The Vertical City

Design Explorations on New Typologies of High-Rise Architecture

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Supervisor: Jonas Lundberg
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CHALMERS
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Abstract

High-rise architecture is becoming more common around the world. The urgent need for more habitable and public space has led to an increasing number of tall buildings in cities that have a low average building height. Tall buildings have a large potential in generating space vertically from a smaller piece of land, making them a fundamental part of cities with increasing urbanization and densification.

Today it seems that many tall buildings are concerned with striving for taller heights and dominance of a city's skyline. Many of the tall buildings that are currently being built have monotonous floor plans extruded vertically with facades consisting of glass panels. The rapid increase of these repetitious tall buildings has sparked discussions and hesitations toward high-rise architecture.

The purpose of this thesis is to understand the ongoing discussions of tall buildings and explore new typologies and potentials of high-rise architecture to reconceive the perception of what a tall building is and could be. The intention is to raise awareness of the potentials of tall buildings by showcasing a new perspective that provides with multifunctional components and has a reinvented expression. As tall buildings are a very current phenomena today, it is important to highlight the value that they can bring to a city.

This thesis departs from mapping the history of tall buildings to understand the evolution of height in architecture over time. Research papers and reference projects are also studied to explore the ongoing discussions and advancements regarding contemporary tall buildings. The literature review results in design principles that drive the design explorations forward through several iterations focusing on geometry, structure and program.

The knowledge gathered in this thesis ultimately results in an architectural design proposal of a tall building consisting of a vertical city, with the main focus being on reconceiving the traditional skyscraper typology.

Keywords: skyscraper, tall building, high-rise architecture, vertical city

Preface

My early interest in high-rise architecture was definitely a large factor behind my choice to enroll the Architecture and Engineering program at Chalmers University of Technology. During these 6 years of studies I have developed many new skills, delving into bridges, passive houses and urban planning to name a few. It wasn't until my fifth year that I got the opportunity to design a high-rise building within the Public Buildings studio. That project, called Vertical Athletics, increased my interest in tall buildings and gave me an introduction to all the challenges and opportunities that come with tall buildings. During a tutorial my tutor said *"you better write your master's thesis in high-rise architecture"*. I suppose he saw my deep interest in the subject and wanted me to explore why I was so fascinated by height in architecture.

Basing my master's thesis on high-rise architecture was a natural choice. I wanted to keep exploring my interest, better understand my (and others') fascination with tall building and also raise awareness of new architectural typologies and possibilities in tall buildings. There is a hesitation for placing tall buildings in cities with low average building height, but also an ever-increasing interest. My hope is that this thesis can both understand and decrease the hesitation by showcasing a new perspective of tall buildings.

Samira Sarreshtedari, June 2023

Thank you,

Jonas Lundberg
For your immensely valuable input during tutoring and reviews.

Kengo Skorick
For inspiring me to pursue this thesis and your valuable input during reviews.

Emelie Yee
For your endless and encouraging support throughout my journey at Chalmers.

Christoffer Krull
For always believing in me and pushing me to higher limits.

Student Background

Samira Sarreshtedari

I am a 24 year old architecture and structural engineering student aiming for a double degree to attain multidisciplinary competence in the interface between architecture and engineering. I am particularly interested in high-rise architecture, public buildings and parametric design.

Education

Msc Architecture and Urban Design 2021 - 2023
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Rhinoceros 3D	●●●●○
Grasshopper	●●●●○
V-Ray	●●●○○
SketchUp	●●●○○
Abaqus	●●●○○
FEM-Design	●●●○○
MATLAB	●●●●○
Python / C#	●●●○○
Photoshop	●●●●○
Illustrator	●●●●○
InDesign	●●●●●

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INTRODUCTION

Reading Instructions

The thesis booklet is divided into 5 sections, where the content ranges from a theoretical standpoint to architectural design explorations.

1. Introduction
Presents the chosen field of research where the problem statement is explained and its relevance to the current discourse. The research questions are presented together with the method, theory and delimitations of the project.

2. Background
Provides theory about tall buildings such as definitions, history of tall buildings, current research and reference projects on contemporary tall buildings and structural systems which the design explorations are based on.

3. Design Explorations
Presents a catalogue of massing and conceptual models that explore a wide range of typologies, principally organizing different functions and structural elements into building geometries.

4. Final Design Proposal
Presents a final architectural design proposal based on the design explorations.

5. Conclusions
Concludes the master's thesis with a summary and own reflections.

Glossary

Tall Building
A tall building is commonly used to describe any structure that has a noticeable height. This is a subjective definition based on the context of the building. *Tall building* and *skyscraper* are usually used interchangeably despite their difference in definition. In this thesis, *tall building* will be the main notion when referring to structures with a significant height.

Skyscraper
A building is considered as a skyscraper if it's height rises to a minimum of 150 meters. In general, a skyscraper is a building which seems to reach the sky.

High-Rise Building
There is no precise definition of a high-rise building, although a building is generally considered as high-rise if it has "many" floors.

Tower
A tower is a structure with a height that is significantly larger than the width. The structure can be of different types, both habitable and non-habitable such as telecommunication towers, solar towers or water towers.

Vertical City
A vertical city refers to a large skyscraper typology where the population lives independently from the ground level facilities and functions as they are provided within the skyscraper. The purpose of the vertical city is to preserve the environment and combat overpopulation.

Sky Bridge
A bridge that is physically connected between two or more buildings above ground level. It is usually an enclosed space, meaning that the movement within the skybridge is under some type of shelter.

Sky Plane
A wider sky bridge that contains functional spaces beyond only movement and circulation.

Unless otherwise stated, all figures are created by the author of the thesis.

Research Statement

Problem Statement
Today it seems that many tall buildings are concerned with striving for taller heights and dominance of a city's skyline (Koolhaas, 2008). Many of the tall buildings that are currently being built have monotonous floor plans extruded vertically with facades consisting of glass panels. The rapid increase of these repetitious tall buildings has sparked discussions and hesitations toward high-rise architecture.

According to the UN (United Nations, 2018), 55 % of the world's population currently live in urban areas. This proportion is expected to increase to 68 % by 2050. The increase of population in urban areas along with the continous growth of the world's population sets demands on already highly-dense cities to provide even more habitable and public space. The lack of ground area has resulted in deforestation, building close to coastlines and even building artificial islands. None of these approaches are sustainable to combat the need for more space.

Tall buildings have a large potential in generating space vertically from a smaller piece of land and thus reducing urban sprawl. This means that they are fundamental in cities with increasing urbanization and densification, which is also why they are becoming more popular. On the contrary, a tall building is generally not a sustainable or ecological building type. They use more energy and material resources to build and operate and therefore need to become more sustainable by for example using bio-based materials or designing vegetated areas in the building.

When being planned and built, tall buildings receive massive attention. They require thorough planning and expertise due to their height and thereby result in prestigious projects. This increases the value of the tall building and since they also provide attractive views, they are usually very expensive to buy or rent.

The urgent need for more habitable and public space has led to an increasing number of tall buildings in cities that have a low average building height. By rushing the building process and erecting monotonous tall buildings that are reserved for wealthier people, it is evident that they are met with discussions and hesitation from both the public and building planners.

Objectives
The purpose of this thesis is to understand the ongoing discussions of tall buildings and explore new architectural typologies to reconceive the perception of what a tall building is and could be.

The intention is to raise awareness of the potentials of tall buildings by showcasing a new perspective that provides with multifunctional components and has a reinvented expression. As tall buildings are a very current phenomena today, it is important to highlight the value that they can bring to a city.

Contribution
The contribution to the current discourse with this thesis is not necessarily new inventions of typologies in tall buildings, but rather a collection of current research in the field translated into design explorations. These explorations can hopefully be useful to other architects and students who want to obtain a deeper understanding of tall buildings in general, what impact they have on a city and how they could be designed differently to the traditional skyscraper typology. Furthermore, the thesis contributes to the discourse on urban densification, tall buildings and sustainable buildings by analyzing, discussing and exploring these subjects.

Research Questions

In what ways do tall buildings cause discussion?

The aim of this question is to explore what types of discussions surround tall buildings. The purpose with this is to understand the drawbacks of tall buildings to be able to adress them when designing, as well as getting a grip of the advantages to further embrace them when designing.

What are the potentials of new typologies of high-rise architecture and how can these overcome the discussions related to tall buildings?

The aim of this question is to present a collection of current research on new typologies of high-rise buildings and translate them into design explorations. The goal is to showcase how new typologies can overcome some of the challenges and discussions related to tall buildings.

Method

The methodology of this thesis has been research for design followed by research by design.

Research for design
The research for design phase mainly encompassed literature studies of different sorts to collect theory about the research field. The history of tall buildings was mapped to understand the evolution of height in architecture over time. Research papers and reference projects have also been studied to present the ongoing discussions and advancements in contemporary tall buildings. Lastly, structural systems of tall buildings have been analyzed to make the design explorations more feasible. Throughout this phase, sketching has been a central part to continuously implement and test ideas to help move the design explorations forward. The literature review was concluded by defining design strategies and principles that the design explorations were based on.

Research by design
The research by design phase consisted of design explorations. These design explorations were based on the foundation of knowledge that was created from the literature studies, where the design strategies and design principles served as a summary of the literature review. The design explorations consisted of 3 iterations where the design resolution increased for each iteration. After each iteration, the models were evaluated based on the design principles to ensure that they responded to a reinvented typology.

Tools
The design explorations and final design proposal were 3D-modeled digitally using Rhinoceros 3D and Grasshopper. Physical models were also produced using a Prusa i3 MK3S+ 3D-printer, with PLA filament. Affinity Designer, Photo and Publisher were used for vector and raster editing of diagrams and renders as well as for creating this booklet.

Figure 1. Diagram of the method.

Theory

Theory
Rem Koolhaas' books *Content* and *Delirious New York* as well as his practical work has been a fundamental reference for learning about why the traditional skyscraper typology needs to be reinvented and how this can be achieved in different ways. The work of Ken Yeang has been of great value to learn about the ecological design approach in tall buildings. Lastly, the book *Tragsysteme (Structure Systems)* by Heino Engel has also provided with an overview of common height-active structural systems and their principles, which the design explorations are based upon.

Delimitations

Delimitations
This thesis mainly focuses on understanding the concept of height in architecture and the exploration of different architectural typologies of tall buildings. As this thesis aims to reconceive what a tall building is, the emphasis is on presenting a catalogue of different design explorations with varying design resolutions. Therefore, technical details and detailed floor plans are not developed. Floor plans and sections are rather envisioned conceptually.

The design explorations are based on conceptual structural designs, but a thorough structural analysis and dimensioning is not included in the project. Fire and other safety concerns are also not fully considered in the design explorations.

Lastly, the thesis will not consider a plan for erecting the proposed designs nor will it consider economical aspects such as costs of constructing the designs.

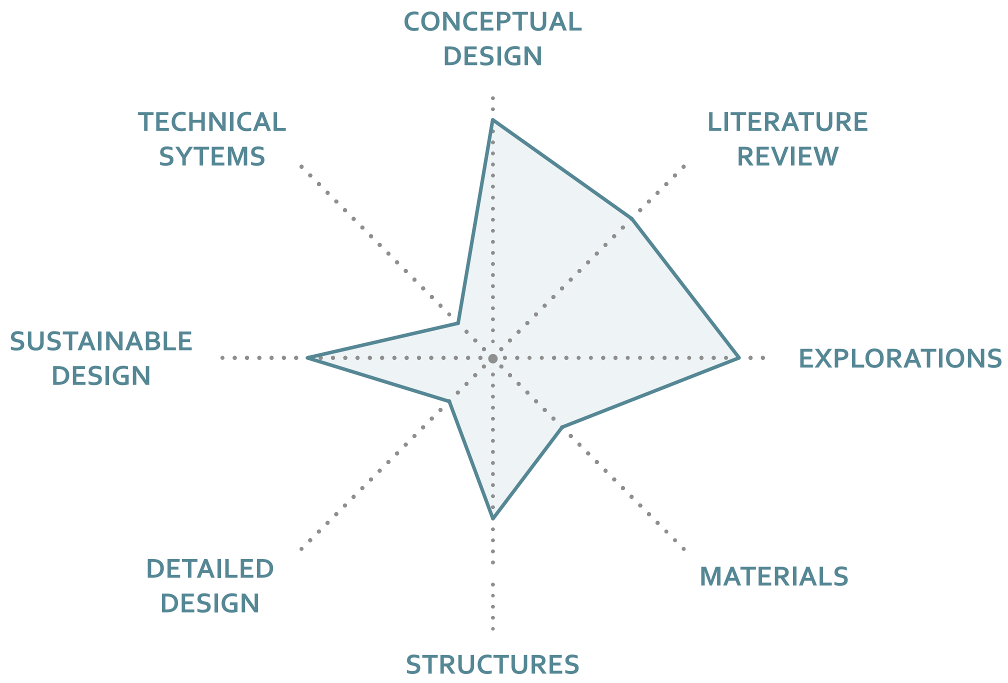


Figure 2. Delimitation diagram.

2
BACKGROUND

"Only if cities around the world free themselves from the competition for height and the mania for technology, and treat people as the main object of concern, while caring about humanity and nature, can a new and humanistic urban civilization be remodeled." (Yosuke, 2014)

Definitions

Tall Building vs Skyscraper
The terms "tall", "high-rise" and "skyscraper" are usually used interchangeably when describing structures that are recognized for their height. However, there is a difference between buildings that are considered tall and skyscrapers.

Tall Building
In general, a tall building is considered to be a structure that has multiple floors and is notable for its height (Cortese, 2018). There is no precise definition of the number of floors or height required for a building to be considered a tall building. A guideline for the threshold for a tall building could be 50 meters (Council on Tall Buildings and Urban Habitat [CTBUH], 2023), but this is not a widely accepted rule. Despite having a height of 50 meters, a building can be considered both tall and low depending on the context in which it is situated. If a 50 meter high building is placed in a low-rise city it would be considered as a tall building since it protudes above surrounding buildings and changes the skyline of the city. However, if placed in a high-rise city it would easily become hidden by other taller buildings and would therefore be regarded as a low-rise building.

Skyscraper
For a building to be considered a skyscraper, the structure must be self-supporting, at least 50 % of its height must be occupiable and the height should rise to a minimum of 150 meters (Cortese, 2018). Communication and observation towers are thus not considered to be skyscrapers. The Council on Tall Buildings and Urban Habitat (CTBUH, 2023) has defined two other categories to distinguish remarkably tall structures from other skyscrapers. These include "supertall" and "megatall" buildings.
Supertall buildings are skyscrapers which have a minimum height of 300 meters, while megatall buildings are skyscrapers with a minimum height of 600 meters.

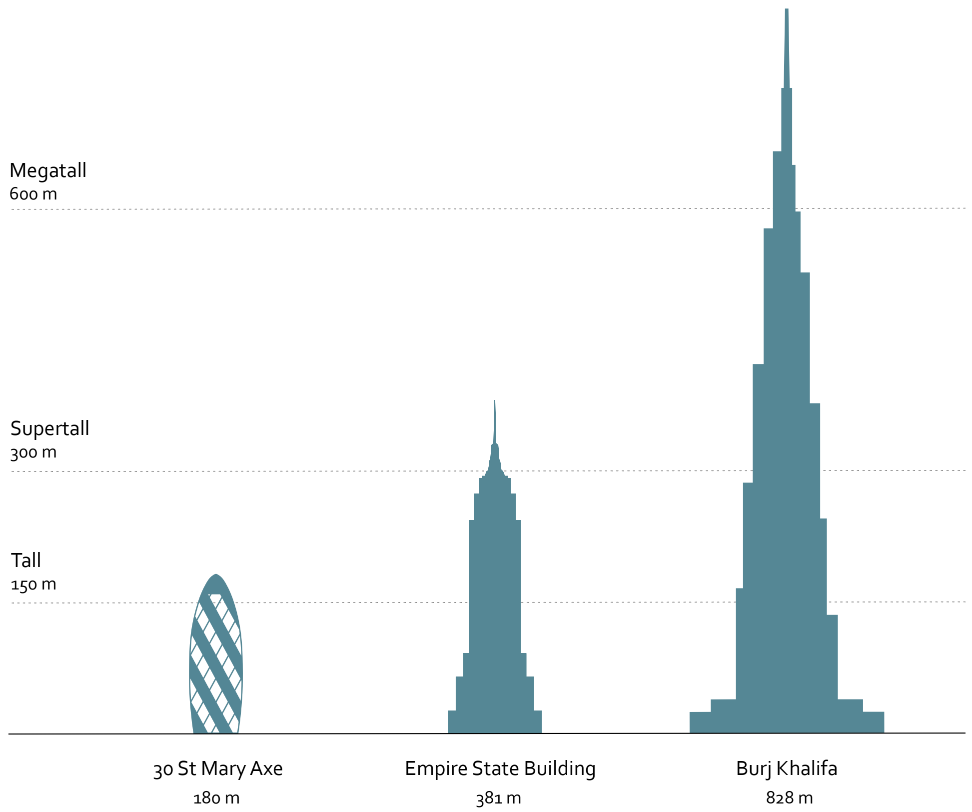


Figure 3. Distinction between tall, supertall and megatall buildings.

The History of Tall Buildings

Introduction
In order to understand how new typologies of high-rise architecture can be developed, it is essential to analyze the evolution of tall buildings to grasp how and why this building type arose and became popular. This chapter will therefore briefly elaborate on the history of tall buildings.

Chicago's Home Insurance Building
The first generation of tall buildings appeared in the 1880's in Chicago and New York (Marshall, 2015). Designed by architect and structural engineer William Le Baron Jenney in 1884, Chicago's Home Insurance Building is considered to be the first tall building of the industrial era. At a height of 42 meters, Jenney utilized a metal-frame design which did not only make the structure fire resistant but it weighed a third as much by using iron and steel rather than stone or masonry. This allowed the building to reach taller heights without being limited by the strength of its outer walls. City authorities were concerned about the safety of the building and halted the construction to conduct several safety tests before allowing the project to continue.

Figure 4. The Home Insurance Building in Chicago (Chicago Architectural Photographing Company, n.d.).

The Chicago School
Chicago's Home Insurance Building ignited a architectural movement called the Chicago School, which consisted of a group of architects in the late 19th century (Marshall, 2015). They included William Le Baron Jenney, Daniel Burnham, John Root, Dankmar Adler and Louis Sullivan. The Chicago School developed innovative tall buildings in a commercial style, driving America's technological advancement forward during the late 19th and early 20th century. Some recognizeable features of the Chicago School include the use of steel-frame structures with masonry cladding in commerical buildings. Today, the influence of the Chicago School's work is evident in major skylines around the world.

The Second Chicago School
From the 1960's, the Second Chicago School emerged from the work of architect Ludwig Mies van der Rohe and structural engineer Fazlur Khan (Condit et al., 1980). Khan introduced a new structural system of framed tubes in skyscrapers, which first appeared in the DeWitt-Chestnut Apartment Building from 1963. His concept used all the exterior wall perimeter of a building to simulate a thin-walled tube structure formed by closely spaced connected exterior columns. This revolutionized the tall building design and laid the groundwork for other future tube-framed structures such as Chicago's John Hancock Center and Willis Tower, New York City's World Trade Center and Kuala Lumpur's Petronas Towers.

