ABSTRACT

Title of Document:	HDB (Housing Development and Board): RE-IMAGINED FOR SITE, WIND, AND WATER
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The thesis aims to challenge the current norm and policy of Singapore's subsidized housing, HDB, to create a type of housing that is more adaptable and responsible to current and future challenges. Through the exploration in progressive construction techniques and technology, HDB housing could function and perform sustainably for the community of HDB dwellers as well as for the environment. The affect of an increase in population count in Singapore results in a higher demand for HDB (government-subsidized housing). Along with housing shortage, Singapore is facing a water crisis. Efforts has been made to conserve, capture, and treat water for the population but Singapore still needs to import about 30% of their water from Malaysia. The research and exploration in this thesis aims to resolve some of the issue involving the limited land surface for storing and harvesting rainwater from the abundant rainfall, in order to meet the water requirement of the population in the near future.

HDB (HOUSING DEVELOPMENT AND BOARD): RE-IMAGINED FOR SITE, WIND, AND WATER

By

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Chapter 1: Introduction

Overview

The population increase in Singapore over the years has affected the housing development throughout the island. The rise in demand results in an increase of subsidized housing, HDB, in an effort to provide Singaporeans with affordable housing. Currently, 82% of Singaporeans reside in an HDB flat, and the number is only going to increase with time as the population of Singapore is predicted to rapidly increase to 6.9 million inhabitants by 2030 (current population is 5.26 million). Along with the issue of housing, Singapore is facing water challenges in the near future, as importing water from Malaysia will no longer be an option to meet the water requirements for the population. The thesis focuses in the exploration in progressive construction techniques and technology to create a new type of HDB (public housing in Singapore) that responds to the growing population of Singapore and the resulting challenges. The thesis aims to challenge current HDB norm and critique the policies to achieve a type of housing that is more adaptable and responsible to the environment.

Historical Background

Singapore's history dates back to the earliest settlement in the 2nd century, and since then Indians, Portuguese, British, and Japanese have invaded the island. It was a major trading post and before the British arrived, the populations were made up of 1,000 people of mostly indigenous Malays and a few Chinese. Since becoming the

capital of The British Straits Settlements, the Chinese from Mainland China started migrating into the island, mostly as coolie laborers. Today, more than 70% of the Singapore population is of Chinese ethnicity.

Singapore became independent on 9 August 1965, where they were able to promote an equal society with no favoritism for a specific ethnic group. All inhabitants who were living in Singapore at that time of independence were given Singapore citizenship. Since their independence, Singapore has continued to promote racial diversity and equality, and recognize Chinese, Malay, and Tamil as the national languages of Singapore.

Demographics

The current population of Singapore is about 5.5 million people and 62% of those are Singapore citizens while the rest are permanent residents or foreign worker/ students. The average household size is about 3.5 persons and the median age is 37 years old. 80% of Singaporeans live in subsidized government housing known as Housing and Development board (HDB). It is quite common to have a live-in domestic helper in Singapore and there are currently about 200,000 in Singapore. The estimated total fertility rate in 2013 is 0.79 children per woman, which is the lowest level in world and is below the 2.1 needed to replace the population. To solve the problem of the decline in the population, Singapore has been encouraging foreigners to immigrate and by 2009, 40% of Singapore's inhabitants were foreigners. Although the government have considered capping these workers, they are vital to the economical growth of the country, where foreign workers make up 80% of the construction industry and 50% of the service industry. The country also has one of the

lowest unemployment rates among developed countries at 2.1% as of January 2014. Currently the majority of inhabitants in Singapore are Chinese (74.2%), followed by Malay (13.4%) and Indian (9.2%). There is a small number of Eurasians and other groups that make up the 3.2% of the population.

It is important to understand the multicultural background that make up the population of Singapore today because the government put great emphasis in the fact that Singapore is not dominated by one race alone, although three quarters of the population is made up by the Chinese, but rather a country that is racially integrated. The ethnic integration in HDB is emphasized in the policy where a maximum percentage of non – Malaysian permanent residents are set in order to avoid an enclave of a certain type of race.

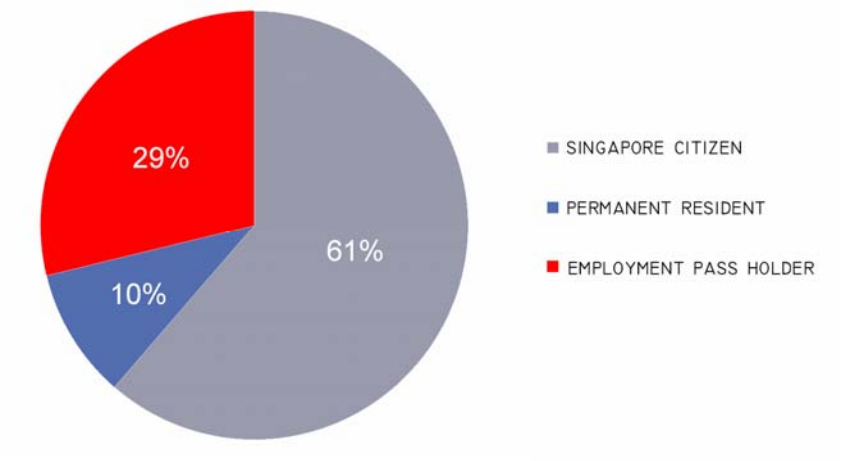

Figure1. Population breakdown

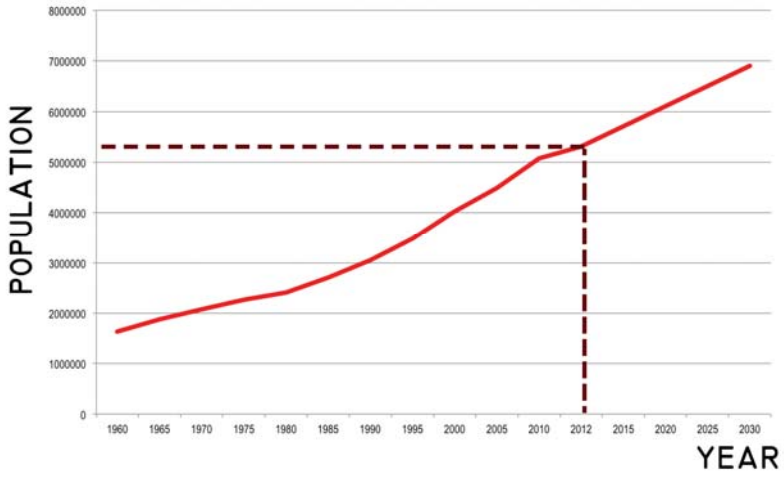

Figure2. Population increase over time

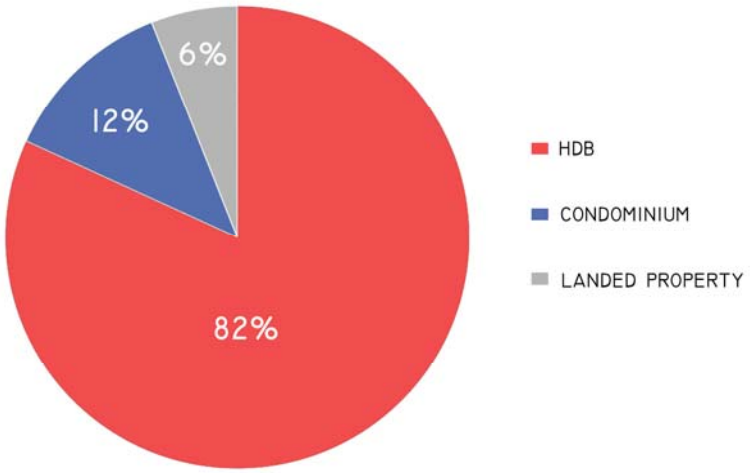

Figure3. Housing type breakdown

Geographical Setting

The island of Singapore lies off the southern tip of the Malay Peninsula and is connected to Malaysia via two bridges, Johor – Singapore Causeway in the north and Tuas Second Link in the west. There are a total of 63 islands in Singapore covering 276 square mile of area. Singapore's land has increased over time due to the on-going land reclamation projects. The island grew from 224 square miles in the 1960s to 276 square miles today, with projected growth of another 40 square miles by 2030. The highest point on the island is located in Bukit Timah at 545 feet. In an effort to improve the quality of life in the city, then Prime Minister Lee Kuan Yew launched Singapore's first tree planting campaign in 1963. Currently 10% of the island is reserved for natural reserves and parks. As a result of this effort, Singapore evolved into Garden City and regulations are made to maintain this vision.

Singapore skyline today is filled will green roofs, vertical greenery and high-rise greenery as a way to keep the Garden City vision for an island with limited area for horizontal expansion. Currently, more than 60 ha of green roofs have been added to more than 500 buildings in Singapore as part of the greening effort.

Nature ways are implemented to provide routes that are planted with specific trees and shrubs to assist with the movement of animals between two parks. The National Park Boards continue to collaborate with communities in providing more nature ways as well as engaging greening efforts in places such as schools, hospitals, and housing estates. They have recently built a wildlife corridor that connects the forested area that was divided by a highway. This allows for wildlife to freely and easily migrate from one part to the other, increasing biodiversity. The country aims to

implement more wildlife corridor in order to achieve a high level biodiversity in Singapore, as a way to support their claim of being a city in garden. Another greening effort that they have implemented into the system is the repurposing of an old rail line into a green corridor that connects the country in the North – South direction. The rail line already provides an open passageway for a trail and a habitat corridor to exist, and so the effort here is in the preservation and protection of the green corridor.

