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Final Architecture Design Studio
Design of

DAVAO CITY PHILIPPINES VERTICAL HOUSING

With Energy Efficient Building and Biomimetics Concepts on Building Envelope

By: Fernan Cagucay Santoso
Supervisor: Prof. Noor Cholis Idham, ST., M. Arch., Ph. D

FINAL ARCHITECTURAL DESIGN STUDIO
DESIGN OF DAVAO CITY VERTICAL HOUSING WITH NEARLY ZERO-ENERGY BUILDING AND BIOMIMETICS CONCEPT ON BUILDING ENVELOPE

by:
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17512129

DEPARTMENT OF ARCHITECTURE
FACULTY OF CIVIL ENGINEERING AND PLANNING
UNIVERSITAS ISLAM INDONESIA
2021

STUDIO AKHIR DESAIN ARSITEKTUR PERANCANGAN KOTA DAVAO PERUMAHAN VERTIKAL DENGAN BANGUNAN ENERGI EFISIEN DAN BIOMIMETICS KONSEP PADA SELUBUNG BANGUNAN

oleh:
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UNIVERSITAS ISLAM INDONESIA
2021

PAGE OF APPROVAL

Bachelor Final Project Entitled :

Design of Davao City Philippines Vertical Housing
Energy Efficient Building and Biomimetics Concept on
Building Envelope

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Student's Full Name : Fernan Cagucay Santoso
Student's Identification Number : 17512129

Final Architecural Design Studio Entitled :

Design of Davao City Vertical Housing Energy Efficient Building and Biomimetics Concept on Building Envelope

Quality of Final Architectural Design Studio Book ~~***average**~~**)*good)*excellent**

So that.

recommended)** ~~not recommended**~~**)**

To be a reference for Final Architectural Design Studio

Yogyakarta, 17/12 2021

Supervisor,

Prof. Noor Cholis Idham,
S.T., M.Arch., Ph.D., IAI

FOREWORD

Praise and gratitude I pray to Allah SWT because with the abundance of His grace, I was successful in finishing a Final Architectural Design Studio with title "Design of Davao City vertical housing With Energy Efficient Building and Biomimetics Concepts on Building Envelope". The completion of this Final Architectural Design Studio was required in order to receive a Bachelor of Architecture (S.Ars) degree at the Faculty of Civil Engineering and Planning at the Universitas Islam Indonesia. In addition, the writing of this Final Architectural Design Studio is intended to provide knowledge to readers about builidng energy efficient and Biomimetics concepts.

This Final Architectural Design Studio was accomplished despite several challenges; yet, the success of the Final Architectural Design Studio cannot be separated from the guidance, motivation, and material and non-material support provided by a variety of parties. Therefore, I do not forget to say thank you to:

1. Allah SWT, who has given smoothness and health in the work of the Final Architectural Design Studio.

2. My Beloved family for the prayer, moral support and for the blessing that has been given to me.

3. Prof. Noor Cholis Idham, ST., M. Arch., Ph. D. as the supervisor for the Final Architectural Design Studio who has provided opportunities, helped and guided patiently so that Final Architectural Design Studio could be completed.

4. Yulianto Purwono Prihatmaji, ST. MT.,Dr. IAI and Putu Ayu Pramanasari Agustiananda,S.T.,MA., Dr-Ing. as the jury lecturers who has provided the opportunity, helped, guided and tested this Final Architectural Design Studio so that it could be completed.

5. My fellow close friends at UII Architecture Haidarullah Dhia Mu Afa, Muhammad Kemal Adro, Abi Dzar Ghifari, Dimas Mbajeng Rudiputra, Yusril Muzakki ,and Bryan Putra Parsada Sinaga as well, who always encourage each other in completing Final Architectural Design Studio.

6. My friends, who always give me enthusiasm in doing my Final Architectural Design Studio.

8. All my friends in Architecture 2017.

9. All parties who have helped me without being able to write one by one.

For all the prayers, support, and assistance that has been given, hope to get a retaliation from Allah SWT. The author realizes that there are still many flaws in this book, therefore all input, criticism, and suggestions are highly expected so that this book can be useful for all of us. May Allah always give His mercy and guidance to all of us. *Aamiin.*

Yogyakarta, December 13th 2021

Fernan Cagucay Santoso

ORIGINALITY STATEMENT PAGE

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I state that this Final Architectural Design Studio Project that I write and work on is my own work, not the transfer of other people's writings or thoughts that I acknowledge as my own results or thoughts. As for the Final Architectural Design Studio work,

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Assalamualaikum Wr. Wb.

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Judul Karya Ilmiah	: DESIGN OF DAVAO CITY VERTICAL HOUSING WITH NEARLY ZERO-ENERGY BUILDING AND BIOMIMETICS CONCEPT ON BUILDING ENVELOPE

Karya ilmiah yang bersangkutan di atas telah melalui proses cek plagiasi menggunakan **Turnitin** dengan hasil kemiripan (*similarity*) sebesar **11 (Sebelas) %.**

Demikian Surat Keterangan ini dibuat untuk dapat dipergunakan sebagaimana mestinya.

Wassalamualaikum Wr. Wb.

Yogyakarta, 12/20/2021
Direktur

UNIVERSITAS ISLAM INDONESIA ★ DIREKTORAT PERPUSTAKAAN ★ YOGYAKARTA

Joko S. Prianto, SIP., M.Hum

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CHAPTER ONE 01

INTRODUCTION

Abstract
Background Framework
Background
Problem Statement
Framework of Thinking
Design Method
Design Process
Originality

Chapter Overview: The introduction chapter gives a general outline of the paper. From the beginning to the end, learn about the issues and how architectural design will help solve it.

1.1 ABSTRACT

Davao City is a 1st class highly urbanized city in the island of Mindanao. it was populated 1,632,991 based on the 2015 census. This translates to an average of four persons per household. The annual population growth rate is at 2.3% in 2015. This result as an issue related with spatial availability, especially in several locations at the center of the city like Bucana. This area is now very dense due to the increasing number of migrants living in the area. Therefore, a vertical dwelling is needed to accommodate this increase in population. Based on data from the World Green Building Council one of the largest energy user sector is occupancy sector, energy consumption in the occupancy sector is dominated by electrical energy that is 71 percent of total energy consumption in 2013. The amount of energy consumption only includes energy activity in residential buildings. It proves that in the post-occupation phase and building operations, residential buildings consume tremendous energy.

The problem arises due to the high cost of living in a housing mainly because of the energy usage, to achieve low expense housing it needed Low Energy Consumption to lower the energy usage. This concept aiming so that the energy fulfillment of buildings can be suppressed and the residents there can improve their standard of living by getting housing that is low expense and livable. One of the strategy of reducing energy is by using building envelope mainly to minimize the usage of air-conditioning and artificial lighting, by using Biomimetics as a approach that relies on the building envelope for function. The main function of the building envelope is to provide the interior space with an external shading system throughout the day allowing natural daylight and minimal heat. The application of the Biomimetics approach on building envelope hoped that will become a building advantage and enhance housing quality in Davao City.

1.2 BACKGROUND FRAMEWORK

Davao City population growth rate

↓

Limited land in Davao city to build a place to live

↓

electrical energy consumption in the Philippines from 2008 to 2017

↓

Concept of vertical living for Davao City

↓

Building envelope as a tool for energy management

↓

Biomimetics as a concept on building envelope

1.3 BACKGROUND

1.3.1 Davao City Population Growth Rate Every Year

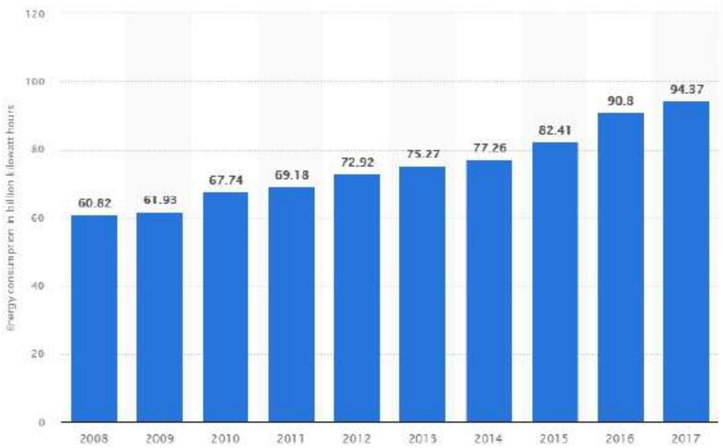


Table 1. Growth rate data
Sources: (Household Electricity Consumption per Capita in the Philippines from 2000 to 2016, 2012)

In 2017, the total electrical energy consumption in the Philippines was about 94.4 billion kilowatt hours. The overall consumption of electric energy in the country has increased over the last ten years. It shows every year the energy consumption will increased therefore it needs responds to the building to lower the energy usage.

1.3.2 Limited land in the squatter area to build a place to live

According to the NSO (2012), Davao City is the only city outside the National Capital Area with a population of more than one million residents out of the country's 33 highly urbanized cities. Davao City had a population of 1.45 million people in 2012. It, like other major cities in the region, has seen a large influx of poor people who have taken up residence in insecure informal settlements. As a consequence, infrastructure is typically one of the most important problems in local economic planning. (Malaque, Bartsch and Scriver, 2015).

1.3.3 Electrical energy consumption in the Philippines.

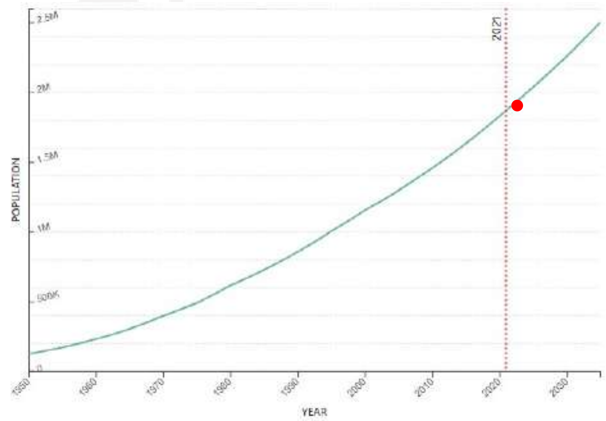


Table 2. energy consumption data
Sources: (Davao City Population 2021, n.d.)

Davao City's 2021 population is now estimated at 1,866,401. In 1950, the population of Davao City was 124,034. Davao City has grown by 40,951 since 2015, which represents a 2.24% annual change. These population estimates and projections come from the latest revision of the UN World Urbanization Prospects. These estimates represent the Urban agglomeration of Davao City, which typically includes Davao City's population in addition to adjacent suburban areas. It predicted that in 2030 Davao City it will be heavily populated. (Davao City Population 2021, n.d.)

1.3.4 Building Typology and Ownership

Due to the problem of informal settlers and land availability, building typology should be a residential vertical housing. The building should be owned by government because the problem arise from the local residents of Davao city which is the government's obligation that needed to solve.

Resettlement project for ISFs along Davao River gets green light

By DHSUD
Published on May 4, 2020

Figure 1. Statement from Department of Human Settlements and Urban Development
Source: (https://pia.gov.ph/news/articles/1040861)

Department of Human Settlements and Urban Development (DHSUD) Secretary Eduardo del Rosario, acting as chairman of the Board of Trustees of the Social Housing Finance Corp. (SHFC), has approved the loan application for the resettlement of more than 200 informal settlers families (ISFs) living along the Davao River.

1.3.5 Concept of vertical living for Davao City

In general, authors (The Policy Press, Bristol) suggested that the term of vertical housing can be replaced with the meaning of multi-storey housing. In addition, (Chandler, et al). stated that this type of vertical housing is usually efficient, flexible and be a good solution to live for families and attractive for single occupants, as compared to a single house, because it can save expenses for daily maintenance. It is also associated with the capabilities and ease of adapting to the situation in urban areas.

Generally, the basic concept of vertical housing policy is to put people who usually come from landed condition into vertical experience (Swasto DF, 2012). With respect to the situation of slums, the empty space created after the overcrowded building was replaced with a vertical housing, then can be utilised as a green or open space. There are several consequences associated with the implementation of vertical housing approaches, such as changes in the behaviour or habits of occupants, the impact on the surrounding environment, changes in the value of land and others. This condition is categorized into physical, social and economic impact by several authors. (Bratt RG & Galster G.)

1.3.6 Building envelope as a tool for energy management

Many researchers have defined the term "building skin." According to (Radwan & Osama, 2016), for example, it is the "The border via which a building's relationship with its surroundings takes place". It reacts to light by forming layers and filters. The elements of air, moisture, sound, and heat are all present. "The capacity to sustain ideal internal conditions that respond to the functions they carry is the most prevalent trait."

The building envelope, according to (Radwan & Osama, 2016), is the barrier between the inside of a structure and the outside, and is defined as the building shell, fabric, or enclosure. (Radwan & Osama, 2016) on the other hand, described the building envelope as the location where the majority of energy and material exchange takes place. It's how a building's identity is perceived. The facade and roof make up the building's envelope. External walls, floors, roofs, ceilings, windows, and doors are all included.

In conclusion building envelope is one of the strategy to manage energy use of the building and it is the way to solve architectural problem of Davao City Vertical housing.

1.3.7 Why Biomimetic concept as an approach on building envelope

Since 1970, a key concern in the world has been energy depletion, as well as high energy use in buildings. Architects are trying to figure out how to manage the energy usage of buildings. Biomimicry, which is described as the applied science that draws inspiration for solutions to human issues by studying natural designs, systems, and processes, is one creative method (Harper Collins, 1998). Building skin, which covers the whole outside of a building, is a category of biomimicry. It is the point at which a building's interaction with its surroundings takes place.

Therefore Building envelope management may significantly lower the energy consumption of a building.

1.3.8 Energy efficient vertical housing with Biomimetics concept on building envelope

In conclusion, in order to solve current general problem of limited land in Davao City in needs to build a Vertical housing, in other hand problem arises which is high energy consumption of a building therefore it needs to solve it.

One of the strategy is by managing building envelope, in this case for building envelope design it uses Biomimetics concept.

To solve architectural problem of how the Biomimetics concept on building envelope will solve the high energy building consumption is by applying Durian principles where the sun shades were inspired from spikes on the durian fruit to prevent overexposure of the spikes act as a protective layer to the fruit.

1.4 PROBLEM STATEMENT

1.4.1 DESIGN PROBLEM STATEMENT

General problem:

-How to accommodate the residence in Davao City that have Limited land issues?
-How to design Vertical Housing that have lower energy usage of the building?

Architectural problem:

-How to design Energy efficient building with Biomimetics concept on building envelope?
-How building envelope with Biomimetics approach will affect the energy consumption of the building?
-How Biomimetics principles can minimize the energy consumption of the building?

Goals

-Providing Vertical Housing that have good quality living space as a solution to limited land in Davao City

-Designing a Vertical Housing with Energy efficient using Biomimetic building envelope that can lower the energy consumption of the building.

-Designing building envelope using Biomimetic principles to lower the energy consumption of the building

-Designing building envelope with chosen Biomimetic concept to achieve low energy consumption

1.5 FRAMEWORK OF THINKING

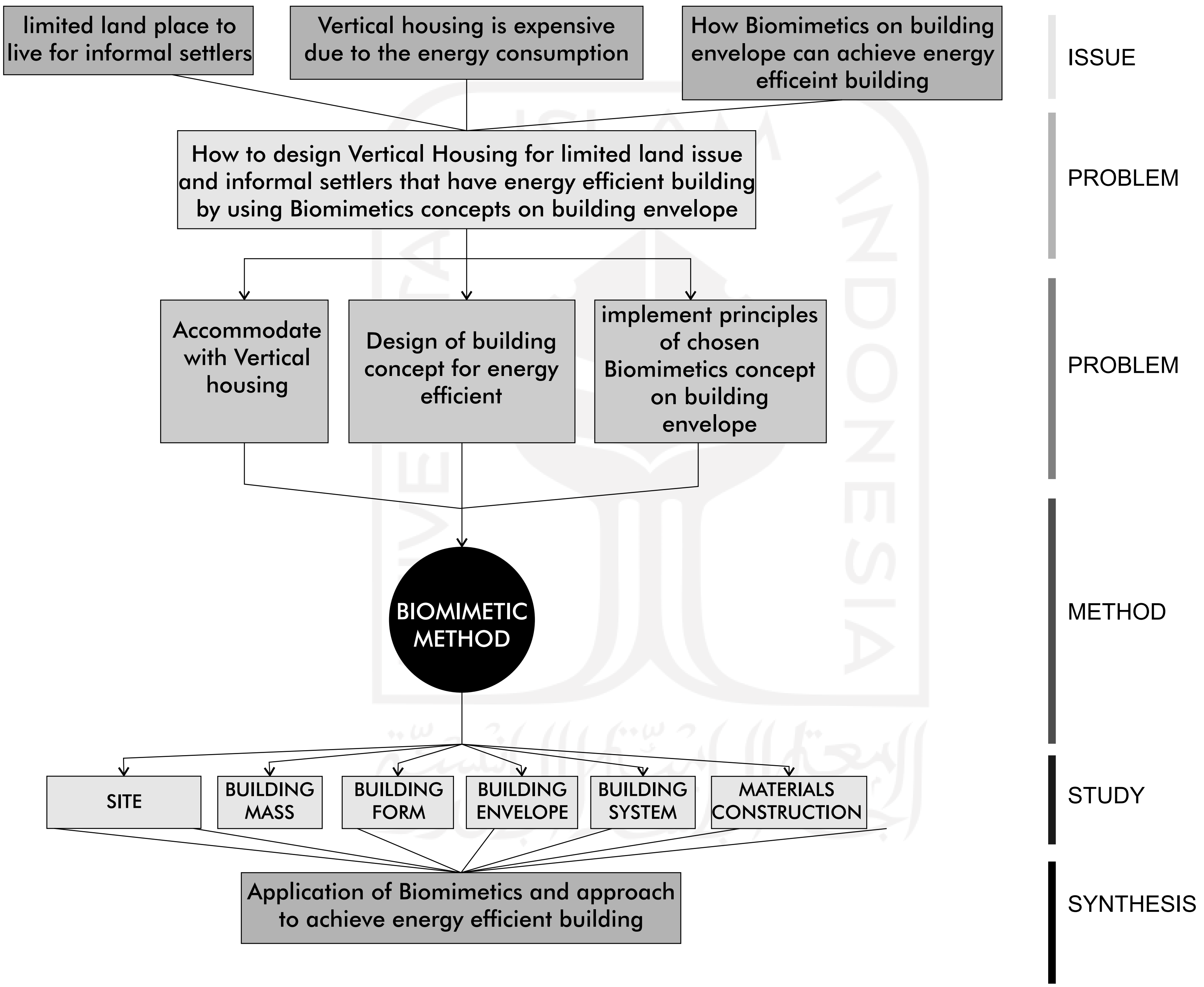


Figure 2. Framework of thinking
Source: (Author, 2021)

1.6 DESIGN METHOD

The design method for designing the "Davao City Vertical Housing with Energy Efficient Building Concepts and Biomimetics Approach on Building envelope" is Performance-Based Design

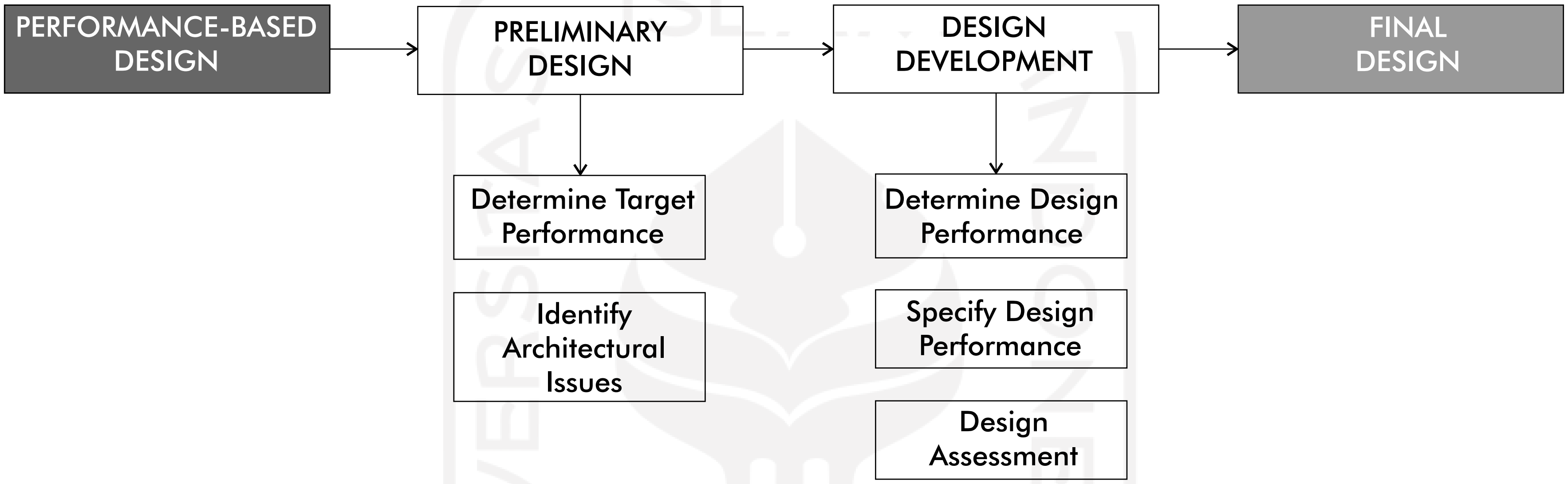


Figure 3. Performance-Based Design Framework
(Source: Author, 2021)

Preliminary design will be based on a literature review, which will include collecting secondary data from scientific journals related to Vertical housing and Biomimetics design, as well as observing the existing site condition and reading through government archives of aggregate quantitative data, building regulations, and other relevant information. Visual and thermal improvement will be the primary emphasis of design development. Physical conditions and journal references will be used to inform the design process, which will then be recreated using software and computations.

The design method used in this research is biomimetic design method. The biomimetic design method is a design method to solve architectural and non-architectural problems with inspiration from nature, both forms or systems that are implemented in the process of design with the aim of designing better sustainable solutions. Therefore, biomimetic design also maximizes the natural sources available around the construction site to achieve these goals. This is in accordance with the design objectives in this study.

1.7 DESIGN PROCESS

To solve issues that have stated, the process of this design phases includes:

1. Design Study Phase
The data and facts are collected in line with the context of the design issue during the design research problem phase. Such information can take the form of field data, precedent studies, and architectural theory connected to the Vertical Housing, Energy Efficient Buildng, Building Envelope, and Biomimetics Concept.

2. Design Variable Analysis Phase
The design problem variable analysis phase begins with a review of the site context, which includes the map, area, documents around the place, microclimate, accessibility, and surrounding circumstances. In addition to primary data from the location, secondary data from literary books and journals on libraries in general, Vertical Housing, Energy Efficient Buildng, Building Envelope, and Biomimetics Concept is used at this stage. The characteristics of the concept and the research of libraries in general are facts that may be utilized as a reference in developing this library.

3. Design Concept Phase.
The design concept phase entails resolving an issue by developing idea alternatives based on the design research and analysis of factors. These elements will be combined to create a Vertical Housing design with Biomimetics Concept

4. Design Synthesis Phase
From the first step to the concept phase, the concept that has been created and is mature will become a full design, which can then be tested during the design test phase. The design test phase is used to determine whether the design is suitable for the quality that must be achieved based on predetermined variables, such as Vertical Housing, Energy Efficient Buildng, Building Envelope, and Biomimetics Concept, as well as to determine how well the design of the design problem adheres to the design approach. The Vertical Housing, Energy Efficient Buildng, Building Envelope, and Biomimetics Concept characteristics are used to create a checklist for design testing. In addition, the checklist will be put through its paces using computational approaches to assess design quality.

1.8 ORIGINALITY

In order to avoid similarity in title and emphasis, it is necessary to review the existing final project. The author searches for the keyword "Vertical Housing" and "Energy Efficient Building", so we get several papers that are similar but different in design titles and emphasis.

A. Tittle: Low Energy Bantul Boarding House Design Application of Passive System: Direct Lighting For Spatial Management With Energy Efficiency Approach

Author: Eko Hari Purwoko Bachelor Thesis Department Architecture Universitas Islam Indonesia
Discussion: Discusses building designs that can maximize solar energy can reduce the burden of using electrical energy
Differences/ Similarities: Has a different design location and similar in concept of energy efficient

B. Tittle: Energy Saving Flats in Jogjakarta Efficiency Flat Houses in Jogjakarta

Author: Risyard Arief Triharja Bachelor Thesis Department Architecture Universitas Islam Indonesia
Discussion: Community settlements are built within the city. The dwellings are arranged in the form of flats or apartment blocks equipped with places of worship, educational facilities up to high school, health facilities, shopping facilities, to sports and recreation facilities.
Differences/ Similarities: Different design location,similar with building typology using similar concept

C. Tittle: REST AREA WITH ENERGY EFFICIENT BUILDING APPROACH IN GAMPING DISTRICT, YOGYAKARTA

Author: Annisa Ramadhani Putri Bachelor Thesis Department Architecture Universitas Islam Indonesia
Discussion: the design that is tested is the design with OTTV calculations to find out how much heat gain due to solar radiation received by the building which will affect the use of energy to cool the building.
Differences/ Similarities: Using the energy efficient concept and design location

CONCLUSION

-From case 1 Low Energy Bantul Boarding House Design it Discusses building designs that can maximize solar energy can reduce the burden of using electrical energy

-From case 2 Energy Saving Flats discusses Community settlements are built within the city. The dwellings are arranged in the form of flats or apartment blocks equipped with places of worship, educational facilities up to high school, health facilities, shopping facilities, to sports and recreation facilities..

-From case 3 Rest Area discusses about design that is tested is the design with OTTV calculations to find out how much heat gain due to solar radiation received by the building which will affect the use of energy to cool the building

CHAPTER TWO 02

DESIGN STUDY

Chapter Overview: The context analysis, literature reviews of approaches, and precedent reviews are all included in the Design Study chapter. In the end section of the article, the analysis is included in the design principle, and the variables learned will be used to assess design efficiency during the design evaluation.

2.1 DESIGN PROCESS DIAGRAM

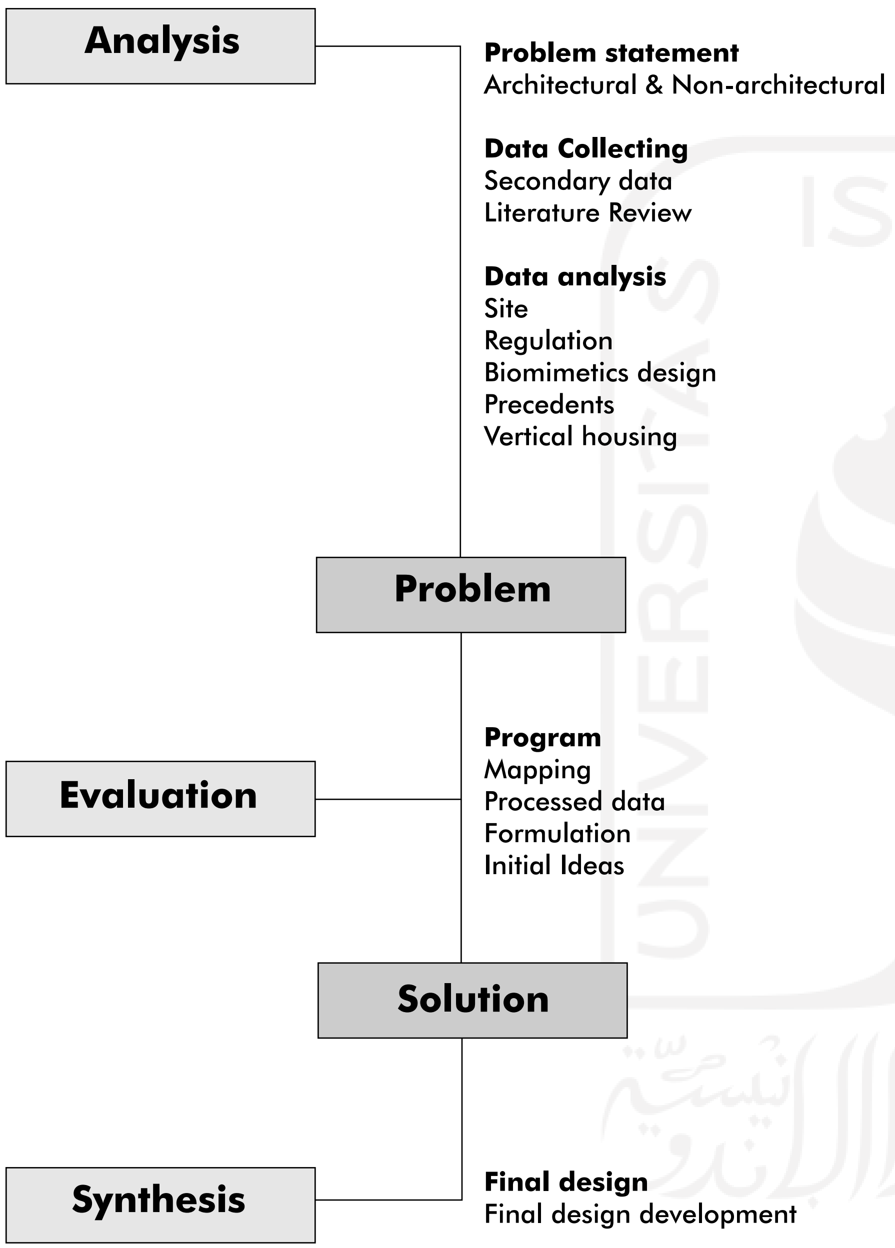


Figure 4. Design Mapping
(Source: Author, 2021)

2.2 CONTEXTUAL REVIEW

2.2.1 LOCATION CONTEXT

Figure 5. Site Location
(Source: Author, 2021)

Davao City is a heavily populated city in the Philippines' southern region. The city covers a gross land area of 2,443.61 km2, making it the Philippines's largest city by land area. It is the Philippines's third-most populated city and the most populous in Mindanao. This triggers some urban problems such as lack of livable place or slum settlements, rising temperatures in the middle of the city. The climate of Davao City is categorized as tropical. Davao City receives heavy rainfall throughout the year. Even the driest month receives a significant amount of rain. Davao City has an average yearly temperature of 26.2 °C | 79.2 °F. The annual precipitation is approximately 1787 mm | 70.4 inch.

2.3 SITE SELECTION

2.3.1 SITE LOCATION

Location: SIR phase 1, Brg. 76-A Bucana, Matina Davao City

Total Site Area: 15,300 m2

Figure 6. Site
Source: (Author, 2021)

Figure 7. 3D site illustration
Source: (Author, 2021)

2.3.2 SITE CONSIDERATION

The location was chosen by considering the location of the SIR phase 1, Brg. 76-A Bucana, Matina Davao City which is close in the side of the river with a fairly dense population. The area along the river is filled with slum settlements. In this area, the number of good quality housing is still lacking. Therefore it needed to resettled with vertical housing.

2.3.3 SITE EXISTING CONDITION AND OWNERSHIP

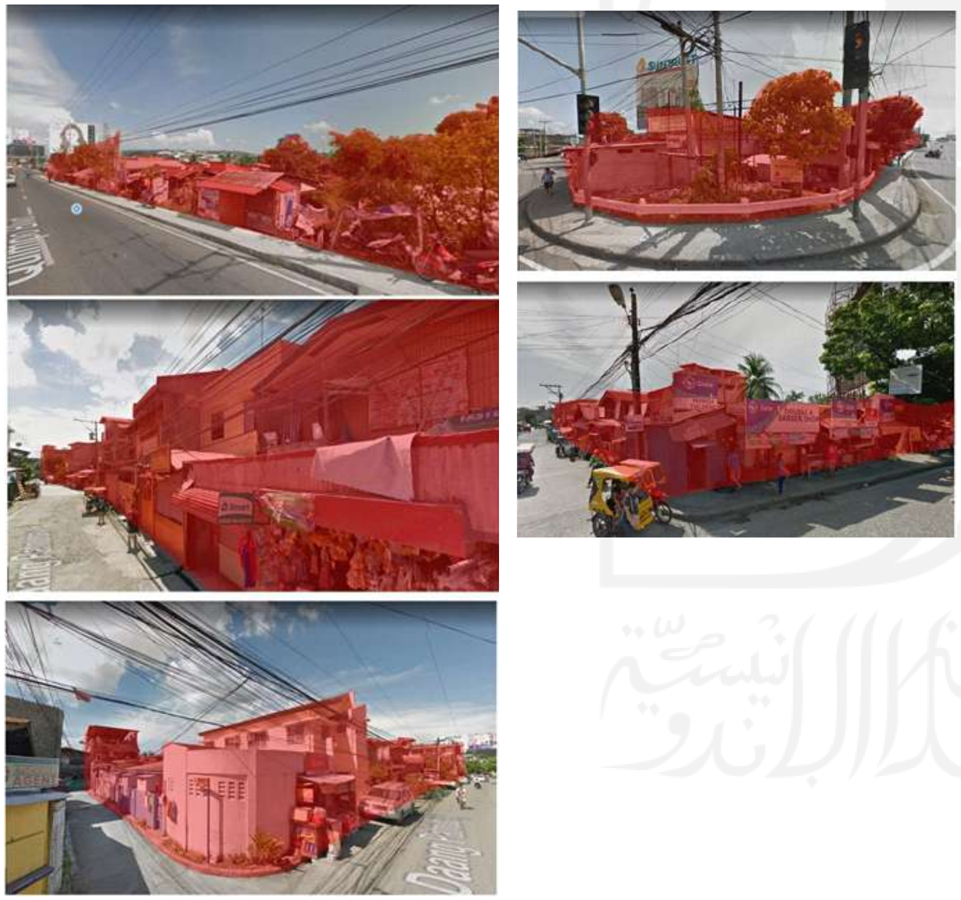


Figure 8. Existing Condition
Source: (Author, 2021)

The site formally used for residential area that is owned by the government of Davao City. The site has a high-density population of informal settlers in total of 104 houses in the area. On average of 4.9 people in 1 family and based on the data family tend to have extended family so roughly in 1 family is having 8 people. The land is owned by the government but it is occupied by informal houses. Residence in the area stayed almost about 50 years consequently the government have a difficulty of relocate them.

Figure 9. Site Ownership
Source: (Author, 2021)

2.3.4 SWOT Analysis of site

Strength	Located near to main road Surrounded with public facilities Proper and effective site shape
Weakness	Noise from main road
Opportunities	Opportunity to have green area in the site since the site located in the middle of city
Threats	Flood from heavy rain and from close river

Table 3. SWOT analysis of selected site
Source: (Author, 2021)

2.3.5 SITE NEIGHBORHOOD

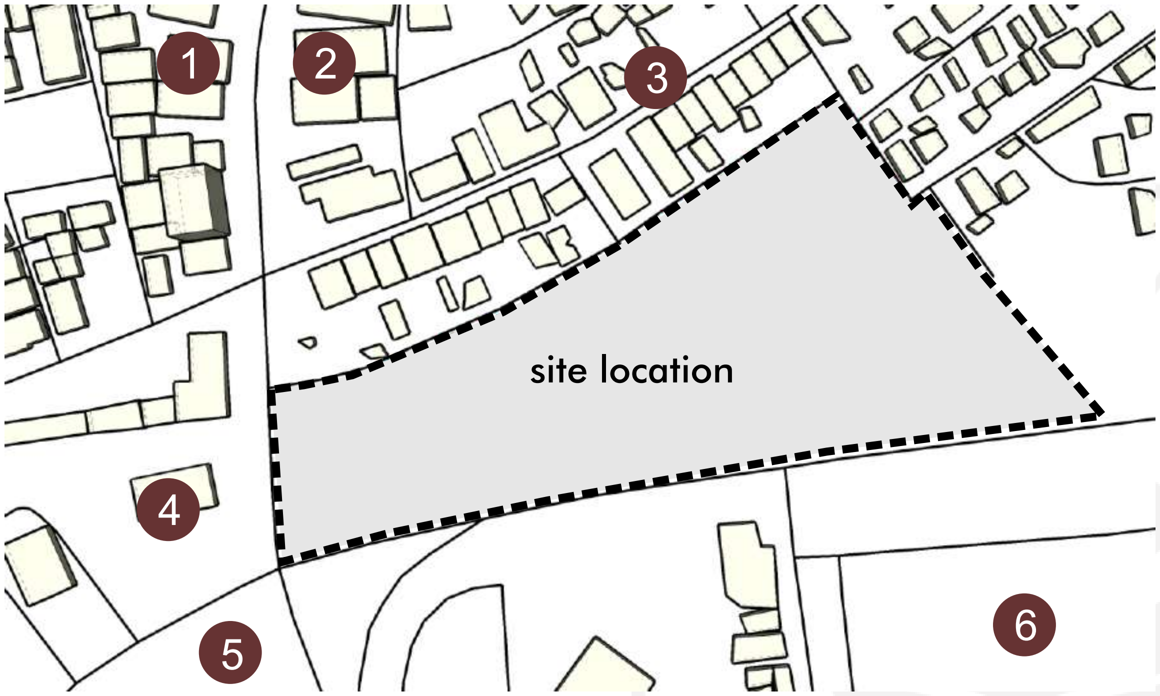


Figure 10. Site neighborhood illustration
Source: (Author, 2021)

1 Multifunction room	4 Commercial area (restaurant etc.)
2 Local ATM	5 Bus Terminal
3 Local Residential Housing	6 Public Sport Facility

This facilities makes the site consideration stronger because of the complete facilities for the user and it has easy access, also this will support the concept of energy efficient because the facility inside the building will be lessen due of the availability of the facilities outside the building.

