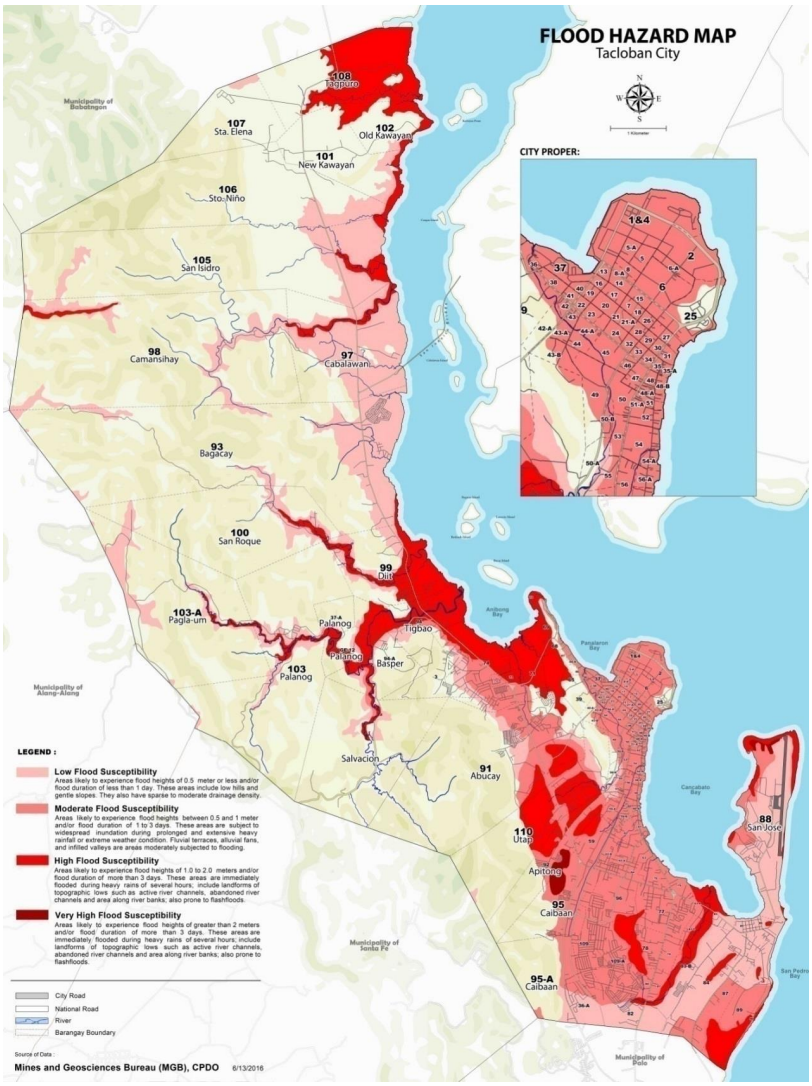


Figure 5.3 - Flood Hazard (Source: City Government of Tacloban, 2018)

Location

Proposed Tacloban Recovery and rehabilitation Plan

Tacloban City has proposed a new project development strategies to combat future super typhoon and the increasing populations. With the propose strategies, the Tacloban city will be divided into three regions; North Coast, Mid Coast and South Coast. The north coast will be concentrated as the new employment and residential area, the mid coast will be the transit and trading area and satellite government area. The last region is the south coast, the

existing downtown area will be converted into a tourist oriented commercial and a historic district, while further south is being proposed to be the new central business district. The city of Tacloban are looking for expanding to have a direct growth to the safer areas of the city with the strategy of using disaster resilient building based on architecture and engineering provisions for future constructions. Any place that is already existing in downtown areas are condemn to be “unsafe” and must be relocated .

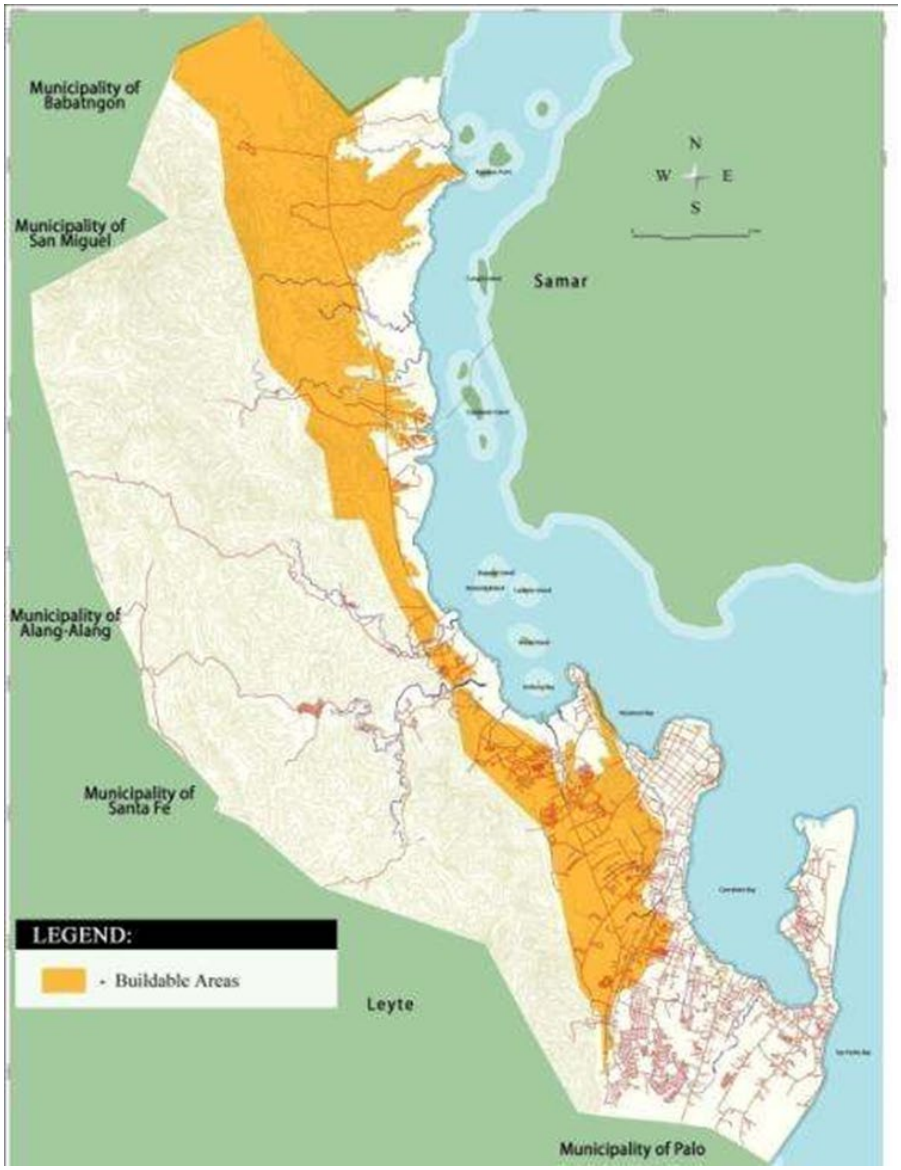


Figure 5.4 - Buildable areas (City Government of Tacloban, 2018)

Site Selection

Figure 5.5 - Site (Source: Author)

Based on the government's proposed strategies and guidelines along with readily available space. The site that will be develop for thesis will be in the area further back of the barangay area known as Utap. The area is close to 50 hectares, enough for a 50,000 people to be able to start a small community. The area is connected with the Pan Philippine highway, the area itself contains some slums and houses that can be redeveloped.

