Human Well-being and Ecological Potential for Public Space in dense Urban Environments

A Biophilic Design for Delfshaven Rotterdam



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Colofon

Human Well-being and Ecological Potential for Public Space in dense Urban Environments
A Biophilic Design for Delfshaven Rotterdam

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Abstract

Urban environments in the Netherlands are under a lot of pressure. Decades of urbanization, emitting greenhouse gasses and diminishing ecology have created far going consequences for our living environments. Cities are experiencing increasing heatwaves, heavier and more frequent rainfall, social problems are getting more and more severe, and congestion is causing much needed space to be taken to widen roads mostly for individual car users.

This research gives an insight in a new potential way of designing our public space that prioritizes sustainable mobility and frees up space for climate and ecological interventions. The research includes a design for Delfshaven, one of the densest neighbourhoods of the Netherlands. The design integrates ecological, mobility, social and climate adaptive solutions that benefit both the natural world as well as the human world significantly. The project achieves un-paving around 45% of public space and creating a continuous network of walkable natural spaces. Special attention is paid to kids, aiming to rejuvenate the idea of kids playing outside and developing important social skills at a young age. The nature-inclusive design has the potential to increase physical- and mental health of all residents significantly. This does not only benefit us directly but can theoretically reduce healthcare costs and earn back funds needed for the transformation. Timeframes and limitations are included to create a comprehensive vision for the future. Overall, the project gives a full image of what the future of Dutch cities could look like and how we can benefit from this change.

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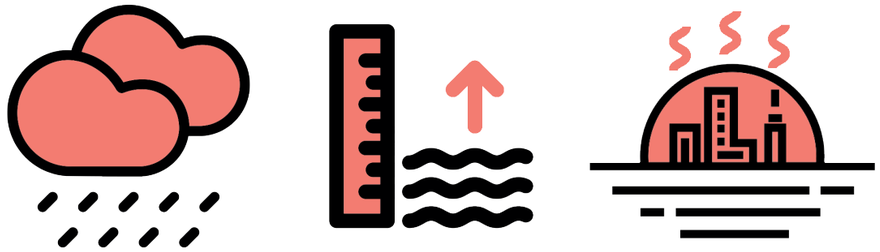
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Climate change



Heavy rainfall Sealevel rise Urban heat island

The climate is rapidly changing. All over the world we see temperatures rising and extreme weather happening more often than ever before. In the latest IPCC report the research done on different scenarios shows a possible increase of 1.8 to 3.9 degrees celcius relative to 1900 (figure 1). The impact of different temperature increases is shown on multiple climate and ecological systems. We see that unique and threatened systems are already in danger and that we are at the flipping point of moving to high risk of extreme weather events.

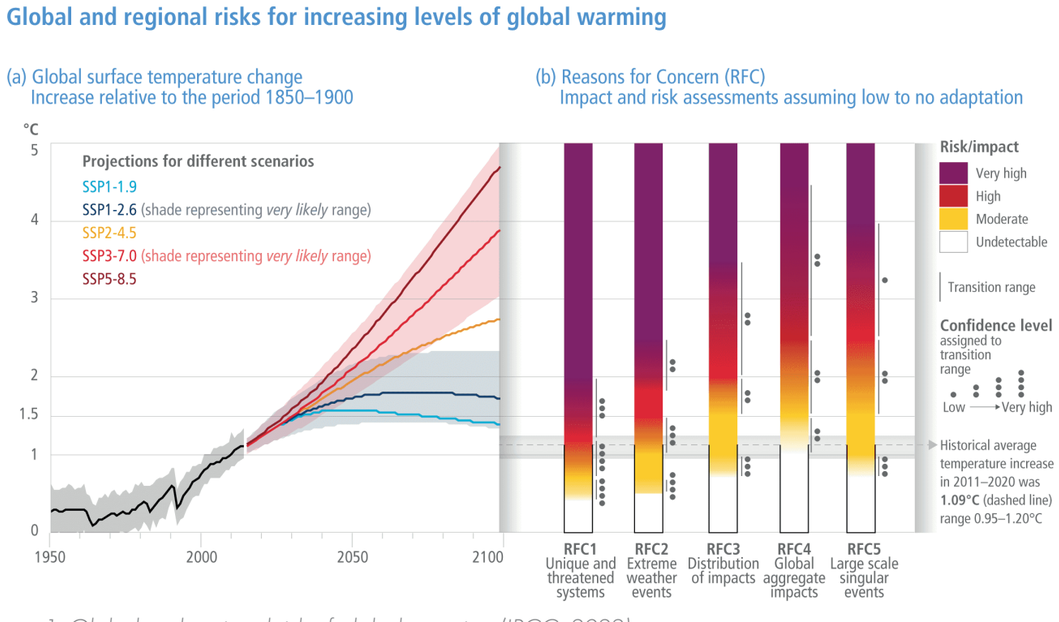


Figure 1: Global and regional risk of global warming (IPCC, 2022)

Heavy rainfall

As shown in figure 1, extreme weather events are already happening more frequentlty and have increasingly bigger impacts. For Dutch cities this mainly means heavier and more frequent rain. Heavy rainfall alternating with periods of drought make it harder to implement solutions for this problem. Heavy rainfall can lead to flooding of urban areas and can put increased pressure on our current water systems.

Sealevel rise

Our seas and oceans hold a lot of water. By far the most of the worlds water is stored here, but 1.7% of the worlds water is stored in ice caps and glaciers (Lisbdnet, 2020). As global temperatures rise, ice starts to melt and this causes the sealevel to rise. Figure 3 shows the sealevel rose over 2.5 meters over the last 140 years. Due to increasing CO^2 emmisions and the fact that most ice laying on antarctica, hasn't started to melt. This rising sealevel is only expected to increase more in the coming decades.

