

High-Rise Buildings: Facing A Time of Climate Crisis, Are They Relevant?

School of Architecture, Built and Natural Environment

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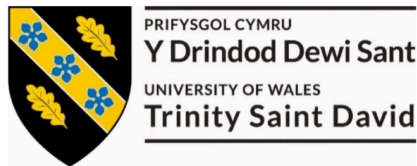
Name: Taraneh Adibmehr

Student Number: 2005918

Module code: ACAA6003

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Abstract

The construction and operation of high-rise buildings are being investigated as the world faces a time of climate crisis. This dissertation seeks to determine whether high-rise buildings are relevant in the context of today and how they may be modified to mitigate their environmental impact.

Through a comprehensive literature review, this dissertation will explore the historical background of high-rise buildings, their benefits and drawbacks and how they have changed over time to fulfil the shifting requirements of society. The environmental effects of high-rise structures, including their energy use, carbon footprint, and role in urban settings will also be considered.

The research will analyse selected case studies of various high-rise buildings in a range of locations to gain a more thorough understanding of the current situation of high-rise buildings and their effects on the environment. An interview will be conducted for each case study with the architect involved in the design of the building in order to examine the building design, construction, and operation, as well as the measures taken to reduce their environmental impact.

The research presented in this dissertation will offer insight into the use of high-rise structures in the modern world and their potential for reducing the effects of climate change. This study will also include guidelines for improving the environmental quality and sustainability of high-rise structures. Ultimately, this research anticipates to add to the continuing debate regarding the future of high-rise structures in the face of a climate crisis.

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I would like to express my sincere gratitude to my tutors, Ian Standen and Dr.Liz Walder. Whose advice and assistance have been instrumental in the completion of this dissertation. Their persistent guidance and insightful feedback has helped me to improve the quality of my research and enhance my understanding of the subject. Their enthusiasm motivated me to persist through challenging circumstances and helped to make this journey an enjoyable experience.

Joost Moolhuijzen, Ken Shuttleworth, and Spencer de Grey have my profound appreciation for their invaluable contribution to my research. It was an absolute honour and privilege to have the opportunity to interview them and gain insights into their design approaches and methodologies. Their willingness to share their expertise and experience with me was crucial in influencing my comprehension of the topic and broadening my outlook. I am truly appreciative of the time they sacrificed to provide me such a unique and memorable experience.

I will always cherish the lessons learned during this dissertation, and I am grateful to have had the opportunity to work with such remarkable people.

Table of Contents

PAGE TITLE	PAGE NO
Author's Declaration	02
Copyright statement	03
Abstract	04
Acknowledgments	05
List of Illustrations	07-08
Introduction	09-12
Methodology	09
Selection of case studies	12
Chapter 1: High-Rise Buildings Then and Now	13-25
Chapter 3: Commerzbank Tower	26-38
Chapter 3: 30 St Mary Axe	39-52
Chapter 4: The Shard	53-64
Conclusion	65-66
Bibliography: Published Works	67-81
Bibliography: Unpublished Works	82
Appendix A: Questions for Joost Moolhuijzen, Renzo Piano Building Workshop	83-85
Appendix B: Questions for – Ken Shuttleworth, MAKE Architects	86-88
Appendix C: Questions for Spencer de Grey, Foster+Partners	89-91

List of Illustrations

CHAPTER 1: HIGH-RISES BUILDINGS THEN AND NOW	PAGE NO
Figure 1: The Home Insurance building after two-storeys were added.	14
Figure 2: Adelaide House.	15
Figure 3: The Wainwright building's organic ornamentation.	17
Figure 4: The Carson, Pirie, Scott and Company building demonstrating the Chicago windows.	17
Figure 5: The Bayard-Condict building.	18
Figure 6: Le Corbusier, Radiant City model.	19
Figure 7: Drawing of the Burj Khalifa.	22
CHAPTER 2: COMMERZBANK TOWER	
Figure 8: Section drawing of Commerzbank Tower in context of surrounding buildings.	26
Figure 9: A perspective drawing of the Commerzbank tower in context of the surrounding buildings.	28
Figure 10: Partial section drawing illustrating the sky gardens.	29
Figure 11: A drawing illustrating the view from inside the Commerzbank office looking out into the atrium and gardens.	30
Figure 12: Analytical drawing of the Commerzbank showing air flow through the building.	32
Figure 13: Drawings explaining the construction method of the Commerzbank Tower.	33
Figure 14: Section drawing of the Commerzbank Tower, indicating the double-skin façade system.	34
Figure 15: Analytical diagrams showing air and light flow through the double-skin façade system, when windows are open/closed.	34
Figure 16: Plan drawing of the Commerzbank Tower.	38
CHAPTER 3: 30 ST MARY AXE	
Figure 17: Drawing of 30 St Mary Axe in context of its surroundings.	39
Figure 18: Section drawing of 30 St Mary Axe.	41
Figure 19: Diagram showing air flow into 30 St Mary Axe.	42
Figure 20: Diagram showing the rotating floor plates of 30 St Mary Axe.	43

Figure 21: Sketch drawing of 30 St Mary Axe, highlighting the glazing.	44
Figure 22: Diagrams illustrating wind deflections on a rectangular building compared to 30 St Mary Axe.	46
Figure 23: Section drawing showing the atrium space against the structural frame of the building.	47
Figure 24: Analytical drawing of the office floor plate.	48
Figure 25: Diagram highlighting the tinted glazing spiralling up and around the building.	48
Figure 26: Diagram showing openable windows facing the atrium spaces.	49
Figure 27: Drawing illustrating the entrance lobby.	51
Figure 28: 30 St Mary Axe's varying floor plans.	52

CHAPTER 4: THE SHARD

Figure 29: A drawing of The Shard in context of the surrounding buildings.	53
Figure 30: A drawing showing floor distribution in The Shard.	55
Figure 31: A drawing of the roof of The Shard showing glass spikes.	57
Figure 32: A drawing showing the structural frame material changes with height.	59
Figure 33: A Section drawing showing the restaurant and bar areas.	61
Figure 34: The Shard Floor Plans illustrating the varying floor plate sizes.	63
Figure 35: Sectional view showing The Shard in relation to the transportation hub.	64

Introduction

The release of greenhouse gases into the atmosphere has led to the urgent worldwide problem of the climate crisis, which has negative environmental impacts, particularly in the energy-intensive nature of high-rise construction that requires research. This dissertation focuses on London as a centre of high-rise development, referencing architectural practices like Foster+Partners, MAKE Architects, and Renzo Piano Building Workshop, whose case studies serve as exemplars for high-rise construction and contribute to the overall development of the dissertation.

Aims and objectives

The two main aims of this dissertation are to:

- Examine the relevance and necessity of high-rise buildings in the context of the current climate crisis,
- Assess the suitability of high-rise buildings as a viable option for the future.

The dissertation will address the following objectives:

- Discover the motivation when designing iconic high-rise buildings,
- Understand the relationships between architect, client and contractor,
- Identify the materials used to build a high-rise building,
- Examine the notion of “sustainability” for high-rise buildings,
- Establish what the future might be for high-rise buildings.

Methodology

For the research of this dissertation, I engaged in two different approaches:

1. Detailed library/ documentary research
2. Interviews with key individuals

1. Detailed library/ documentary research

Detailed documentary research was undertaken for the dissertation as there were many articles available on the selected case studies.

2. Interviews with key individuals

The interviews with designers of the selected case studies proved to be equally invaluable and enlightening. Joost Moolhuijzen of Renzo Piano Building Workshop, Spencer De Grey of Foster+Partners, and Ken Shuttleworth of MAKE Architects all offered deep insights into the design process, client relationship and philosophy of designing for high-rise structures.

Visiting high-rise buildings in London was initially considered, but unfortunately accessibility limitations of these structures meant it was not feasible. Similarly it was proposed to gauge public perception of high-rise, with questionnaires sent to users of such buildings. However, insights of residents living in garnered from the interviews with key individuals listed above proved extensive, making these questionnaires redundant.

The historical background of high-rise buildings

Although the term "high-rise" building has diverse meanings around the world, all high-rise schemes must meet certain height requirements. For example, in Germany, high-rise structures are defined as those with a height of 22-metres or more¹, whereas in the UK, high-rise structures are defined as those with a height of at least 18-metres, or at least seven-storeys (History.com Editors, 2018).

Confusingly, high-rise structures with more than 40-storeys are referred to as "skyscrapers" (Statista, 2023). Yet, in the past, structures of merely ten-storeys were known as skyscrapers. However, in the modern era, it is widely acceptable that a towering structure which transforms the skyline of a city is also referred to as a skyscraper.

While careful design and engineering are necessary for all building types, higher-span structures call for additional construction considerations, such as the capacity to maintain their own weight, withstand wind and earthquakes, and provide protection from fire. Due to a larger dead load than a live load, taller buildings often utilise more structural material in the lower levels than the higher levels (Statista, 2023).

High-rise structures can be used for a range of needs, including offices, homes, hotels, and various business' and residential uses. Mixed-use buildings are growing in number, so the use of high-rises housing many facilities in a single location are encouraged. Such use is

¹ Department for Levelling Up, Housing & Communities, 2022

generally quite advantageous for the user/resident as their ongoing costs and 'green footprint' will be reduced.

Building vertically allows for more space, therefore one of the major benefits to high-rises is that where area is limited, most typically in densely populated urban city centres, spaces can be created by building skywards. This lessens urban sprawl, allowing for the preservation of natural sites while also reducing road traffic². Modern building techniques have made room for creative approaches to construction, enabling the use of recycled materials and the development of more energy-efficient buildings. If constructed in appropriate areas that are close to transportation hubs, high-rise development will encourage public transportation.

High-rise development has the added benefit of offering reasonably priced communal living. Apartments within high-rise buildings are frequently used by social housing providers to offer affordable housing since the volume of tenants allows for reduced rent costs (Benchmark Fabricated Steel, 2020).

Despite the benefits of high-rise buildings, if not carefully considered, they may also have drawbacks. One challenging problem is the ground level connection to the immediate surroundings when a tall structure might become too dominating and isolate its occupants from regular encounters with everyday life creating an unpleasant environment to be at ground level for the public.

Blocking sight of lower buildings and historic structures are some of the other significant challenges and drawbacks to a high-rise building. Even though this is under the control of laws and planning authorities, conflicts might still arise. Safety concerns such as strategies for evacuation in the event of a fire is one of the much more critical difficulties. The safety of the building occupants must be guaranteed because of the size and nature of high-rise buildings (Benchmark Fabricated Steel, 2020).

The carbon footprint of high-rise construction is another significant drawback. Buildings contribute to carbon emissions in a variety of ways, such as through their construction, use, and location. In order to successfully handle this issue, it is critical to comprehend how it occurs precisely. To comply with the Paris Climate Agreement's objectives, all structures must be net zero-carbon by 2050. Energy-efficient building designs and renewable energy sources are one approach to achieve decarbonization of the construction industry. Any efficient buildings can either be new build or on an existing fabric (Budds, 2019).

² Benchmark Fabricated Steel, 2020

The Designers of High-Rise Buildings

Up until the modern period high-rise building, tall structures have gone through many changes. During the 1880s and 1890s key architects inspired and contributed lots of creativity towards this style which has now become the modern high-rise building that the world recognises. Several of the prominent high-rise structures that are familiar would not exist without the American technological revolution (Latham, 2023).

Visionaries like Dankmar Adler, William Le Baron Jenney, and Louis Sullivan contributed to achieving flexibility that went beyond the constricting limits of the past (Latham, 2023).

Introduction of the selected case studies

Examining specific case studies within London, will allow the author to understand the design and sustainable aspect of high-rise buildings, over a 16-year-period.

The Commerzbank in Frankfurt by Foster+Partners, which was designed in 1997, and was the world's first ecological high-rise building, will be the first case study of this dissertation. The second case study is 30 St Mary Axe, designed by British architect Ken Shuttleworth, when he was a Director at Foster+Partners and which opened in 2004. The third and final case study is The Shard, designed by Renzo Piano Building Workshop in 2013.

All three case studies were selected because of their unique shape, and their contribution to the field of innovative architectural design.

Literature review

A range of works which have been used throughout this dissertation. Key works include:

- Engineering The Shard, London: tallest building in western Europe.
- Louis Sullivan: 15 Projects by "Father of Skyscrapers".
- Reaching Heights. Building Control; London.
- Anatomy of a global skyline. Financial Times

The author that was found extremely useful in this piece of research was, John Parker.

Chapter 1: High-Rise Buildings Then and Now

This chapter of the dissertation will discuss the history and definition of high-rise buildings, highlighting their development, their origins and journey to their standing in the modern world. This chapter will also discuss population expansion and its effect on architecture. A more in-depth understanding of the roles that high-rise buildings play in the modern world, particularly the environmental and social effects on cities, will also be examined.

Due to advances made during the industrial revolution and a population movement from rural to urban areas, a widespread adoption for high-rise construction was embraced across the globe. As cities grew in population with a lack of land for housing, the simplest solution for accommodating residents was to build higher.

The US was the first country which began developing high-rises for general accommodation. Buildings that rose vertically rather than horizontally were in demand in places with growing land prices and high population densities (Ali, Al-Kodmany, 2012).

The world's first high-rise structure, the Home Insurance building in Chicago, Illinois, was constructed in 1885 against a backdrop of conventional masonry structures of the era which were overly heavy and restricted in height. Designer and engineer, William LeBaron Jenney³, created a ground-breaking steel frame approach that allowed for the building's intended and unheard-of height. In 1931, the Home Insurance building was, ironically, demolished to make way for a new high rise, now known as the LaSalle Bank Building, which is 45-storeys (History.com Editors, 2018).

The original structure of the Home Insurance building had ten storeys and was 42-metres in height. Local officials were hesitant and concerned about the new construction at the time, and work on it was delayed until safety was guaranteed. The building was raised two further storeys after five years, giving it a new height of 55-metres (History.com Editors, 2018).

³ US architect Jenney (1832-1907) trained at the École Centrale des Arts et Manufactures (École Centrale Paris) to study engineering and architecture, graduating in 1856, a year after his classmate, Gustave Eiffel, the designer of the Eiffel Tower.



Figure 1: The Home Insurance building after two-storeys were added. (Rand, McNally & Co.'s Bird's Eye View and Guide to Chicago, 1893)

As well as designers in the US creating a new generation of steel-framed skyscrapers, many other building improvements were established including quick and secure elevators, conventional plumbing and wind bracing (History.com Editors, 2018).

The great Chicago fire of 1871, offered a huge opportunity for reconstruction of the city's skyline, which led to a rejuvenation of the city's economy. Using the Home Insurance building as a precedent, new materials including steel, stone, and iron were employed to construct the new structures (History.com Editors, 2018).

This modern style of architecture adopted by Jenney allowed for the pioneering of a new architectural style known as the 'Chicago School', introduced by a group of architects and engineers who developed the idea of a skyscraper (History.com Editors, 2018).

Modern High-Rises

Essentially the height of buildings has altered the most in the last century. However, this does not imply that tall buildings always looked as artistically stunning as they do today. Engineers and architects are always striving to create cutting-edge ideas that push the envelope. Every city has a unique illustration of aspiration and creativity. Where there was an Art Deco movement at the beginning of the 20th century, there is now a more contemporary, neo-futuristic style. Buildings serve as a visual chronicle of the development of urban design (Huber, 2019).

High-Rise Buildings in The UK

High-rise development in London changed significantly in the 21st century, creating a distinctive and modern skyline. Planning authorities across the capital have approved the construction of 400 new high-rise buildings in locations like Paddington, Stratford, Lambeth, and Canary Wharf, ensuring that there will be many more ahead (Extension Architecture, 2022).

The UK's first high-rise structure was Adelaide House, erected on the north-side of the 'new London Bridge' in 1924. At a height of 43-metres at the time, Adelaide House, designed by Sir John Burnet and Thomas Tait, was London's tallest steel-frame structure. The structure was named Adelaide in honour of King William IV's wife, who performed the opening ceremony for London Bridge in 1831.⁴ Adelaide House was also the first office building in the UK to have central ventilation and telephones on each storey (e-architect, 2012).



Figure 2: Adelaide House. (Photo by, David Bank)

⁴ The building was named Adelaide in honour of King William IV's wife, who performed the opening ceremony for London Bridge in 1831.