2.3.6 SITE BOUNDARY

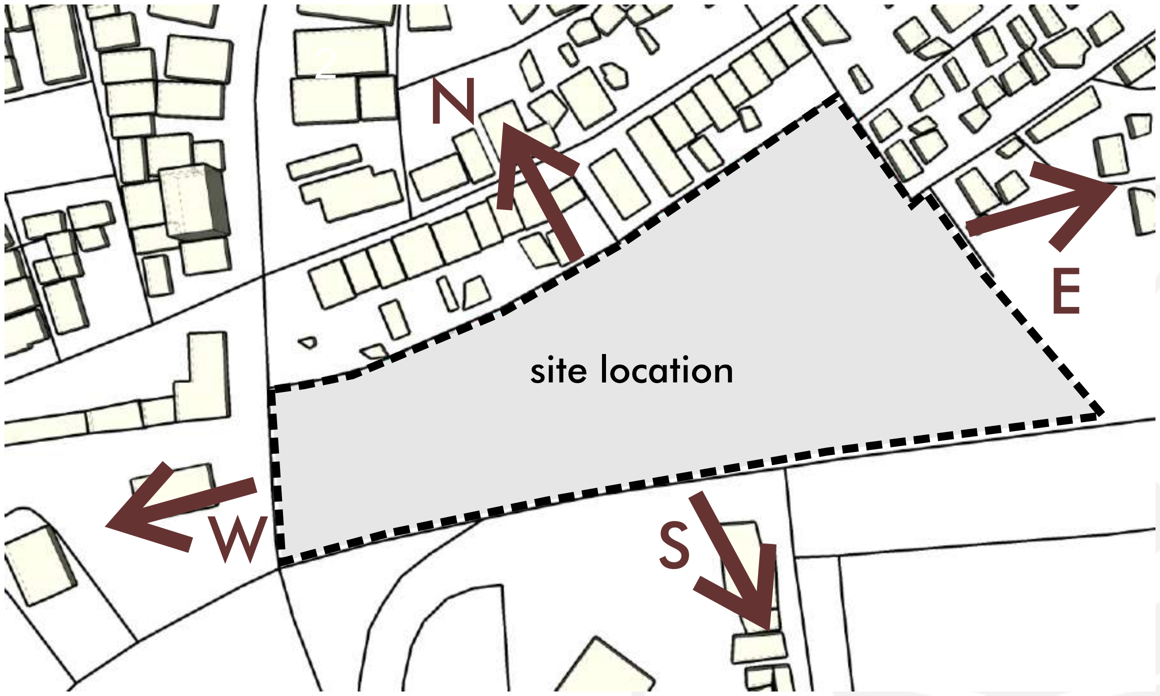


Figure 11. Site boundary illustration
Source: (Author, 2021)

Site Boundary

North : Local resident houses
South : Quimpo diversion road (Main road)
East : Local resident houses
West : Commercial area

The surrounding of the site is very dense in mass and it is crowded. Local resident houses on north and east means the northen part of site is mainly houses. Diversion road on south is the main road close to the site usually it is a busy street so the noise must be avoid it. Commercial area on west is similar on probability of noise coming from it at main road west part also surrounded with restaurant.

2.3.7 SITE ACCESSIBILITY

Figure 12. Site accessbility illustration
Source: (Author, 2021)

Because the location is so close to the major road, it has a designated pedestrian walkway, which means there is adequate room to drop people off if they commute by Jeepney (local transport). They may then access the site immediately, or if they utilize private transportation, they can also enter and exit the site directly.

The suggestion site access also support the energy efficient concept because it will lessen the distance of a vehicle circulate inside the site therefore it will reduce the usage of energy fossil from the vehicle.

2.4 REGULATION AND BUILDING CODES

Table 4. Building codes of philippines
Source: (IMPLEMENTING RULES AND REGULATIONS OF THE NATIONAL BUILDING CODE OF THE PHILIPPINES (PD 1096)

Group B – Residential (Buildings/Structures, Hotels and Apartments)				
General Classification of Use/Character of Occupancy of Building/ Structure	USE			Zoning Classification
	PRINCIPAL	ACCESSORY	CONDITIONAL	
Division B-1	1. All uses permitted in Divisions A-1 and A2 (or for R-1 class and R-2 class) buildings/structures 2. Leased single-detached dwelling unit, cottage with more than one (1) independent unit and duplexes	1. All customary accessory uses allowed in Divisions A-1 and A-2 (or for R-1 class and R-2 class) buildings/ structures 2. Branch library and museum 3. Hometel 4. Vocational school	1. All conditional uses in R-1 and R-2 with appropriate regulations	Residential R-3 - a high-density residentialuse or occupancy,characterized mainly as a lowrise or medium-rise building/ structure for exclusive use as multiple family dwellings with mixed housing types. R-3 structure may include low-rise or medium rise residential condominium buildings that are already commercial in nature and scale. There shall be two (2) general types of R-3 use or occupancy, to with: a. Basic R-3 : rowhouse building/structure of from one (1) storey up to three (3) storeys in height and with each unit for separate use as single-family dwellings; and b. Maximum R-3 : medium-rise multi-level building/ structure of from six (6) up to twelve (12) storeys in height and for use as multiple family dwellings

Based on, IMPLEMENTING RULES AND REGULATIONS OF THE NATIONAL BUILDING CODE OF THE PHILIPPINES (PD 1096)

Davao vertical housing classified as Division B-1 Residential type R-3 which include low-rise or medium rise residential housing buildings. there are 2 types of R-3 and Davao vertical housing project is consider as Maximum R-3 type which medium-rise multi-level building/ structure of from six (6) up to twelve (12) storeys in height and for use as multiple family dwellings. In apartments or residential condominiums of five (5) storeys or more, at least one (1) passenger elevator shall be kept on twenty-four (24) hour constant service.

Floor Area Requirement for Family Dwelling Unit

The minimum floor area of family condominium units shall be 36 square meters and 22 square meters for open market and medium cost condominium project respectively. (HLURB, 2009)

Building Coverage Ratio (KDB)	Maximum of 80%
Floor Area Ratio (KLB)	Min of 6-12 floors | 7.10 up to 8.10
Building boundaries (GSB)	8 meters

2.5 CLIMATOLOGY

2.5.1 Average Temperature in Davao City

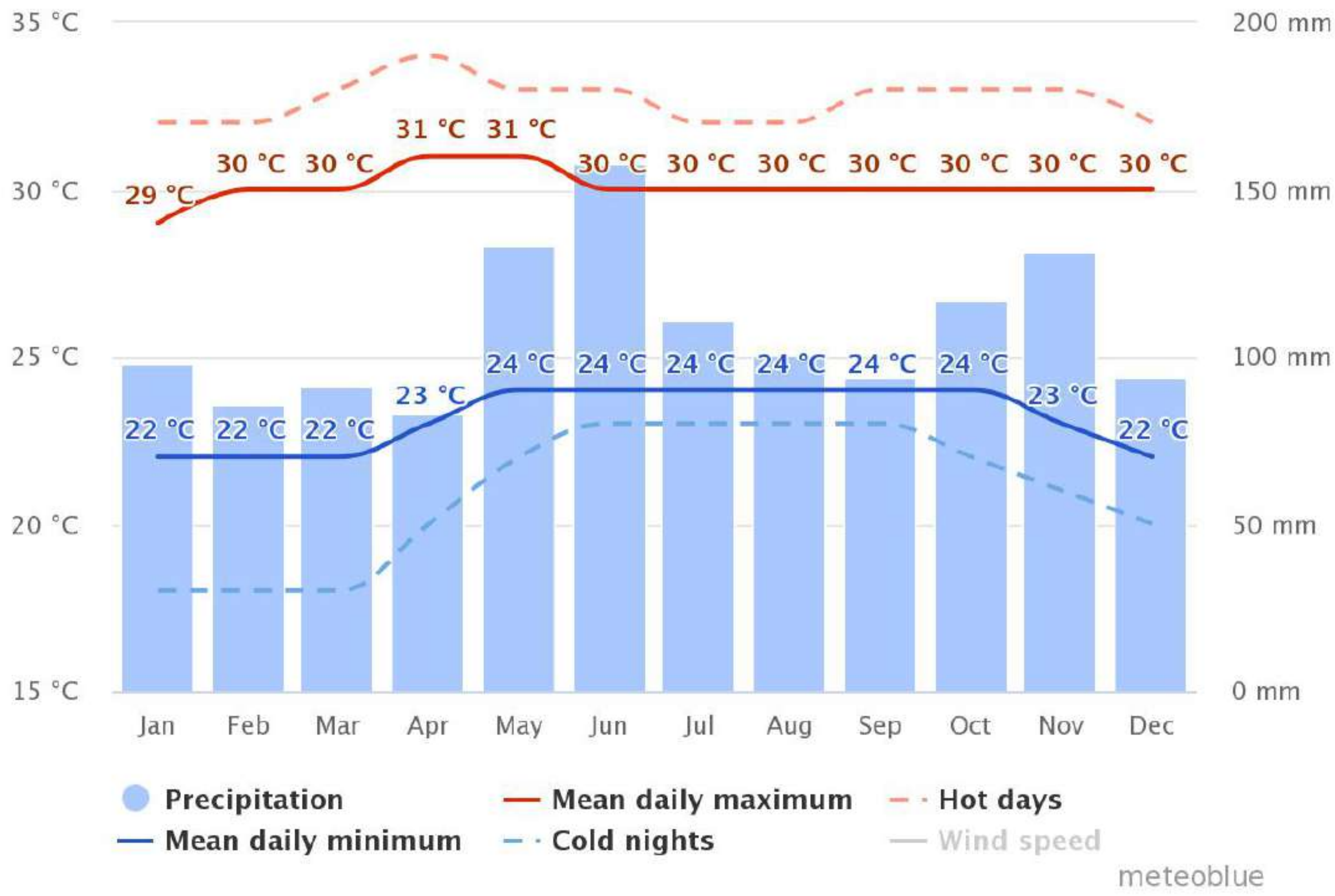


Figure 13. Average Temperature
Source: (source: www.meteoblue.com, 2021)

Humans generally feel comfortable between temperatures of 22 °C to 27 °C therefore the average temperature of Davao City is not too high it can be solve by using passive cooling design and not adding active cooling like AC this will support and achive energy efficient building concept.

2.5.2 Relative Humidity in Davao City

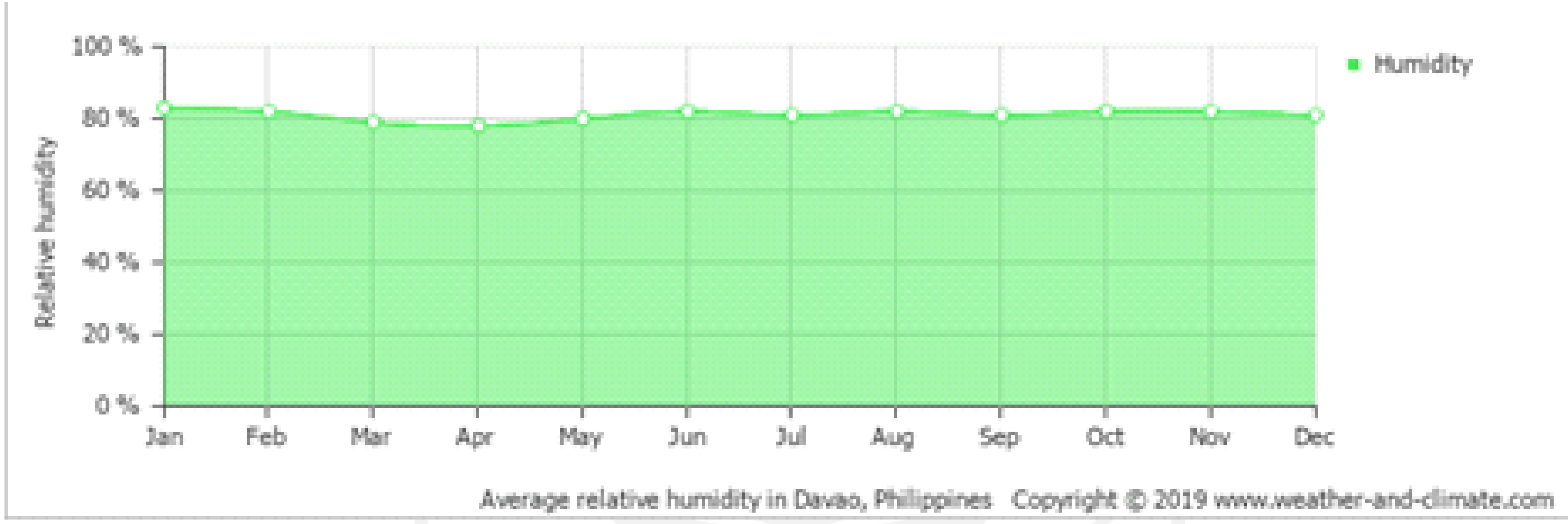


Figure 14. Relative Humidity
Source: (source: weather-and-climate.com, 2021)

The average annual percentage of humidity is 81.0% On a year-round basis, the Relative Humidity is very high, as can be seen in the graph. The comfort level is about 40% to 60%, so some adjustment is needed to make it comfortable and addition of cross ventilation for every mass and room. (weather-and-climate, 2021)

2.5.3 Windrose

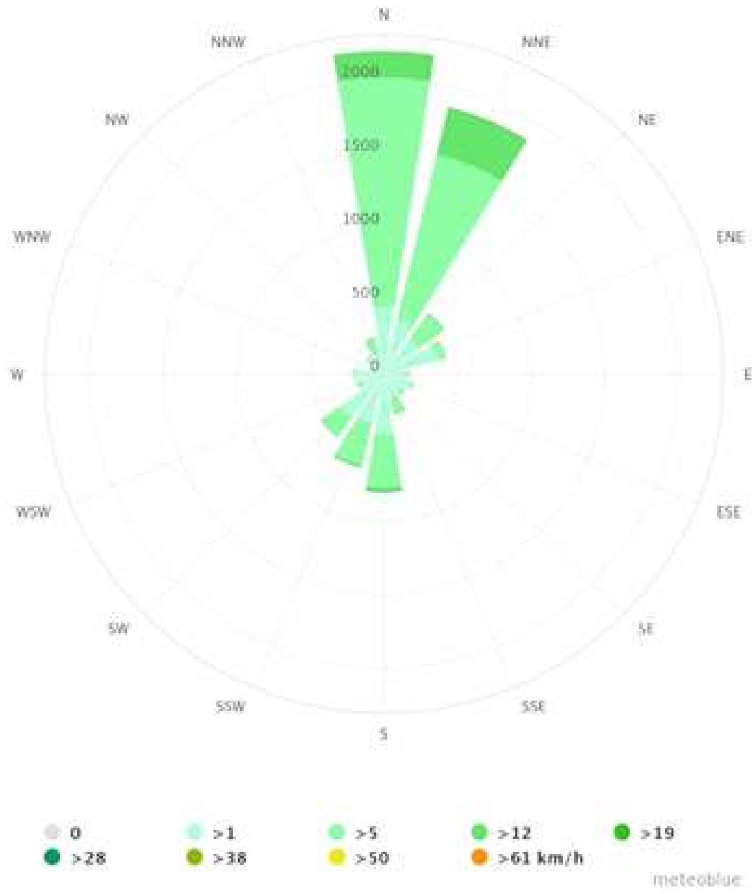


Figure 15. Windrose
Source: (source: www.meteoblue.com, 2021)

According to the windrose index, Davao City has the highest wind exposure rate from the north and northeast to the south. The direction of the wind can influence the shape and envelope of a building's architecture, particularly when it comes to its orientation. It gives advantages to make opening in the north part of the building to let airflow enter to the building. (Meteoblue, 2021)

2.6 SITE CONDITION

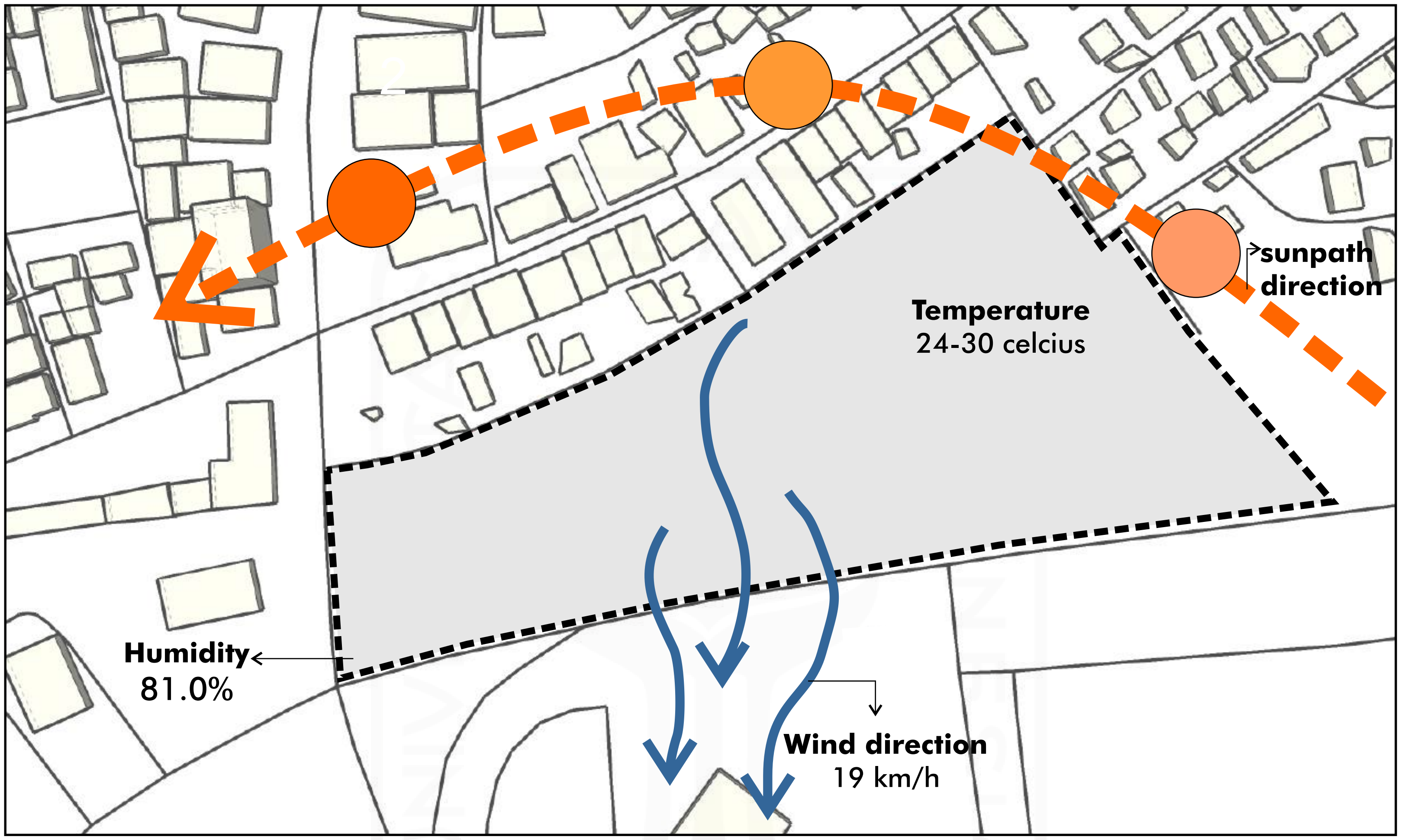


Figure 16. Site condition
Source: (Author, 2021)

The setting of the Davao City location was considered and analyzed when designing this building. As a result, this design was created specifically for the Bucana region and would be inappropriate if constructed elsewhere. According to prior data analysis, the average wind speed at the site is more than 19 km/h, and it blows from the north to south . It is advised that the wind speed at the location be reduced since it is excessively high. The sun shines from the east (the long side of the site) to the west (the short side) (west). This is due to the fact that the site's long side (front side) faces north. The advantage of this site is clear since the short side faces the sun as it rises and sets, allowing direct solar radiation to be minimized. Furthermore, the site's long side faces directly into the wind, allowing the incoming wind to be used as an advantage when planning building openings with a passive cooling design.

2.7 PRELIMINARY DESIGN STUDIES

2.7.1 Energy efficient building design

Energy efficient building design involves constructing or upgrading buildings that are able to get the most work out of the energy that is supplied to them by taking steps to reduce energy loss such as decreasing the loss of heat through the building envelope.

(US Green Building Council, 2015) Energy efficient homes, whether they are renovated to be more efficient or a built with energy efficiency in mind, pose a significant number of benefits. Energy efficient homes are less expensive to operate, more comfortable to live in, and more environmentally friendly. (Natural Resources Canada, 2015)

Inefficiencies that are not removed in the building process can pose issues for years. However, keeping energy efficient building design in mind when construction is underway is a more effective way to approach making a home more efficient, which is less expensive for a homeowner in the long run. Building codes exist around the world to ensure that buildings are energy efficient to a certain degree, however sometimes it is wise to go above and beyond these recommendations to have an even more energy efficient home.(Natural Resources Canada, 2015) As well, since a house operates as a system, a home must be looked at as a whole in order to fully increase the energy efficiency. For example, expensive heating and cooling equipment do nothing to improve the energy performance of the house if insulation isn't keeping heat in during the winter and out in the summer. (Natural Resources Canada, 2015)

2.7.2 Vertical Housing

Residential architecture is a place where humans grow and develop physically and psychologically, most of the time human life is in the house.

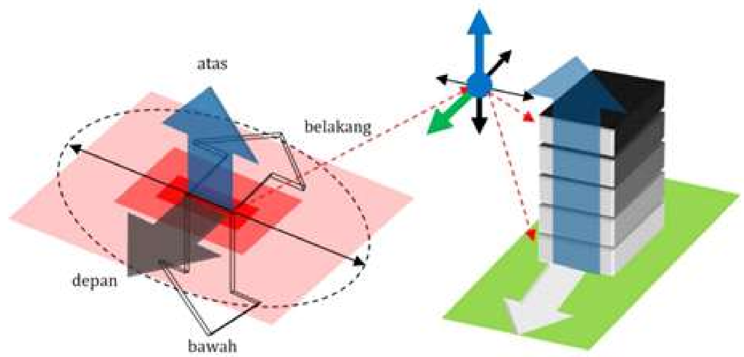


Figure 17. Vertical Building
Source: (Sabaruddin, 2018)

Vertical occupancy is a way to resolve urban land density which results in the absence of an area that can be used to build landed houses. Vertical housing can be a solution to fulfilling one's rights to housing experiencing land crises. Vertical occupancy is the result of the change and evolution of the socio-culture of the world community which is influenced by the events of the industrial revolution. This event occurred in the 18th century in England, finally began to spread to various parts of the world. Indonesia started in the 20th century, this was due to changes in the agrarian lifestyle into an industry that occurred at that time. (Sabaruddin, 2018)

2.7.3 Building design parameters considering low economic users

2.7.3.1 Building construction cost to support EE

Hotels, motels, flats, dorms, barracks, condos, and multi-family housing are typically built in mid-rise structures, which range in height from three to nine floors. The cost and configuration of the structure are heavily influenced by structural features. As a result, choose the proper material is crucial. Every additional square foot added to a project increases the building owner's potential revenue. Greater storeys and density equal more money from the same amount of land. For the building construction the Vertical housing mainly using concrete. Concrete is so integral to the communities because it is the only building material that cost-effectively delivers the lowest carbon footprint for a structure or pavement over its life cycle, unparalleled strength, durability, longevity and resilience for after construction performance. Also concrete maximized energy efficiency via thermal mass to support EE and low maintenance costs.

2.7.3.2 Operational cost consideration

To support energy efficient concept the vertical housing is not using active air-conditioning system and using less artificial lighting because of the passive system that will be applied in the building system concept.

2.7.3.3 Choose of building materials

Pre-fabrciated is recommended in the vertical housing materials this is to support low cost that includes steel, concrete etc.

2.7.3.4 Steel as a material for the facade

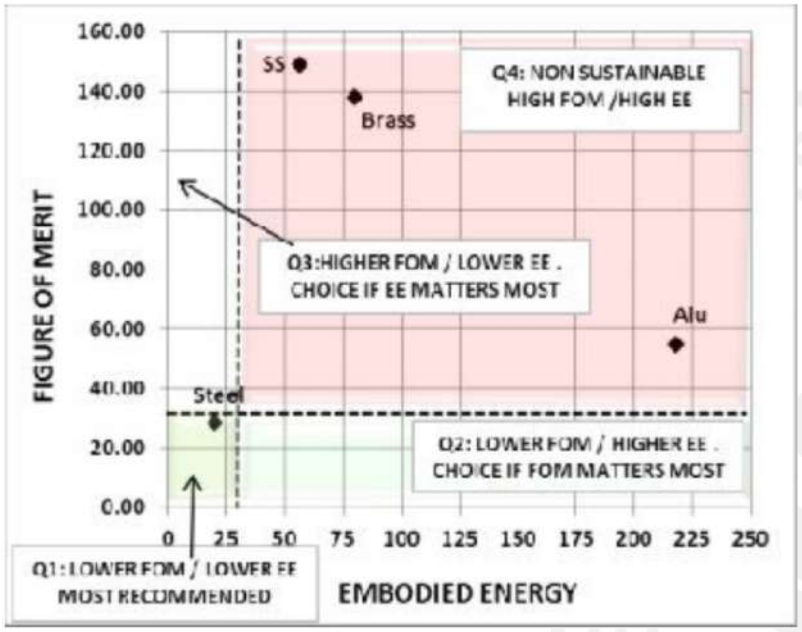


Figure 18. FoM-EE Acceptability Criteria for Metals
Source: (Sabnis & Pranesh, 2017)

Figure 18 shows that steel falls into Q1 with a low FoM value and low embodied energy, making it the most suited material. When recycled steel is utilized, its applicability improves. The embodied energy of virgin steel is approximately 12 to 15% more than that of recycled steel. Stainless steel, brass, and aluminum, which are all in quadrant 4, are not suited as sustainable building materials. (Sabnis & Pranesh, 2017)

2.7.3.5 Maintenance cost consideration

Considering affordability maintenance cost must be low, for that the vertical housing mainly using concrete structure which concrete outlasts other building materials by decades and actually strengthens with time. This lowers the overall cost of ownership while also reducing the environmental effect of more regular maintenance or reconstruction.

2.7.3.6 Local craftmanship Davao City consideration

The Vertical housing project will collaborate with local company which is Ulticon Builders Incorporated that has been established since 1993. The company focuses its business on infrastructure development, an area of activity it considers important and vital to the socio-economic development of the country. This strategy also makes its construction management and monitoring cost effective resulting in minimum mobilization cost and better utilization of its construction equipment and facilities.

2.7.4 Biomimicry

2.7.4.1 Biomimicry Definition

Many researchers have attempted to characterize Biomimicry. Biomimicry, for example, is "a modern discipline that explores nature's best concepts and then imitates the designs and processes to solve human problems," (Benyus, J.M., 1998) according to Benyus. Though Pederson Zari pointed out that one of the challenges facing architects is the lack of a consistent concept from the many alternatives available to them in their projects. As a result, it's critical to assess the right way for thoroughly implementing the best Biomimicry system and reaping the benefits (Zari, M.P. 2007). Biomimicry, on the other hand, is described by Guber as "the study of overlapping fields of biology and architecture that demonstrate creative potential for architectural problems." (Bar-Cohen Y., 2005)

2.7.4.2 Various ways of incorporating biomimicry into design

Biomimicry is a rapidly developing topic of research in architecture and engineering since it provides new and inspiring solutions. While creating the prospect of sustainability in the built environment, The problem-based approach and the solution-based approach are two primary methods to the design process in Biomimicry, according to researchers.

2.7.4.2.1 Problem-solving approach to biology (Design to biology):

This method is inspired by biology and involves a series of phases that are either non-linear or dynamic in nature. In the loops, this offers input as well as refinement (Yowell, J., 2011). The designers use this method to look for solutions by first identifying the problem. This encourages the scientists to look for an organism that has addressed a challenge comparable to the one at hand. The objective of the problem-based approach is to identify goals and design constraints. (Mazzoleni, I., 2013)

2.7.4.2.2 The solution-oriented strategy From biology to architecture:

The biology influence design, bottom up approach, and solution driven biological inspired design are all terms used to describe this method. This method is utilized when the design process is based on biologists' and scientists' scientific understanding rather than human design difficulties. For example, scientific examination of lotus blooms that emerged clean from swamp water resulted in a slew of new designs. This includes the STO Lotusan, which lets a structure to clean itself (Zari, M.P. 2007).

2.7.4.3 Biomimicry levels

When tackling a design challenge, there are three major degrees of Biomimicry that may be used. Form, process, and ecosystem are some of them (Steadman, P. 2008.). A solution can be found in nature by examining the organism or ecosystem, shape, and process. It's crucial to figure out which part of biology is replicated for this application (Webb, S., 2005). This is referred to as leveling.

2.7.4.4 Application of Biomimicry in different fields

Biomimicry is being used in a variety of disciplines. Biomimicry has been used in a variety of sectors, including transportation, the automobile industry, electronics, and textiles. Biomimicry research can provide new technical improvements and contribute to advancements in a variety of sectors (Rankouhi, A, 2012).

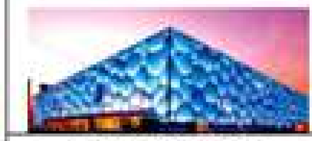
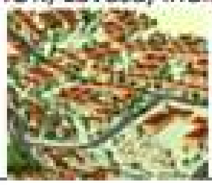
Eiffel Tower 	Thighbone	-The flare on the outside mimics that of a femur bone. -Metal studs and braces are used to construct the lattice.	Wind bending and shearing impacts are not a problem. -The ventilation issue has been resolved	Organism Level
National Aquatics Center, Bejing 	Water bubbles	-A membrane of illuminated blue bubbles of pneumatic cushion made of ETFE covers the surface, creating a bubble appearance.	-Solar energy is collected by the bubbles, which is used to heat swimming pools. -It's possible to regulate the temperature.	Organism Level
Bejing National Stadium 	Birds Nest	-Includes ETFE panels that insulate by inserting small bits of material into the branches, as well as panels that shield and filter sunlight.	-Openings in the facade allow for natural ventilation. -panels lower the roof's dead load; -cost savings; -durability; -recyclability.	Behavior Level
Eastgate Center, Harare 	Termite Mound	To assist fans, the center opens and pulls additional air, which is pushed up through ducts in the building's center.	There is no need for HVAC equipment because the temperature is maintained throughout the year.	Behavior Level
HOK, Lavasa, India 	Termite Mound	-The foundation holds water, and the drip tip system cleans the surface.	-It reacts to seasonal floods. -Transports extra water.	Ecosystem level

Table 5. Applications of Biomimicry in architecture
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

2.4.3.5 Building envelope as a tool for energy management

Many researchers have defined the term "building skin." According to (Rankouhi, 2012), for example, it is the "The border via which a building's relationship with its surroundings takes place". It reacts to light by forming layers and filters. The elements of air, moisture, sound, and heat are all present. "The capacity to sustain ideal internal conditions that respond to the functions they carry is the most prevalent trait."

2.4.3.6 Biomimicry and Building skin

It is necessary to examine the similarities between building skin and biomimicry in order to draw analogies. This involves assessing the key parallels and driving forces that influence both nature and the architectural design process (Mazzoleni, I., 2013). The skeleton (structure) of a building is covered with a thin membrane that governs the organs (mechanical, plumbing, and electrical) and defines the interior areas. The building skin is comparable to real skin in that it is made up of layers and filters that react to light, air, moisture, sound, and heat in the same way as natural skin does. Natural skin is known for its capacity to sustain interior conditions while being responsive to its function. The building skin, like real skin, serves as a barrier between the regulated and uncontrolled environments. It is the consequence of both internal and external forces arranged in a certain way. They both serve as filters in the process of permitting and preventing certain items from entering and exiting (Yowell, J., 2011).

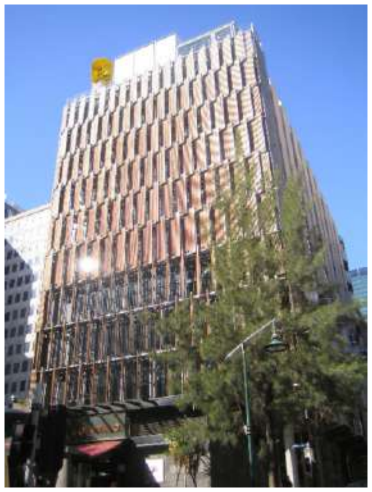
2.7.4.7 Analytical Comparison Study of Precedent for Biomimetic Concept

This section of the paper will present an analytical study of three international examples of Biomimicry approaches on Building skin for reducing energy consumption, focusing on techniques and strategies used, with the goal of obtaining a Biomimicry design matrix that abstracts characteristics from various natural organisms to achieve the desired goals.

2.7.4.7.1 The Council House 2, Melbourne CH2

(CH2) is a ten-story sustainable structure located in Melbourne, Australia. It was constructed between 2004 and 2006, and it was designed by the City of Melbourne in collaboration with Mick Pearce in design Inc. The structure's design was highly creative since it questioned established methods to sustainability and architectural design by mimicking the bark of a tree. Design to biology was the biomimic method (Webb, S., 2005). The green rating of the building is. The CH2 is an amalgamation of art and science. It was centered on connecting the building to its exterior environment and live creatures surrounding it in order to achieve the goals. As a result, it responds to its surroundings holistically (Webb, S., 2005).

The Council House



Aims

- -Energy Efficiency
- -Sustainable
- -Usage of natural Resources
- -Light house environment

Design Concept

Outcomes

- -Air is 100% filtered
- -Natural lighting and ventilation saved by 65%
- -Maximizes natural

Figure 18. illustrates the overview of the entire project of the Council House
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

The use of biomimicry was evident throughout the structure. The west facade, for example, is the tree's epidermis. It was inspired by how the exterior climate would be moderated by the facade. The north and south facades were modeled like the tree's bronchi. As illustrated in [figure 0], these were used as wind pipes and allowed for air ducts on the outside of the CH2. The eastern core and facade, which included the service core and toilets, were designed to seem like tree bark (figure 0). In the ventilated moist region areas beyond, the skin served as a protective barrier, filtering light and air. Finally, in order to attach the louvers, the overlapping layers of the facade are made with perforated metal with polycrabonate walling (Webb, S., 2005).

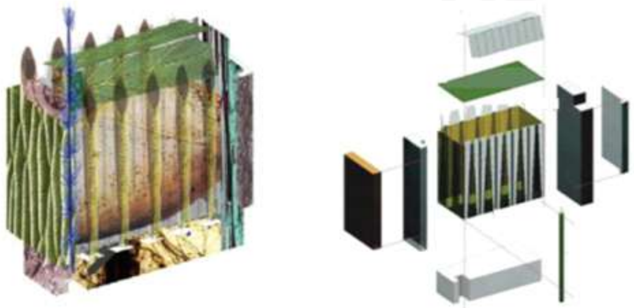


Figure 19. wind pipes on the north facade & overlapping layers of the facade
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

The design approach was beneficial since it resulted in the separation of typical industrial solutions. Despite the fact that future buildings may not look like the CH2, the CH2 symbolizes a living kind of architecture (Webb, S., 2005). As a consequence, it was decided that future structures should include the following features:

- Interact with the surroundings
- Communicate climate and culture
- Facades should communicate orientation.

2.7.4.7.2 Water cube, Beijing

The Beijing National Aquatic Centre, commonly known as the water cube, was constructed between 2004 and 2007 primarily for the 2008 Olympic Games. Chriss Boss, Tristam Carfrae, PTW Architects, CSCEC, CCDL, and Arup designed the four-story structure. The Biomimic was demonstrated in the structure by simulating the shape of soup bubbles, which also reflected the fundamental swimming ideal. Biomimicry is a design approach to biology (The China National Aquatic Center, 2007).

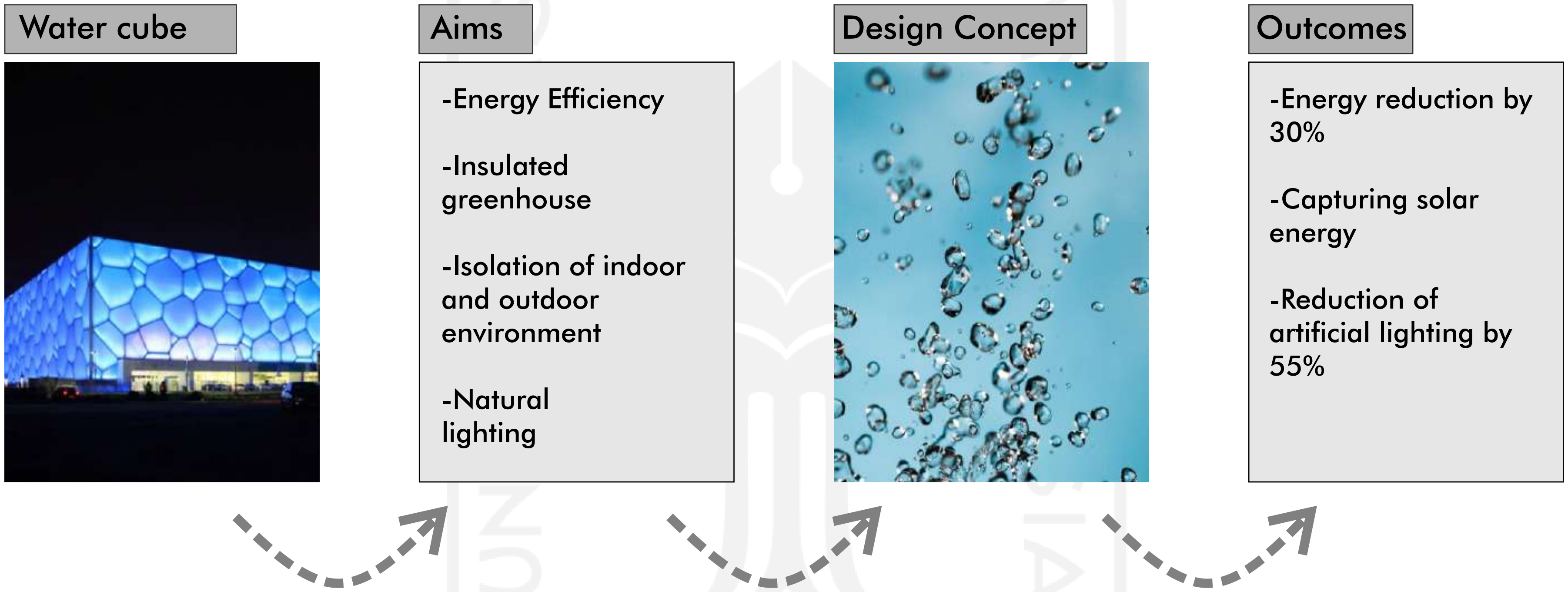


Figure 20. illustrates the overview of the entire project of the Water Cube
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

The building skin has to be able to partition the spaces into equal-sized cells while still containing a little amount of surface area. At the same time, in order to be energy efficient, the building skin required to collect solar radiation. Tristan Carfrae, the water cube's creator, discovered that earlier scientists, such as Lord Kelvin, established in the 19th century that the tetrakaidechedron allows a space to be split into equal-sized cells with the least amount of surface area between them. Plateau, a Belgian scientist, has studied soap bubbles and the principles that govern how they connect three faces together to form a line. The surface area and surface energy of the soap layers in the bubbles can be reduced. Because the surface tension of the partitions lowers the surface area of the bubbles, this coincidentally solved Kelvin's query. The most economical technique to split a space turned out to be geometry (The China National Aquatic Center, 2007).