Chapter 6: Ecosystem Level (Urban Strategy)

Existing Conditions

Figure 6.0 - Existing Conditions (Source: Author)

The current existing conditions of the site has a low topography land which is very susceptible to flood for up to 3 to 6 feet. The area is completely surrounded by the two existing road, one which is a main highway that connects to Manila and consist of commercial buildings and the back road which is underused. The site itself has a gorgeous background view of Mount Naga Naga. The site soil is mostly made of silt/clay due to the proximity of the coastline. There are some houses nearby but most of them are slums and or illegally settled.

Assets and Opportunity

Figure 6.1 - Asset and Opportunity (Source: Author)

The asset and opportunity of the site is the existing river called Mangonbangon River that spans back to Cancabato Bay for 2.48 miles, the river can be used as an advantage to redirect and manage storm water back to the bay. With the area being susceptible with water table, this is a good opportunity to expand and revitalize the area and turn it into a constructed wetland. Along with the river, Mt Naga Naga could be used as a watershed for the storm water and a view for the residentials. Based on the form of the mountains topography, the trench can collect where the area of the mountain's topography meets in a concentrated area and can be easily redirect back to the bay area. Along with connecting the watershed with the

trench. This will form as a main street for the site connecting the two road and activating the site.

Figure 6.2 - Expanding the River (Source: Author)

Another asset can be use is the existing wind rose, to understand the pattern of the wind, the use of diverting wind based on the placement of the building block is very important in order to withstood the potential high wind velocity incoming from the coastal area. The most appropriate wind diversion is the 45 degree orientation, by facing the corner of the block, it can divide the prevailing wind and transfer the wind to another block that will keep dividing the wind till its weak. Another advantage to diverting wind is redirecting and allowing cross ventilation to happen in each building block. By layering the wind diverting

block like the mangrove system (layering). It will reduce the wind energy while redirecting the wind pattern.

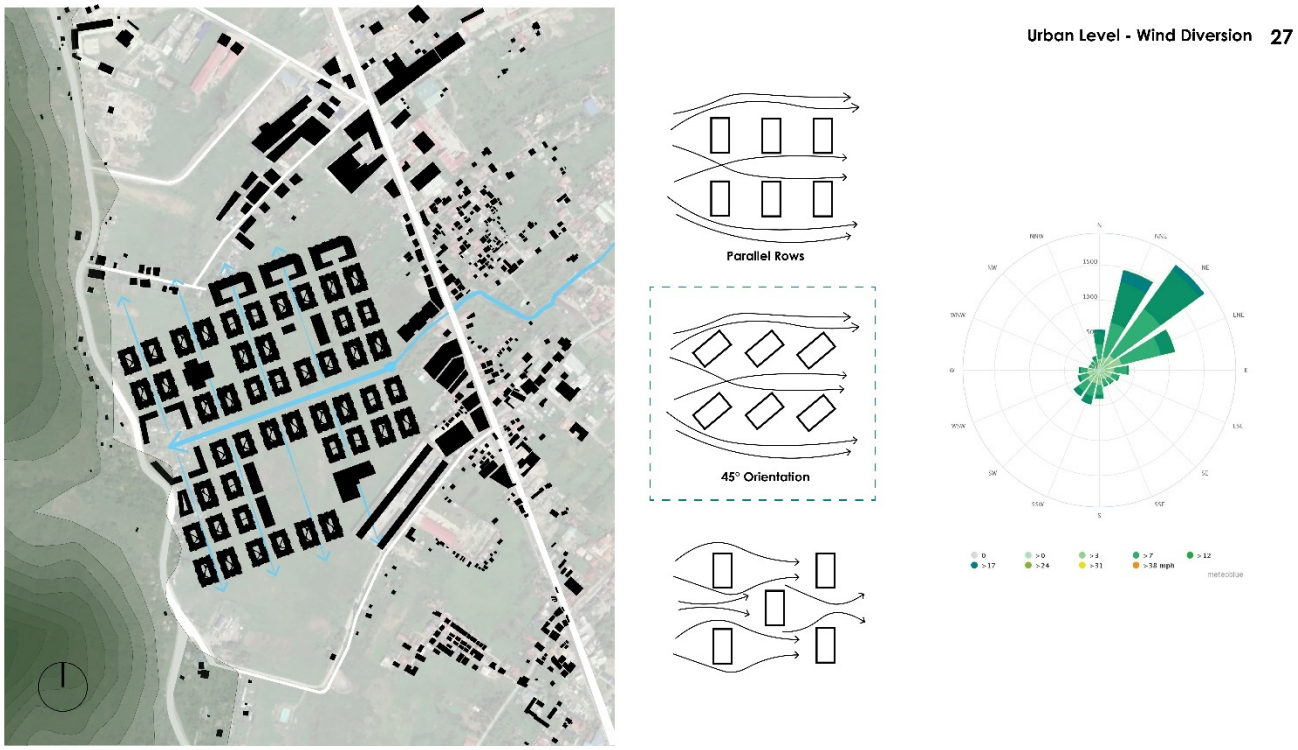


Figure 6.3 - Wind Diversion and Wind Rose (Source: Author)

Urban Grafting

It is important to understand the density and the pattern that will be created in the site, whether it's a new urbanism or following the existing urban condition in the area, it is rather important to establish a new infrastructure in the area that can be potentially be expanded and influence nearby areas to follow the guidelines and the urban fabric. By creating overlays on the site, it helps understand the appropriate size of the blocks and the building.

Figure 6.4 - Existing Site Overlay (Source: Author)

Figure 6.5 - Germany Site Overlay (Source: Author)

Figure 6.6 - Queens, New York Site Overlay (Source: Author)

Figure 6.7 - Washinton, DC Site Overlay (Source: Author)

Figure 6.8 - Sketch block exploration (Author: Source)

Result

After many iterations and explorations on the density and block size. The result:

Figure 6.9 - Urban Map (Source: Author)

Diagrams

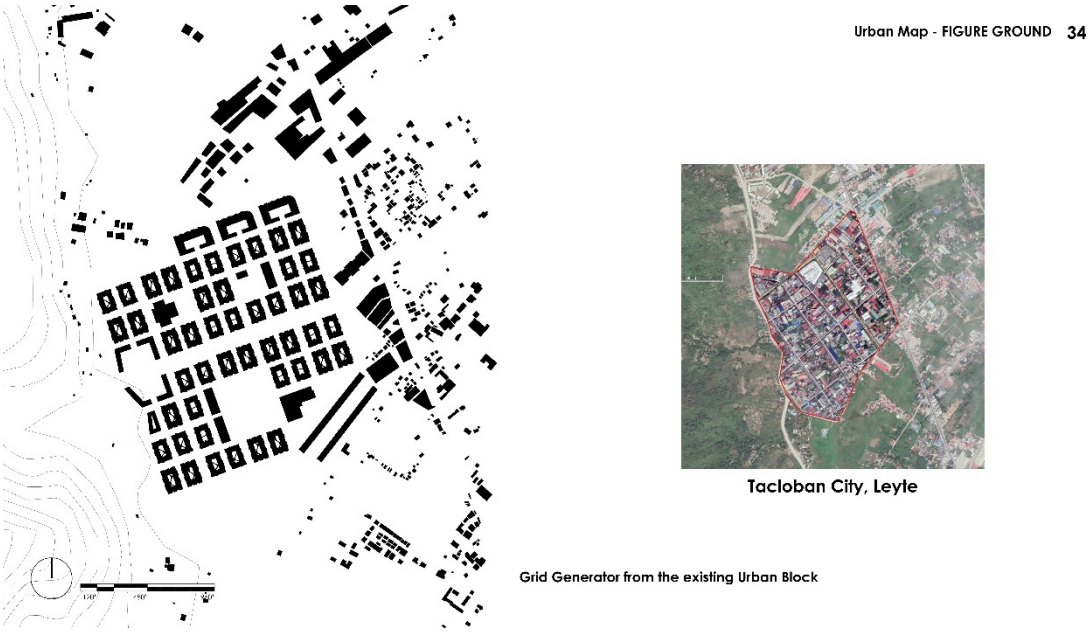


Figure 6.9.1 - Figure Ground Grid Generator (Source: Author)

Figure 6.9.2 - Land Use (Source: Author)

By creating an anchor retail to the site, it will activate the area and attract nearby local neighborhood and tourist that are coming from the highway. Establishing a community areas around the residential goal is to create a place and establish self-dependent community.