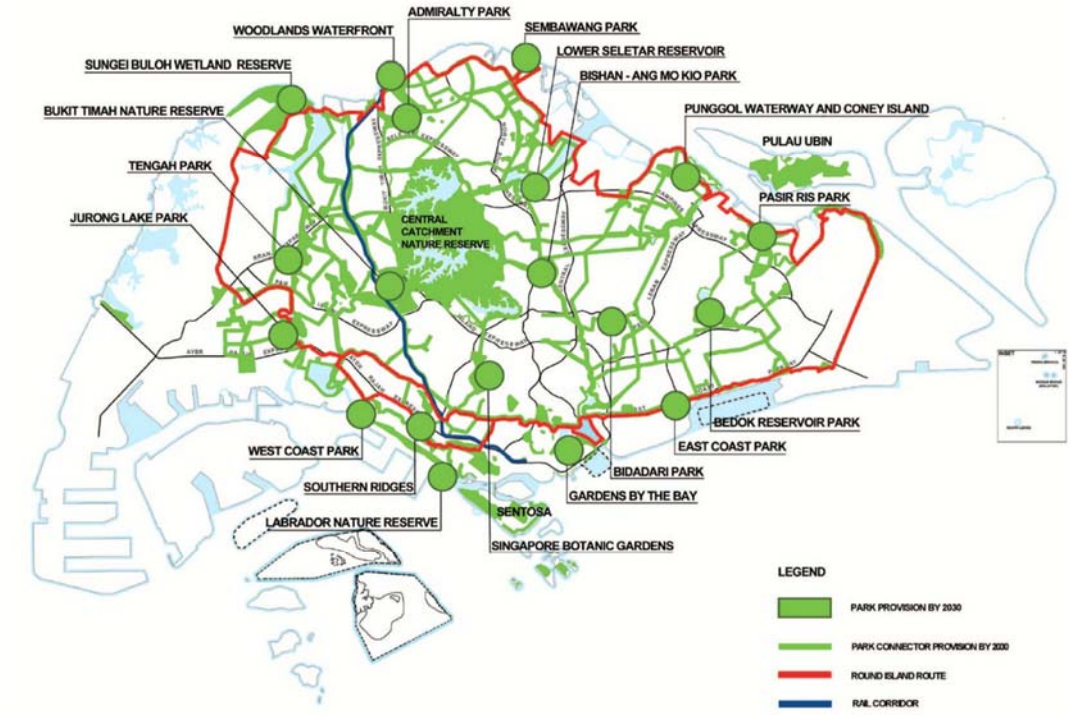

Figure4. Future plan for Park Connectors

Climate Condition

The climate condition in Singapore is categorized as a tropical rainforest climate (equatorial climate), which is characterized by high humidity, frequent heavy rainfall, and uniform temperature and pressure. Typical daily temperature ranges from

22 to 35 degree Celsius (72 – 95 degree Fahrenheit) and the hottest months are April and May, followed by the monsoon season from November to January.

Monsoon Seasons

Monsoon is similar to sea breezes but in a larger scale and seasonal. It is a seasonal prevailing wind where it blows from the land towards the sea in the winter months and blows from the sea towards the land in the summer months. Singapore's weather is divided into four main seasons; Northeast Monsoon, Southwest Monsoon, and two inter-monsoon seasons. The characteristics are as follows:

Northeast Monsoon (December – early March)

During this season, Singapore experiences heavy winds. The sky remains cloudy most of the duration of the season and heavy rainfall is experienced during the day. At times rain showers may prevail for three days. In the months of February and March, rainfall lessens but the wind speed increases.

First Inter – Monsoon (late March – May)

Severe thunderstorms are often experienced in the afternoon and early evening. Temperatures in the afternoon are at times higher than usual.

Southwest Monsoon (June – September)

The weather condition in Singapore during this period tends to be misty, especially in the morning hours. Heavy winds are experienced early in the morning and rainfall occurs in the morning or afternoon.

Second Inter – Monsoon (October – November)

Severe thunderstorms occur during the afternoon and early evening. This period is generally wetter than the previous inter – monsoon.

Other Weather Conditions

Sumatra Squall

It is an isolated thunderstorm unit that forms overnight over Sumatra Island in Indonesia or over the Straits of Malacca and moves eastward affecting Singapore. The showers can last up to 2 hours and usually occurs in the predawn hours. Strong wind gusts up to 80 km/hr (50 mph) often accompany a Sumatra Squall. It can develop any time during the year but unlikely during the Northeast Monsoon season.

Waterspouts

A waterspout is a weather phenomenon that occurs during an intense thunderstorm. It can last anywhere between a few minutes to thirty minutes. Waterspout forms over the sea and usually dissipates as it reaches the coast and intense thunderstorms, strong winds, and flash floods can be expected. Although waterspouts can occur anytime during the year but they usually form between the months of March and October where the intense thunderstorm formation is very likely to occur. An average of three waterspout occurrences over the Singapore waters is recorded yearly.

Humidity

The relative humidity in Singapore ranges between 90% in the mornings to 60% in mid – afternoons. During the rainy season, the humidity level can reach up to 100%.

SEASON	NE MONSOON						INTERMONSOON						SW MONSOON						INTERMONSOON		NE MONSOON			
	JAN		FEB		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPT		OCT		NOV		DEC	
TEMPERATURE	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
DAILY MEAN	26.5	79.7	27.1	80.78	27.5	81.5	27.9	82.22	28.3	82.94	28.3	82.94	27.9	82.22	27.8	82.04	27.6	81.68	27.6	81.68	27	80.6	26.4	79.52
RAINFALL																								
MEAN TOTAL RAINY DAYS	13.8		8.1		12.7		14		13.2		12.7		13.2		13.7		13.3		14.7		18		18.5	
TIME OF DAY OF HIGHEST OCCURANCE	15:00		17:00		15:00		17:00		13:00		14:00		13:00		13:00		14:00		14:00		15:00		17:00	
	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH
MONTHLY MEAN	255.8	10.071	107.4	4.2283	171	6.7323	151.2	5.9527	163.9	6.4527	132.3	5.2087	150	5.9055	151.9	5.9803	157.3	6.1929	158.8	6.252	262.4	10.331	329.5	12.9724
SURFACE WIND																								
DIRECTION	N/NE		N/NE		N/NE		VARIABLE		S/SW		S/SW		S/SW		S/SW		S/SW		VARIABLE		VARIABLE		N/NE	
	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH	M/S	MPH
MEAN SPEED	2.6	5.816	2.8	6.2634	2.1	4.6976	1.4	3.1317	1.5	3.3554	1.9	4.2502	2.3	5.145	2.4	5.3686	1.9	4.2502	1.4	3.1317	1.3	2.908	1.9	4.25018
MAX GUST SPEED	20.3	45.41	17.8	39.817	21.9	48.989	23.9	53.463	18.1	40.489	21.4	47.87	23.9	53.463	21.9	48.989	21.4	47.87	20.3	45.41	21.1	47.199	17.2	38.4753
THUNDERSTORMS AND LIGHTNING																								
MEAN THUNDER DAYS	4.8		5.3		12.1		19.4		19.2		15		13.6		13.5		14.6		18		18.7		12.3	
MEAN LIGHTNING DAYS	5.9		5		13.9		22.4		22.1		17.4		14.5		12.3		13.5		19.6		23.5		15.7	
RELATIVE HUMIDITY (%)																								
24-HR MEAN	84.7		82.9		83.8		84.7		84.3		82.8		82.7		82.9		83.4		84		86.3		86.9	

Figure 5. Climate chart

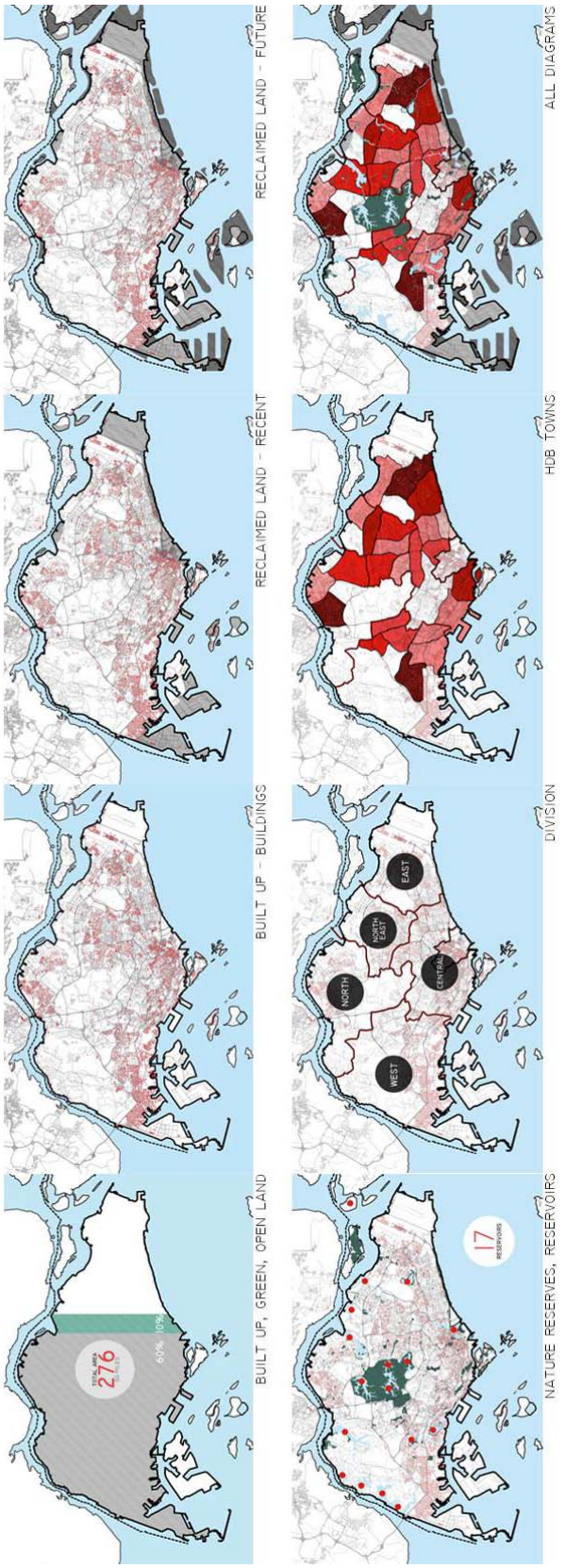

Figure 6. Singapore - diagrams

Chapter 2: HDB (Housing Development and Board)

Overview

HDB was created in response to the shortage of housing in the 1950s and since then, they have built more than one million units for the citizens and permanent residents. They vary in unit sizes depending on the needs of applicants and they are spread throughout the island, providing location choices for applicants. In the beginning of HDB project, some of the units were built close to downtown in order to provide amenities for the inhabitants. But due to the economic boom and the rise in population over the years, the area became too crowded and too expensive for HDB projects.