The Second Chicago School is closely related to the type of architecture that was taught by Mies van der Rohe at the Illinois Institute of Technology and used by him in his own architectural practice (Condit et al., 1980). The main charachteristics of this type of architecture include focus on structure, minimalism and use of glass and steel. One of his most celebrated buildings include the Lake Shore Drive Apartments from 1951, which was one of the first buildings realizing the steel and glass structure characterized by the Second Chicago School. Mies van der Rohe's work had a highly influential role in the 20th century architecture.

Skidmore, Owings & Merill
The first large firm to put up the steel and glass high-rise buildings that conform to the main features of the Second Chicago School was the Chicago office of Skidmore, Owings & Merrill (SOM) (Condit et al., 1980). The Inland Steel Building from 1975 was the archetype for SOM's principle "form follow function" (SOM, 2021). The building was notable for its steel frame structure, columns placed outside the curtain walls and the column-free interior. This changed the American office culture during the second half of the 20th century.

Today, the most highly regarded SOM buildings include the John Hancock Center from 1969 and the Willis Tower (formerly known as Sears Tower) from 1974 (Condit et al., 1980). Both of these structures are currently among the tallest in Chiacago and are notable for their tubular frame originally invented by Fazlur Khan.

Why did Chicago develop tall buildings?
There are several factors behind Chicago's production of high-rise buildings from the 1880's. The Great Chicago Fire of 1871 destroyed a majority of the buildings in the city, which gave an opportunity to rebuild the city (Glancey, 2015). A building boom arose and the city's population was at the same time rapidly growing. This caused an increase in property prices and landlords therefore had to add value to their investments by building upwards.

Two other factors that played a role in the development of tall buildings were the invention of an electric motor for safety elevators and the cheaper price of steel (Glancey, 2015). This allowed for an increase in speed and height for ascent and further development of steel-frame designs.

Rivalry between Chicago and New York
Simultaneously as Chicago was moving the technological advancement of tall buildings forward, New York was following the trend of building high-rises (Barr, 2014). By 1929, Chicago and New York contained 68 % of the USA's tallest buildings, making them leading cities of tall buildings.

In general, tall buildings have demonstrated a tendency of competition (Barr, 2014). There are several factors behind this tendency, one of them is the competition for industrial growth. Businesses, job growth and expanding populations need to be housed and if the space isn't provided in a city, another city will provide the space instead.

Another factor is that a tall building can serve as a monument due to its symbolic and aesthetic expression (Barr, 2014). The tall building can advertise and promote a city, leading to increased tourism, urbanization and pride in the citizens.

The building height also seems to be significantly important (Barr, 2014). If one city builds particularly tall, then the other city will respond by building even taller. Since Chicago and New York were the leading cities of tall buildings, their respective development of tall buildings were linked. In fact, newspaper reporter Don Hayner wrote in 2000:

"Chicago wanted to be better than the best, but never felt like it was. So it kept challenging New York… " (Barr, 2014)

This indicates that there was a sense of pride and being "better" involved in constructing tall buildings.

Height Policies and Regulations
When the first generation of skyscrapers appeared in New York during the 1890's, they were not subject to any height regulations which led to developers maximizing the plot area by building taller (Barr, 2014). In 1916, New York implemented their first zoning rules which regulated the allowed building height and shape for all lots in the city. These rules were introduced to reduce shadows, sunlight blockage and congestion that was created from densely packed tall buildings. In 1961, New York implemented an incentive zoning law which encouraged developers to design their lots as public spaces such as squares or plazas (Olshammar et al., 2018). This led to more available public space in densely packed districts and increased the street life around high-rise buildings.

Likewise, Chicago introduced direct building height limits between 1893 and 1923 (Barr, 2014). In 1920, Chicago implemented a new approach to height regulations. The law allowed for structures with occupiable spaces up to 79.2 meters and structures up to 122 meters that were only used as ornaments. This suggests that buildings were erected for advertising and monumental purposes.

Conclusions

Technological Innovations
To conclude, there are several factors behind the development of tall buildings. The main component is the technical innovations and advancements that were developed in Chicago during the 1880's followed by the Second Chicago School in the 1960's. Innovations such as safety elevators and steel-framed structures also had a major impact in the development of taller buildings. SOM was the first large firm who dedicated themselves to tall buildings and led the technolgical advancements forward, still being world experts in tall buildings today.

Population and Industrial Growth
Other factors which rapidly increased the need for taller buildings included growing city populations, increased property prices and industrial growth. Both Chicago and New York were expanding their businesses and with limited ground area on particularly Manhattan, the only way to provide more habitable space was to build upwards. Due to this, property prices increased which also forced landowners to increase the value of their property by erecting taller buildings.

Symbolic Monument
Lastly, tall buildings were also developed as a symbolic monument with the aim of promoting a city. It also seemed that cities wanted to be the "best" by having the tallest building in their skyline, resulting in a competition for the ultimate the building height. There was a sense of pride involved in this to show of the city as a whole with the tall building, but also to improve the city's skyline for the inhabitants.

Contemporary Tall Buildings

In this context, contemporary tall buildings are considered as buildings built during the past two decades. To understand why contemporary tall buildings tend to cause discussions and how they differ from older ones presented in the previous chapter, this chapter elaborate on the current tall building typology.

Currently, the population worldwide is rapidly increasing, resulting in an increased rural-to-urban migration (Al-Kodmany, 2012). In order to accommodate large populations in urban areas, tall buildings have become more common in both low-rise and high-rise cities. In high-rise cities such as New York and Singapore, the geographical boundaries limit the horizontal growth of the city, leading to increased land prices and the necessity to expand the city vertically. In several low-rise cities in Europe, high-rise buildings are being built and planned for. The main reasons behind this are urbanization in combination with limited space in urban areas and to promote the cities as international and modern.

During the past few decades, skyscrapers have been considered as isolated towers that abruptly wipe out the street life (Al-Kodmany, 2012). As a tall building accommodates a large number of people, these people are separated from the street, resulting in a city detached from street life. The people in a tall building are also further away from nature and social interaction which is typically provided in areas with low-rise buildings. Therefore, it is important that tall buildings contain recreational spaces and vegetated areas, to compensate for the drawbacks associated with high-rise cities.

Tall buildings are also recognized as buildings that help reduce carbon emissions and energy consumption due to decreased travel time (Al-Kodmany, 2012). The compact development that tall buildings contribute with are therefore needed to combat climate change, rather than expanding a city out into the suburbs. In fact, studies show that denser cities in terms of population per hectare have lower carbon emissions from transportation compared to less dense cities, as illustrated in Figure 5 below.

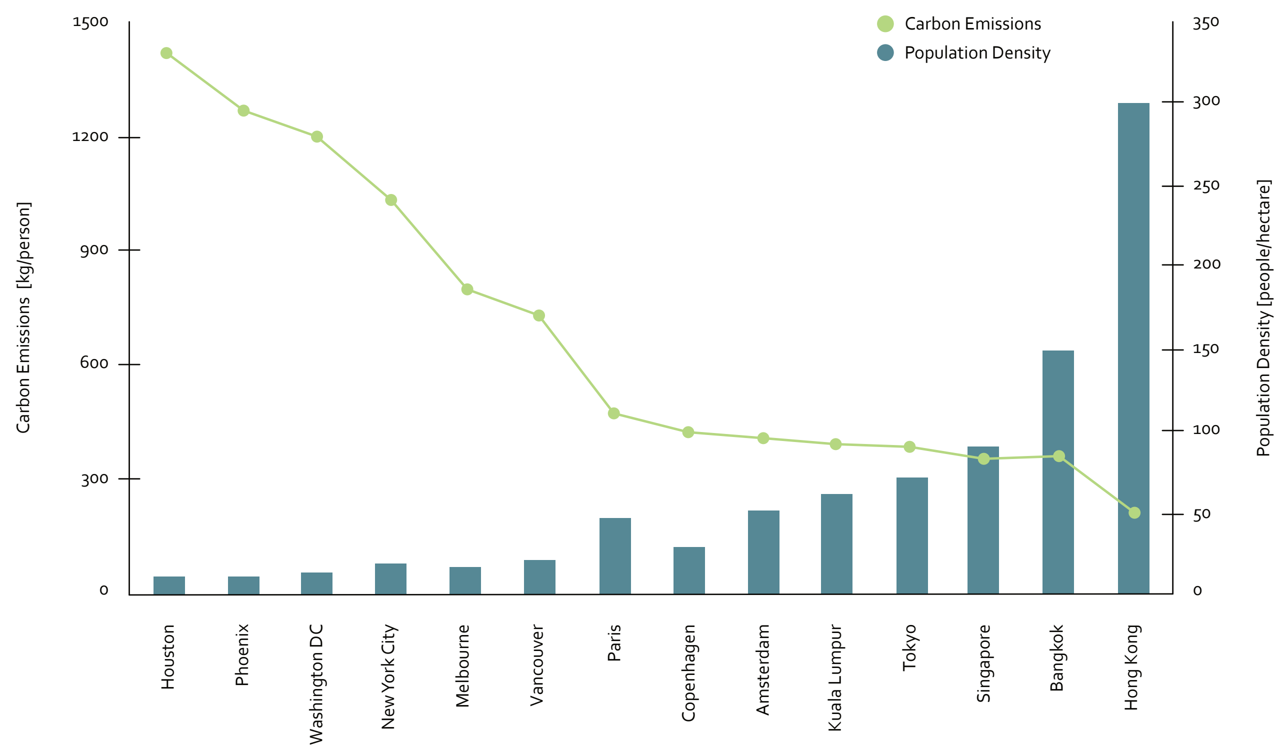


Figure 5. Graph showing that denser cities tend to have lower carbon emissions from transportation compared to less dense cities (Graph adopted from Al-Kodmany, 2012).

Glass-wrapped Skyscrapers
As seen in the historical case of Chicago and New York, cities today still compete on a global level to achieve the title of the tallest building (Al-Kodmany, 2012). This is mainly to announce the city's prosperity and wealthiness. Creating a certain image of a city has always been a primary concern in architecture as cities strive to be significant and recognizable. In recent years, the aspiration to build taller has progressed at the cost of design, functionality and integrity. Contemporary tall buildings are often fully clad with glass panels due to their adaptability and versatility. Glass is also considered as the epitome of modern materiality and although it can improve a buildings appearance and ambiance, there are also challenges related to the material.

A major issue with glass-wrapped skyscrapers is the unlimited access of sunlight to the building (Epstein, 2019). Since the entire building is covered in a glass skin, the heat is trapped inside which requires large amounts of air conditioning to cool down. In other words, glass-wrapped skyscraper fight the environment rather than work with it. Without the air conditioning, glass-wrapped skyscrapers can be seen as tall greenhouses. On one hand, this could be used to the building's advantage by placing agricultural and aquaponic opportunities close to the perimeter of the building - something that should occur more frequently in tall buildings.

Another concern with glass-wrapped skyscrapers is the loss of individuality and integrity between cities (Davidson, 2017). The glass-wrapped skyscraper typology is relatively easy and quick to design and erect, but most often they don't fit into their surroundings that usually consist of rich architectural details.

Karlatornet, Gothenburg
Karlatornet is a 245 meter tall building that is currently (2023) being built in Gothenburg, Sweden. The proposal was presented in early 2016 and is owned by a single landowner; Serneke (Olshammar et al., 2018). When being presented, Serneke stated that Karlatornet will stand as a symbol and a point of pride for all residents in Gothenburg. Yet, Karlatornet mainly consists of expensive apartments, thus excluding all inhabitants to take part of the building which has a segregating effect on the city (Kruse, 2017). Furthermore, Karlatornet has also received critique for not resembling the city or the local context in its design and height.

Even though the project has received critique, it has also been praised by the public and authorities. The building is designed by Skidmore Owings & Merrill (SOM), who are world experts in high-rise buildings and have designed the world's tallest building Burj Khalifa in Dubai (Ekberg, 2014). For being a relatively small city that Gothenburg is compared to other cities where SOM commonly design high-rises, it's remarkable that they have been involved in changing Gothenburg's sillhouette - something that the city should be proud of. Others claim that the building stands as a symbol for modernity and prosperity, which makes the city more attractive (Olshammar et al., 2018).

Figure 6. Render of Karlatornet in Gothenburg (Serneke, n.d.)

New Typologies of Tall Buildings

Introduction
In this chapter, current and past research on new typologies of tall buildings will be elaborated on. The research will range from several architects that have challenged the status quo to research papers regarding new typologies of tall buildings.

"Kill The Skyscraper" - Rem Koolhaas
In his book *Content*, architect Rem Koolhaas titled a chapter *Kill The Skyscraper*, where he argued that the typology of most skyscrapers had become cliché and repetitious (Koolhaas, 2004). Additionally, he endorsed that it was time to consider new approaches and typologies when designing tall buildings.

"... the skyscraper has become less interesting in inverse proportion to its success. It has not been refined, but corrupted: the promise it once held - an organization of excessive difference, the installation of surprise as a guiding principle - has been neglected by repetitive banality." (Koolhaas, 2004)

A decade later, Koolhaas was awarded Best Tall Building Worldwide from the Council on Tall Buildings and Urban Habitat for his CCTV Headquarters in Beijing, China (Fairs, 2013). As Koolhaas believed that the traditional skyscraper was lacking creativity, his CCTV building took an unusual take on the high-rise typology. Instead of competing for the ultimate height, the CCTV building provides a 3D experience by joining two tower blocks and thereby reinforcing social interaction between the towers. The design violates the high-rise convention and redefines the skyscraper typology.

Figure 7. The CCTV Headquarters in Beijing (Dayton12345, 2019).

Challenging The Status Quo
In Koolhaas' book *Delirious New York*, he states that he sees the skyscraper as city within a city, containing a rich inner life (Koolhaas, 1994). What makes the tall building unique is that it can enclose several different independent activities and functions, where each function attracts a specific population. By seeing the skyscraper typology like this, it can be thought of as an extension of the city vertically, where the elevators and staircases act as public lanes between the stories. When entering the skyscraper, the visitor leaves the public street to enter a semi-public and semi-private context. The building could contain a range of functions such as housing, offices, restaurants, cinemas and sport venues. Creating recurring lively hubs that vary in height, quantity and form would be fundamental in this typology.

The skyscraper could also be realized as an extension of the street network on the ground floor by having horizontal connections to adjacent buildings (Olshammar et al., 2018). This could be implemented through sky bridges and planes that would preferably be placed at different locations and heights throughout the building. The sky bridges and planes would not only act as circulation between different buildings but could also accommodate common spaces such as sky gardens, terraces and open-air cafes, enriching both the buildings and the city.

A challenge with vertical "streets" compared to horizontal ones is the difficulty of moving upwards (Olshammar et al., 2018). A solution that is commonly used in tall buildings today is to place elevators, stairs and corridors in an interior open court or atrium. This would also allow for the visitor to appreciate and be exposed to the height of the building, although there is presumably a psychological limit to how high this type of space could be without provoking discomfort.

The problem of realizing this typology is that the semi-private building would contain public "streets" that should be as available as regular streets on the ground level, which would demand a close collaboration between municipal authorities and private authorities (Olshammar et al., 2018). The building would also demand monitoring around the clock if the public "streets" should be regarded as regular streets.

Rethinking The Elevator
Despite many technological advancements since the elevator was first invented around 150 years ago, the elevator has not changed since then (PLP Architecture, 2022). The elevator consists of a single cab that only moves up and down on a one-way trajectory. Looking at how movement and transportation systems work in a city, they are looped and multi-directional. Trains, buses and trams are followed by their next as soon as they pass their stop. This system is effective and versatile, utilizing movement in different directions by several vehicles followed by each other.

London-based architecture firm PLP Architecture have challenged the traditional elevator by developing transportation systems in tall buildings that operate in a similar way to how transportation works in a city (PLP Architecture, 2022). Their research project IUMO/v explores the possibility of integrating infrastructure throughout a tall building. The transportation system consists of tracks placed on the outer surface of the building, where pods are attached to the tracks using a system of magnets that push and pull as the pods move along the tracks. This system is similar to how Maglev trains operate. The pods can move left to right as well as up and down, allowing for a more versatile and efficient transportation system in tall buildings.

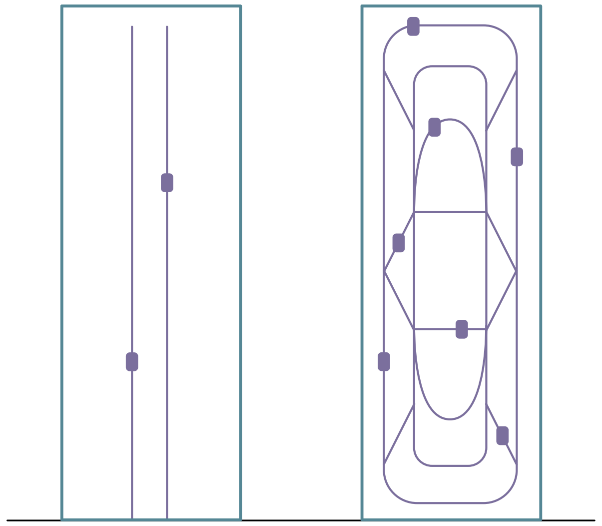


Figure 8. Left: Traditional transportation system of the elevator. Right: Reinvented transportation system in a tall building, where the movement is looped and multi-directional, similar to how transportation operates in a city.

Eco Skyscrapers
A tall building is generally not a sustainable building type since it requires more material in its structural system to withstand higher bending moments caused by the wind (Yeang, 2007). It also demands higher energy consumptions to transport materials and services to the higher floors during construction. With the demands of growing cities and increasing urbanization, the tall building typology is inevitable. Therefore, it is fundamental to mitigate the environmental impacts by designing green tall buildings, also called Eco Skyscrapers.

Architect and researcher Ken Yeang has layed the groundwork for ecology-based architecture since 1971 and has combined that with his interest in tall buildings (Yeang, 2007). His ecological design approach is based on environmental bio-integration, meaning that the built environment should be seamlessly integrated with the natural environment - an approach called ecomimesis. If this is achieved, the environmental impact of tall buildings will be minimal or even positive.

The fundamental design principle of ecomimesis is to imitate the nature's processes and functions (Yeang, 2007). An ecosystem has no waste as everything is recycled within the system, thus by imitating this function the built environment should produce no waste. All products and emissions of the built environment should be reused and recycled. Therefore, use of renewable energy and material sources should also be implemented.

By perceiving the built environment as an imitation of of the natural environment, a building is essentially an enclosure that enables human activities inside (such as housing, offices or manufacturing) while simultaneously protecting from external weather conditions (Yeang, 2007). This means that a building should not be seen as an object, but rather an artifact that is integrated with nature. As a building's material composition is mainly inorganic, this must be balanced by appropriate levels of biomass and increased biodiversity. A primary misconception of ecological design is that solar panels, recycling systems or double-skinned facades generates an building ecological. Although these technological systems are relevant, they are simply not enough in developing ecologically responsive buildings.

Reference Projects

EDITT Tower, Singapore
The EDITT (**E**cological **D**esign **I**n **T**he **T**ropics) Tower in Singapore is a project designed by Yeang to increase the surrounding biodiversity and improve the local ecosystem (Yeang & Yeang, 2008). The multifunctional building is designed for expo events including functions such as retail, exhibition spaces and auditoriums. The overall geometry of the building displays an organic composition, both in terms of public space and circulation. The building incorporates several features that resemble eco skyscrapers, including vertical landscapes, sky courts and sky plazas. The street life on ground level is connected to the upper parts of the building through vegetated and landscaped ramps that create a continuous spatial flow throughout the building and also assist in cooling the facade. The rooftop as well as parts of the facade serve as rainwater collectors, where a water recycling system is integrated throughout the building.