For the Netherlands the rising sealevel means that salty seawater can infiltrate into the groundwater easier and flow into our low laying areas. The salination of groundwater threatens our fresh water systems and causes land to become less suitable for agriculture.

Urban heat island

With rising urban temperatures and increasing extreme weather events cities become less pleasent places to live. Streets can be flooded and on hot days cities can become unbearably hot. Due to the high amount of paved areas, low amount of open water en the influx of heat from air conditioning, motorized vehichles and other human oriented technologies cities become even warmer. The larger the city, the bigger this effect gets. The figure below shows how air temperatures differ between different urban areas (figure 2). An European heatwave in 2003 caused 80.000 deaths and it is estimated that for every degree above 20ºC, eight people die daily within the Netherlands alone (Rahola et al., 2009).

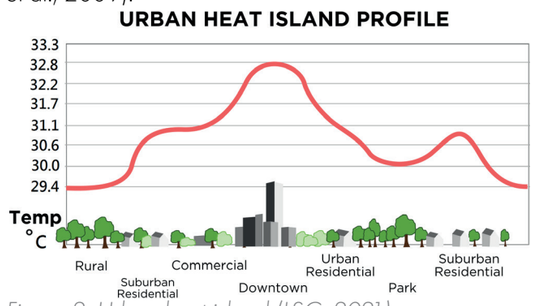


Figure 2: Urban heat island (LSC, 2021)

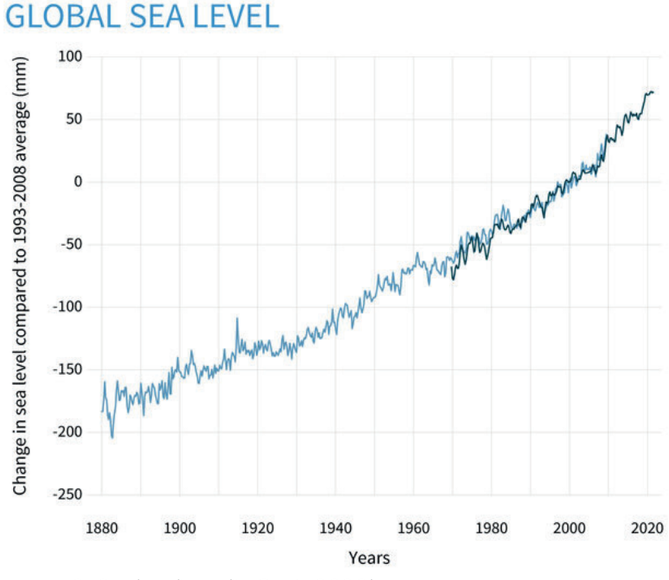


Figure 3: Sealevel rise (NOAR, 2020)

Urbanization



Urban expansion | Population growth | Changing households

Urbanization happens all around the world. With industrializing economies people move to the cities looking for jobs and opportunities. In the Netherlands this rapid increase in urban populations has led to big expansion of the build environment. In figure 5 you can see how the Dutch urbanization progress went over time. You can clearly indicate a rapid increase in urbanization over the last decades. If we continue building our cities like this, our country will be full within this century. Adding to this problem of urbanization and population growth we also see a change in household compositions. Less people live in the same amount of houses as before (Statista, 2022). This is caused by many different reasons such as a decrease in family size, more people living alone and old people often occupying a house that is too big .

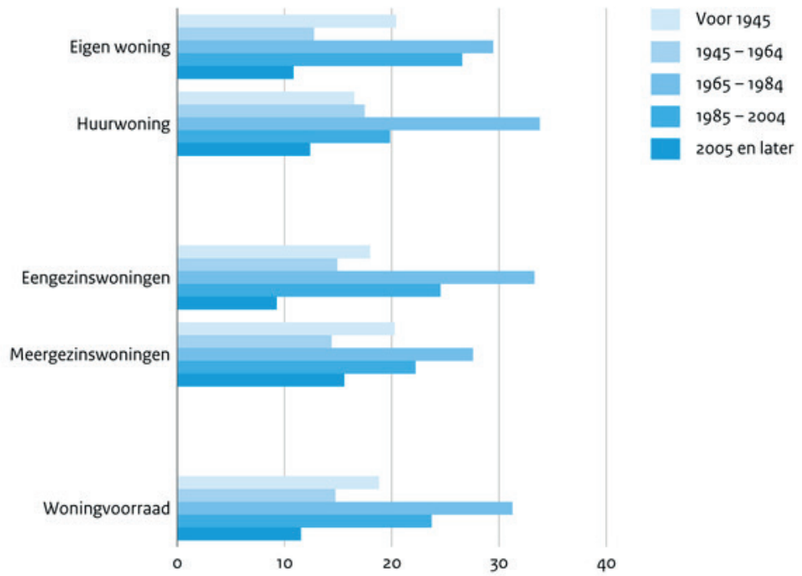


Figure 4: Ownership, dwelling type and building year of housing in the Netherlands (CBS, 2020)