As an effort to ease the congestion of the downtown region, Singapore has introduced satellite towns after the start of the Housing Board Development in 1960. The towns were built to be self-sustaining, with the idea that residents would work or shop closer to where they live. These towns are categorized as HDB towns, which means that the land parcels are dedicated for the development of the HDBs. There were a few smaller development called *estates* that were built in the central region but they were halted in favor of building public housing in HDB towns. Currently there are 23 HDB towns and 3 other estates in Singapore.

Each housing block is considered a vertical community with a common area built into the design to promote social interaction. The design of the blocks started as a slab building with a common corridor that run the length of the building, which was

inspired by the kampong settlements that promote a sense of community through constant interactions between inhabitants. The long stretched corridor, though ideal for interactions amongst neighbors, provided no privacy for the inhabitants. The HDB style later evolved into point blocks with fewer units on each floor, providing more privacy. The few that have unique designs are considered landmarks for the towns. The design of the HDB blocks is sensitive to the site and orientation of the buildings, where sun shading and cross ventilation are highly considered in order to provide a comfortable living environment. Slab style HDBs has single loaded corridors with window openings on either side of the unit, while the point block HDBs are designed efficiently to ensure maximum cross-ventilation. The newer HDB has green roofs and terraces incorporated into their design as part of the greening effort by the government, in keeping with their *vertical garden city* ideals. As HDB design is constantly evolving to a better version, it is important to question the ability for HDB to provide a better living standard for Singaporeans and to ensure a good and healthy environment in which the population can grow into.

Housing in Singapore has a set of rules and regulations that is used in the process of distribution. The allocation of housing is controlled fully by the government through an extensive application process and a lottery system. Categories such as financial ability, racial segregation, and family sizes play a big role in determining the types, location, and size of housing. For example, in the lottery system, a family of five will have more priority than a family of two, which could potentially mean that they will be able to receive a unit sooner. An effort is also being made to separate the different races applying for housing, so that in every

neighborhood there is not one race dominating, but rather a collection of the different races that forms a community that defines the population of Singapore. The percentage of how much subsidy provided by the government depends on the financial ability of applicants. There are multiple financial options provided by the HDB as well as a wide range of housing that differs in cost depending on the size, location, and amenities.

The process of analyzing the current state of HDB, in terms of its policies, process, and function specifically as a response to the growing population of the country, leads to the realization that factors relating to rules and regulations set by the government cannot be solved through this Architecture thesis project. Instead, this thesis will look at the potential outcome of population growth and its effects with the focus on producing HDB that is more sustainable, adaptable, and flexible.

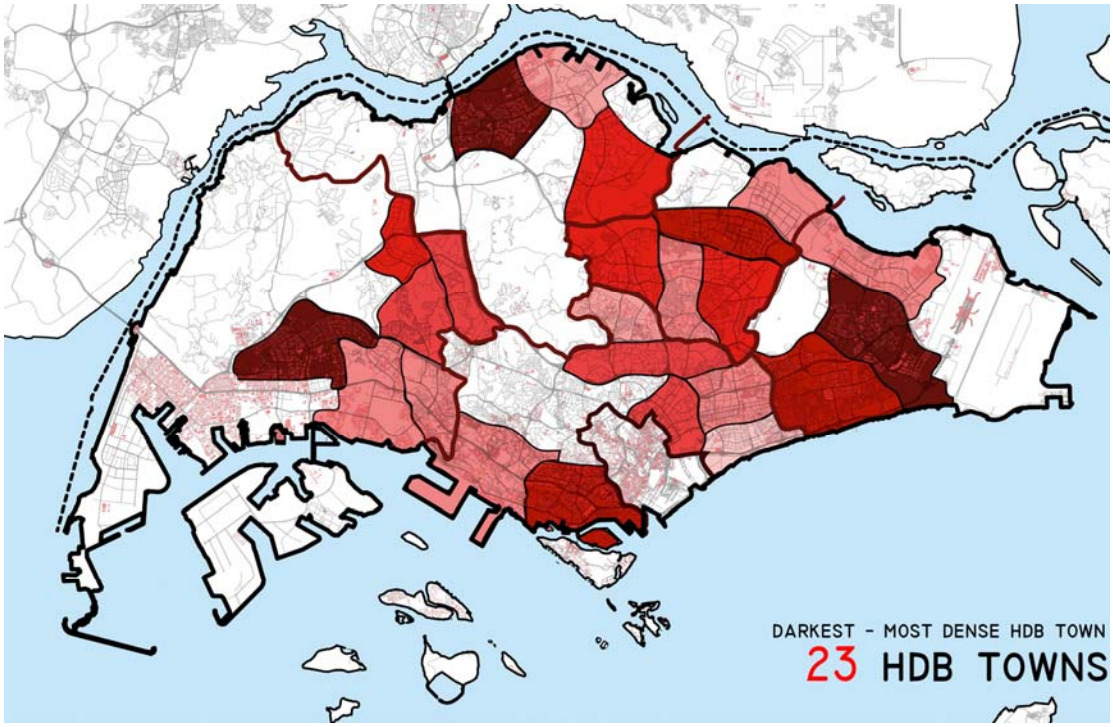

Figure 7. HDB Towns

Traditional Housing in Singapore

Before skyscrapers form Singapore's skyline, the island consisted of several types of traditional housing, all with its own cultural influences. The verandah house was the most common form of housing as it was associated with the fishing villages and is related to the Malay culture. The Malays were the first ethnic group to reside in in the island of Singapore, due to its proximity to Malaysia. The verandah house was also found in land villages. Similar to the Malay culture, the design of the verandah house promotes interaction between neighbors. The house is set back allowing for a covered porch to act as the semi private area between the village street and the privacy of the home. The verandah is the place where the sense of community is at its highest because it is the place where one can see the neighbors and interact with neighbors easily. It is also apparent that this type of housing is found in villages where houses act as a collective unit rather than individual instances.

The courtyard house is another type of housing that was found in Singapore. It was greatly influenced by the Chinese culture that migrated to Singapore in the early days. The idea of the courtyard is ideal for the tropical setting of Singapore where often times a pool is placed in the center to increase the cooling affect of the wind. The courtyard is also a place to gather for the family residing in the house. The courtyard house is often times a multi-generational housing type. Due to the limited landmass in Singapore, these types of housing are converted into shop houses. The style has evolved into a style that is unique to Singapore, called the *Peranakan* style. The *Peranakan* is the term used to describe the decedents of the Chinese immigrants who moved to Malaysia and Singapore between the 15^{th} to 17^{th} century.

The pavilion house is a type of housing that is associated with the wealthy, and it is an adaptation of the British Colonial style. The British Colonial style was widely used for the architecture of the powerful and the wealthy, and so the pavilion house is typically grand in scale with a lush garden attached to the house. Today, these houses are part of the preservation effort in Singapore to restore them to its former glory. Several of them have been converted into hotels and resorts and some remain as private residences.

HDB – Slab Block

Early HDBs were in a form of a slab block design, where units are arranged next to each other and are connected by a long corridor. The blocks were designed to be similar in height; usually 12 to 15 floors, and each block are paced equidistant from one another. Later on, they introduced different height blocks as to break the uniformity of the design. The units share a common corridor, which is considered public property and therefore may not be obstructed by objects or personal belongings. Residents at the end of each corridor may purchase the area and convert them into their patio. The units themselves have windows facing outwards but also on the elevation facing the corridor. Although it promotes cross ventilation into the units, it limits the privacy of the inhabitants. As mentioned previously, though Singaporeans enjoy interactions with neighbors, this type of unit arrangement doesn't allow for a semi-private zone, such as the verandah, to act as that place for contact. There is no buffer zone between the families living in the units with the interior street that is the corridor, where people walk by regularly.

HDB – Point Block

The point block design came as a response to the privacy issue that resulted from the older slab black design. In addition, it also provides more exposure to daylight and cross ventilation, as there is more flexibility in window placement. The point block design consists of four to six units on each floor, which is significantly less than the slab block design that allows up to 12 units per floor. For this reason, point block HDB are usually taller than the slab block in order to make up the number of units loss on each floor. Nowadays the designs for HDB are at times a combination of the two types as to maximize the benefits of both.

Void Deck

Void Deck is a term unique to Singapore public housing. It is the term used to describe the ground level of HDB blocks that are open and devoid of units. The space is open for the use of the HDB residents and it can be utilized for different types of activities. In the newer HDB blocks, some of the void spaces have been filled up for permanent use, including kindergartens, community police centers, clinics, and small convenient shops. Other types of activities that take place in a void deck include, weddings, funerals, a night market, and place to gather and play.

The void deck has always been underneath the HDB blocks but it might be beneficial for the HDB dwellers to have more than one space to gather. By having multiple “void decks”, which includes terrace level and roof tops, the HDB dwellers can have designated spaces for each activities that can happen simultaneously, resulting in a vertical community that integrates every aspect of vertical living.

