RESEARCH PLAN | AE STUDIO

PERSONAL INFORMATION

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STUDIO

Architectural Engineering (Open Building)

Design tutor: Mauro Parravicini

Research tutor: Hans Hoogenboom

Studiochoice:

My way of designing in general is to provide (technical) solutions for environmental and social problems in the built environment. I see myself as a true architectural engineer and therefore this studio is the best fit for me

TITLE

Sustainable Highrise Designed with Data

Sustainability, Highrise, Structure, Computational Design, Parametric Design, Carbon Footprint, Embodied Energy

PROBLEM STATEMENT | P.1

POPULATION GROWTH

The world is changing and so are our cities. One of the major changes we are facing is population growth. A growing population means we need more space in cities to accommodate residences, workspaces, and other facilities. When looking at the Netherlands especially it is quite an interesting phenomenon. When looking at Figure 1 you can see that the population of the Netherlands is growing unabatedly. According to the Netherlands' central office for statistics (CBS) the population is estimated to grow due to immigration and increasing lifespan at a higher rate rather than birthrate alone. (CBS, 2020a). This is also the main reason why the Netherlands is on the verge of a huge challenge. According to the report from ABF research to the Netherlands' Ministry of Internal Affairs, it is estimated that the Netherlands needs at least 1.044.500 residences by 2030 due to population growth (Groenemeijer, 2021). You can also presume that the growing population needs workspaces and (basic) facilities on top of the extra residences needed in the future. In summary, due to population growth we need more buildings.

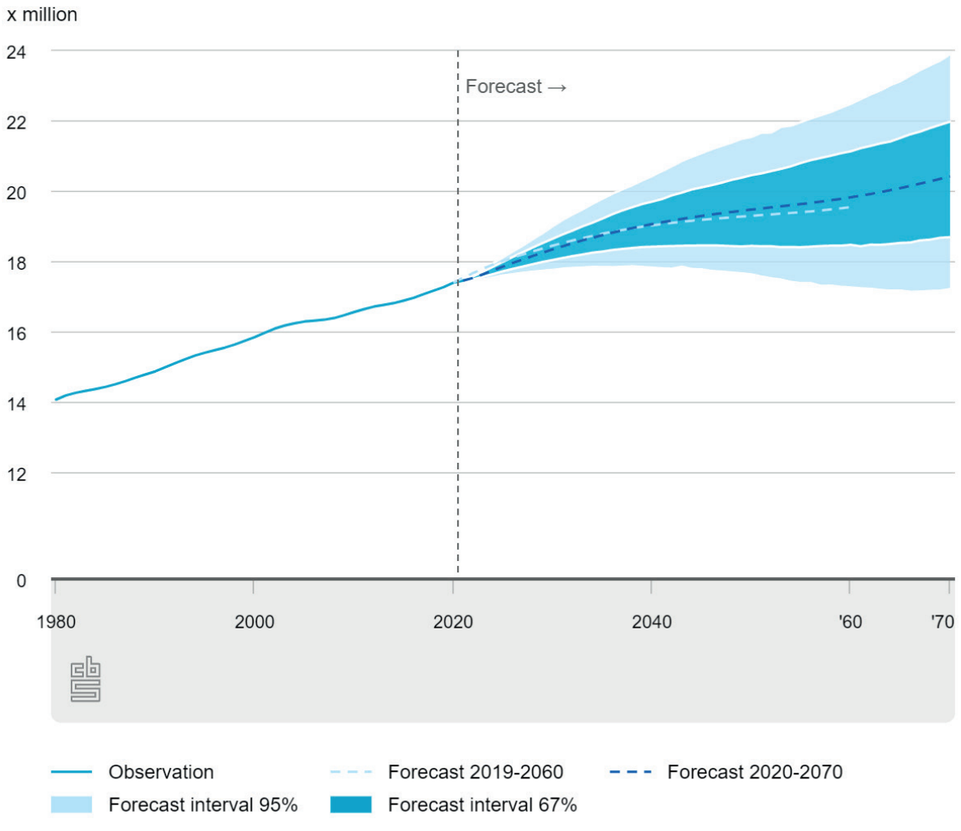


Figure 1: Estimated Population Growth in the Netherlands (CBS, 2020b)

URBANISATION

Existing cities as we know have been developing up to the point that it becomes highly concentrated with buildings. This is the effect of rapid urbanization. Urbanization is according to the website of the United States' Environmental Protection Agency the concentration of human population into discrete areas. This leads to land being transformed for residential, commercial, industrial and transportation purposes (US EPA, 2022). The most significant form of urbanization can be seen within Figures 2 and 3. As you can see the city of Dubai has transformed from almost nothing to an entire metropole within an approximately 40 years span and this occurrence has and is happening to cities all over the world. So also within cities in the Netherlands.

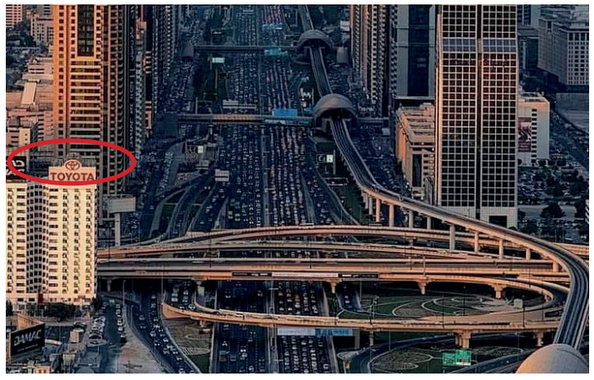


Figure 2, left: Dubai in the 80s (NLR Group, n.d.)