Figure 6.9.3 - Placemaking Diagram (Source: Author)

The placemaking will allow the community to capitalize local and potential assets to create public spaces that promotes the people's health and well-being. The placemaking makes sure that the underutilized space are to enhance the urban experience at the neighborhood scale of the community.

Figure 6.9.4 - Street Hierarchy (Source: Author)

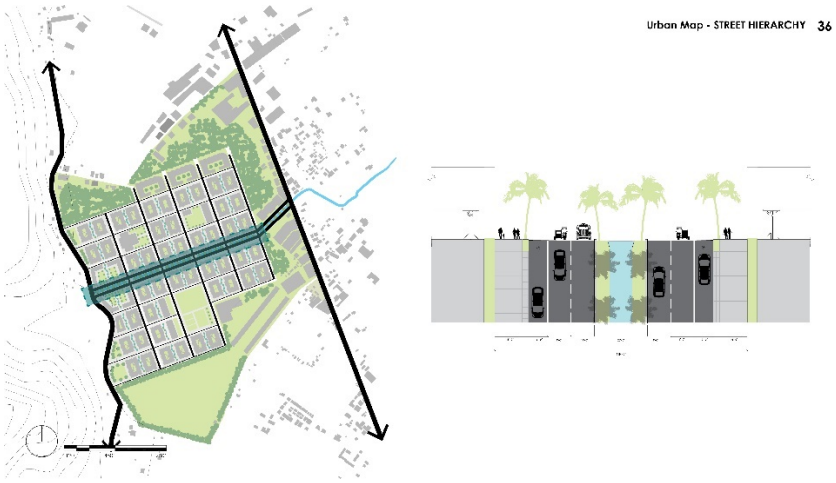


Figure 6.9.5 - Main Street Section (Source: Author)

Figure 6.9.6 - Secondary Street Section (Source: Author)

Figure 6.9.7 - Tertiary Street Section (Source: Author)

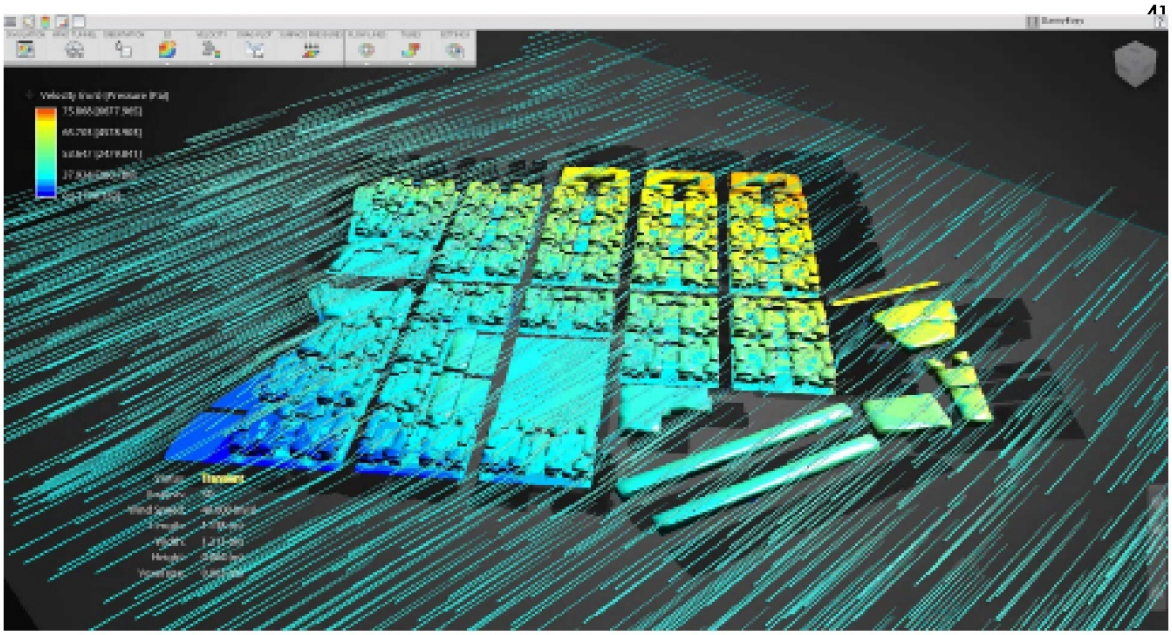
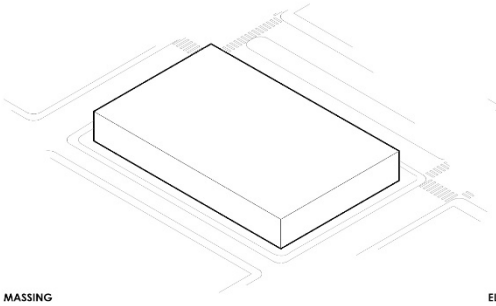


Figure 6.9.8 - Wind Shedding (Source: Author)

With the use of flow design program, it is indicated that the urban form and orientation has successfully diverted and reducing the wind velocity of the incoming prevailing wind and potentially the hurricane high speed winds.

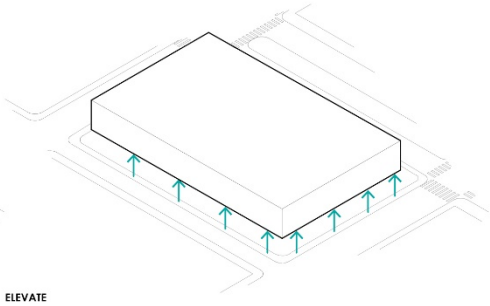
Chapter 7: Behavioral Level (Building Design)