Louis Sullivan

Famously referred to as Chicago's "father of skyscrapers"⁵, Louis Sullivan (1856- 1924) was a significant and influential American architect, and alongside Frank Lloyd Wright and Henry Hobson Richardson, is recognised as the top-three American architects. The title of "father of skyscrapers" would not have been possible without the success and initial training of his business partner Dankmar Adler⁶ (Shapell Manuscript Foundation, 2023). Also known as the "father of modernism"⁷, Sullivan greatly contributed to the modernist era by paying close attention to the details of the big structures of the late 19th century. He designed mostly on the philosophy "Form follows function"⁸, a phrase for which he became known. This expression implies that a building's purpose and function should be taken into account before its aesthetic forms. It suggests that the building's architecture, including its structure and decoration, should represent the building's intended use (Designing Buildings, 2020a).

When Sullivan was only 24 years old, he and Adler formed Adler and Sullivan, a notable partnership in American architecture⁹. Sullivan was also a mentor at the Chicago School of Architecture where he mentored renowned architect, Frank Lloyd Wright (Sethuraman, 2022).

The Wainwright building, built in 1891 in St. Louis, Missouri was one of the most significant high-rise structures created by Sullivan and Adler. The National Register of Historic Places recognised this structure as a prototype for the contemporary steel office skyscraper, and PBS¹⁰ named it as one of the 'top 10 structures that revolutionised America' in 2013 (GPSMYCITY, 2023).

The Wainwright building is a prominent example of Sullivan's organic ornamentation whereby the most noticeable exterior surfaces such as those around the main entrance's door, the spandrels between the windows on various floors, and the frieze below the cornice are heavily ornamented. The ten-storey red-brick terracotta skyscraper intentionally

⁵ Mervyn D. Kaufman, 1969

⁶ German-born American architect and civil engineer Dankmar Adler (1844-1900) is best remembered for his 15 year partnership with Louis Sullivan.

⁷ Chambers Biographical Dictionary, 2007

⁸ Sethuraman, 2022

⁹ GPSMYCITY, 2023

¹⁰ America's Public Broadcasting Service

eschewed the neoclassical architectural style in favour of a more contemporary design (GPSMYCITY, 2023).



Figure 3: The Wainwright building's organic ornamentation. (Photo by, University of Missouri)

High-rise buildings now have significantly more windows than solid walls thanks to steel frame construction. The Carson, Pirie, Scott and Company building in Chicago, Illinois, constructed in 1889 by Sullivan, has bay-wide windows that bring in natural light. The Chicago window; which is a three-part window with two smaller double-hung sash windows on either side, originated with this design (Sethuraman, 2022).



Figure 4: The Carson, Pirie, Scott and Company building demonstrating the Chicago windows. (Photo by, Kevin Zolkiewicz)

The Bayard-Condict building in New York, also designed by Sullivan in 1899, was notable for its height as well as the proportion of windows to solid walls, foreshadowing today's curtain-of-glass high-rises. This 13-storey structure has a lavishly ornamented façade, especially at the top (Sethuraman, 2022).



Figure 5: The Bayard-Condict building. (Architectural Preservation Studio, 2023)

Le Corbusier

One of the forerunners of modern architecture, Swiss-French architect Le Corbusier¹¹ was dedicated to improving living conditions for city residents and designed all heights of structures.

The 1952-built Unité d'Habitation, a residence in Marseille, France, is one of Le Corbusier's most well-known creations. This was one of le Corbusier's first housing projects which focused on communal living¹².

One of Le Corbusier's most influential proposals for high-rise urban planning was the Radiant City design, developed in the 1920s. This plan incorporated high-rise buildings in a park-like setting, demonstrating his belief in the potential of vertical architecture to improve urban living¹³. Le Corbusier believed that high-rise buildings had the potential to solve the problem of limited space in populated cities. Le Corbusier's plan is divided into separate zones for residential, commercial, and industrial activities, and intentionally includes green spaces to enhance the quality of life for its residents. His utopian vision features broad boulevards that highlight his devotion to efficiency and standardisation as well as his emphasis on logical design principles (Kroll, 2023).

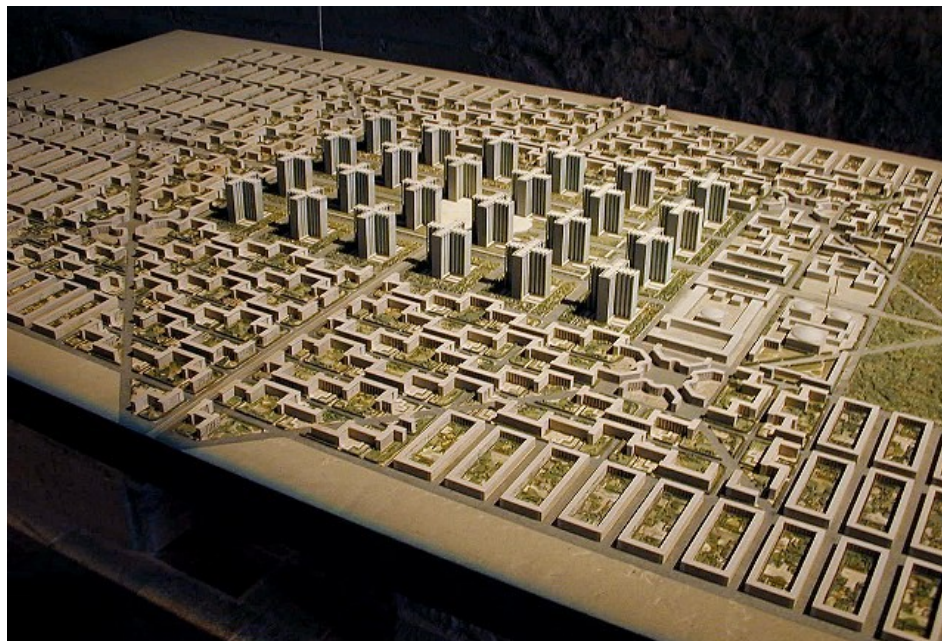


Figure 6: Le Corbusier, Radiant City model. (Photo from, Land8.com)

¹¹ Charles-Édouard Jeanneret (1887-1965), better known as Le Corbusier, was a pioneer of urban planning across a five decade career.

¹² Kroll, 2023

¹³ Kohlstedt, 2018

Conventional towns, in Le Corbusier's opinion, were inefficient and disordered due to inadequate organisation and planning¹⁴. His high-rise designs, though influential in the 20th century, have received criticism in recent years from modern architects and urban planners who are instead focused on designing high-rise buildings that prioritise sustainability, community engagement, and the well-being of their residents¹⁵.

Skidmore, Owings and Merrill

Architecture firm Skidmore, Owings and Merrill (SOM) was founded in 1936 in Chicago by partners Louis Skidmore (1897-1962) and Nathaniel Owings (1903-1984) with engineer John Merrill (1896-1975) joining in 1939 (SOM, 2021). The practice eventually expanded with the opening of offices in several locations¹⁶ and became one of the largest architectural firms in the US and the world. Since its establishment, the company has worked on modernism and skyscraper development¹⁷. Still in existence today, SOM takes great pleasure in building for the future, from transforming city skylines to attaining some of the most notable architectural and engineering accomplishments. They have created some of the world's tallest buildings including the One World Trade Centre in New York (2014), Trump Tower in Chicago (2009) and Burj Khalifa in Dubai (2010)¹⁸ which is currently the world's tallest building, towering at just over 828 metres¹⁹.

Dubai's skyline has been completely transformed by the Burj Khalifa that illuminates the entire city²⁰. The mixed-use skyscraper holds seven world records, including:

1. Tallest building in the world (since 2010);
2. Tallest free standing structure in the world (since 2010);
3. Highest occupied floor in the world (since 2010) (Emaar Properties PJSC, 2023b).

Before the Burj Khalifa Taipei 101, formerly known as the Taipei World Finance Centre, in Taiwan was the tallest building in the world at the time with a height of 508-metres and was

¹⁴ Pash Classics, 2020

¹⁵ Pash Classics, 2020

¹⁶ Chicago Architecture Centre, 2023

¹⁷ Peregoy, 2016

¹⁸ Chicago Architecture Centre, 2023

¹⁹ Emaar Properties PJSC, 2023b

²⁰ Institution of Civil Engineers, 2023

the first high-rise structure to exceed the 500 metres milestone²¹. Taipei 101 was designed by Chinese architect C.Y. Lee (b. 1938)²².

The Burj Khalifa has 163-storeys and is used for a range of commercial, residential and leisure activities²³. The tower's setting and location were thoroughly considered in the design phase in an effort to have it correlate to the heritage of the surrounding landscape. This is particularly clear as the Burj Khalifa is reminiscent of the onion domes that are common in Islamic architecture when viewed from the ground. Hymenocallis flowers, which are graceful and well-balanced, served as inspiration for the building's design²⁴; and can be observed in Burj Khalifa's form, which has a triple lobed plan. The three components are positioned around the building's central core to form a Y-shaped structure that maximises views of the Persian Gulf from every angle²⁵. As the building rises in height, its shape changes, reducing elemental impacts on it, such as wind²⁶ (Institution of Civil Engineers, 2023).

Special studies were conducted to assess the scope of changes which the building would need to satisfy in order to maintain the safety of its occupants. Almost 40 wind tunnel tests were conducted, ranging from preliminary studies of Dubai's windy climate to larger structural analysis models and façade pressure tests to microclimate studies of the effects at terraces and base level²⁷.

²¹ Council on Tall Buildings and Urban Habitat, 2023a

²² C.Y.LEE & Partners, 2023

²³ Emaar Properties PJSC, 2023a

²⁴ Institution of Civil Engineers, 2023

²⁵ Emaar Properties PJSC, 2023a

²⁶ The Burj Khalifa has established Dubai as a global leader in the construction, business, and tourism sector.

²⁷ Emaar Properties PJSC, 2023a

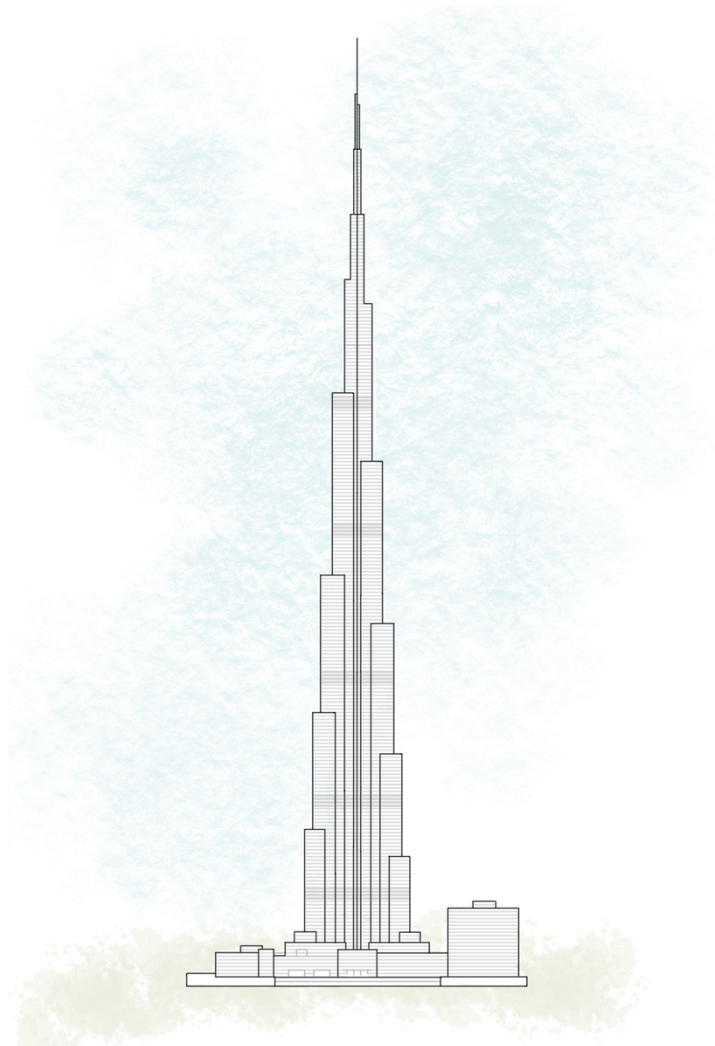


Figure 7: Drawing of the Burj Khalifa. (T. Adibmehr, 2023)

High-rise buildings facing a time climate crisis

Although high-rises have traditionally solved population expansion challenges, this does not imply that all skyscrapers have been essential; some have simply been created as a result of a competition between cities and architects to see who can construct the tallest structure. Buildings of the Burj Khalifa style are a fantastic example of this.

High-rise buildings have been used as a prestige symbol for advancement in both economy and technology. Tall structures have historically been a means for cities or countries to increase their respectability, power, and influence²⁸. Urban growth is now fuelled by the race to construct the tallest or most recognisable skyscraper. The race to build the tallest building

²⁸ Thompson, 1981, p. 189

has also stirred up debate, with some considering it a waste of resources while others praising the advantages these enormous structures provide for the economy²⁹.

High-rise buildings have also been criticised for their lack of attention to functionality and sustainability. Buildings have a negative impact on the environment in general due to their carbon footprint which makes them responsible for 36% of the world's energy consumption and 39% of energy-related carbon dioxide emissions³⁰, which are among the main causes of climate change. There are typically two methods used to measure building emissions;

- A) Operational carbon emissions, which are daily energy consumptions for systems such as heating and cooling.
- B) Embodied carbon, which is the quantity of carbon produced during the manufacturing of the building's components and during the entire construction process (Budds, 2019).

Today's architects are encouraged to place more emphasis on creating buildings that prioritise sustainability and promote community interactions rather than only focusing on height. This shift in design enhances environmental and social elements in architecture as it is more receptive to the requirements of their occupants and surroundings.

The Burj Khalifa required 31,400 metric tonnes of reinforcement-rebar³¹. If the amount of reinforcement- bar used was placed end to end, it would span more than a quarter of the way around the globe. Nonetheless, the concrete and steel foundation, which has 192 piles buried more than 50-metres deep, was built with more than 45,000m³ of concrete that weighs more than 110,000 tonnes³².

Despite this, it is important to note that the Burj Khalifa is a prime example of a green agenda high-rise structure that embraces circular economy. Solar panels on the structure heat more than 140,000 litres of water per day³³. To water the buildings plants and landscaping, 15 gallons of water is gathered annually through an irrigation system that uses condensation from the air-conditioning³⁴.

²⁹ Ali, Al-Kodmany, 2012

³⁰ Ali, Al-Kodmany, 2012

³¹ This is a metal bar that is used in concrete to increase the strength of it (McCarrick, 2010).

³² Emaar Properties PJSC, 2023a

³³ This allows the occupants to daily utilise this water.

³⁴ Institution of Civil Engineers, 2023

Although Dubai's rising urbanisation has caused environmental problems including pollution and resource scarcity, it has made tremendous progress in recent years towards creating greener infrastructure³⁵.

High-rise buildings and population expansion

High-rise buildings are more popular in urban areas than suburban and rural areas around the world, especially in townscapes with a growing population. Cities like Tokyo, New York and Dubai are known for having lots of high-rise buildings. Due to rapid urbanisation economic development in developing countries such as China and India, high-rise construction has increased.

Hong Kong, China is the tallest city in the world with over 3,000 buildings over 150-metres in height, and has just over 100 building with a height of 300-metres or more. New York is the second tallest city in the world with over 800 buildings with a height of 150-metres or more and 30 buildings with a height of 300-metres or more. The third tallest city in the world is Dubai which has just over 300 buildings of 150-metres or more and 32 buildings with a height of 300-metres or more³⁶.

It is not surprising that the majority of the world's most populous cities are found in China and India, two of the world's most populous countries. The first and second most populated cities in the world are Tokyo with a population of 37.2 million people (since 2023) and Delhi with a total population of 32.9 million people (since 2023) (World Population Review, 2023). Other cities with very high populations include:

- a) Shanghai: 29.2 million (since 2023)
- b) Dhaka: 23.2 million (since 2023)
- c) Sai Paulo: 22.6 million (since 2023) (World Population Review, 2023)

These cities are all well-known around the world and popular tourist destinations. London is the world's 36th most populated city and houses 9.6 million people. Other cities with around the same population include Tehran and New York. There are many cities with smaller populations which are still very popular and culturally rich which on the other hand provide higher living standards³⁷.