Figure 3, right: Dubai as we know ([[Dubai nowadays]], n.d.)

Urbanization also affects the liveability of the city. Health, personal well-being and traffic density are negatively influenced by this process (Ahlfeldt et al., 2018, p.4). An increase in density within a city also means a decrease in green spaces (Dekker, 2017).

Due to urbanization cities all over the world have been concentrated to a point where there exists a decrease in liveability with hardly any opportunities to densify in the city. This has inevitably consequences for the Netherlands since cities in the Netherlands are in high demand of housing due to the housing crisis, and in order to reach one million residences by 2030 they need to rethink ways to densify to provide for this demand. The hardest part of this is trying to do it without losing the aspect of liveability.

PROBLEM STATEMENT | P.2

HIGHRISE

You can think of strategies such as renovation, transformation, repurpose or new-build projects. Within the densest part of the city, new build-projects are difficult to realize and therefore in this context probably the hardest challenge. The concept of developing new-build highrise buildings might be a proper solution for accommodating the growing population within urbanized cities, see Figure 4 for reference. With this building approach, densification within a relatively small footprint becomes possible as seen in Figure 5. Also according to various sources, implementing the concept of highrise is a great choice from a viewpoint of land prices, demographic change, urban regeneration, infrastructure, transportation, attracting investors, multifunctional use and land preservation (Short, 2013; Binder, 2015; Kim and Lee, 2018; Abbood et al., 2021). Highrise is especially the best fit within city centres since that is mostly the densest part of the city. As Al-Kodmany has argued in his article:

"To accommodate the influx of urban population while reducing urban sprawl, we must engage the vertical dimension of cities" (Al-Kodmany, 2022, p. 1).

Figure 4: (ZESO Architects, ca. 2018)

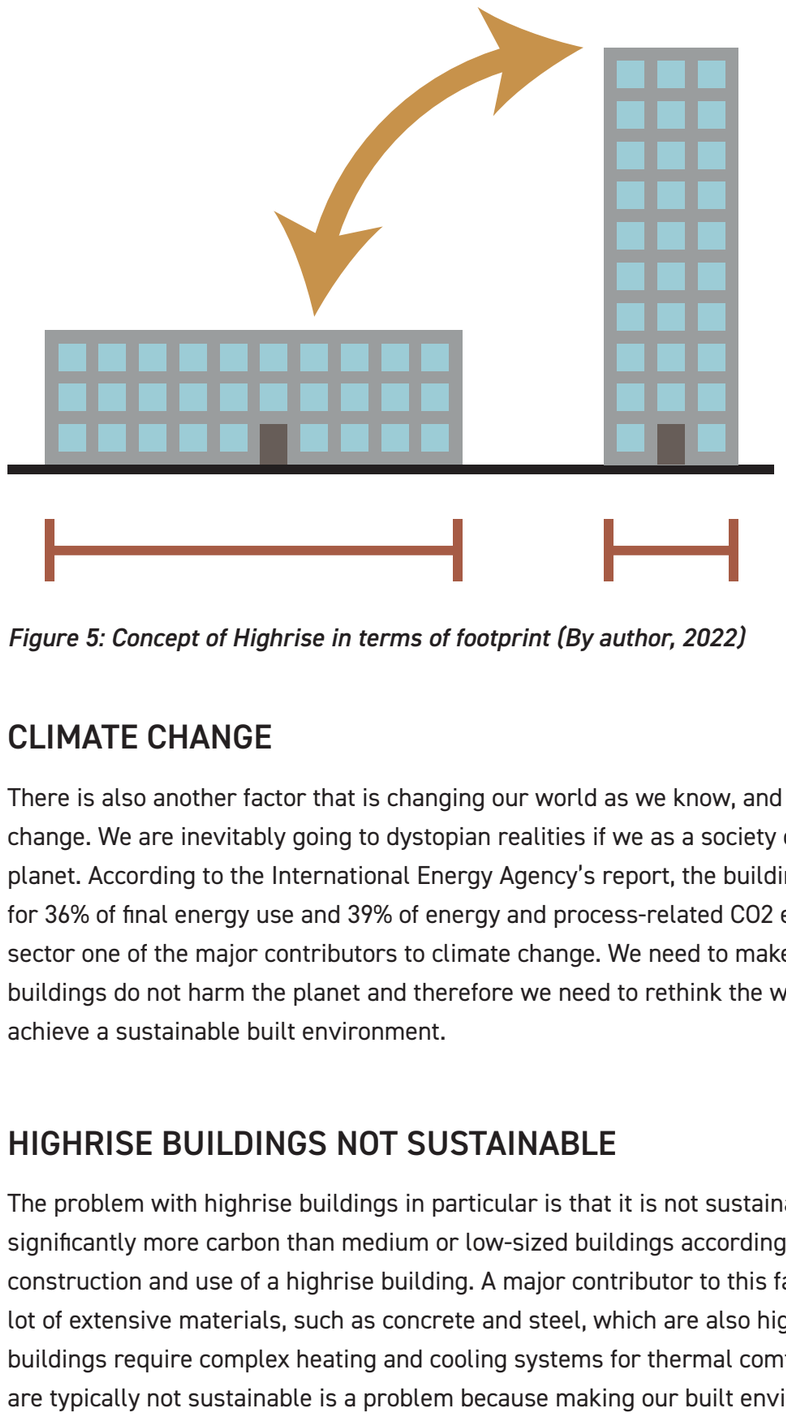


Figure 5: Concept of Highrise in terms of footprint (By author, 2022)

CLIMATE CHANGE

There is also another factor that is changing our world as we know, and it has everything to do with climate change. We are inevitably going to dystopian realities if we as a society do not change the way we treat our planet. According to the International Energy Agency's report, the buildings and construction sector accounts for 36% of final energy use and 39% of energy and process-related CO2 emissions in 2018. This makes this sector one of the major contributors to climate change. We need to make sure existing and newly-build buildings do not harm the planet and therefore we need to rethink the way how we design our buildings to achieve a sustainable built environment.