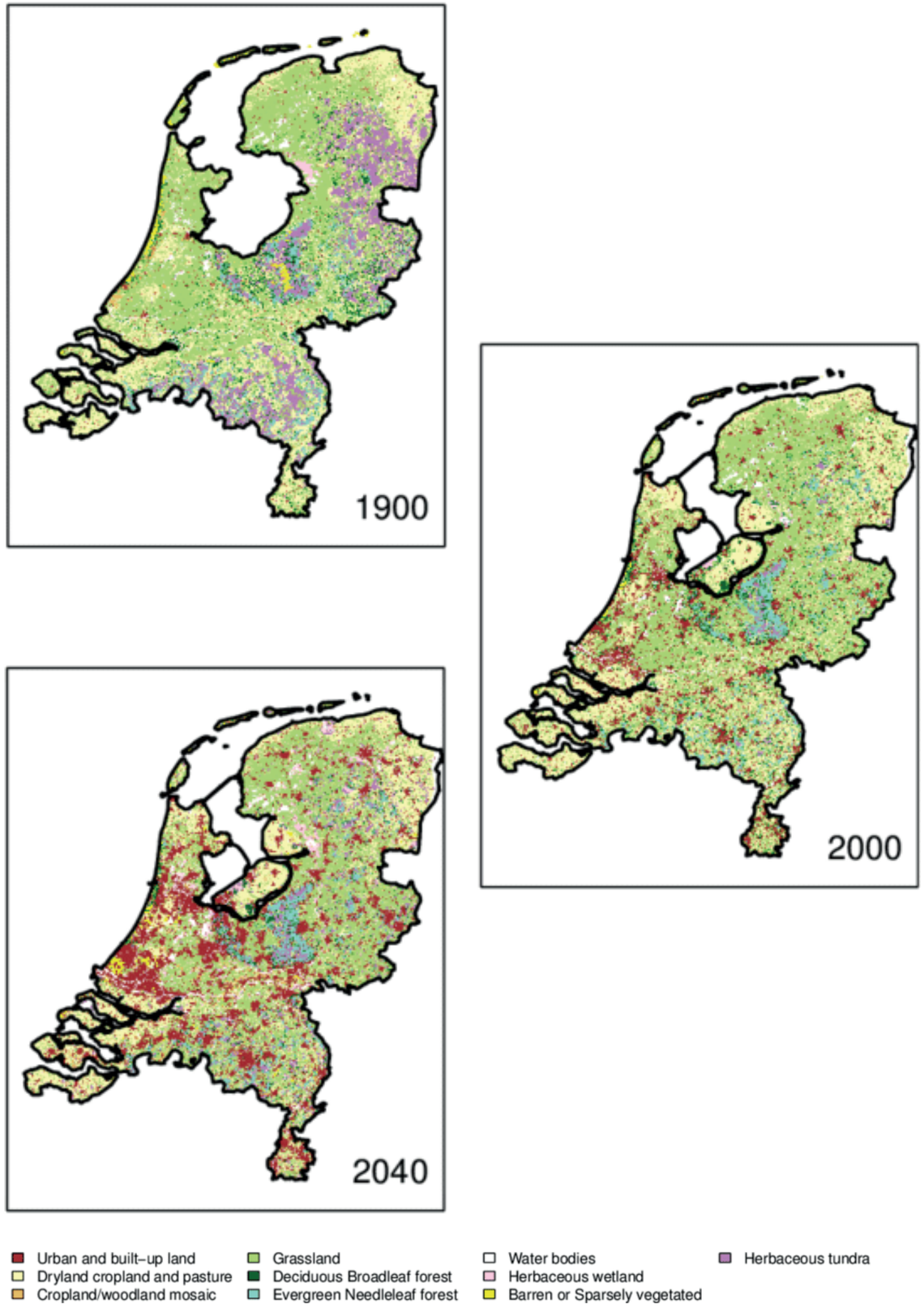
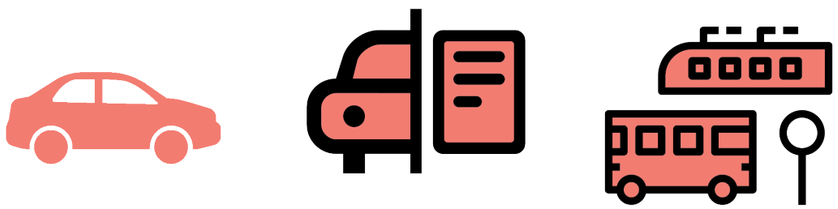


Figure 5: Urbanization of the Netherlands (PBL, 2014)

Mobility



Car oriented design | Increased ownership | Limited capacity

Cities have been growing rapidly. Originally this was mostly organic growth and moderate expansion. Due to the rapid urbanization and the invention of the car this process was gaining more speed. New modern ways of city planning were introduced where the car had plenty of space to move between destinations and park close to the destination. This car oriented design has led to high amounts of paved land. Paired with increasing car ownership and limited accessability and capacity of public transport this meant that space became much more crowded and could not be used for other urgent purposes.

Human Well-being



Wealth inequality | Unaffordable housing | Gentrification

Cities are getting more unaffordable. Housing prices go up and transformation projects cause old residents to be pushed out by richer new residents. This causes the wealth inequality gap to increase.

The difference in wealth and way of living cause the urban population to be very divided. The problem is also rapidly increasing as is shown in figure 6, showing average house prices over the past 20 years.

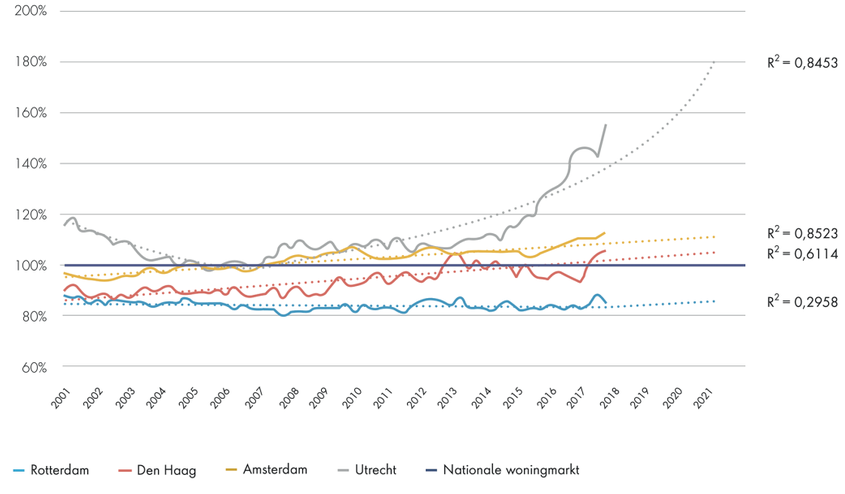


Figure 6: housing prices in the Netherlands (gemeente Rotterdam, 2021)

Problemization

Below a summary of the four previously explained problems. All problems need space to be solved. Climate change requires climate adaptive solutions, urbanization in its current form need space to expand, mobility needs space to increase capacity and socio-economic inequalities need space to fascilitate for a more diverse population.