³⁵ Institution of Civil Engineers, 2023

³⁶ Council on Tall Buildings and Urban Habitat, 2023b

³⁷ World Population Review, 2023

Overall, the industrial revolution's innovations and the population shift from rural to urban areas contributed to the widespread embrace of high-rise development. The development of high-rises for general accommodation originated in the US. The Home Insurance building in Chicago³⁸ is regarded as the first high-rise building in history, and gave rise to a new architectural style known as the 'Chicago School'.

The height of buildings has changed significantly over the past century owing to modern technology and outstanding design. The 21st century has seen substantial changes in high-rise construction in London, resulting in a distinctive and contemporary skyline.

As the "father of skyscrapers," Louis Sullivan was a notable and influential American architect who helped shape the modernist movement by paying special attention to the details of buildings. One of the most famous high-rise buildings designed by Sullivan and Adler, the Wainwright building in St. Louis, Missouri³⁹ and is regarded as the forerunner of the modern steel office skyscraper⁴⁰.

³⁸ Built in 1885

³⁹ Completed in 1891

⁴⁰ Steel frame construction has made high-rise buildings substantially more window-filled than those with solid walls

Chapter 2: Commerzbank Tower

This chapter will critically evaluate the Commerzbank Tower in Frankfurt, Germany, which was constructed in 1997⁴¹ by world renowned architectural firm Foster + Partners. At 259 metres high, it is the tallest building in Germany⁴² and upon completion was the tallest building in Europe, until 2005⁴³. However, the main intentions of the design came before consideration of the building's height.

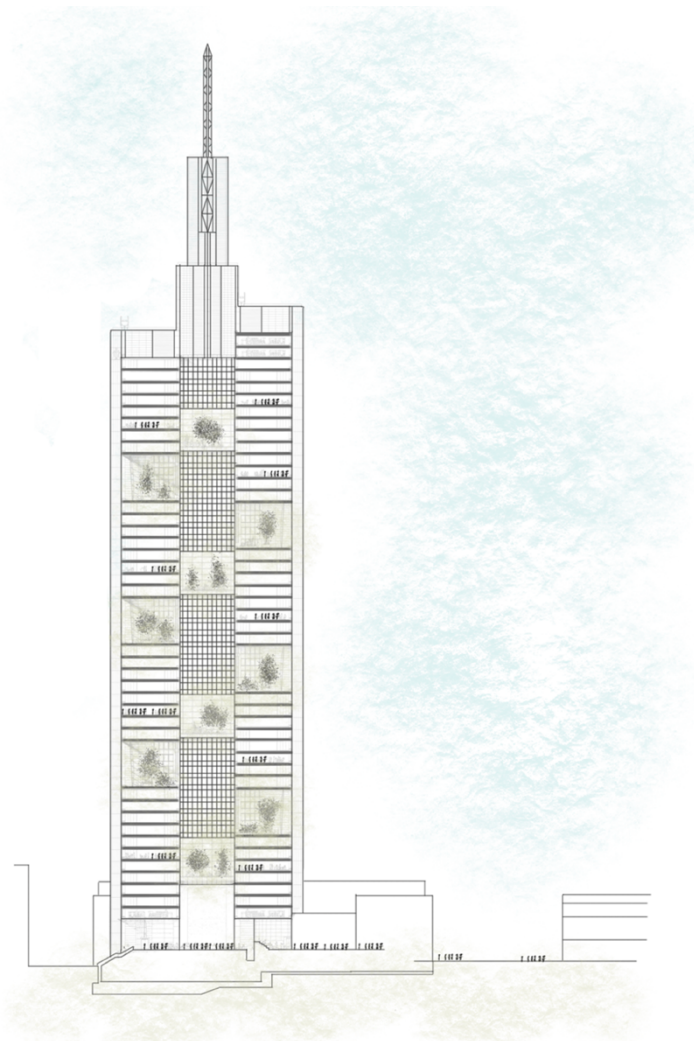


Figure 8: Section drawing of Commerzbank Tower in context of surrounding buildings. (T. Adibmehr, 2022)

⁴¹ Allen, 2022

⁴² Council on Tall Buildings and Urban Habitat, 2023c

⁴³ Spengler, 2023a

The Commerzbank is the first ecological and sustainable high-rise office tower⁴⁴ in the world making it a suitable case study for this topic. Commerzbank Tower is an example of an older high-rise building and although the building has a conventional exterior, the interior offers an interesting contrast.

The background of the building

There are several awards won by the Commerzbank Tower. The 'Green Building Frankfurt' award and the RIBA Award are two of several awarded between the years 1997 and 1998⁴⁵.

The building is primarily used as an office building⁴⁶ and is the headquarters of Commerzbank AG, one of the largest banks in Germany. Commerzbank is the leading bank in Berlin and was established as an international commercial bank with offices in over 50 countries in 1870⁴⁷. The structure containing the headquarters of Commerzbank AG has established itself as a landmark in Frankfurt's skyline and is illustrative as a representation of the city's reputation as a significant financial hub in Europe⁴⁸.

Within the structure, there are 53-storeys, providing just over 120,000m² of floor area⁴⁹, the majority of which is dedicated office spaces for the corporate offices of the bank as well as office space for other companies and organisations⁵⁰.

⁴⁴ Foster+Partners, 2023a

⁴⁵ urban systems design, 2023a

⁴⁶ SkyscraperPage, 2023

⁴⁷ Commerzbank, 2015

⁴⁸ Commerzbank, 2023a

⁴⁹ Foster+Partners, 2023a

⁵⁰ The structure also has other amenities including restaurants and parking for its occupants in addition to office space (SkyscraperPage, 2023).

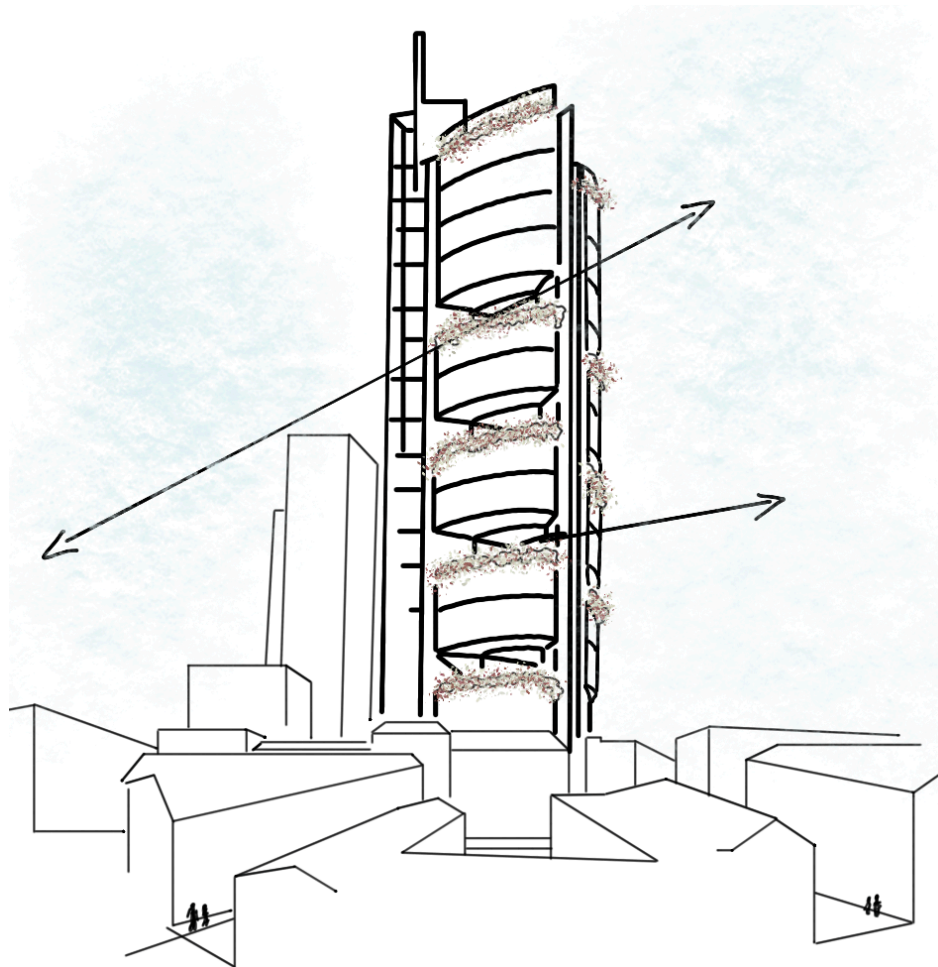


Figure 9: A perspective drawing of the Commerzbank tower in context of the surrounding buildings. (T. Adibmehr, 2022)

Architect's philosophy

Buildings are one of the greatest sources of carbon emissions after transportation and energy production, and the Commerzbank Tower was an early leader in highlighting this⁵¹. When developing the Commerzbank, the architect's principal design objective was to address sustainability⁵². The approach to architecture taken by Foster+Partners often lays a greater emphasis towards sustainability and environmental responsibility.

⁵¹ Allen, 2022

⁵² de Grey, 2022

Investigating the features of typical office buildings led to the development of creative ideas for the workplace in the Commerzbank Tower⁵³. The Commerzbank project "tackled quite a lot of the fundamental issues" with high-rise buildings⁵⁴ (de Grey, 2022).

The building was designed with a reliance on natural lighting and ventilation⁵⁵. It incorporates a number of energy efficient techniques including a double skin façade, with openable windows, which aids in reducing heat gain/loss, as well as innovative ventilation systems such as sky gardens, that minimise the buildings energy usage⁵⁶.

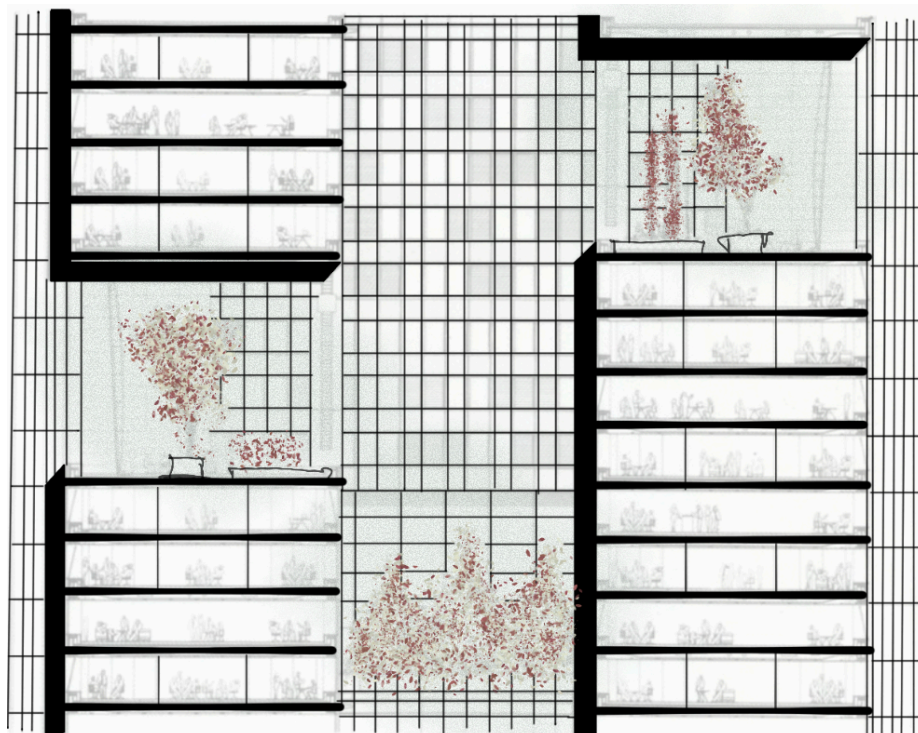


Figure 10: Partial section drawing illustrating the sky gardens. (T. Adibmehr, 2023)

The architectural layout is centred on the idea of giving each workspace adequate access to a sky garden. The sky gardens additionally help in dispersing the building's mass⁵⁷ and provide a sense of lightness and external transparency⁵⁸. This idea paved the path for the

⁵³ Foster+Partners, 2023a

⁵⁴ According to Spencer de Grey, a member of the team that worked on the Commerzbank project who is currently Senior Executive Partner and Head of design at Foster+Partners

⁵⁵ Jones, 2022

⁵⁶ de Grey, 2022

⁵⁷ de Grey, 2022

⁵⁸ Foster+Partners, 2023a

building's unique triangular form⁵⁹ which is composed of three segments organised around a full-height central atrium⁶⁰. There are a series of nine sky gardens⁶¹, rotating at a 120-degree angle every fourth floor of the building⁶². Since there are three gardens, each one facing east, south, and west⁶³, each is allocated a botanical theme from one of three geographical areas: North America, Asia, or the Mediterranean⁶⁴. The gardens provide a distinctive identity for the interior views and are used for informal gatherings for workers and staff breaks⁶⁵. The introduction of the gardens was intended to break away from the normality of day to day office work and build a work atmosphere which is more sustainable and builds longevity into the way that the work space is used⁶⁶.

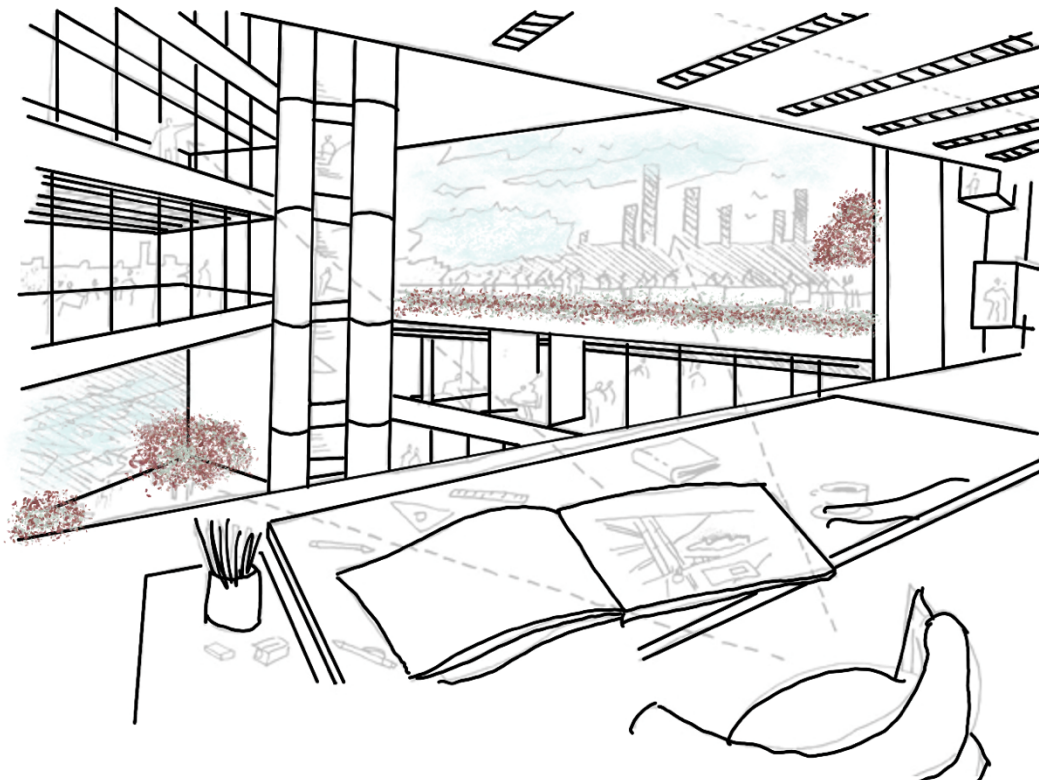


Figure 11: A drawing illustrating the view from inside the Commerzbank office looking out into the atrium and gardens. (T. Adibmehr, 2023)

⁵⁹ urban systems design, 2023a

⁶⁰ AJ Buildings Library, 2007

⁶¹ Commerzbank, 2023a

⁶² urban systems design, 2023a

⁶³ Commerzbank, 2023a

⁶⁴ Foster+Partners, 2023a

⁶⁵ Buchanan, 2023

⁶⁶ de Grey, 2022

Design challenges

The naturally ventilated sky gardens presented a design challenge because the German regulatory body strongly opposed the idea. However, this problem was quickly resolved once careful testing on site demonstrated that the gardens received enough air changes per hour to qualify as having fresh air⁶⁷.

Construction methods

The Commerzbank Tower was constructed using traditional methods as well as innovative construction and design techniques. The building's construction started in 1994 and was completed in 1997⁶⁸.

Besides steel and concrete which make up the unique structure of the building⁶⁹, the structure sits on a pile foundation that is supported by 111 reinforced concrete piles that are almost 50 metres deep in the ground to prevent settlement⁷⁰.