Transformation Diagram



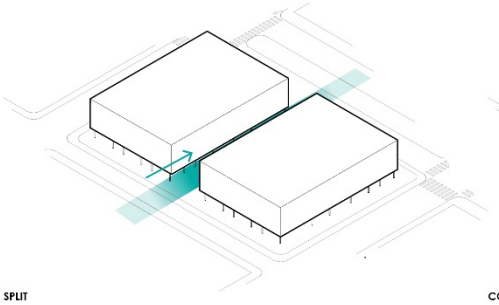
MASSING

Maximize Square Footage



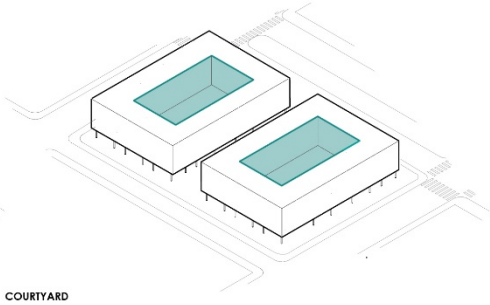
ELEVATE

Flood proof and Activate public realm



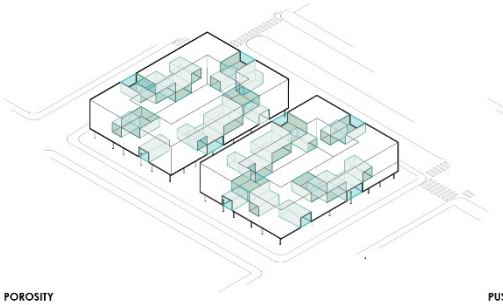
SPLIT

Bioswale



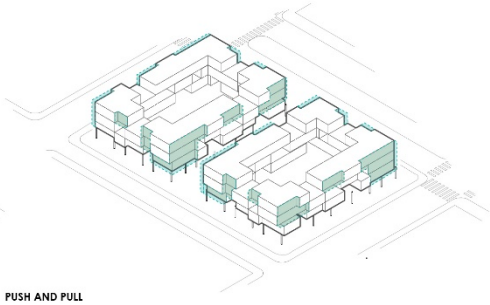
COURTYARD

Vernacular



POROSITY

Mangrove canopy



PUSH AND PULL

Mangrove canopy and Breaking Wind Velocity

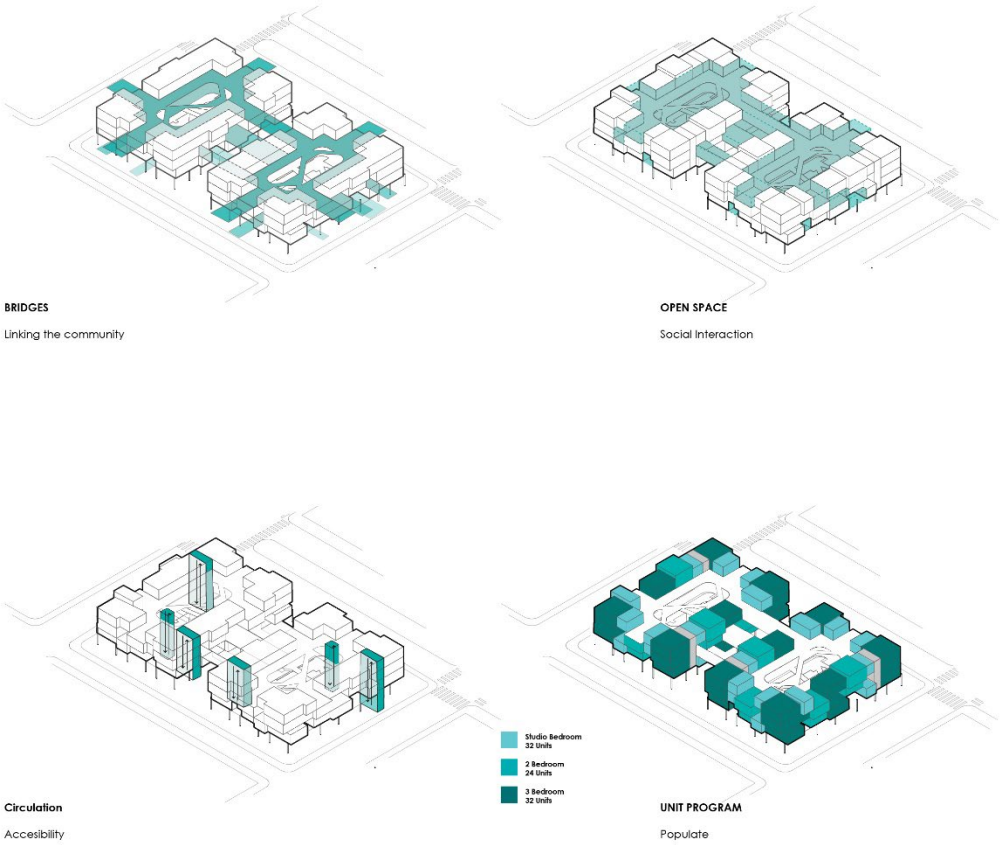


Figure 7.0 - Transformation and Program Diagram (Source: Author)

The building design is based on the form of the Mangrove trees. With the base of the building elevated, it allows the storm surges to come through and prevent from the forces of the wave and the wind to destroy the structural integrity of the foundation columns. The form of the building mimics the canopy of the mangrove; the function of the porosity and the push and pull allows the wind to hit the massing and weakening the wind velocity that works together in a system with the overall urban site. By splitting the massing into two blocks allows the gutter to redirect the rain to the bioswale to come through and connect the constructed wetland. While during a storm surge or flooding, connecting the two blocks by bridging allows to strengthening the community and social aspect of the block allowing the

people to walk freely as they want too without going down to the ground level and go back up. The open spaces in the site allows for social gathering or storage giving a flexibility activity within the building. The program will provide a mixture of housing units (studio, 2 bedroom and 3 bedroom) to accommodate the different type of tenants ranging from self-independent young professionals to a nuclear family.

Floorplans

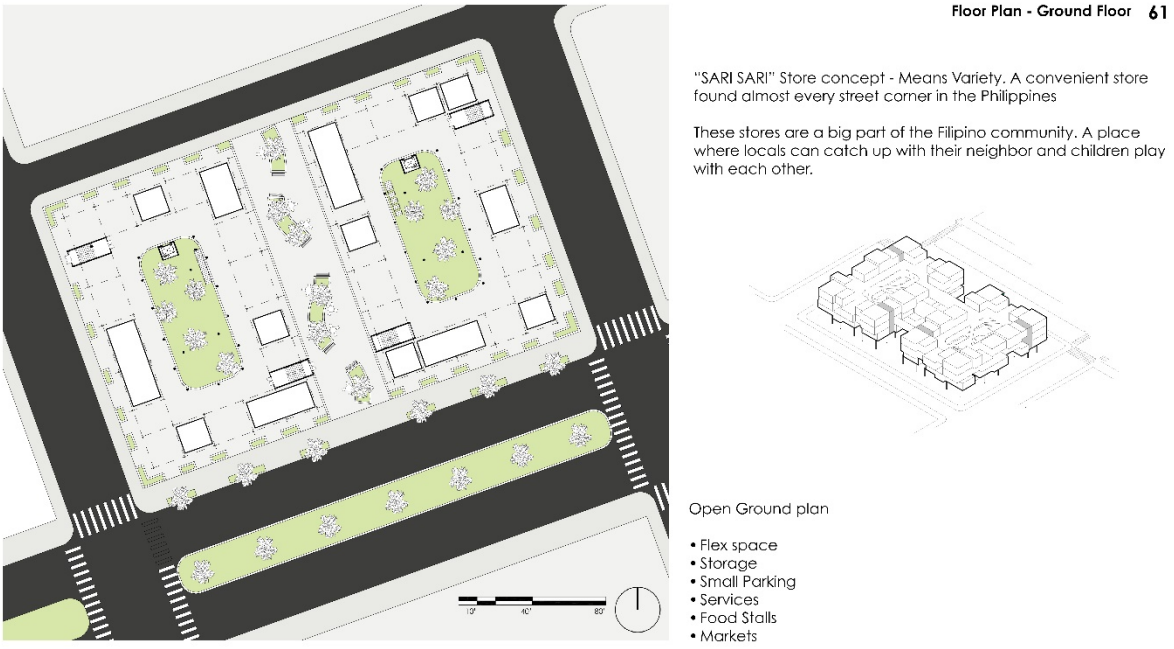


Figure 7.1 - Open Ground Plan (Source: Author)

The ground floor of the building is an open floor plan that allows the flexibility and an option for the locals to use for their own space. The flexibility will range from turning it into a storage, a small parking for moto cycles/tricycles, establishing food stalls or markets and other services. Depending on where the block is, the closer to the main street the more food stalls and service will most likely be located there. While further back storages and parking are utilized. With the "Sari Sari" store concept, the open ground plan won't be difficult to be

occupy by the locals. The central courtyard will be their space to socialize and a place where children can play that includes playgrounds and vegetations.