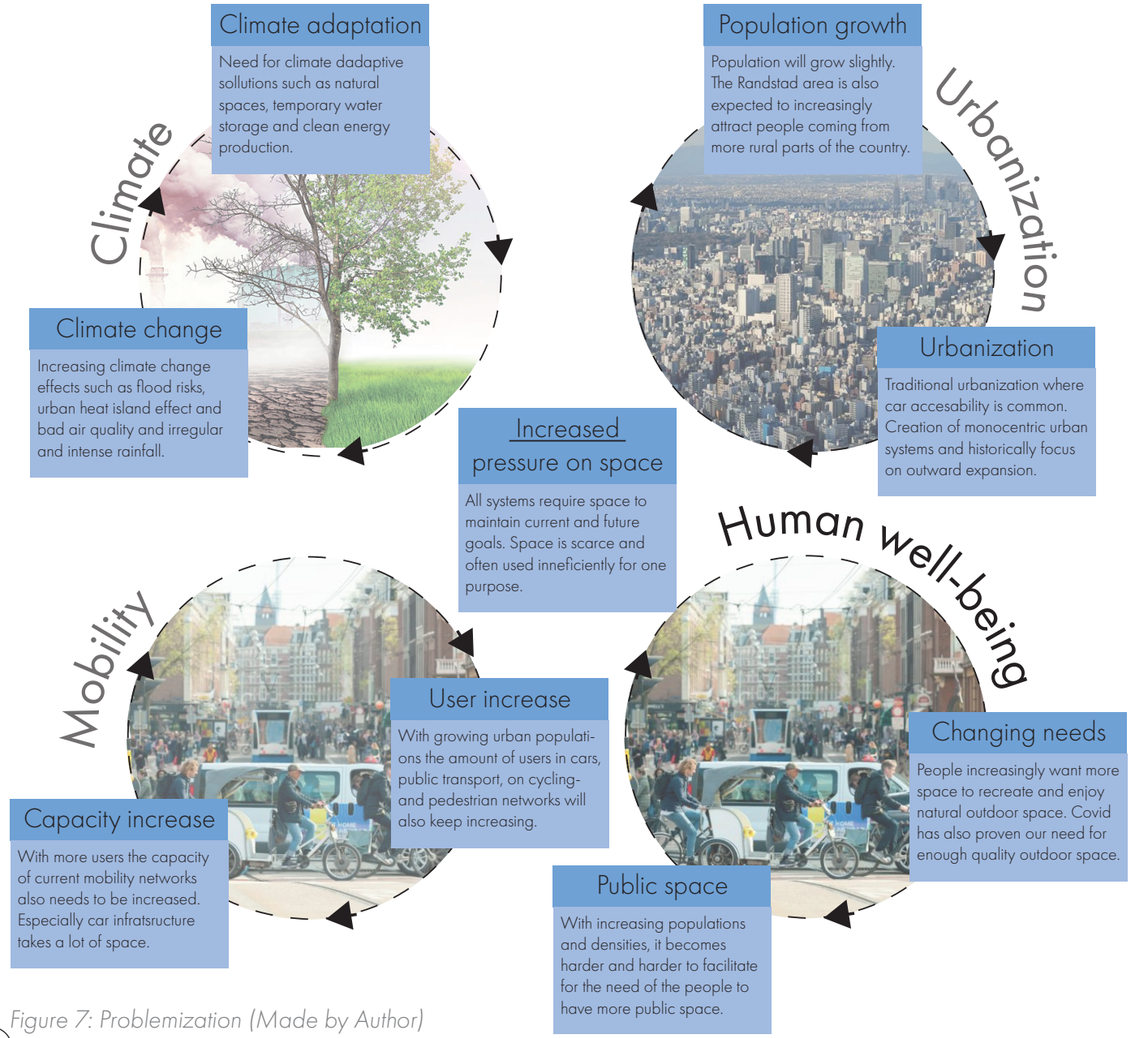


Figure 7: Problemization (Made by Author)

To put problems in a perspective a graph of the population of the Netherlands is shown below. During the period of rapid urbanization we also see a big increase in population. The population however is not growing as much as it used to and is expected to peak between 2030 and 20240. After this the population is expected to decline slowly.

When population decreases the pressure on space to be transformed into urbanized landscapes decreases and thus the problem becomes less distressing.