The centre of the structure is a 200-metre tall atrium that promotes air flow throughout the building in addition to also letting natural light flow through the entire structure⁷¹.

⁶⁷ de Grey, 2022

⁶⁸ Council on Tall Buildings and Urban Habitat, 2023c

⁶⁹ Spengler, 2023a

⁷⁰ Commerzbank, 2023b

⁷¹ de Grey, 2022

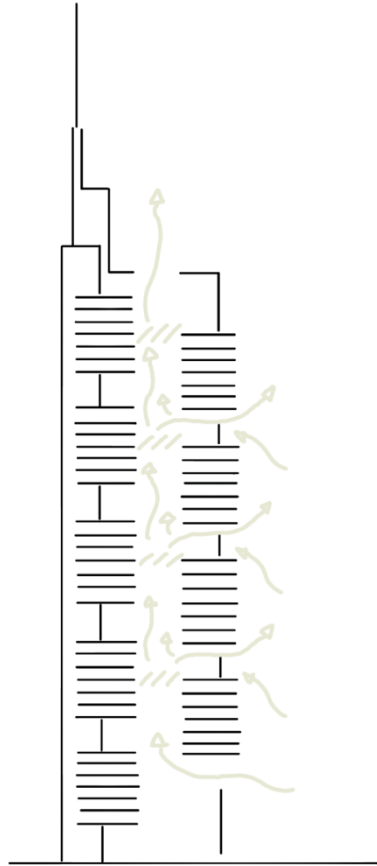


Figure 12: Analytical drawing of the Commerzbank showing air flow through the building.
(T. Adibmehr, 2023)

The structural steel-composite columns⁷² at the corner zones of the triangle-shaped building house the service shafts⁷³ and vertical circulation which is typically found in the centre core of tall buildings⁷⁴. 34-metre column-free zones in each sky garden are provided by a Vierendeel truss system, an innovative steel framing design⁷⁵.

⁷² Spengler, 2023a

⁷³ SKYLINE ATLAS, 2023

⁷⁴ GPSMYCITY, 2023b

⁷⁵ SKYLINE ATLAS, 2023

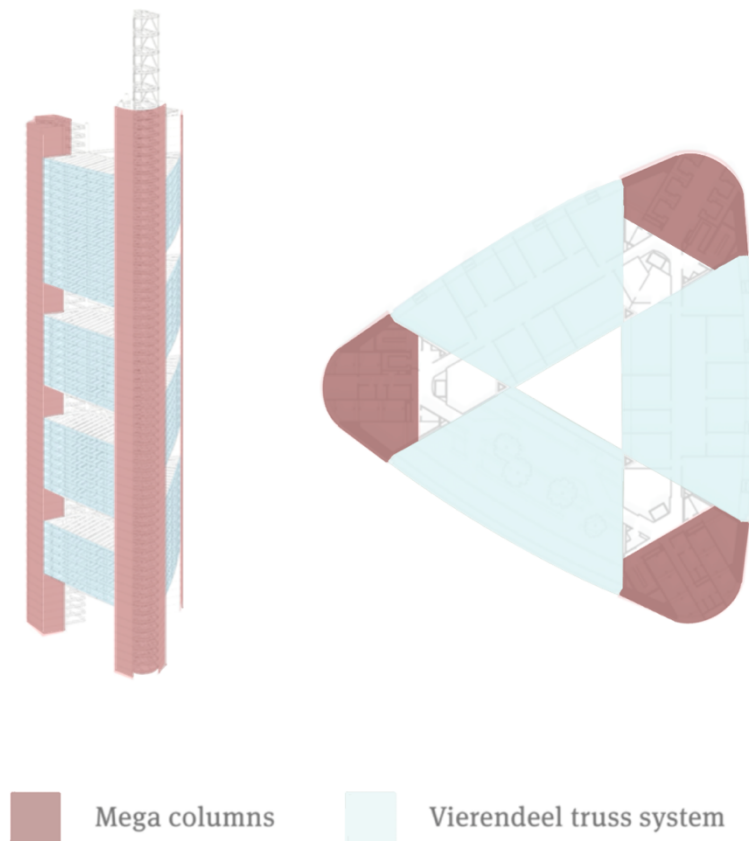


Figure 13: Drawings explaining the construction method of the Commerzbank Tower. (T. Adibmehr, 2023)

Ventilation system

The Commerzbank is the first high-rise building in the world to have an effective system of natural ventilation⁷⁶.

Calculations made during the design phase showed that the structure could employ windows for 60% of the year⁷⁷. However, with intricate management, the period of time that the building would rely on natural ventilation was raised, increasing from 60% to 85% of the year⁷⁸.

⁷⁶ Abel, 2006

⁷⁷ Since during the remaining 40% of the year the weather is either too hot, too cold, or too windy (de Grey, 2022) and therefore, the Buildings Management System (BMS) would activate (Commerzbank, 2023b)

⁷⁸ de Grey, 2022

The offices in the Commerzbank Tower were designed so that half of them would overlook the outside world and the other half would look into one of the sky gardens⁷⁹. For the offices that face the outside, a double skin envelope system serves as a bridge between the building's interior and exterior⁸⁰. The glazing system consists of a laminated outer glass pane that lets sheltered fresh air flow into a 165mm ventilated cavity with motorised Venetian blinds⁸¹. The last component is the inner layer which is a bottom-hinged glass unit that opens inwards. This system is motorised, so it can either be overridden by the building's BMS or controlled by the occupants⁸². As a naturally ventilated high-rise building, this double-skin system was essential, since it would not have been protected from strong winds, that are unfavourable for natural ventilation⁸³.

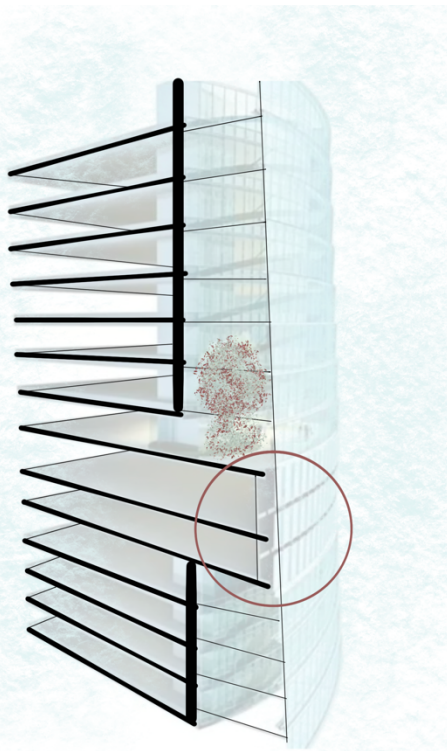


Figure 14: Section drawing of the Commerzbank Tower, indicating the double-skin façade system (T. Adibmehr, 2023)

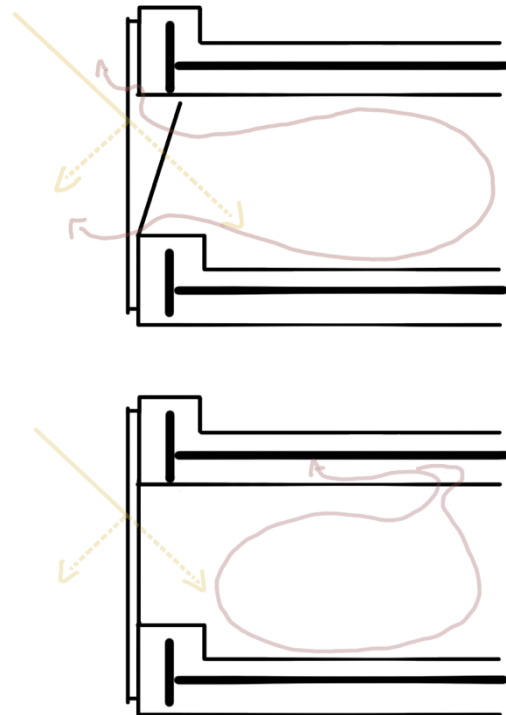


Figure 15: Analytical diagrams showing air and light flow through the double-skin façade system, when windows are open/closed (T. Adibmehr, 2023)

⁷⁹ de Grey, 2022

⁸⁰ Chan, 2023

⁸¹ That either block or reflect sun radiation (Chan, 2023)

⁸² Chan, 2023

⁸³ de Grey, 2022

Overall, the concept was for the occupants to have control over their environment⁸⁴. In return this system halves the energy consumption of the building when compared to a typical office block⁸⁵.

Sustainability and materials

The Commerzbank Tower was a ground-breaking structure which was well ahead of its time in terms of sustainability⁸⁶. Foster+Partners has proceeded to include sustainability into the design of subsequent following high-rise structures which they have designed, such as that at 30 St Mary Axe.⁸⁷

In the first ten years that the Commerzbank Tower was in use, from 1998 to 2008, the energy consumption data of the building showed that 85% of the time the building was naturally ventilated⁸⁸.

Beside the energy consumption aspects of a high-rise building, a “sustainable high-rise” primarily refers to a high-rise that, in terms of its location, is close to a transportation hub, blends well into the city, and has a positive impact on the area where it is built (de Grey, 2022).

In terms of how it impacts the surrounding area, the Commerzbank's location within the courtyard of six-storey buildings is crucial. As a result, the contrast between the Commerzbank and the rest of the city at ground level is not very strong. The building's base was intended to blend in with its surroundings by having a restaurant that is accessible to the public and contains curated and changing art exhibitions (de Grey, 2022). The lobby of the building includes large human sculptures made by J Seward Johnson⁸⁹ including one of a window cleaner⁹⁰.

⁸⁴ Through having openable windows and natural daylighting.

⁸⁵ AJ Buildings Library, 2007

⁸⁶ The design of the Commerzbank Tower has addressed a range of issues, the majority of which remain highly relevant in high-rise buildings today (de Grey, 2022).

⁸⁷ By working in collaboration, the architect and client of the Commerzbank Tower created an environmentally and climate-friendly structure that uses natural ventilation in order to contribute towards climate protection over time (Commerzbank, 2023a).

⁸⁸ urban systems design, 2023a

⁸⁹ American artist J Seward Johnson II (1930-2020) was known for trompe-l'œil painted bronze statues.

⁹⁰ GPSMYCITY, 2023b

High-rise building construction is heavily influenced by the sustainability agenda and what it can achieve and provide to an area. Achieving high densities is a typical strategy for creating a pleasant and prosperous city environment for people to work and live within. If carefully thought out and well-designed, high-rise buildings can greatly improve city life by adding density, which is a very significant contribution to the city, however, not all high-rises meet these requirements. High-rise structures still present many challenges, therefore this does not imply that they are suitable for any location (de Grey, 2022).

In terms of the Commerzbank Tower, the aforementioned points somewhat counterbalance the embodied energy of the structure since, overall, the form of construction is what makes issues regarding high-rise development more challenging to solve. Essentially, more ecologically friendly concrete is being developed, as well as the production of steel that is manufactured without the use of fossil fuels. Interestingly, therefore, even the most fundamental structural form of a high-rise building is slowly becoming more sustainable (de Grey, 2022).

Engineers primarily prefer steel and concrete for high-rise structures because these materials are durable and strong.⁹¹ Skyscrapers often have a steel frame, whereas residential tower blocks tend to be constructed of concrete⁹² because concrete is stable enough to allow for a thinner structure which can result in providing extra floor space and the necessary fire and acoustic separation⁹³.

However, due to advances in engineering and material studies, the use of timber for high-rises is becoming increasingly more popular. This is much better for the environment as timber is a natural material.⁹⁴ This is a super strong and viable option against steel and has thermal efficiency as well as fire resistant qualities. Another benefit to timber construction is that it stores CO₂ from the atmosphere, giving timber buildings the potential to be carbon negative. Timber framed high-rise buildings are already becoming a common alternative for projects across the world⁹⁵.

⁹¹ These characteristics allow modern high-rise designs to be so innovative and original (The Concrete Centre, 2015).

⁹² Facilitator, 2022

⁹³ The Concrete Centre, 2015

⁹⁴ To achieve the same strength as steel and concrete, cross-laminated timber (CLT) can be used.

⁹⁵ COX GOMYL, 2023

The world's largest cross-laminated-timber building is a residential project in London. Dalston Lane⁹⁶ is a 33-metre tall building constructed from 3,852m³ of CLT.⁹⁷

Analysis of the building's plans

The interior of the Commerzbank offers a glimpse of what an energy-efficient office skyscraper of the future could be. As the Commerzbank rises from its foundation, the pattern of the existing fabric of the neighbouring buildings¹ is carried over. The building's base is accessible to the public, which further integrates it to the site where it is located⁹⁸.

The lifts are located in the round corners of the unique triangular building⁹⁹, where they are visible from the outside¹⁰⁰. This innovative design contrasts with the layout of traditional high-rise structures where the lifts are placed at the centre of the building. The placement of the lifts in the Commerzbank not only allowed for the inclusion of a full-height triangular atrium, but also established a dynamic relationship between the movement inside the tower and outside. The experience of ascending and descending the tower is due to the windows in each lift¹⁰¹. This provides occupants with a visual connection to the outdoors which is often absent in standard lifts since people are isolated from other parts of the building and are unable to relate to the height that the lift is covering, making the journey through the building is considerably less meaningful. The exposed lifts also allow the public to feel a sense of connection with the building as they are provided with a slight visual of what is happening inside¹⁰².

Office walls are made of glass in an effort to reduce the hierarchical barriers between co-workers and promote communication and space sharing¹⁰³.

⁹⁶ High-density housing block, Dalston Lane was designed by Waugh Thistleton Architects in 2017 and was the overall winner of the Structural Timber 2017 Solid Wood/Housing Award.

⁹⁷ Engineering, design and consultancy company Ramboll believe that Dalston Lane will save 2,400 tonnes of carbon compared to an equivalent block with a concrete frame (COX GOMYL, 2023).

⁹⁸ Buchanan, 2023

⁹⁹ Commerzbank, 2023a

¹⁰⁰ Botham, 2023

¹⁰¹ Botham, 2023

¹⁰² Botham, 2023

¹⁰³ Chan, 2023

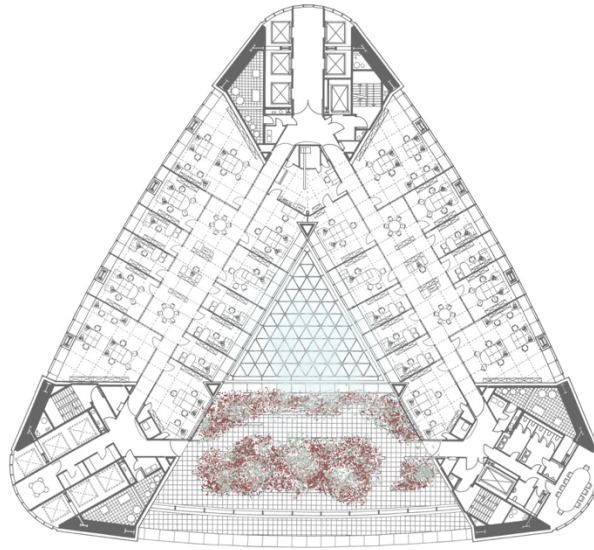


Figure 16: Plan drawing of the Commerzbank Tower. (T. Adibmehr, 2023)

In summary, the Commerzbank Tower was the first skyscraper to tackle the vast majority of ecological and social challenges associated with skyscrapers in an adequate manner. It is interesting to note that the building of naturally ventilated double curtain walls has increased since the construction of the Commerzbank¹⁰⁴.

Although since the Commerzbank more research has been done to adopt more environmentally friendly construction techniques, this particular building stands as a blueprint for how sustainability in high-rise constructions goes beyond mere material use. Overall, the Commerzbank demonstrates that a high-rise structure may be sustainable if it is carefully designed with the aim of addressing the current climate crisis.

¹⁰⁴ Chan, 2023

Chapter 3: 30 St Mary Axe

London's first ecological tower; 30 St Mary Axe, previously known as the Swiss Re Building and commonly referred to as "The Gherkin" due to its unique curved shape, is a commercial high-rise building in London's financial district¹⁰⁵. Designed by architect Ken Shuttleworth, the building stands at 180 metres tall housing 41 occupied floors. Construction on the building begun in 1997 and was completed in 2004¹⁰⁶.