The EDITT Tower displays a building typology that is integrated with the natural environment by providing habitats for small creatures and containing a wide variety of vegetation throughout the building.

Jian Mu Tower, Shenzen
The Jian Mu Tower in Shenzen is a project developed by Carlo Ratti Associati where the facades of the building consist of vertical hydroponic farms that provide food for the needs of around 40000 people per year (Carlo Ratti Associati, 2021). Hydroponic farming constitutes the growing of plants using water based and mineral nutrient solutions instead of soil. As opposed to farming using soil, this method allows for organizing and growing crops in a vertical formation.

The building has a self-sustained food supply chain, where cultivation, harvest, sale and consumption all take place inside the building (Carlo Ratti Associati, 2021). The hydroponic farms also help the building with solar shading while simultaneously taking advantage of the exposure to sunlight through the production of food. In addition to the vertical farms, the tower also contains offices, supermarkets, food courts, sky gardens and landscaped terraces. The sky gardens are integrated with the interior spaces, seamlessly overlapping the natural with the artificial. The landscaped terraces contain a wide variety of flora and promote the biodiversity of the building as well as the city.

Figure 9. Conceptual render of the EDITT Tower in Singapore (T.R. Hamzah Yeang Sdn Bhd, 2008).

Figure 10. Conceptual render of the Jian Miu Tower in Shenzen (Carlo Ratto Associati, 2021).

Conclusions

Repetitious Typology
To conclude, there are several aspects to consider when developing new typologies of high-rise architecture. One of the main arguments against the traditional skyscraper typology is that it is too repetitious in terms of geometry, expression and functionality. The current typology needs to be challenged by varying the expression, functionality and geometry with height to fully take advantage of the versatility that tall buildings entail.

Multifunctionality
Another aspect to consider is to allow for the tall building to be seen as a vertical city. The vertical city translates into a multifunctional building that has all functions and features that a regular horizontal city contains. This means that the vertical city operates independently from the ground level activities, although it's nonetheless seamlessly connected to the ground level activities.

Eco Skyscrapers
Furthermore, recent research has shown that integrating nature into our built environment is essential to combat climate change and to provide high quality spaces. Since tall buildings demand more materials and consume larger amounts of energy, it is essential to mitigate their environmental impact by integrating them with the natural environment. Other aspects to consider is in the design of eco skyscrapers is urban farming, rainwater collection systems and landscaped terraces that are vegetated.

Horizontal Movement
Tall buildings need to consider multidirectional and looped transportation systems to ensure effective and flexible circulation throughout the building. This can be achieved by imitating how transportation systems work in a regular horizontal city where trains, buses and trams are followed by each other and operate in a loopee system.

Glas cladding
Lastly, tall buildings are usually fully clad in glass panels due to their versatility however there are challenges related to this. A main issue is the large amount of sunlight that the building is exposed to. This requires large amounts of air conditioning to cool down, making the tall building an additional burden to the environment. The large amount of sunlight should rather be taken advantage of in combination with agricultural opportunities.

Design Strategies

The points that tend to cause discussions around tall buildings are summarized below as they are vital when evaluating and developing the design explorations to ensure that they respond to a reinvented typology. Each point has a design strategy for overcoming the problem along with at what design resolution the problem should be reflected in the design explorations.

The design strategies are then combined with other relevant points that several architects and research papers have raised as prominent when realizing new typologies.

Examples of these points include horizontal connections to other tall buildings and varying the form, expression and program with height. This results in design principles presented on the next page, where the design principles are a general and broader version of the design strategies.

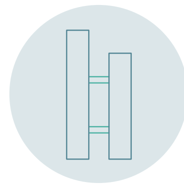
The problem "Tall buildings strive for taller heights at the cost of design, functionality and integrity" is not included in the design principles since this problem will automatically be fulfilled when exploring a reinvented typology.

PROBLEMS	DESIGN STRATEGY	DESIGN RESOLUTION
Tall buildings kill the street life	Incorporate a interior street life and consider the relation between the building and the street	Massing, Conceptual, Final Proposal
Tall buildings move people further away from nature and socialization	Include vegetation, recreational areas and community spaces in the building	Massing, Conceptual, Final Proposal
Tall buildings are covered in glass panels and lose their individuality	Use other cladding materials to obtain another expression and to decrease the income of heat	Final Proposal
Tall buildings strive for taller heights at the cost of design, functionality and integrity	By exploring a reinvented typology, the building will accordingly not only focus on the height	Massing, Conceptual, Final Proposal
Tall buildings only contain functions directed to a portion of the population	Incorporate multifunctional components in the building	Conceptual, Final Proposal
Tall buildings only have vertical movements between each floor	Provide horizontal connections to other tall buildings and horizontal movement between floors	Massing, Conceptual, Final Proposal
Tall buildings are unsustainable as they require more materials	Incorporate vegetation, biomass and biodiversity in the building	Final Proposal

Design Principles for New Typologies

Vary the form, expression and program with height

Tall buildings should not be repetitious vertical extrusions of a simple floor plan, but should rather vary in form, expression and program with height to fully utilize the versatility of tall buildings and for the building to have its own integrity.



Incorporate connections between tall buildings and horizontal movements

The only physical connection between tall buildings should not solely rely on the ground plane. Sky bridges and sky planes have a massive potential in allowing movement between tall buildings and providing elevated common spaces. The movement between floors in the building should not only be vertical but also consider horizontal movements.

Provide public and common recreational spaces

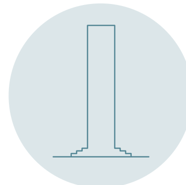
Open and public spaces improve the social sustainability of a tall building. Public spaces also provide a sense of community and are available for different types of socioeconomic groups that are often excluded from tall buildings.

Bring all aspects of the city up in the sky

The essential elements of the ground level such as education, health and recreation need to be incorporated into tall buildings. This includes implementing parks, sports facilities, retail and other public functions into the single building to support the functions on the ground level.

Incorporate vegetation throughout the building

Vegetation and green spaces should be a vital part of tall buildings both internally and externally. By introducing vegetation, the building can generate oxygen, provide natural habitat for small animals and agricultural opportunities.



Seamlessly intregrate the building with the street

By adjusting the lower floors of the building to consist of courtyards, public spaces or incorporating landscape, the tall building has a clear connection to the surrounding street life and involves it rather than creating a barrier between it.

Structural Systems in Tall Buildings

In the design of high-rise buildings, the structural stability becomes increasingly complex and critical with extending heights (Evans et al., 2013). A brief overview of different structural systems in tall buildings will therefore be presented as the design explorations in the next chapter will to take this into account to make them more feasible.

The structural systems in tall buildings can be divided into two groups; interior structures and exterior structures (Evans et al., 2013). As the name suggests, interior structures have their main stability located within the interior of the building, usually through shear walls or cores. On the contrary, exterior structures use the perimeter of their skin to form a stiff structure that provides stability.

Rigid or Braced Frame
In the rigid or braced frame, the lateral stability is provided by structural cores, shear walls or rigid beam-to-column connections (Engel, 1997). This makes the elements of the braced frame capable of withstanding bending moments, shear, and axial loads.

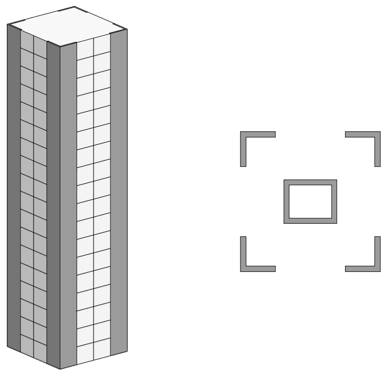


Figure 11. Diagram of the shear walled system.

Outrigger System
By using the outrigger system, the stability is provided by structural cores with an additional stiffness from belt trusses that are spaced att regular storey intervals (Engel, 1997). These belt trusses are connected to outrigger columns, resulting in an increased lever arm for the lateral loads to be distributed over.

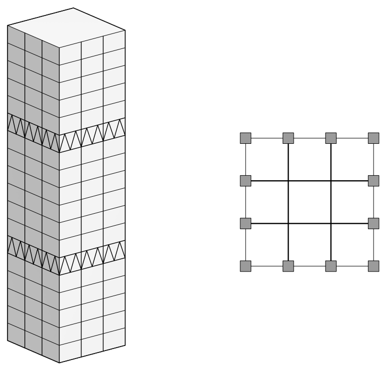


Figure 12. Diagram of the outtrigger system.

Framed Tube
For the framed tube, a number of closely spaced columns at the perimeter of the building are connected to the floor slabs through fixed connections to deep beams (Engel, 1997). This allows the columns and beams to act as a large external core, increasing the width compared to an internal core which makes it more efficient.

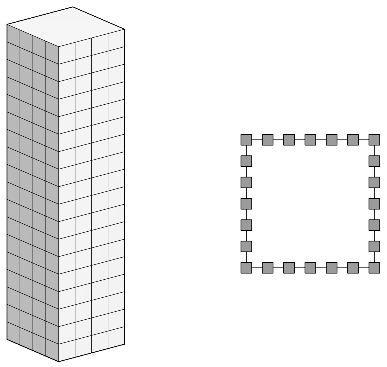


Figure 13. Diagram of the framed tube.

Braced or Trussed Tube
The braced or trussed tube is a similar system to the framed tube but the external core is mainly created by a braced truss in combination with broader spaced columns at the perimeter of the building (Engel, 1997). This creates a rigid box that is capable of resisting lateral shear forces axially rather than through flexure. The relatively broader column spacing allows for more clear space for windows.

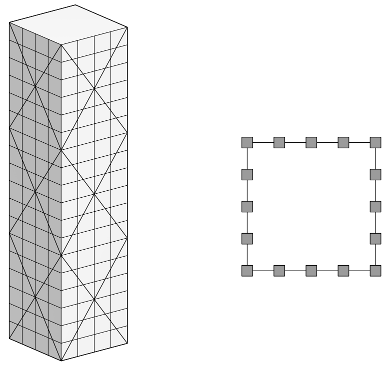


Figure 14. Diagram of the braced tube.

Bundled Tube
The bundled tube consists of a number of framed tubes that are structurally connected to utilize their combined strength to withstand lateral loads (Engel, 1997). All tubes may not be of the same height to increase the height-to-width ratio of the building.

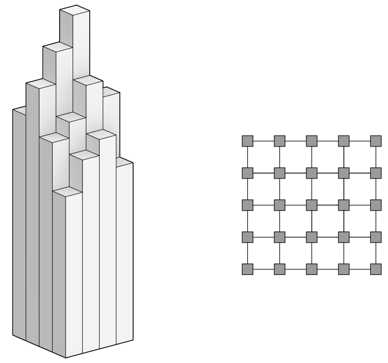


Figure 15. Diagram of the bundled tube.

Diagrid Structure
A diagrid structure is essentially a braced tube that uses a diagrid instead of a braced truss to form a structural perimeter tube (Evans et al., 2013). The diagrid structure is commonly used in high-rise buildings that have a complex and curved geometry.

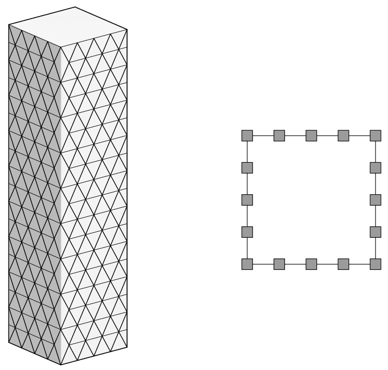


Figure 16. Diagram of the diagrid tube.

Buttressed Core
The buttressed core system consists of a interior core that is reinforced by three buttresses that from a Y-shape (Evans et al., 2013). The buttressed core supports itself both laterally and torsionally, eliminating the need for columns.

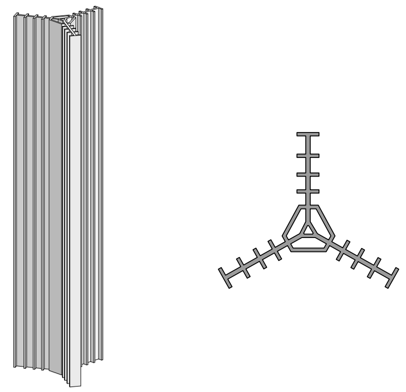


Figure 17. Diagram of the buttressed core.

3
DESIGN EXPLORATIONS

Design Explorations

Using the knowledge gained from the literature review, design implementations on new typologies of tall buildings are explored in 3 iterations. In thia chapter, iteration 1 and 2 are presented, while iteration 3 is presented in the next chapter called *Final Design Proposal*.

The first two iterations consist of developing massing and conceptual models of new typologies that resonate with the design principles previously set, where different design principles are related to each iteration due to the difference in design resolution. For each iteration, the design resolution increases and the last iteration, which is the final design proposal, should conform to all the design principles. After each iteration, the designs are evaluated according to their respective design principles. This is to ensure that the final design proposal reconceives the traditional typology of tall buildings by complying to all the design principles.

Massing Models
The first step in the design explorations is to produce massing models. These models are developed based on interesting shapes in tall buildings, aiming to explore a wide range of typologies. Most of the models are generated parametrically using Grasshopper, while others are manually designed in Rhino. The slenderness ratio of the geometries are set to around 10:1 to resemble a tall building. The potentials and qualities of the massing models are then carefully studied and evaluated according to their design principles, where two different types (A and B) are selected to further develop into conceptual models.

Conceptual Models
The conceptual models aim to principally organize different functions into a building geometry, where each type focuses on specific architectural qualities and both types should comply to their design principles. The conceptual models increase the design resolution from the massing models and include conceptual programmatic qualities and functions. The conceptual models are then evaluated according to their design principles in the *Analysis of Conceptual Models* chapter, where the goal is to choose one model to further develop into a final design proposal. Although one model is selected, qualities from the other model may also be chosen to be incorporated in the final design proposal.

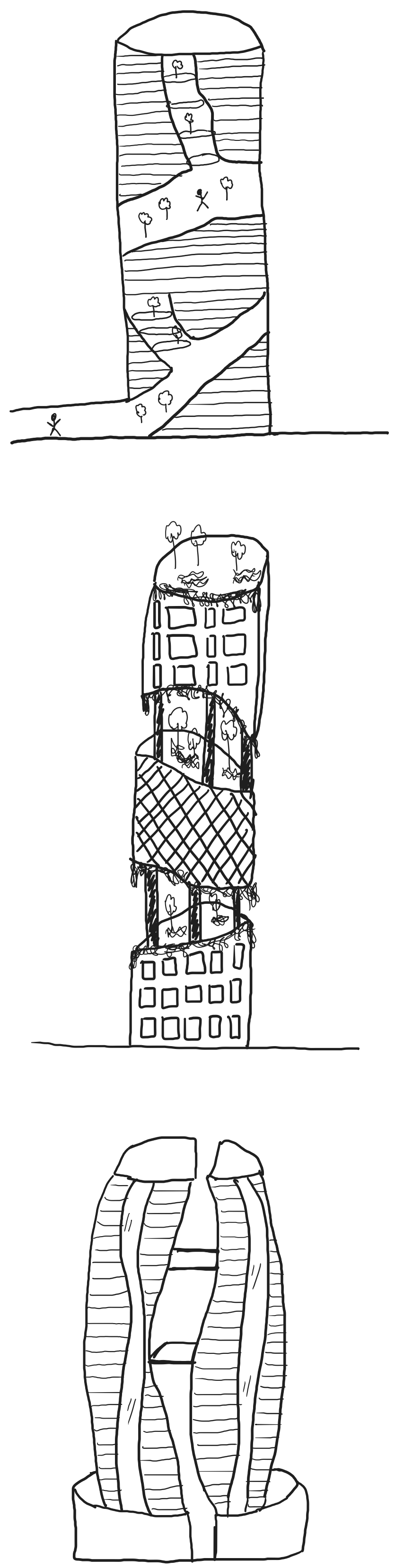
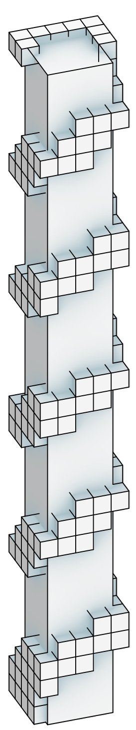
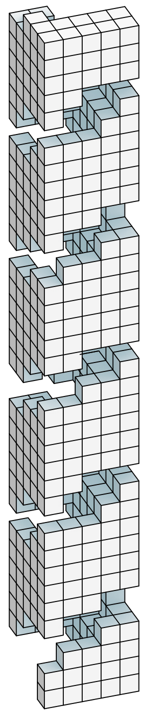
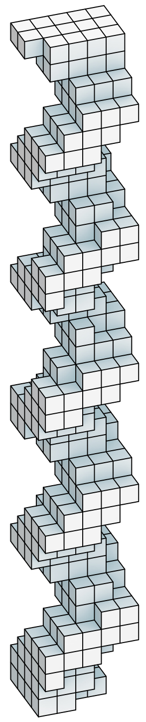


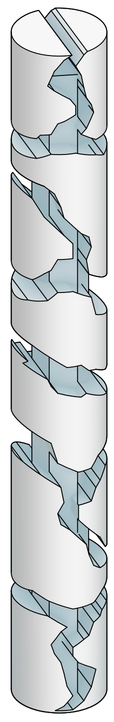
Figure 18. Early sketches.