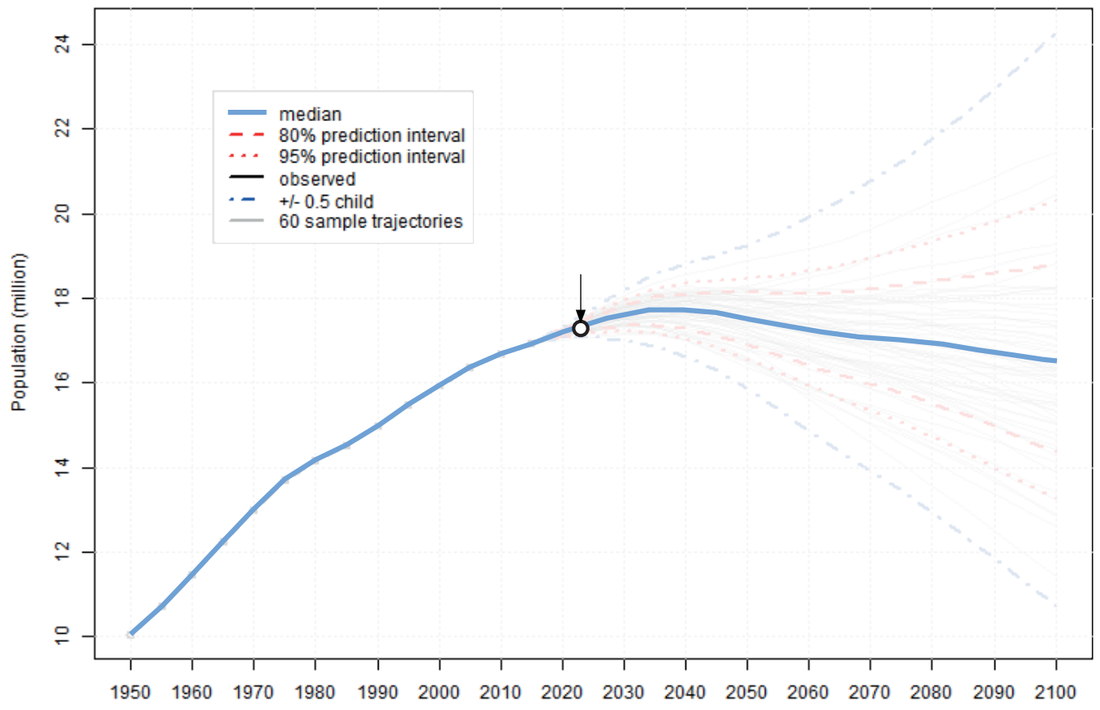


Figure 8: Population growth (UN, 2019)

The excessive amount of land used by cars wasn't always a problem. The problem began when planners and designers took accessibility for the car as an undebateable priority. To change the system we have to design not for cars, but for people cycling, walking and using public transport. Figure 9 shows just how much more efficient these mobilities are.

To change the system, a switch is proposed where private car use and ownership are severly limited and can only be used in exceptional situation such as for emergency vehichles and specific jobs like plumbers. The private car will be replaced by shared mobility where, when neccesary, people can use a car.

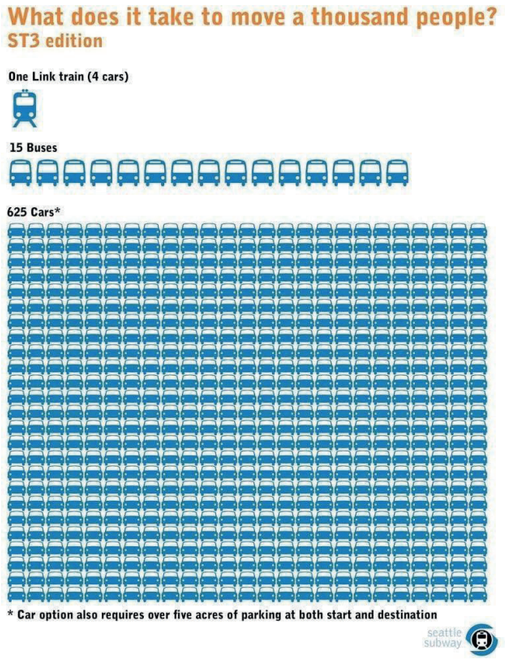


Figure 9: Problemization (Seattle subway, 2017)

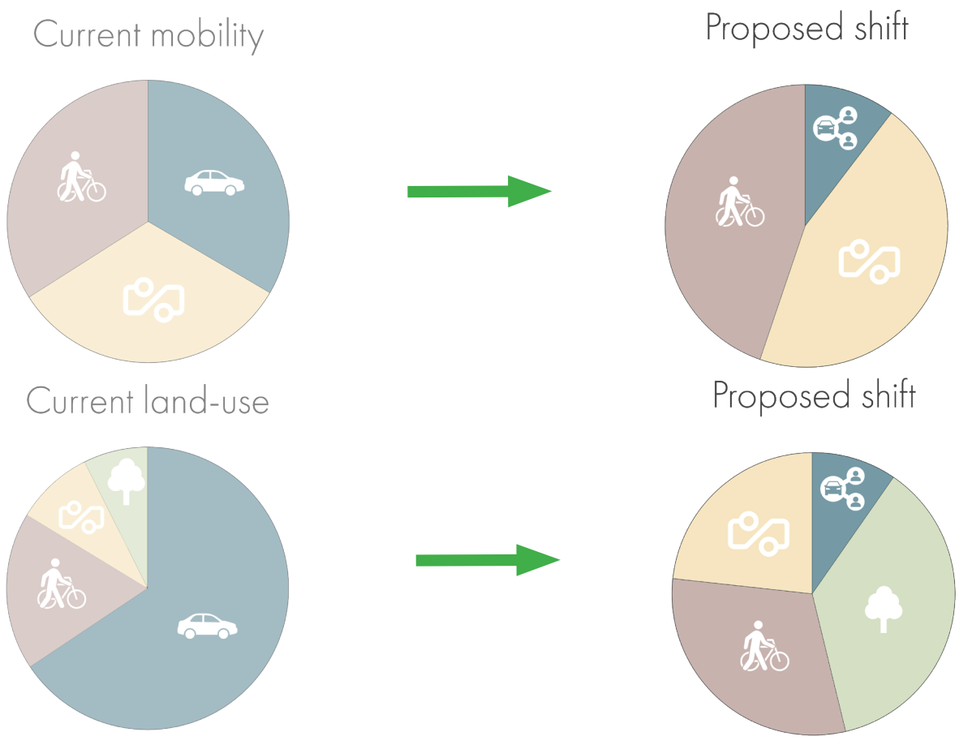


Figure 10: Mobility shift (Made by Author)

Adjusted problemization

When looking at the problemization again we can now adjust the less urgent problems of urbanization and mobility (due to the proposed shift). With this knowledge two problems remain very urgent and are therefore the problems that this research will focus on.