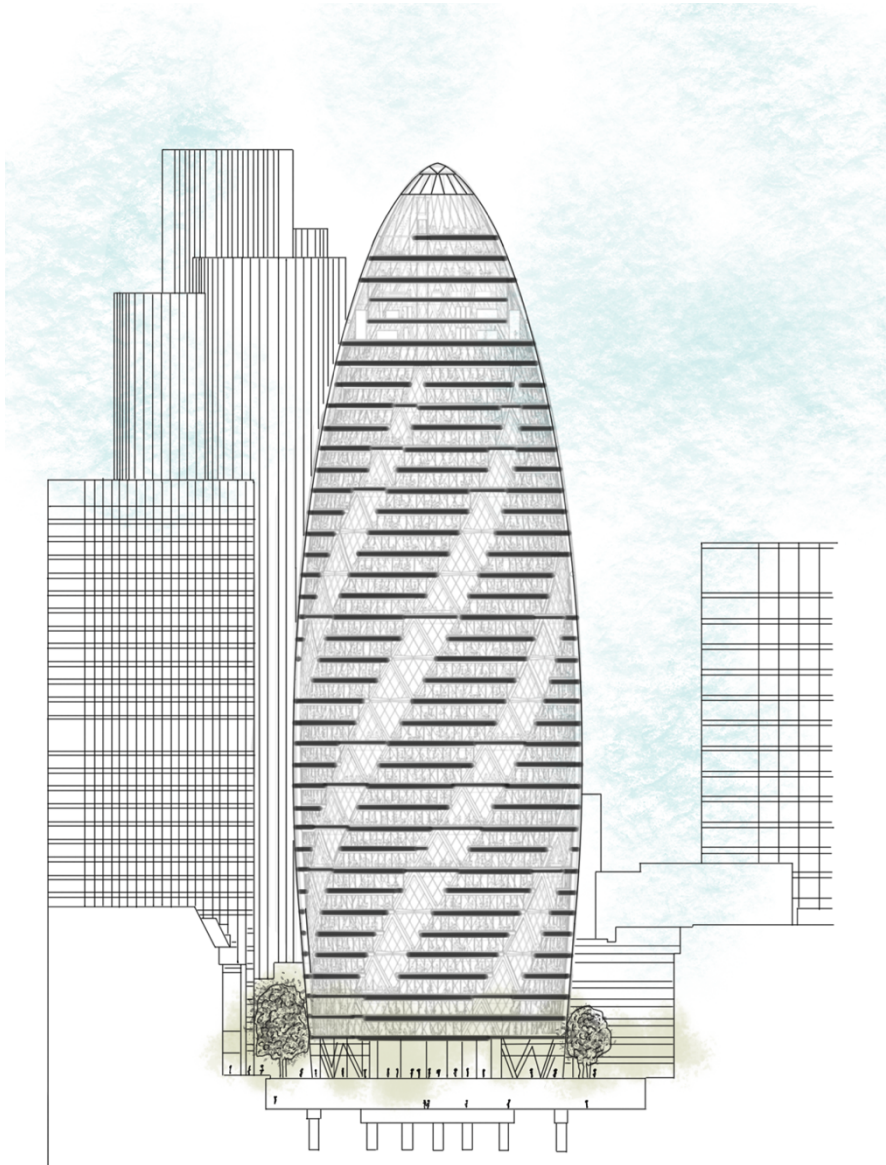


Figure 17: Drawing of 30 St Mary Axe in context of its surroundings. (T. Adibmehr, 2023)

¹⁰⁵ Designing Buildings, 2023

¹⁰⁶ Foster+Partners, 2023b

30 St Mary Axe is the second case study in this dissertation since it serves as an important illustration of modern high-rise buildings in the UK and contributes significantly to London's skyline due to its distinctive silhouette. 30 St Mary Axe has similarities to the Commerzbank Tower, discussed in Chapter 2 of this dissertation.

The background of the building

¹⁰⁷The Swiss Re Reinsurance Company commissioned Foster+Partners to design a building suitable to house its London headquarters¹⁰⁸ and remains the building's primary occupant, although various businesses and organisations have been using the floors more often in recent years.

The building was created in the modernist architectural style and has an ovular shape resembling a gherkin¹⁰⁹. The peculiar form of the building caused controversy with critics arguing that the unconventional shape of it is unnecessary, and even HRH Prince Charles¹¹⁰ expressed scepticism about the structure, adding that London has grown into a "absurdist picnic table"¹¹¹.

¹⁰⁷ The Baltic Exchange Hall, which had been severely damaged by an IRA explosion in 1992, previously occupied the site of 30 St Mary Axe (SKANSKA, 2023).

¹⁰⁸ A.H., 2008

¹⁰⁹ Masterclass, 2021

¹¹⁰ A passionate critic of architecture, the former Prince of Wales, Prince Charles (b. 1948), had strong opinions about the built environment. As Charles III, he acceded to the British throne in 2022.

¹¹¹ Skylines, 2012

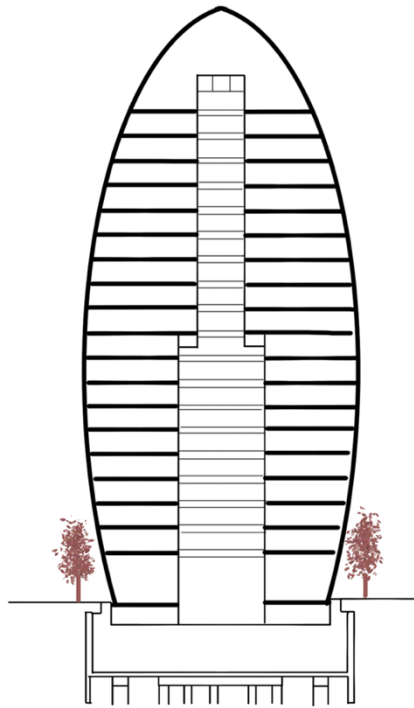


Figure 18: Section drawing of 30 St Mary Axe. (T. Adibmehr, 2023)

Ultimately, the building's distinctiveness as a feature of London's skyline is a result of its skewed shape, and its success is a testament to the benefits of challenging traditional architecture and embracing innovative design¹¹². Since its completion, 30 St Mary Axe received multiple awards, but one of the most notable was winning the prestigious RIBA Stirling Prize¹¹³ in 2004¹¹⁴.

In order to have people living and working in the same location, high-rise buildings are essential for densely populated locations, such as the City of London, where there is a high demand for high-rise buildings. The land in such areas is extremely precious, making tall and dense construction developments, more valuable. In contrast, there is an abundance of land in locations such as the Middle East where there is less requirement to construct high-rises. Depending on the location, the necessity of high-rise constructions are generally justified¹¹⁵.

Architect's philosophy

¹¹² A.H., 2008

¹¹³ Named after the architect James Stirling (1926-1992), the Stirling Prize is awarded annually for excellence in architecture.

¹¹⁴ The Gherkin, 2023

¹¹⁵ Shuttleworth, 2022

The architectural concept of 30 St Mary Axe once again reflects Foster+Partners' dedication to producing innovative, sustainable architecture that responds to its environment. The construction is a high-tech high-rise that uses half as much energy as another building of its size¹¹⁶ by using a variety of advanced methods, such as a double-skinned façade and atriums to promote natural ventilation, similar to the Commerzbank Tower¹¹⁷.

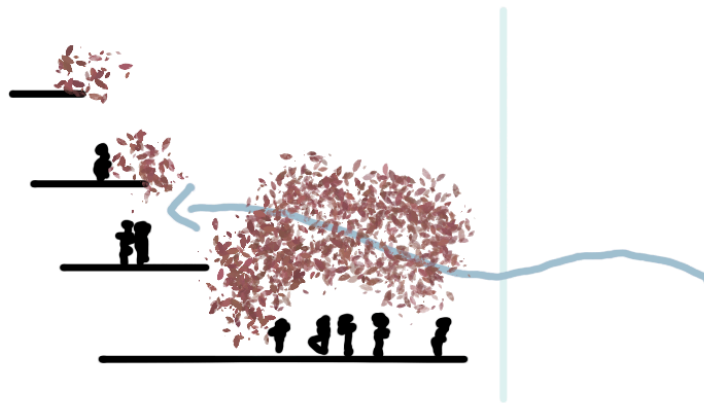


Figure 19: Diagram showing air flow into 30 St Mary Axe. (T. Adibmehr, 2023)

There are several comparisons between 30 St Mary Axe and the Commerzbank. The design for both buildings started from the concept of a stacked and rotating plan. In the case of 30 St Mary Axe the floor plates of the building vary in size as it rises and its circular plan provides 360-degree views of the city and supports the demands of a busy urban location¹¹⁸. The building's curved form is a response to the constraints of the site, sustaining a comfortable atmosphere at street level and encourages pedestrian flow around its base and significantly reduces wind deflections¹¹⁹.

¹¹⁶ Masterclass, 2021

¹¹⁷ Buchanan, 2023

¹¹⁸ Buchanan, 2023

¹¹⁹ urban systems design, 2023b

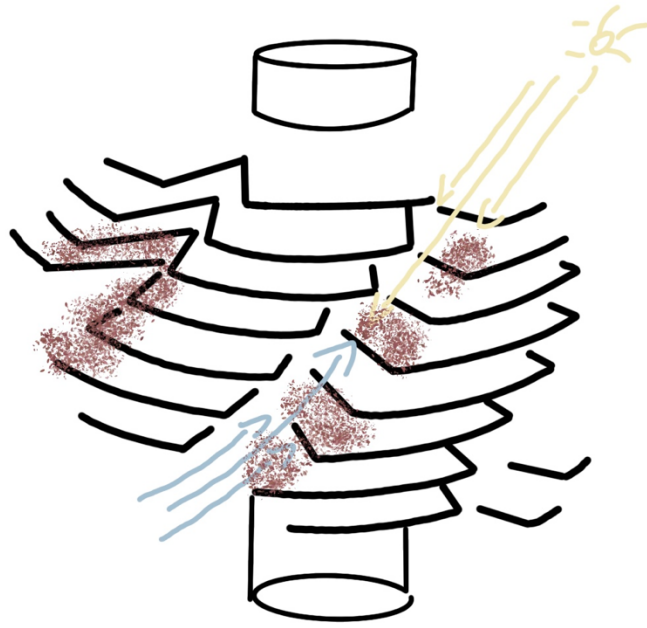


Figure 20: Diagram showing the rotating floor plates of 30 St Mary Axe. (T. Adibmehr, 2023)

Despite having a curved structure, the building is entirely covered with straight glass panels, with the exception of the curving glass dome at the top of the building¹²⁰.¹²¹ These structures are also far more expensive to construct since unique shapes, like the double curves of 30 St Mary Axe, need more complex engineering than that of a traditional rectangular building¹²².

¹²⁰ Masterclass, 2021

¹²¹ Ironically, Ken Shuttleworth, the principal architect of 30 St Mary Axe and advocate for low-energy buildings, campaigns to reduce the amount of glass in skyscrapers (Shuttleworth, K., 2022).

¹²² Shuttleworth, 2022

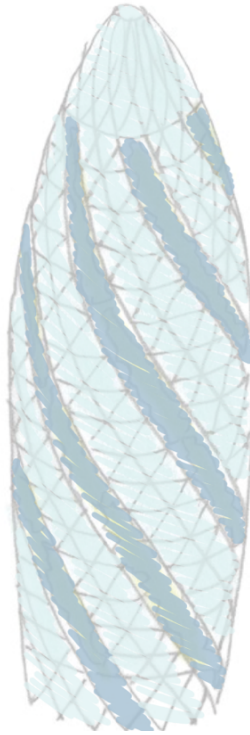


Figure 21: Sketch drawing of 30 St Mary Axe, highlighting the glazing. (T. Adibmehr, 2023)

The current recession has made architects far less ambitious with their designs. Although there is a great possibility that this will change and there will be another phase where architects are more confident erecting more expensive structures in the future¹²³.

Design challenges

Although the distinctive curvature of 30 St Mary Axe offered captivating atmospheres¹²⁴, it also provided a number of complicated challenges for effectively utilising the floor space given the circular shaped plans. Since the building's form and orientation change, every floor has its own specific size and shape¹²⁵.

A general challenge to high-rise construction is how it contacts the ground and ensuring that the ground plate is not windy or an undesirable place to be so that the site is public and

¹²³ Shuttleworth, 2022

¹²⁴ Munro, 2023

¹²⁵ Burr-Jones and Brewer, 2023

accessible. A building's ability to blend in with the streetscape and major transportation hubs is crucial¹²⁶. 30 St Mary Axe is a great example in satisfying this requirement.

Densification in cities is vital for concentrating as many people in one area as possible, rather than dispersing them over a large area¹²⁷. People will spend less energy to get around a city that is smaller and denser. Therefore, it's essential to avoid sprawling suburban in order to minimise CO2 emissions¹²⁸.

Construction methods

Despite its complex geometry, the construction of 30 St Mary Axe cost was equivalent to or cheaper than that of other London high-rise building¹²⁹ and it required approximately 35-kilometres of steel to build it¹³⁰, which is 20% less than the steel needed for an average structure of its size (Buchanan, 2023).

The structural frame of the building is a diagrid of intersecting steel tubes¹³¹ that create a web of a-framed steel diamonds¹³², which follow the curvature of the structure. The structure is wind-resistant owing to this rigid structural system, which also provides column-free floor areas (Munro, 2023).¹³³

Since energy conservation was not a major concern when 30 St Mary Axe was first built, if the building was to be designed again, it would undoubtedly adapt to the solar path in order to keep the solar gain to an absolute minimum. The south side would have less glazing, compared to the north side. Although the building's shape would remain the same, the façade would be entirely reclad to reduce the quantity of glass on the south side (Shuttleworth, 2022).

Ventilation system

¹²⁶ Shuttleworth, 2022

¹²⁷ such as in Los Angeles, where the infrastructure is dispersed across a large area and forces people to travel.

¹²⁸ Shuttleworth, 2022

¹²⁹ Buchanan, 2023

¹³⁰ SKANSKA, 2023

¹³¹ Munro, 2023

¹³² Masterclass, 2021

¹³³ 3D modelling was used in order to ensure accuracy of installation with regard to how various building components will be constructed (SKANSKA, 2023).

The form of the building was intended to significantly reduce wind deflections compared to a rectilinear high-rise structure of the same size. Despite creating a more pleasant ground level environment, the building also creates external pressure differentials that are exploited to drive a unique system of natural ventilation¹³⁴ which substitutes for mechanical ventilation for up to 40% of the year¹³⁵.

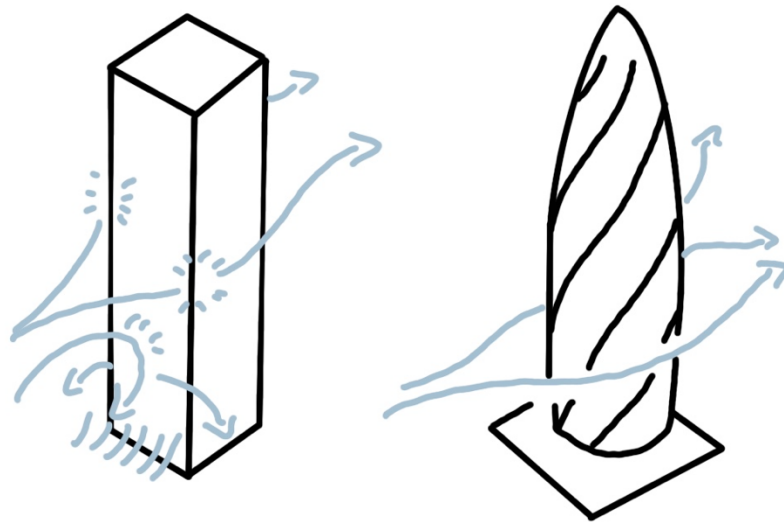


Figure 22: Diagrams illustrating wind deflections on a rectangular building compared to 30 St Mary Axe. (T. Adibmehr, 2023)

30 St Mary Axe expanded on concepts considered in the design of the Commerzbank¹³⁶, such as the double-skinned glazing system. This features a vented cavity between a single-glazing layer with vertical laminated glass screens and louvre blinds facing the offices and a double glazing exterior layer (Foster+Partners, 2004).

Since the building is designed to rely on the use of natural light and ventilation the need for artificial lighting and air conditioning is minimised through a highly glazed façade and increased air flow in the building¹³⁷. 30 St Mary Axe has six spiralling atriums that provide air flow through the building as well as flooding the areas with natural lighting. These light wells are an essential part of the environmental strategy of the building (Munro, 2023).