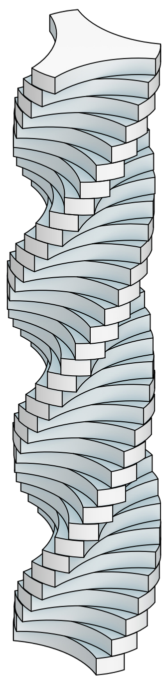
Massing Models

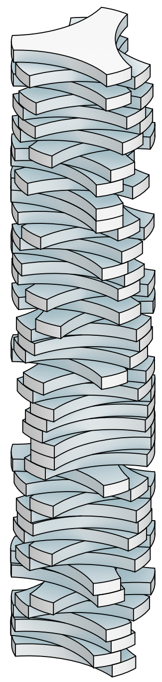

Massing Model 1

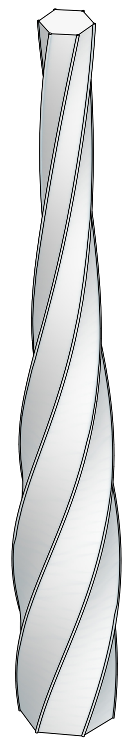

Massing Model 2

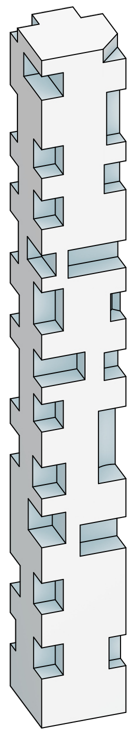

Massing Model 3

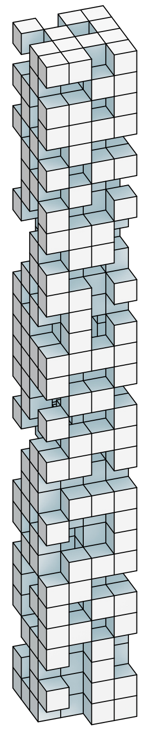

Massing Model 4

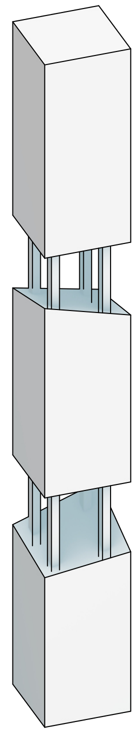

Massing Model 5

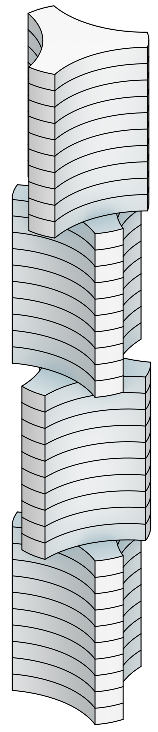

Massing Model 6

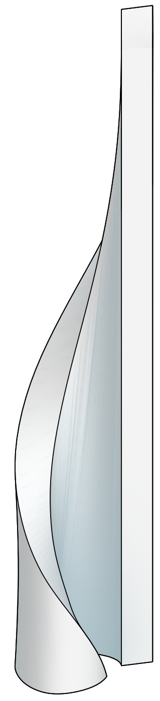

Massing Model 7

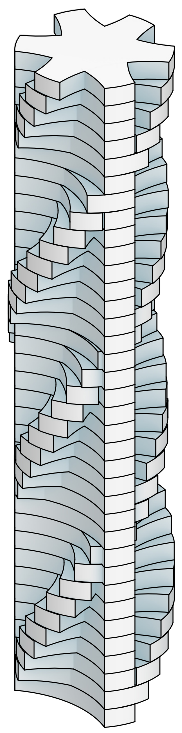

Massing Model 8

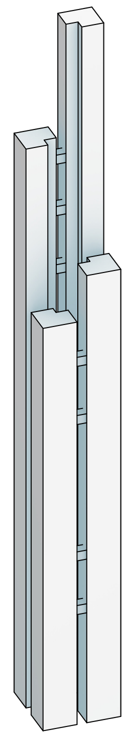

Massing Model 9

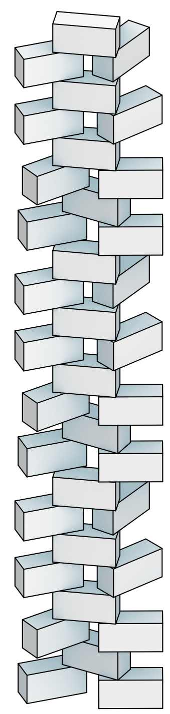

Massing Model 10

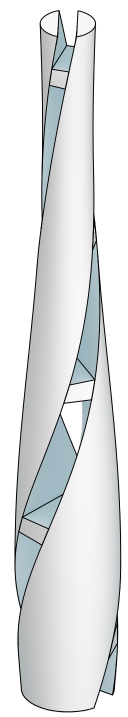

Massing Model 11


Massing Model 12


Massing Model 13


Massing Model 14


Massing Model 15


Massing Model 16

Physical Models

Figure 19. 3D-printed models of 6 different massing models using PLA filament. Scale 1:40.

Massing Model - Type A

The Type A typology mainly focuses on breaking up the facade in different ways. By doing so, the building geometry allows for several architectural qualities such as terraces, niches and variation in form and expression with height. This makes the general volume of the building less repetitious.

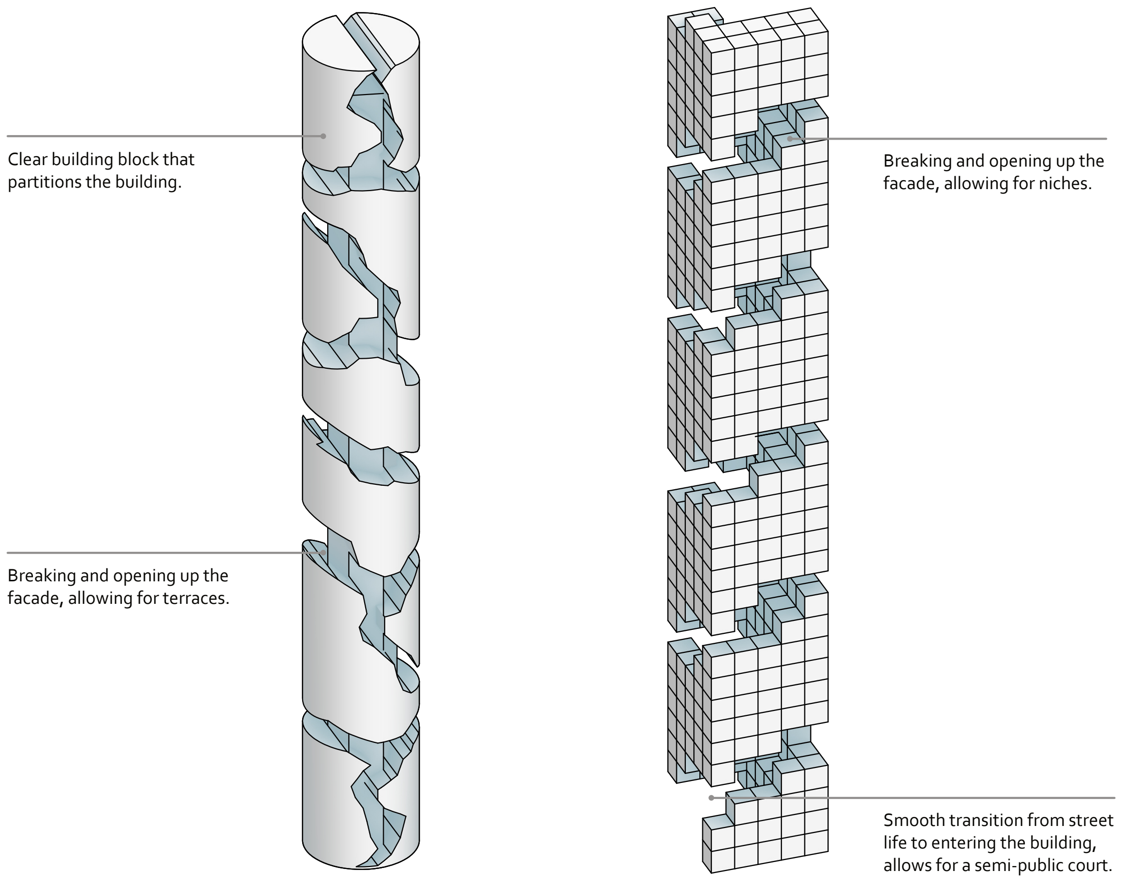


Figure 20. Architectural qualities of the Type A massing model.

Massing Model - Type B

The Type B typology mainly focuses on uniting several building blocks together. This enhances the building as a number of united communities, thereby allowing for elevated movement between the building blocks. This typology also adapts to the street life on ground level, blurring the interface between the public street and semi-private building making the building an integral part of the city.

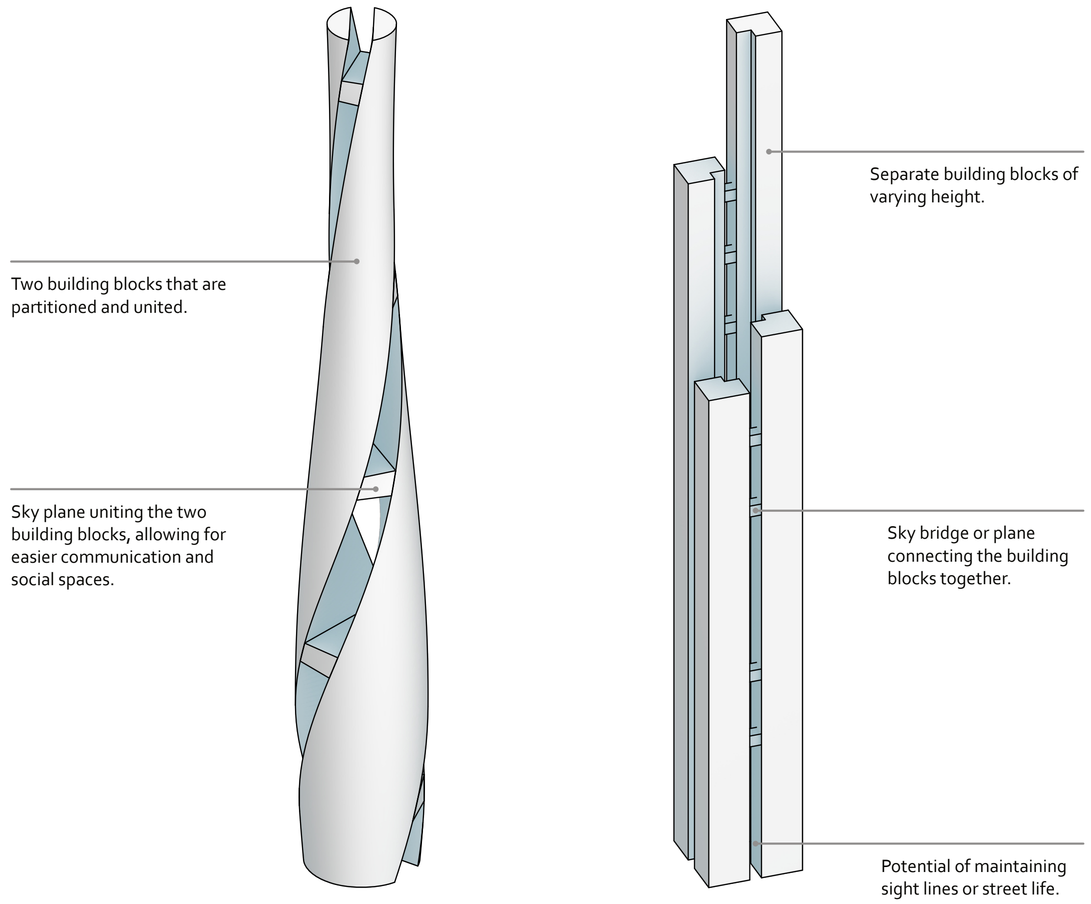


Figure 21. Architectural qualities of the Type B massing model.

Analysis of Massing Models

In general, the massing models showcase a large variety of new geometrical typologies of tall buildings. The design principle *vary the form and expression with height* is fulfilled in almost all the models, except for model 1 and 15 that have a repetitive geometry. All other models present a change of geometry or height throughout the model.

When it comes to the design prinicple *provide public and common recreational spaces*, these type of spaces need to be envisioned by the observer since no programmatic details are suggested in the massing models. By twisting the floor slabs or portions of the geometry in model 5, 6, 11 and 15 terraces are automatically created which could correspond to public and recreational spaces. The same applies for model 1, 2, 3, 4, 8, 9 and 10 where portions of the geometries are carved out resulting in terraces. Model 14 and 16 consist of several geometries that are united into a single geometry. The united parts of the geometries could potentially be seen as public and common spaces, creating a connection and enabling socialization between different parts of the geometry.

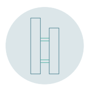
Model 14 and 16 also fulfill the design principle *incorporate connections between tall buildings and horizontal movements* since their united parts can easily be seen as horizontal connections. Although horizontal movements in the interior of the geometries can be difficult to imagine since the they are somewhat closed, model 1, 2, 3, 4, 8 and 9 are carved out and have the potential of incorporating other tansporation systems than the vertical elevator. This is because their geometry has a spiraling effect, allowing movement horizontally as well as vertically. This could also be the case for the twisting models 5, 6 and 13 although moving in a horizontal or spiraling manner is not as self-evident.

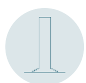
Lastly, the design principle *seamlessly integrate the building with the street* also need to be envisioned conceptually in the massing models. Model 2, 3, 4 and 9 fulfill this by their carved out geometry which allows for a seamless integration of the street with the building. Inhabitants could be envisioned to naturally "fall into" the building when walking nearby. Model 5, 6, 12 and 13 also have a similar effect, with the difference being that they lower geometry capsules a part of the street, creating a semi-public environment. The space between united building parts in model 14 and 16 also has the potential to maintain the street life as the street is allowed to pass through the building as a whole.

The design principles related to the massing models are the following:

Vary the form and expression with height


Provide public and common recreational spaces


Incorporate connections between tall buildings and horizontal movements


Seamlessly integrate the building with the street

Conclusions

From this evaluation of the massing models according to the above design principles, it is evident that model 2, 3 and 4 show the most potential in envisioning public and recreational spaces in the terraces and nisches that they create with their geometry. Their geometry also allow for a seamless integration of the street with the building as well as allowing for horizontal movements throughout the building in a spiraling manner. This typology is therefore grouped together and called **Type A**.

Furthermore, model 14 and 16 show the most potential in incorporating connections between tall buildings and integrating the street with the building due to their geometries consisting of several building parts that are united. The uniting elements also allow for elevated public and social areas. This typology is therefore grouped together and called **Type B**.

Type A and B are further developed into conceptual models in the next iteration, where the design resolution increases.

Program

The exact program of the conceptual models are unspecified due to their comprehensive versatility. Instead, the conceptual models adopt a building principal with a shell and structural integrity that house a general program. The general program is divided into 3 broader groups; residential, commercial and urban features. Within each group, several specific functions are proposed aiming to suggest different functions that could be contained within each group.

Residential
The residential category contains functions related to different types of accommodations. These include housing of different sizes and types such as student and senior housing, co-housing and regular apartments. Functions related to residency include playgrounds, community spaces, parking and farming. These functions are in many cases not of uttermost necessity to incorporate in residential areas but provide the residents with facilities that increase their well-being and flexibility.

Commercial
The commercial category involves buildings that intend to make a profit such as restaurants, stores and hotels. These functions are advantageously placed strategically to make them more accessible to the public. Other building types that are included in the commercial category include different types of offices such as large corporations, private businesses and rentable office spaces.

Urban Features
The urban features category contains functions and features that are commonly present in urban environments. These include non-profitable buildings such as museums, libraries and schools that provide the public with cultural activities and services. Other functions related to urban features include parks, plazas and street life.

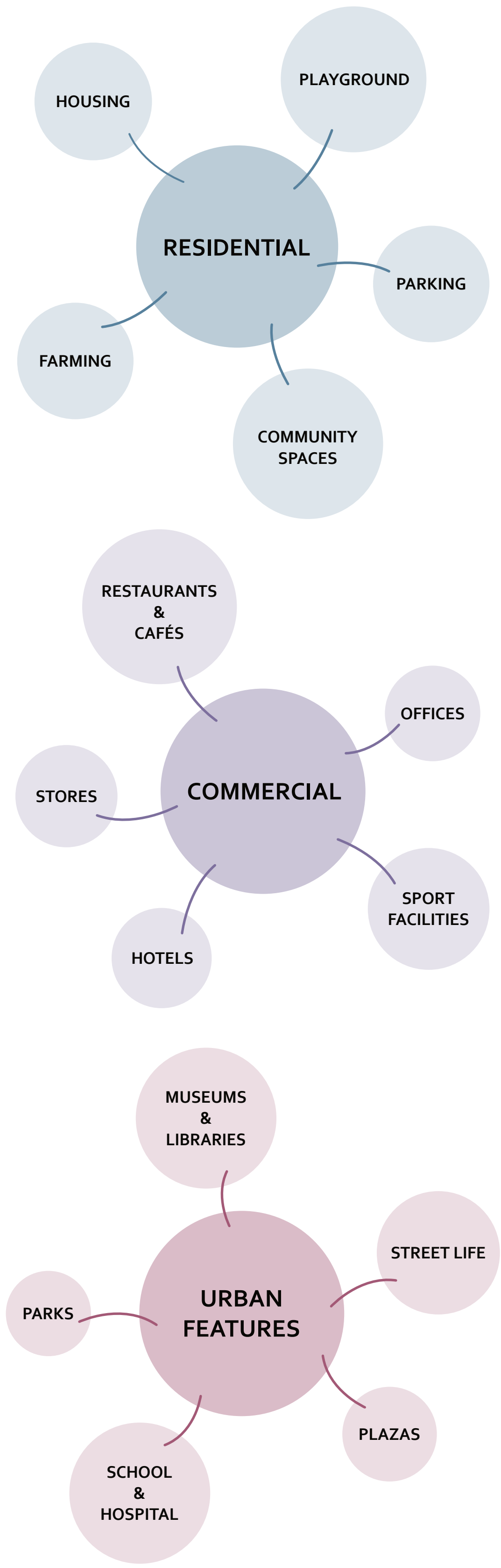


Figure 22. Diagram showing the general program that is divided into 3 different groups, with suggested functions within each category.

Conceptual Model - Type A

The Type A conceptual model consists of a broken up building typololgy. This reduces the wind loads acting on the building while also allowing for niches and terraces that could act as resting areas similar to a park or plaza in a traditional city layout. The openness also hints at the interior life of the building and divides the building into numerous communities.

The building has a central structural core and indented megacolumns at the edges of the building. This increases the effect of a lightweight and broken up building typology compared to placing the columns at the outermost edges. The megacolumns consist of a timber and steel truss with a width of 5.2 meters to increase the stiffness of the columns.

Height: 490 m
Width: 60 m
Length: 85 m

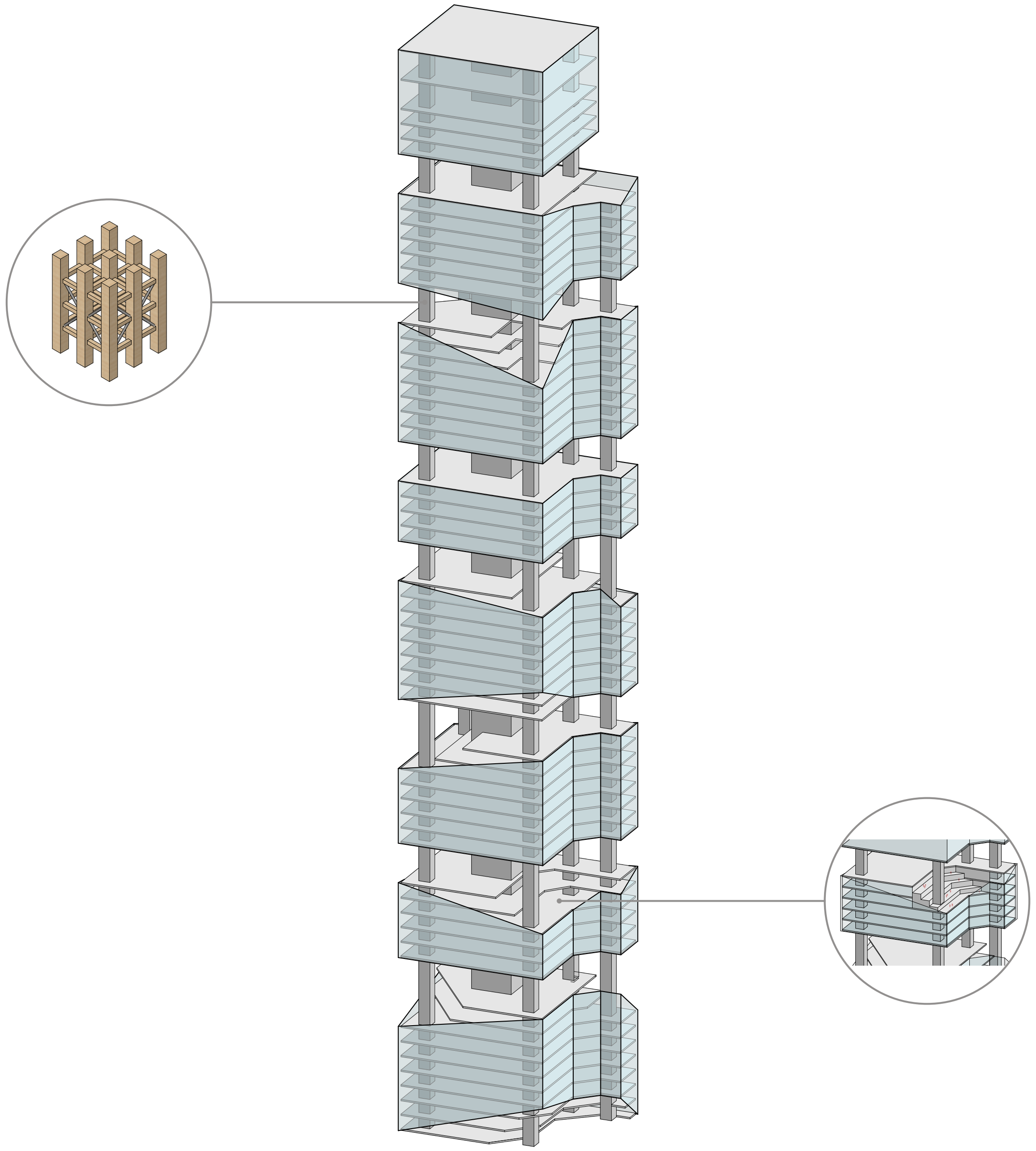


Figure 23. Conceptual model of the Type A typology.