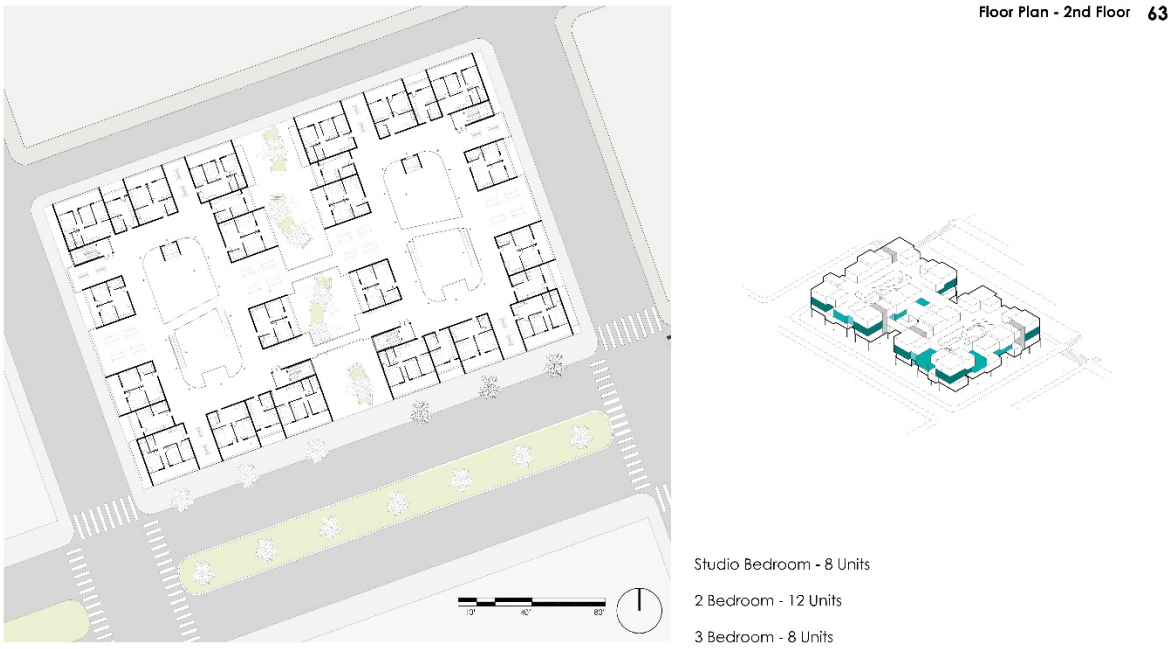


Figure 7.2 - 1st Floor Plan (Source: Author)

Figure 7.3 - 2nd Floor Plan (Source: Author)

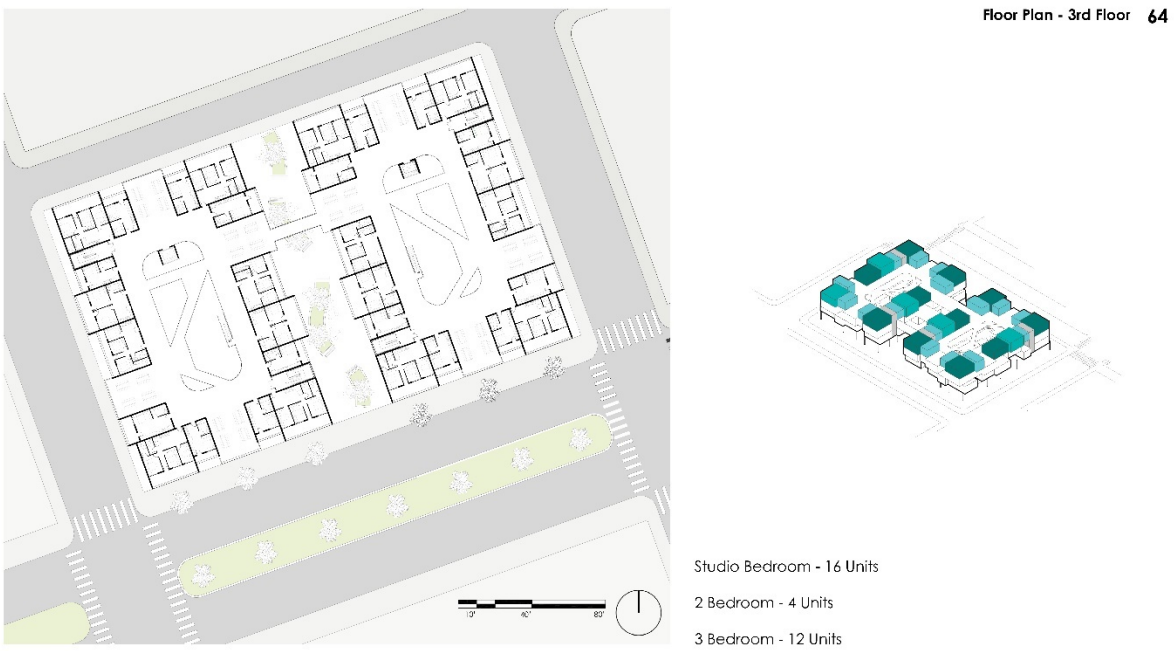


Figure 7.4 - 3rd Floor Plan (Source: Author)

Each floorplan is unique and offers open spaces to be use as a flex space for social gathering, storages or even a place for people to leisure. The internal bridging provides ease of access for people to experience and for viewing.

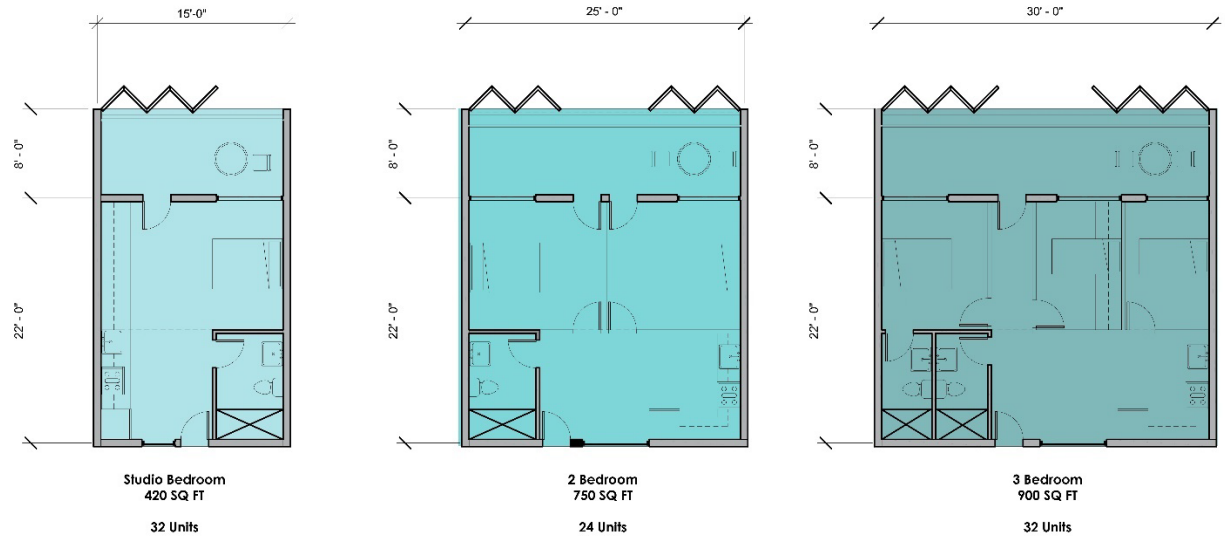


Figure 7.5 - Typical Unit Plans

Sections and Elevations

Using the same local material allows the development to be cheap and blend with the environment. The material will allow simple techniques when it comes to the construction but still have complex form to produce typhoon proof characteristics. The building voids allows air to come thru and provide natural cross ventilation within the courtyard.