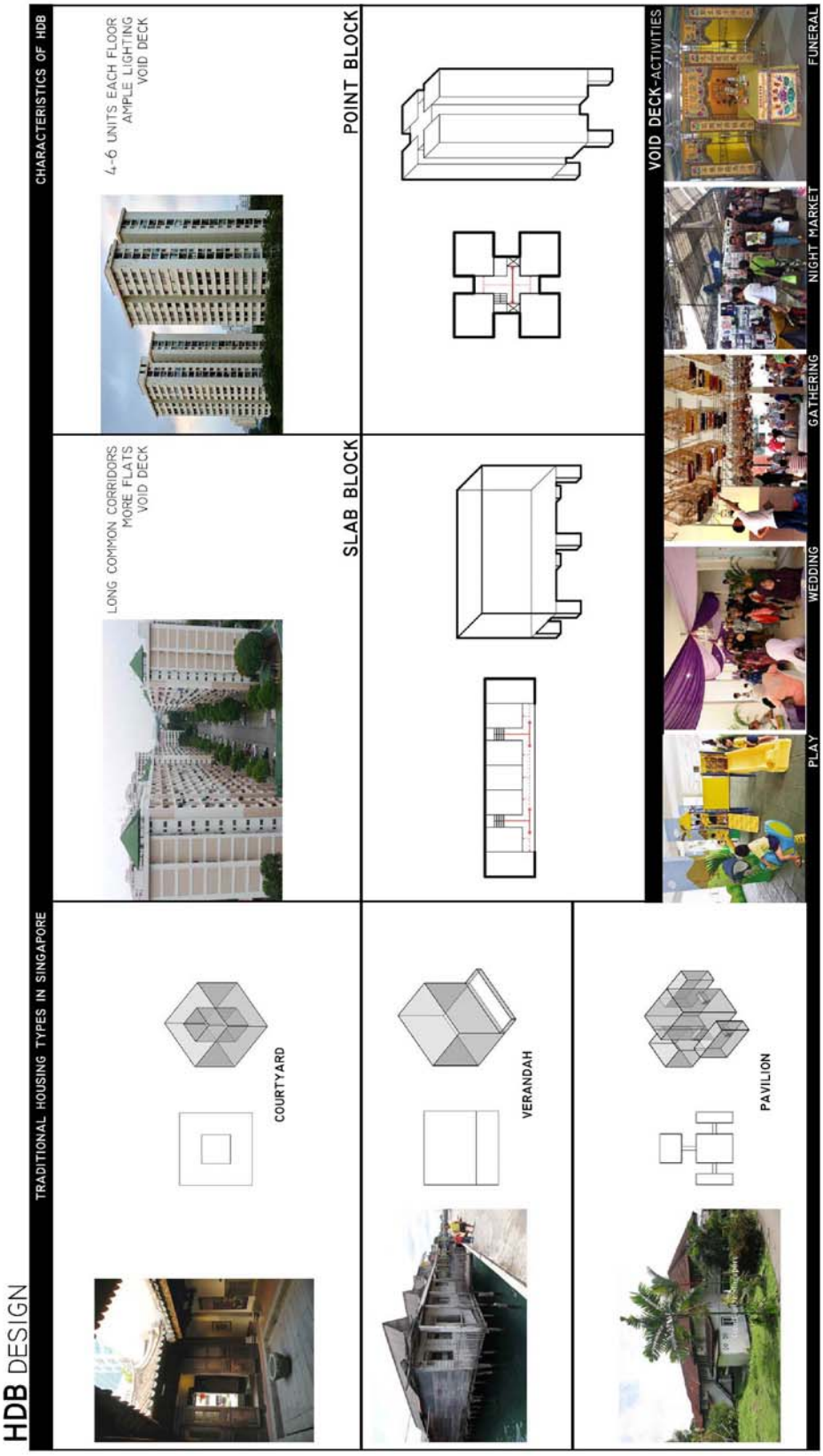

Figure 8. HDB Design overview

Chapter 3: Water Scarcity

Overview

Since Singapore's independence in 1960, the island-state has been focusing on the improvement of the housing solution to clear out squatter settlements throughout the island. The effort was successful and most people were relocated to high-density urban settlements. Alongside the issue of housing, Singapore has put a lot of effort in finding solution for the country's water shortage problem. Since the 1960s, Singapore has invested more than 2 billion dollars in the research for water solution. The Chief Executive of Singapore's National Water Agency, Chew Men Leong, explains: "Due to the country's small land mass and limited water storage facilities Singapore has historically been forced to rely on imported water from Malaysia, despite its relatively high and regular rainfall."

It is unfortunate that utilizing the abundant of rainfall in Singapore is limited to the surface area of the island. This is due to the fact that water solutions have been competing with economic development and housing since the country's independence. Currently Singapore has four solutions to its water issue, which is referred to as the Four National Tabs that includes local catchment, recycled water, desalination, and imported water.

Local Catchment

The largest water resource in Singapore is through the local catchments that consist of 17 reservoirs on the island connected through a system of drains, canals and rivers. Rainwater is collected and channeled to the reservoirs for storage and treatment. A separate system is used to collect used water. Today, the catchments covers two thirds of Singapore's land mass with the goal of reaching 90% of Singapore's and surface by 2060. Singapore is one of the few countries in the world that harvests the urban storm water at a large scale for the use of the country's water supply.

Recycled Water

The recycled water treatment in Singapore is referred to as NEWater and the process involves treating used water that is further purified to produce clean drinking water. The process of purification includes the use of advanced membrane technology and ultraviolet disinfection, which results in quality drinking water that surpasses the standard set by the World Health Organization. The first NEWater plant opened in 2003 and the second opened in 2010 and combined they provide 30% of the current water need of Singapore. The goal for the future is to be able to meet 55% of the water demand by 2060.

NEWater is currently used mostly for industrial and air conditioning cooling purposes at wafer fabrication plants, commercial buildings, and industrial estates. During the dry season, NEWater is added into the local reservoirs to mix with raw water before it is being treated and distributed to consumers as tap water.

There is a NEWater visitor center that serves as an educational center for the public. Daily tours are available for visitors and it serves to inform guests about water sustainability in Singapore and the awareness of the water issue that the country is faced with.

Desalination

The first desalination plant in Singapore opened in 2005 and it is capable to produce 30 million gallons of water per day. The process starts by removing suspended particles from water before going through a reverse osmosis process, the same type of technology that is used to produce NEWater. Minerals are added into the water before it is mixed with treated water and distributed to homes and industries in the western part of Singapore. A second larger plant was built short after with the capacity to produce 70 million gallons of water per day. Today both plants are able to meet 25% of the water need in Singapore. PUB (Public Utility Board) is planning to increase the capacity of water obtained from desalination to meet the higher demand for water in the near future.

Imported Water

The earliest solution to Singapore's water issue was to import water from the neighboring country, Malaysia. They have been importing water under two bilateral agreements, the first expired in 2011 and the second agreement will expire in 2061. Currently, imported water meets 30% of the Singapore population's water needs. The pipe that carries the water runs along the Johor-Causeway Bridge, the highway that links Singapore to Malaysia.

Efforts have been made to increase the awareness on the water issues in Singapore to the general population, which resulted in the decrease of domestic water usage per capita. Although it is a necessary step towards water conservation, it will not be sufficient to cover the loss from the imported water by 2061. Singapore aims to achieve self-sufficiency by increasing the capacity of the other National Taps by the year 2061.

Chapter 4: Design Opportunities

Water Solution

As Singapore tries to improve their water solution, especially with the imported water agreement with Malaysia expiring in the year 2061, they are focusing still on the three competing issues of water solution, housing, and industrial growth on a limited land. It appears that there is a missed opportunity in which water solution can be an integral part of housing and industries, rather than competing with the two.

Singapore's public housing board are planning to build 700,000 more units by 2030, which means that there are going to be a large number of HDB blocks being built in the next 15 years. As to not repeat the mistake of the past, where consideration for design, site, and environmental factors have taken a back seat, this could be an opportunity for HDBs to reinvent themselves. Singapore has been promoting green living and sustainability movement for a long time and it has been implemented in many private and civic buildings, but it has failed to be applied into the design and construction of public housing. 82% of Singaporeans live in HDB and with the increase in population of Singaporeans, the percentage of Singaporeans living in HDBs will likely increase as well. This suggests that HDBs are likely one of the most common type of building in Singapore.

With that said, if all new HDBs have the capacity to incorporate water catchment system that could either be used to meet the water requirements for the estate or be channeled to the closest reservoir, then this could eliminate the issue of

limited land mass for water catchment or storage. It also means that, as HDBs become part of the rainwater catchment system, Singapore can move towards a future of self – sufficiency.

Figure 9. Competing issues; water, industrial growth, housing

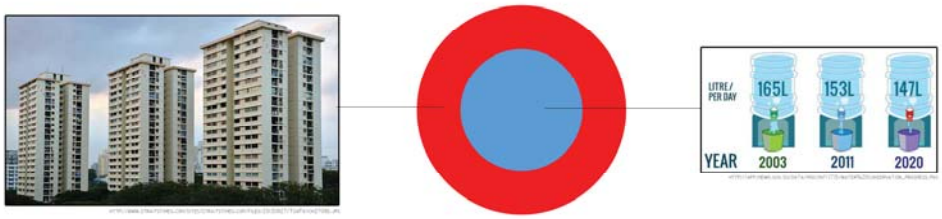

Figure 10. Opportunity; housing + water

Precedent: EDITT Tower

The EDITT Tower is an example of Ken Yeang's later work that embraces a new direction of green design. His approach was focused on the creation of habitats through the built form. The tower was a competition entry organized by the URA (Urban Redevelopment Authority) of Singapore and NUS (National University of Singapore). Yeang received second place for his entry for a mixed-use, multi-level, cultural, leisure, and multi media complex on a site near the National Library. His approach was to study the site's ecology and its properties, along with meeting his client's program needs. He created a ecological taxonomy for the site that specifies the findings of the research on the site and mapped it against a hierarchy of ecosystems. "Using this taxonomy, Yeang identified the area as a *zeroculture* site, essentially a devastated ecosystem with little remaining topsoil or tertiary flora and fauna. The ideal response to such condition would, in Yeang's terms, be to rehabilitate the site by reintroducing organic mass, enabling ecological succession – balancing the existing inorganic mass of the urban site" (Hart, 194). Ken Yeang's approach in solving a design and architectural problem is to first study the environment surrounding the site and analyze the issues at hand. In this case it was the lack of an ecosystem in the area and so Yeang's design approach is to reintroduce the ecosystem in the building system and let the biodiversity grow overtime. Due to Singapore's climate condition, Yeang also designed the building to collect rainwater. He devised shading system with a scallop shape that acts as both solar shading devices as well as rain collecting system to minimize the roof surface.

Although Ken Yeang's focus in the EDITT Tower project is on the biodiversity of the site, his approach could be applied to any design process where emphasis is placed on the environment surrounding the site as well as the deeper issues that perhaps the architecture can solve.