Program Diagram - Type A

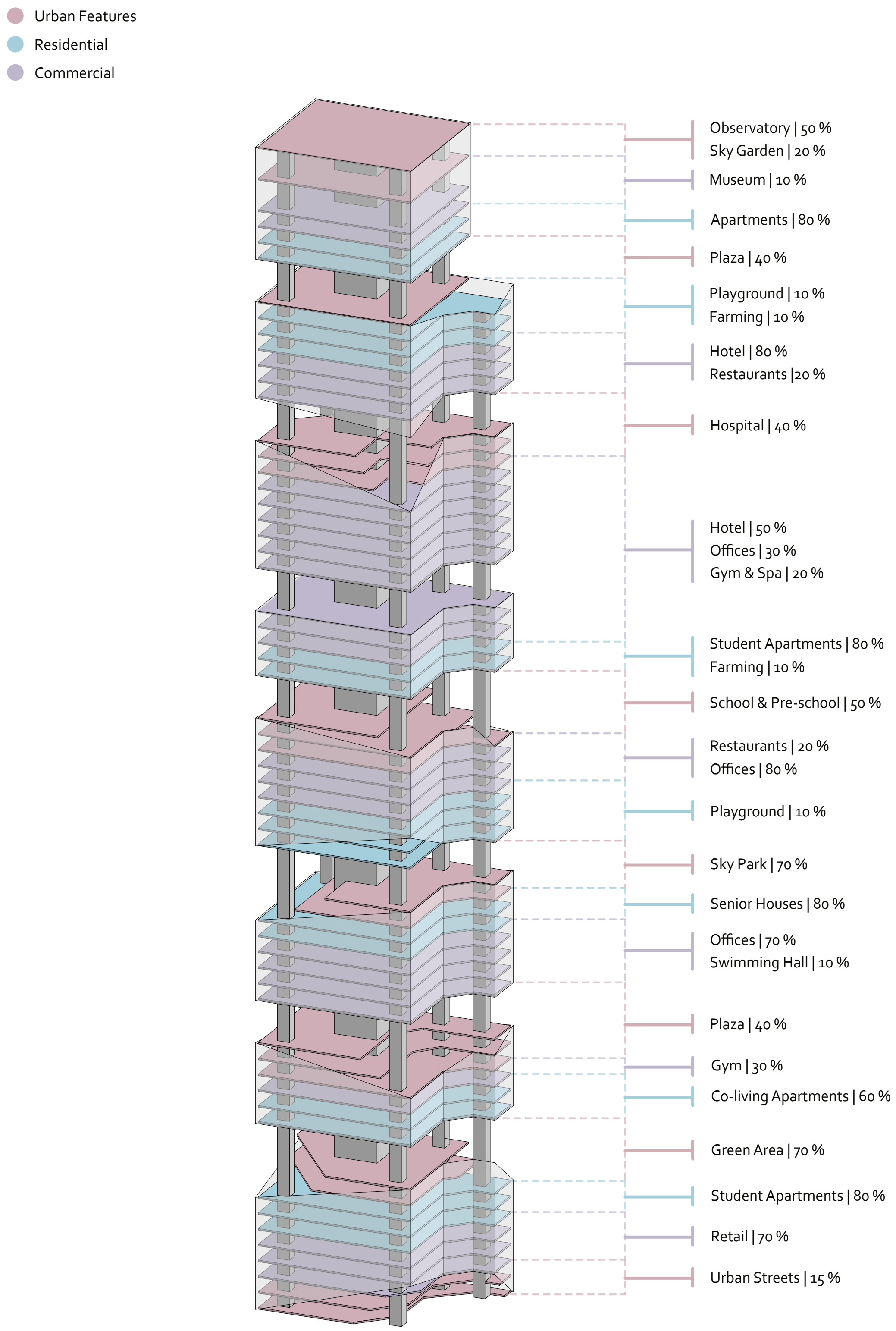


Figure 24. Program diagram showing the organization of urban, residential and commercial functions along with a suggested distribution of the program. The suggested functions are indicated with a approximated % of the total floor area that they occupy.

Conceptual Model - Type B

The Type B conceptual model consists of two building parts that are united by mutual floor slabs and an atrium. The building centers around an open volume, enabling community spaces in between each half of the building. The geometry allows for maintaining a potential sight line and hints at the interior life of the building.

The two building parts have their own structural core, meaning that they operate as independent buildings that are connected by mutual slabs and trusses at the perimeter of the atrium.

Height: 600 m
Width: 86 m
Length: 83 m

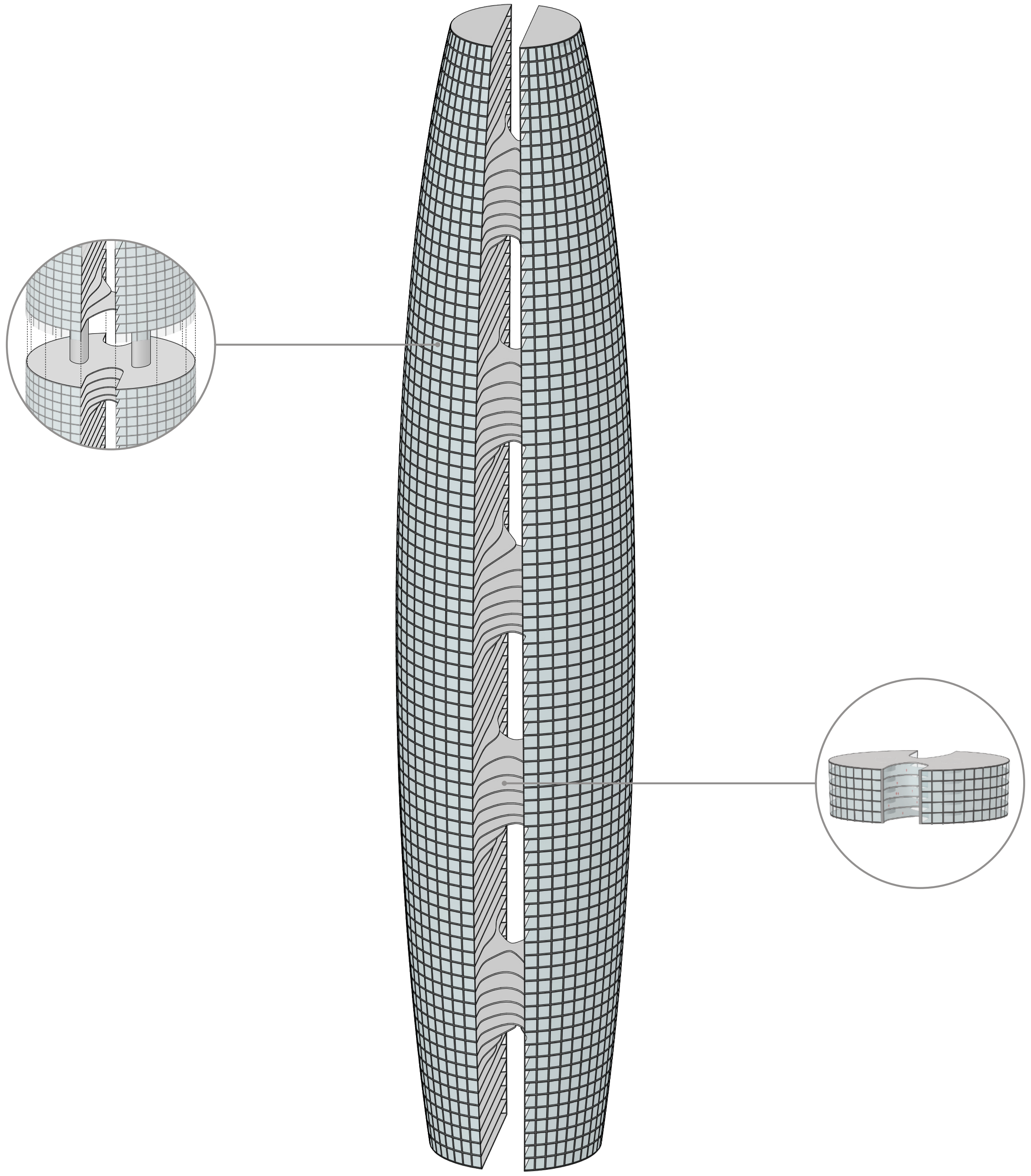


Figure 25. Conceptual model of the Type B typology.

Program Diagram - Type B

- Urban Features
- Residential
- Commercial

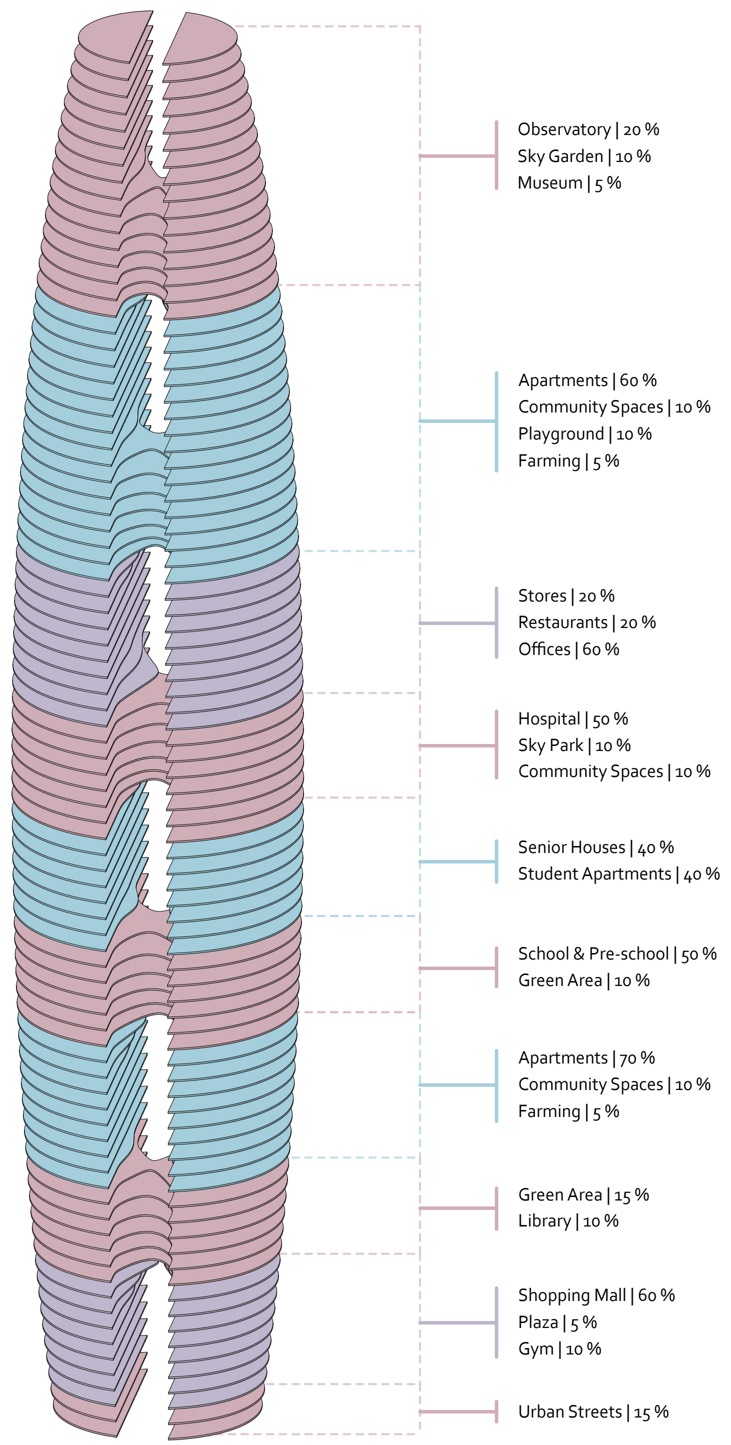


Figure 26. Program diagram showing the organization of urban, residential and commercial functions along with a suggested distribution of the program. The suggested functions are indicated with a approximated % of the total floor area that they occupy.

Analysis of Conceptual Models

Both Type A and B showcase a variety of new typologies in terms of geometry and program, and they achieve the design principles in different ways. Both of the models achieve the design principle *vary the form, expression and program with height* with their versatile and varied program. Their diverse programs also naturally fulfill the design principle *bring all aspects of the city up in the sky.* Type A is slightly better at varying the form and expression with height as the building blocks have different forms and heights. The geometry of Type B could be seen as repetitive when looking at the closed facade, although there are possibilities of varying the aesthetics of the facade and lowering the height of one building part.

Both of the models fulfill the design principle *provide public and common recreational spaces*, where Type A does this through the top parts of each building block and Type B through the mutual floor slabs in between each building part. It could be argued that Type A has more floor area of these types of spaces compared to Type B, although Type B has a unique take on the type of space that is provided.

Type B naturally fulfills the design principle *incorporate connections between tall buildings and horizontal movements* through the mutual floor slabs that unite the two building parts. However, connections to other tall buildings could have a deviating look due to the stretched dome shape of the building. Type A is better suited for connecting it to other tall buildings. As for horizontal movements, Type A has the potential of spiraling movement throughout the building, although this needs to be carefully considered together with the structural integrity of the building.

Lastly, when it comes to the design principle *seamlessly integrate the building with the street*, both typologies achieve this in different ways. Type A has the possibility of integrating the lowest building block with the street, although this could be difficult to achieve from all 4 facades of the building. Type B is currently better adapted to meet the street life since it allows the street to pass through the building. However, the other two facades are closed and here it could also be difficult to open up the building and meet the street. A solution to both typologies could be to place the buildings on a wider landscaped structure, which could be a part of the building while also acting as a bridge between the buildings and the street.

The design principles related to the conceptual models are the following:

- **Vary the form, expression and program with height**
- **Provide public and common recreational spaces**
- **Incorporate connections between tall buildings and horizontal movements**
- **Seamlessly intregrate the building with the street**
- **Bring all aspects of the city up in the sky**

Conclusions

From this evaluation of the conceptual models according to the above design principles, both typologies present strong qualities in different ways. Overall, it seems that Type A is slightly better than Type B. This is mainly due to the closed and somewhat repetitious facade of Type B which makes it difficult to adapt the shape and functionalities without getting a deviating look of the building. Type A also has more public spaces and has the potential of a spiraling movement throughout the building. Both typologies are slightly weaker in integrating the building with the street. Although Type B allows for the street to continue through the building, the other facades are closed and a solution such as placing the building in the middle of a landscaped structure is presumably in question for both typologies.

It could therefore be argued that **Type A** should be further developed in the next iteration. Some qualities of Type B could however be of value to incorporate in Type A, such as the mutual floor slabs and allowing the street to pass through the building.

4
FINAL DESIGN PROPOPSAL

"What if the built environment could be a solution to the climate crisis, rather than part of the problem? What if buildings could act like trees - capturing carbon, purifying the air, and regenerating the environment?" (Skidmore, Owings & Merill, 2021)

Final Design Proposal

Introduction
The final design proposal is derived from the two previous iterations, where the Type A typology from the most recent iteration laid the basis for the design of the final proposal. The goal of the final proposal is to showcase an alternative design and typology of the conventional tall building by exploring the untapped potentials of what a tall building could contain and look like. As this is the main goal of the final design proposal, the building is not situated in a specific context.

Compared to the Type A conceptual model from the previous iteration, the design resolution increases in the final design proposal to include a elaborated program, movement throughout the building and other details that resonate with a building design proposal. Sections, plans and elevations are presented to showcase the multifunctionality of the building as well as details of the building envelope.

Design Process
The main design elements from the Type A conceptual model that inspired the form of the final design proposal were the overall geometry, the broken up facade and the indented megacolumns with a central structural core. The broken up facade and layout of the floor slabs from the previous iteration needed to be redeveloped to allow for a adequate movement and program distribution throughout the building.

The Proposal
The final design proposal consists of a 500 meter tall building consisting of a vertical city within the perimeter of the building envelope. The building is clad in a double-skin facade where vertical farming takes place in the cavity between the glasses. This facade typology acts as solar shading and insulation while simultaneously taking advantage of the solar energy to enable the growth of crops in the facade. The different kinds of crops growing at different levels and parts of the building also gives the building a green and varied expression.

Furthermore, the final design proposal contains a wide range of different functions, making it into a independent building that does not need to rely on the functions provided on street level to operate as a city of its own. Rather, individuals could easily spend their days in the building as they could live, work, socialize, exercise and catch some fresh air all within the same building.

The building acts as an extension of the street network by integrating vegetated terraces, plazas and a central semi-open atrium in the building. These spaces act as urban functions that connect the street life on ground level to the upper parts of the building, enabling a continuous spatial flow throughout the building. The main movement throughout the building takes place via elevators that operate in a loop system. This transportation method allows for a effective and versatile system where several cabs follow each other and can move horizontally as well as vertically.

In addition, the urban features of the building contain a generous amount of greenery, seamlessly integrating the natural with the artificial. The rich biodiversity and biomass that is contained in the building provides small creatures with a habitat and balances out the CO_2 emissions that the building gives out during production and maintenance. The biomass also provides occupants a closer connection to nature which improves their well-being.