HIGHRISE BUILDINGS NOT SUSTAINABLE

The problem with highrise buildings in particular is that it is not sustainable at all. Highrise buildings emit significantly more carbon than medium or low-sized buildings according to Logan (2021). This accounts for the construction and use of a highrise building. A major contributor to this fact is that highrise buildings require a lot of extensive materials, such as concrete and steel, which are also high-emission materials. Also, highrise buildings require complex heating and cooling systems for thermal comfort. The fact that highrise buildings are typically not sustainable is a problem because making our built environment sustainable is one of the challenges we need to realize in order to save our planet.

DESIGN OBJECTIVE

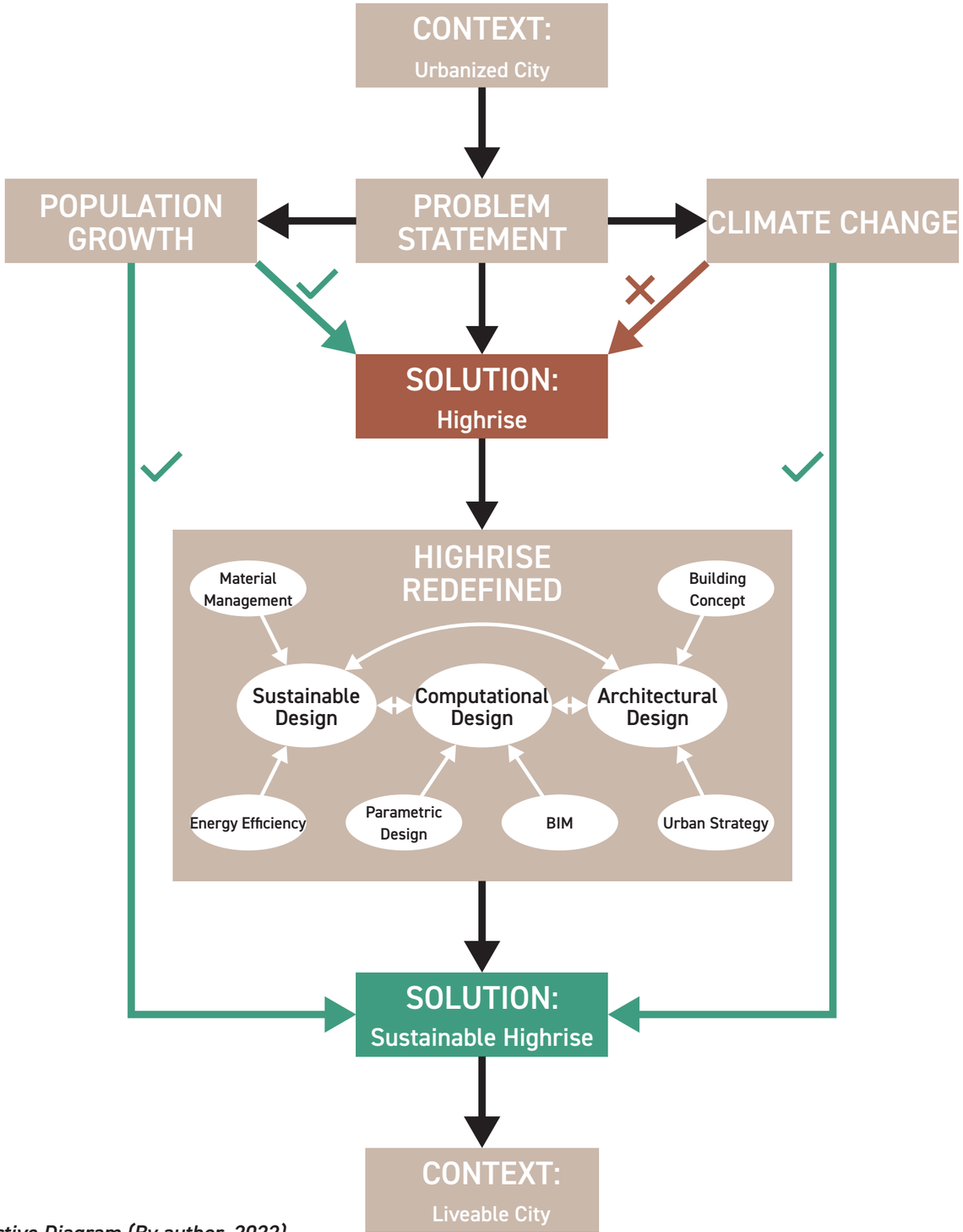


Figure 6: Design Ojective Diagram (By author, 2022)

In order to provide a solution for population growth and climate change, highrise as we know can't be the one due to its carbon footprint properties. We need to rethink the way we design our highrise buildings. That is why I am going to reconceptualize highrise through architectural and sustainable design with the help of computational design methods. The goal is to provide a healthy and sustainable highrise in relation to the existing cityscape. I believe that when this is goal is achieved, it will not only contribute to accommodation of the growing population without damaging the planet, but also to a more liveable city. Ultimately, the building will be hotspot for living, working and leisure with respect to nature and people living close to the building. See Figure 6 for reference.Therefore the overall design question will be:

How can we design a sustainable highrise concept for an urbanized modern city to account for population growth and climate change while also making sure that it contributes to a liveable city and building environment?