¹³⁴ Foster+Partners, 2023b

¹³⁵ Arquitectura Viva, 2023

¹³⁶ Foster+Partners, 2023b

¹³⁷ SKANSKA, 2023

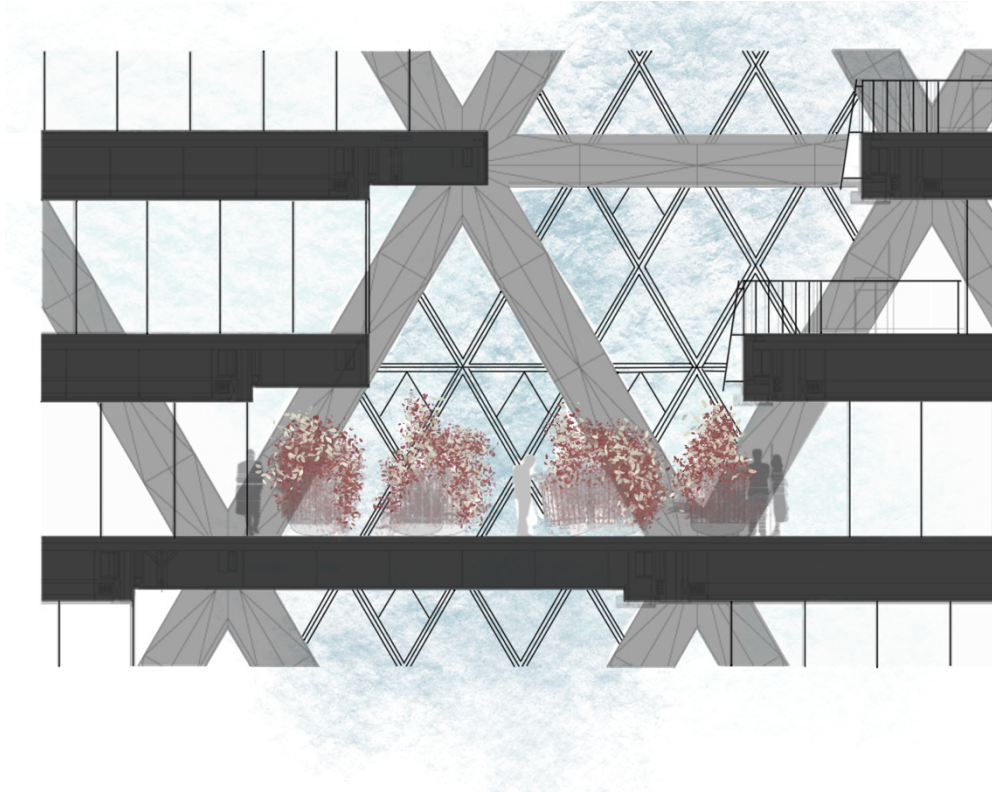


Figure 23: Section drawing showing the atrium space against the structural frame of the building (T. Adibmehr, 2023)

Triangular atriums, which have the benefit of leaving the office spaces rectangular¹³⁸, were created by removing six V-shaped slots from the floor plates to create rectangular spaces that are considerably easier to subdivide due to the constraints of designing within a circular layout (Buchanan, 2023).

¹³⁸ AJ Buildings Library, 2003

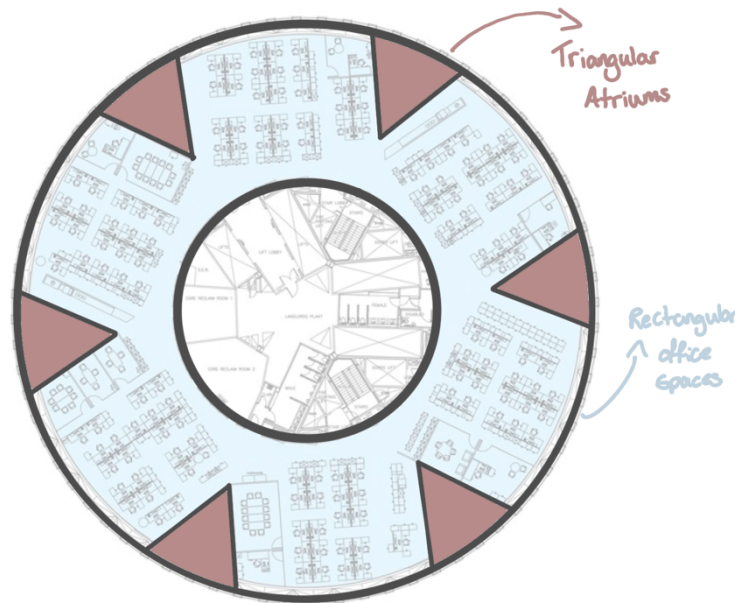


Figure 24: Analytical drawing of the office floor plate. (T. Adibmehr, 2023)

The floors are then rotated by five degrees each creating a series of light-wells that spiral up and around the building. The single-glazing facing these are lined with tinted glass (Buchanan, 2023).¹³⁹



Figure 25: Diagram highlighting the tinted glazing spiralling up and around the building (T. Adibmehr, 2023)

¹³⁹ These serve as the building's 'lungs' by allowing fresh air to enter through openable panels on the façade (Foster+Partners, 2023b).

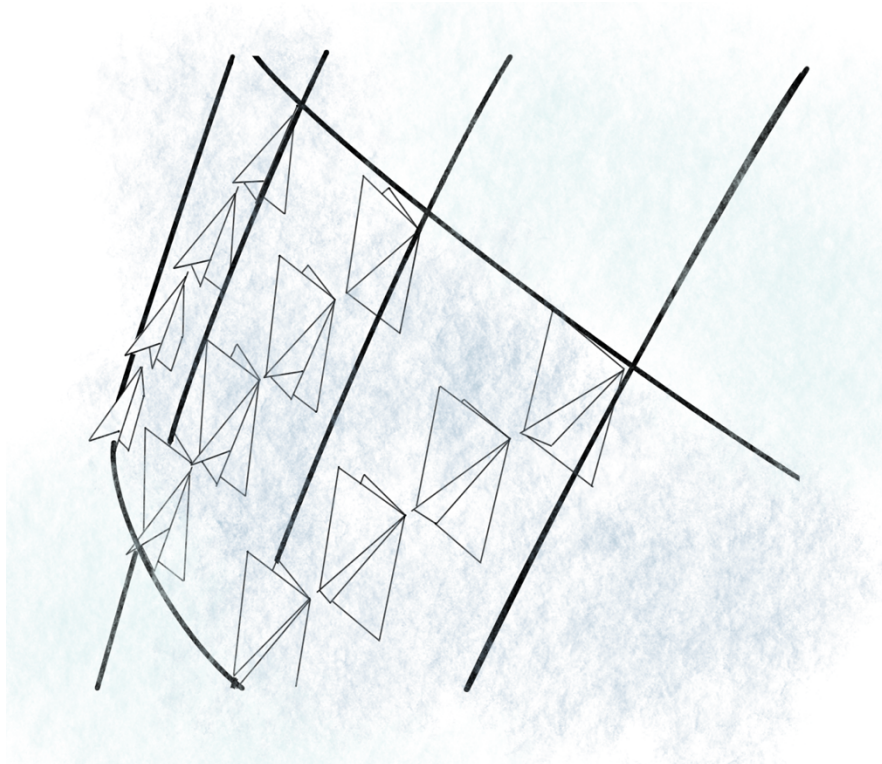


Figure 26: Diagram showing openable windows facing the atrium spaces. (T. Adibmehr, 2023)

Similarly to the Commerzbank's full-height atrium, the light-wells of 30 St Mary Axe close every six storeys, to minimise excessive winds and enhance public safety by preventing the spread of fires (Buchanan, 2023).

Overall, high-rise buildings should mostly be naturally ventilated rather than completely sealed as that requires more energy making the building more carbon intensive as well as creating unpleasant environment for its occupants. Although it would be challenging to accomplish this in areas such as the Middle East due to the extreme heat, and also in Hong Kong because of the excessive humidity, natural ventilation is appropriate in places like London where it is cold and not overly humid (Shuttleworth, 2022).

Sustainability and materials

30 St Mary Axe is an outstanding representation of an environmentally-friendly addition to London's skyline and has been recognised for its high sustainability standards of design and

construction¹⁴⁰. The innovative environmental strategy, significantly reduces energy consumptions when compared to other prestigious office high-rise buildings of the era¹⁴¹. This was made possible by the building's aerodynamic shape that minimises wind loads similarly to the edges of the Commerzbank, and maximises the use of natural lighting and ventilation to stabilise the buildings climate and lower energy costs (Shetty, 2021). Despite 30 St Mary Axe being designed to have outstanding energy saving measurements, all tenants, with the exception of the Swiss Re, have opted for full-time air conditioning¹⁴².

A rainwater harvesting system in the building collects and reuses rainwater for irrigation and flushing toilets. This lessens the building's need for fresh water and eases strain on the sewage system of the city¹⁴³.

The building's exterior is covered in more than 5,000 triangular and diamond-shaped glass panels of varied sizes¹⁴⁴, totalling 24,000 square metres (Foster+Partners, 2004).

In order to limit the amount of carbon and energy consumed and to use materials that are sustainable and derived from sustainable sources, it is crucial to adopt a correct approach and employ the appropriate materials. The use of timber, recycled steel, 3D-printed building components, and cement use, are just a few of the many materials that are the subject of ongoing research. Cement, which is used to bind the concrete, is the biggest problem that exists in the construction industry, as it is the most carbon intensive product used (Shuttleworth, 2022).

Although 30 St Mary Axe has achieved high sustainability standards, the tall and thin nature of a high-rise means that the amount of energy it consumes will be significantly higher than that of a lower building; consequently, the amount of surface area it has draws more sunlight and allows for more heat to be dissipated. As a result, taller buildings are unable to equal the energy efficiency of a low-rise building. It is vital that architects consider whether a high-rise building is indeed necessary and whether a lower building may satisfy the same client needs (Shuttleworth, 2022).

Analysis of the building's plans

¹⁴⁰ SKANSKA, 2023

¹⁴¹ Foster+Partners, 2004

¹⁴² City, People and Sustainability, 2015

¹⁴³ 3M Design and Construction, 2016

¹⁴⁴ SKANSKA, 2023

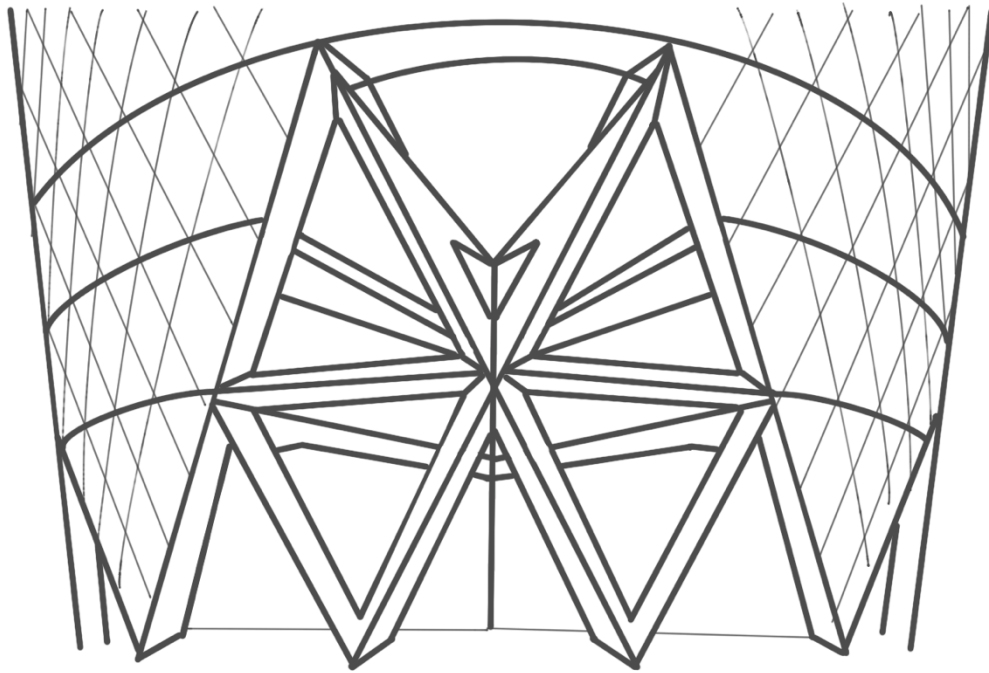


Figure 27: Drawing illustrating the entrance lobby (T. Adibmehr, 2023)

The entrance of 30 St Mary Axe includes a striking X-shaped entrance that opens onto a vibrant public square, promoting a mixture of urban life (Foster+Partners, 2004). With changing floor plate sizes as the building rises, the building has a total floor area of approximately 64,500 square metres (Foster+Partners, 2023b). Offices are arranged around the core of the building's circular plan. The form of the structure becomes wider towards the middle, where the widest point is on the 17th floor, having a radius of 57-metres, before tapering off to a radius of 25-metres at the building's top (Arquitectura Viva, 2023). Organic connections between floors are made possible by the balconies that surround each atrium, which also serve unofficial gathering spaces for occupants (Foster+Partners, 2004).¹⁴⁵

¹⁴⁵ 30 St Mary Axe houses 18 lifts in total, each with a six-metre-per-second maximum speed (Masterclass, 2021).

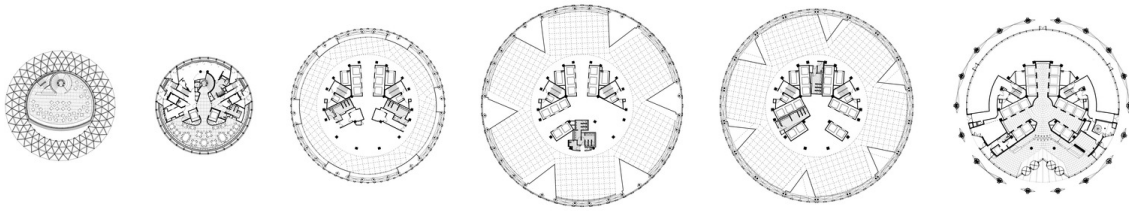


Figure 28: 30 St Mary Axe's varying floor plans (Foster+Partner)

In summary, 30 St Mary Axe, London's first ecological tower, is a distinctive high-rise structure that stands out in the city's skyline. The unorthodox shape of the structure sparked debate but went on to become a recognisable part of the city's skyline. The building's successes serve as a testament to its benefits of challenging conventional design and architecture. It also demonstrates Foster+Partners' commitment to creating avant-garde, environmentally conscious architecture.

The building's distinctive curvature provided a number of complicated challenges for effectively utilising the floor space. Despite these challenges, the building received multiple awards, including the prestigious RIBA Stirling Prize in 2004.

The building is a technologically advanced high-rise that employs cutting-edge techniques to encourage natural ventilation, such as a double-skinned façade and atriums. Although the economic downturn has caused architects to be less ambitious in their designs, this may shift in the future. Ultimately, 30 St Mary Axe is a remarkable achievement in modern high-rise building design, and its success continues to inspire new generations of architects and engineers.

Chapter 4: The Shard

This chapter will analyse the third case study of the dissertation which is the London Bridge Tower or more popularly known as 'The Shard': the tallest building in the UK since completion in 2012. Designed by Italian architect Renzo Piano, The Shard reaches up to almost 310 metres in height. Before The Shard, the tallest building in the UK was the 235 metre tall One Canada Square Building (Designing Buildings, 2020b). The Shard is a mix-use high-rise building with offices, apartments, restaurants, a hotel and an observation deck overlooking the city of London (The Shard, 2023a).