Design Process

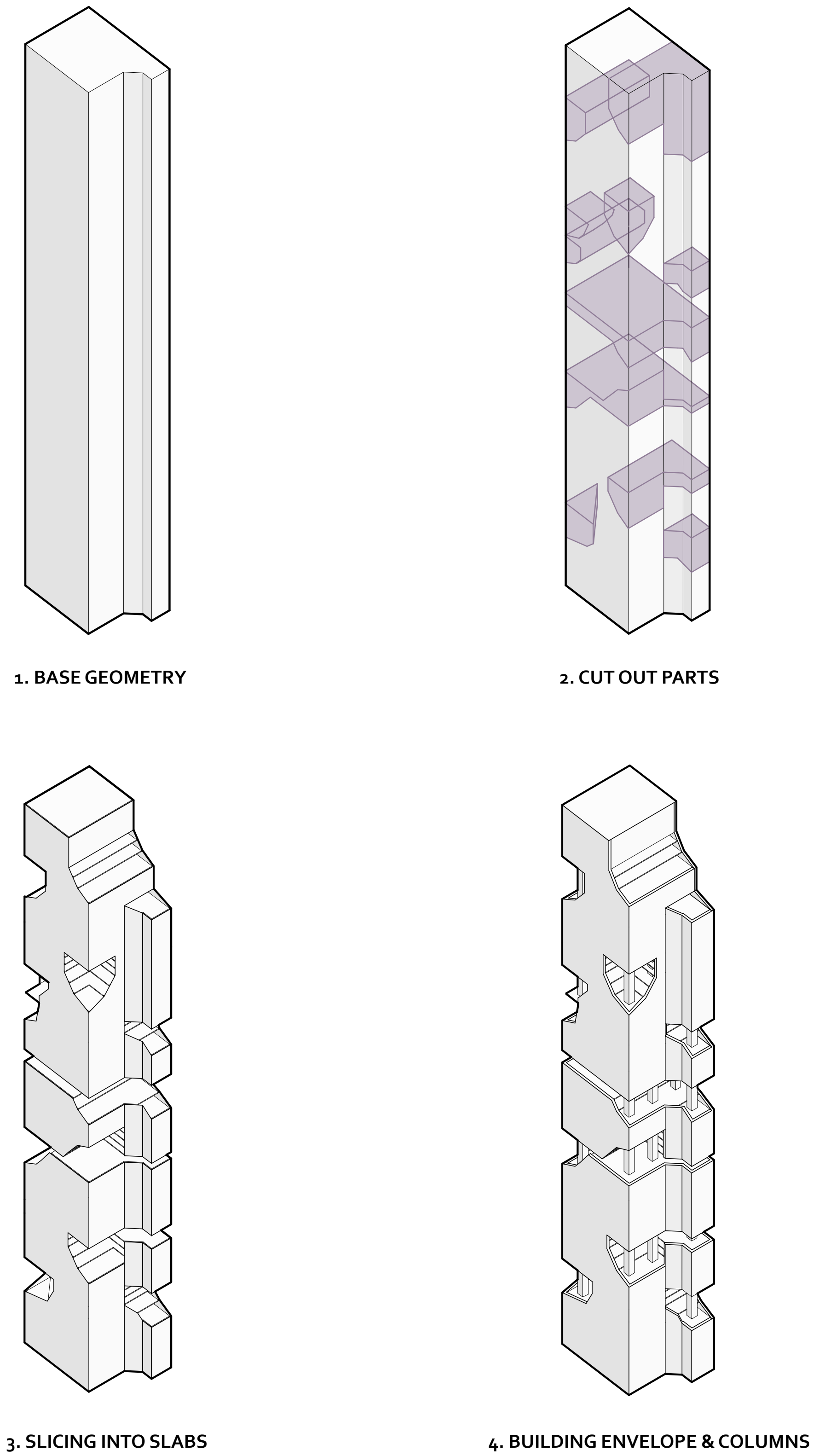


Figure 27. Process diagram showing the development of the final form.

Structural System

The structural system of the building consists of a central structural core and indented megacolumns at the edges of the building. The megacolumns consist of a timber and steel truss with a width of 5.2 meters to increase the stiffness of the columns. The structural core also acts as an atrium where the main movement througout the building takes place via elevators that move up and down as well as left to right in a loop system.

The structural stability in the building is provided by the megacolumns and the structural core with an additional stiffness given by transfer levels that are spaced at regular storey intervals. The transfer levels are pure structural levels that are connected to the megacolumns, with the aim of increasing the lever arm for lateral loads to be distributed over.

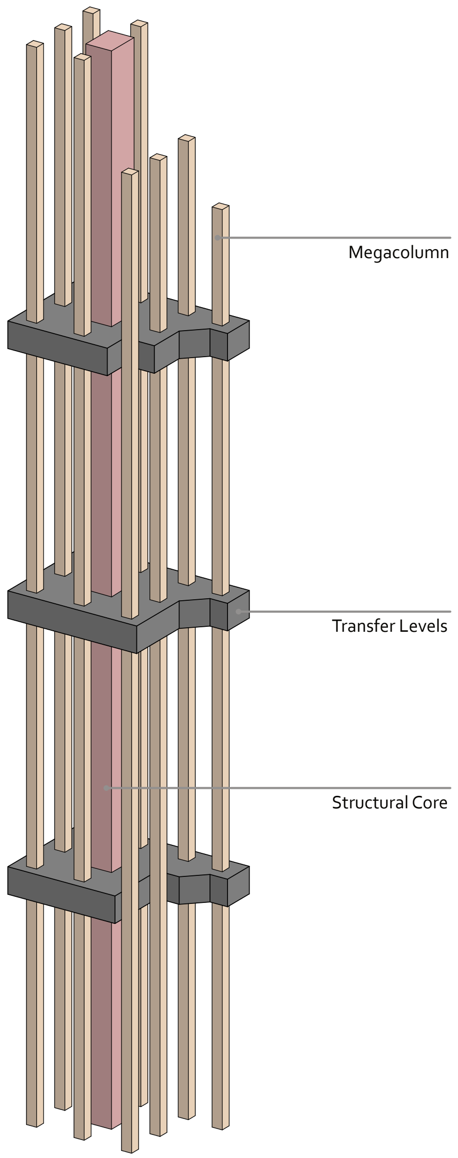


Figure 28. Diagram of the structural system showing the megacolumns, structural core and transfer levels.

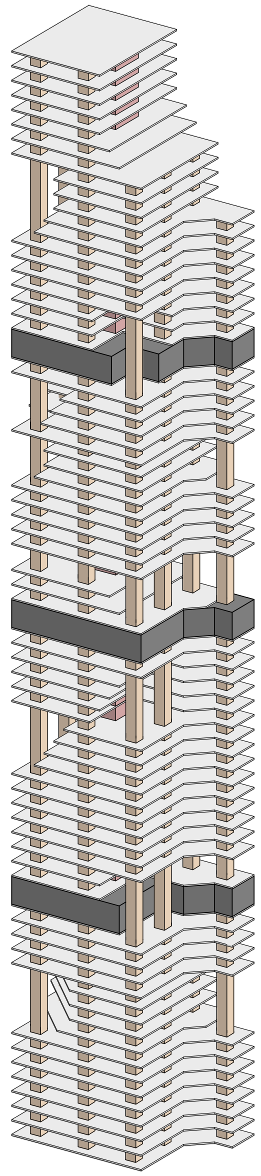


Figure 29. Diagram of the structural system showing the megacolumns, structural core and transfer levels along with the floor slabs.

Elevations

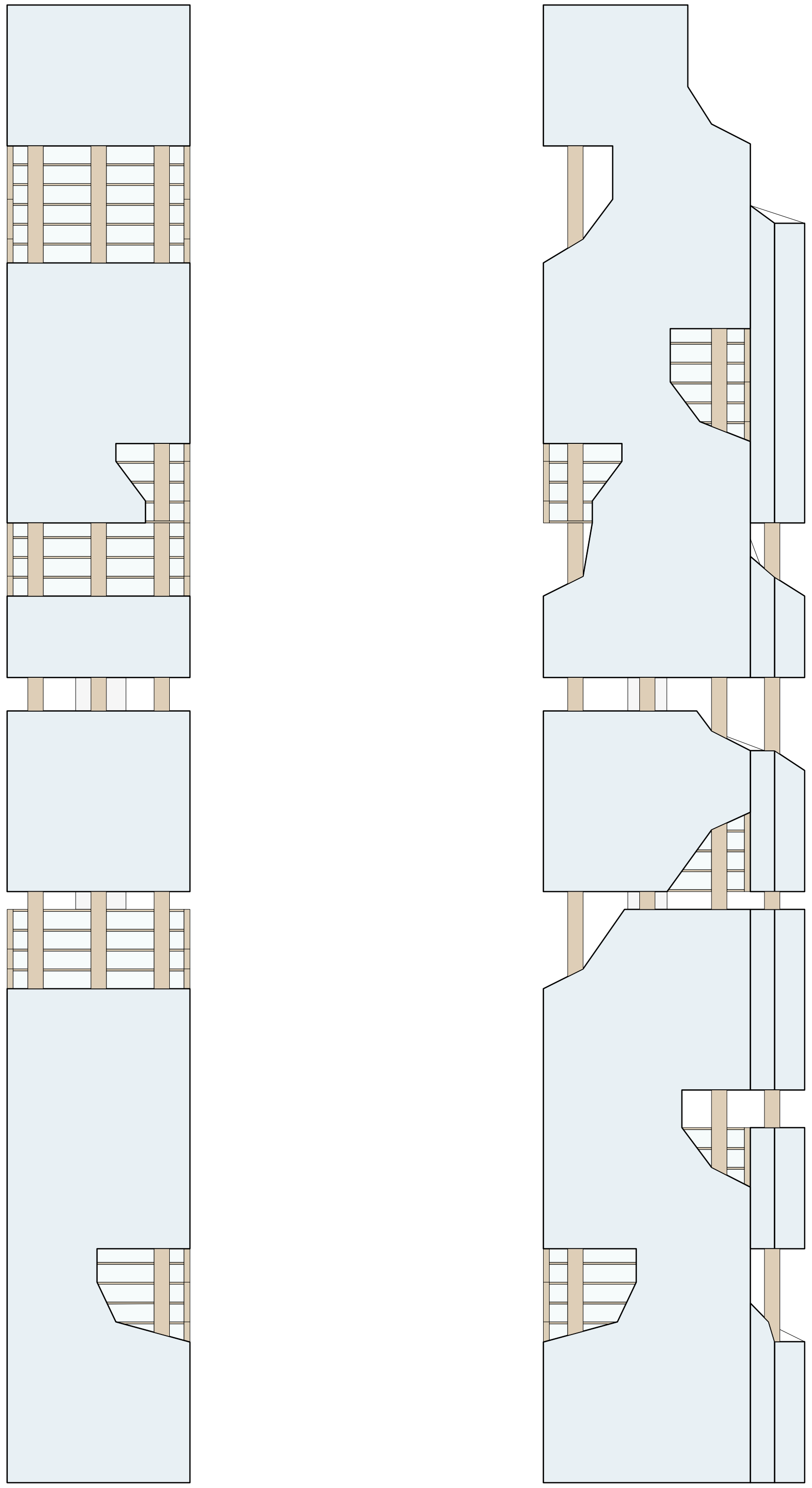


Figure 30. Elevations. Scale 1:2500.

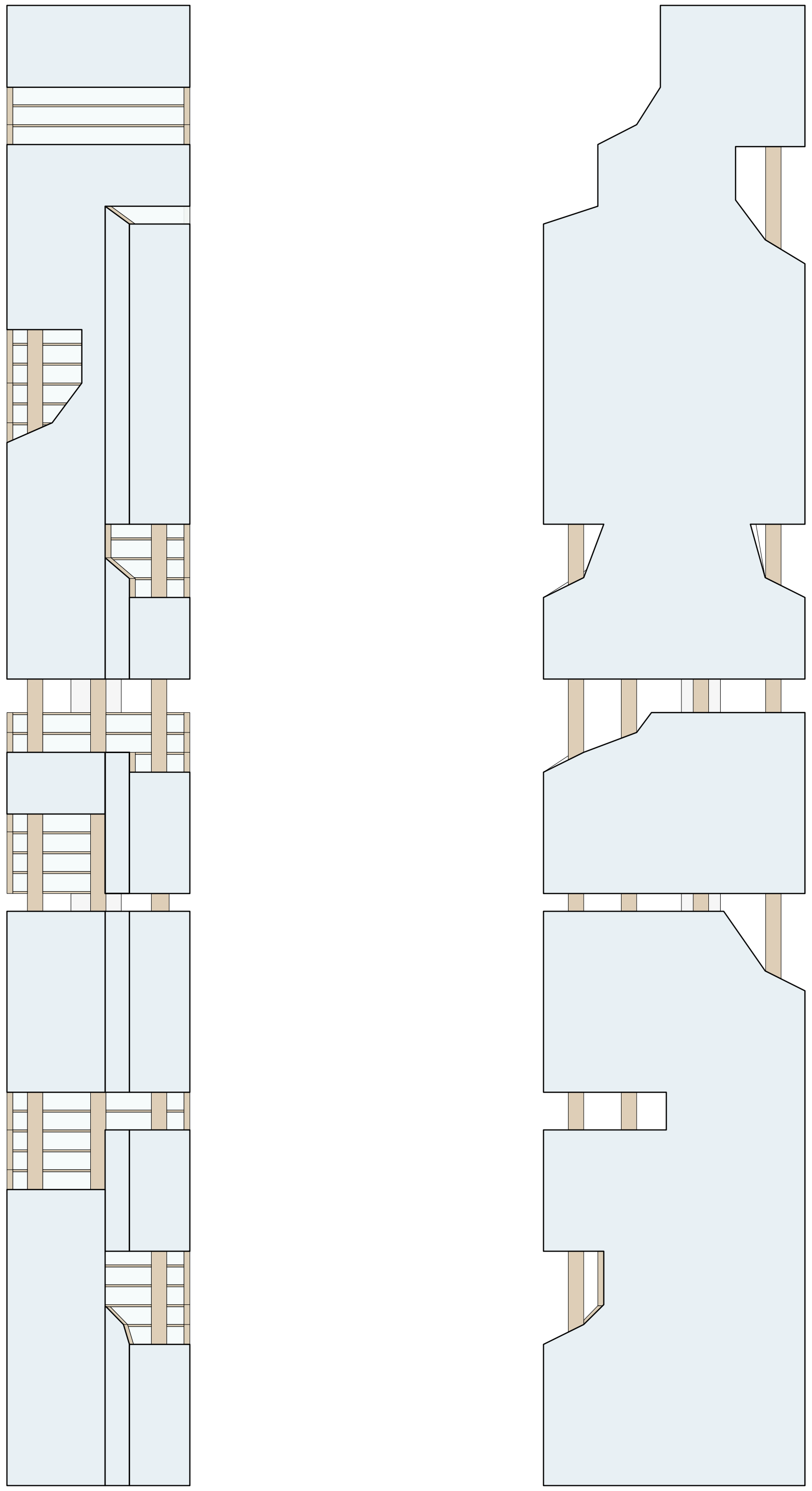


Figure 31. Elevations. Scale 1:2500.

Facade

The building is clad in a double-skin facade consisting of 2 layers of glass that are 2 meters apart. Within this cavity, the growth of different types of crops such as vegetables, berries and herbs takes place. The facade therefore acts as a vertical garden, where different farming methods such as hydroponic and aquaponic systems are installed. This facade typology utilizes the large amount of solar energy that the building is exposed to by growing crops in a vertical formation, while simultaneously acting as solar shading. This significantly reduces the need for air conditioning and decreases the energy consumption of the building.

The vertical farms give the building a green and varied expression, as shown in Figure 33. For occupants, this brings them closer to nature as they are surrounded by vegetated areas. The vertical farms also allow occupants and the public to buy fresh groceries in one of the food markets in the building. This means that occupants do not need to rely on buying groceries on street level and also decreases the need for importing groceries to the building.

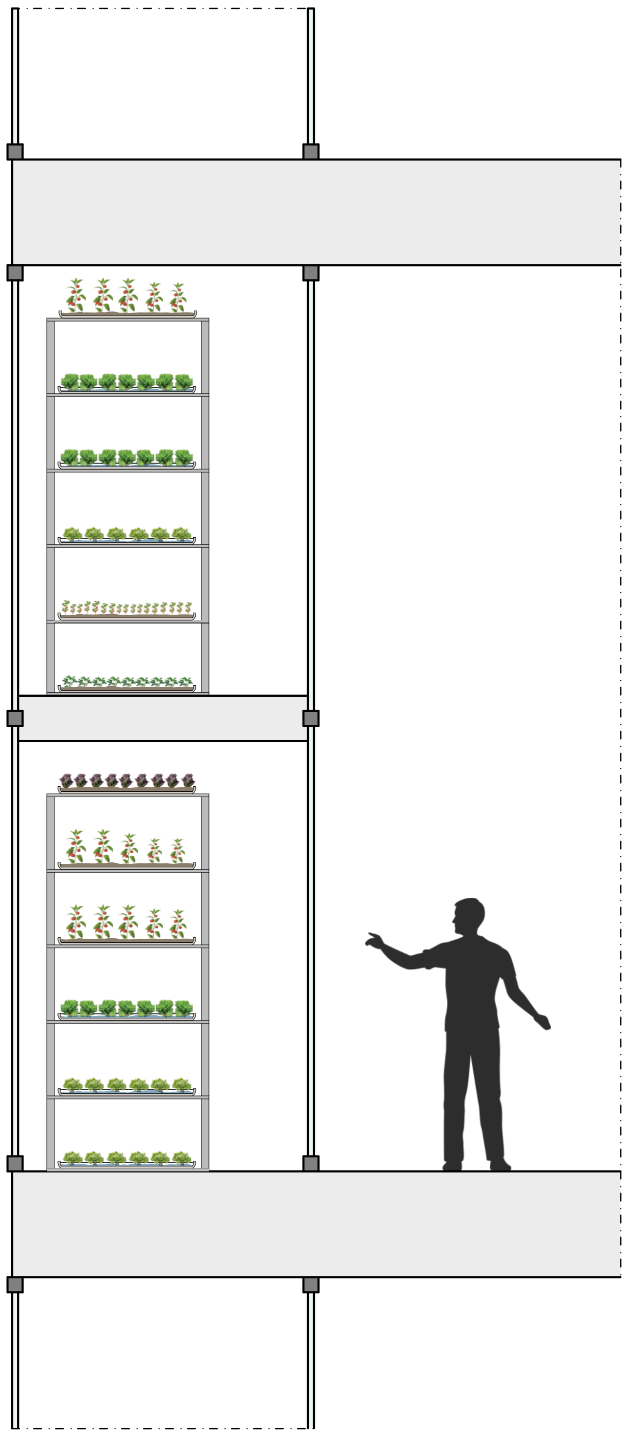


Figure 32. Facade detail showing the double-skin facade where vertical farming takes place. Scale 1:50.