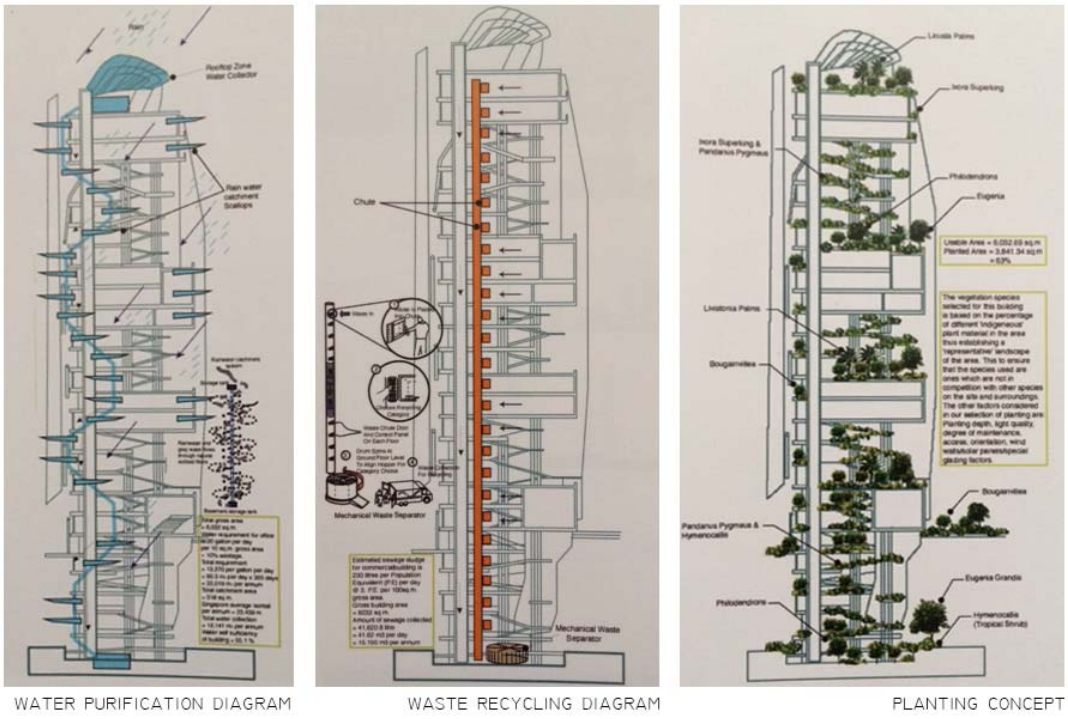

Figure 11. EDITT Tower – Ken Yeang

HDB

Since its beginnings, HDB has strived to improve the living standards of Singaporeans. The organization was formed to improve the living condition in Singapore, which at that time was made up of squatter settlements. Their effort was a success as they moved people from the squatter settlements into high-density housing units. As the population of Singapore grew, so does the demand for public housing. In order to meet the high demands, HDB had to compromise design to build more units faster. As a result, for a period of time, Singapore's high-rise landscape was made up of repeating towers of concrete architecture that is HDB. In the recent years, efforts have been made to improve the HDB design as well as the quality of live for the HDB dwellers. The organization has put more thought in the design, site, and sustainability factors. But with the prediction of a rapid growth of population in Singapore, there is a question whether the efforts that has been made to improve the quality and design of HDB will revert back to the old ways of compromising those factors in order to meet the high demands for the future. One can hope that it will not be the case, as Singapore is moving steadily towards a sustainable future.

Looking specifically at the community of HDB dwellers, the void deck is the place where people come together. The void deck provides a space for many different activities to take place, whether it be weddings, funerals, a nigh market, or just a place for neighbors to meet and mingle. Although it is a great space, it seems to limit the idea of HDB as a vertical community. This is because the space that is dedicated for gathering is only at the void deck level. If terrace spaces are introduced in multiple levels of the HDB tower, residents can enjoy more activities and have more

space to gather. As HDB is moving towards a sustainable future, it is important that the focus is not only on the environment but also on the communities. Creating a sense of belonging to a neighborhood is what HDB aims to do and by introducing "void deck" spaces vertically as well as horizontally is a way to connect everyone in a particular neighborhood. In addition, each floor can be used as a place of gathering, where units can be configured in such a way that promotes interaction. By introducing a forecourt or a verandah space, HDB dwellers can maintain the privacy that was lacking the slab block construction and have a space where they can meet and interact with neighbors. The space can also be individualized to each owner by adding plants, seating area, or colors.

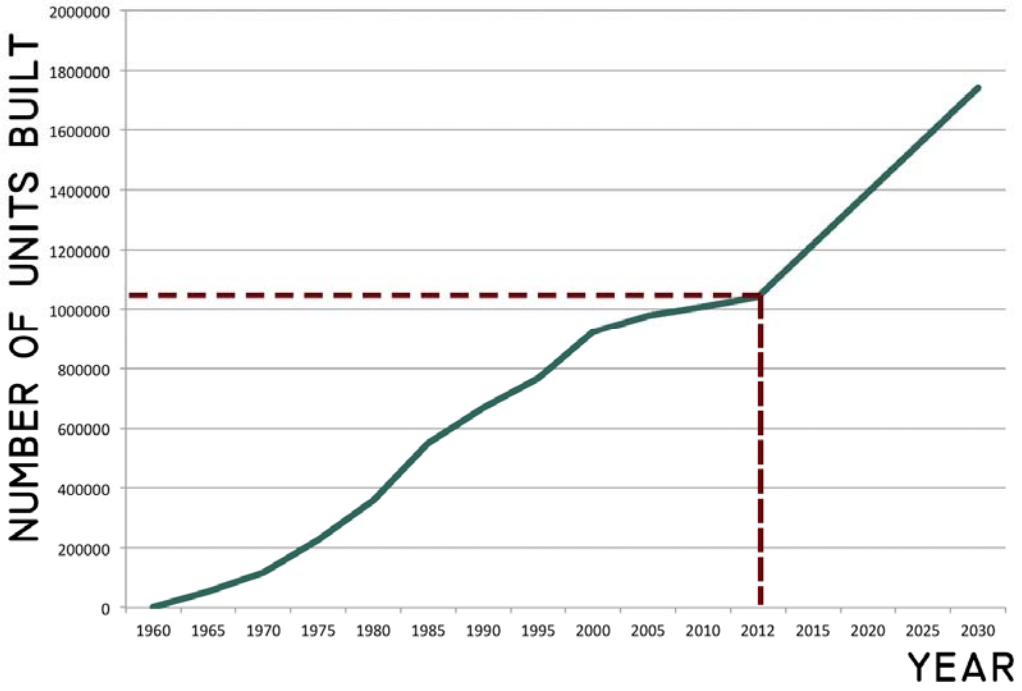

Figure 12. No. of HDB units to be built by 2030

Precedent: Bedok Court

Bedok Court condominium was built in 1985 by Cheng Jian Fenn of Design Link Architects in Singapore. The apartment complex has 280 apartment units distributed between three blocks with various heights. Surface parking lots, a swimming pool, landscaped gardens, and tennis courts are part of the amenities of the condominium. What makes Bedok Court unique is the semi-open forecourts and balconies that each unit has. About 30 – 40% of each unit is dedicated for the open spaces. The architect chose to design three different interior street configurations between the three buildings. The first is a single loaded corridor along its north elevation, the second has a central wing with two side wings perpendicular to it, and the third is a double loaded corridor with staggered configuration of apartments. Inspired by the architect's first-hand experience of living in a verandah style house in a village, his goal is to create a strong sense of community and security with the apartments, the same feeling that he had living in the village. The architect also wanted each resident to own a piece of "green" in the sky, as to get the feel of living in a landed property. A survey was conducted by Joo-Hwa Bay to assess the quality of community life and the environment of the forecourt, and the findings are as follows:

1. 86% of residents interviewed preferred the verandah space to any other space including the interior, balcony, lift, lobby, playground, swimming pool, and the parking area.
2. Majority of residents use the verandah space for social activities such as receiving guests, parties, or play area for the children.

3. Most residents felt comfortable during the warmest months of the year.
4. The residents found that the day lighting into the verandah spaces is acceptable.
5. Most responded that they are comfortable with the level of acoustics in the space.
6. 90% of the residents felt a fair amount of privacy. Although some people are more comfortable with total privacy, the majority would rather give up some privacy to increase social contact.
7. Most residents felt a strong sense of ownership and belonging. [1]

"Introduced in 1986, a year after the completion of Bedok Court, changes in planning and building regulations, effectively discouraged developers from providing semi-open balconies and forecourts. As a result, most apartments built since 1986 have been conceived as sealed air-conditioned envelopes with almost no outside verandah and balcony space" (Bay, Ong, 68). The change in regulation affected a lifestyle change in the people as well, where air-conditioned spaces are considered to be the place of comfort. This has also affected Singaporeans socially because this lifestyle change promotes isolation instead of interaction.

Although the enclosed apartment designs dominate in the 90s and early 2000, recently more apartments are designed with the consideration for maximum cross ventilation for comfortable living conditions. HDB design have always opted for maximization in cross ventilation, but in doing that they have compromised designing

[1] Bay and Ong. *Tropical Sustainable Architecture*

for social interaction. This thesis aims to critique that design type and challenge the idea that there will be great benefit in achieving both social and environmental design intentions in Singapore based on the study of the Bedok Court condominium.