As a result, the strategy was to view the foam array in a certain orientation before removing the foam block to acquire the structure's geometry. It is built around a repeating unit that is tiled in 3D space, rotated, and then sliced across the axes to produce the geometric form seen in [figure 5]. Even though the geometric structure is very regular, it seems entirely random and organic when viewed from a specific perspective. The transparent building skin combines the mystery of the bubble system with the transparency of water. As a consequence, it engages people both inside and outside of the building to feel water (The China National Aquatic Center, 2007).

Figure 21. illustrates the Water Cube's geometric form
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

Through the use of a biomimic methodology, the Water Cube was able to accomplish a number of environmental benefits, including an energy efficient design and the completion of all challenges and objectives. The following are some of the outcomes:Energy costs reduced by 30%
Artificial illumination has been decreased by 55%.

- Green house project
- Visitors get a taste of water transparency. Through effective filtration and backwash systems, rainwater is collected and recycled.
- ETFE energy savings are comparable to solar panels covering the entire roof.
- Solar energy is captured and utilised for heating to the tune of 20%.

The Water Cube was designed using biomimicry to find a geometric form that maximized surface area in a three-dimensional environment while being energy efficient. There were several biomimicry lessons learnt in this endeavor, including (The China National Aquatic Center, 2007):

- Nature's experience in the context of the environment
- Facades should convey a sense of direction.
- Creating a receptive and welcoming atmosphere
- Geometry and spontaneous form creation are extremely important.

2.7.4.7.3 The Esplanade Theatre, Marina bay

The structure is a two-story structure built by DP architects, Micheal Wilford. The Esplanade Theatre is located near the historic Singapore River in Marina Bay. After the first design was criticized for including too much glass and being too Western, the decision to employ a Biomimic approach was made. The design was also chastised for being disrespectful to Singapore's tropical environment. As a result, the new design sought to create a structure that reacts to its surroundings and culture while remaining traditional. The building skin, which is inspired on the biology of the tropical durian fruit, is one-of-a-kind in that it offers shade and repetition in the face of the scorching temperature, borrowing inspiration from nature. The structure, which was finished in 2007, takes a biomimic approach to life (Asian building and construction, 2001).

Esplanade theater

Aims

-Energy Efficiency

-Insulated greenhouse

-Isolation of indoor and outdoor environment

-Natural lighting

Design Concept

Outcomes

-Energy reduction by 30%

-Capturing solar energy

-Reduction of artificial lighting by 55%

Figure 22. illustrates the overview of the entire project of the Esplanade Theater
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

Design concept

Sun shades were inspired by the spikes on the durian fruit to avoid overexposure to the sun. The spikes, like the Esplanade theatre's sunshields (Bar-Cohen Y., 2005), function as a protective covering for the fruit. Sunshields made of aluminum are built into each shell. The form is representative of traditional Asian culture and provides a sense of serenity. The sunshades on the east and west façade (Bar-Cohen Y., 2005), which get the most sun and heat, are the longest. The north and south facades, on the other hand, were significantly smaller. The theatre is made of steel. Both the interior and exterior layers are connected by an internal grid and bracing system. Natural materials such as wood and stone were employed in various parts of the theatre. The majority of the floors are stone-paved. Sandstone cladding is also used on the inside walls. The triangle shades are composed of insulating glass with aluminum fittings at the corners.

The playhouse has a number of environmental consequences. The building's dynamic sun shield made it a landmark, and its Biomimic influence gave it a distinct Singaporean identity. At the same time, the Biomimicry method addressed the difficulties that had been expressed by the public (Asian building and construction, 2001). The following are some of the outcomes:

- Provides a comfortable atmosphere for users
- Provides protection from Singapore's heat Allows
- natural light to penetrate while protecting the interior from overheating
- HVAC usage was reduced. Many of the lessons acquired, such as the use of biomimicry, were used to tackle the primary challenges that arose throughout the design process. The application of biomimicry permitted the following:
- Instilled a feeling of culture in the structure
- Patterns and geometry are used
- Use of a sun path to offer protection in places where it is essential

2.7.4.8 Case Study Comparison

Case Study	Levels of concept and biomimicry	Objectives	The comparison was used for a variety of reasons.	Material for Skin Construction	Creating positive skin outcomes
The Council House 2, Melbourne 	Concept: Organism and Behavior at the Tree Level 	Environmental project including a lighthouse Environmentally friendly -Energy efficient -Improve well-being -Respond to the environment -Sustainable	-The use of integral solutions -Model for complicated issues that works -Trees have a protective skin and a louver system. -Trees are extremely energy efficient. -Trees moderate the external climate.	All recycled -Timber -Steel -Concrete	-Air is 100% filtered -Natural illumination and ventilation are reduced by 65% -Natural ventilation is maximized - Works with the natural environment - Shading for visual comfort
The Water Cube, Beijing 	Water bubbles as a concept Organism is the highest level. 	-Build a well-insulated green home -Efficient in terms of energy -Natural light entry -Isolation of the interior and outside environments	-Use of geometric shapes and forms -Reduced surface area due to surface tension of bubbles -Created the illusion of water transparency	-Steel -ETFE sheets	-A 30% reduction in energy use -A 55 percent decrease in artificial illumination -ETFE helped the environment by conserving energy.
The Esplanade Theatre, Singapore 	Level: Organism and Behavior Concept: The Durian Fruit 	Climate considerations: -Follow the sun's route diagram. -Importance of location -Creating a shading system -Energy Efficiency	-Use of geometric shapes and forms -Protection of spikes against heat -Durians form allow for optimum view of the bay	-Aluminum -Insulated -glass Steel	-User comfort - Heat protection -Natural illumination -Lowerened HVAC levels

Table 6. Case study comparison
Source: ((Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

2.7.4.9 Object Matrix

Comparing the case studies and their aims is the next stage in obtaining building skins design guidelines. An analysis of the numerous criteria satisfied throughout the three case studies was done, as shown in [table 0], in order to evaluate the level of energy efficiency and the strength of each case study.

- Case study 1 : CH2
- Case Study 2 : Water Cube
- Case Study 3 : Esplanade theatre

Key:

- Fulfilled ●
- Partially fulfilled ◑
- Not fulfilled ○

DISCUSSION:

The overall cost reductions are a direct result of the many criteria that were achieved during the project. Solar panels, the sun path map, and visual comfort, for example, all contributed to the ultimate result of overall energy savings, HVAC savings, and natural lighting and ventilation. for each case study, shows the proportion of savings (Figure 0)

The most efficient and strongest case study was Council House 2, as indicated in (Figure 0), since its overall savings were the largest when compared to the other two case studies. The most recyclable and renewable material was used in the first case study. It exploited the primary qualities of a tree in terms of energy efficiency and thoroughly filtered its air. It also made the best possible use of its biomimic analogies. However in Davao Vertical housing the suitable case to apply is Case 3 because of the climate context of the case which is tropical climate that as we know it is the same with Indonesia and different from the 2 cases.

Criteria		case 1	case 2	case 3
Efficiency	Energy savings	82%	30%	30%
	Natural ventilation and lighting	65%	55%	45%
	Air filtration	●	○	○
	Working with natural environment	●	●	●
	Heat protection	●	●	●
	Visual comfort	●	●	●
	Following sun path diagram	●	●	●
	Usage Photovoltaic panels and solar panels	●	●	○
	HVAC level lowered	20%	30%	15%
Materials	Recyclable	●	◑	◑
	Renewable	●	◑	◑
Approach	Biology to design	○	○	○
	Design to biology	●	●	●
Biomimic Level	Organism	●	●	●
	Behavior	●	○	○
	Ecosystem	○	○	○

Table 7. Case study comparison table
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

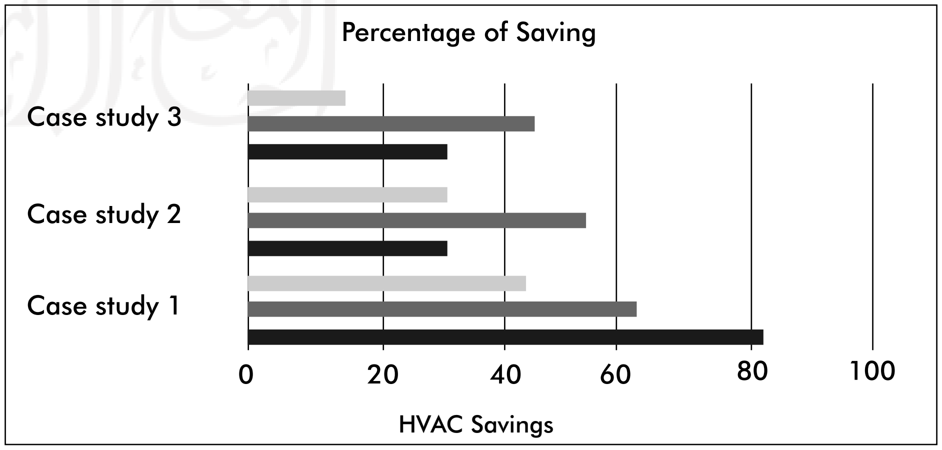


Figure 23. illustrates a comparison of the percentage of savings for each case study
Source: (Dr.Gehan.A.N.Radwana* & Arch. Nouran Osama, 2016)

2.8.5 Precedent for Building envelope to support energy efficient

2.8.5.1 SDU Campus Kolding / Henning Larsen

Architects: Henning Larsen
Area: 13700 m²
Year: 2014

The building's facade is an integral element of it, and together they form a distinct and varied expression. Throughout the day and year, the amount of daylight changes and varies. As a result, Kolding Campus has dynamic solar shading that adapts to changing weather and usage patterns to deliver optimal sunshine and a suitable internal environment along the façade. (Archdaily SDU Campus kolding, 2021)

As the conclusion this design can inspired for the Davao City vertical housing to support the concept of energy efficient by creating facade that allow daylight enters the building and allow airflow enter the building through facade and minimizing the heat gain from the sun.

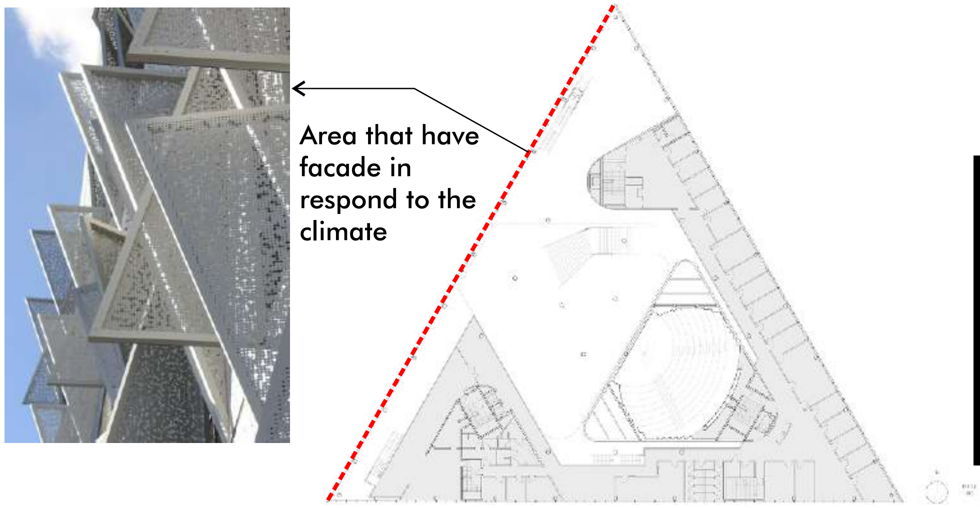


Figure 24. SDU Campus Kolding / Henning Larsen
Source: (Archdaily SDU Campus kolding, 2021)

Figure 25. SDU Campus Kolding / Henning Larsen facade
Source: (Archdaily SDU Campus kolding, 2021)

2.8.5.2 The Esplanade Theatre, Marina bay

Architects: Michael Wilford & Russell Johnson
Year: 2002

Sun shades were inspired by the spikes on the durian fruit to avoid overexposure to the sun. The spikes, like the Esplanade theatre's sunshields (Bar-Cohen Y., 2005), function as a protective covering for the fruit. Sunshields made of aluminum are built into each shell. The sunshades on the east and west façade (Bar-Cohen Y., 2005), which get the most sun and heat, are the longest. The north and south facades, on the other hand, were significantly smaller. The theatre is made of steel. Both the interior and exterior layers are connected by an internal grid and bracing system.

As the conclusion this design can inspired for the Davao City vertical housing to support both the concept of energy efficient and Biomimetic by creating facade that inspired by durian spike and facade that protect the building from overexposure to the sun.

Figure 26. Esplanade cultural center facade
Source: (Esplanade cultural center, 2021)

Figure 27. Esplanade cultural center
Source: (Esplanade cultural center, 2021)

CHAPTER THREE 03

DESIGN EXPLORATION

Space programming
Siteplanning
Building system concepts
Interior unit
Building envelope concept
Material and construction

Chapter Overview:

The idea exploration in this chapter is based on the design research from the previous chapter. A few options were created based on the theory and variables, from which the best one could be chosen.

Conceptual Framework

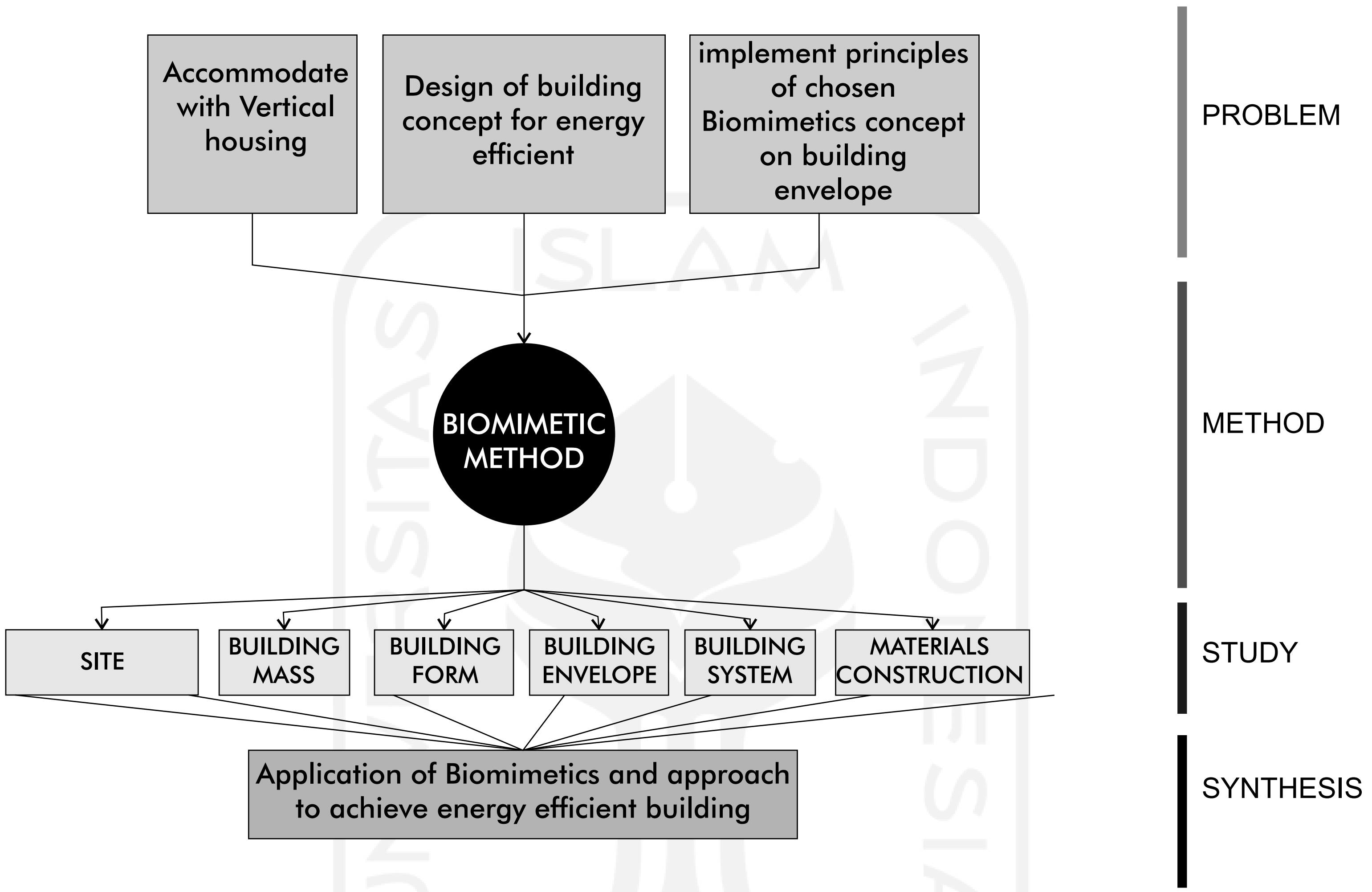


Figure 28. Design Framework
Source: (Author, 2021)

To ensure that the design process in this building proceeds in a logical order, a conceptual framework is created, starting with the broadest design components such as climate, location, and neighborhood and working down to the smallest design elements such as ME systems and other building systems. Furthermore, the conceptual framework is utilized as a guide and benchmark to ensure that the design process in this building stays on track with the specified topic and theme. This design framework was also created to ensure that the complete building design can address all planned design issues. A biomimetic design method is used to create a conceptual foundation for a community hub:

3.1 Space Programming for Davao City Vertical Housing

3.1.1 User Activity and it's function in Davao City Vertical Housing

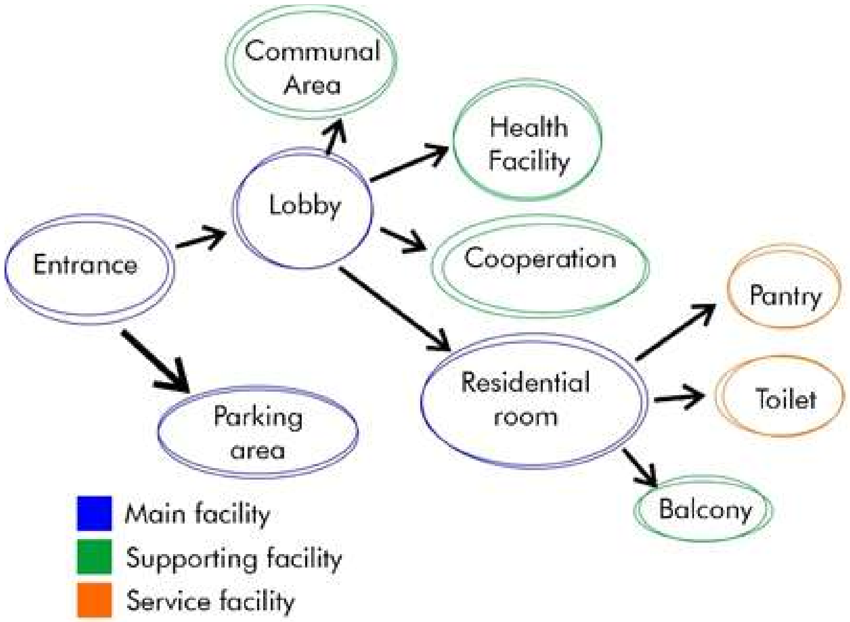


Figure 29. Occupant Room Movement Flow
Source: (Author, 2021)

Initially the occupants will pass through the entrance / building entrance, then there will be 2 further room options. Parking aims to accommodate residents who bring motorized vehicles. Later there will be basement parking and parking on the ground floor. Meanwhile, going directly to the lobby aims for residents who do not use vehicles. The lobby room will also be the axis or center of the support room in this vertical residence. The lobby will have access to a prayar room, Communal Area, and Health Facilities. Then the occupants will go to their respective residential rooms on the 1st floor. The residential rooms will have 4 main rooms, namely a bedroom, pantry, toilet and balcony.

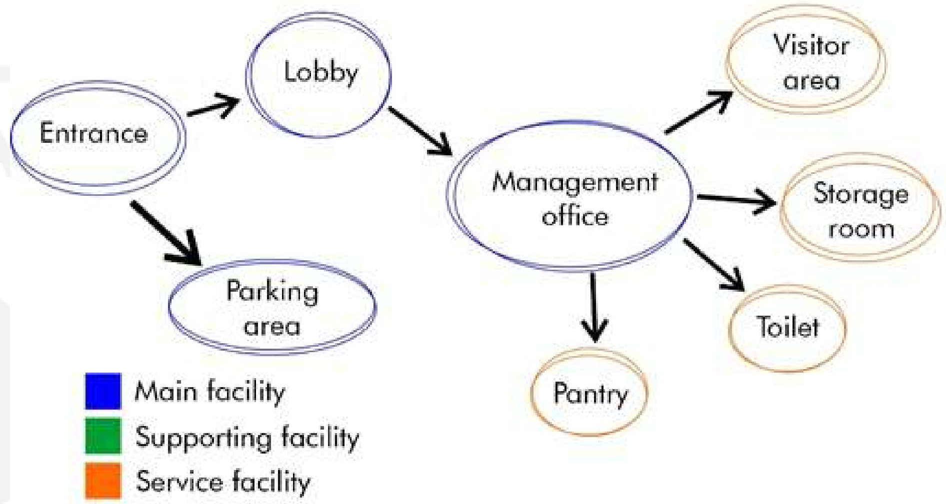


Figure 30. Management Room Movement Flow
Source: (Author, 2021)

The manager will also start the movement from the entrance, then will be given 2 options, namely lobby and parking. Then the manager will go directly to the manager's office where access can be through the lobby. The management office will have 5 main rooms, namely a living room, work room, pantry, toilet and warehouse

The rooms in this residence will be divided into 3 types, namely:

1. Main Room, which is a room that will often be used as an activity area for users building
2. Supporting Room, which is a room that will support activities and activities building users
3. Service Room, which is a room that will support other rooms.

3.1.2 Space Programming for the vertical housing

The amount of space below is determined based on the standard size of space from several sources such as Architect Data, Standard Time Saver for Buildings, and Architect Handbooks. The size of the space is also determined based on the author's analysis of the studies that have been carried out in accordance with the typology of the building and the applied concepts.

No	Floor	Room name	Area(m2)	Amount	Total (m2)
1	Ground Floor	Lobby	195.48	1	195.4
		Management Room	80	1	80
		Information Center	18	1	18
		Commercial areas	480	1	480
		Food Stall	239	1	239.3
		Health facilities	120	1	120
		Living Room	66	1	66
		Pantry	14	1	14
		Praying room	101	1	101.25
		Cooperative	18.75	1	18.75
		Control Room	6.65	1	80
		Public toilets	113.5	1	6.65
		People with disabilities	113.5	1	133.35
		Vertical Circulation Area	130	2	260
		Circulation	378.8	1	378.8
2	1st Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
No	Floor	Room name	Area(m2)	Amount	Total (m2)
3	2nd Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
4	3rd Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
5	4th Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
6	5th Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
5	Rooftop	Circulation	234.3	1	234.35
		Roof	1543.2	1	1543.2
		Roof water tank			
	Total Building area				

Table 8. Programming
Source: (Author, 2021)

3.1.3 Determining area based on building codes

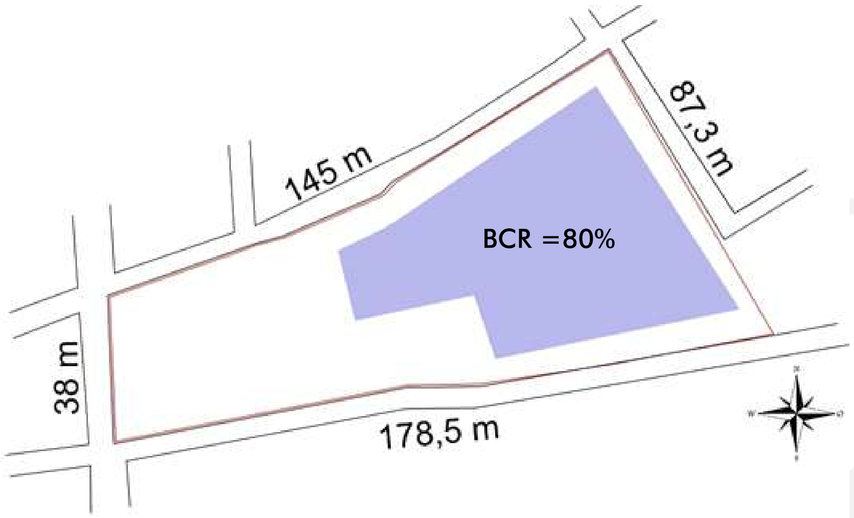


Figure 31. BCR maximum of 80%
Source: (Author, 2021)

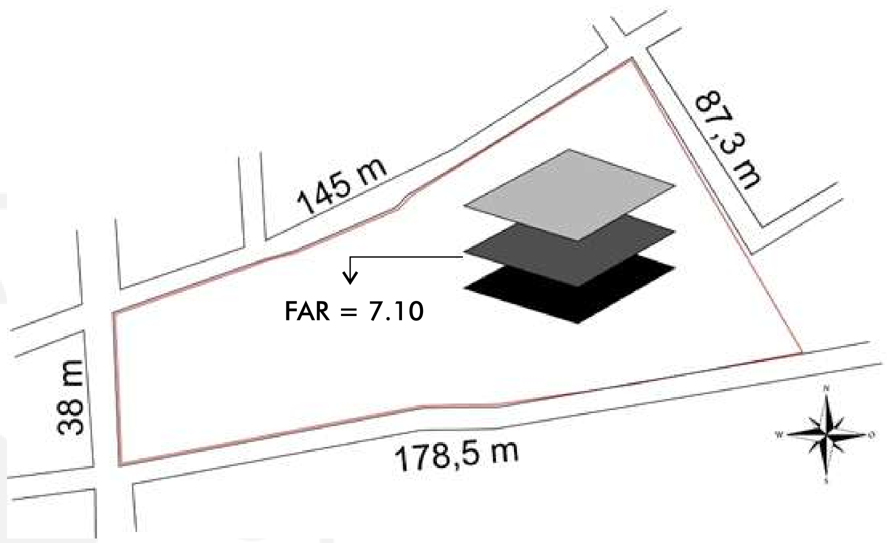


Figure 32. FAR = 7.10
Source: (Author, 2021)

Building Coverage Ratio (KDB)	Maximum of 80%
Floor Area Ratio (KLB)	7.10
Building boundaries (GSB)	8 meters

CALCULATIONS

BCR = Total area x BCR
= 15.300 x 60% → Using 60% of BCR to provide more green area in the site
= 9.180 m2

FAR = FAR x Total area
= 7.10 x 15,300
= 108.630 m2

Total floors = FAR / BCR
= 108.630 / 9.180
= 11.8
= 11 Floors

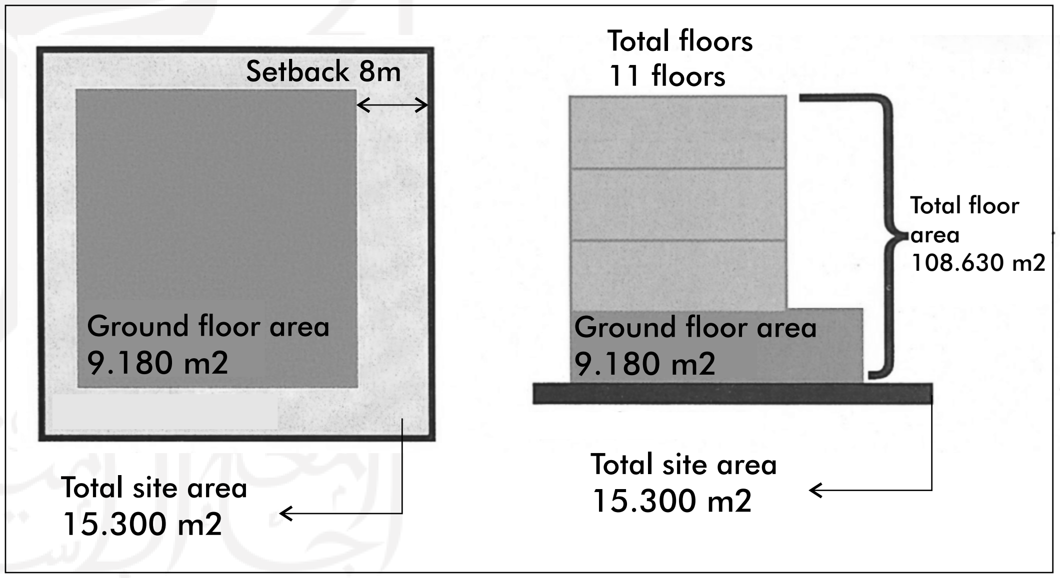


Figure 33. Illustration of total building areas
Source: (Author, 2021)

It concluded that the design of Vertical housing is using mid-rise building because to support and considering affordability for the concept. The building required a elevator because it reaches the minimum requirement of 5 storeys.

3.1.4 Resettlement for the informal settlers in the site

The site has a high-density population of informal settlers in total of 104 houses in the area. On average of 4.9 people in 1 family roughly the total of user of the vertical housing is 520 people and also considering extended family therefore the vertical housing should able to resettle it.

The size of unit consider the standard of Davao city which minimum of 36 sqm, and to accommodate average of 8 people per family the unit should be 3BR type of unit which has 54 to 108 sqm.

Figure 34. Existing houses in the site
Source: (Author, 2021)

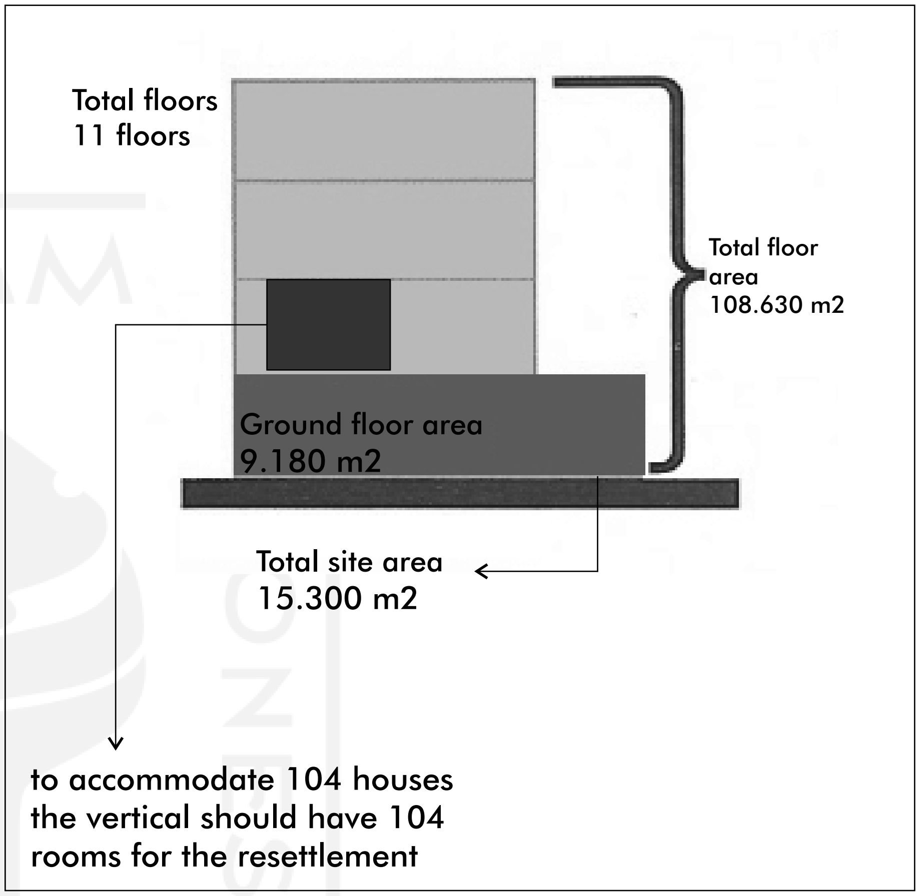


Figure 35. Total of rooms for the vertical housing
Source: (Author, 2021)

3.2 Site planning for energy efficient based on Davao City climate respond

3.2.1 Site zoning responding to Davao City climate

Site zoning is divided into three zones, namely the building mass zone, the pavement zone and the green zone. Zoning plots are placed based on existing conditions around the site in Davao. The pavement zone is located at the front of the site and is mostly for circulation and vehicle parking areas. In the green zone is placed around the building with the aim of supporting the Energy efficient concept in Vertical buildings and reducing the noise that coming from south part of the site, namely by creating harmony with the environment around the site. The building mass zone is in the middle of the site where the vertical housing are built

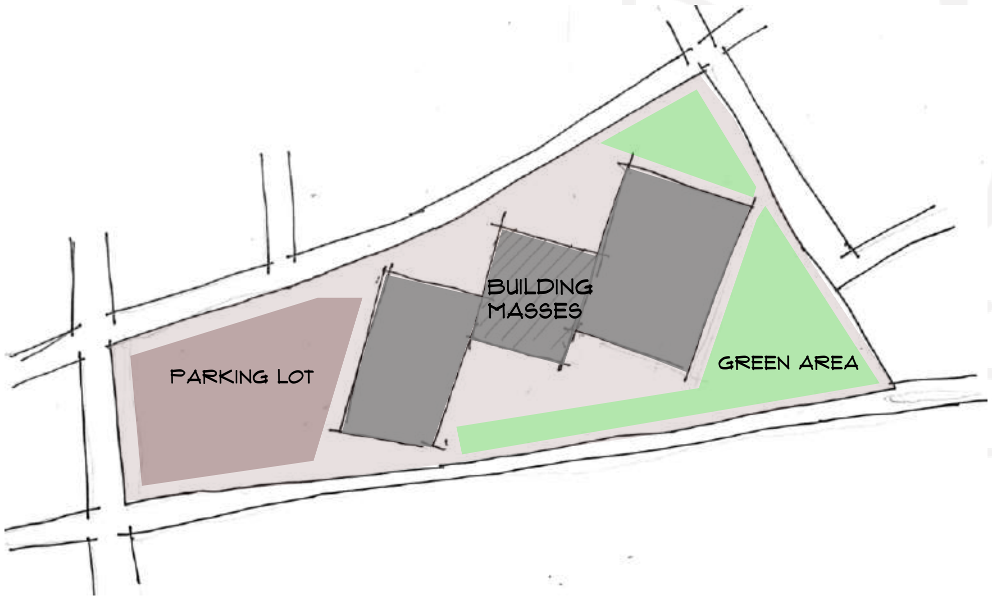


Figure 36. site zoning
Source: (Author, 2021)

3.2.2 Function arrangement inside of the building mass

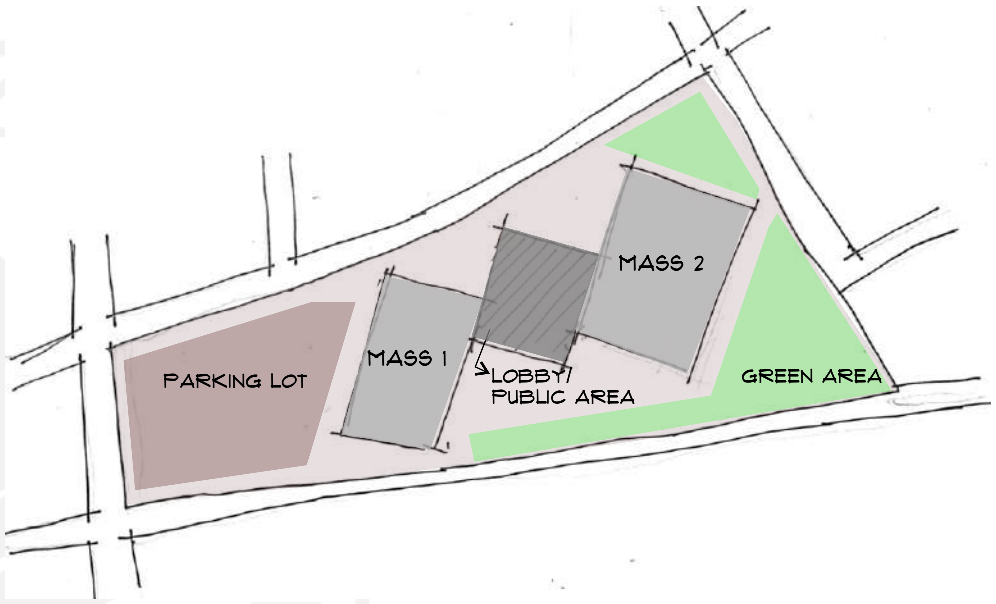


Figure 37. Function arrangement inside of building mass
Source: (Author, 2021)

Lobby for main space and as well as entrance could be placed in the center of building this to user easily access and circulate from both 2 building masses. Followed up 2 big masses for the main function of rooms for the vertical housing. Supporting function are place outside of the mass zone namely green area and parking lot.