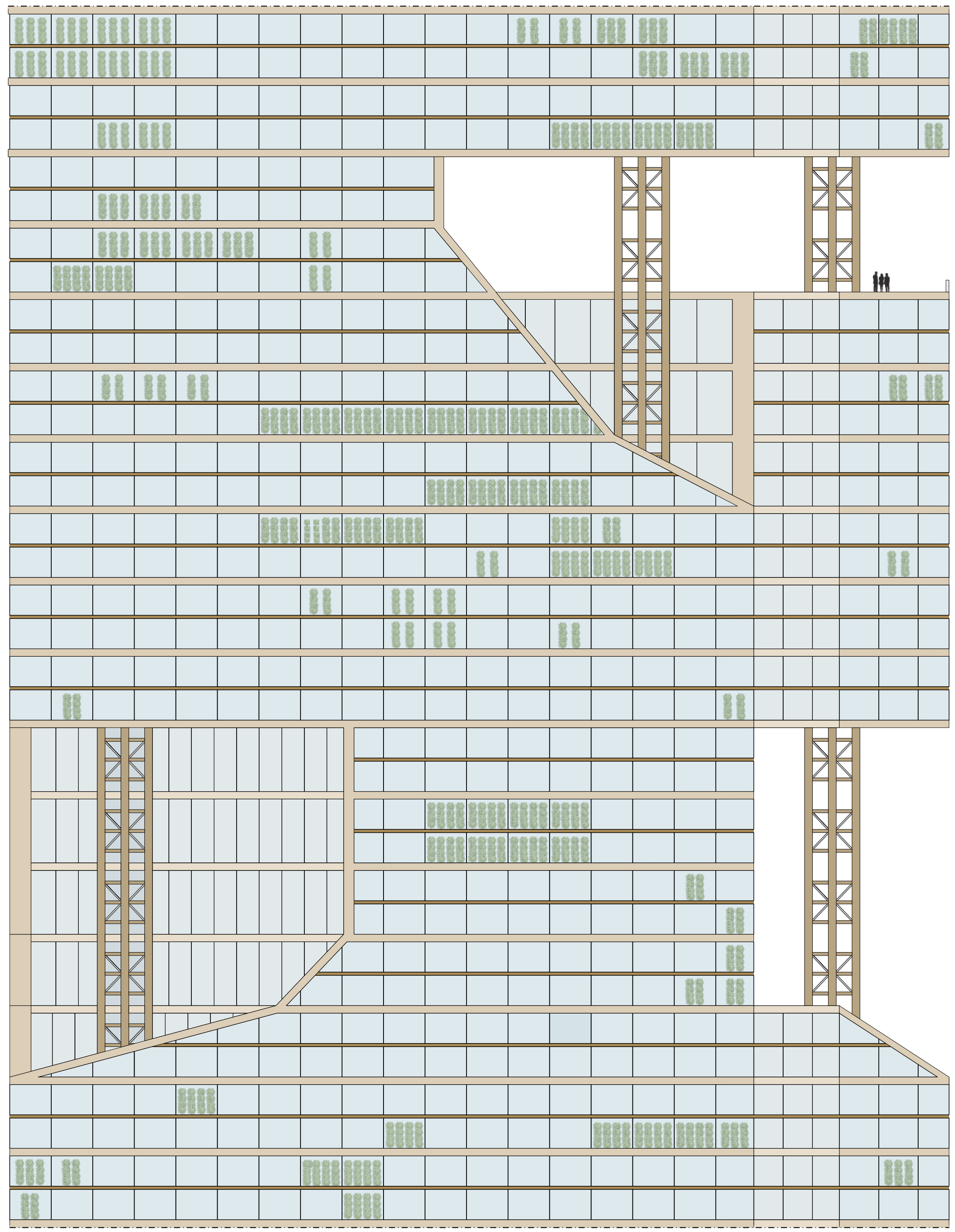
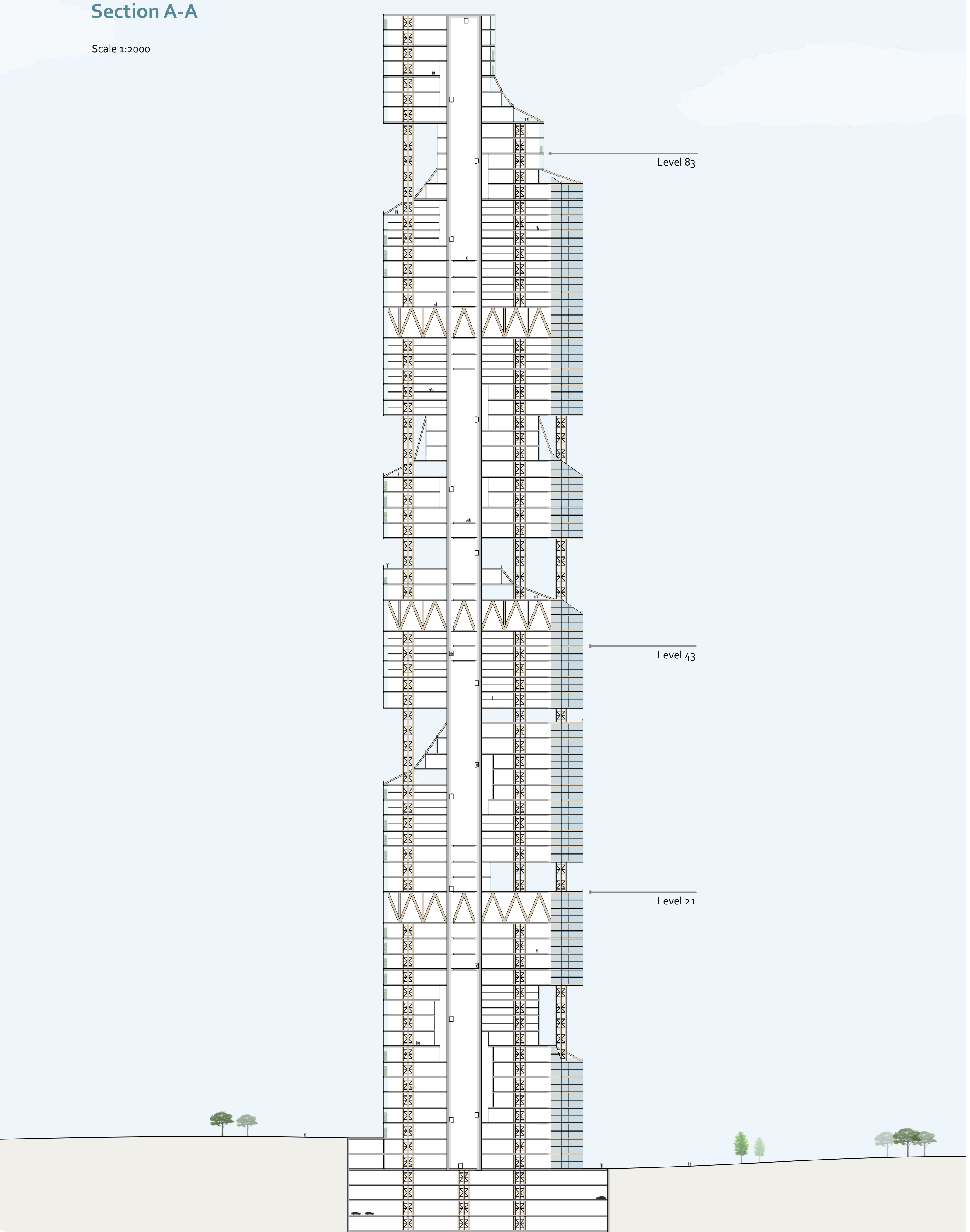


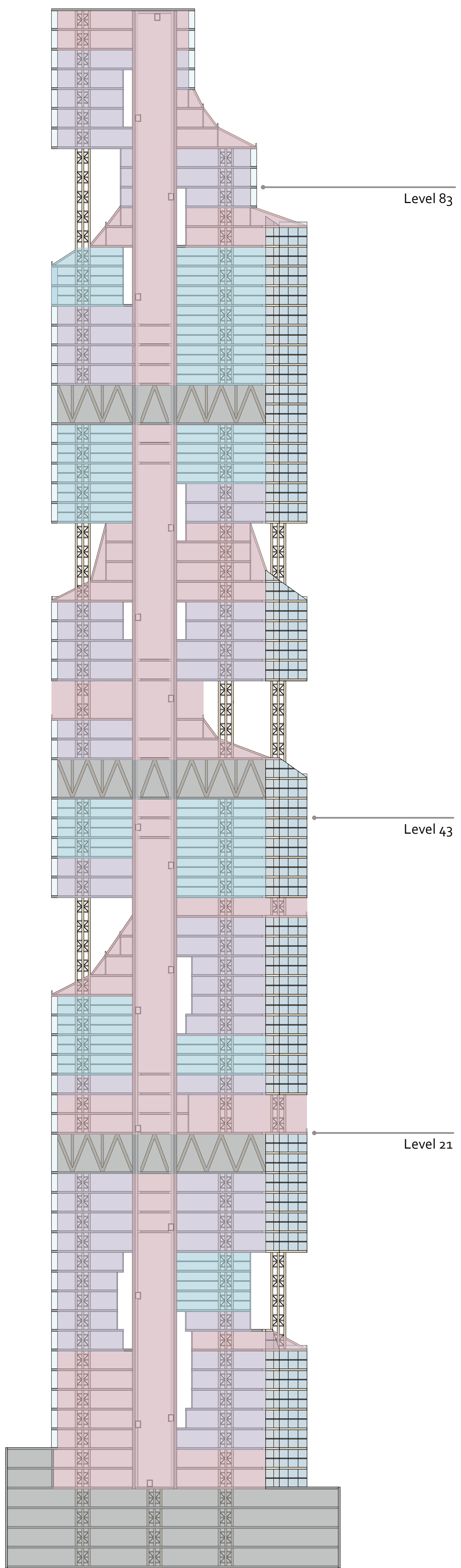
Figure 33. A part of the facade showing the vertical garden. Scale 1:600.

Section A-A

Scale 1:2000



Program Diagram



FINAL DESIGN PROPOSAL | SECTION

Level 21-29

Movement

As shown in Section A-A, the main movement throughout the building takes place via elevators that operate in a loop system. This enables several cabs to follow each other and the movement is not limited to a one-way trajectory but rather enables a versatile and effective transportation system. Consequently, the need for several elevators in the building is eliminated and less space is occupied by service cores.

Program

The division of the program is organized according to the general program previously shown in Figure 22. The program of the building is organized in clusters, creating different addresses for each cluster. Just like a regular horizontal city has a specific function located at a certain address, the vertical city adopts the same principle. Here, property owners or companies can buy or rent available space at a certain address.

Figure 34. Section A-A showing level 19 to 24. Scale 1:250.

Level 78-84

The central atrium with the looped elevators act as the main street of the building and is open to the public. The public functions within the commercial and urban categories are mainly located further down in the building to better integrate the building with the street life, and thus allowing calmer and more private areas higher up where tenants house. Nonetheless, public functions are also present higher up to ensure that the building as a whole is for everyone to use.

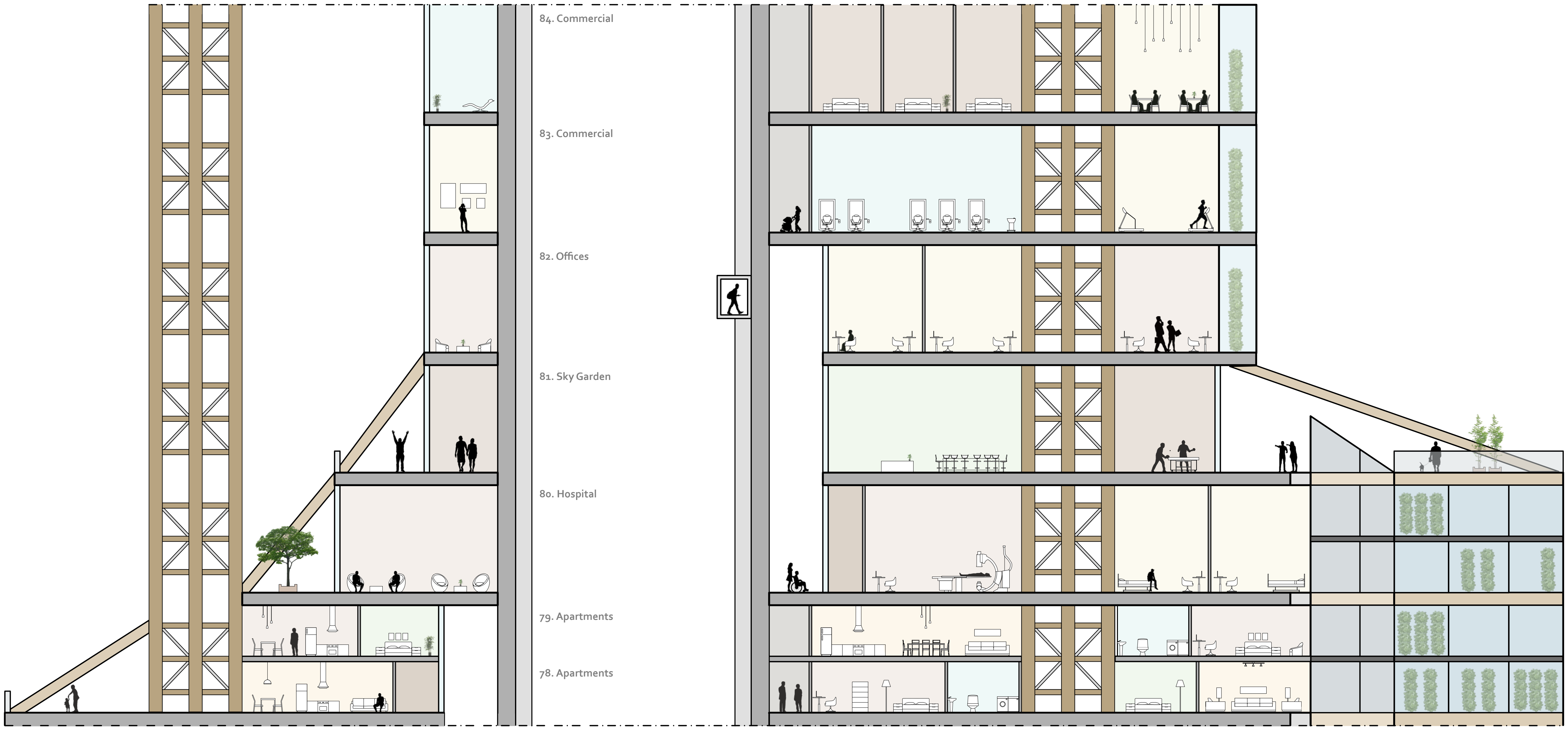


Figure 35. Section A-A showing level 61 to 66. Scale 1:250.

Plan - Level 21

The floor plan of level 21 is an urban level situated right above the first transfer floor. This makes level 21 into a natural plaza where elevator cabs pass by frequently and occupants meet up to catch some fresh air, socialize or buy fresh groceries from the food market. Service operators are responsible for the growth and harvest of crops at the facades on these urban floors.

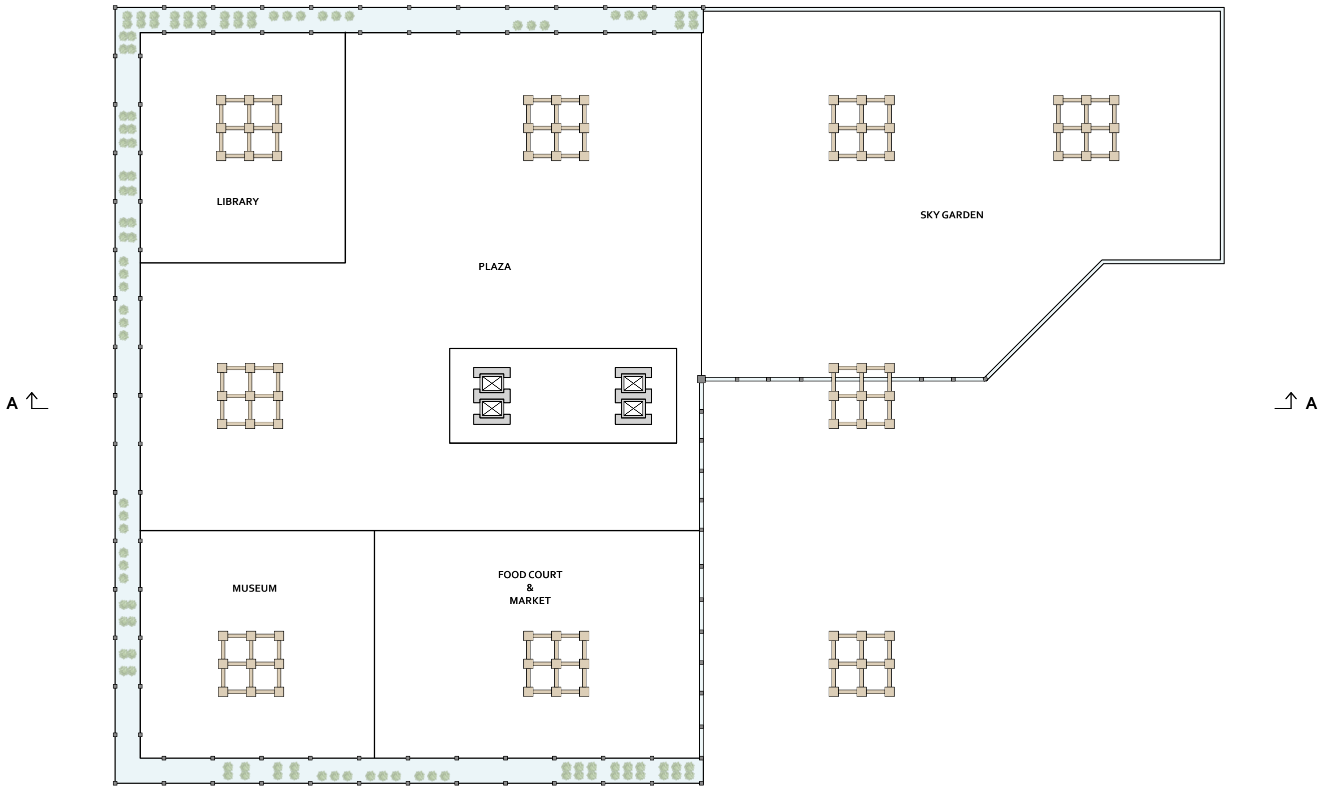
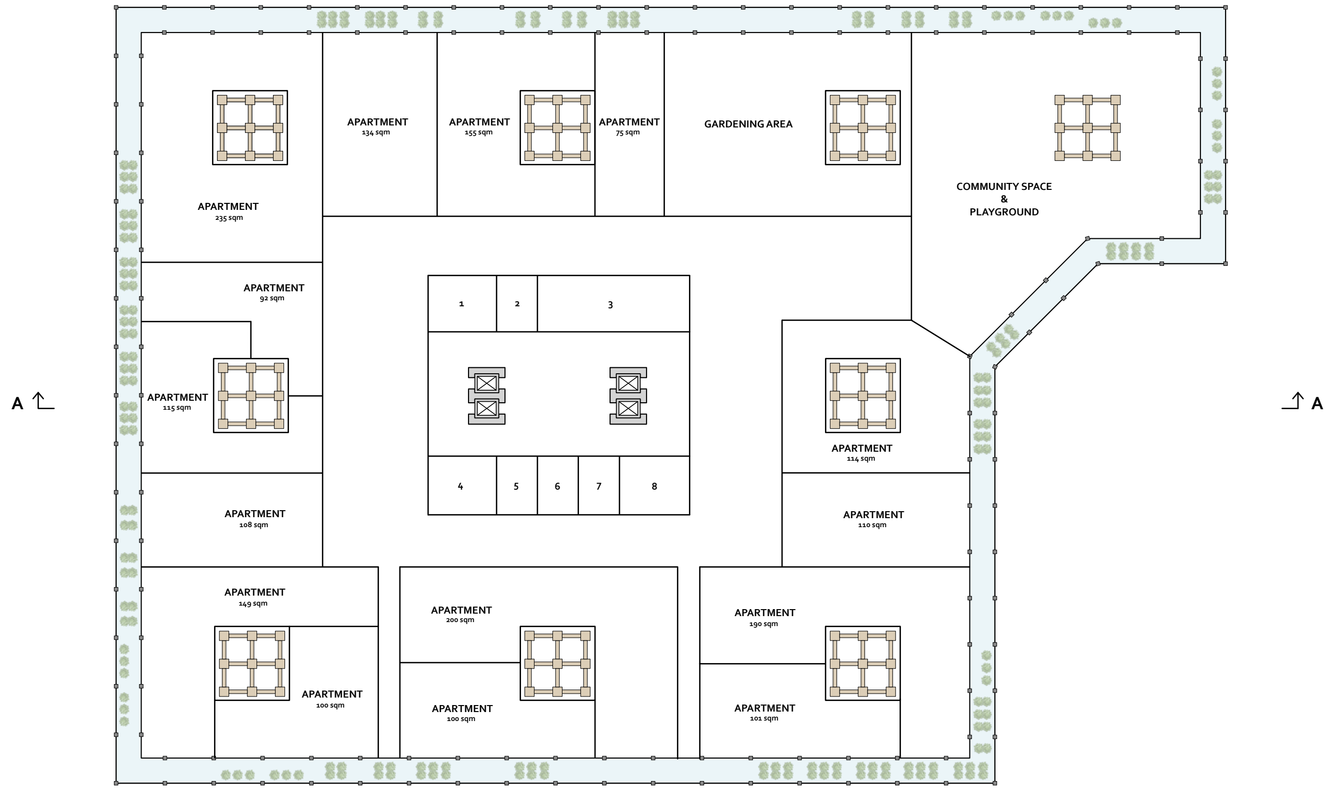


Figure 36. Plan level 21. Scale 1:600.