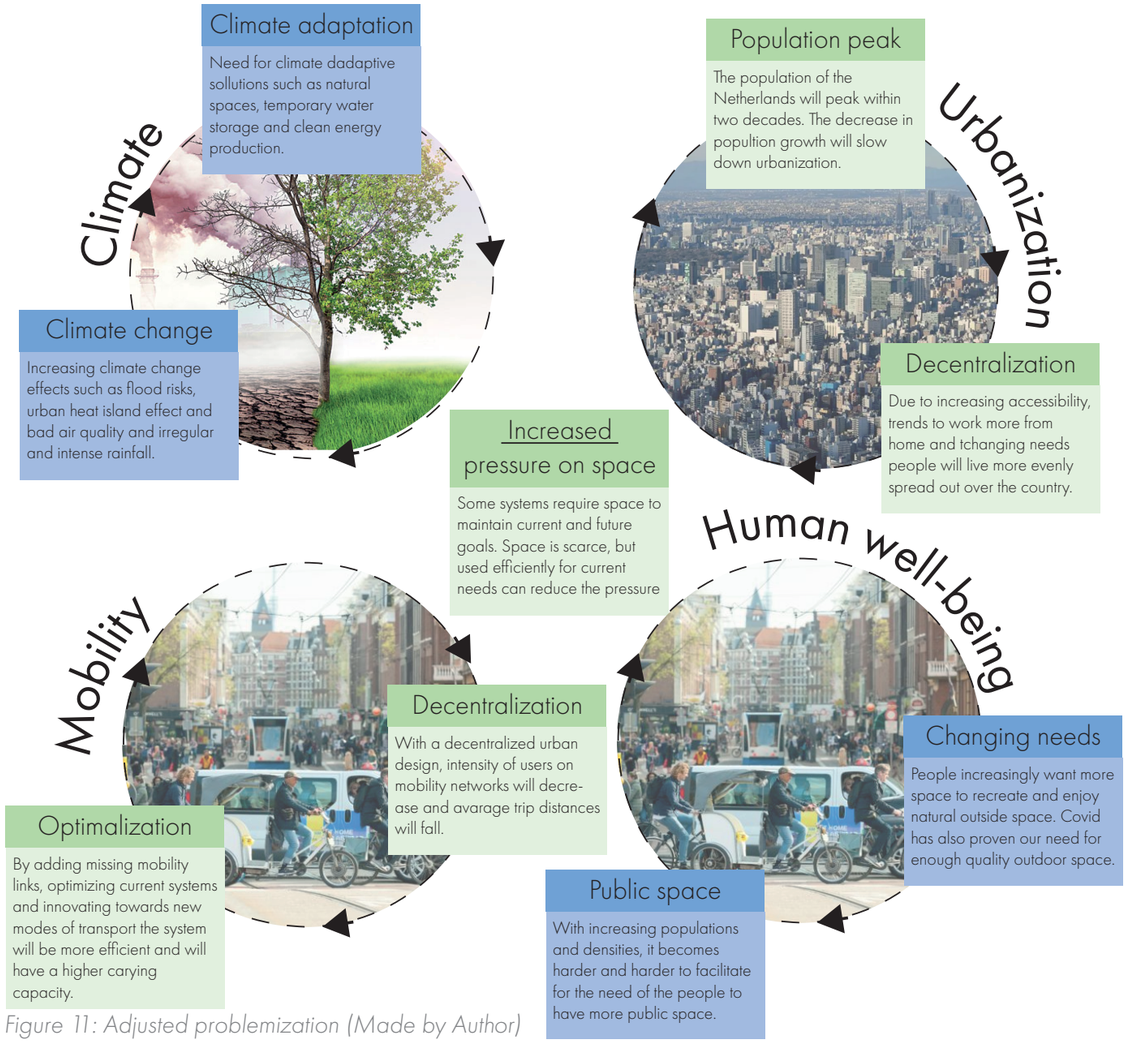


Figure 11: Adjusted problemization (Made by Author)

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In this report solutions will be researched and designed for problems that require space to be solved. Solving these problems is harder in areas with little public space, than for areas with abundance of public space. To challange ideas and interventions in the best way, a project location is chosen based on the scarce availability of public space. To understand the analyses in this chapter a quick explanation of densities is given on the following page.

Densities

Densities can be described in many different ways that give varying results. It is therefore important to understand what conclusions can be made from different density measurements. In many situations density is described as the amount of people living in a given area. Since the density of people is highly dependent on trends such as average household composition and transformations done to buildings and can therefore change drasticially over generations, urbanists often look at more static definitions of density. Three of these densities will be described here.

FSI = Floor Space Index
FSI is the amount of total floor space within buildings in a given area.

GSI = Ground Space Index
GSI is the amount of space within a given area that is build on. For example a GSI of 0.4 means that 40% of the area is build on and 60% is not.

OSR = Open Space Ratio
OSR is the ratio to how much unbuilt space is available for each m² of floor space within buildings.

The project

This project will research and propose changes in the public space to solve current problems such as climate change, loss of biodiversity, social problems and mobility. All these interventions require space, therefore GSI and OSR densities are analysed since the availability and demand of space is directly related to the balance of build and unbuild and the ratio in which people have to share space.