Figure 7.6 - Building Elevation (Source: Author)

Figure 7.7 - Building Section (Source: Author)

Natural Environmental Systems

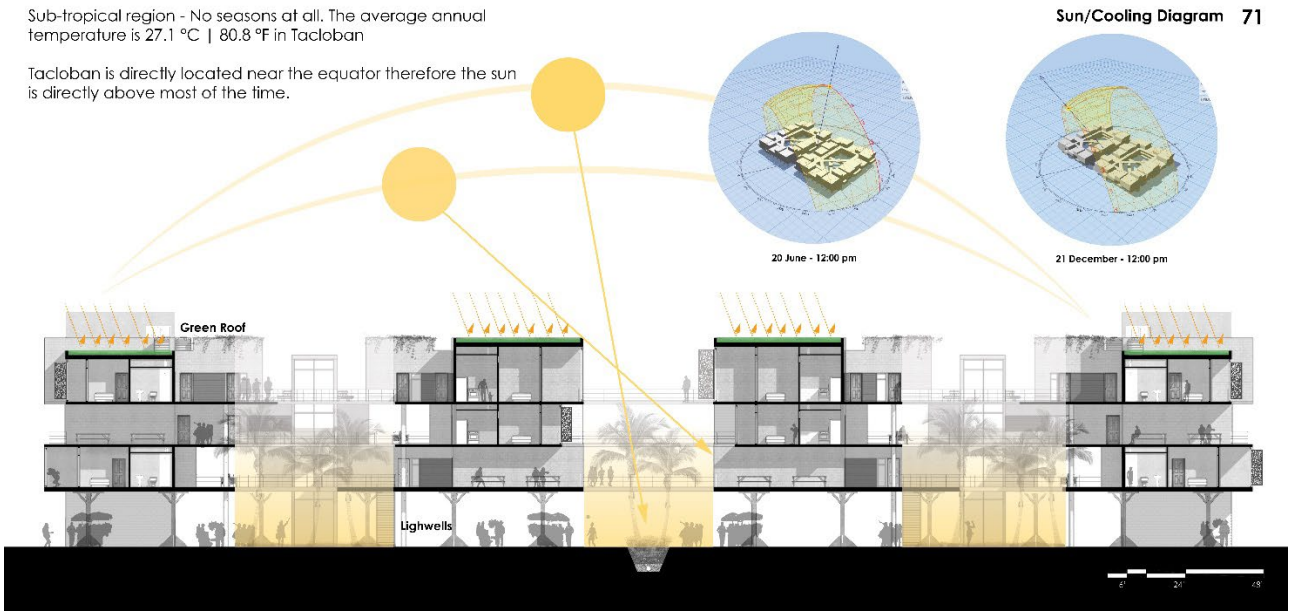


Figure 7.8 - Sun and Cooling Diagram (Source: Author)

Since HVAC system is not prominent in Tacloban City, the use of cross ventilation and green roofs are integrated in order to adapt in the sub-tropical environment in Tacloban City all year long. Tacloban is located near the equator means that there is no pattern in seasons. With the average of 80 degrees Fahrenheit, integrating green roof is important to deflect and absorb the harsh sun light allowing the building to cool down naturally. The green roof can be also accessed by the people to have their own options to grow their vegetables and gardens. The courtyard will be utilized complete due to the suns position.

Figure 7.9 - Rainwater Collection (Source: Author)

Tacloban city has significant rainfall even in the driest month every year with over 89.9 inch per year. The green roof collects any excess water and to be use for grey water system for during emergency or normal use. If there still too much rain water, the gutter can redirect the storm water to the bioswale then to be taken to the constructed wetland.

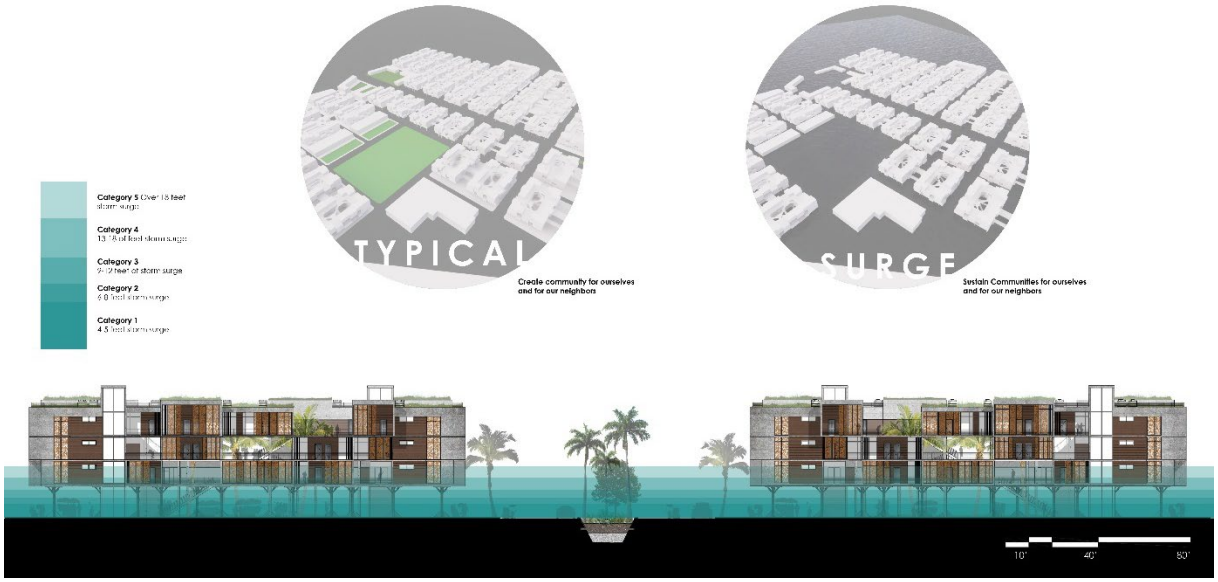


Figure 7.9.1 - Storm Surge Level (Source: Author)

Chapter 8: Organism Level (Tectonics)

Cross Ventilation

Since HVAC is not common in Tacloban City, the use of transom is integrated in the units to allow natural air to enter. The transom are located at the top of the partition walls and exterior walls. The large opening windows came from the inspiration of the use of large windows from the vernacular architecture were they use it for cross ventilation. The wind flow program gives a better visualization on how the transom window works with cross ventilation.