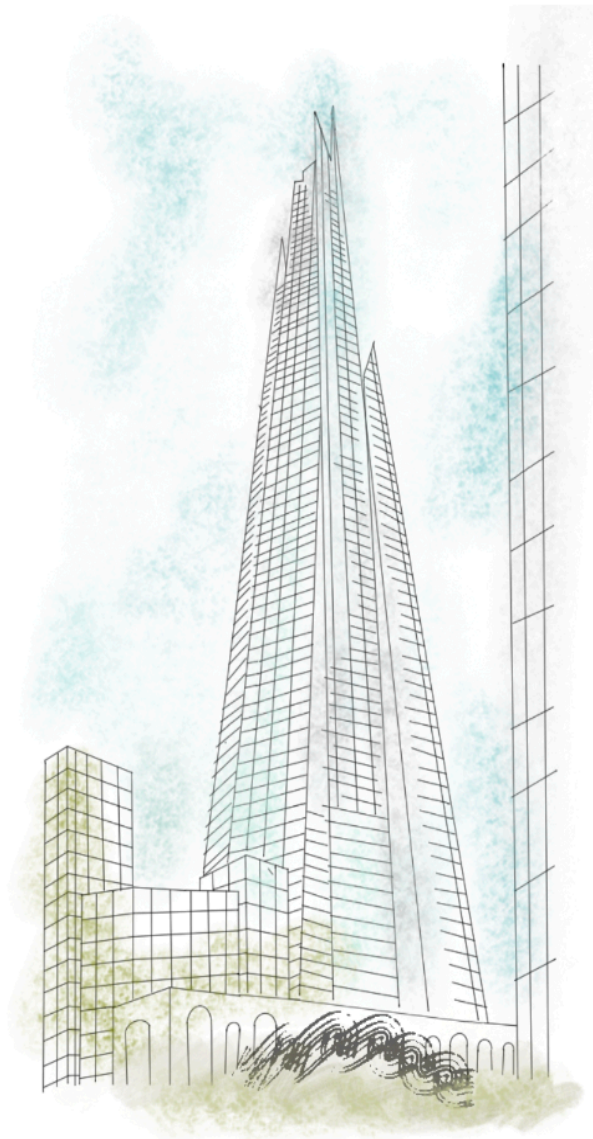


Figure 29: A drawing of The Shard in context of the surrounding buildings. (T. Adibmehr, 2023)

The Shard is a suitable case study for this dissertation due to its contemporary design and unique shape, which is different from the standard high-rises of the past. The Shard is one of the key examples of high-rise buildings in Britain.

The background of the building

The Shard has won a number of awards including the 'Most Eagerly Anticipated Luxury Launch' in 2013¹⁴⁶ and 'Best Commercial Building', awarded by the RIBA in 2014 (The Shard, 2014).

In order to reduce the carbon emissions from cars, the UK government encouraged developers to construct high-density complexes close to transportation hubs. During this time, property developer and owner of the 1970s Southwark Towers, Irvine Seller was eager to re-develop the office buildings which previously occupied the site of The Shard (Fairs, 2012).

Due to Piano's conflicting views on high-rise structures, Seller served as the project's primary driver. High-rise buildings were controversial in Piano's eyes, and he believed they deserved their bad reputation as symbols of arrogance and power¹⁴⁷. Piano's architecture practice; Renzo Piano Building Workshop, contains relatively few high-rise projects in their portfolio, especially before 2000¹⁴⁸. However, the elegance of the river Thames along with the opportunity to design a multi-purpose building near a transportation hub sparked Piano's interest¹⁴⁹. High-rises should be constructed when there is a compelling justification. However, not all issues can be solved by a high-rise structure¹⁵⁰.

The Shard adds vertical emphasis to a generally horizontal city, creating contrast between the contemporary design of The Shard against the Victorian surroundings, in particular London.

Piano's initial concept for The Shard was sketched on a napkin while having lunch with Seller¹⁵¹. Church spires on the buildings around London served as one of Piano's primary sources of inspiration while designing The Shard (Frearson, 2019).

¹⁴⁶ The View From The Shard, 2023

¹⁴⁷ Fairs, 2012

¹⁴⁸ Moolhuijzen, 2022

¹⁴⁹ Fairs, 2012

¹⁵⁰ Moolhuijzen, 2022

¹⁵¹ The Shard, 2023a

The innovative 'vertical city' approach of The Shard consists of 72 occupiable floors (Parker, 2013). The pyramidal structure offers a 360-degree panoramic view of the city and contains apartments, a hotel, restaurants, offices, and a basement (The Shard, 2023c).

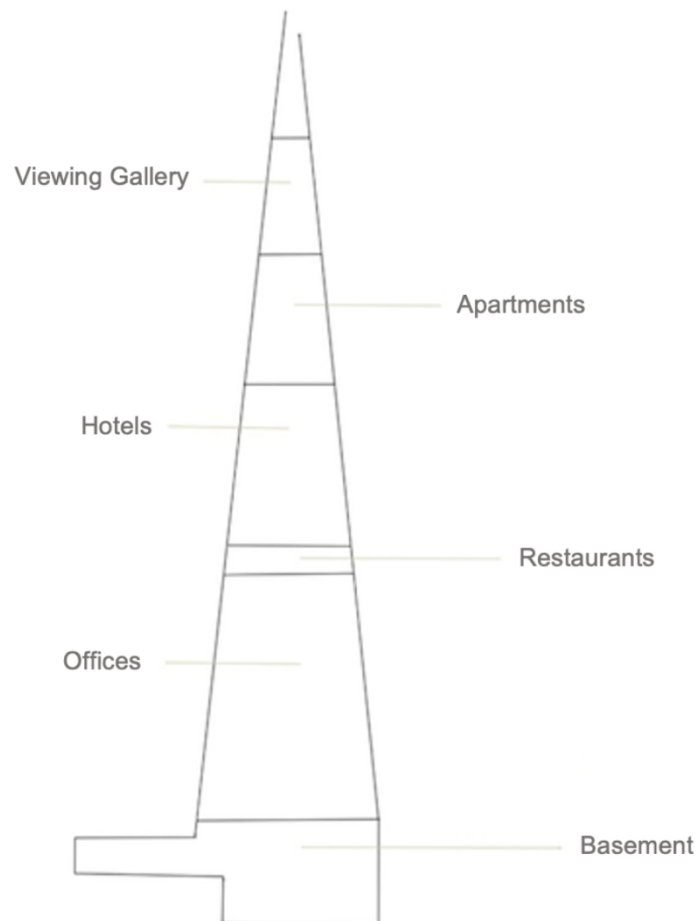


Figure 30: A drawing showing floor distribution in The Shard. (T. Adibmehr, 2023)

Architect's philosophy

Even though, prominent structural frameworks were a common feature in many of his designs, Piano prefers to follow a logical and practical approach to projects rather than limiting himself to a specific style of architecture (Frearson, 2019). With The Shard, Piano wanted to avoid a continuously shaped structure in order to convey lightness and introduce a delicate skyscraper to London's skyline. The tapered shape of The Shard along with its reflective-glass-façade perfectly illustrates this approach (JLL, 2018).

Contrary to most clients Irvine Seller did not have any specific design requirements but merely asked for the construction of a one-million square-foot building. This made the idea of a mixed-use building immediately apparent because it would provide a more appealing and dynamic end product that operated around the clock (Moolhuijzen, 2022).

The ground level connection between high-rise buildings and urban life is one of the most crucial aspects of high-rise development. The Shard was designed to be accessible, permeable, and light on the ground, in contrast to the arrogance that can characterise other skyscrapers. Rather than being a sign of authority, The Shard is more about the intensity of city life, the variety of uses, and the exhilaration of city living (Moolhuijzen, 2022).

As well as there being a 300 meters height restriction because of the aviation lanes, there were also concerns about the proposal obstructing views of the historic St Paul's Cathedral. Therefore, in terms of the design the building being tapered was essential for such a sensitive location (Moolhuijzen, 2022). The idea that the building narrows as it rises benefits the building's performance since it allows air to flow through the structure and creates an organic connection between the inside and the outside (The Shard, 2023a).

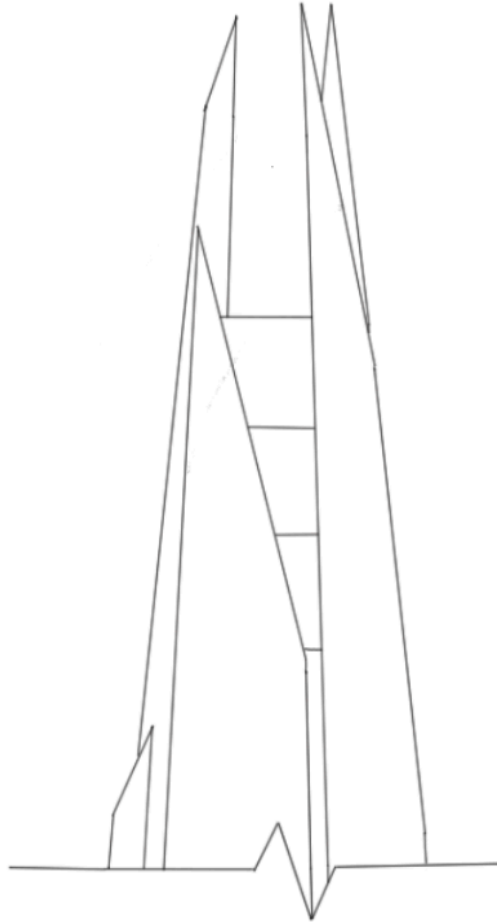


Figure 31: A drawing of the roof of The Shard showing glass spikes. (T. Adibmehr, 2023)

Design challenges

Naturally the scheme attracted a lot of controversy and apart from overcoming the site's limiting height restrictions and avoiding blocking views of St Paul's Cathedral, there were challenges regarding planning committees, public inquiries and financial issues raised on by the 2007 economic crisis (Moolhuijzen, 2022).

As opposed to New York City, where buildings are arranged close together, the lack of high-rise structures surrounding The Shard presented a significant challenge in terms of wind and sun reflection (Construction News, 2015).

Also, the World Trade Centre¹⁵² disaster in 2001 had a profound effect on how people viewed skyscrapers and it caused the proposal to undergo considerable construction modifications such as upgrading the building's central core and evacuation routes (Phillips, 2019).

Other challenges regarding construction included, the new foundation to be constructed around the existing foundation of the previous building as there was a realisation that demolishing the Southwark Towers foundation would be too challenging due to the removal of the weight relaxing the ground which could have potentially affected neighbouring buildings (JLL, 2018).

Construction Methods

Since the rise of the first skyscraper in Chicago, building technologies have become very advanced. This is reflected in the design and construction methods of modern skyscrapers such as The Shard, which used the latest tools and techniques in their construction.

The structure of the building is made up of steel and concrete. The lateral stability of The Shard is provided by a concrete core¹⁵³ which reaches to level 72, after which steel is used for the construction of the spire¹⁵⁴.

As oppose to the higher residential levels, which are constructed with concrete, the offices on the lower floors are made of steel, which is significantly lighter (Moolhuijzen, 2022). Steel is a superior choice for the frame of the lower floors since they are wider and steel can support longer spans, while concrete is better suited for the smaller floor plates. Utilising concrete for the residential floors not only lowered the floor-depth per floor¹⁵⁵ but additionally, concrete performs better in terms of acoustics and vibration (Card, 2014).

This top-down core construction method is an innovative technique¹⁵⁶ as it allows the building to be less affected by wind reducing sway, as the top of the building has a heavier

¹⁵² The World Trade Centre (also known as The *Twin Towers*) by Minoru Yamasaki as lead architect and Emery Roth & Sons, completed in 1973 dominated the Manhattan skyline for three decades before their destruction in 2001.

¹⁵³ Card, 2014

¹⁵⁴ Parker, 2013

¹⁵⁵ Card, 2014

¹⁵⁶ Parker, 2013

weight. In order to prevent the occupants from noticing the swaying, the acceleration must be minimised (Moolhuijzen, 2022).

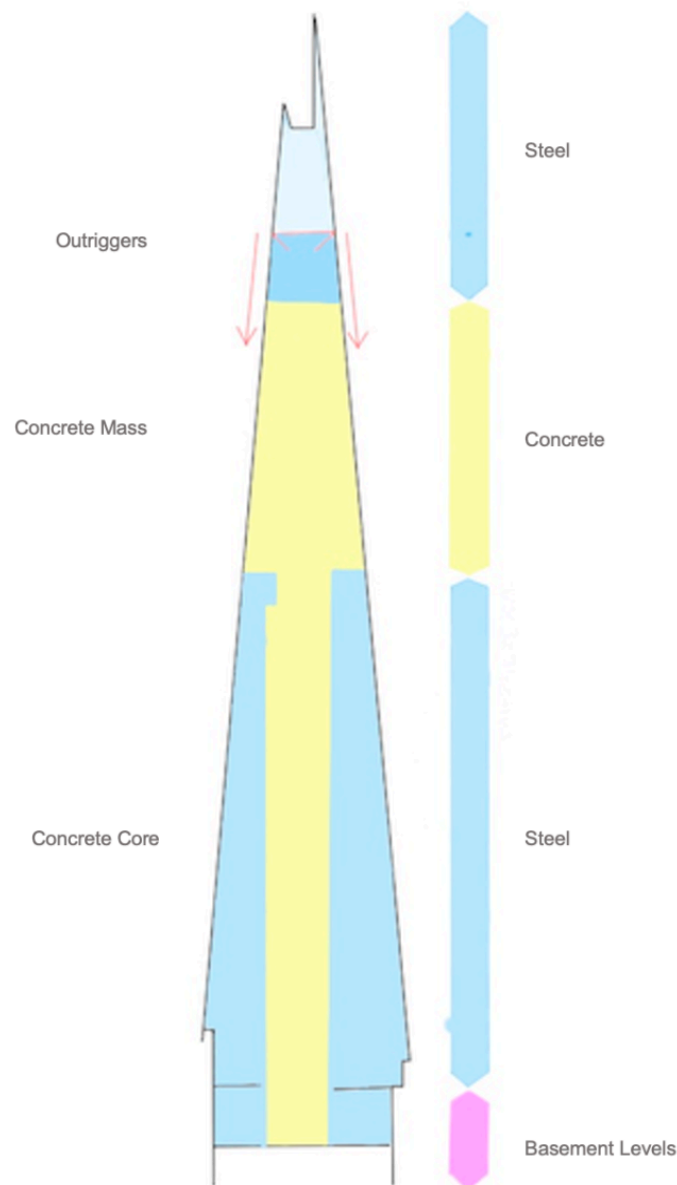


Figure 32: A drawing showing the structural frame material changes with height. (T. Adibmehr, 2023)

The embedded carbon in buildings comes from the materials, and using less of it means using less energy. The Shard succeeds in terms of material use coming very close to the most optimised and simple structure with an average height of 150 metres (Moolhuijzen, 2022).

Ventilation System

The location and mixed-use nature of The Shard, suggested that a fully mechanical ventilation system be appropriate. Approximately 56,000 square-metres of the building is office area, with large floor plates, these areas would be very challenging to naturally ventilate. The same reasoning can be applied to the building's hotel component, where the pressure changes make it difficult to naturally ventilate. Given that the air in London is extremely polluted, the building's location further discourages natural ventilation (Moolhuijzen, 2022). The Shards method of ventilation is in contrast to the ventilation system of the previous case studies. The Commerzbank Tower and The Gherkin were both designed with the intention of using the least amount of energy possible, which led to their unique and innovative approaches to naturally ventilation the structure.

Overall, natural ventilation, makes much more of an environmental sense in structures that are not as tall as The Shard, particularly in residential structures (Moolhuijzen, 2022).¹⁵⁷

¹⁵⁷ The 100-metre-tall Shard Place, which is adjacent to The Shard, includes an in-house all-house system providing natural ventilation (Moolhuijzen, 2022).

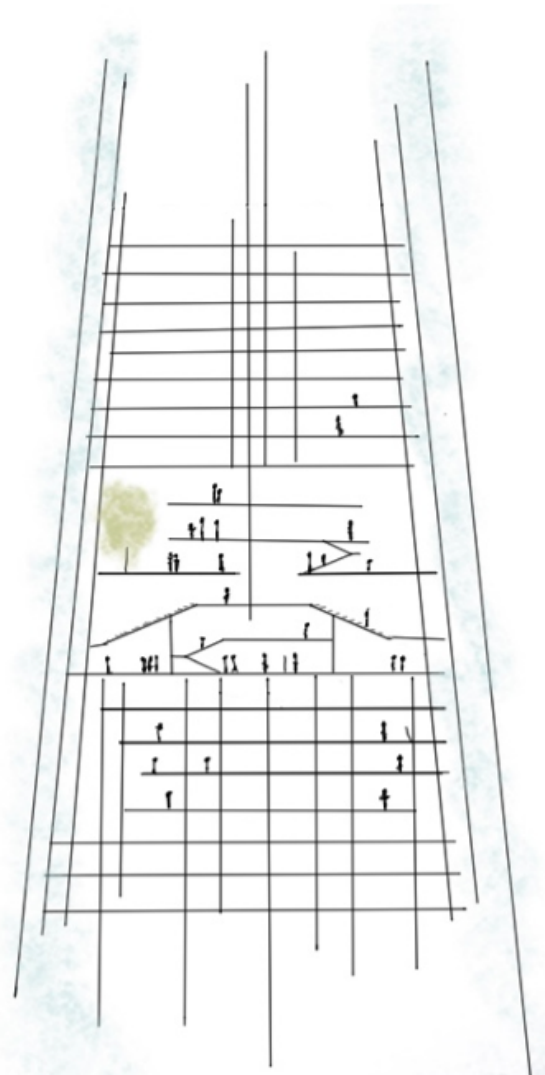


Figure 33: A Section drawing showing the restaurant and bar areas. (T. Adibmehr ,2023)

Sustainability

High-rise buildings are generally not the most energy efficient buildings especially in comparison to low-rise buildings which use significantly less materials. However, The Shard has taken measures to ensure a sustainable design which is reflected by the material performance, construction and overall function as a mix-use 'vertical city' structure. High-rise buildings such as The Shard, which sit within a densely packed area, can also support sustainability in terms of land-use (Moolhuijzen, 2022).