THEMATIC RESEARCH | P.1

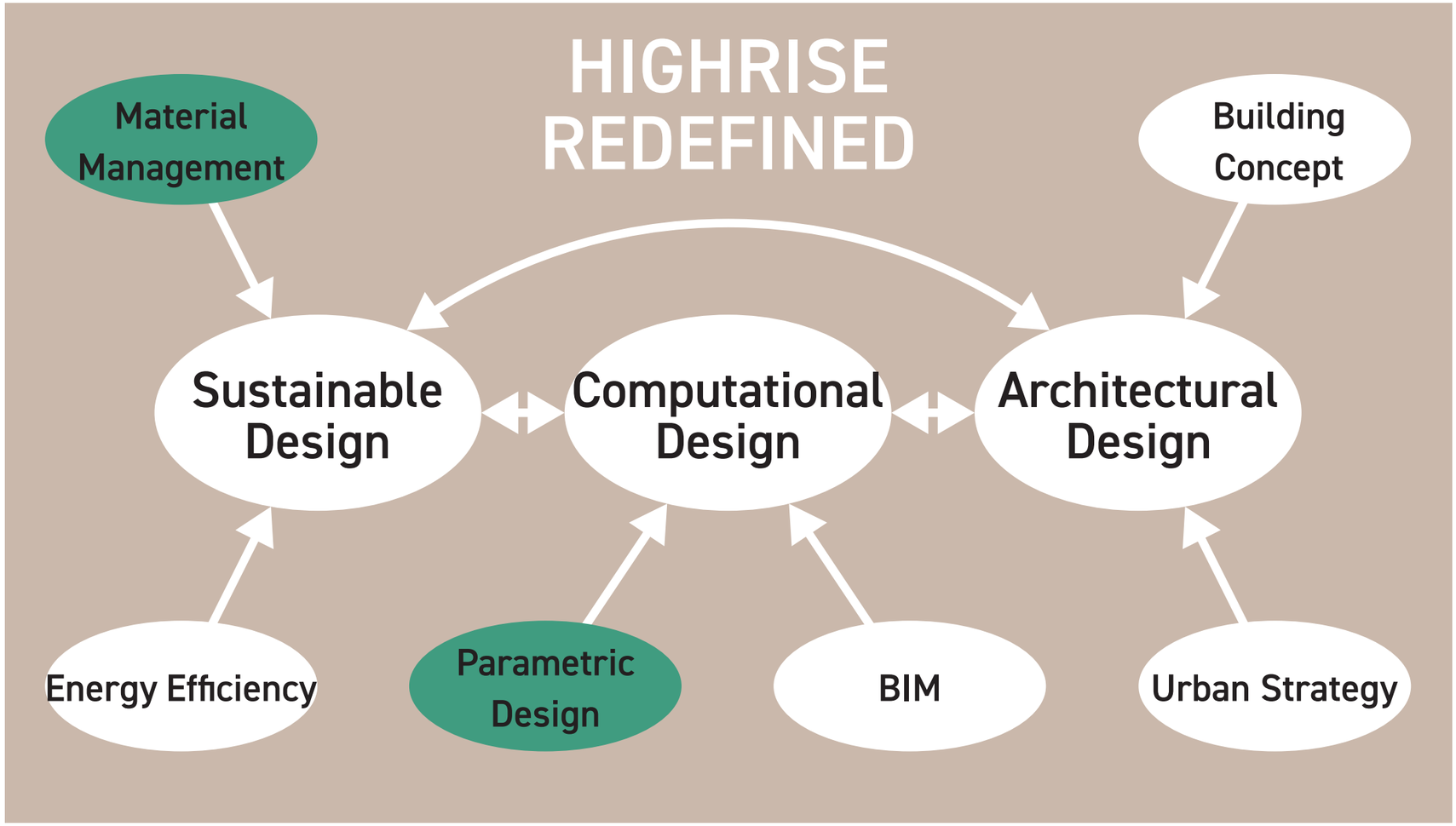


Figure 7: Specific approach for Thematic Research (By author, 2022)

For the thematic research I want to dive deep into sustainability and architectural highrise design with the implementation of computational design methods. Obviously with this approach the research will be too broad. The thematic research needs to be rather more specific and should be a point of guidance for design choices during the design phase of the project. That's why I will focus more specifically within the themes displayed in Figure 7.

When thinking about sustainability you can identify two domains. Material management and Energy efficiency. Material management has anything to do with reducing carbon footprint and energy efficiency with integral climate design strategies (see Figure 8 for reference). I have chosen for the domain material management and more specific with highrise structures because I see the most challenges in this domain. Computational design is also a broad term and therefore I must choose a specific direction within this field. I have chosen for parametric design because that has the most potential in terms of optimization and exploration. Therefore the thematic research question will be:

To what extent is it possible to reduce carbon footprint of a highrise structure?

Subquestion 1:

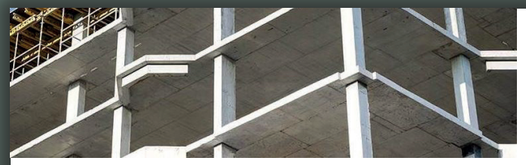
Why are highrise structures not sustainable?