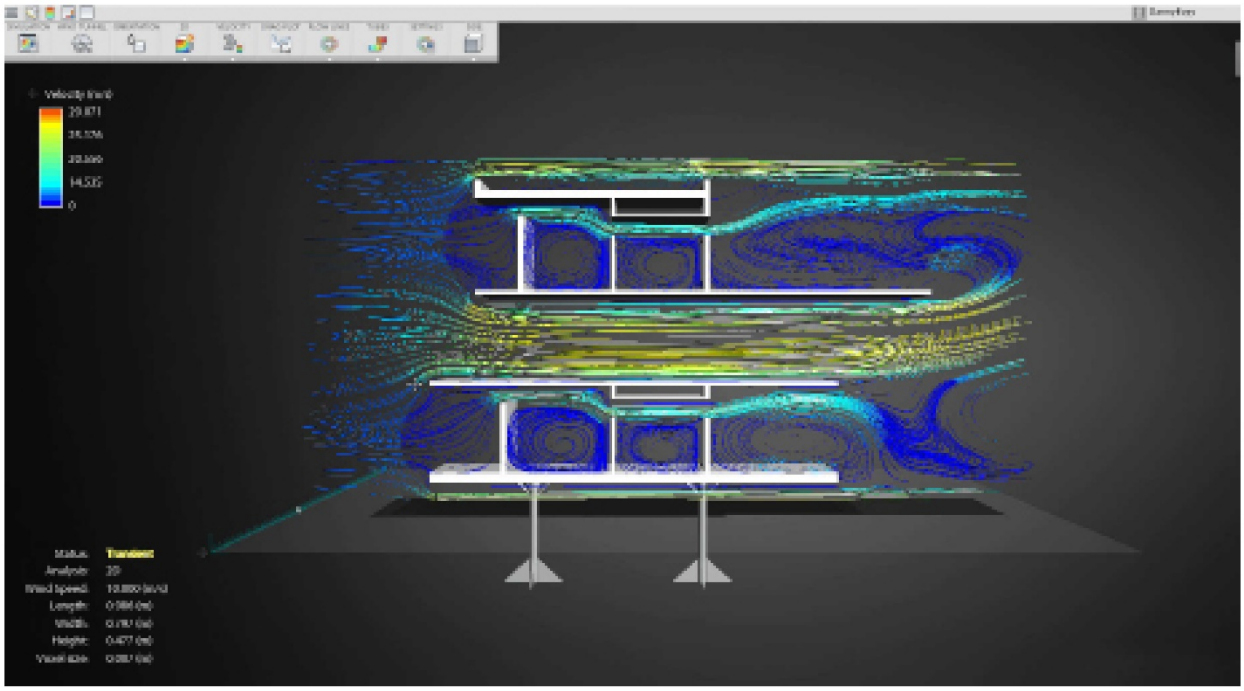
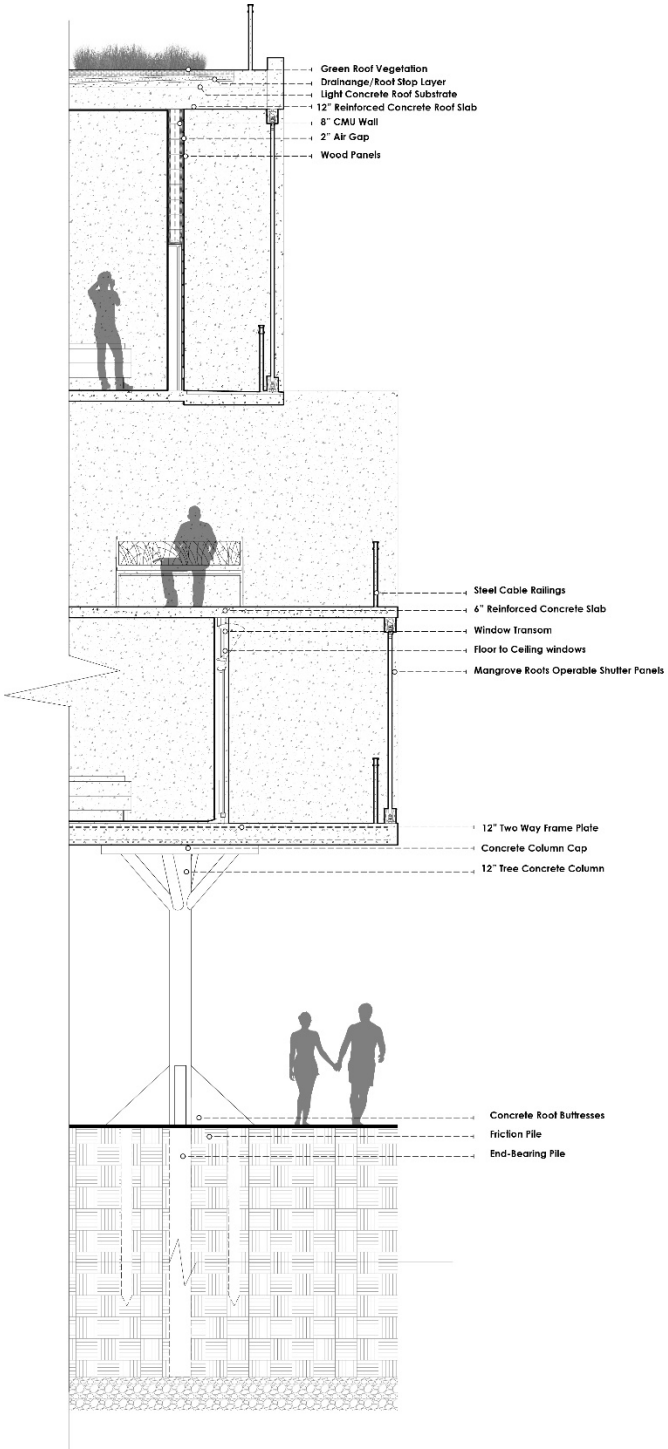


Figure 8.0 - Cross Ventilation (Source: Author)

Wall Section



The materials and the structural component of the building will mostly consist of concrete materials due to its cheap material and labor cost. Concrete is considered a low tech than wood in the Philippines because it is more common to find aggregate mixture than acquiring wood and due to its durability to the frequent typhoons. The 8 inch concrete walls are the main load transfer for the building that connects in each level and then the load will be transferred to a 12 inch two way frame plate system where it will direct its load to the columns. All concrete structure that deals with load transfer will be reinforced concrete while the partitions are mostly made of CMU blocks.

Figure 8.1 - Wall Section Detail (Source: Author)

Tectonic Biomimics

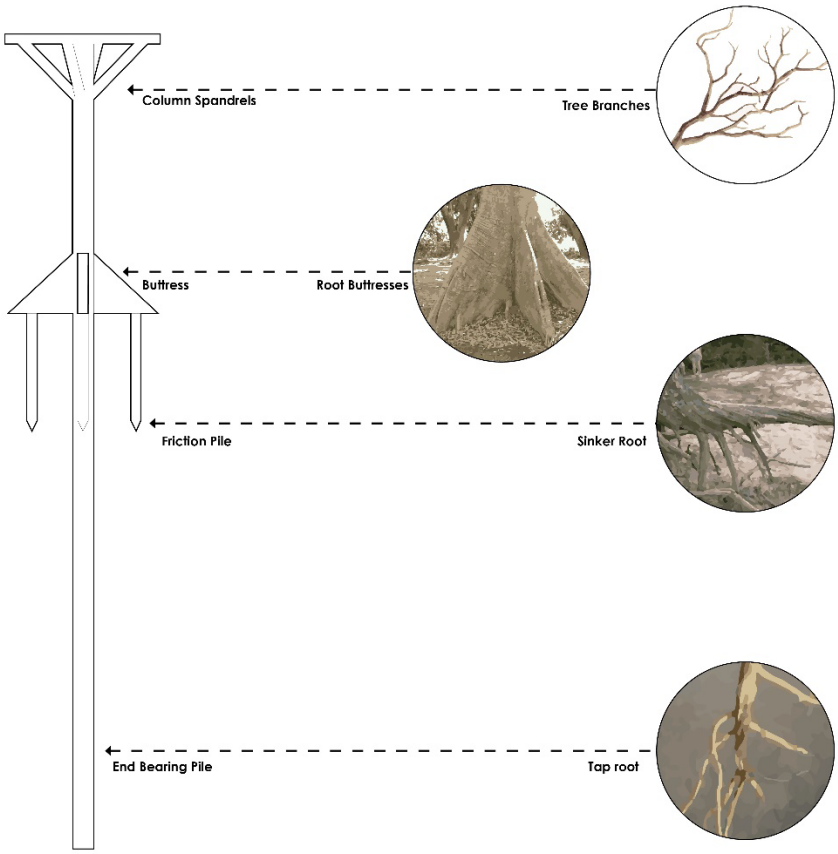


Figure 8.2 - Foundation Tree Column (Source: Author)