3.2.3 Building mass arrangement concepts responding to Davao City climate

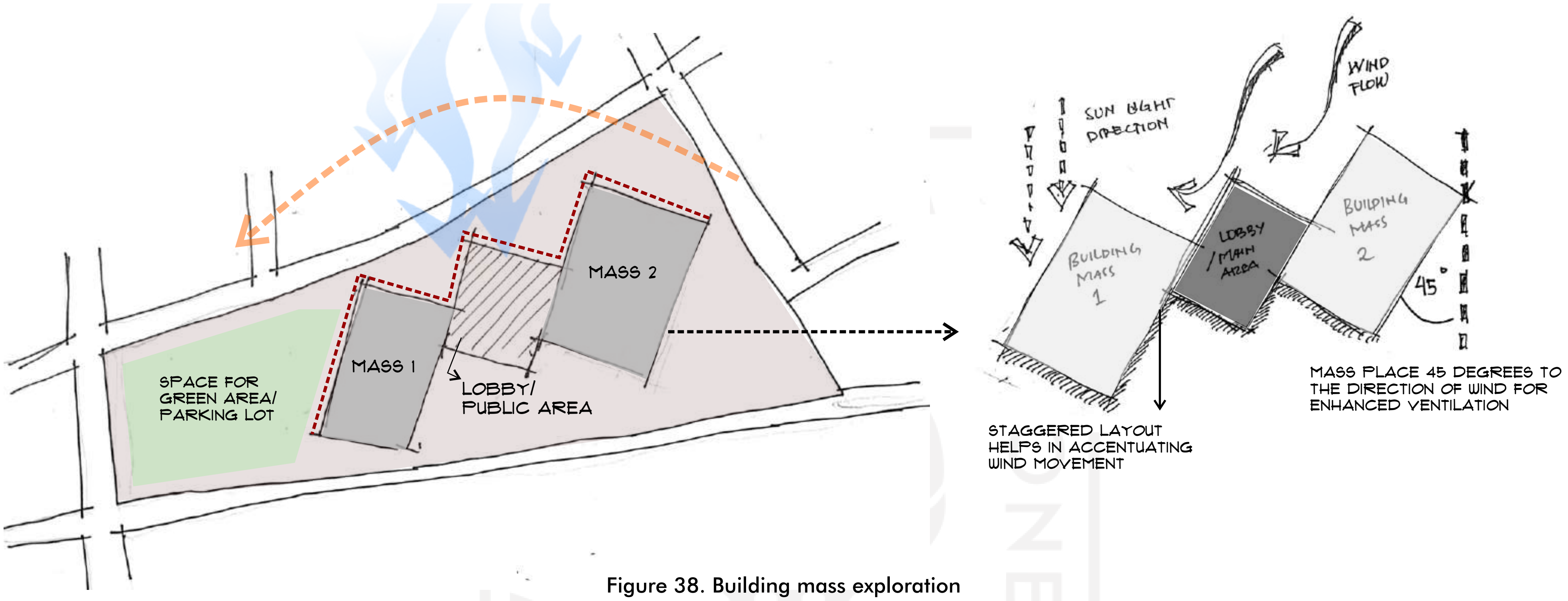


Figure 38. Building mass exploration
Source: (Author, 2021)

It can be seen from the Climatology Data in Chapter 2 that first, sunshine arrives mostly from the east side of the site, and second, the highest wind current comes from the north to the south. The reaction of the sun would most likely be determined by the mass of the building. The wind current course, on the other hand, needed to be steered a little to ensure that the wind breezed through the site and the building. Directing the highest wind current. As a result, achieving a stronger cross ventilation scheme in a building mass would be simpler.

As the result the vertical housing have 3 masses and for the center it is for the lobby which will be lower that the mass 1 and mass 2. The mass orientation turned 45 degrees to avoid direct hit of the sunlight this will help reduced the heat gain by the building. The staggered layout also optimize passive cooling for the building because it helps in accentuating wind movement.

3.2.4 Access circulation to support user's accessibility in the vertical housing

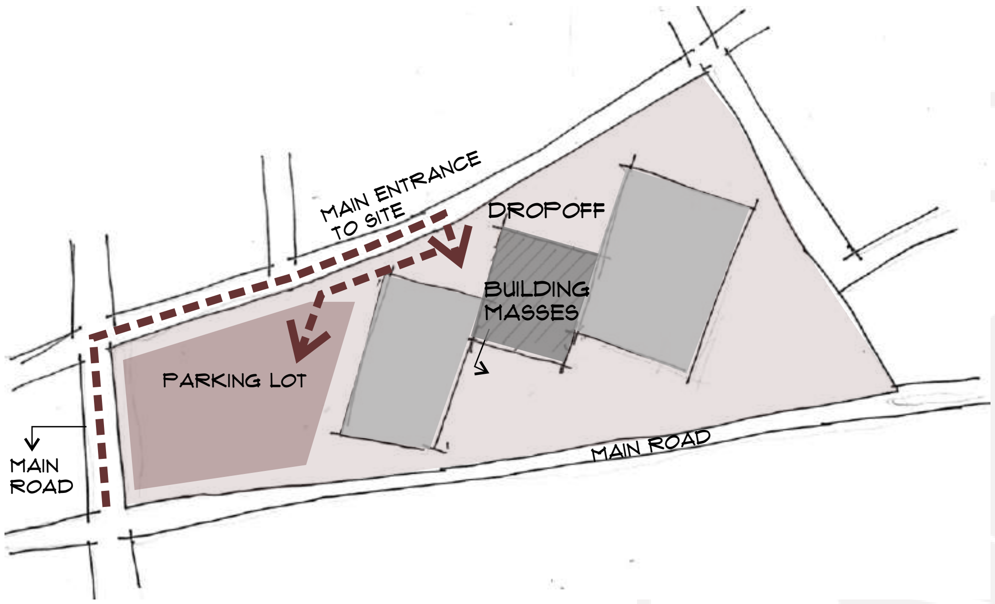


Figure 39. Access circulation
Source: (Author, 2021)

The main entrance is from the secondary road simply because the main road to busy and crowded it will cause traffic. Because of the different locations and placements of each function on the site. Users going via the inner lobby, users should be able to travel from one location to another through a lobby/ public area. This accessibility idea can be supplemented by a specialized circulation building in the middle, from which people can reach the both mass on the side.

3.2.5 Vegetation Arrangement to Reduce Surrounding Noise from the main road and responding to windrose

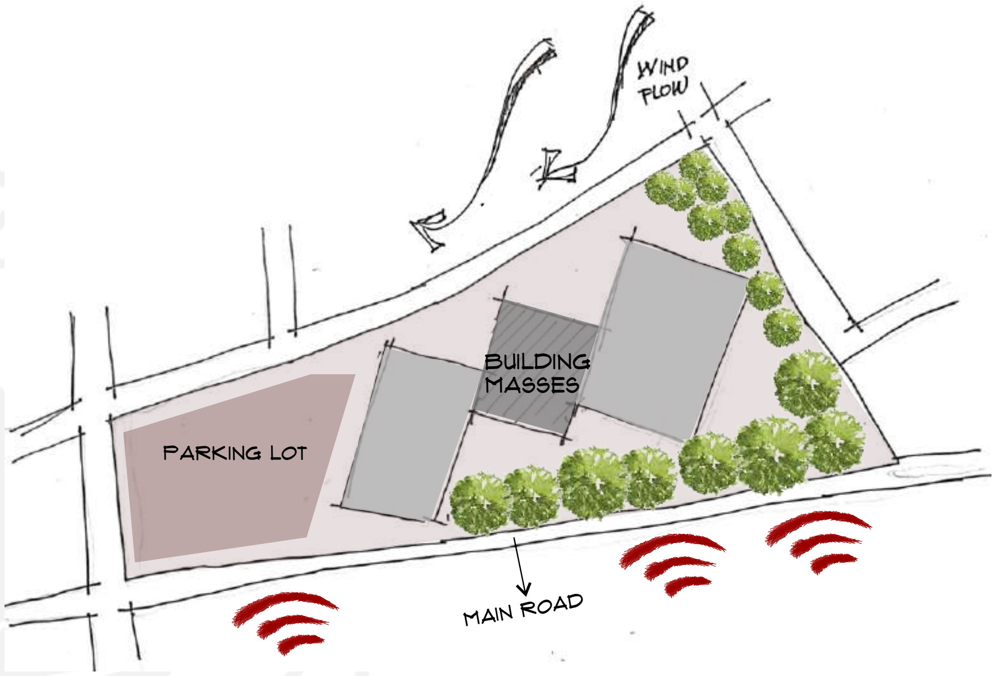


Figure 40. Trees arrangement for noise reduction
Source: (Author, 2021)

In terms of the noise source, it is necessary to cancel the noise at the source. Because the noise source is located in the south side of the area, some vegetation must be planted there to cancel or reduce the noise. In the case of windrose, because the greatest wind was blowing from north to south, a change in windflow was required. Windflow may be directed to the building mass using vegetation as a wind guider, supporting cross ventilation system concept.

3.3 Buildings form and its systems concepts for energy efficient and Biomimetics approach

3.3.1 Energy efficient passive approach for vertical housing buildings form

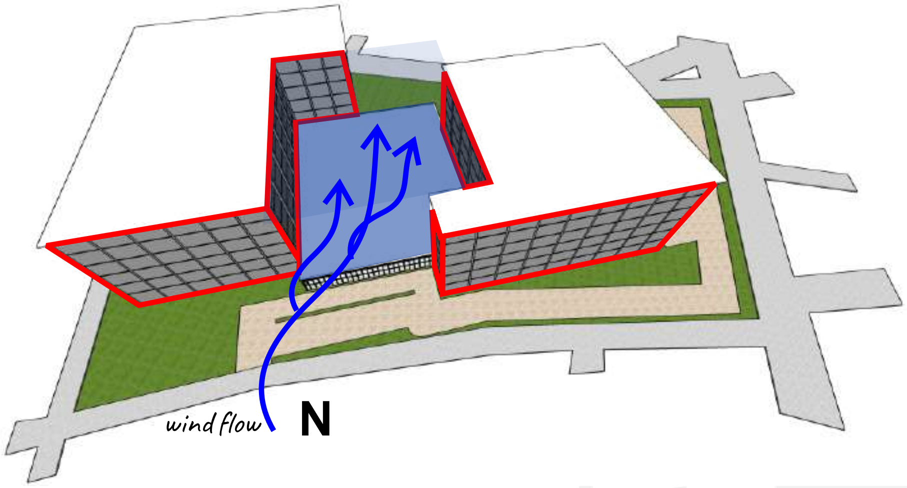


Figure 41. Form exploration of energy efficient
Source: (Author, 2021)

The form is created by 2 masses and using void at the center this help accentuating the wind the comes from north part of the site. The 2 masses formed into L shape so that it also give more surface to hit by the wind.

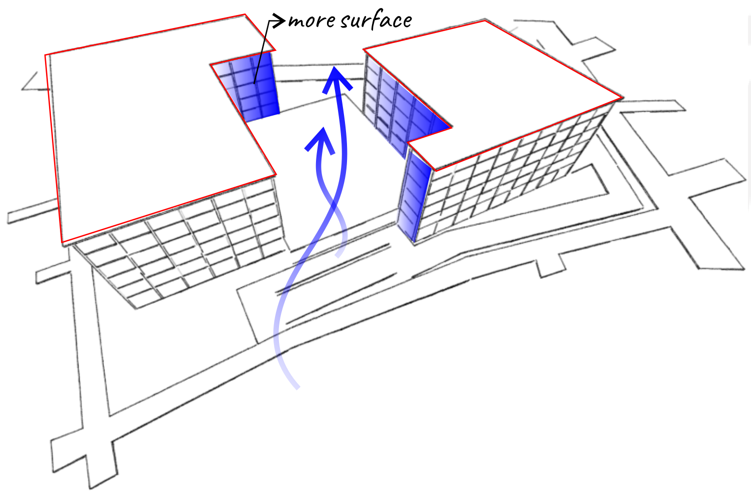


Figure 42. L shaped form
Source: (Author, 2021)

3.3.2 Applying principle of Biomimetics durian concept to the building mass

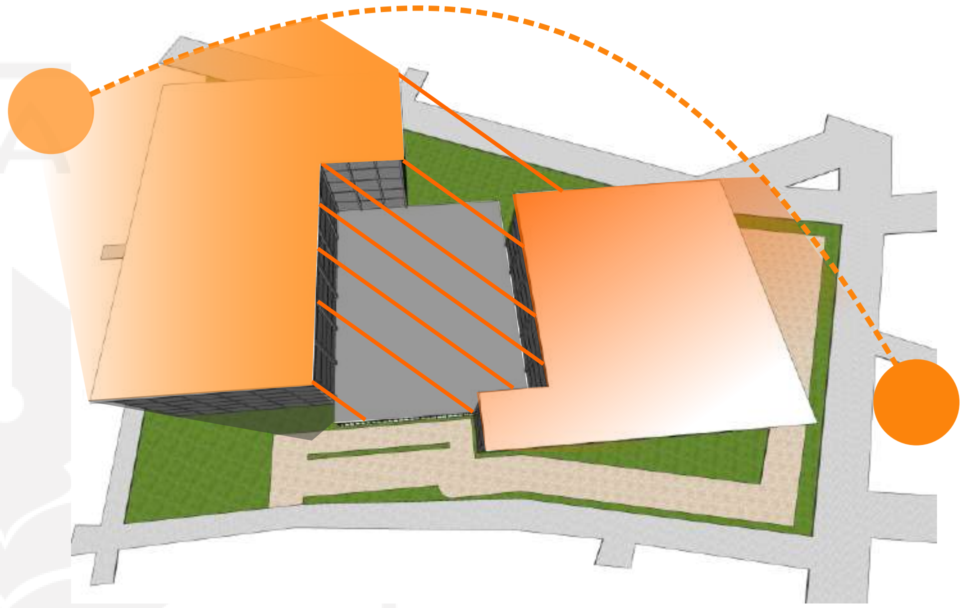


Figure 43. Biomimetic principle of form
Source: (Author, 2021)

From the analytical study of chapter 2 it concluded that the durian concept has the principle of the spike protecting the fruit from overexposure sun. The two masses were inspired by the spikes on the durian fruit to avoid overexposure to the sun. As the result the two masses located at the east and west part of the site which get the most sun and heat are the longest this concept is to minimize direct heat from the sun. on the other hand it allow wind to pass through into the center of the masses.

3.3.3 Davao City vertical housing passive building systems for energy efficiency

3.3.3.1 Application of facade building supporting energy efficient performance

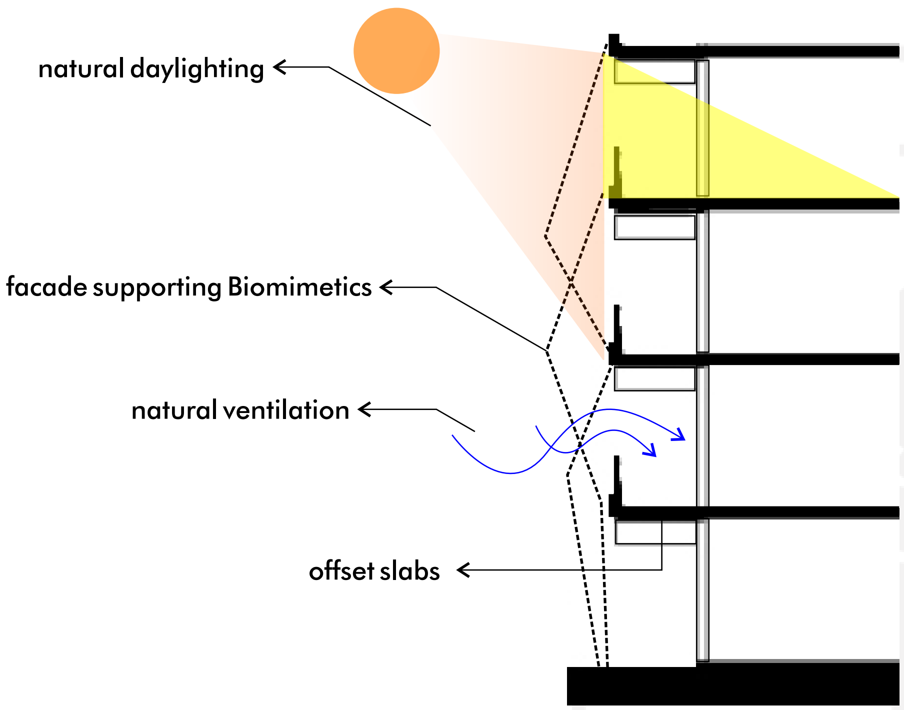


Figure 44. Building section showing passive system
Source: (Author, 2021)

The Davao vertical housing is applied with passive strategies including daylighting, natural air ventilation and building orientation. Using also the facade of durian principle applied in the part of the building but still allowing wind and sunlight enters. Also in attempt of minimizing direct sunlight the slab on every floor is offset and the length will be based on the calculation of sunpath simulation.

The Davao vertical housing is not using active AC because the temperature of Davao City is not too high for the comfort of people therefore passive systems can solve it and high humidty and can be solve by cross ventilation.

3.3.3.2 Application of void in the building for Cross Ventilation and Daylighting purpose

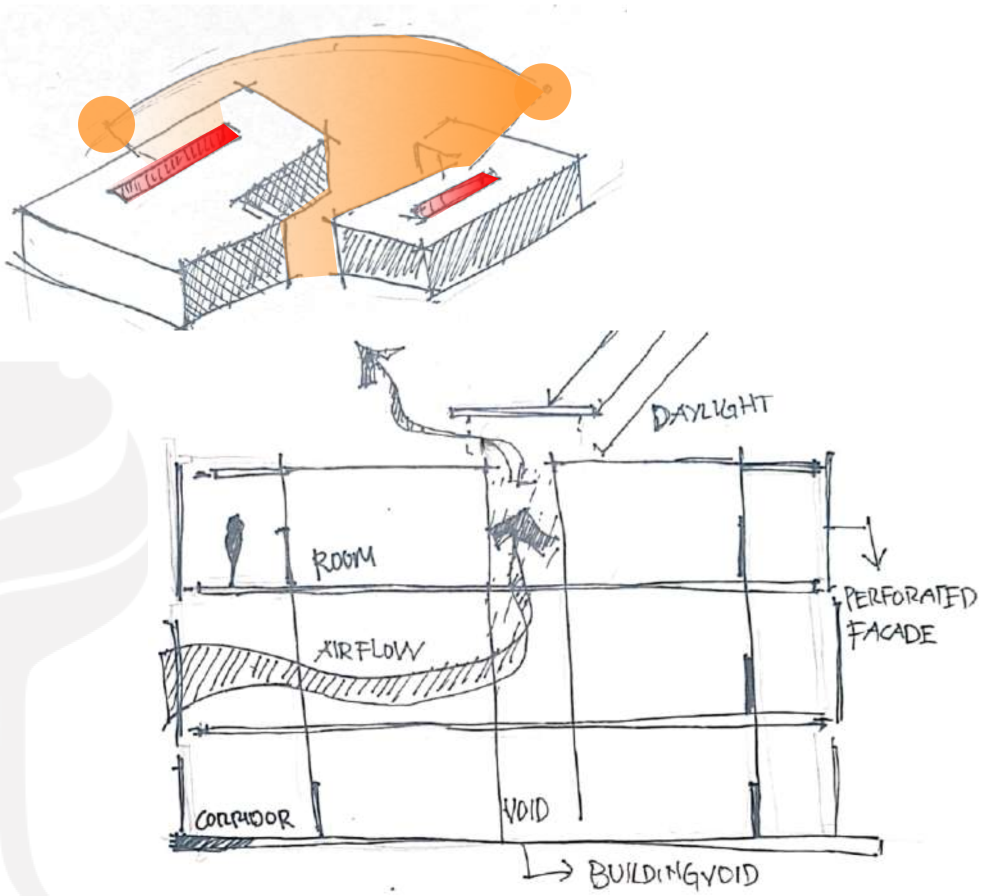


Figure 45. Building vioid
Source: (Author, 2021)

The introduction of voids is one of the most significant architectural solutions for improving natural ventilation in Vertical housing. The void is the passive architectural element found in the center of both masses. It's critical to think about how voids are configured in structures to improve natural ventilation, especially in multi-story dwellings.

This also helps to reduce the high humidity in Davao city which will affect in the comfort for the user

3.3.3.3 Electrical building system for Davao City vertical housing

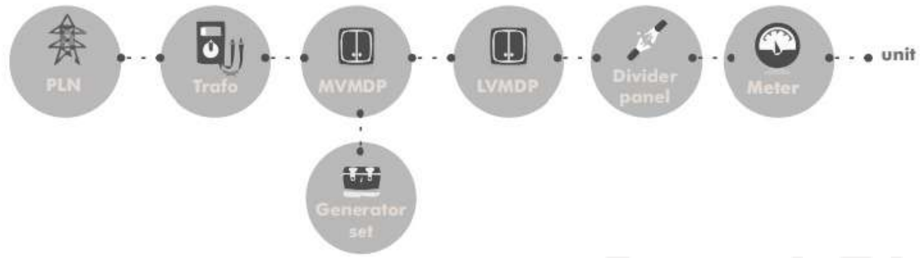
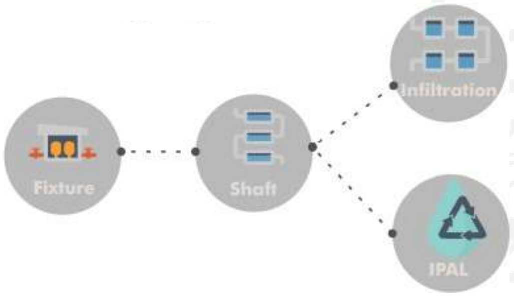


Figure 46. Electrical scheme
Source: (Author, 2021)

The building will use 2 electrical source. Main source come from the PLN and the alternative using Generator set. The system from PLN, the voltage changed by transformator, then go to Medium Voltage Main Distribution Panel (MVMDP) then to Low Voltage Main Distribution Panel (LVMDP), then to Divide panel in every story. then go to meter unit on every unit for electricity distribution.

3.3.3.4 Electrical building system for Davao City vertical housing



Source: (Author, 2021)

The system of sewerage water, the pipe go to IPAL separated to grey water and black water. Shaft sewerage at the core and continue to Sewerage treatment.

3.3.3.5 Clean water distribution system for Davao City vertical housing

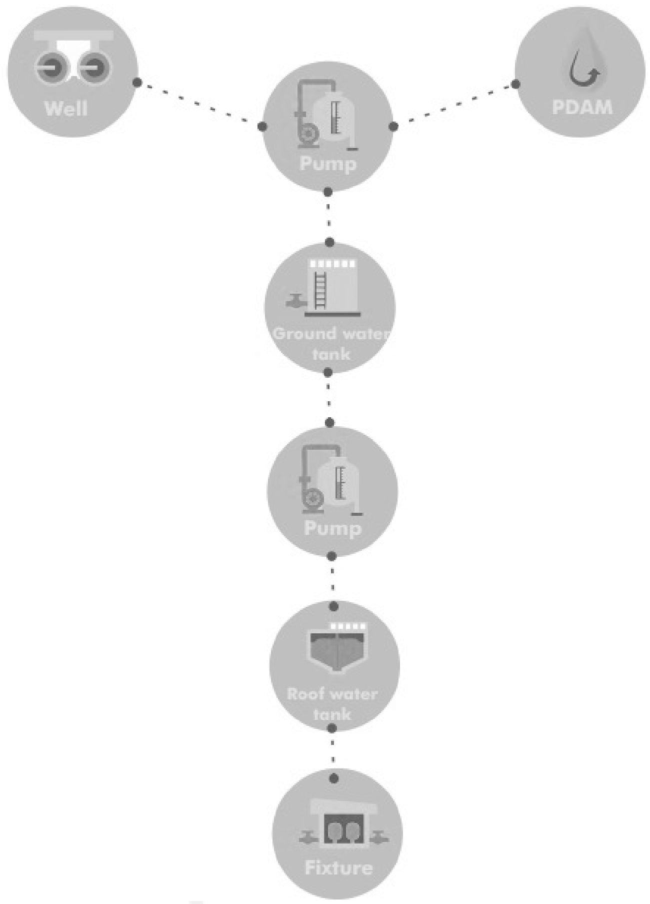
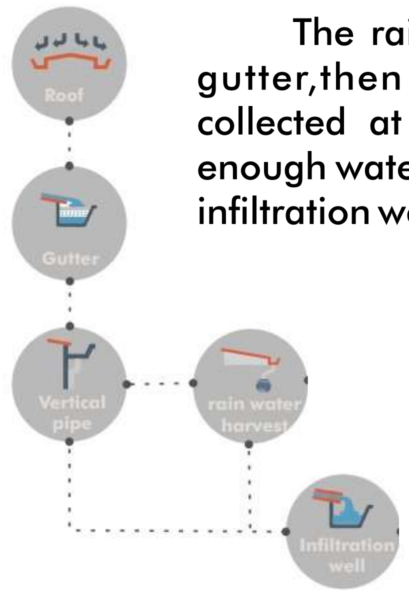


Figure 48. Water distribution scheme
Source: (Author, 2021)

The system of clean water is using down feed system which is the water from source pumped to ground tank first then pumped to roof tank, then distributed to all the floor by gravitation force.

3.3.3.6 Drainage system for Davao City vertical housing



The rain water will be distributed to gutter,then vertical pipe and will be collected at rain water harvest, or if its enough water it will delivered directly to the infiltration well.

Figure 49. Electrical scheme
Source: (Author, 2021)

3.3.3.7 Fire protection system for Davao City vertical housing

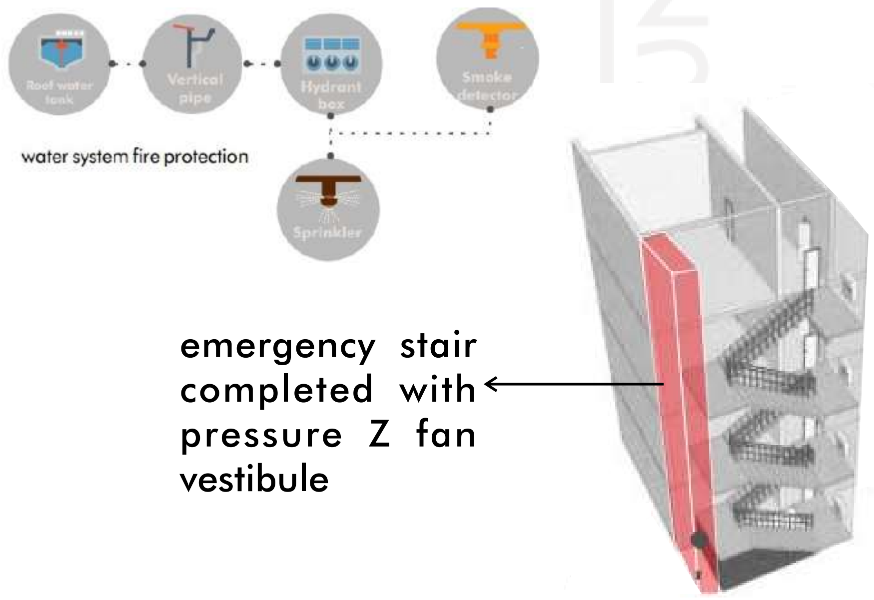


Figure 50. Fire protection system
Source: (Author, 2021)

3.4 Vertical housing building interior to accommodate resettled users

3.4.1 Space configuration for Vertical housing room and Ventilation indoor quality

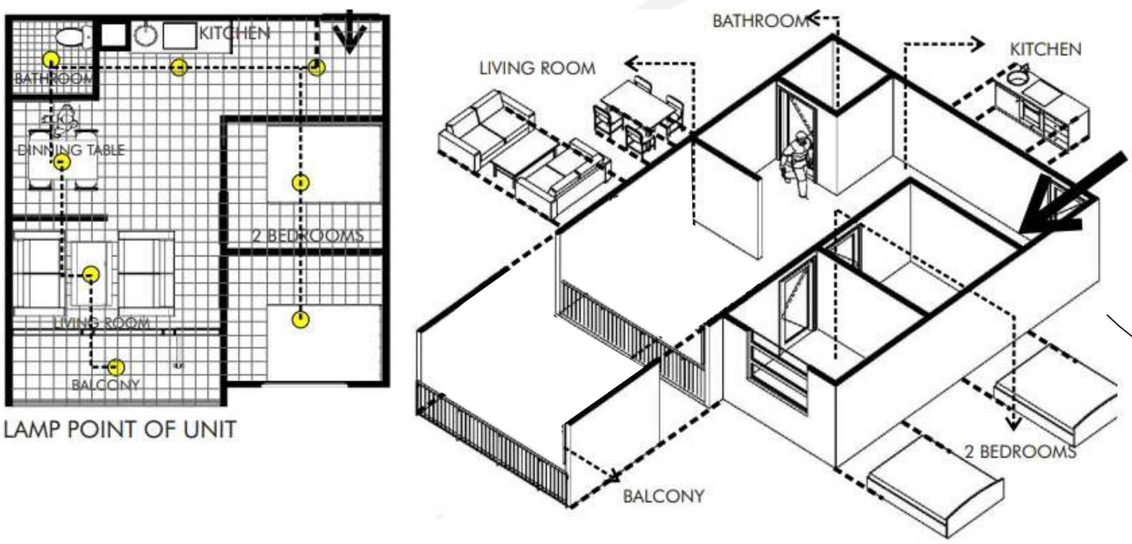


Figure 51. Space configuration
Source: (Author, 2021)

Maintain and improve air quality inside room by doing the introduction of outdoor air in accordance with the ventilation rate requirements for health of building users.

tested space configuration that is suitable for the heat comfort mainly the hot side is in the edge to counter that it need shading on it.

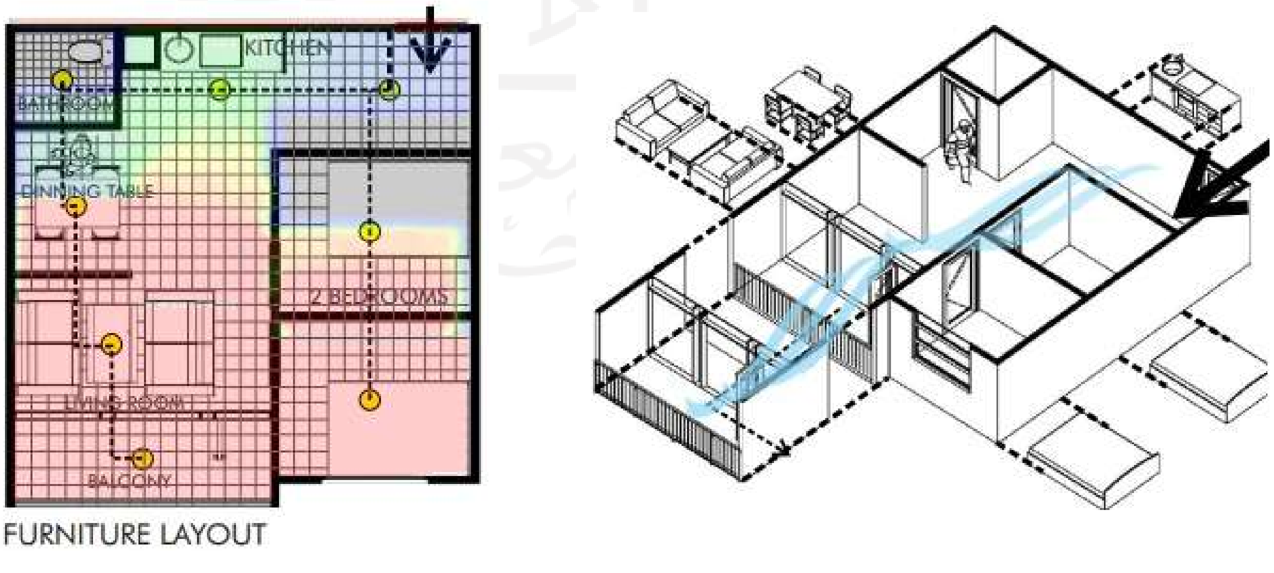
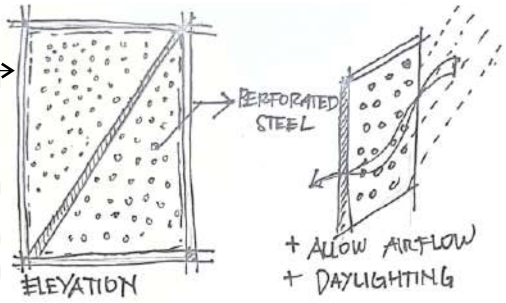
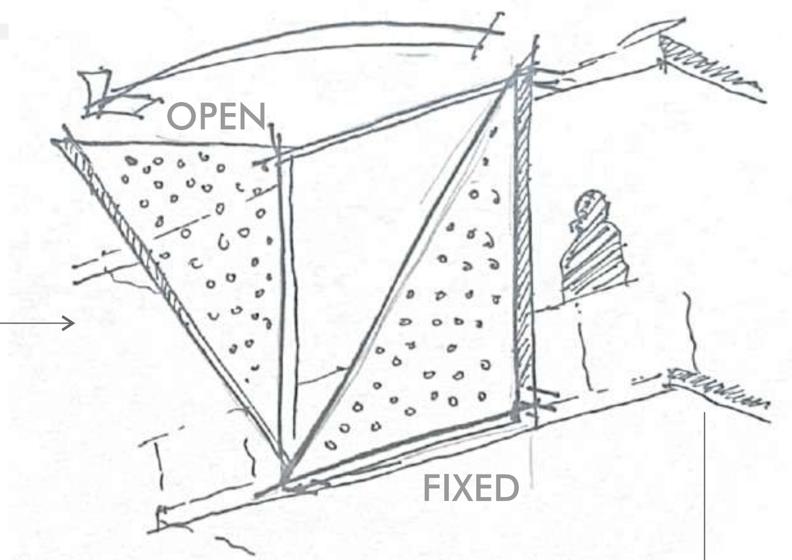


Figure 52. Illustration of wind and heat in the unit
Source: (Author, 2021)

3.5 Building envelope concepts considering Biomimetics and energy efficient

3.5.1 Biomimetic approach for vertical housing building envelope





The building envelope in this building is used for daylight control and allowing airflow pass through the facade and avoiding direct sunlight enter the building. Using facade that inspired from SDU Campus Kolding where the facade has dynamic solar shading that adapts to changing weather and usage patterns to deliver optimal sunshine and a suitable internal environment along the façade.

The designed also to support the concept of cross ventilation in the building to solve the high humidity of Davao City, mainly the material of facade using perforated steel as a way wind flow enter the building. The design of facade support the concept of Biomimetic principles of Durian where the facade act as a spike protecting building from overexposure sun.