There are various methods to consider in order to improve the performance of a high-rise building. The performance of the façade is essential in terms of the building's energy use. In The Shard, solar shading was necessary to prevent excessive energy from entering the structure and raising the temperature, which would then require cooling. The building's G-values are significantly reduced because sun radiation is blocked out by using mechanical blinds that offer shading and a double-skin façade system (Moolhuijzen, 2022). made up of 11,000 panels of glass. The single glazed exterior layer is followed by a double glazed interior layer that acts as a cavity and provides ventilation (HP Development Company, 2019).

The ultra-white glass used in this innovative active façade system has a silver coating¹⁵⁸ that gives it a crystal-like appearance and reflects the changing sky. This detail is in contrast to the tinted glazing used in neighbouring high-rises.

Considering it is intended to use 30% less energy than previous high-rise structures and 90% of the materials used in its construction, including 20% of its 500-tonne steelwork, are recycled, The Shard received a "Excellent" grade from BREEAM (HP Development Company, 2019).

Analysis of the building's plans

The approach for the design of the building was always to create a 'vertical city'. This vision inspired the slender shape of the structure.

In total, there are 36 lifts with an average speed of achieving six metres per second and 306 flights of stairs (The Shard, 2023a).

The lower levels of the building, which have larger floor plates, were chosen for offices since the base allows for the most staff interaction for workers to be on the same floor.

Because every hotel room would need views of the city, the bigger floor plates provided by the lower levels would not have been appropriate for the hotel element of the project. As a result, the hotel was located within the middle of the building. This also made an essential corridor close to the core.

Near the top of the building, the apartment levels occupy an entire storey, and occasionally even two storeys. The varying floor plates of the building provided efficient spaces for the mixture of uses that the building incorporates (Parker, 2013).

¹⁵⁸ HP Development Company, 2019



Figure 34: The Shard Floor Plans illustrating the varying floor plate sizes (ArchDaily, 2022)

In conclusion, The Shard's design deviates from a typical London skyscraper yet has influenced the design pattern of other high-rise structures. However, architects and developers must be sceptical of the expanding high-rise development and in the 21st century are asked to justify why building high-rises are required would be advantageous at particular locations. In these instances, a vital site visit is necessary to understand the substantial impact on sustainability challenges.

The Shard's mixed-use function encourages sustainability because it already combines the majority of building uses. However, its substantial reliance on non-renewable energy sources falls short of promoting energy efficient design which will in long term increase the building's carbon footprint. Although, the double-skinned façade provides ventilation, the building's high energy consumption for heating and cooling is mainly due to the excessive use of glazing.

Additionally, while extremely tall skyscrapers may be aesthetically pleasing, their occupants often lose “connection” with the urban environment below, thus it is recommended it's necessary to build residential apartments at a reasonable height in order to preserve a sense of belonging. Height is therefore less significant than location, views, communication, and contact with the city at street level.

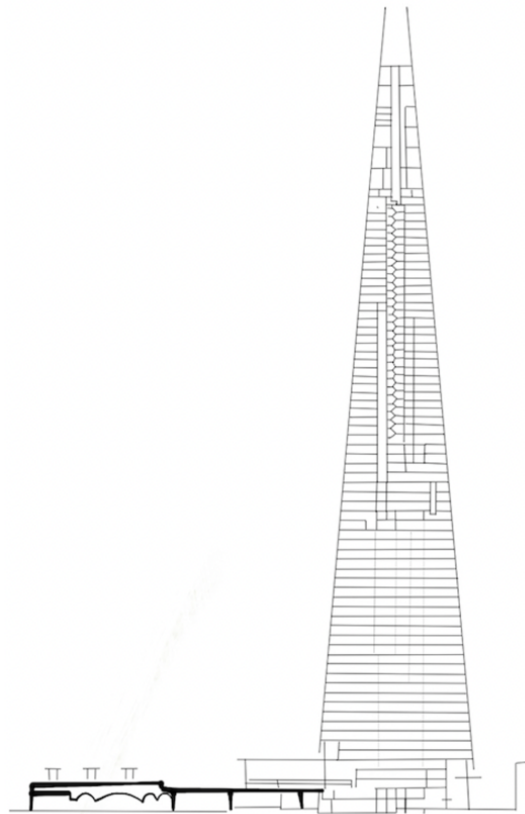


Figure 35: Sectional view showing The Shard in relation to the transportation hub. (T. Adibmehr, 2023)

For new constructions, another method to ensure a building's sustainability is to design with adaptable floor plans that allow for flexibility in the building's future usage. Reusing and modifying old structures rather than demolishing them to make room for new ones will be beneficial for sustainability and the fight against climate change.

Conclusion

As urban populations continue to grow, the need for high-rise buildings in city centres is inevitable. To ensure that high-rise buildings are sustainable solutions of the future, architects and engineers must prioritise sustainability in their designs, given that these structures are energy-intensive and contribute significantly to greenhouse gas emissions during construction, operation, and maintenance. However, advanced technologies offer the opportunity to implement renewable energy sources and energy-efficient technologies that can minimize the building's carbon impact, making it crucial that high-rise structures be designed to meet the highest sustainability standards.

When considering the advantages of high-rise buildings over low-rise structures in terms of energy, water usage, and waste strategies, there may not be significant benefits beyond the ability to accommodate significantly more people and house most, if not all, utilities on the same site. In most cases, low-rise and smaller structures are more advantageous, especially when it comes to financial considerations, cost-effectiveness, ease of use, and the provision of larger floor spaces that are well-suited for commercial tenants. Consequently, high-rise structures may not offer many advantages other than their ability to fit neatly within urban areas where land is scarce, and the only viable option is to build vertically. Since high-rise structures require more lifts, complex structures, and additional materials compared to lower buildings of the same area, it can be challenging to justify high-rise buildings as environmentally friendly beyond their ability to offer high population density.

However, high-rise buildings do provide an efficient use of space in densely populated areas where land is limited. By offering a smaller footprint, high-rises help to minimize urban sprawl and preserve natural sites. Moreover, high-rises address the increasing demand for housing in cities as their populations grow at an unprecedented rate, making them a viable option for meeting this need compared to low-rise homes. Additionally, high-rise buildings generate economic benefits by providing retail and office spaces while also creating jobs during their construction phase. Thus, it is essential to consider the bigger picture when assessing the benefits of high-rise buildings, beyond just their material use. High-rise structures offer a holistic approach that addresses various urban challenges, including the need for more efficient land use, housing, and economic development.

The relevance and necessity of high-rise buildings during a time of climate crisis is determined by how and where they are built and operated. It is crucial that the energy consumption and resource intensive nature of these buildings are addressed so that their long-term relevance is ensured.

Innovation and studies on building materials and construction methods have helped to mitigate the negative environmental impact of high-rise buildings. Historically, sustainability was not a priority during the early days of high-rise construction. However, today, there are specific measures in place to encourage architects and engineers to consider the environmental impact of the structures they create. With the use of recycled materials, energy-efficient HVAC systems (heating, ventilation, and cooling), green or blue roofs, and solar panels, high-rise buildings have the potential to be more sustainable than ever before. Thanks to these options, architects and engineers can design high-rise buildings that are both visually impressive and environmentally friendly, demonstrating the potential for high-rise buildings to be sustainable solutions for urban growth.

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Interview with Joost Moolhuijzen, Partner at Renzo Piano Building Workshop, 22 November 2022

Interview with Ken Shuttleworth, Founder of MAKE Architects, 08 December 2022

Interview with Spencer de Grey, Senior Executive Partner and Joint Head of Design at Foster + Partners, 15 December 2022.

Appendix A: Questions for Joost Moolhuijzen, Renzo Piano Building Workshop

The following questions were asked, during a MS Teams conversation, to Joost Moolhuijzen, Partner at Renzo Piano Building Workshop.

The questions were devised by the author of this dissertation.

Design philosophy

1. What motivated you to design high-rise buildings?
 - Design challenge
 - Design brief
 - Interest in high-rise buildings
 - Other...

2. Which part of the design process are you mostly involved in?
 - Overall concept design
 - Technical/practical details
 - Both

3. What are the client relationships like when designing tall buildings? Do you find they are demanding?
What is the most tricky part of it?

4. What advantages do taller buildings, in your opinion have over lower ones?

5. Do you think that building high-rises in London where buildings are closely together, presents a greater challenge?

6. Many high-rises in the world appear to be iconic structures. When you design or work on high rise building projects, do you consider them to be iconic?

7. Do you think high rise buildings contribute and deal with the practical issues of the city life? Do you see them as an essential part of the cityscape?

Construction methods

1. In the light of the Grenfell disaster, do you think that emergency access and fire strategies in high-rise buildings are adequate?
2. Do you have any specific strategies that you use and would encourage others to use?
3. In your experience of high rises, have the fire safety issues been further examined or developed?
4. How are the high-rise buildings you create ventilated?
 - Mechanically
 - Naturally
 - Mix-mode
 - Other...

Sustainability

1. What do you define as a sustainable high-rise?
2. Do you believe that high-rise buildings can be seen as sustainable in terms of their energy strategy, material use and land use?
3. Is land utilisation a critical factor when considering a high rise project?
4. How significant is sustainability to you when working on high-rise projects?
5. Do you think that concerns with sustainability and high rises can be improved considering water usage, waste and energy usage?

Innovation

1. Innovation may be critical to how we deal with climate change moving forward, what innovative principle strategies or material have you used in your most recent building?
2. Considering you were the partner in charge from inception to completion of The Shard, are there any innovative elements that it has or that you would include if you could do it again?
3. In the economic downturn we are going to face, will the development of high-rise buildings be limited or will they be unaffected?

Future developments

1. How do you see high-rise buildings of the future in terms of scale, material use and in their relevancy?
2. Have you seen an increased activity in the tall building world in the past 10 years?
3. Is there a particular type of high-rise you look forward to working on in the future? If yes, what scale and in what location?

Responses were received during MS Teams conversation with Joost Moolhuijzen which was held on 22 November 2022.

Appendix B: Questions for – Ken Shuttleworth, MAKE Architects

The following questions were asked, during a MS Teams conversation, to Ken Shuttleworth, Founder of MAKE Architects.

The questions were devised by the author of this dissertation.

Philosophy

1. What motivated you to design high-rise buildings?
 - Design challenge
 - Design brief
 - Interest in high-rise buildings
 - Other...
2. Which part of the design process are you mostly involved in?
 - Overall concept design
 - Technical/practical details
 - Both
3. What are the client relationships like when designing tall buildings? Do you find they are demanding?
What is the most tricky part of it?
4. What advantages do taller buildings, in your opinion have over lower ones?
5. Do you think that building high-rises in London where buildings are closely together, presents a greater challenge?
6. Many high-rises in the world appear to be iconic structures such as the Gherkin which you designed. When you design or work on high rise building projects, do you consider them to be iconic?
7. Do you think high rise buildings contribute and deal with the practical issues of the city life? Do you see them as an essential part of the cityscape?

Construction Methods

1. In the light of the Grenfell disaster, do you think that emergency access and fire strategies in high-rise buildings are adequate?
2. Do you have any specific strategies that you use and would encourage others to use?
3. In your experience of high-rises, have the fire safety issues been further examined or developed?
4. With an emphasis on 30 St Mary Axe, how are the high-rise structures in which you have been involved ventilated?
 - Mechanically
 - Naturally
 - Mix-mode
 - Other...

Sustainability

1. What do you define as a sustainable high-rise?
2. Do you believe that high-rise buildings can be seen as sustainable in terms of their energy strategy, material use and land use?
3. Is land utilisation a critical factor when considering a high rise project?
4. How significant is sustainability to you when working on high-rise projects?
5. Do you think that concerns with sustainability and high rises can be improved considering water usage, waste and energy usage?

Innovation

1. Innovation may be critical to how we deal with climate change moving forward, what innovative principle strategies or material have you used in your most recent building?
2. Are there any innovative elements that the Gherkin has or that you would include if you could do it again?
3. In the economic downturn we are going to face, will the development of high- rise buildings be limited or will they be unaffected?
4. I read somewhere that you campaign against iconic and expensive buildings in the capital. If you were given the brief for the gherkin today how would you go about designing it?

Future Developments

1. How do you see high-rise buildings of the future in terms of scale, material use and in their relevancy?
2. Have you seen an increased activity in the tall building world in the past 10 years?
3. You stated that the era of the tall glass boxes and the days of designing buildings with crazy shapes, silly profiles and double curves is over. What do you think the next stage for high rise buildings is and how do you see high rise buildings of the future?
4. If you were to do the Gherkin again, is there a significant change that you would have designing it today?
5. Is there a particular type of high-rise you look forward to working on in the future? If yes, what scale and in what location?

Responses were received during MS Teams conversation with Ken Shuttleworth which was held on 08 December 2022.

Appendix C: Questions for Spencer de Grey, Foster+Partners

The following questions were asked during a visit to Foster + Partners, 22 Hester Road, London SW11 4AN to Spencer de Grey, Senior Executive Partner and Joint Head of Design at Foster + Partners.

The questions were devised by the author of this dissertation.

Philosophy

1. What motivated you to design high-rise buildings?
 - Design challenge
 - Design brief
 - Interest in high-rise buildings
 - Other...
2. Which part of the design process are you mostly involved in?
 - Overall concept design
 - Technical/practical details
 - Both
3. What are the client relationships like when designing tall buildings? Do you find they are demanding?
What is the most tricky part of it?
4. What advantages do taller buildings, in your opinion have over lower ones?
5. Do you think that building high-rises in London where buildings are closely together, presents a greater challenge?
6. Many high-rises in the world appear to be iconic structures. When you design or work on high rise building projects, do you consider them to be iconic?

7. Do you think high rise buildings contribute and deal with the practical issues of the city life? Do you see them as an essential part of the cityscape?

Construction Methods

1. In the light of the Grenfell disaster, do you think that emergency access and fire strategies in high-rise buildings are adequate?
2. Do you have any specific strategies that you use and would encourage others to use?
3. In your experience of high-rises, have the fire safety issues been further examined or developed?
4. With an emphasis on Commerzbank tower, how are the high-rise structures in which you have been involved ventilated?
 - Mechanically
 - Naturally
 - Mix-mode
 - Other...

Sustainability

1. What do you define as a sustainable high-rise?
2. Do you believe that high-rise buildings can be seen as sustainable in terms of their energy strategy, material use and land use?
3. Is land utilisation a critical factor when considering a high rise project?
4. How significant is sustainability to you when working on high-rise projects? I understand we've gone through a couple of the factors already but would you say it's initial with the way you go forward?
5. Do you think that concerns with sustainability and high rises can be improved considering water usage, waste and energy usage?

Innovation

1. Innovation may be critical to how we deal with climate change moving forward, what innovative principle strategies or material have you used in your most recent building?
2. Are there any innovative elements that the Commerzbank tower has or that you would include if you could do it again?
3. In the economic downturn we are going to face, will the development of high- rise buildings be limited or will they be unaffected?

Future Developments

1. How do you see high-rise buildings of the future in terms of scale, material use and in their relevancy?
2. Have you seen an increased activity in the tall building world in the past 10 years?
3. Is there a particular type of high-rise you look forward to working on in the future? If yes, what scale and in what location?

Responses were received during the visit with Spencer de Grey which was held on 15 December 2022.