Sub-question 2:

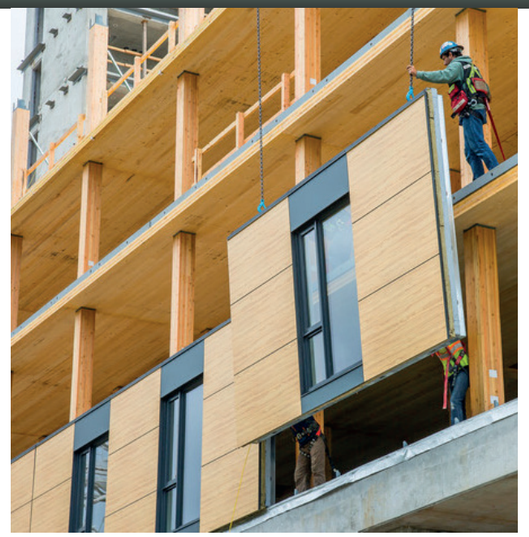
How do you reduce carbon footprint of structural materials?

Subquestion 3:

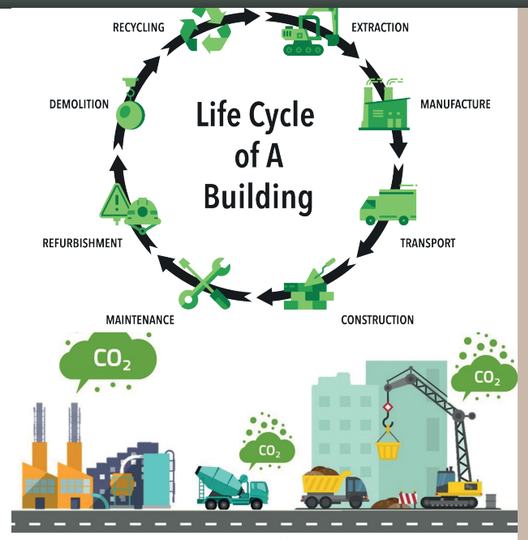
How do you generate a structure with the least carbon footprint possible with parametric design?