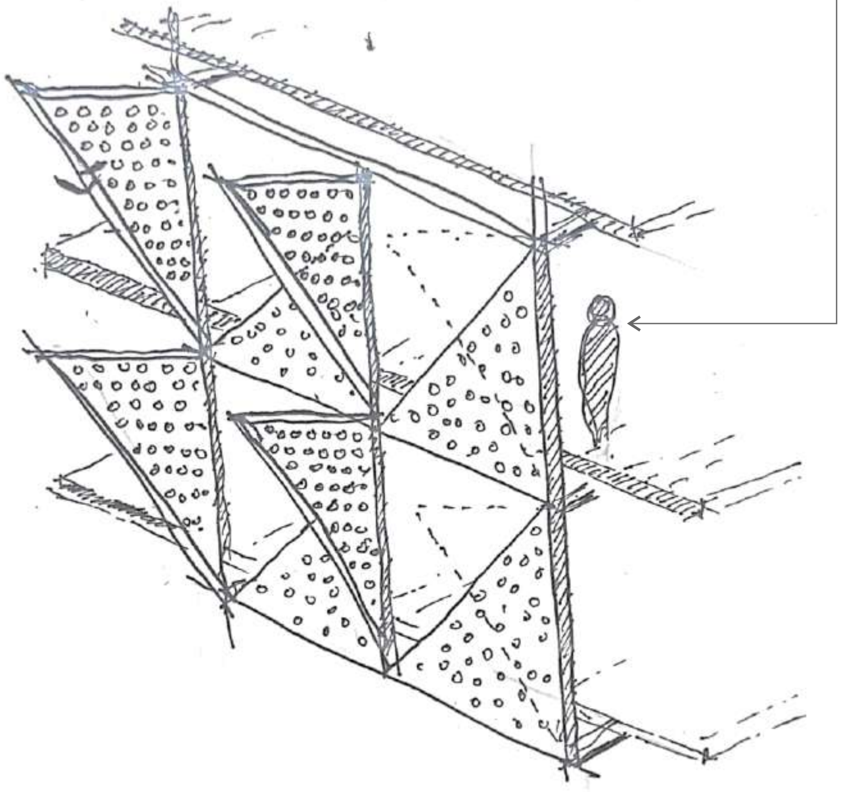


Figure 53. Building envelope exploration
Source: (Author, 2021)

3.5.2 Building elements responding to energy efficient concept

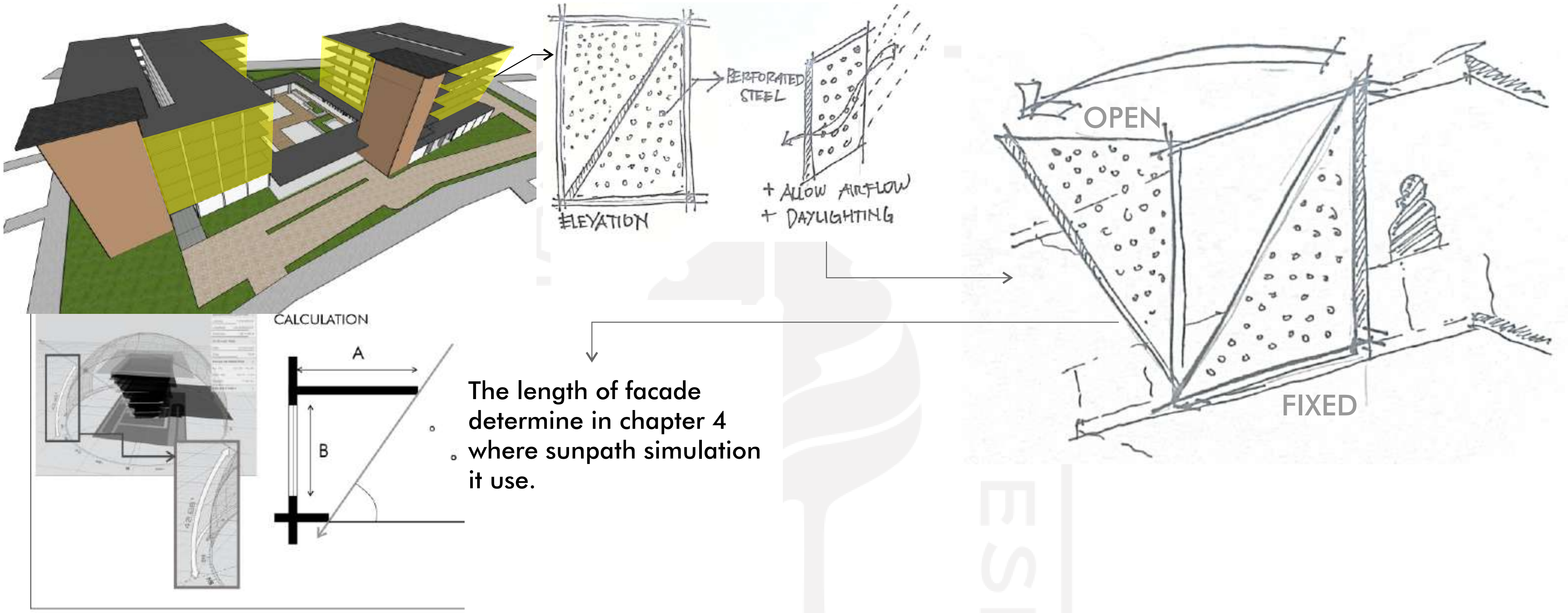


Figure 54. Building elements exploration
Source: (Author, 2021)

In supporting energy efficient building the Vertical housing is not using active AC because the average temperature of Davao City based on chapter 2 exploration is not too high and it can be solve by passive design. As a result by adding facade that allowing windflow and daylight enter the building it makes the building cooler.

It also makes cross ventilation system in the building in respond of high humidity in Davao City. The length of the facade in every part of the is determine by sunpath that will be used in chapter 4

3.6 Building materials and constructions considering Biomimetics and energy efficient concept

3.6.1 Performance of chosen material for energy efficient approach

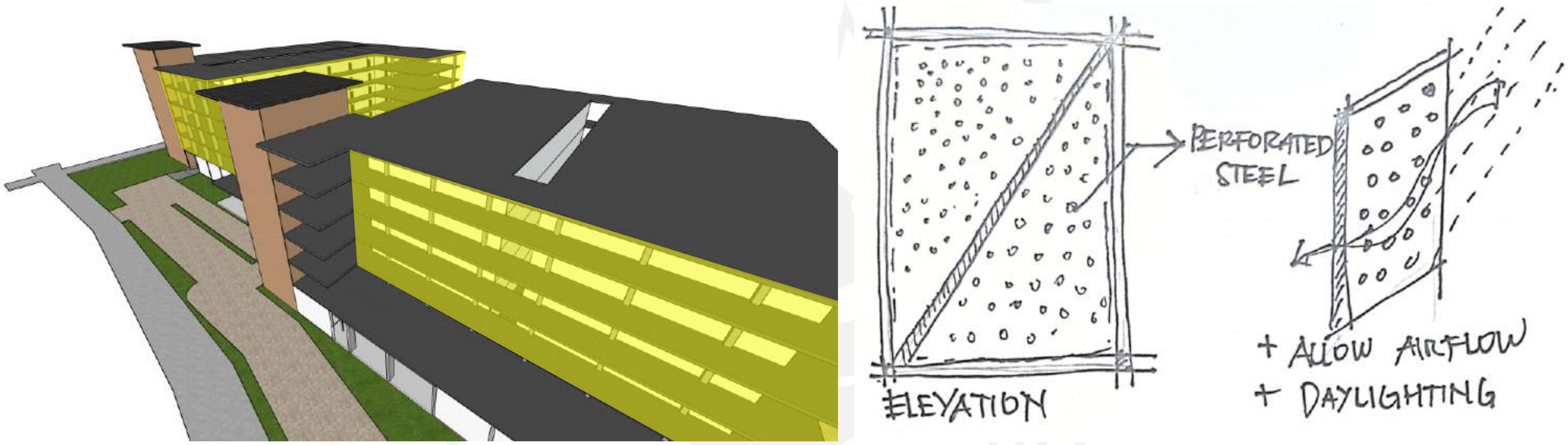


Figure 55. Material performance
Source: (Author, 2021)

Perforatedmetal sheet is technological and can be used for noise reduction, since the holes in the metal sheet are involved in sound absorbing. Perforated material can also be effectively used for shielding electromagnetic fields. A great effect of Perforatedmetal can be achieved when they are used as barrier for solar radiation and wind. Nowadays, glass panels of building's windows and doors are well insulated and therefor in cold seasons of the year less energy is consumed for heating premises.

The use of perforated material not only serves as a shielding, but also is able to contribute to the formation of the necessary cooling to reduce energy consumption with using solar screens. Perforated steel can scatter direct sunrays and provide better comfort protecting from the excess of direct light

CHAPTER FOUR 04

DESIGN DEVELOPMENT

Design framework
Vertical housing unit design
Integration of siteplan & building mass
Building form and mass design
Building elements and systems
Building unit and interior design
Biomimetics concept on building envelope design
Building design simulation
Design result

Chapter Overview:

The chapter contains final design based from concept exploration done in previous chapter. The final design will focus on solving main problems regarding Biomimetics on envelope and energy efficient performance to building.

4.1 DESIGN FRAMEWORK

This section 4 describes the design outcomes as well as talks about the design progress of the previously presented concepts. The notion of energy efficient and design on builiding envelope, the concept of building form based on a Biomimetic approach, and the concept of designing building elements are among these concepts. These designs additionally address the design issues that were previously identified.

4.2 Vertical housing Unit Design for Social problem

4.2.1 Building explode showing units for the resettlement

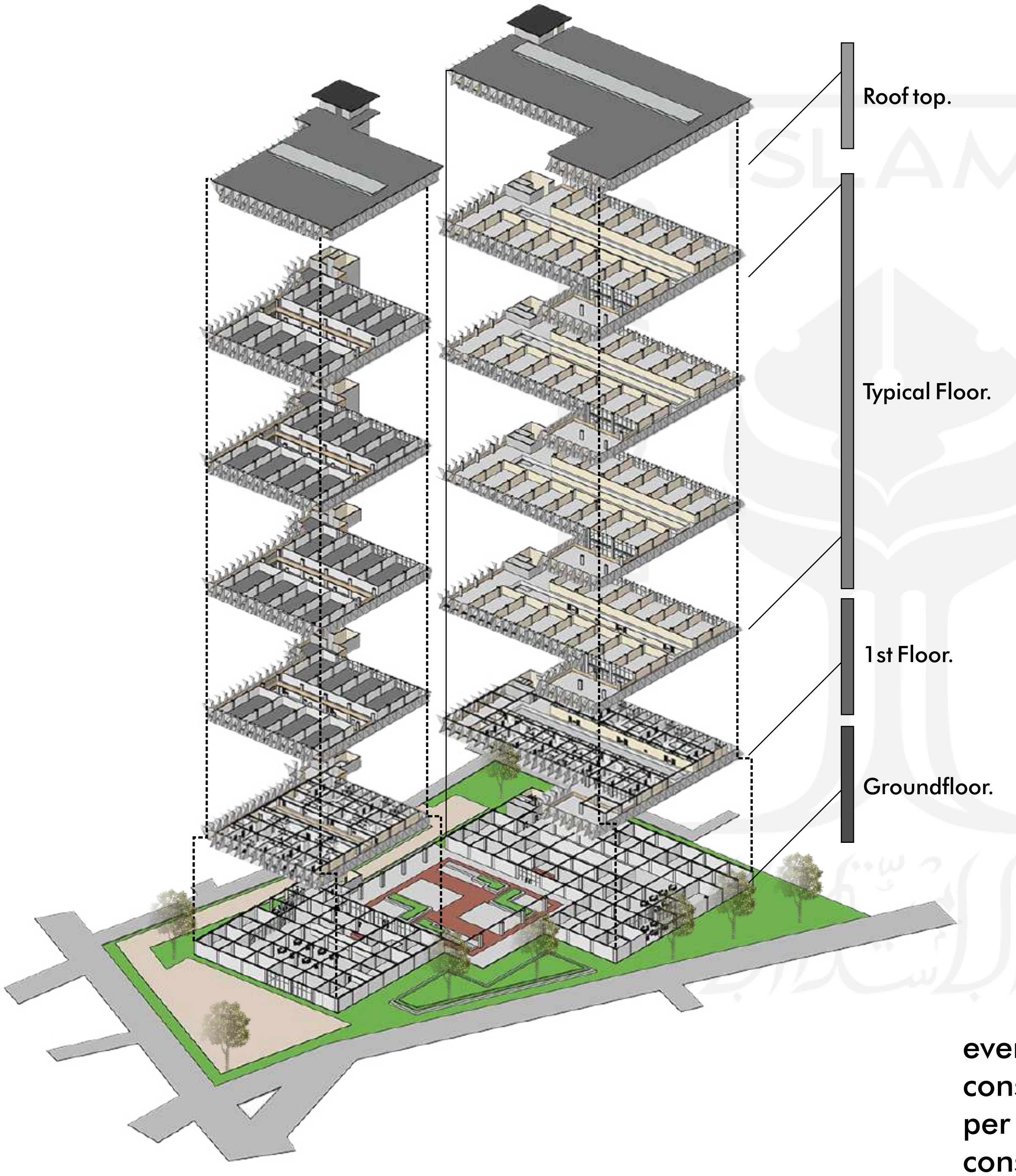


Figure 56. Building Explode
Source: (Author, 2021)

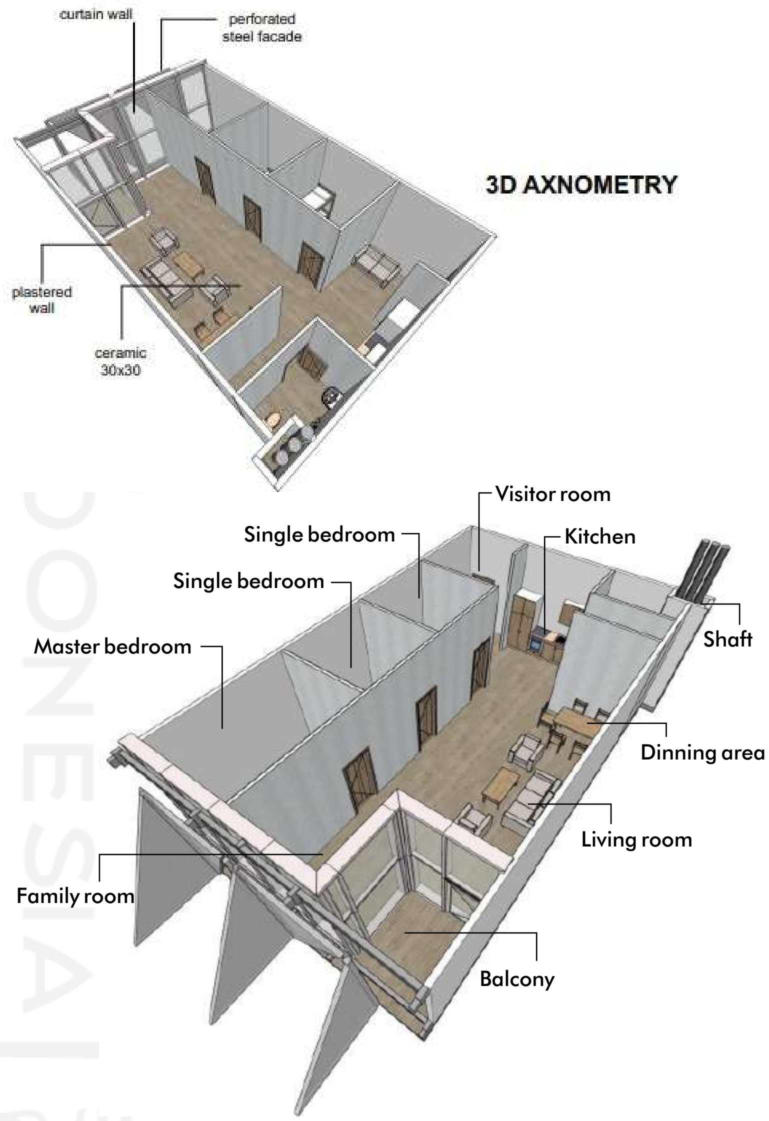
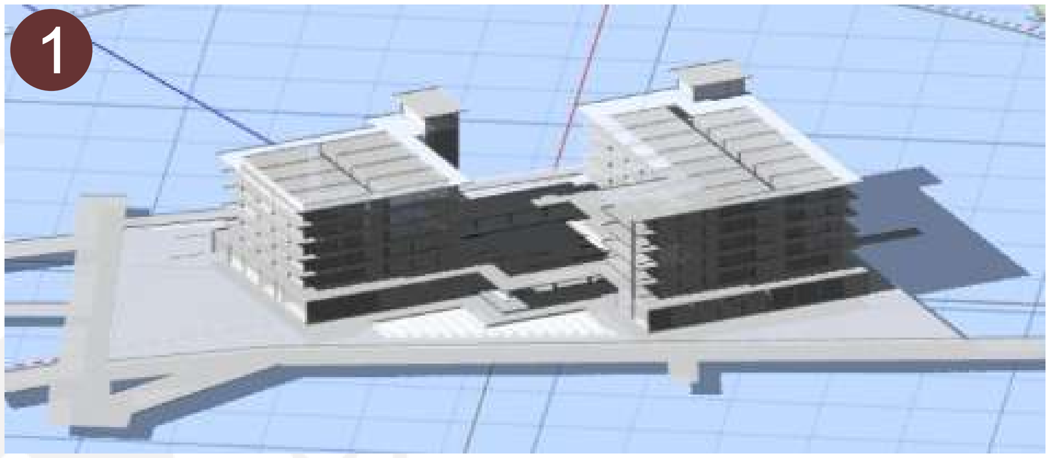


Figure 57. Axonometry unit
Source: (Author, 2021)

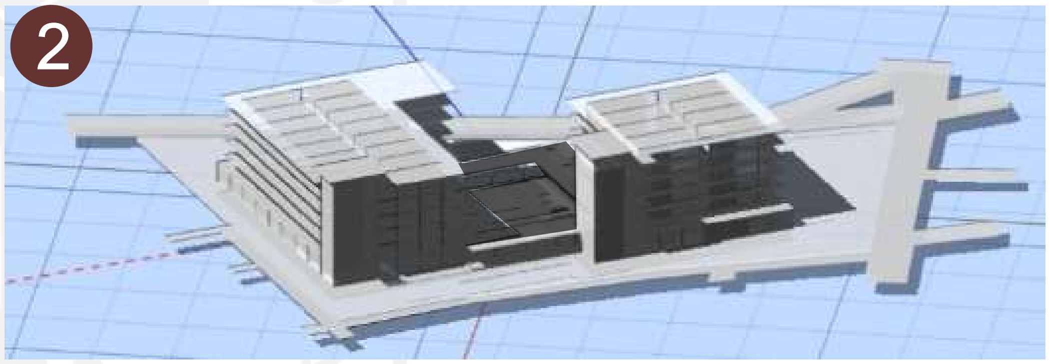
The total of units in the building is 105 and every unit can accommodate 5 people. The building consist of 5 floors for residential and have 21unit per floor. The unit have total area of 105.2 m2 consist of masterbedroom, 2 single bedroom, living room, family room, balcony, dinning area, kitchen, visitor area, and bathroom.

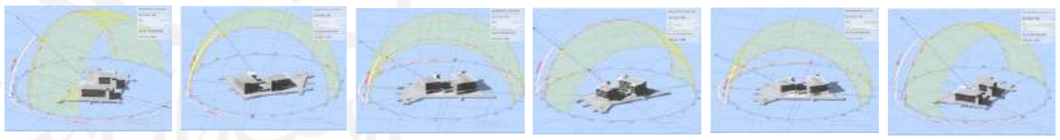
4.3 Integration of Siteplanning and Building mass

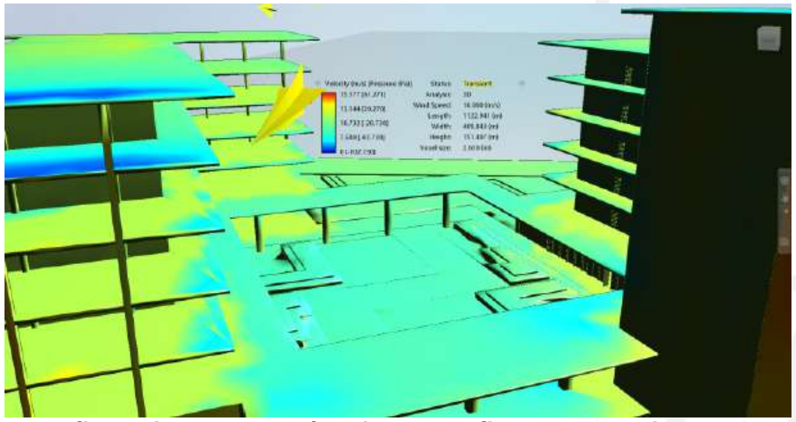
4.3.1 Building Mass Arrangement to Maximize Passive Systems



sunpath simulation no. 1 in January 21at 15:00
sunpath simulation no. 2 in Januaru 21 at 9:30
As the result it shaded in between the 2 masses







360 flow design result where airflow entered between building mass

Figure 58. Passive system for building mass result
Source: (Author, 2021)

It can be seen that the building mass avoid each other direct sun radiation from morning to afternoon, while the center of building is protected by huge mass both side of it. it can be seen that the building mass placement respond from the strongest wind flow to provide airflow in the building and cross ventilation system, while the center of it will have communal area/ open plaza for users that not hit by direct sunlight radiation

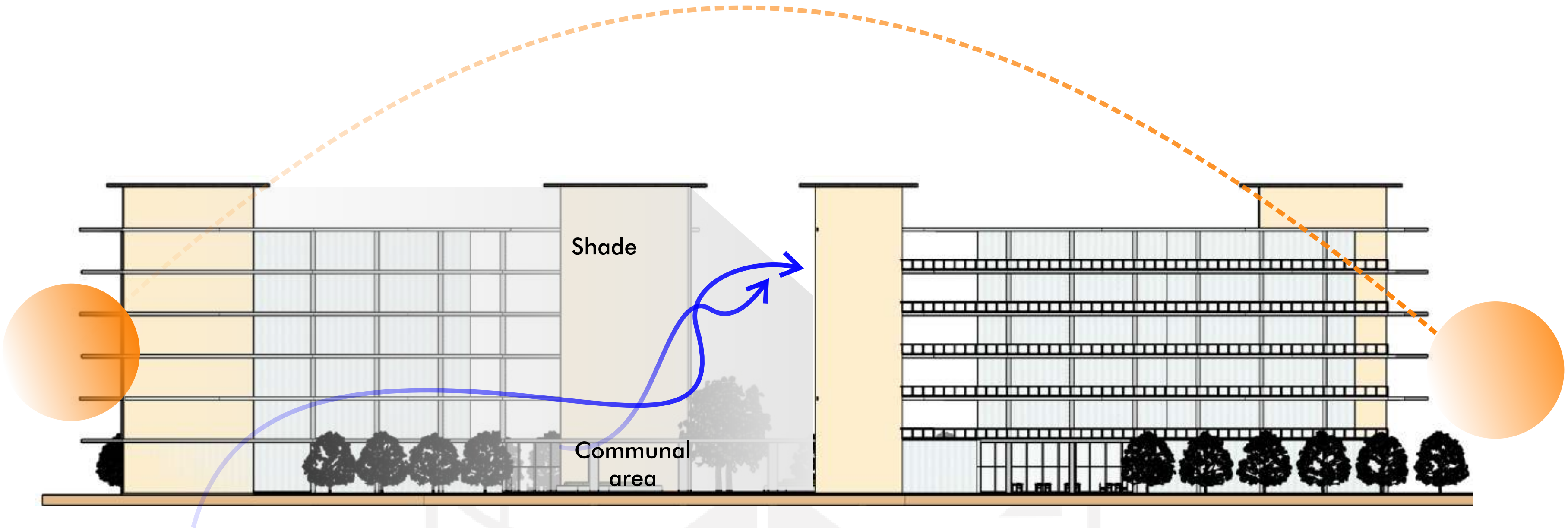


Figure 59. Elevation
Source: (Author, 2021)

It can be seen that the building mass placement respond from the strongest wind flow to provide air circulate in the building, while the center of it will have communal area/ open plaza for users that not hit by direct sunlight radiation. To prove the airflow the simulation is using 360 flow design and as the result in between the masses it have color teal which means the air circulate succesly.

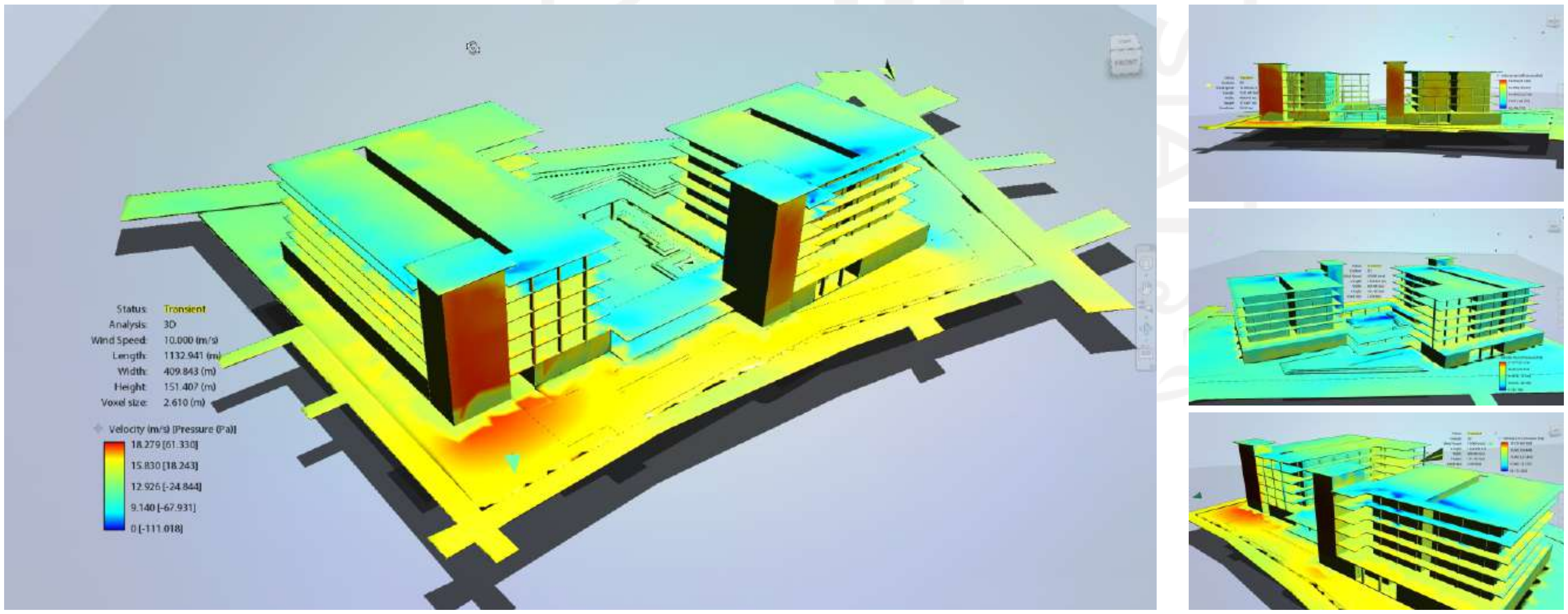


Figure 60. 360 flow design simulation
Source: (Author, 2021)

4.3.2 Function Arrangement inside of the Building Mass

Figure 61. Siteplan building access
Source: (Author, 2021)

Communal area/ open plaza positioned in front as the building's primary attracting functions, followed up by entering the building for 2 direction. The plaza serve as the focal point of the site, allowing visitors to move freely from one function to the next. Supporting features placed on the back.

SITEPLAN

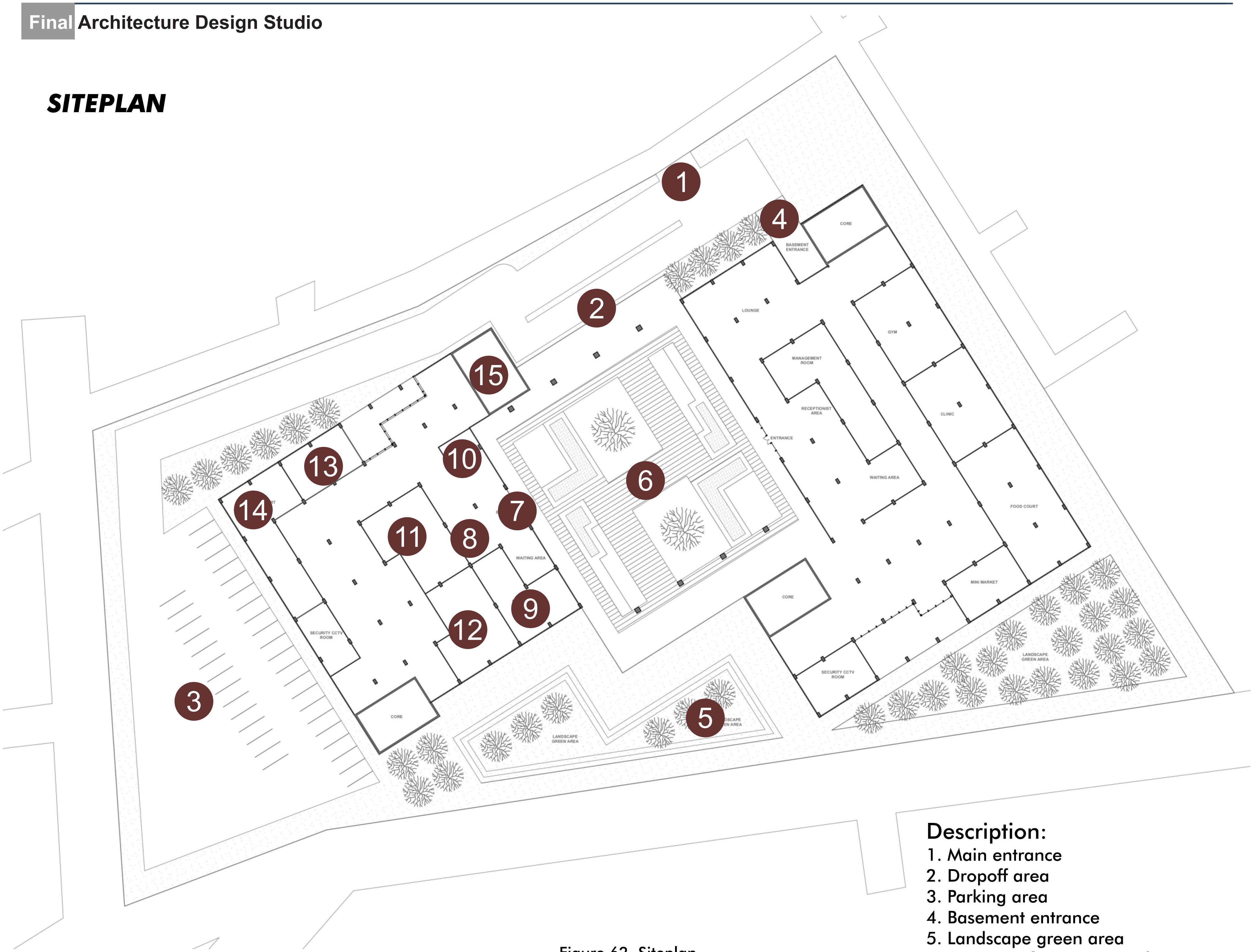


Figure 62. Siteplan
Source: (Author, 2021)

Description:

1. Main entrance
2. Dropoff area
3. Parking area
4. Basement entrance
5. Landscape green area
6. Communal area/ open plaza
7. Building Entrance
8. Receptionist area
9. Management office
10. Lounge
11. Gym
12. Clinic
13. Mini market
14. Foodcourt
15. Vertical circulation

3D Visualization

Figure 63. 3D Visualization
Source: (Author, 2021)

4.3.3 Vegetation Arrangement to Reduce Surrounding Noise

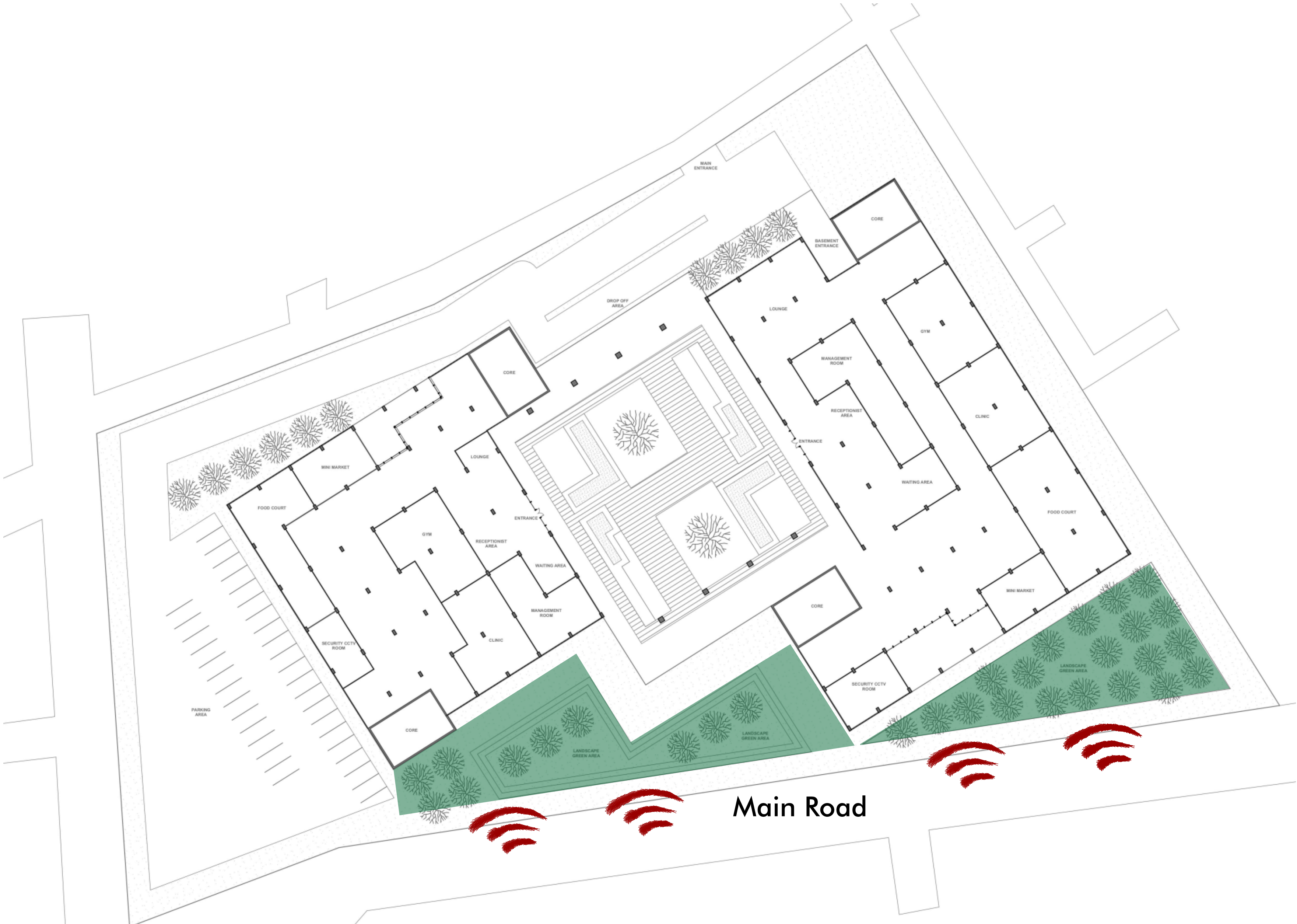


Figure 64. Vegetation Arrangement Reason
Source: (Author, 2021)

One considerating factors in deciding landscaping is noise source. As for noise source, it is needed to cancel the noise directly from the source. Due to the noise source comes from south part which is main road of the site, some vegetations are needed to be arranged there to cancel or minimize the noise.

4.3.4 Access Circulation to Support User's Accessibility

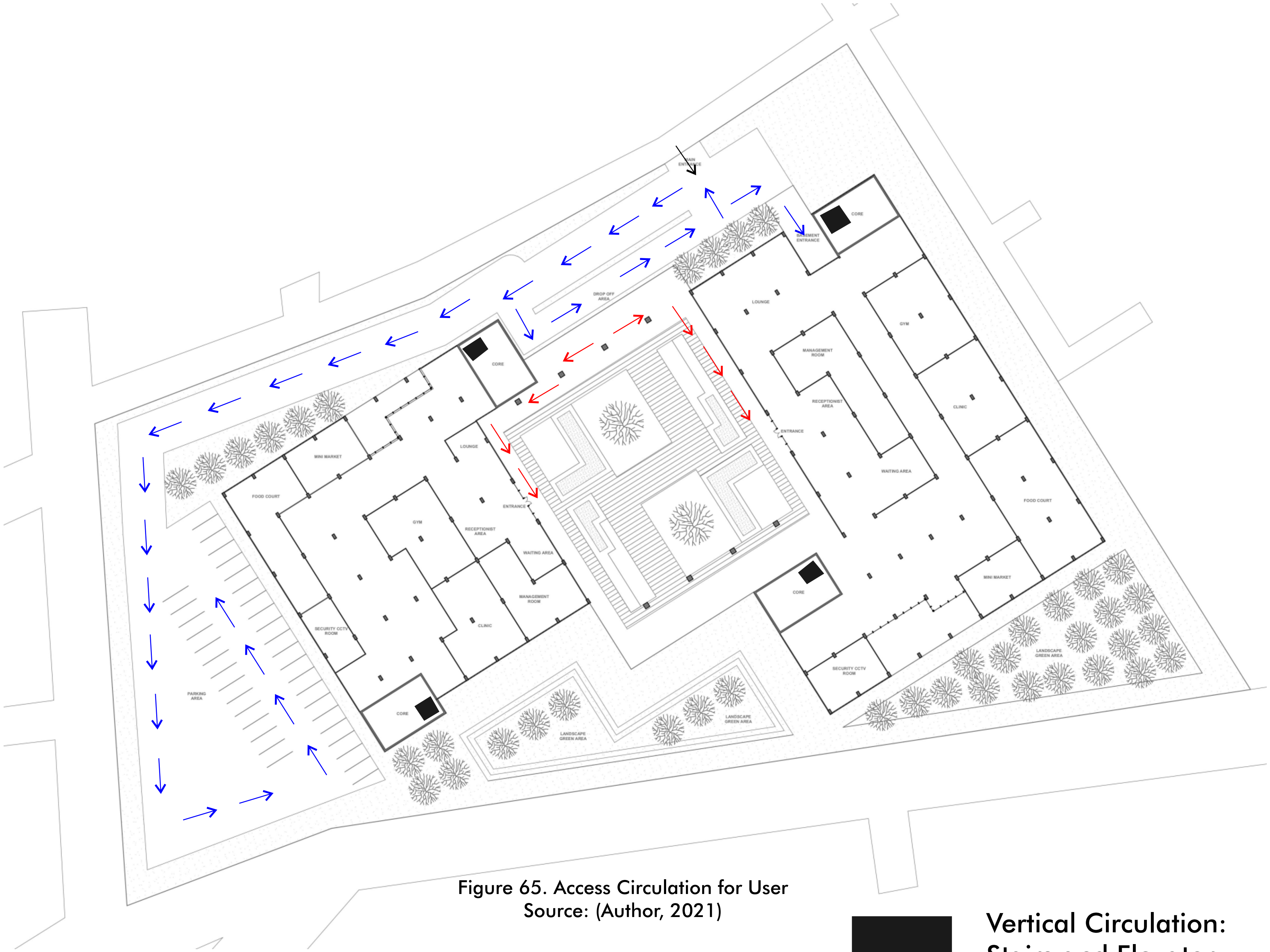


Figure 65. Access Circulation for User
Source: (Author, 2021)

Vertical Circulation: Stairs and Elevator

User's Circulation

Vehicle Circulation

Elevator, stair are placed in corners of building and in the center building have Communal area for easy accessibility for both normal and difabled users.