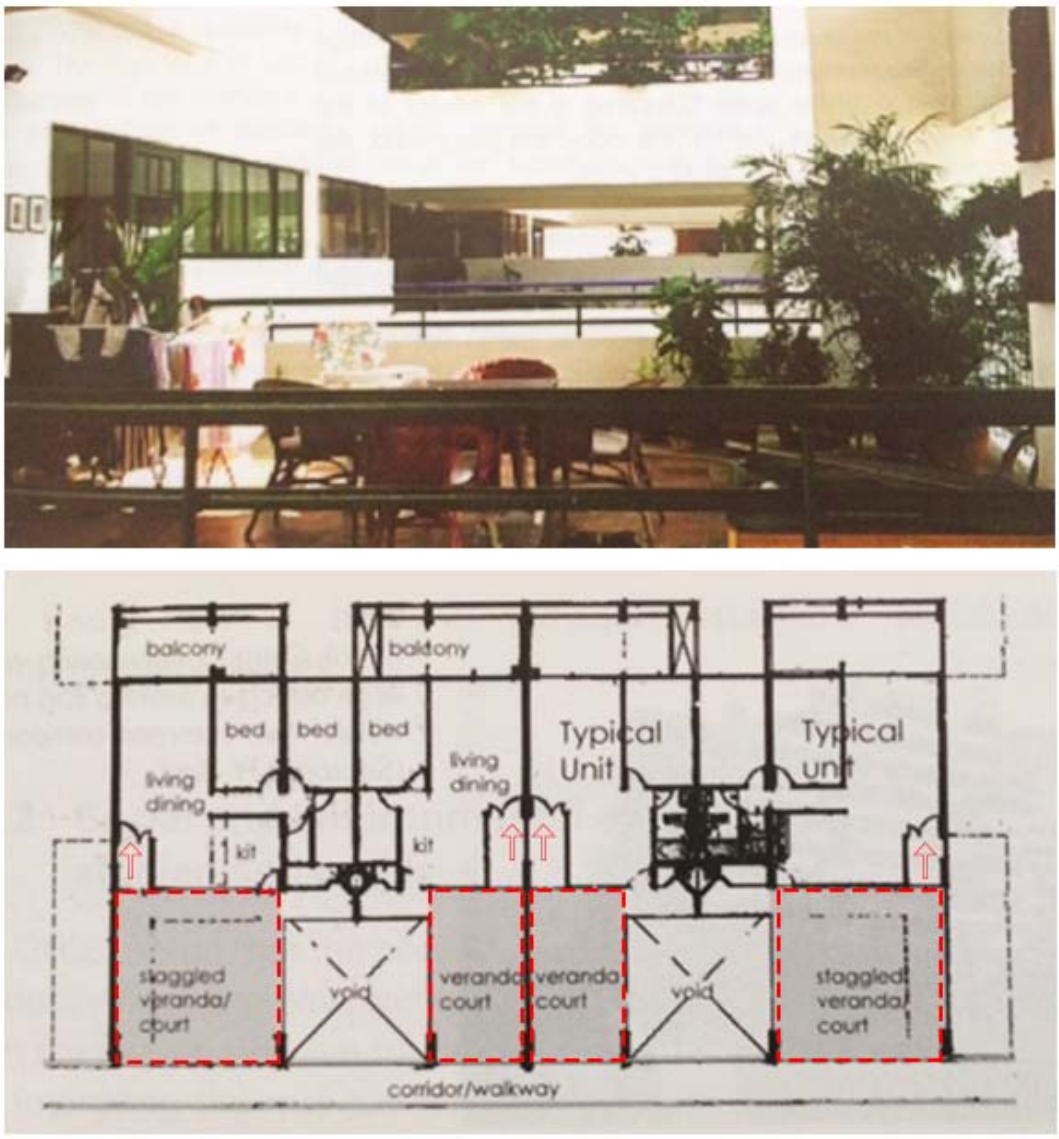

Figure 13. Bedok Court – Cheng Jian Fenn.

Chapter 5: Site Selection and Analysis

Woodlands

Woodlands is a suburban town located in the northern part of Singapore. The development of the town is concentrated at the center, east, and the south, leaving the rest of the land open in the north. The name was perhaps derived from the abundance of rubber tree at the area before it was developed. It was the natural trading port of Singapore because of the connection to Malaysia via the Johor-Singapore Expressway. The town is still in the process of growing with future development in transportation, housing, education, and entertainment.

Currently 5% of Singapore population resides in Woodlands and the majority of them live in an HDB flat. Only 4% of Woodlands live in private properties. Woodlands is a relatively new township and their population is dominated by inhabitants below the age of 15. This may be the reason that supports the 3 – bedroom flat as the most popular unit type in Woodlands.

Site

The site selected for the thesis is located at the edge of the Woodlands Township bordering Sembawang Township. The west end of the site is bordered by HDB housing and the east end is an open landscape that is not part of the development plan for the next 15 years. Rows of office buildings and industrial buildings line the north of the site and the south of the site is currently vacant with

development plans for the year 2030. The plot of land that is the site is open for bidding from developers. It calls for an executive HDB development, which is a type of HDB that have the option to be built by private developers and are more expensive. 390 units are expected to be built and the height restriction for the area is approximately 30 levels of HDB housing. The surrounding HDBs are on average 12 – 15 stories high, which is well below the restriction level. A water canal is located across the street from the site on the north side and it functions as an outlet drain. It used to be a river but it was channelized during the British occupation, and it now acts as a drain of the water runoff from the surrounding areas. There have been multiple occasions of flash flood that happened in the Woodlands and Sembawang area, which could explain the canal going outward into the sea.

The main form of public transportation that is within the quarter mile radius is a public. Bus stops are located right on the north side of the site, and a few other bus stops are located within a five-minute walk. There is an MRT (underground rail system in Singapore) that serves the Woodlands Township but it is not located within a comfortable walking distance from the site.

The immediate area around the site is lacking in amenities such as grocery store, schools, park, etc. Those amenities are part of the development plan for the area for the year 2030. A school will be built adjacent to the site on the south side as well as commercial and industrial developments.

Figure 14. Site Selection

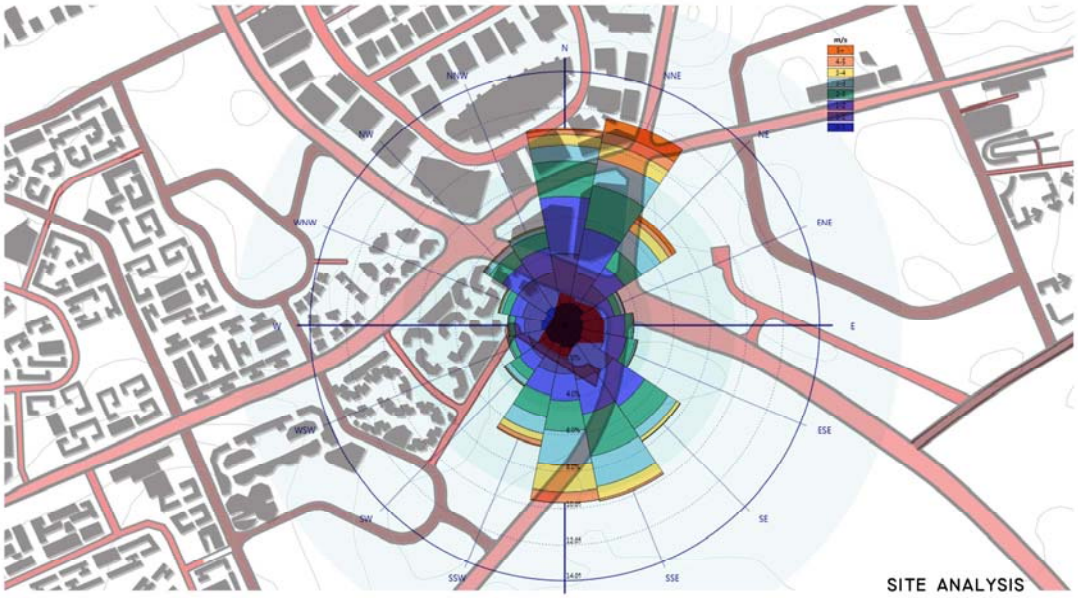

Figure 15. Wind Rose – Singapore

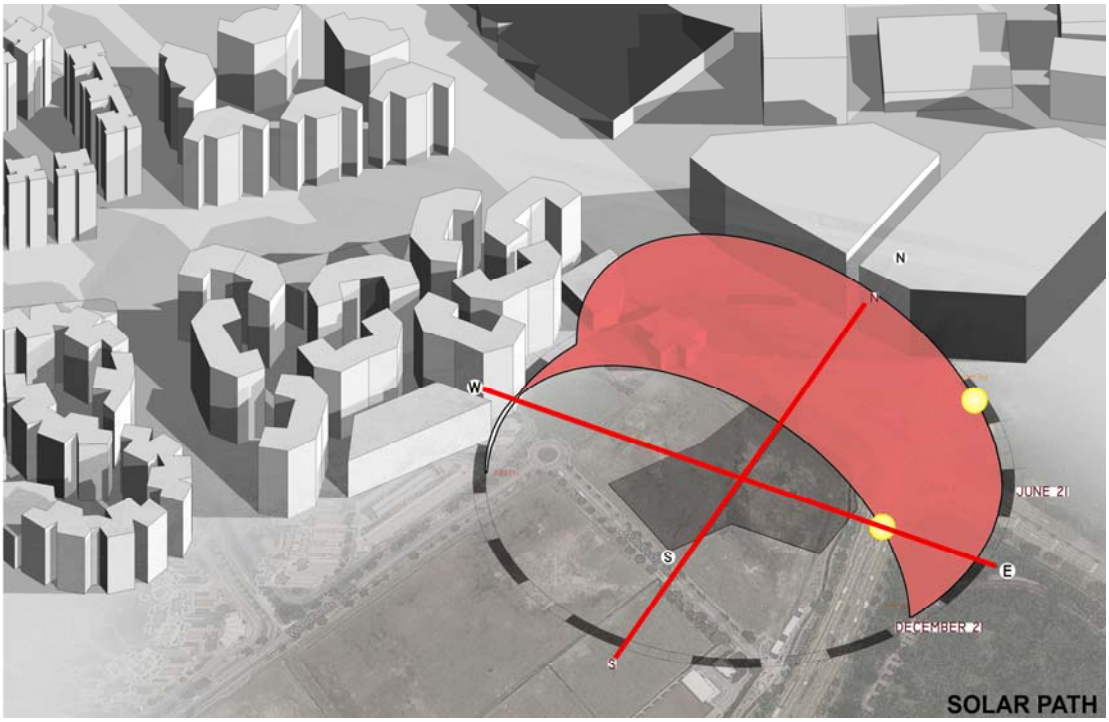

Figure 16. Solar Path – Singapore

Chapter 6: Design Strategies

The design strategies for the thesis aims to solve the underlying issue of water scarcity and housing in Singapore. The approach is focused on site analysis, climate and condition analysis, as well addressing the programmatic needs for the project. As public housing design in Singapore is going through a positive change towards a sustainable future, it is important to note that sustainable design applies to more than just “green washing” but also takes into account designing for the appropriate climate, environment, site, and community. This thesis not only aims to produce sustainable design but to address a broader issue, such as water scarcity, to achieve a functional and responsible architecture.

Building Design

The first step in the building design is to recognize the importance of building orientation according to the prevailing wind direction. This is done to ensure the maximization of rainwater falling on the vertical surfaces, as well as to maximize the potential for harvesting water from air. By orienting the long surface of the building against the prevailing wind also ensures the full potential for cross ventilation. As to meet the program requirements of 390 units, the first step was to create two parallel bars that are facing Northeast/ Southwest direction, perpendicular to the direction of the prevailing wind. The bars are then “fitted” to the site, where the bars are adjusted to meet the setback line of the property. The setback lines are determined by the building and construction guidelines that require setback distances from the different

types of road, ranging from a highway to a residential street. Along with the setback, the guidelines require a green buffer along the major roads, which in the case of this particular property are located along the north and the east side.