The foundation columns is a combination of many parts of the plant species. Each of which has different functions and roles. The column tree spandrels function is to redirect the load from the frame plate on to the column faster than a regular column due to the additional branches that is absorbing the load rather than a direct point. The root buttresses role is to resist the lateral load allowing the columns to stay in place and fixed securely during the

storm surges and high speed winds. Attaching to the root buttress is the sinker root or friction pile; it prevents from the column to be lifted or uprooted. The friction pile and the end bearing pile's function is to hold the building in place due to the conditions of the soil in the site. The silt loam clay in the site is not suitable for a normal foundations therefore by integrating the friction pile that functions like sinker root, it will hold it securely through friction, the end bearing pile is the main foundation for the column foundation that stretches until it hits the bedrock.

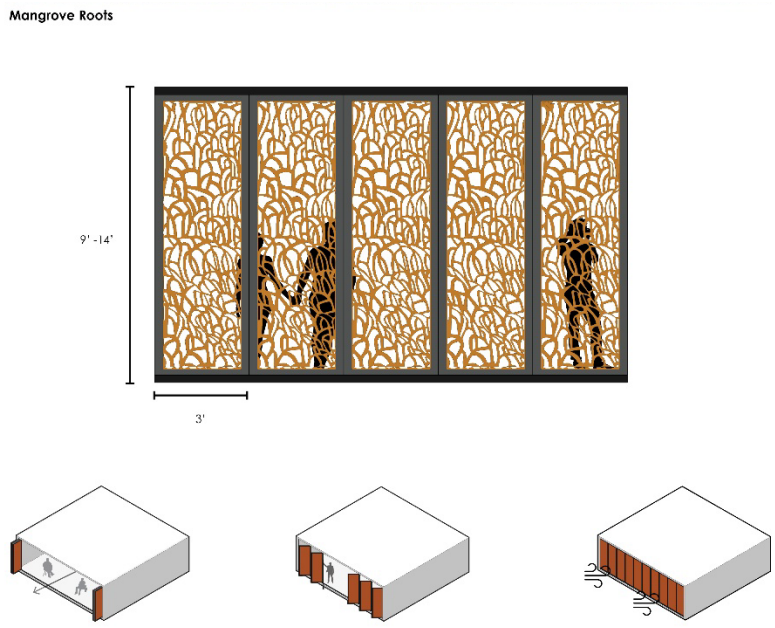


Figure 8.3 - Mangrove Roots Shutter Panel (Source: Author)

The last building detail is the Mangrove roots operable shutters; inspired by the roots complex system; the function of the shutters is to protect and reduced the typhoon destruction. The complex root facade allows to trap any debris or large objects from entering through the units during the storm. During a normal day it also functions as a sun shading device and privacy. The shutters offers a protection while still gives a aesthetic appealing look

Chapter 9: Experience

Figure 9.0 - Interior Courtyard (Source: Author)

Figure 9.1 - Ground Floor Perspective (Source: Author)

Figure 9.2 - Bioswale (Source: Author)

Figure 9.3 - Center Bridge (Source: Author)

Figure 9.4 - Flood Perspective (Source: Author)

Figure 9.5 - Close Flood View (Source: Author)

Figure 9.6 - Before Typhoon (Source: Author)

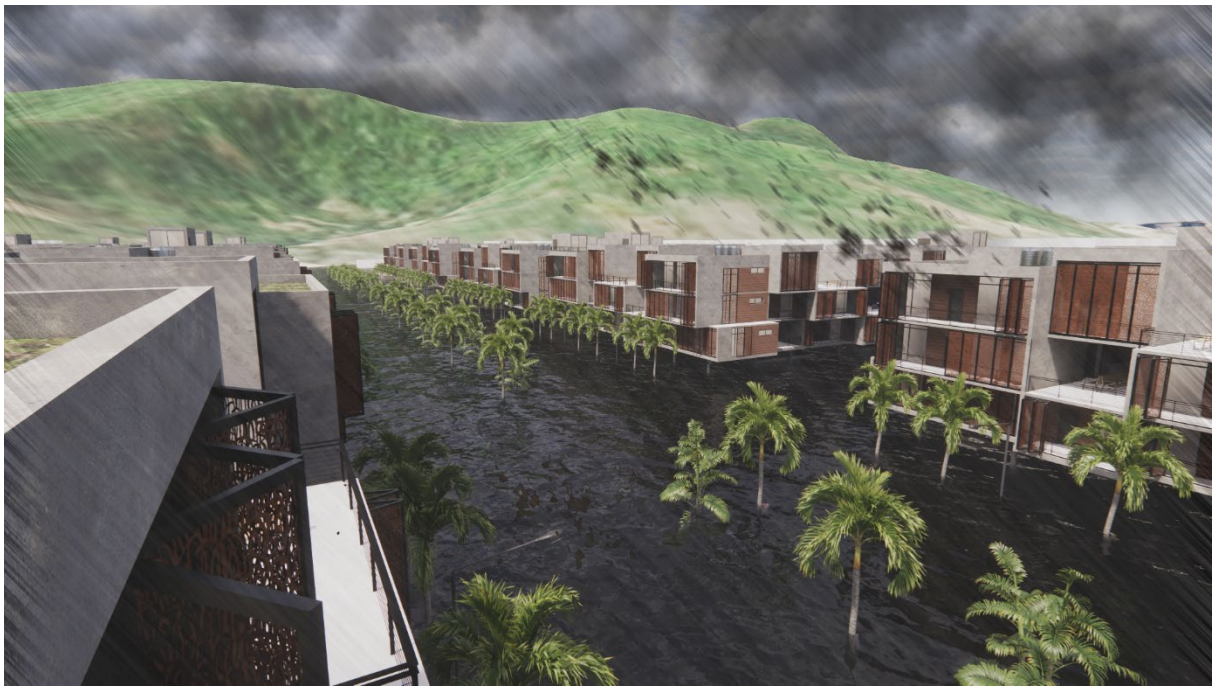


Figure 9.7 - After (During) Typhoon (Source: Author)

Conclusions

Ultimately, this thesis present itself as an exploration that seeks to adapt in a natural disaster all year long, while creating an environment that promotes community and social interaction within the Waray people. Through research and design process the design problem becomes clear and easy to solve through the applications of architectural design principles. This thesis investigated a new integrated urban and building design typology for climate adaptation that uses Biomimicry as a design technique, this exploration hopes to use as a standard design criteria in the Philippines where typhoon is very prominent.

Figure 9.8 - Perspective View of the Building. (Source: Author)

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