4.4 Building Form and Mass Design with Energy efficient and Biomimetic Concept

4.4.1 Building mass to support energy efficient design

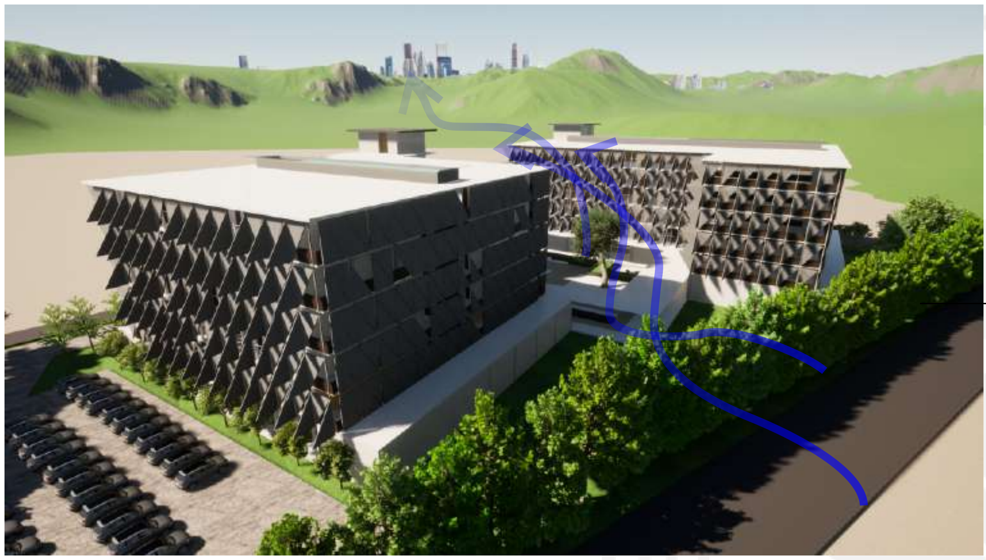


Figure 66. Building mass to support energy efficient
Source: (Author, 2021)

building mass
design responding
to wind

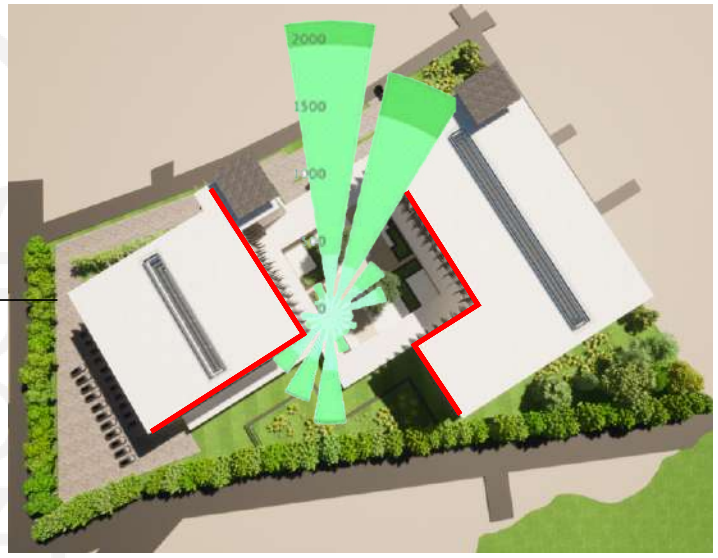


Figure 67. Building mass layout responding to wind
Source: (Author, 2021)

The form is created by 2 masses and using void at the center this help accentuating the wind the comes from north part of the site. The 2 masses formed into L shape so that it also give more surface to hit by the wind. The design proved using 360 wind flow simulation and it showed (Figure 0.) the wind entering between the building mass and flowed around it

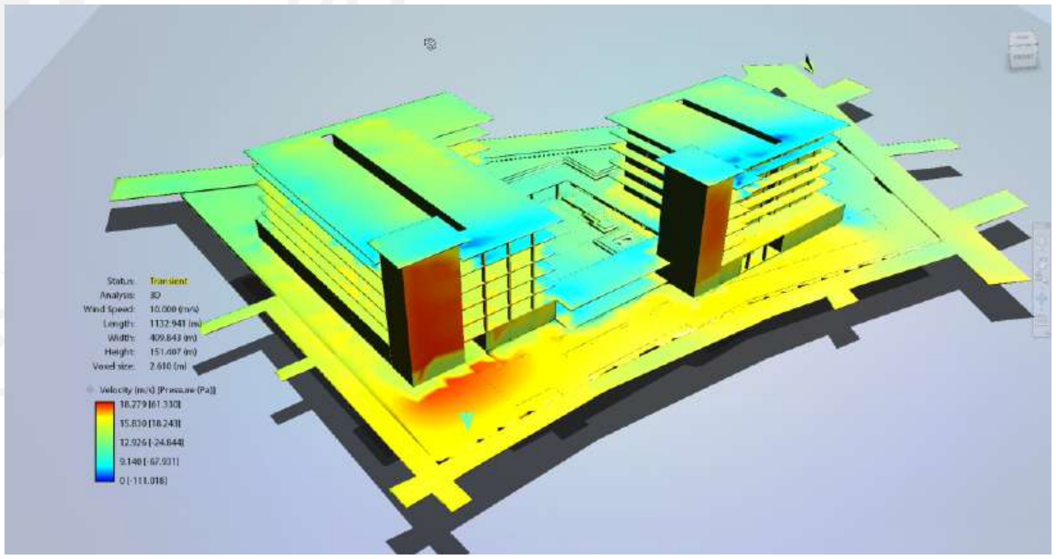
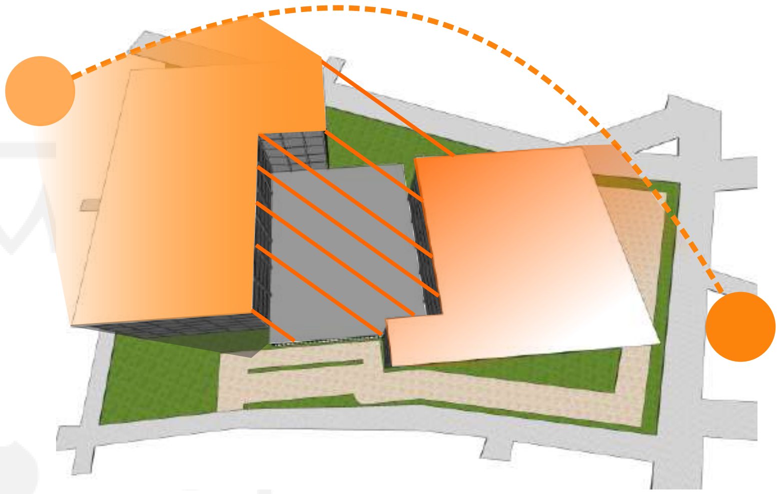


Figure 68. 360 wind flow simulation on Vertical housing
Source: (Author, 2021)

4.4.2 Building Form Design with Biomimetics Design Approach

Figure 69. Building mass to support Biomimetics design
Source: (Author, 2021)



sunpath simulation no. 1 in January 21at 15:00
sunpath simulation no. 2 in Januaru 21 at 9:30
As the result it shaded in between the 2 masses

From the exploration of chapter 3 it concluded that the durian concept has the principle of the spike protecting the fruit from overexposure sun. The two masses were inspired by the spikes on the durian fruit to avoid overexposure to the sun. As the result to support the Biomimetics concept design the two masses located at the east and west part of the site which get the most sun and heat are the longest this concept is to minimize direct heat from the sun. on the other hand it allow wind to pass through into the center of the masses. The design proved using sunpath simulation that showed the area that hit directly by the sun radiation is in January 21 at 15.00 and January 21 at 9.30.

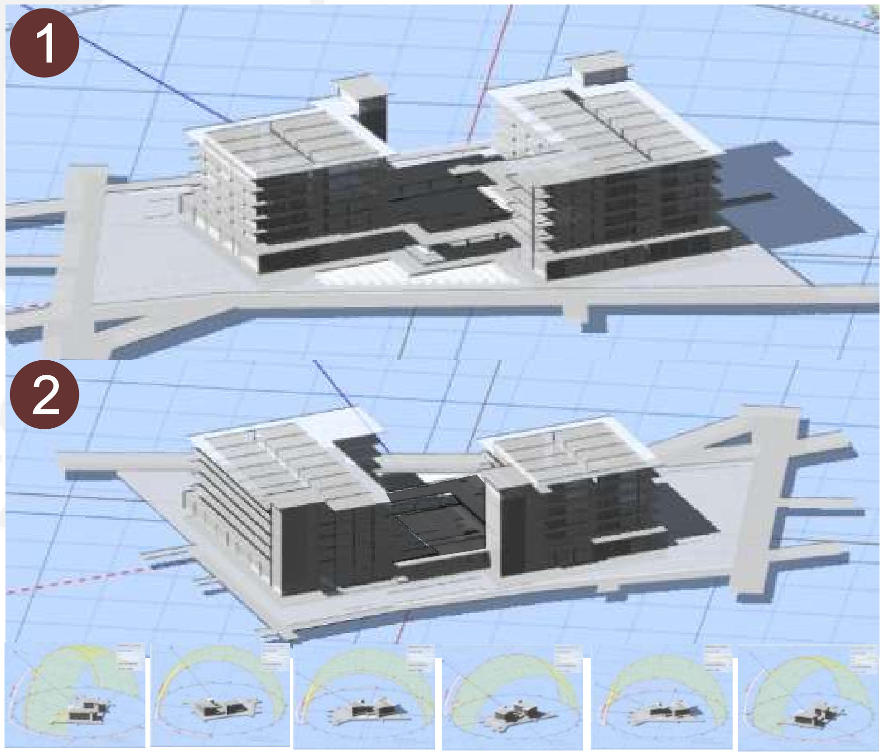


Figure 70. Passive system for building mass result
Source: (Author, 2021)

4.5 Building Elements and Systems Design Supporting Biomimetics and Energy Efficient

4.5.1 Perforated steel facade as implementation of energy efficient

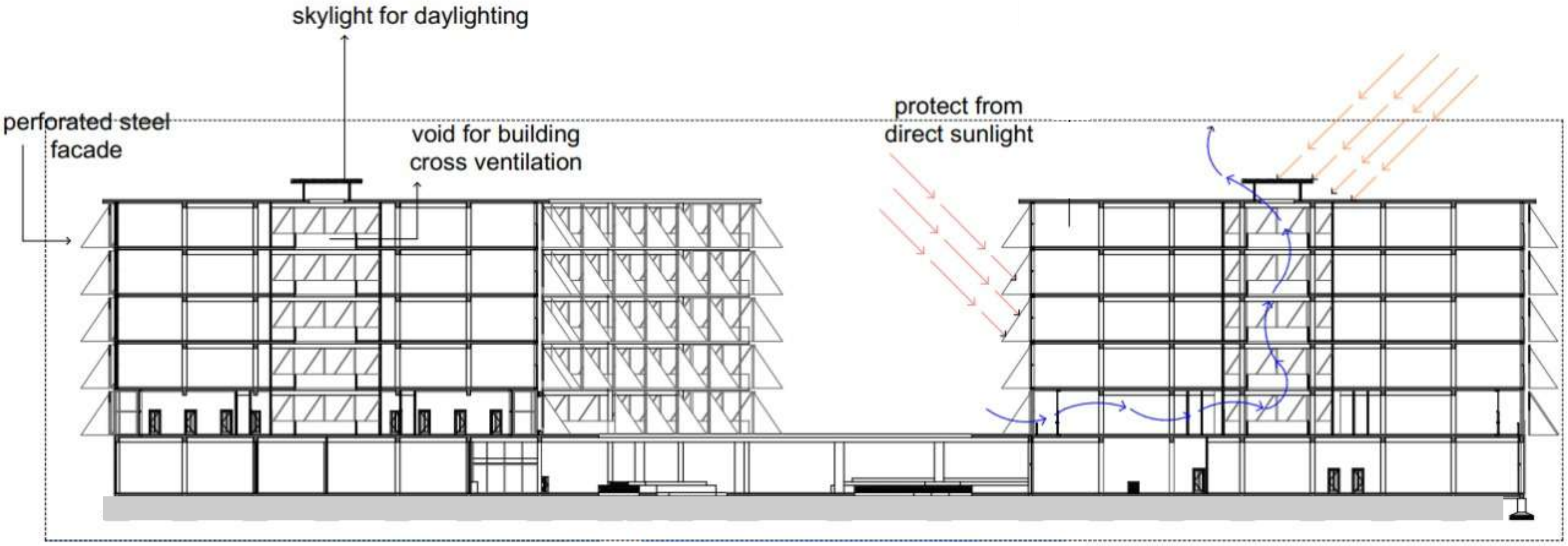


Figure 71. Building section
Source: (Author, 2021)

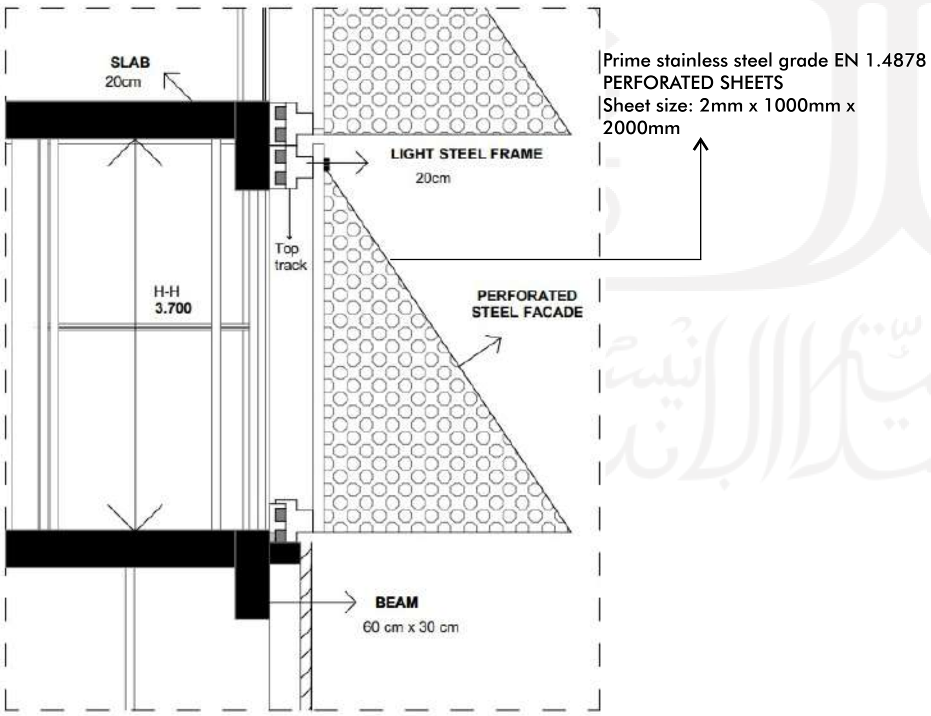


Figure 72. Facade detail
Source: (Author, 2021)

The design of perforated steel facade mainly for the purposed of allowing airflow and natural daylight enter to the building while protecting from overexposure sun. The result is giving natural cooling system in the building for that it do not need active cooling in the unit.

4.5.2 Building void and skylight as a passive design system in building

In order to support energy efficient design the building gave skylight and void at the center of the building, this design is to allow natural daylighting to reduce the usage of artificial lighting and eventually support energy efficient building. Additionally the design creating cross-ventilation system where it needed due to the high humidity in the Davao City.

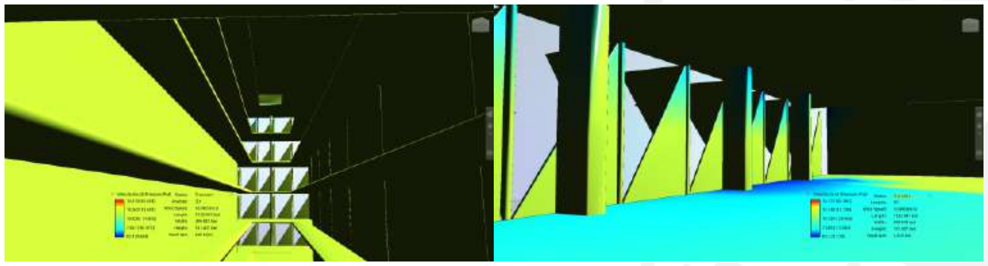


Figure 73. Simulation showing flow cross-ventilation
Source: (Author, 2021)

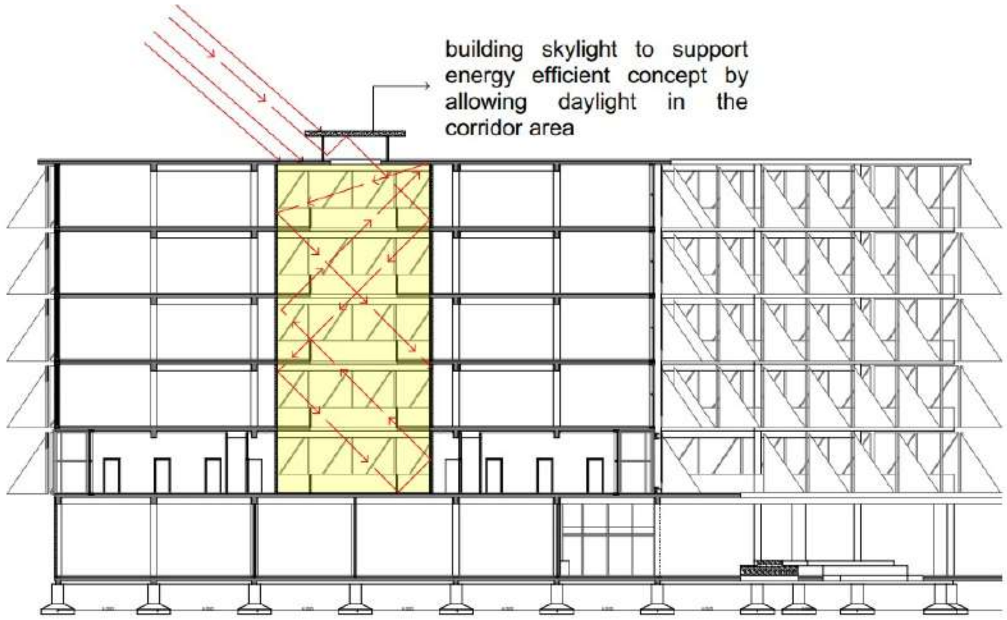


Figure 74. Building section showing skylight
Source: (Author, 2021)

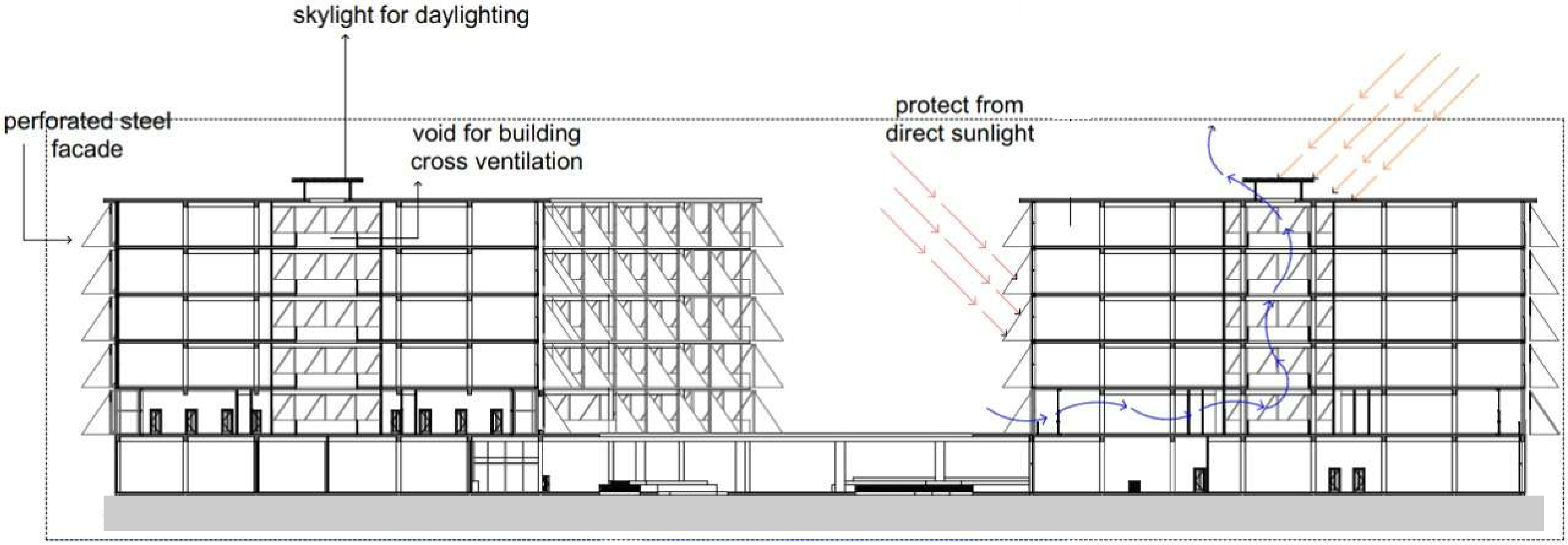


Figure 75. Building section showing passive design
Source: (Author, 2021)

4.5.3 Building infrastructure for Vertical housing

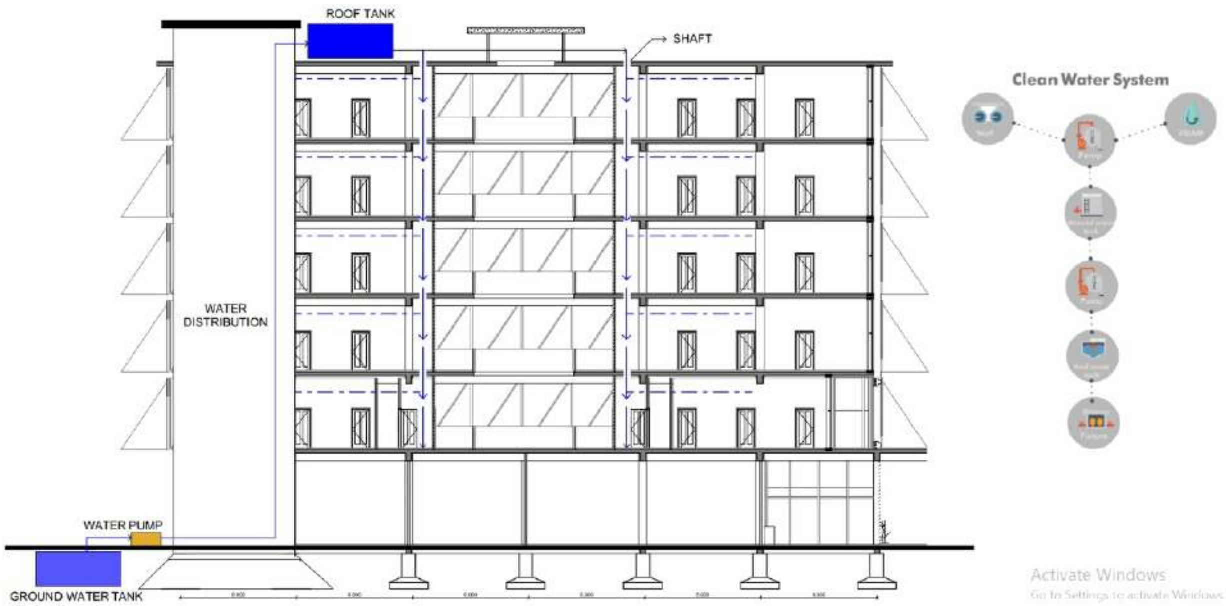


Figure 76. Water distribution scheme
Source: (Author, 2021)

The system of clean water is using down feed system which is the water from source pumped to ground tank first then pumped to roof tank, then distributed to all the floor by gravitation force.

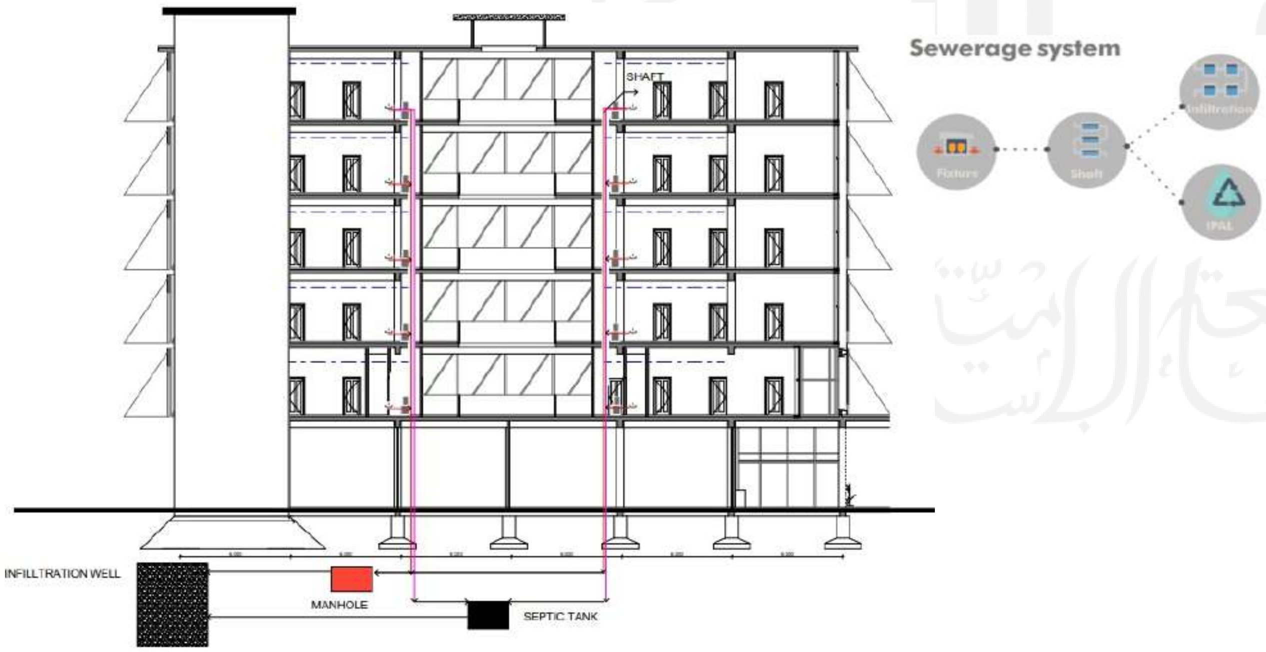


Figure 77. Sewerage system scheme
Source: (Author, 2021)

The system of sewerage water, the pipe go to IPAL separated to grey water and black water. Shaft sewerage at the core and continue to Sewerage treatment.

4.6 Building Unit interior design based on social issue

4.6.1 Vertical housing unit design to accommodate 1 family consist of 5 people

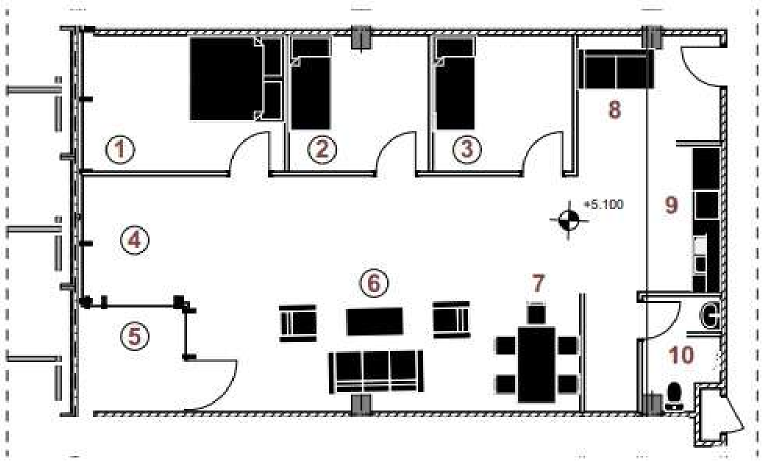


Figure 78. Unit plan
Source: (Author, 2021)

DESCRIPTION

1. Master bedroom
2. Single bedroom
3. Single bedroom (with double deck bed)
4. Familly room
5. Private balcony
6. Living room
7. Dinning area
8. Visitor area
9.Kitchen
10. Bathroom

Vertical housing unit with total area of 104 m2 | 13 m x 8 m that 1 family consist of average 5 people. The unit completed with 1 master bedroom, 2 single room, living room, family room, dinning area, visitor area, kicthen and bathroom.

Figure 79. Axonometric unit
Source: (Author, 2021)

4.7 Implementing Biomimetics on Building Envelope Design

4.7.1 Perforated steel facade comparison to normal horizontal shading

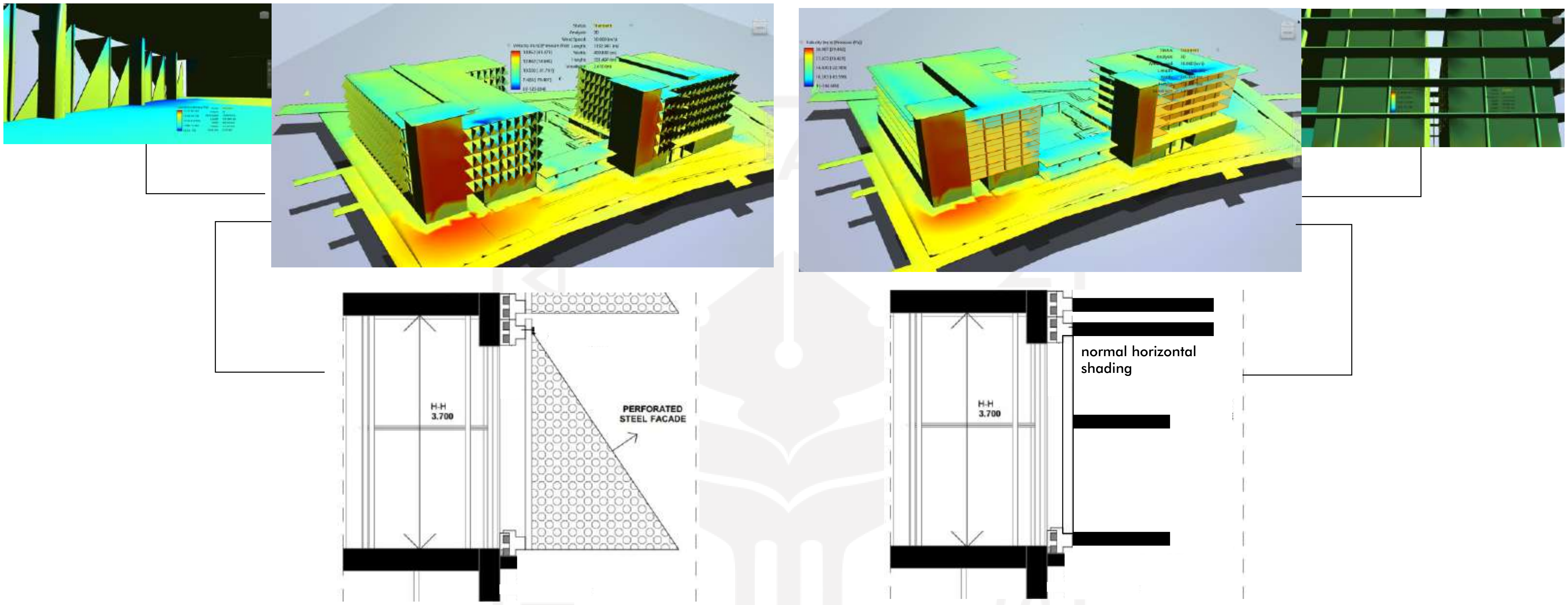


Figure 80. Shading comparison
Source: (Author, 2021)

In order to proof that the perforated triangular shape facade have an advantage compare to normal horizontal shading it simulated using 360 flow design. As a result the perforated steel facade allows and catch wind to the building resulting cooler result. It can seen it he shading comparison perforated steel facade tend to have blue area rather that normal horizontal shading.

4.7 Implementing Biomimetics on Building Envelope Design

4.7.2 Building envelope design orientation on different part of building

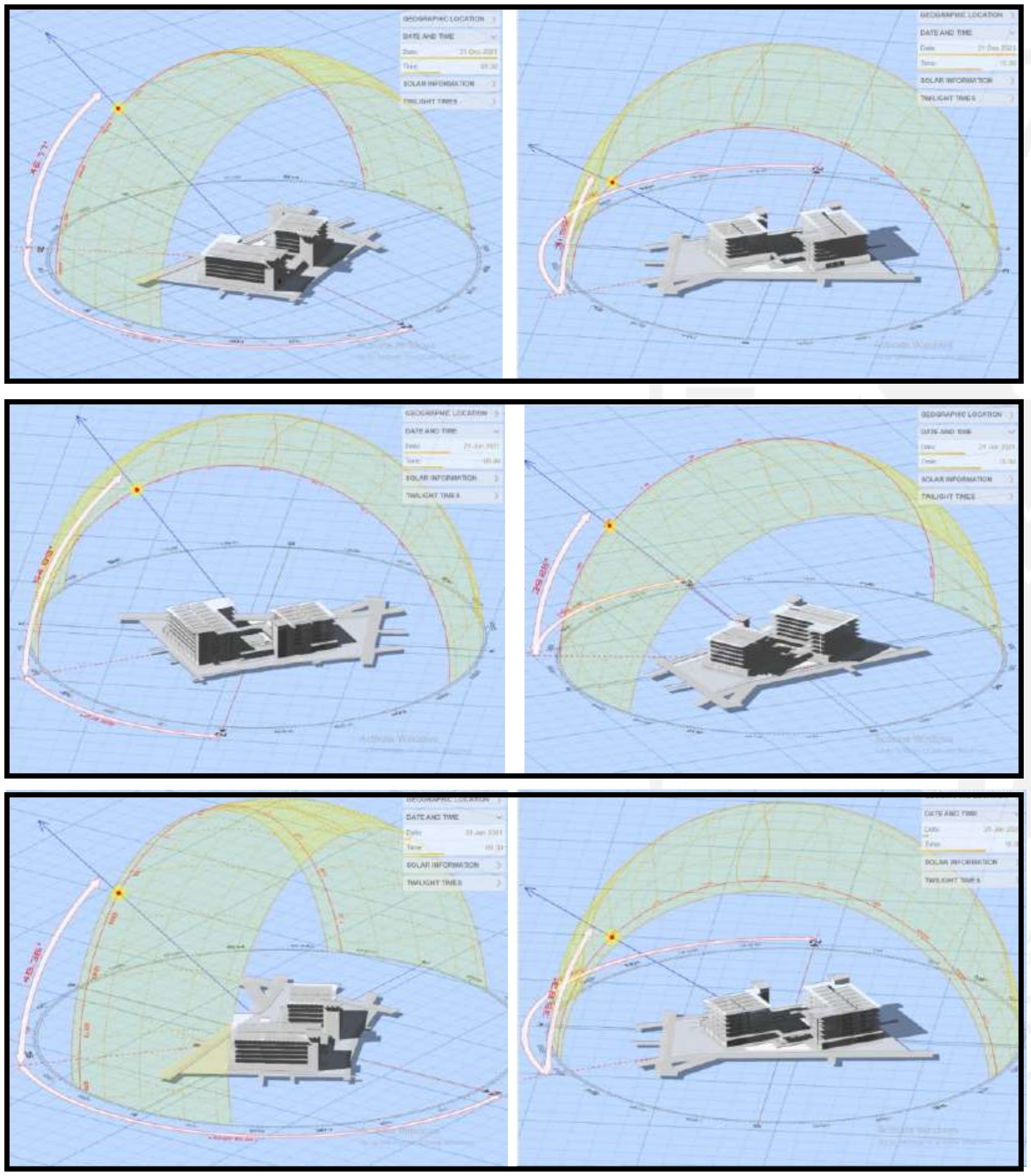


Figure 81. Sunpath simulation to determine the facade orientation
Source: (Author, 2021)

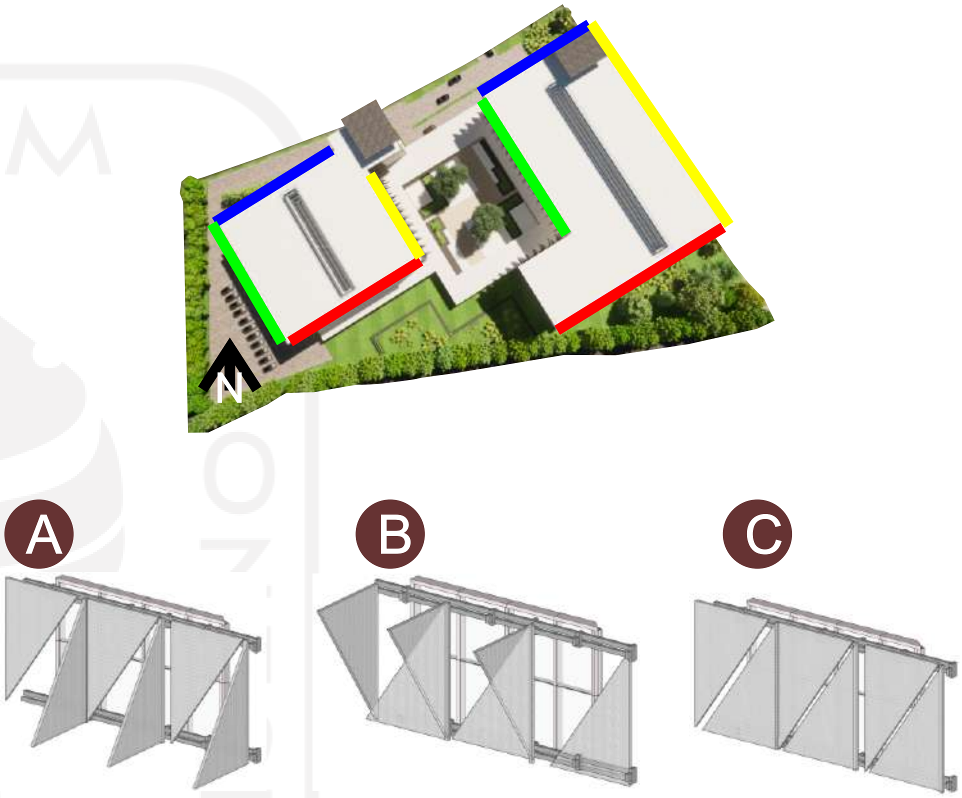


Figure 82. Siteplan and facade orientation
Source: (Author, 2021)

Based on the Sunpath simulation to determine the orientation of the facade the north part of the building facade (blue and yellow line) is using A facade mostly avoiding sun from June and January time, mean while the (green line) part is using B facade in respond to December time sunpath which very steep latitude and it need to avoided. The last one is (red line) using C facade which is fully closed to respond the longest hit by direct sun which in month of January, June,and december.