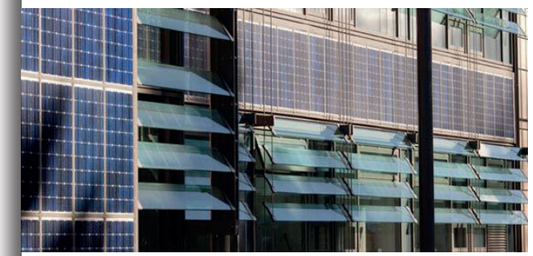
HIGHRISE STRUCTURE TYPOLOGY



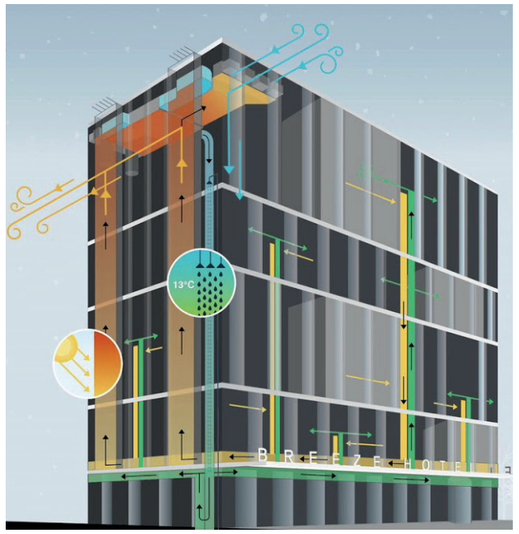
MODULARITY



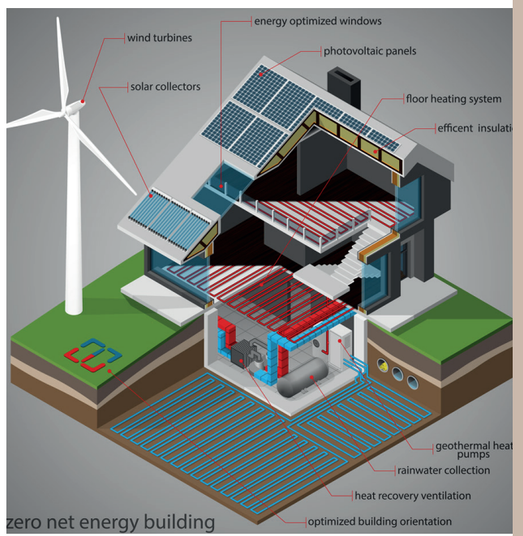
LOW EMBODIED ENERGY/ CARBON FOOTPRINT



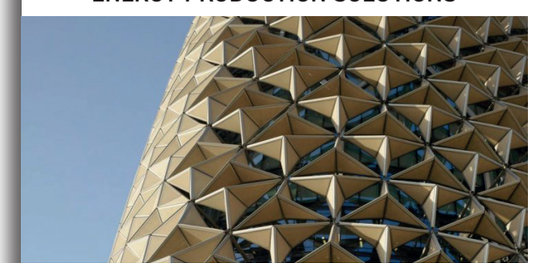
ENERGY PRODUCTION SOLUTIONS

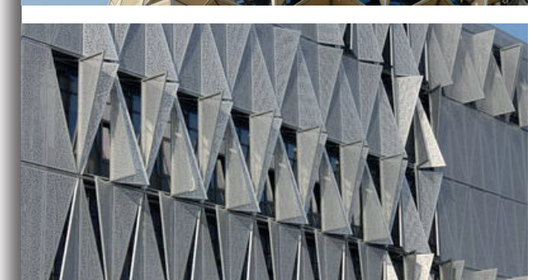


REDUCE NEED OF ENERGY

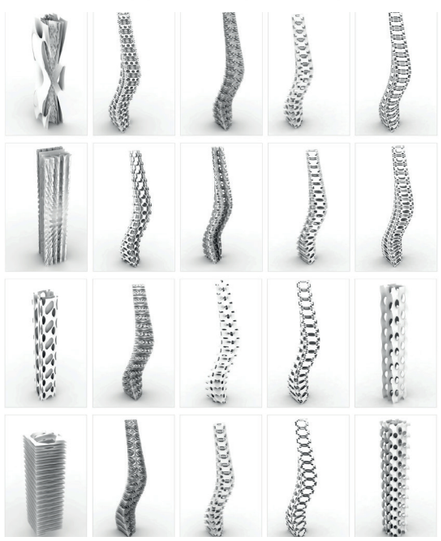


INTEGRAL CLIMATE DESIGN STRATEGIES





PARAMETRICALLY DESIGNED SYSTEMS



PARAMETRIC EXPLORATION & OPTIMIZATION

BIM AIDED DESIGN

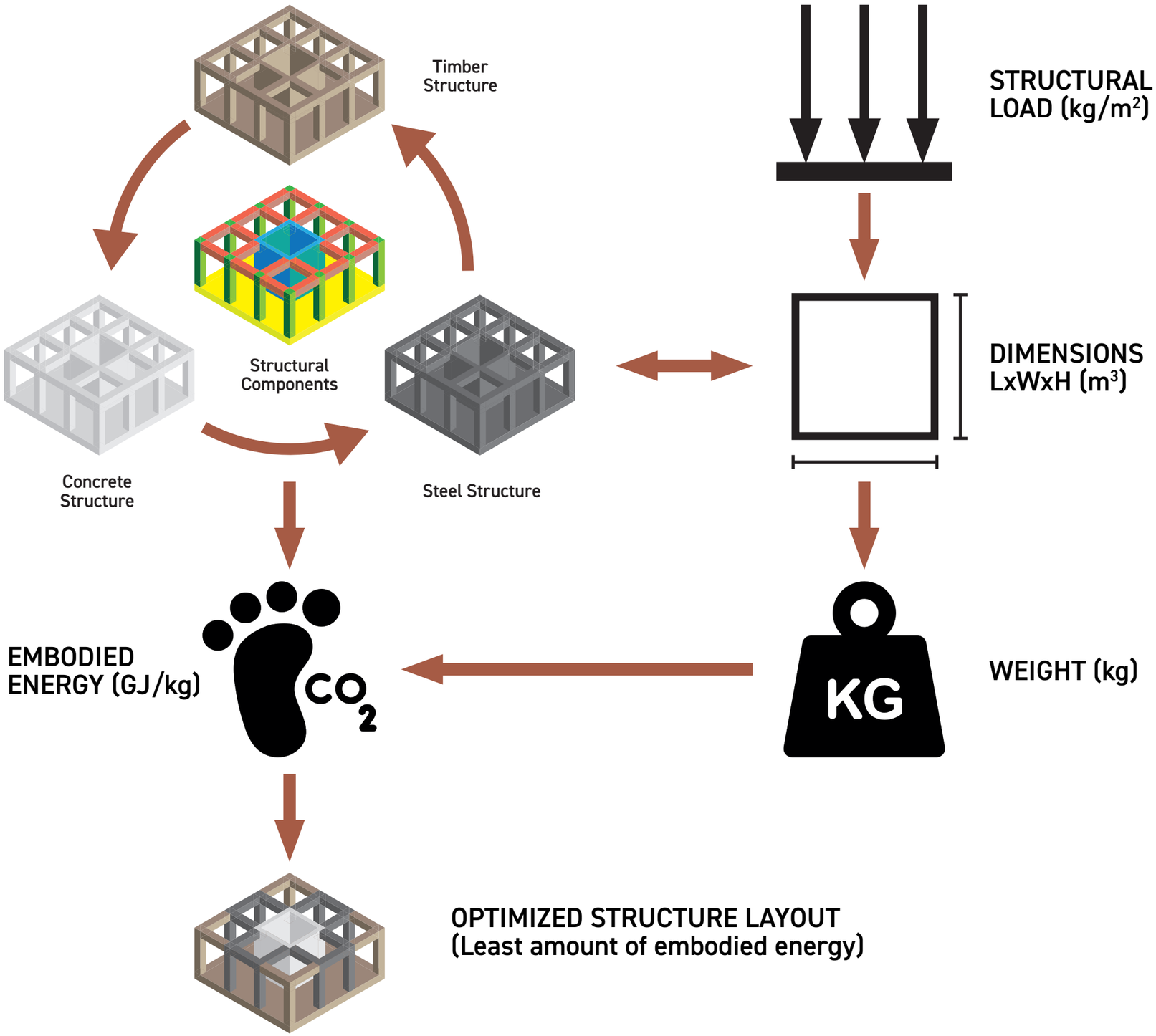
ENERGY EFFICIENCY

MATERIAL MANAGEMENT

COMPUTATIONAL DESIGN

Figure 8: Themes within Sustainable Highrise Design (By author, 2022)

THEMATIC RESEARCH | P.2



Research Methods

Within the first sub-question I will be making explicit how a highrise structure works, what structural components are present and why it is not sustainable through literature research.