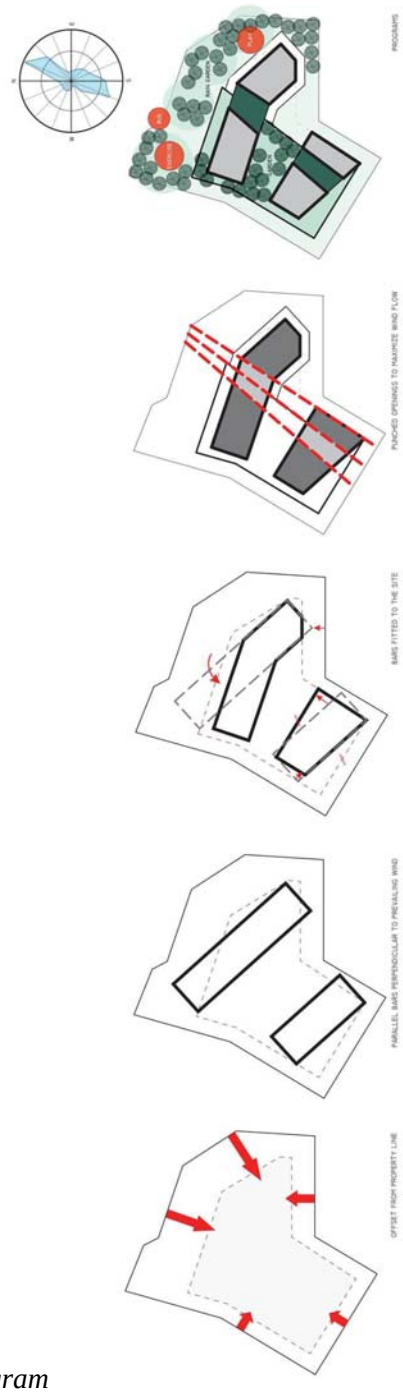

Figure 17. Plan Diagram

Designing with Computational Fluid Dynamics

As wind is a crucial element in determining the design, it was necessary to experiment with a CFD (Computer Fluid Dynamics) program. The experiment is done to determine the best orientation, form, and openings to maximize wind flow in and around the buildings. As soon as the initial forms of the buildings were determined, multiple tests were conducted to determine the best possible solutions for the thesis project. Although the CFD program does not provide an accurate study for the building design, but it provides the basic understanding of how wind behaves with the different types of forms.

The end result of the form is determined by the movement of the wind that hits the surfaces perpendicular to the prevailing wind direction, the increased wind speed through the openings, and the amount of wake that forms when the wind comes together after being separated by the object. The Northeast orientation is the most beneficial during the Northeast Monsoon season. This is because of the direction of the wind, which is coming from the Northeast, combined with the heavy rain that is experienced during this time. By having the building oriented against the direction of the wind, the vertical surface of the building can act as a water catchment system where it directs water down towards a storage cistern. The same applies for the building surface that is facing the Southwest direction, as to maximize the catchment of water during the Southwest Monsoon season.

The idea of the opening to increase the velocity of the wind is to maximize the harvesting of water from air. There are systems that have been designed to harvest

water form the humidity in the air, which can be maximized by increasing the wind speed. After further research, these systems require large investments, which is one of the main reasons that they are currently rarely used. With that in mind, this method is not ideal for the purpose of this thesis. But despite the findings regarding the system of water harvesting from air, the design of the building is still relevant for potential wind harvesting for multiple purposes.

And lastly, the wake of the wind that is the resultant of the wind coming together after being separated by an object is said to be beneficial for the purpose of cross ventilation. With that in mind, the final design of the building form is also determined by the resultant wake. After several analyses, it is clear that the two buildings needed to be at a certain distance form each other in order for the wake and wind flow to be maximized. As a result, the design requires the buildings to be placed at the farthest ends of the property setback lines towards the north and the south, with opening on both buildings at equal height, and finally with the exterior surfaces facing the direction of the prevailing wind.

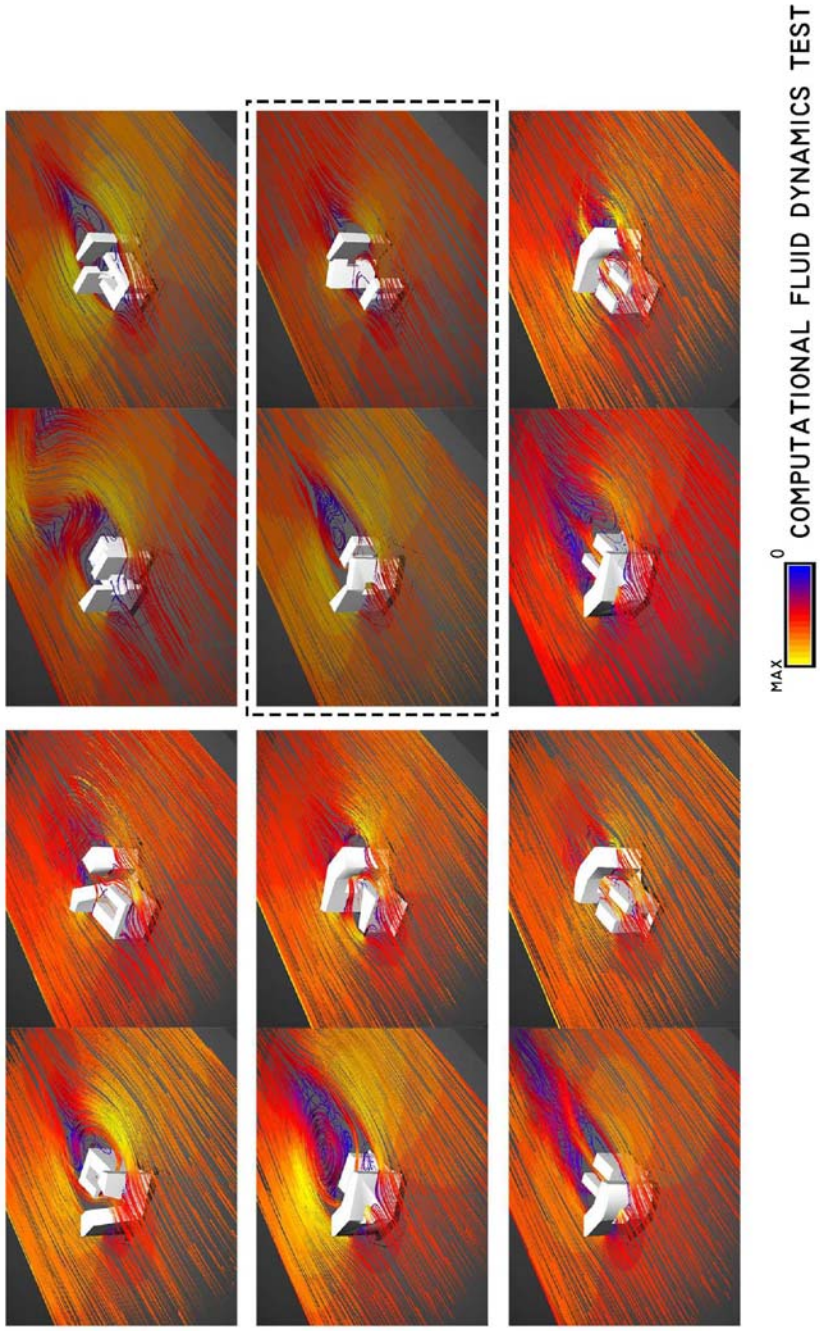

Figure 18. CFD Test

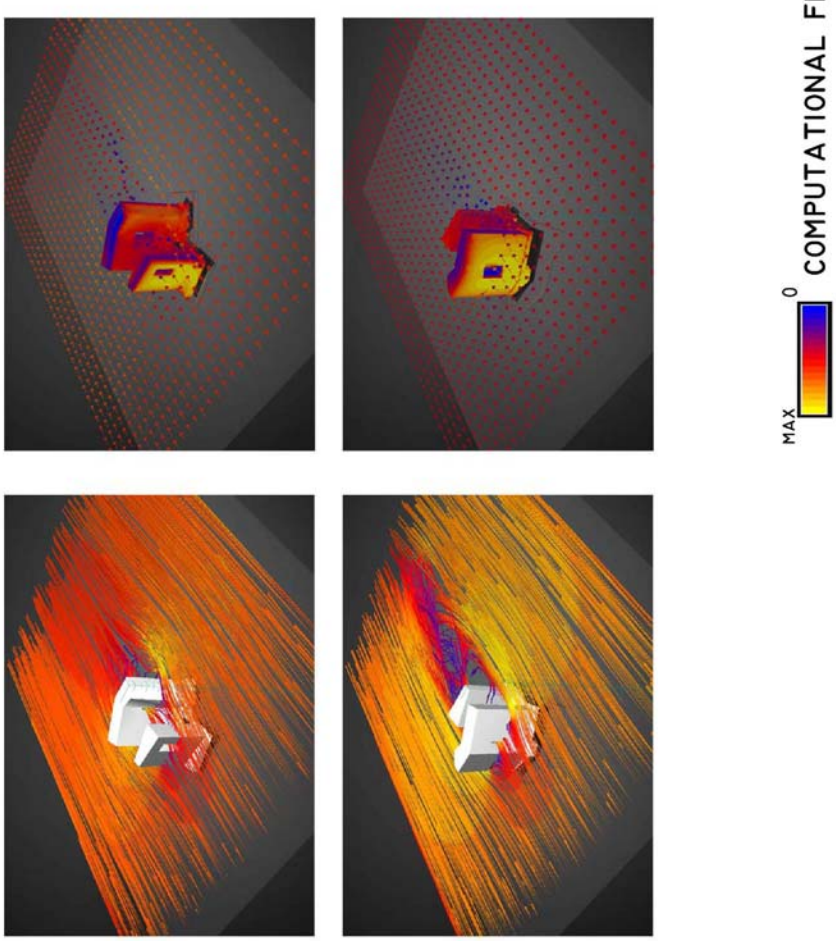

Figure 19. CFD Final Test

Water Solutions

There are several solutions to the building design that encourages the solution for water harvesting. The first being the orientation of the buildings, as mentioned previously, to face the Northeast and Southwest Monsoon seasons in Singapore. The second solution is to maximize architectural elements to support the harvesting, storing, and filtering of rainwater. As rainwater is usually obtained from a horizontal surface, the rooftop one of the surfaces to investigate. The design for the rooftop is then divided into two areas; one part of the roof is dedicated to the storage of the water that stretches out horizontally rather than vertically as to maximize the surface area for rainwater to fall into the large cistern. The secondary roof element is a tilted roofline with maximum distances in which it can be structurally supported, where it would rainwater would fall on and be directed towards the storage cistern. The size of the cistern is determined by the amount of water that is needed by the people living in the buildings. As the current domestic water use per unit in Singapore is determined to be 155 liters/ day (41 gallons/ day), the roof surfaces on both buildings are able to meet 30% of the water need for the 390 units on site for a year. This rough calculation is determined by the average rainwater fall in a year in inches, which is then multiplied by the surface area in which the rainwater is captured, and finally multiplied by a constant of 0.6[2].