4.8 Building Design Simulation on Sunpath, Velux, Flow design

4.8.1 Sunpath building simulation

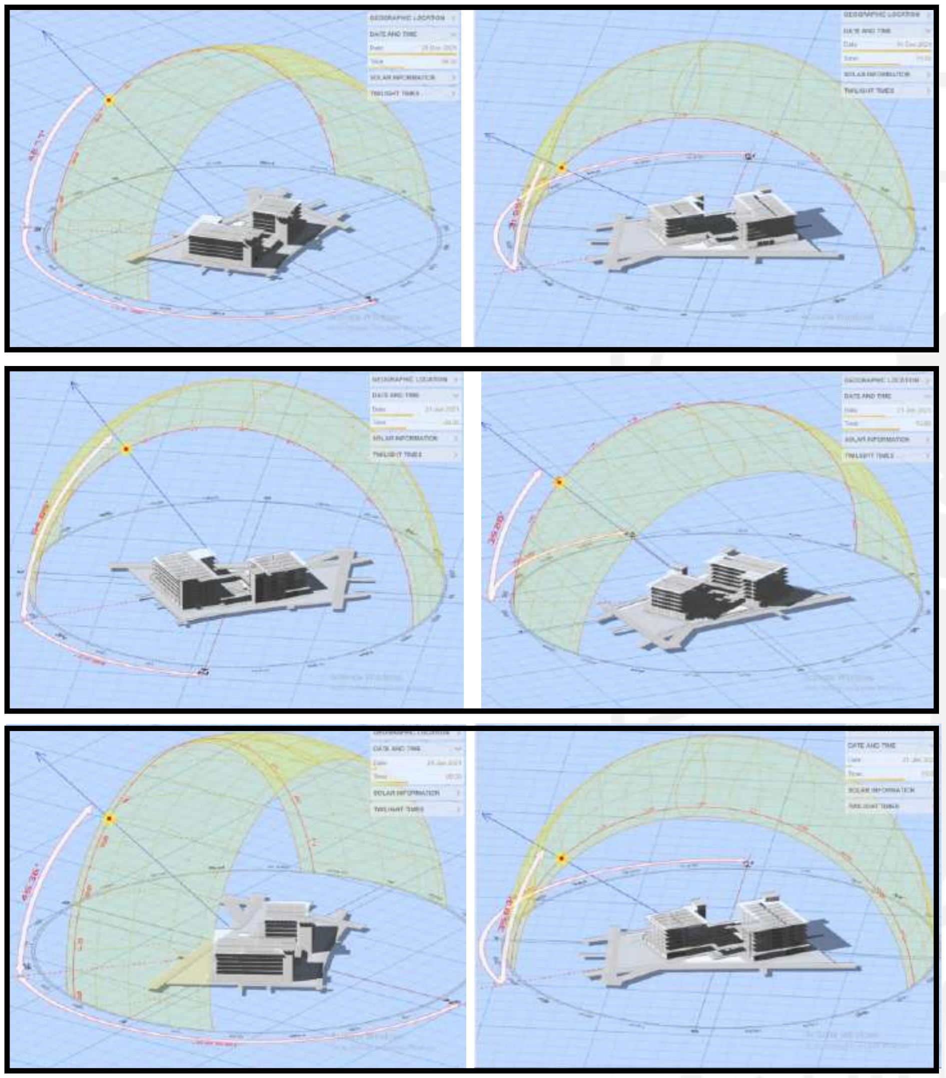


Figure 83. Sunpath simulation to determine the facade orientation
Source: (Author, 2021)

Using date and time of January, June, and December at 9.30 and 15.00.

4.8.2 360 Flow design building simulation

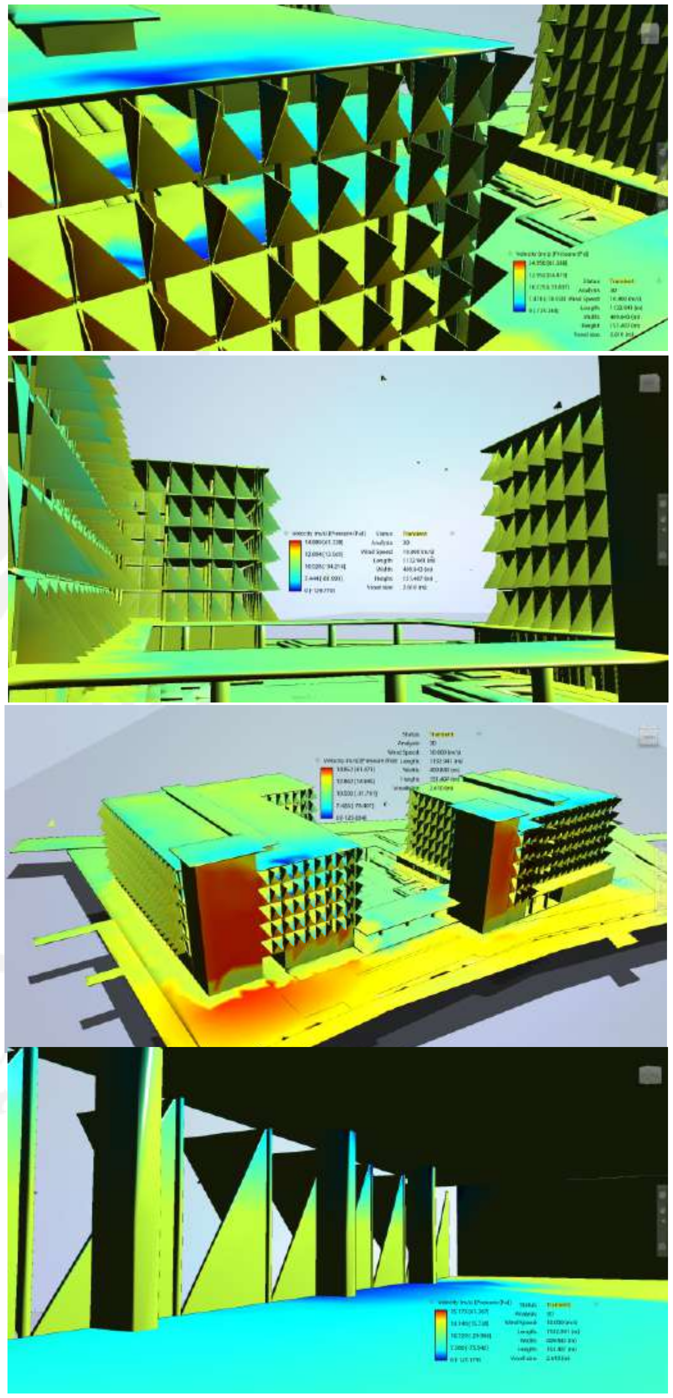


Figure 84. 360 Flow design simulation
Source: (Author, 2021)

4.8.3 Velux building simulation

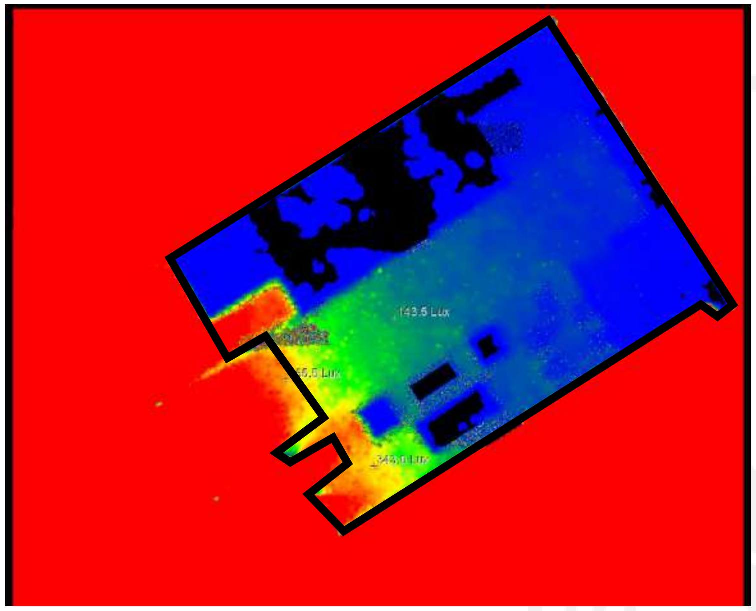


Figure 85. Unit plan velux design simulation
Source: (Author, 2021)

Unit plan showing more than 300 lux inside the unit.

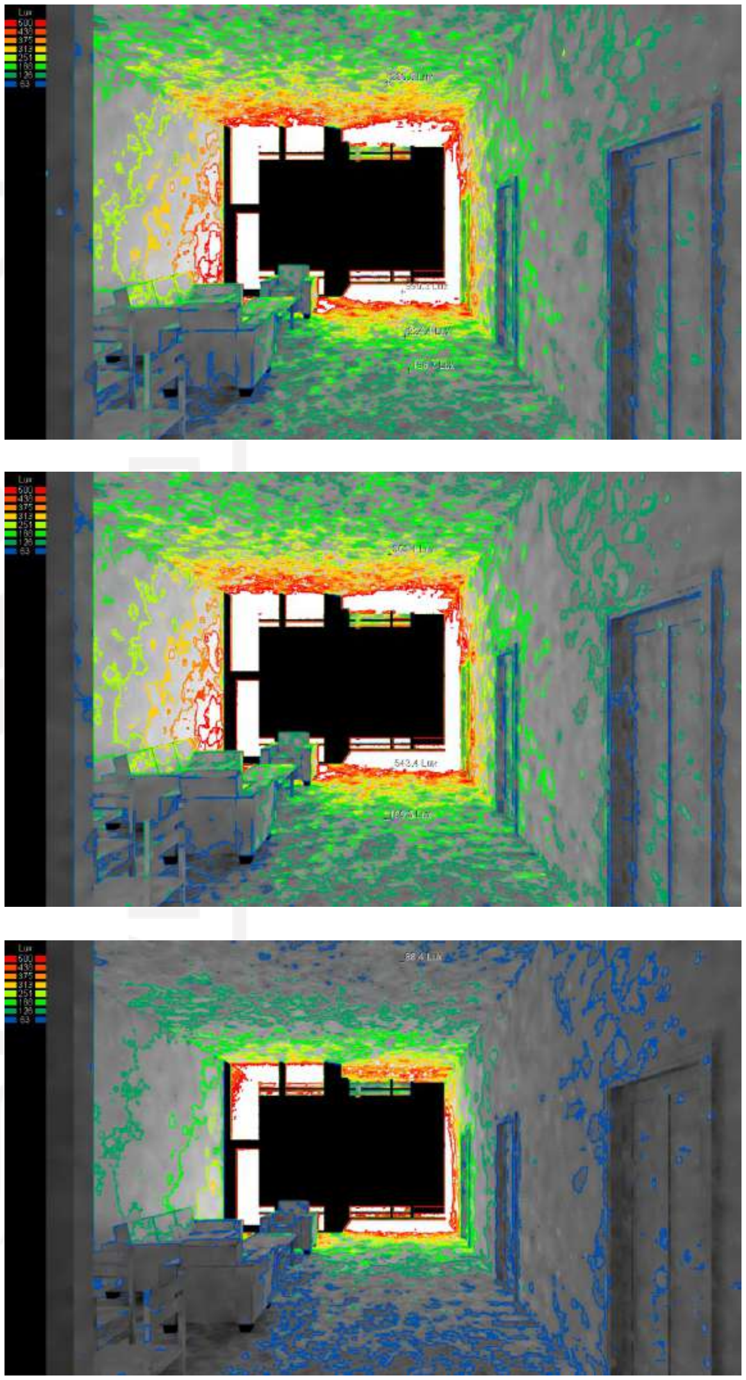
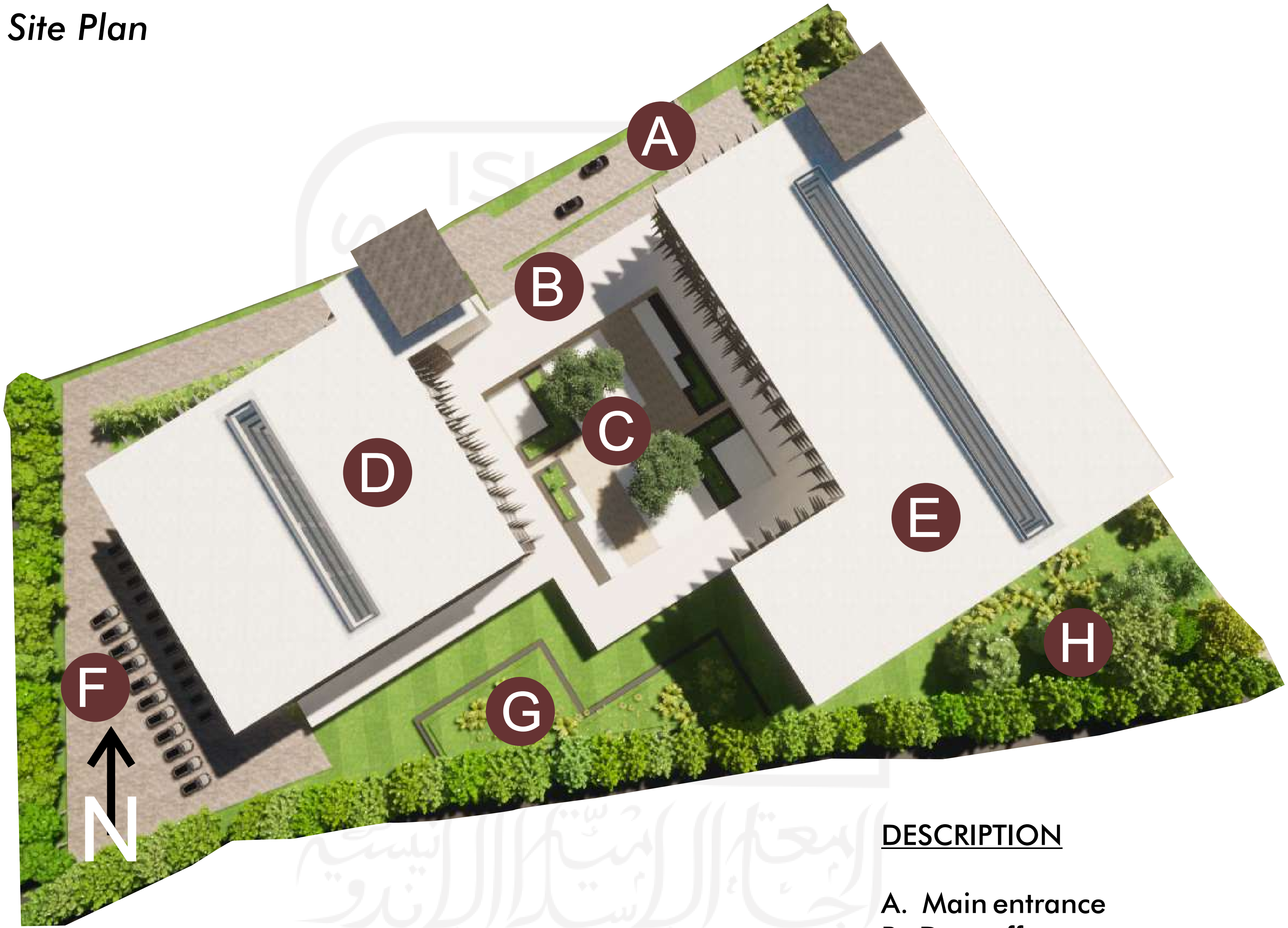


Figure 86. Unit perspective velux design simulation
Source: (Author, 2021)

4.9 Design Result

Site Plan

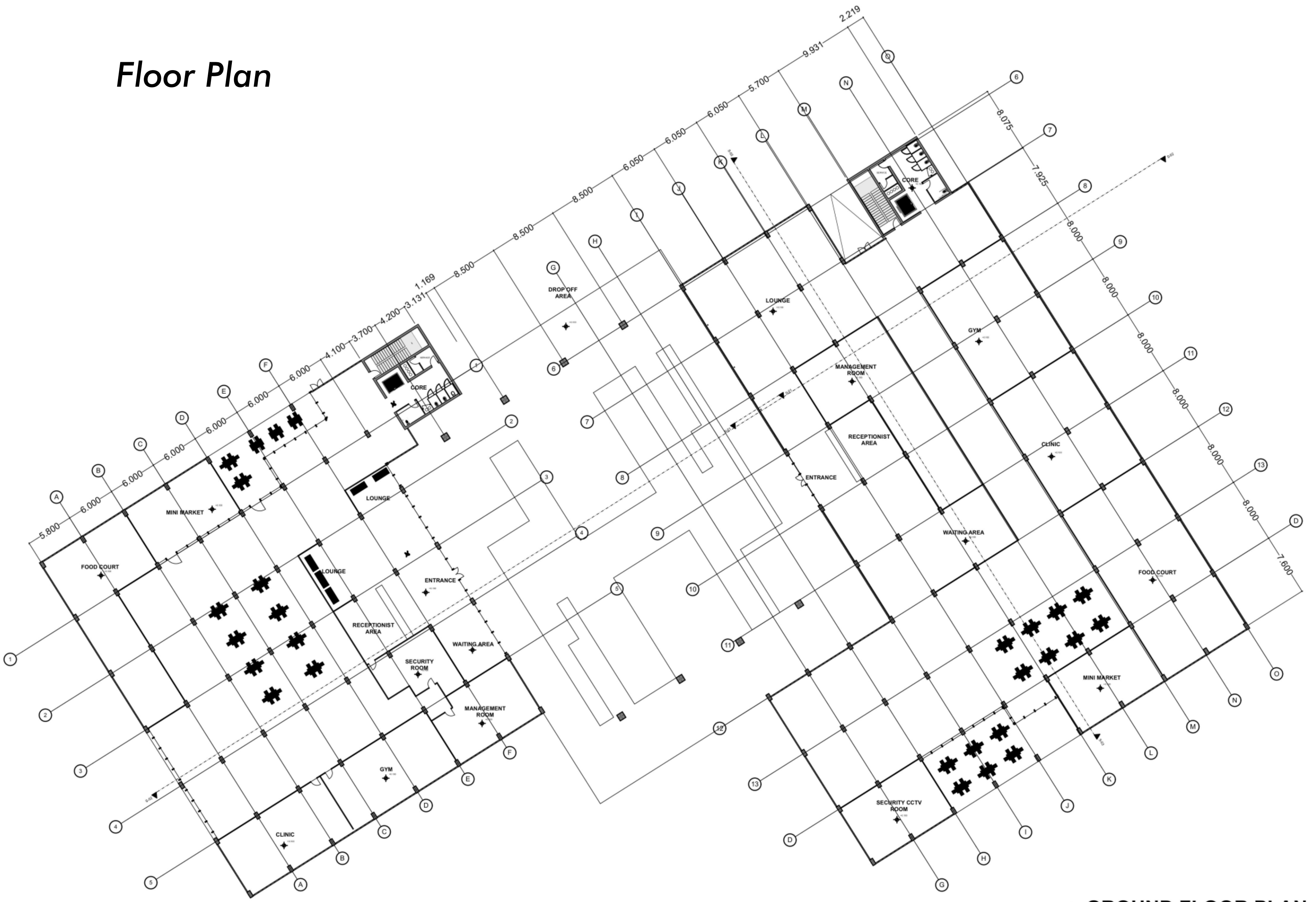


DESCRIPTION

A. Main entrance
B. Drop off area
C. Communal area/ Innercourt
D. Vertical housing 1
E. Vertical housing 2
F. Parking Area
G. landscape
H. Green area

Figure 87. Siteplan
Source: (Author, 2021)

Floor Plan



GROUND FLOOR PLAN

SCALE 1:350

Figure 88. Groundfloor
Source: (Author, 2021)

Floor Plan

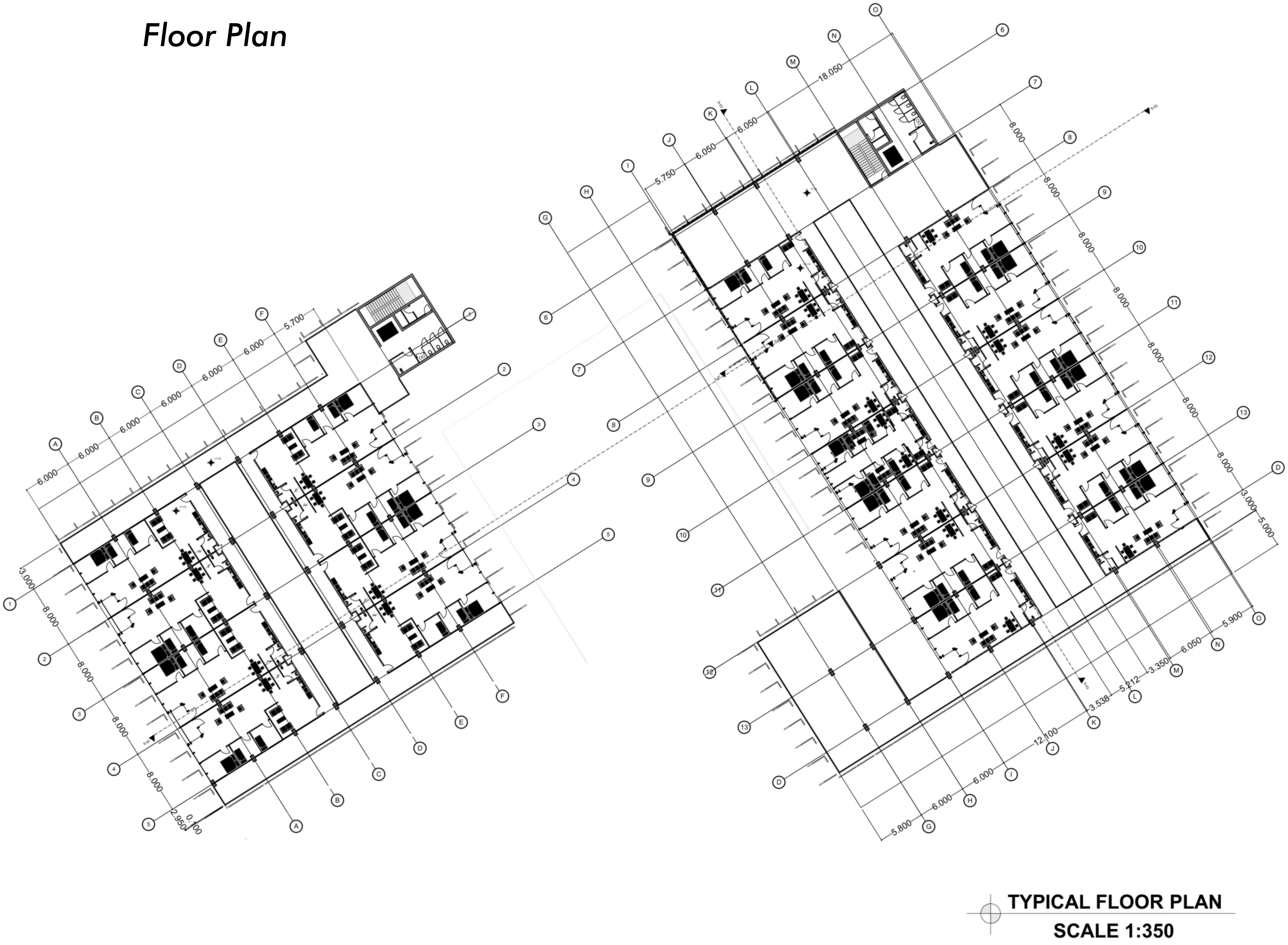


Figure 89. Typical floorplan
Source: (Author, 2021)

Elevations

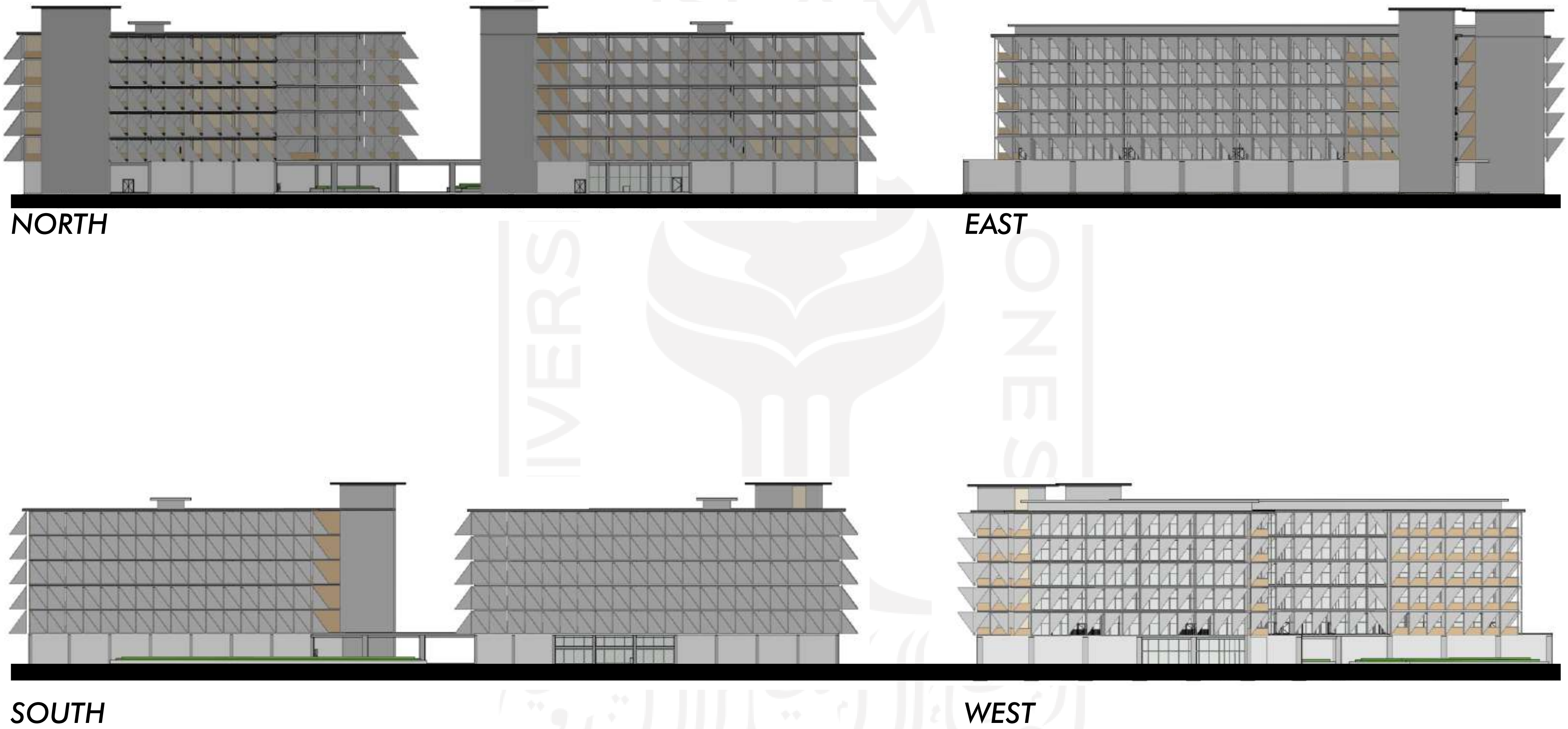


Figure 90. Elevations
Source: (Author, 2021)

Building Detail Section

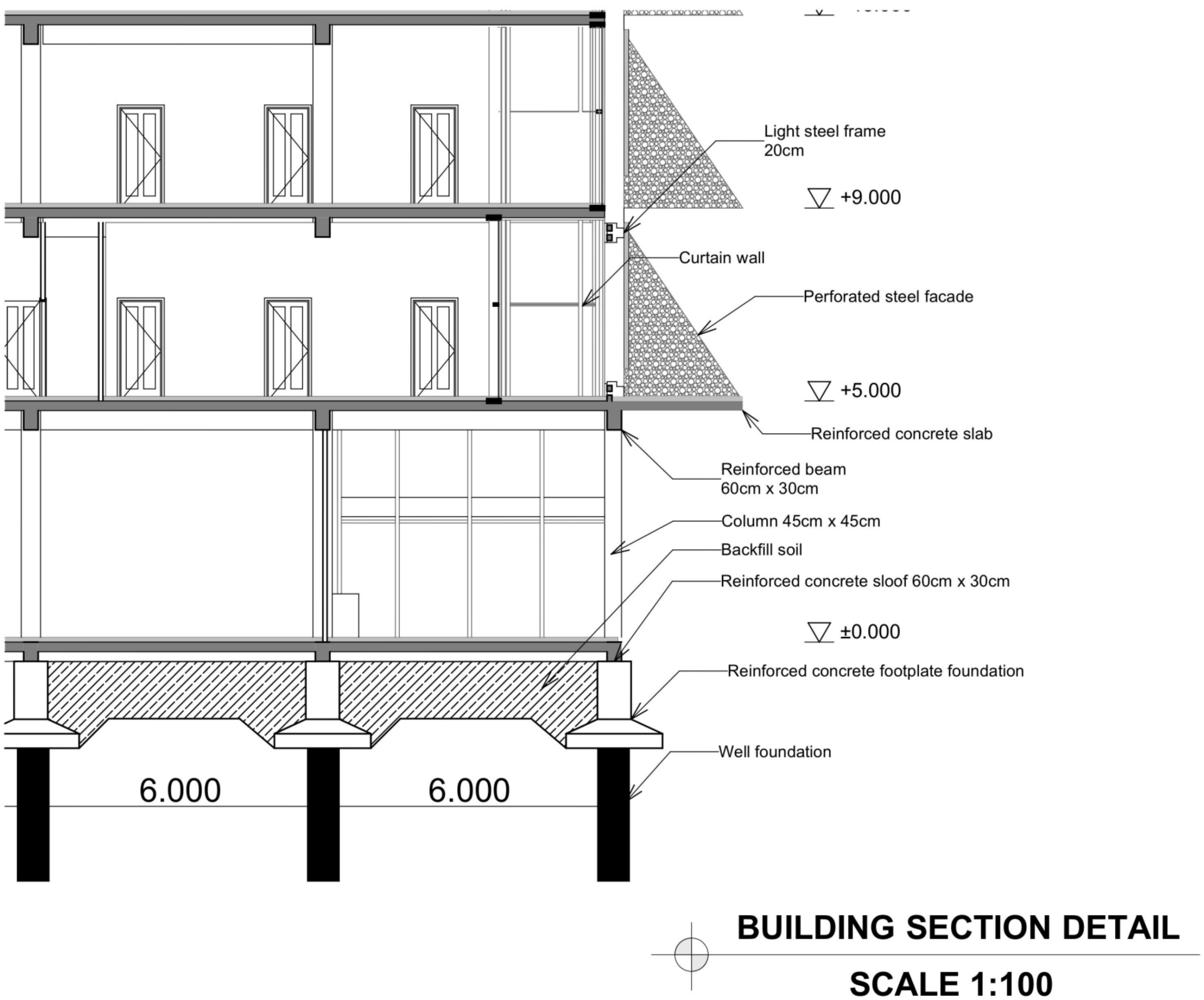


Figure 91. Building section detail
Source: (Author, 2021)

Facade Section

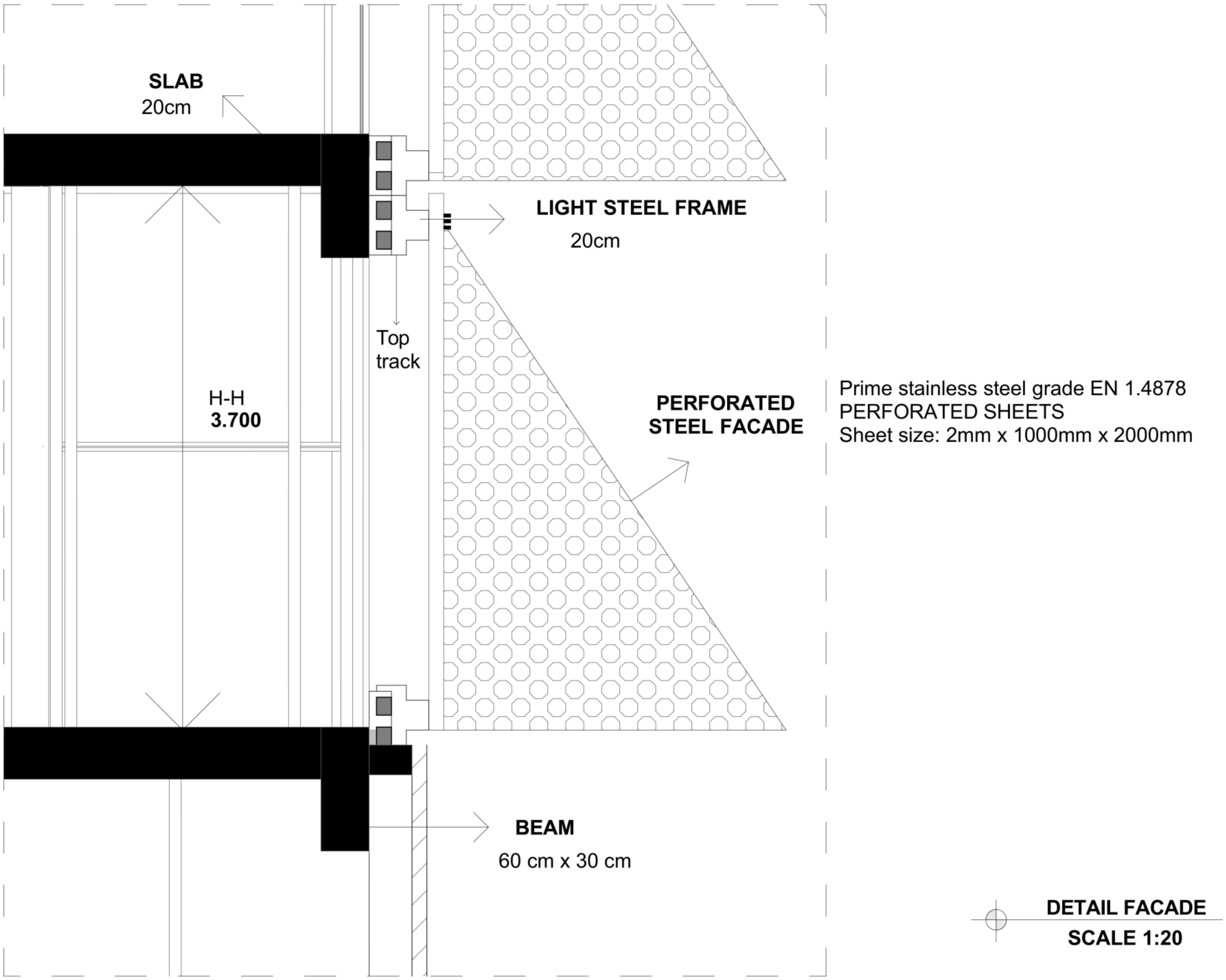


Figure 92. Detail facade
Source: (Author, 2021)

Axonometry Building

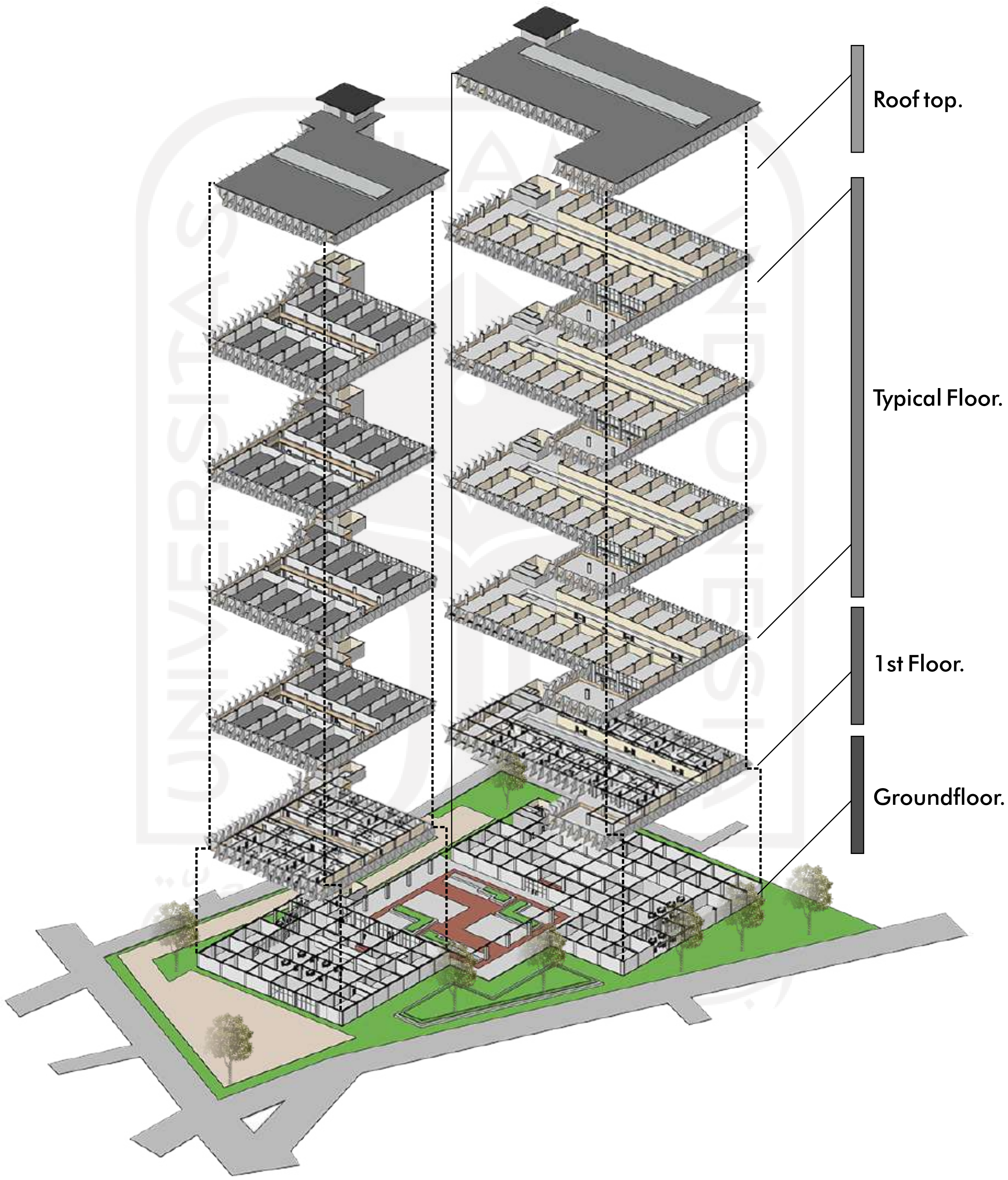


Figure 93. Building Explode
Source: (Author, 2021)