Plan - Level 43

The floor plan of level 43 is a residential level consisting of apartments of different sizes. This level is intended to be a private floor for the residing tenants. The tenants have a shared balcony for children to play and adults to socialize or relax. Close to the elevators, several facilities are provided to increase their flexibility and well-being. These include the Workshop & Repair, which consists of a makerspace area where they can repair broken items, share tools or create own projects.

Furthermore, the tenants have a common gardening area where they can help each other to grow their own crops. Hydroponic and aquaponic opportunities are also provided centrally as these spaces tend to be darker due to the depth of the building. Since these farming methods don't require natural sunlight, the dark areas are utilized for urban farming. All apartments also have access to the vertical gardens at the facades, where it's optional to grow own crops.



1. Workshop & Repair
2. Storage & Supplies
3. Bike Storage
4. Recycling Room
5. Hydroponic Farming
6. Aquaponic Farming
7. Storage & Supplies
8. Workshop & Repair

Figure 37. Plan level 43. Scale 1:600.

Plan - Level 83

The floor plan of level 81 is a commercial level consisting of a variety of different functions including offices, sports facilities, restaurants and a hotel. This floor has an open atrium, where occupants can look down to sense the verticality of the building or enjoy the view of the panorama windows. The vertical gardens at the facades on commercial levels are managed by service operators.

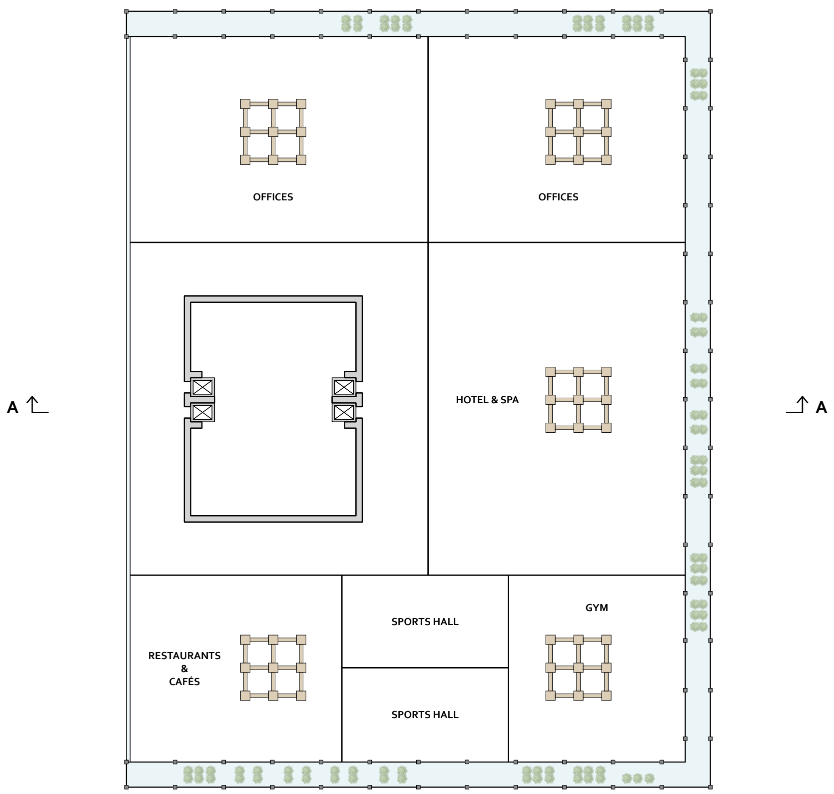


Figure 38. Plan level 83. Scale 1:600.

Perspective - Level 21

Figure 39. Perspective showing the sky garden at level 21.

Physical Model

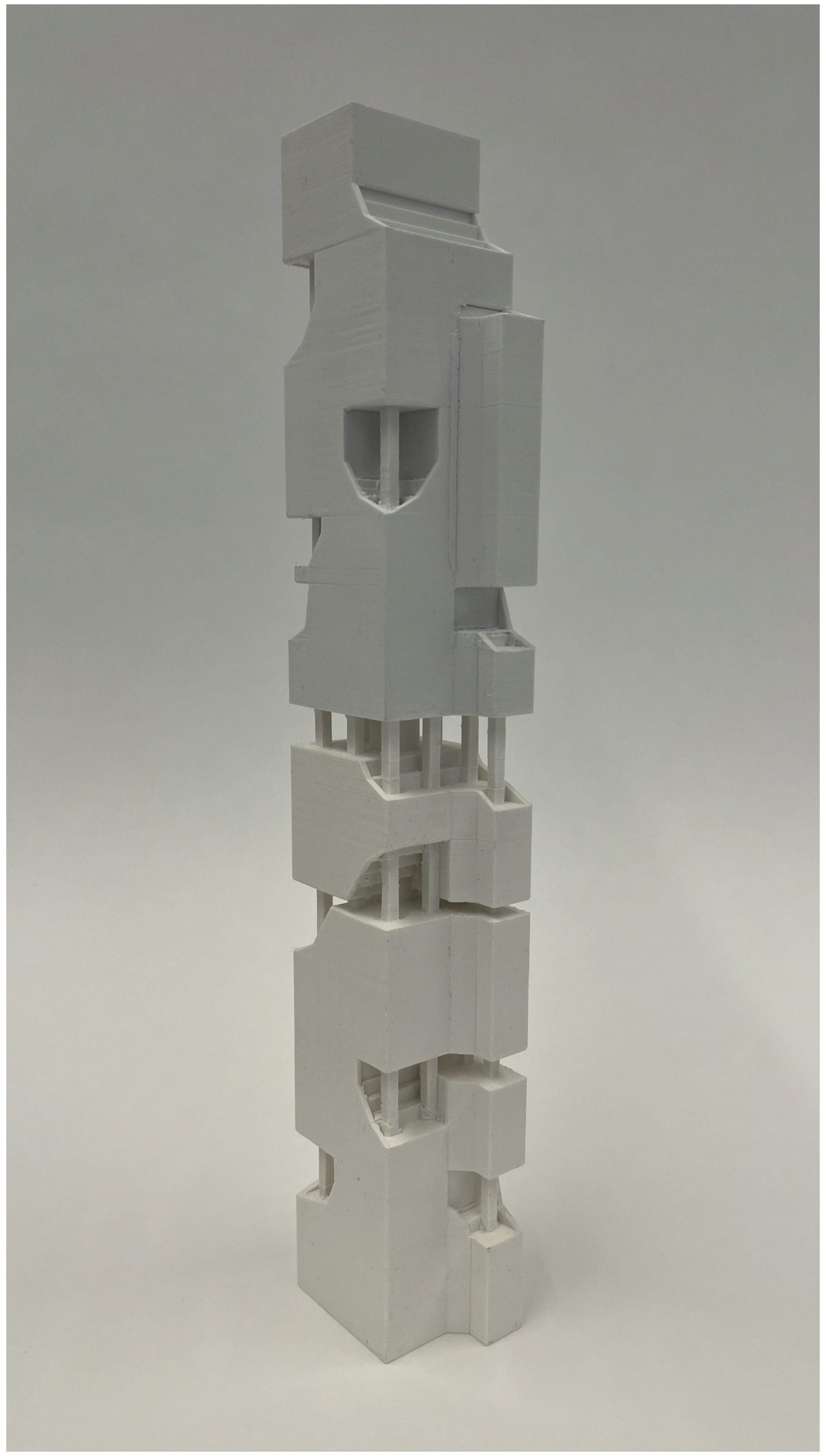


Figure 40. 3D-printed model of the final proposal using PLA filament. Scale 1:1000.

Analysis of Final Design Proposal

In general, the final design proposal showcases a new building typology that is rich and varied in its program and geometry. When it comes to the design principle *vary the form, expression and program with height*, the final proposal achieves this without hesitation. The program is diverse and contains functions that are usually not present in tall buildings, such as sky gardens, plazas and a care center. With this, the design principle *bring all aspects of the city up in the sky* is also fulfilled.

The geometry of the building is also varied with the broken up facade typology, creating several different nisches and terraces. However, the building is clad in glass panels, making the expression of the building somewhat repetitive. On the contrary, the growth of crops in the glass facade gives the building a varied and green expression, as well as acting as solar shading and provides with food for the occupants. At this stage of the design, the advantages of the glass facade outweigh the somewhat repetitive look. There is however potential to further develop the facades in terms of material and ornamentation.

The transportation system in the building is presented conceptually but nevertheless shows the idea of having a similar system to how buses, trams and trains operate in a horizontal city where cabs are followed by each other. The circulation in the building could be further developed, but at this stage it could be seen as fullfilling the design principle *incorporate connections between tall buildings and horizontal movements* as the transportation system is rethinked compared to the traditional elevator. It is also worth mentioning that the final design proposal does not consider connections to other buildings as the proposal is contextless, but this is also something that could be further developed at a later stage.

Furthermore, the final proposal incorporates vegetation in different forms throughout the building, fulfilling the design principle *incorporate vegetation throughout the building*. The facades are an integral part of the vegetation in the building, as well as the plazas, sky gardens and terraces that are filled with trees, bushes and plants. This increases the well-being of the occupants as they are closer to nature and allows the building to be seen as an artifact that is integrated with nature. Ultimately, this results in decreased CO_2 emissions and less environmental impacts on ecosystems in the surroundings.

The design principles related to the final proposal are the following:

- Vary the form, expression and program with height
- Provide public and common recreational spaces
- Incorporate connections between tall buildings and horizontal movements
- Seamlessly intregrate the building with the street
- Bring all aspects of the city up in the sky
- Incorporate vegetation throughout the building

The vegetated areas such as the plazas, sky gardens and terraces also provide the occupants with common recreational spaces, fulfilling the design principle *provide public and common recreational spaces*. These spaces encourage occupants to socialize and also gives them the opportunity to catch fresh air without having to descend to ground level. In addition, the residential levels provide the residents with common gardening areas and private terraces that aim to create a feeling of unity.

Lastly, the building acts as an extension of the street life on ground level through its urban functions that connect the street life to the top parts of the building. The urban functions are mainly concentrated to the lower parts of the building to better attract and invite the public to the building. Through this, the design principle *seamlessly integrate the building with the street* is fulfilled. However, since the building is contextless, the design has not been adapted to the ground level. Here, there is massive potential in doing so which could better integrate the building with the street on ground level.

Conclusions

From this evaluation of the final design proposal according to all of the design principles, it can be concluded that the final design proposal consists of a tall building that reinvents the traditional skyscraper typology. This is achieved by varying the program and geometry of the building, turning the building into a vertical city that has similar functions to a regular horizontal city. Furthermore, the inclusion of vegetation throughout the building turns it into an artifact that is integrated with nature, rather than an object that conflicts with the environment.

The purpose of the final proposal is not to merely strive for a tall height or dominance of a skyline, but rather add value to a city through a building that is available for everyone and contains multifunctional components. The building provides a large amount of habitable space from a small portion of land, making it into an essential part of cities that struggle with increased urbanization. Lastly, the building has a unique expression and geometry with the broken up facade and exposed megacolumns, making it into a unique and distinct building that is not necessarily similar to the traditional skyscraper typology.

5
CONCLUSIONS

Conclusions

This thesis aimed to understand the ongoing discussions of tall buildings and explore new typologies with the goal to reinvent the traditional skyscraper typology and raise awareness of the potentials of tall buildings.

The first part of the thesis, consisting of the literature review in chapter 2 *Background*, answered the research question ***In what ways do tall buildings cause discussions?*** It was found that one of the main concerns regarding contemporary tall buildings is their repetitious typology in terms of geometry, expression and functionality. The traditional tall building consists of a simple geometry with a floor plan extruded vertically. In addition, the typical tall building is today completely clad in glass, eliminating the individuality and integrity of the building.

Furthermore, tall buildings have a tendency to strive for taller heights and dominance of a city's skyline, at the cost of design and functionality. This tendency seems to depend on a sense of pride in having the tallest building in a city's skyline, regardless of the building's architectural qualities and the added value that the building could bring to the public. This has turned the tall building into a prestigious building that is mainly reserved for a portion of the population.

Lastly, a major factor behind the increased number of tall buildings is urbanization and limited ground area. This thesis has found that tall buildings have a massive potential in generating more habitable space from a small footprint and that they are essential and inevitable in growing cities. Due to this, tall buildings need to be multifunctional and vegetated to meet the needs of the occupants and to combat climate change. The tall building should be independent of the ground level, acting as a vertical city in a horizontal city. This also means that the tall building should be open to the public by incorporating urban features such as plazas and "streets" in the building. These urban features are advantageously filled with biomass to ensure high quality spaces that mitigate the environmental impact that tall buildings entail.

The second part of the thesis, consisting of the design explorations and final design proposal, answered the research question ***What are the potentials of new typologies of high-rise architecture and how can these overcome the discussions related to tall buildings?*** To answer this question, design strategies and principles were set that respond to the conclusions drawn in the literature review. This was done to ensure that the design explorations were a direct response to the discussions and drawbacks related to tall buildings. Also, to incorporate current research on new typologies of tall buildings in the design explorations.

The design explorations conducted in this thesis were performed in 3 iterations, where the design resolution increased for each iteration. This means that different design principles were related to different iterations, but for the last iteration, the final design proposal, all design principles were fulfilled. The conclusions that can be drawn from the design explorations is that a reinvented geometry and expression of the building are essential in developing new typologies. The geometry and expression should add value to the city and the public, by creating niches, terraces and balconies. The geometry could also account for maintaining a sight line, however this was not considered in this thesis as the final design proposal was contextless.

In addition, another essential aspect in developing new typologies is to envision the tall building as a vertical city, meaning that it should contain all functions that are contained in a regular horizontal city, making the vertical city independent of the ground level. This includes a multifunctional building that is vegetated and provides different types of spaces and qualities, as opposed to maximizing the floor area on each level that is common in contemporary tall buildings. The movement and circulation around the building also needs to be reinvented, to not only involve vertical movement from elevators but also horizontal movements. This aspect was addressed in the final design proposal, but could be further developed at a later stage.

Lastly, the thesis found that the environmental impact from tall buildings needs to be mitigated by introducing vegetation and biodiversity in the building. This does not only entail lower CO_2 emissions and a building that is integrated with the environment, but also high quality spaces for the occupants that reside, work or stay in the building.

To conclude, this thesis contribute to the discourse on tall buildings and how their typology may look like in the future when urbanization has grown to a level where tall buildings are essential in providing more space in city centers. The explorations in this thesis can hopefully serve as inspiration and guidance in designing new typologies of high-rise architecture.

Reflections

The final design proposal in this thesis mainly focused on the larger scale, similar to how an urban plan of a city lays out a strategy for how functions are distributed and arranged without focusing on the details of each individual building. This is a reasonable approach considering the time frame of a master's thesis, but it was a bit frustrating working with such a large scale project and not being able to delve into certain aspects of it. In particular, I believe that the movement and transportation system in the final proposal requires more consideration. How would a proper transportation system work in such a building? Is it possible to envision "bus stops" inside the building and having multidirectional cabs? There are a lot of logistics and technological advancements to solve to be able to realize such a transportation system, but I hope that such a system is possible to envision in the future.

Another aspect that could be further researched is how the multifunctionality works in practice. There are several challenges involved in this, one being who the owner of the building is. The most reasonable solution is probably to allow different actors to buy parts of the building. One actor could buy retail space and open their own stores while another actor could buy an apartment cluster and rent these to tenants. Furthermore, the urban spaces are also a challenge since several tall buildings around the world, including the Shanghai tower and 30 St Mary Axe in London, have promised sky gardens that are accessible to the public but have failed to do so (Al-Kodmany, 2018). Instead, the lower parts of the buildings are open to the public and the top parts are reserved for tenants. Urban spaces in tall buildings are generally underused, thus the design and accessibility of these spaces need to be carefully studied and considered.

As previously mentioned, the final proposal is a semi-public building that is available for all socioeconomic groups. However, is this actually possible to achieve? The tall building is today regarded as a luxurious building where property owners generate large amounts of money by providing hotel rooms, restaurants and apartments with the best views in town. It is evident that the most attractive spaces will be those that are higher up in a tall building, and that the value of those spaces would be significantly higher. I believe that tall buildings should be for everyone, particularly if it stands as an iconic monument that represents a city, but I think that tall buildings in the near future will still be reserved for wealthier people or the tenants of the building. If high-rise architecture becomes a common phenomena, this problem may go extinct, but that is probably many decades ahead.

This thesis has been an incredible journey where I have deepened my knowledge in tall buildings, their value and how they may be designed in the future as a response to climate change and rapid urbanization. Tall buildings are complex and versatile buildings, but their typology hasn't been challenged enough. As seen in this thesis, there lies massive potential in tall buildings and I look forward to seeing new typologies of high-rise architecture in upcoming buildings around the world.

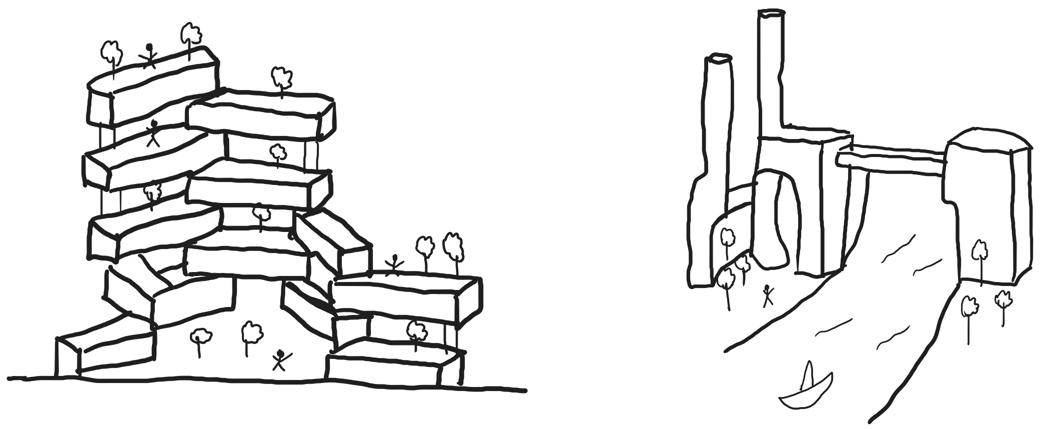


Figure 40. Early sketches.

6
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