In addition to the roof surfaces, there are other surfaces that are dedicated to the harvesting of the rainwater. The elevated terrace area in between the two buildings is a dedicated play zone with permeable surfaces and drains along the edges

[2] http://cals.arizona.edu/cochise/waterwise/waterharvest.html

to collect rainwater. Rain gardens are placed on the ground floor around programmed zones. This not only creates a green buffer from the busy street along the north side of the property but it is also a way to increase awareness for people walking along or in between the gardens.

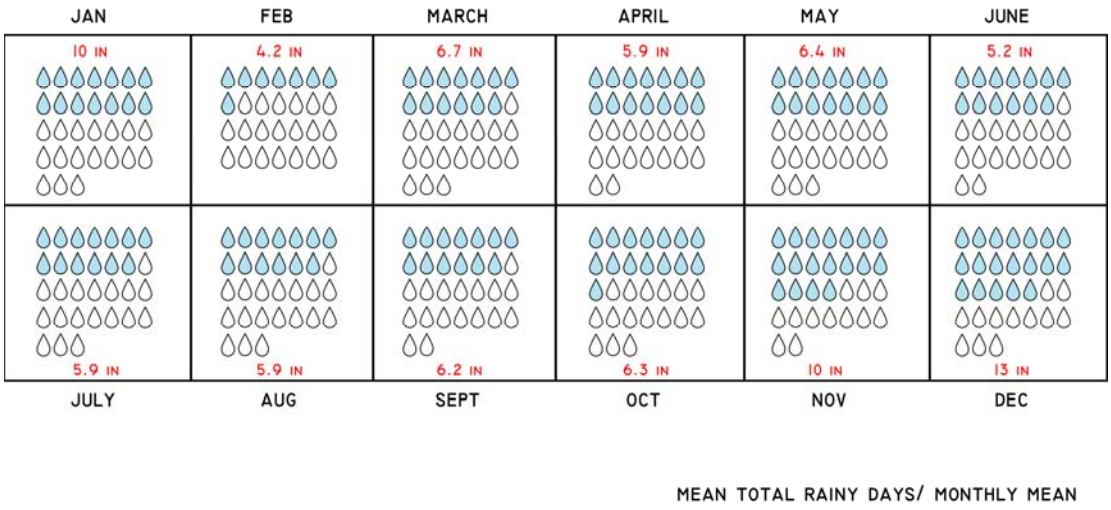

Figure 20. Rain Chart

Figure 21. Elevation

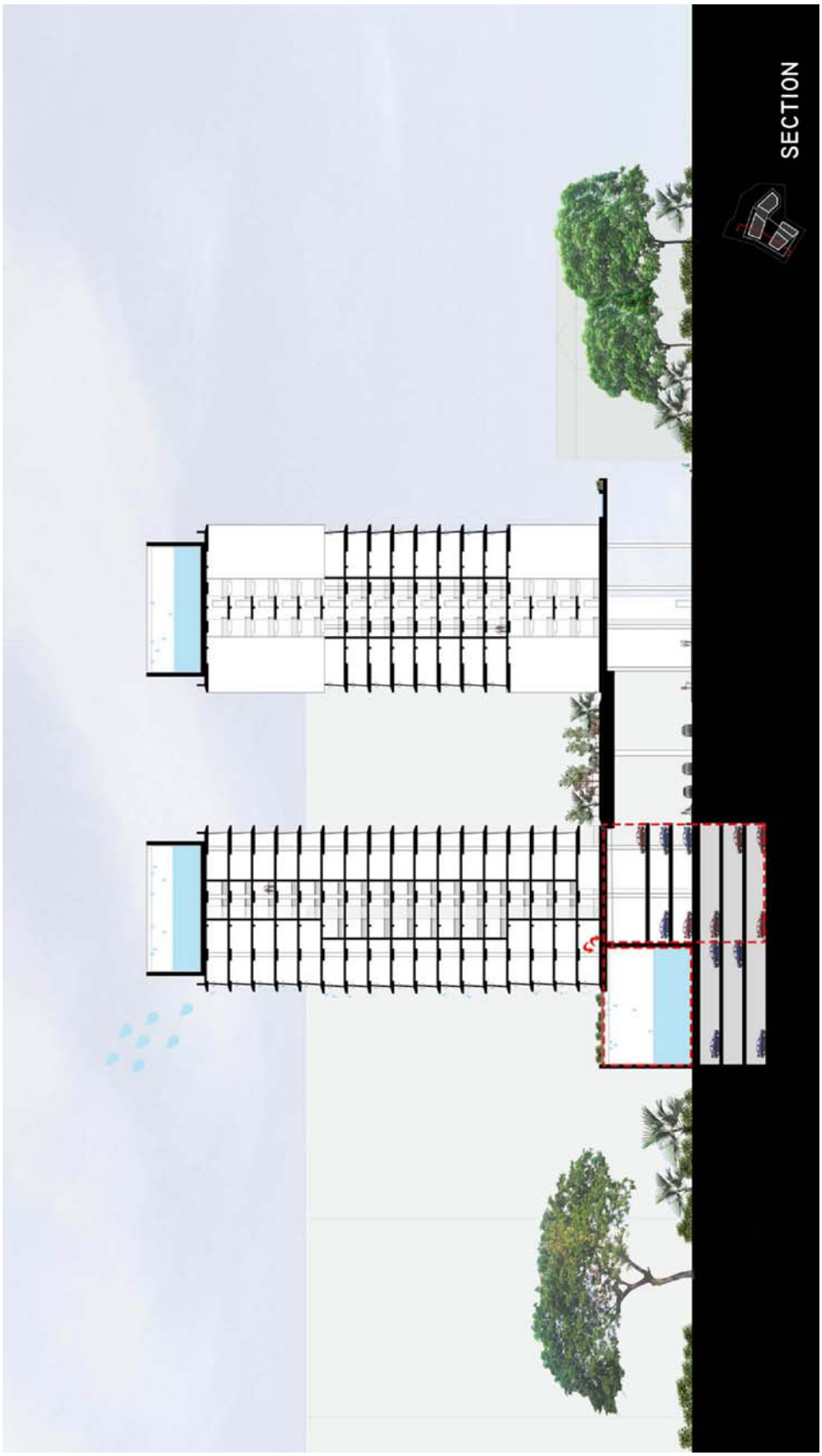

Figure 22. Section

Designing for the Community

As important as water is in this project, there are design problems that should be addressed in an HDB that affects the community of HDB dwellers. The ideals that are implemented by the HDB program are that the blocks are considered as a vertical community, as an extension of the neighborhood. Currently, void decks are the spaces used by the HDB dwellers to interact, play, or connect from one block to another. This thesis proposes that the void deck is split into multiple terraces located on multiple levels on the buildings. This is to promote the idea of HDB blocks as a vertical community, where the place to meet and mingle is on multiple levels of the blocks, instead of being on the ground floor of the blocks. By having multiple terraces, the activities and programs that take place in a void deck can be split into different spaces, and multiple activities can happen at the same time. For example, the raised terrace space in this thesis design project is dedicated but not limited to a play area. This means that the children can play safely above the ground floor, away from the vehicular traffic. The terrace area also connects the two buildings together. The roof and the terrace at the building opening level are also dedicated areas for the community.

Another solution is to introduce the idea of a forecourt or a verandah into each unit, as to activate the interior corridor on each floor. This addition will allow residents to receive guests and personalize their space with vegetation or colors. The double loaded corridors allow for the protection from heat gain and the punctured openings that is a result of the arrangements of the different types of units allow for wind to penetrate into the corridor. Due to the tropical rainforest climate, it is

important to design accordingly, which includes thermal comfort and solar radiation. As a result, the double loaded corridor with openings promotes an area that is protected from the sun and yet opens for cross ventilation.

Figure 23. Typical floor plan

Chapter 7: Conclusion

> *We are all only too aware of the numerous pressing global social issues that need to be addresses. These include tackling abject poverty, providing clean water, adequate food, enclosures and proper sanitation. But ultimately if we do not have a clean environment – clean air, clean water and clean land – all those other pressing global issues become even more difficult and costly to resolve. Thus saving our environment has to be the most vital task facing humankind today, feeding into our fears that this millennium may be our last.*
>
> – Ken Yeang

Ken Yeang's approach to design has always been related to saving the environment, wherever the location of the project is. He takes the opportunity to use architecture as an infrastructure for improving the environment. He believes that green design in the form of ecoinfrastructure, which includes, *green* (nature), *blue* (water), *grey* (engineering infrastructure), and *red* (human built systems and spaces)[3]. This idea is essentially the driving force of this thesis project, the idea that architecture could perform in ways to contribute back to the environment and the society.

Singapore has been dealing with the issues of housing, water, and industrial growth since its independence. These issues are seen as three separate entities that are competing against each other. The thesis aims to challenge the current norm and

[3] Hart. *EcoArchitecture: The Work of Ken Yeang*

policy of Singapore's subsidized housing, HDB, to create a type of housing that is more adaptable and responsible to current and future challenges. Through the exploration in progressive construction techniques and technology, HDB housing could function and perform sustainably for the community of HDB dwellers as well as for the environment. The thesis looks into the possibilities of water being a part of the two instead of a separate entity, as a way to solve the water problem of Singapore. With that said, there is an opportunity for architecture to be part of the solution. Through design, water catchment and storage can be maximized, which is a step towards the self-sustaining and green future for Singapore.

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