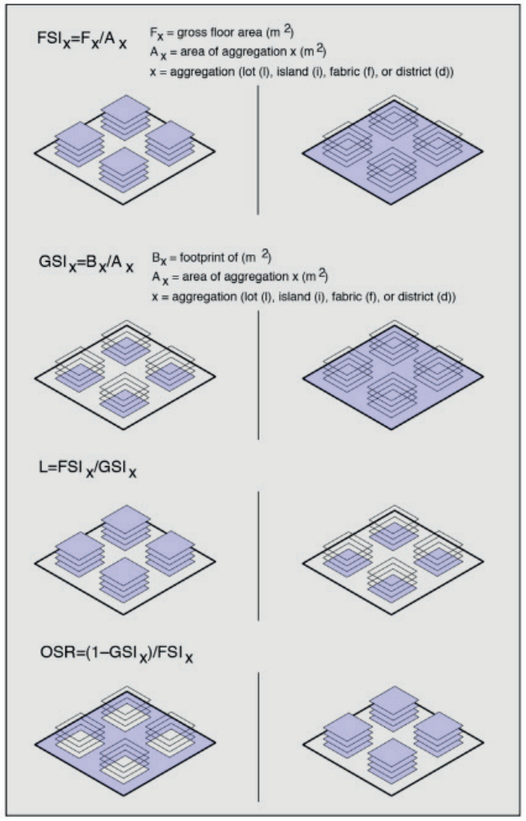


Figure 12: Densities (B&C)

Macro scale

In figure 13, a FSI densitymap of the Netherlands is shown. Areas where the lack of space is most urgent and thus designing interventions to solve this problems are most relevant are shown within the red circles. The areas marked by red circles are the agglomeration of Amsterdam and the metropol area of Rotterdam and The Hague. For this project a location within the area of Rotterdam has been chosen.

Two (Dutch) news articles are shown that indicate that this area of the Netherlands will keep urbanizing further in future.

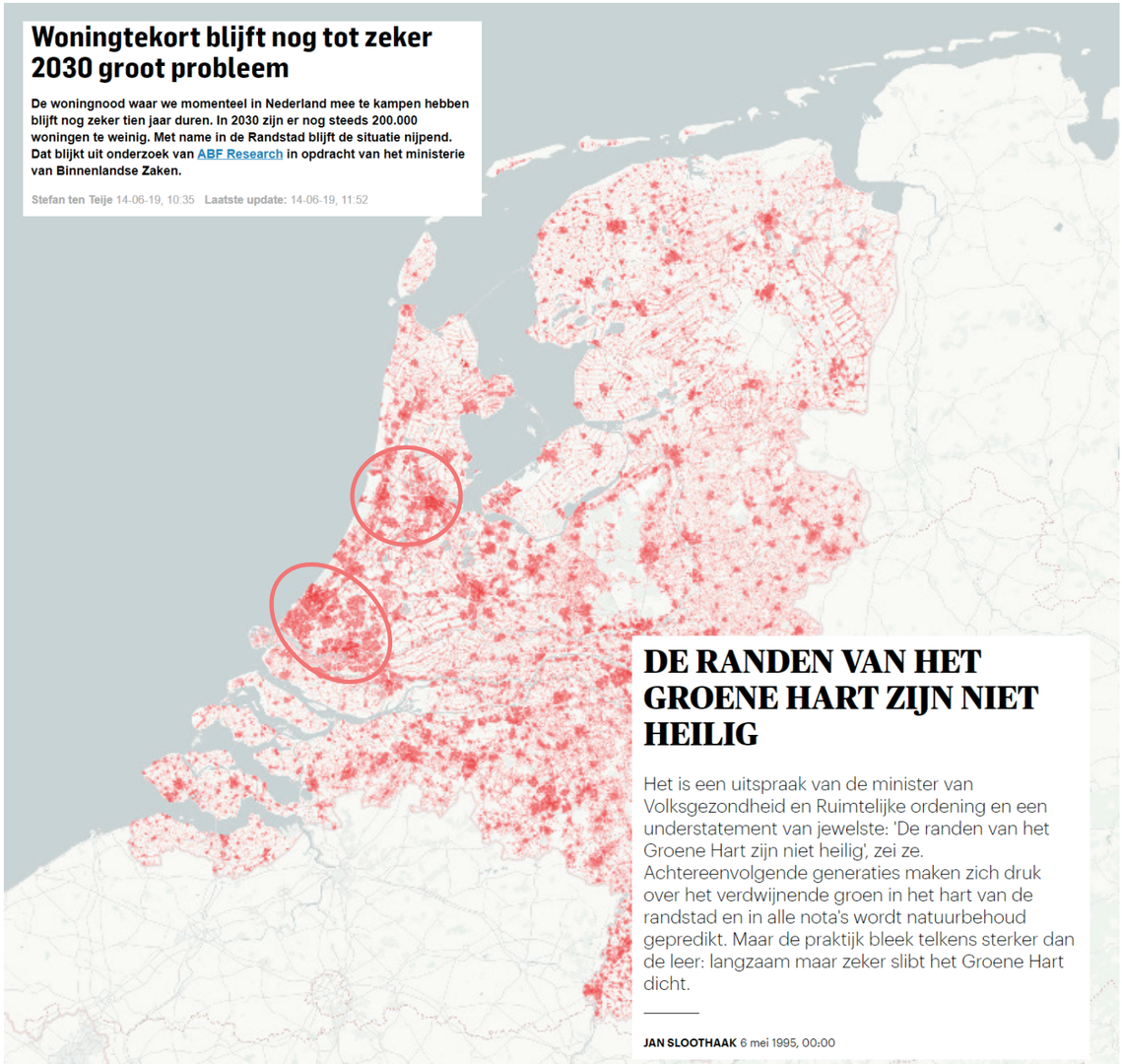


Figure 13: Density map of the Netherlands (GIS data from RUDIFUN)

Meso scale

When we zoom in on Rotterdam we see a clear pattern of higher densities in the center and decreasing densities towards the outer neighbourhoods. Especially the older neighbourhoods and the city center have a relative high density. If we look at the neighbourhood average we see one neighbourhood stands out. With a high FSI density and a low OSR density, this place has one of the lowest amounts of open space per square meter floor space and it is likely there are more people using the existing public space space.