Within the second sub-question I will be making explicit how carbon footprint is measured, how you can reduce it and comparing the carbon footprint properties of concrete, steel and timber components usually used in highrise structures through literature research and data analysis.

Within the last sub-question I will be generating a parametric grasshopper script from a “simple” highrise structure reference in the form of a wireframe layout. From that point I will make sure that every structural component, such as columns, floorslabs, beams and core, can be interchangeable in different types of materials while making sure that the profile of that material can support the theoretical load. This will automatically change the weight of the structural component. Once connecting this information to calculate the embodied energy, I will run an optimization to find out which structural configuration has the least carbon footprint. See Figure 9 for reference.

Figure :9 Parametric Strategy Diagram (By author, 2022)

CONTEXT CHOICE

Figure 10: Highrise Zone and Mobility Hubs (By author, 2022)

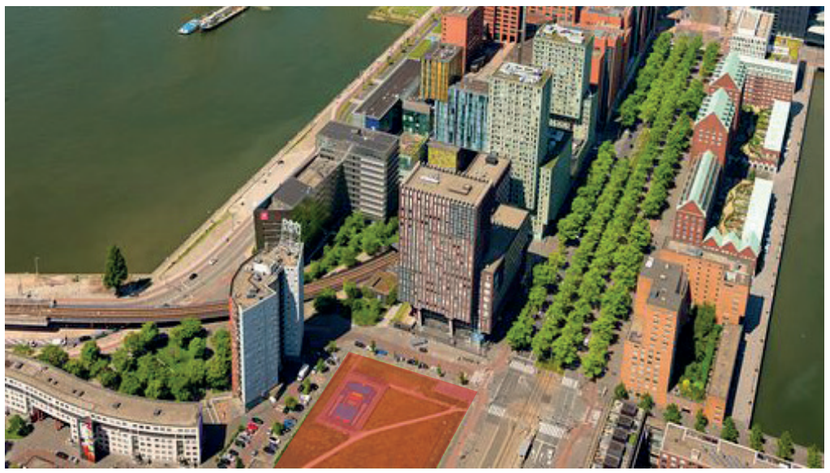


Figure 11: Kop van Zuid, Aerial photo (Aerophotostock, 2022)

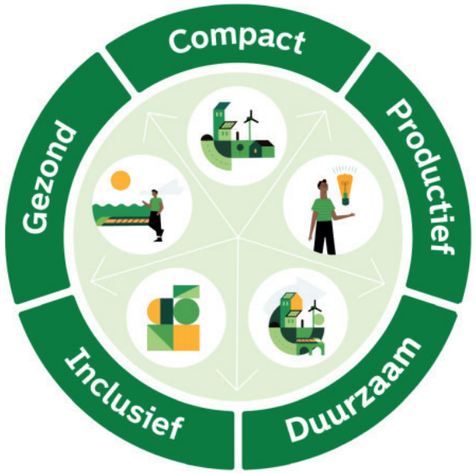
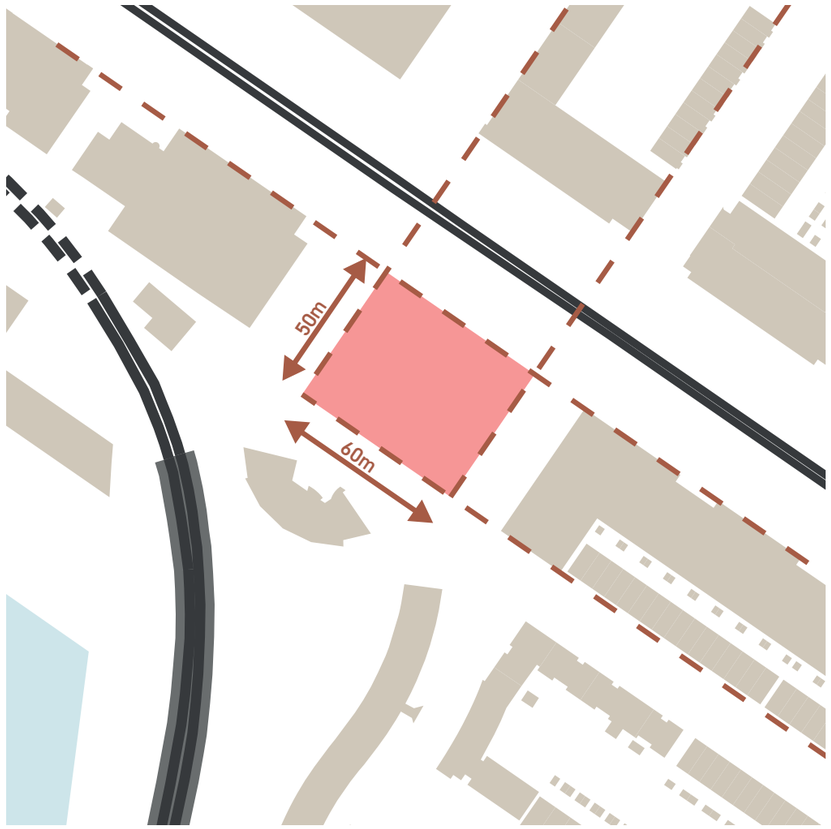


Figure 12, above: The Five Perspectives (Gemeente Rotterdam, 2021a)

Figure 13, below: Building envelope dimensions (By author, 2022)



In order to design a sustainable highrise concept for the rapid growing population and climate, it is important that the location must be a rapid-growing (modern) city with limited space for densification. The municipality of Rotterdam has stated that the city has shortage in spaces to densify, and that the population is expected to grow in the coming years. And with the energy transition agenda in mind, they recently developed a masterplan to provide for these demands while also making sure that the city becomes a more liveable environment (Gemeente Rotterdam, 2021b). With the five perspectives on a circular, healthy, compact, inclusive and productive city they want to provide guidance for the future (see Figure 12 for reference). Because the city of Rotterdam experiences the same problems as in my problem statement and the fact that they want to densify with similar strategies in the aim of liveability and sustainability, I see Rotterdam as the perfect candidate for this graduation project.