Axonometry Unit

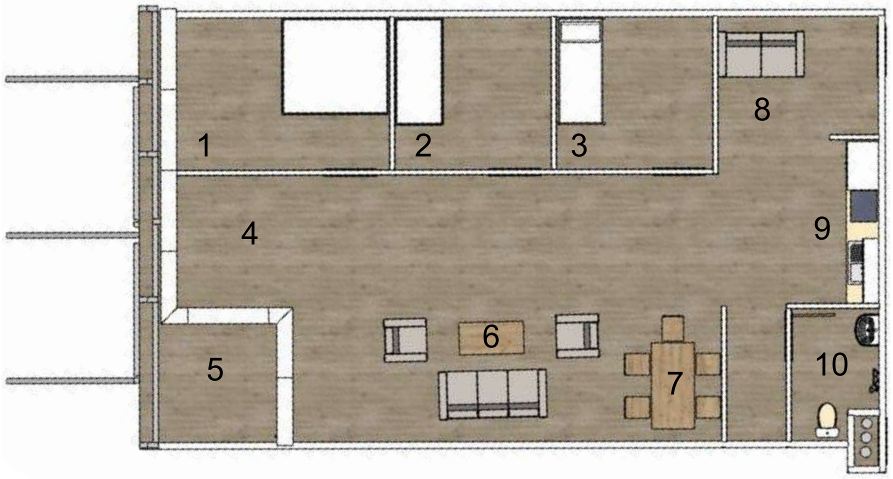


Figure 94. Unit plan layout
Source: (Author, 2021)

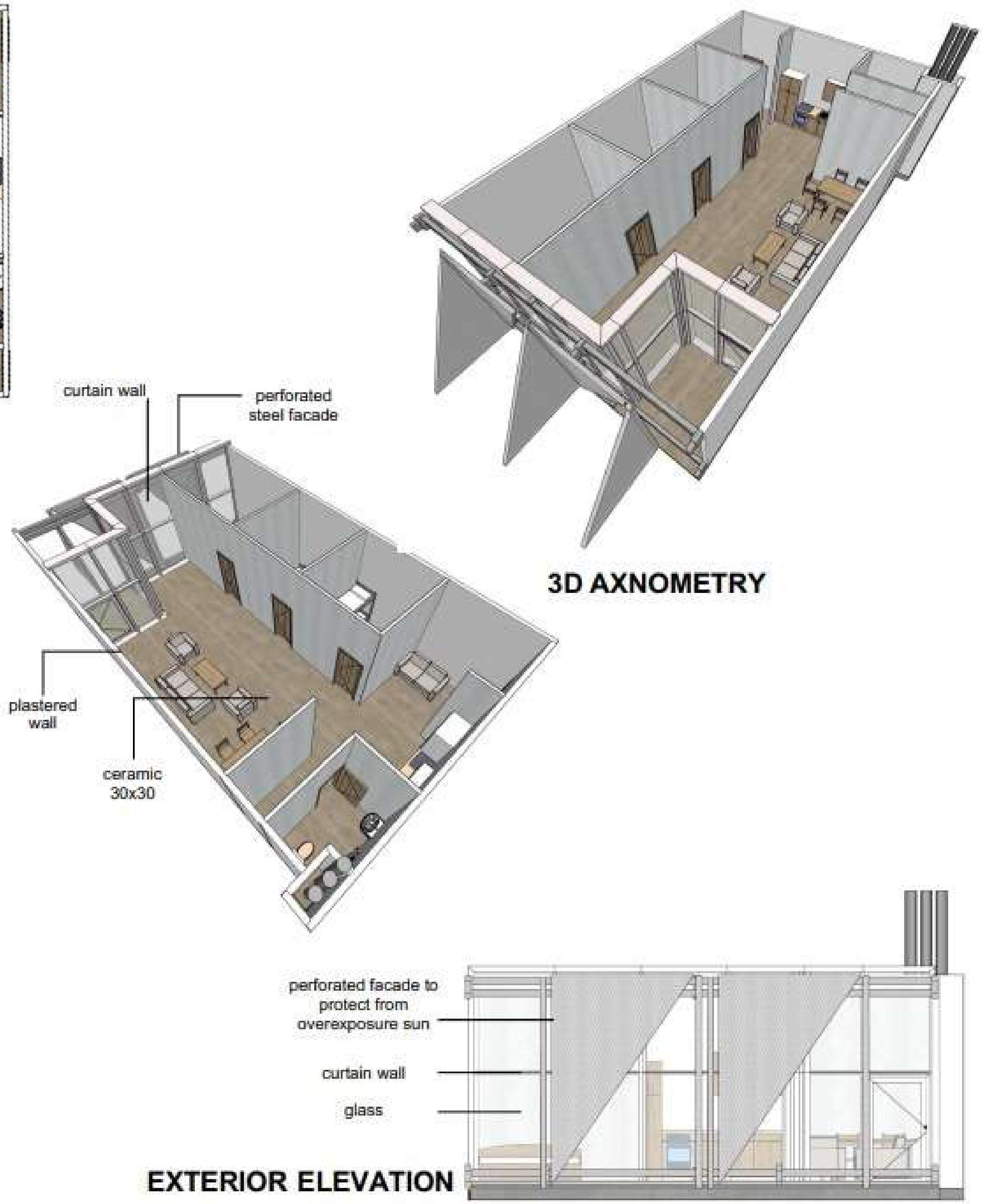


Figure 95. Axonometric unit render
Source: (Author, 2021)

<u>DESCRIPTION</u>

1. Master bedroom
2. Single bedroom
3. Single bedroom (with double deck bed)
4. Familly room
5. Private balcony
6. Living room
7. Dinning area
8. Visitor area
9.Kitchen
10. Bathroom

3D Model

Figure 96. 3D perspective render
Source: (Author, 2021)

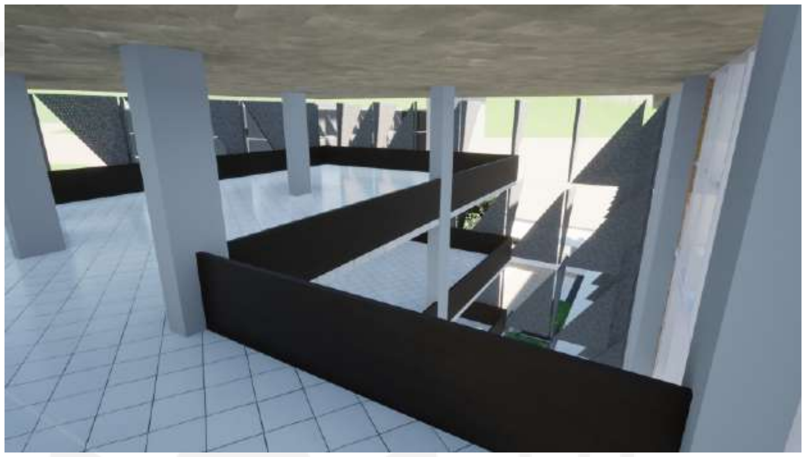
3D Model

Figure 97. 3D Exterior perspective
Source: (Author, 2021)

3D Model

Figure 98. 3D Communal area perspective
Source: (Author, 2021)

3D Model

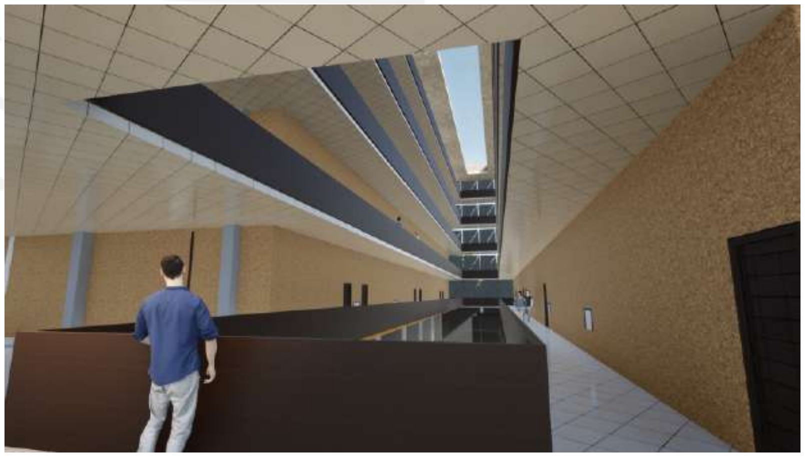



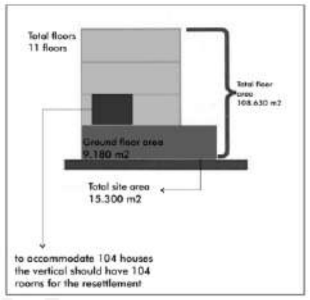
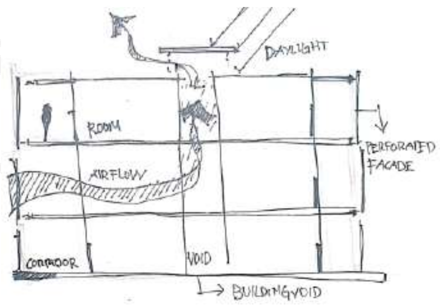
Figure 99. 3D Interior perspective
Source: (Author, 2021)

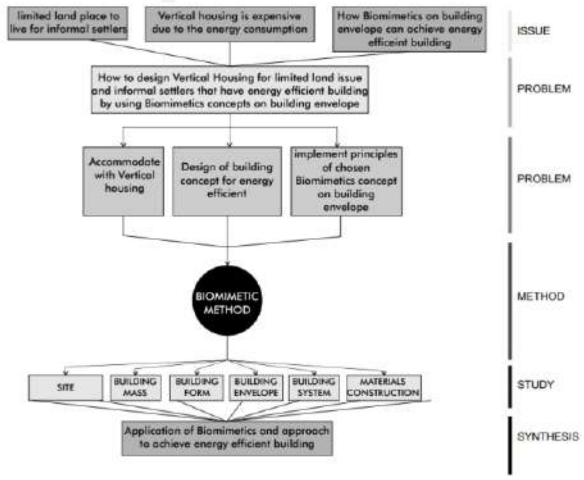
CHAPTER FIVE 05

DESIGN EVALUATION
Jury's Evaluation Response
Conclusion

Chapter Overview:
The jury's final design evaluation and reaction are included in this chapter. It also includes the design's conclusion.

5.1 Jury's Response

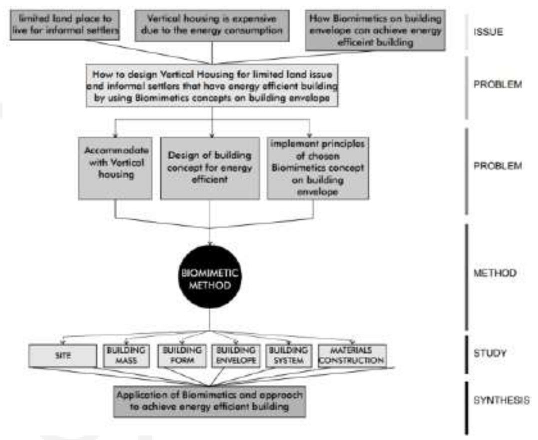
Jury	Comment	Response	Detail	Page
Dr. Yulianto P. Prihatmaji, S.T., M.T., IAI, IPM	What are the classification of housing unit in sqm based on philippines standard?	<u>Floor Area Requirement for Family Dwelling Unit</u> The minimum floor area of family condominium units shall be 36 square meters and 22 square meters for open market and medium cost condominium project respectively. (HLURB, 2009)	The size of unit consider the standard of Davao city which minimum of 36 sqm, and to accommodate average of 8 people per family the unit should be 3BR type of unit which has 54 to 108 sqm. 	20
	How many floors before an elevator is required based on Philippines standards? & what are the consideration of design mid-rise building?	It concluded that the design of Vertical housing is using mid-rise building because to support and considering affordability for the concept. The building required a elevator because it reaches the minimum requirement of 5 storeys.	IMPLEMENTING RULES AND REGULATIONS OF THE NATIONAL BUILDING CODE OF THE PHILIPPINES (PD 1096)	20
	what are the consideration of using double loaded corridor?	The consideration are to support energy efficient in improving cross ventilation system in the building this is also to respond the high humidity that should be solve.	The introduction of voids is the solutions for improving natural ventilation in Vertical housing. The void is the passive architectural element found in the center of both masses. 	51

Jury	Comment	Response	Detail	Page
Dr. Yulianto P. Prihatmaji, S.T., M.T., IAI, IPM	Formulate and respond ALL questions at the Design Brief dan Comprehensive stage by showing the sketches, analyses, concepts and schematic designs that have been carried out. As we in Lab. of TKB show us a PBD approach also.	Responded on Chapter 1, 2, 3 showing the Biomimetics and Energy Efficient sketches, analyses, concepts and schematic designs.		1 12 41
	What your design to accommodate the residence in Davao City against limited land issues? Why vertical housing chosen as alternative to do lower energy usage in building?	The proposed design is Vertical housing in order to solve the limited land issue. Why vertical housing? as we know Based on data from the World Green Building Council one of the largest energy user sector is occupancy sector, dominated by electrical energy that is 71 percent of total energy consumption and it needed to be reduce.	It stated in Abstract on page 2 the reason of choosing vertical housing as a design and why it needed to lower the energy usage.	2
	What is importance solve lower energy usage to have energy efficient building and improve building envelope in vertical housing? What a design indicators, how to achieve it, and point out in your design. Prove and show it in your design.	The importance is concerning about the affordability and low expense for the government to build this project of vertical housing. The indicators are SITE, BUILDING MASS, BUILDING FORM, BUILDING ENVELOPE, BUILDING SYSTEM, MATERIALS CONSTRUCTION		8

<table>
<tr><th>Jury</th><th>Comment</th><th>Response</th><th>Detail</th><th>Page</th></tr>
<tr>
<td>Dr. Yulianto P. Prihatmaji, S.T., M.T., IAI, IPM</td>
<td>What is urgent to use Biomimetics Approach and Energy consumption in vertical housing design? What a design indicator, how to execute it, and prove it in your design.</td>
<td>Explained on subtitle 1.3.7 Why Biomimetic concept as an approach on building envelope

Biomimicry
which is described as the applied science that draws inspiration for solutions to human issues by studying natural designs, systems, and processes, is one creative method

The indicators are SITE, BUILDING MASS, BUILDING FORM, BUILDING ENVELOPE, BUILDING SYSTEM, MATERIALS CONSTRUCTION

The design explored and executed in Chapter 3 and Chapter 4.</td>
<td>

1.3.7 Why Biomimetic concept as an approach on building envelope

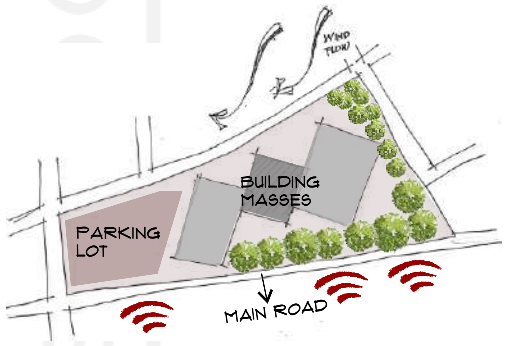
CHAPTER THREE 03
DESIGN EXPLORATION
Space programming
Siteplanning
Building system concepts
Interior unit
Building envelope concept
Material and construction

CHAPTER FOUR 04
DESIGN DEVELOPMENT
Design framework
Vertical housing unit design
Integration of siteplan & building mass
Building form and mass design
Building elements and systems
Building unit and interior design
Biomimetics concept on building envelope design
Building design simulation
Design result</td>
<td>8

6

41

58</td>
</tr>
</table>

Jury	Comment	Response	Detail	Page
Dr. Ing. Putu Ayu P. Agustiananda S.T., M.A	Consideration of social and economic issues (affordability, local habits, culture, local building material & craftsmanship, etc) of the informal settlers in order to come up with the best solution in your design?	Building design parameters considering low economic users. Discussion: Building construction cost to support EE, Operational cost consideration, Choose of building materials, Steel as a material for the facade, Maintenance cost consideration, Local craftmanship Davao City consideration	located in subtittle: ***2.7.3 Building design parameters considering low economic users***	26
	Please explain how you carefully analyzed and synthesized the vegetation and landscape elements that would greatly support energy efficiency in your project.	In the case of windrose, because the greatest wind was blowing from north to south, a change in windflow was required. Windflow may be directed to the building mass using vegetation as a wind guider, supporting cross ventilation system concept.		49

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ATTACHMENTS

Plagiarism Test Result
APREB
Capture 3D Modeling

Attachment 1: PLAGIARISM TEST RESULT

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Assalamualaikum Wr. Wb.

Dengan ini, menerangkan Bahwa:

Nama	: Fernan Cagucay Santoso
Nomor Mahasiswa	: 17512129
Pembimbing	: Prof. Noor Cholis Idham, S.T., M.Arch., Ph.D., IAI
Fakultas / Prodi	: Teknik Sipil dan Perencanaan/ Arsitektur
Judul Karya Ilmiah	: DESIGN OF DAVAO CITY VERTICAL HOUSING WITH NEARLY ZERO-ENERGY BUILDING AND BIOMIMETICS CONCEPT ON BUILDING ENVELOPE

Karya ilmiah yang bersangkutan di atas telah melalui proses cek plagiasi menggunakan **Turnitin** dengan hasil kemiripan (*similarity*) sebesar **11 (Sebelas) %.**

Demikian Surat Keterangan ini dibuat untuk dapat dipergunakan sebagaimana mestinya.

Wassalamualaikum Wr. Wb.

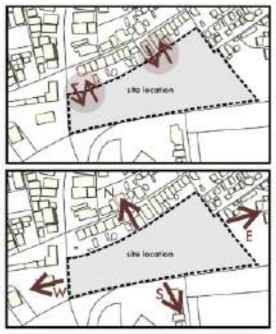
Yogyakarta, 12/20/2021
Direktur

UNIVERSITAS ISLAM INDONESIA DIREKTORAT PERPUSTAKAAN YOGYAKARTA

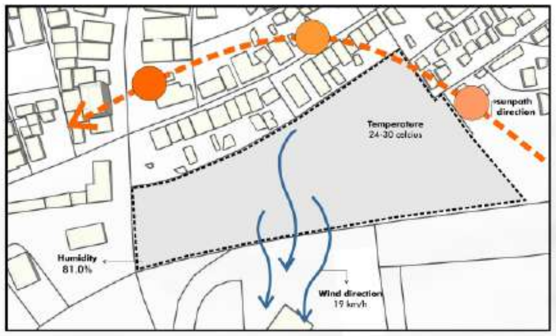
Joko S. Prianto, SIP., M.Hum

Attachment 2: APREB

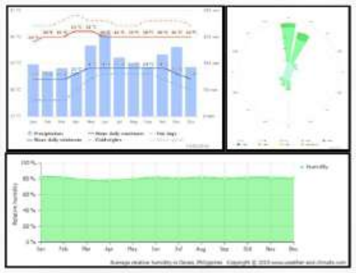
SITE ANALYSIS



The setting of the Davao City location was considered and analyzed when designing this building. As a result, this design was created specifically for the Bucana region and would be inappropriate if constructed elsewhere. According to prior data analysis, the average wind speed at the site is more than 19 km/h, and it blows from the north to south . It is advised that the wind speed at the location be reduced since it is excessively high. The sun shines from the east (the long side of the site) to the west (the short side) (west). This is due to the fact that the site's long side (front side) faces north. The advantage of this site is clear since the short side faces the sun as it rises and sets, allowing direct solar radiation to be minimized. Furthermore, the site's long side faces directly into the wind, allowing the incoming wind to be used as an advantage when planning building openings with a passive cooling design.



CLIMATOLOGY

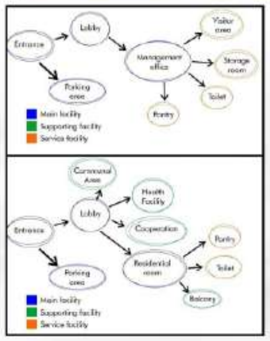


Humans generally feel comfortable between temperatures of 22 °C to 27 °C therefore the average temperature of Davao City is not too high it can be solve by using passive cooling design and not adding active cooling like AC this will support and achive energy efficient building concept.

The average annual percentage of humidity is 81.0% On a year-round basis, the Relative Humidity is very high, as can be seen in the graph. The comfort level is about 40% to 60%, so some adjustment is needed to make it comfortable and addition of cross ventilation for every mass and room.

Davao City has the highest wind exposure rate from the north and northeast to the south. The direction of the wind can influence the shape and envelope of a building's architecture, particularly when it comes to its orientation.

USER ACTIVITY & ROOM PROGRAMING



No	Floor	Room name	Area(m2)	Amount	Total (m2)
1	Ground Floor	Lobby	196.48	1	196.4
		Management Room	88	1	88
		Information Center	18	1	18
		Commercial area	400	1	400
		Food Stall	239	1	239.3
		Health facilities	120	1	150
		Living Room	66	1	66
		Pantry	14	1	14
		Praying room	101	1	101.25
		Cooperative	18.75	1	18.75
		Control Room	8.65	1	88
		Public toilet	110.5	1	6.65
		People with disabilities	110.5	1	133.55
		Vertical Circulation Area	130	2	260
		Circulation	378.8	1	378.8
2	1st Floor	1 Residential Type	48	13	480
		2 Residential Type	56	13	673
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	500.00	1	500.88
No	Floor	Room name	Area(m2)	Amount	Total (m2)
3	2nd Floor	1 Residential Type	48	15	480
		2 Residential Type	56	15	672
		Communal Indoor space	72	1	72
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
4	3rd Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
5	4th Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
6	5th Floor	1 Residential Type	40	12	480
		2 Residential Type	56	12	672
		Communal Indoor space	72	1	72
		Lobby	271	1	271
		Control Room and Warehouse	40	1	40
		Circulation Area Vertical	130	2	260
		Circulation	588.88	1	588.88
8	Rooftop	Circulation	234.3	1	234.36
		Roof	1543.2	1	1543.2
		Roof water tank			
		Total Building area			

BUILDING CODES & REGULATION

Figure 31. BCR maximum of 60%
Source: (Author, 2021)

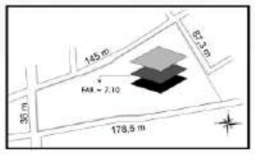


Figure 32. FAR = 7.10
Source: (Author, 2021)

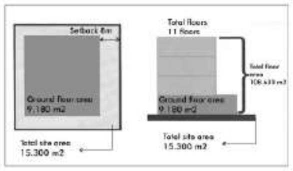
Building Coverage Ratio (KDB)	Maximum of 80%
Floor Area Ratio (KLB)	7.10
Building boundaries (GSB)	8 meters

CALCULATIONS

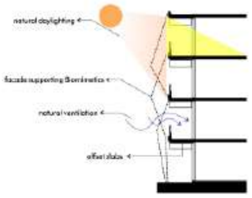
BCR = Total area x BCR
= 15.300 x 60% → Using 60% of BCR to provide more green area in the site
= 9.180 m2

FAR = FAR x Total area
= 7.10 x 15,300
= 108.630 m2

Total floors = FAR / BCR
= 108.630 / 9.180
= 11.8
= 11 Floors



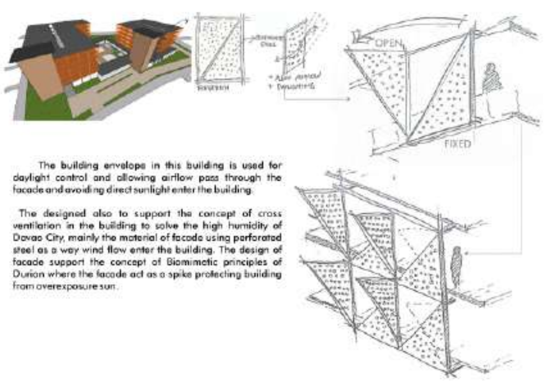
BUILDING PASSIVE SYSTEMS CONCEPT FOR EE



The Davao vertical housing is applied with passive strategies including daylighting, natural air ventilation and building orientation. Using also the facade of durian principle applied in the part of the building but still allowing wind and sunlight enters. Also in attempt of minimizing direct sunlight the slab on every floor is offset and the length will be based on the calculation of sunpath simulation.

The Davao vertical housing is not using active AC because the temperature of Davao City is not too high for the comfort of people therefore passive systems can solve it and high humidty and can be solve by cross ventilation.

BIOMIMETICS ON BUILDING ENVELOPE CONCEPT



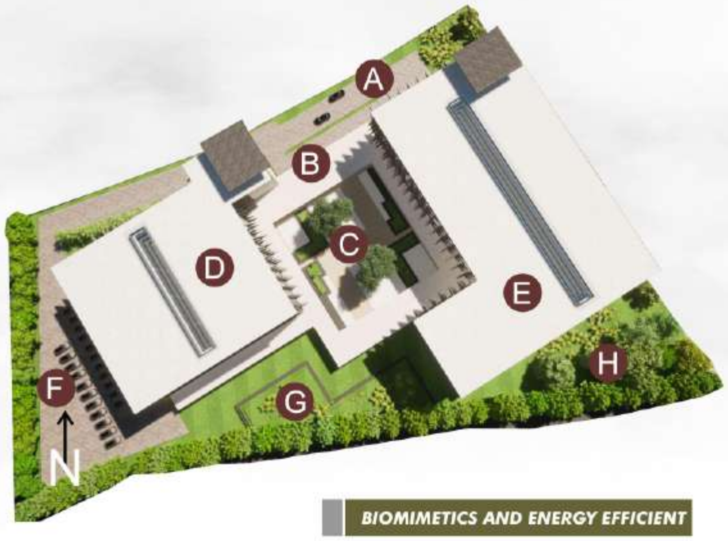
The building envelope in this building is used for daylight control and allowing airflow pass through the facade and avoiding direct sunlight enter the building.

The designed also to support the concept of cross ventilation in the building to solve the high humidity of Davao City, mainly the material of facade using perforated steel as a way wind flow enter the building. The design of facade support the concept of Biomimetic principles of Durian where the facade act as a spike protecting building from overexposure sun.

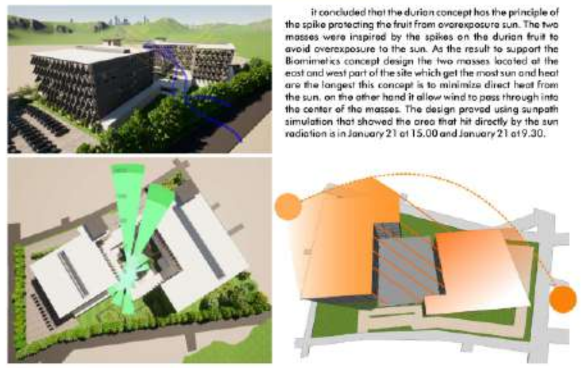
SITE PLAN

DESCRIPTION

A. Main entrance
B. Drop off area
C. Communal area/ Innercourt
D. Vertical housing 1
E. Vertical housing 2
F. Parking Area
G. landscape
H. Green area

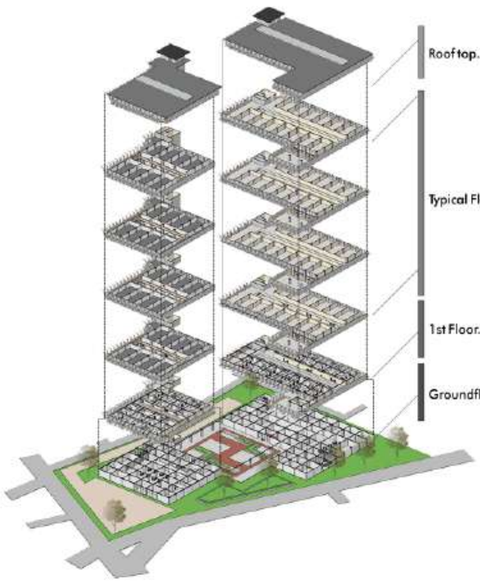


BIOMIMETICS AND ENERGY EFFICIENT

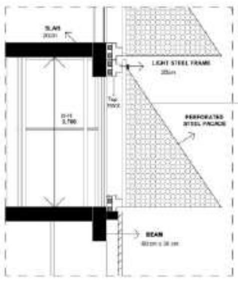


it concluded that the durian concept has the principle of the spike protecting the fruit from overexposure sun. The two masses were inspired by the spikes on the durian fruit to avoid overexposure to the sun. As the result to support the Biomimetics concept design the two masses located at the east and west part of the site which get the most sun and heat are the longest this concept is to minimize direct heat from the sun. on the other hand it allow wind to pass through into the center of the masses. The design proved using sunpath simulation that showed the area that hit directly by the sun radiation is in January 21 at 15.00 and January 21 at 9.30.

BUILDING AXONOMETRY



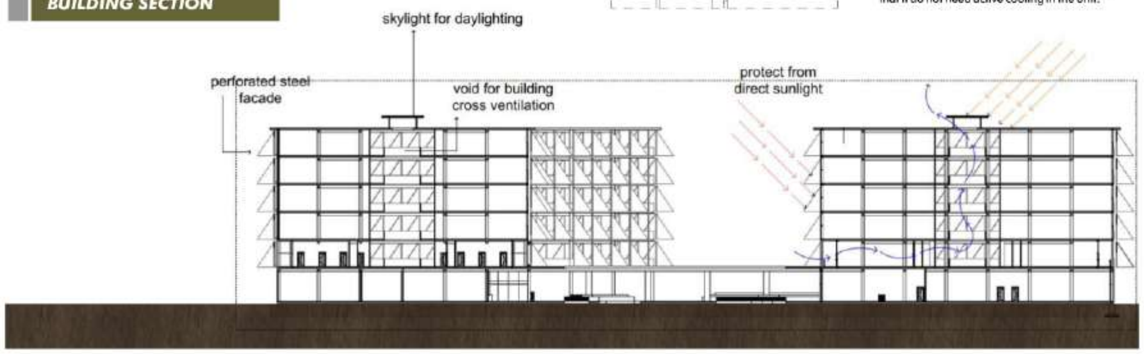
DETAIL FACADE



Prime stainless steel grade EN 1.4878
PERFORATED SHEETS
Sheet size: 2mm x 1000mm x 2000mm

The design of perforated steel facade mainly for the purposed of allowing airflow and natural daylight enter to the building while protecting from overexposure sun. The result is giving natural cooling system in the building for that it do not need active cooling in the unit.

BUILDING SECTION



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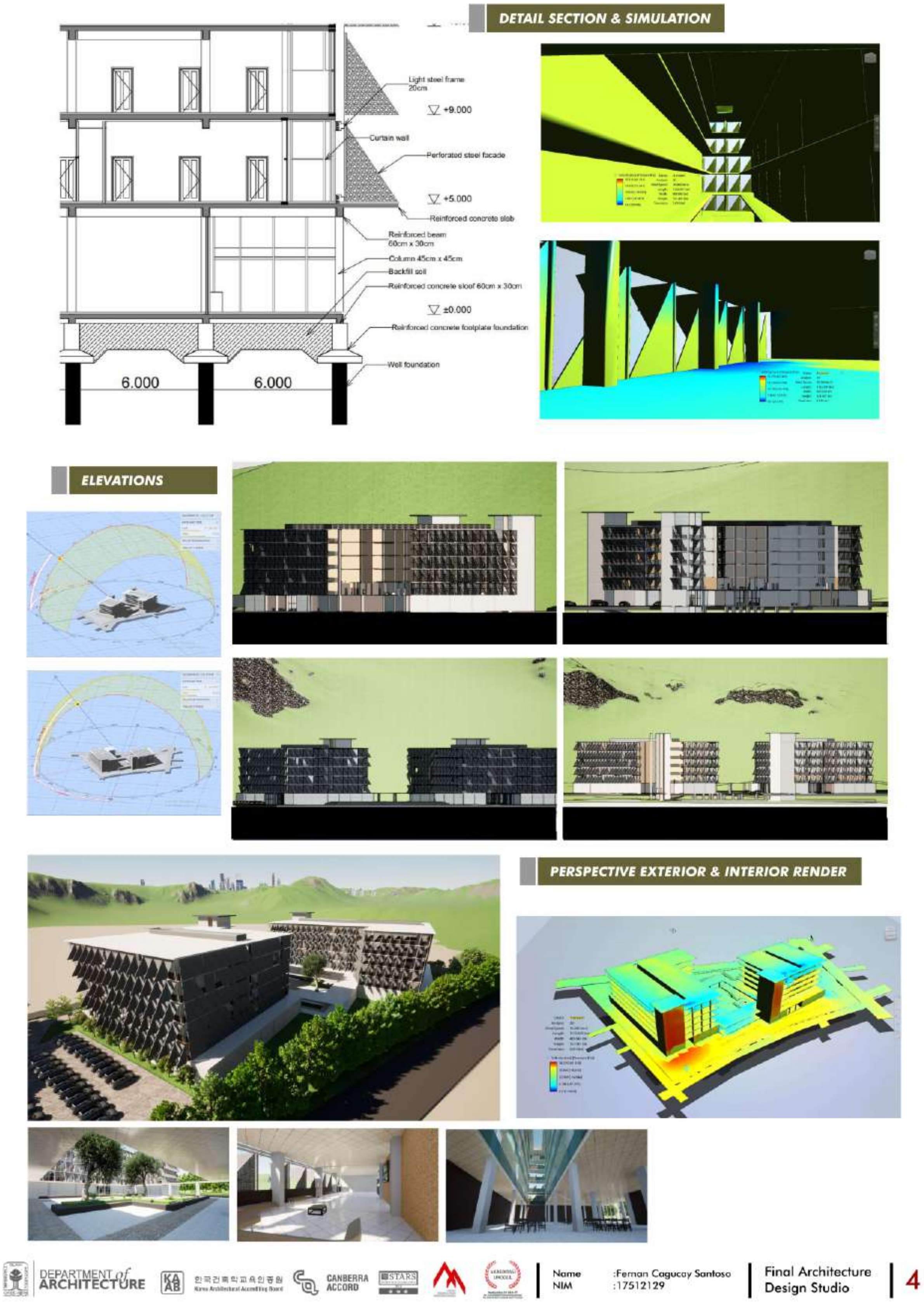
DETAIL SECTION & SIMULATION
Light steel frame 20cm
+9.000
Curtain wall
Perforated steel facade
+5.000
Reinforced concrete slab
Reinforced beam 60cm x 30cm
Column 45cm x 45cm
Backfill soil
Reinforced concrete sloof 60cm x 30cm
±0.000
Reinforced concrete footplate foundation
Well foundation
6.000
6.000
ELEVATIONS
PERSPECTIVE EXTERIOR & INTERIOR RENDER
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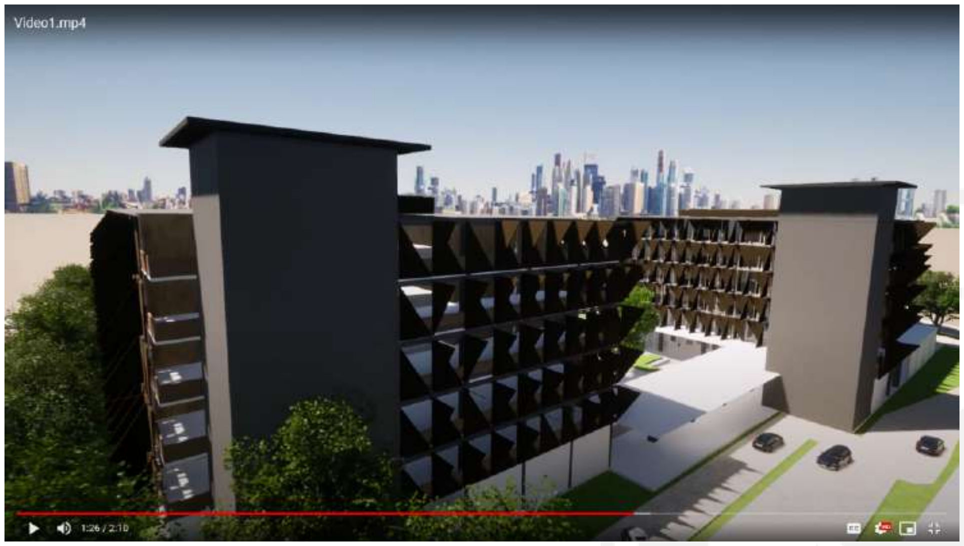
4

Attachment 3: Capture 3D Modeling



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