Now is the question where specifically in Rotterdam. The site in Rotterdam needs to be a place where space is most limited. Because the densest area in Rotterdam is the city centre, I focused on finding a location within this area. According to the municipality of Rotterdam, high quality densification projects in the city centre need to be within mobility hubs to maximize accessibility (Gemeente Rotterdam, 2021b). Also on the perspective on highrise buildings, the municipality of Rotterdam provided a masterplan on this matter where they stated that highrise above 70m should be permitted within the barriers of the highrise zone (Gemeente Rotterdam, 2019). As you can see in Figure 10, The building envelope location that I have chosen is near mobility hubs and is situated within the highrise zone. Also in Figure 13 you can see that the building envelope dimensions are relatively compact. Lastly, in Figure 14 you can see that the site is located within a highrise hub. Therefore this location is the best fit to develop a highrise building in terms of context features and city policy.

RESEARCH TIMELINE

The timeline within Figure 14 represents research and preliminary design activities up to the P2 presentation. For the research my main activity will be generating the grasshopper script and for the preliminary design I will mainly be developing detailed program requirements to develop the building concept.

WEEK	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10
MONTH	SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER				JANUARY			
RESEARCH	Research Theme			Developing Research Plan				P1	TRIP TO SURINAM		Literature Research				Writing Paper			EXTENSION	P2	
DESIGN	Design Theme			Analyzing Context							Developing Program Requirements				Developing Building Concept					
TOOLS	Creating Map templates				Developing 3D model						Developing Grasshopper Model				Analyzing Data					

Figure 14: Research timeline for P2 (By author, 2022)

LITERATURE

Joarnal Article

Abbood, I. S., Jasim, M. A., and Sardasht, S. W. (2021). High rise buildings: design, analysis, and safety – an overview. *J. Arch. Eng. Technol.* 8, 1–13. doi: 10.15377/2409-9821.2021.08.1

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Al-Kodmany, K. (2022). Sustainable High-Rise Buildings: Toward Resilient Built Environment. *Frontiers in Sustainable Cities,* 4. https://doi.org/10.3389/frsc.2022.782007

Kim, T. Y., and Lee, K. H. (2018). Suggestions for developing integrated risk assessment method for high-rise buildings in Korea: based on analysis of FEMA's IRVS. *J. Arch. Eng. Technol.* 5, 1–9. doi: 10.15377/2409-9821.2018.05.1

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Dekker, F. (2017, September 5). *Verharding in stedelijk gebied*. Rainaway. https://rainaway.nl/inspiration/verharding-in-stedelijk-gebied/

Logan, C. (2021, December 20). The hidden carbon footprint of highrises. *Canada's National Observer*. https://www.nationalobserver.com/2021/11/17/news/hidden-carbon-footprint-highrises

US EPA. (2022, April 26). *Urbanization - Overview.* https://www.epa.gov/caddis-vol2/urbanization-overview

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Gemeente Rotterdam. (2021b). *Omgevingsvisie Rotterdam, De Veranderstad: Werken aan een wereldstad voor iedereen.* https://www.rotterdam.nl/wonen-leven/omgevingsvisie-waarom/

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Book

Binder, G. (2015). *Tall Buildings of China*. Mulgrave, VIC: Images Publishing.

Short, M. (2013). *Planning for Tall Buildings.* New York, NY: Routledge.

Image

Figure 1:

CBS. (2020b, December 16). [Forecast of the population growth in the netherlands]. https://www.cbs.nl/en-gb/news/2020/51/forecast-population-growth-unabated-in-the-next-50-years

Figure 2:

NLR Group. (n.d.). [Dubai in the 80's]. What's On. https://whatson.ae/2018/05/dubais-iconic-toyota-building-has-lost-its-sign/

Figure 3:

[Dubai nowadays]. (n.d.). Bluesyemre. https://bluesyemre.com/2021/04/04/dubai-1981-vs-2016/

Figure 4:

ZESO Architects. (ca. 2018). *Night Rendering of the CBD Highrise Building.* https://zeso.dk/en/projekter/highrise-cbd/

Figure 5:

Own Work, 2022

Figure 6:

Own Work, 2022

Figure 7:

Own Work, 2022

Figure 8:

Own Work, 2022

Figure 9:

Own Work, 2022

Figure 10:

Own Work, 2022

Figure 11:

Aerophotostock. (2022, June 15). [Rotterdam, Kop van Zuid luchtfoto]. https://www.aerophotostock.com/-/galleries/all/-/medias/dc1e2d6f-e499-49e2-8406-dc2fdce85ad4-rotterdam-kop-van-zuid-luchtfoto-met-links-de-rijnhaven-en-re

Figure 12:

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Figure 13:

Own Work, 2022

Figure 14:

Own Work, 2022