For this project the most eastern part of this area is chosen as design area. This is the neighbourhood of Delfshaven.

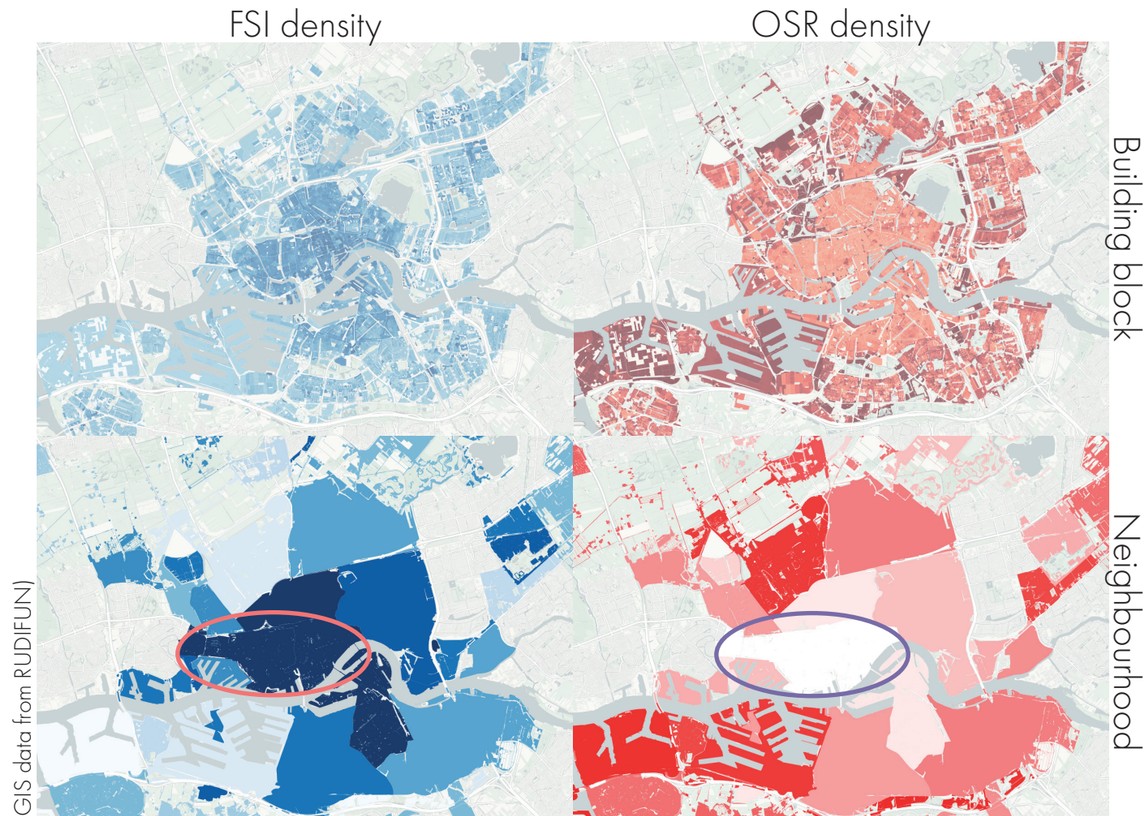
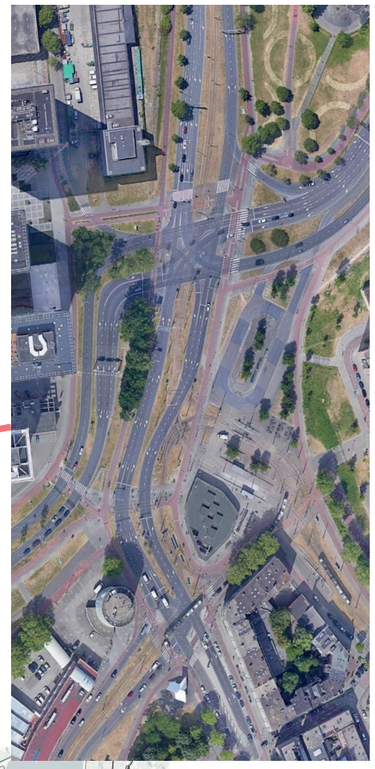


Figure 14: Density maps of tRotterdam (GIS data from RUDIFUN)

Meso scale

After the demolition of most of the center of Rotterdam during world war 2, much of the city was redesigned with a modernist focus. This is very visible near the area of Delfshaven as two major intersections that cover huge amounts of space are located in close proximity. These are the intersections of Marconiplein and the roundabout at the exit of the Maastunnel.

Since we stated that one of the main challenges was the disproportionate amount of space used by cars, this location serves as a good example to show the potential benefits of using car infrastructure space for new uses.



Micro scale





Figure 15: Main car infrastructure Rotterdam (PDOK & Google Maps)

Meso scale

Rotterdam is surrounded by natural areas. Most of these areas are however agriculture lands with limited ecological performance. Within the city are many smaller, primarily recreational pieces of green space. There are only few real ecological areas within proximity of the city.

Further away are greenhouses that, unlike the data set suggest are not ecological and only contribute more to problems such as the urban heat island effect, storm water drainage and carbon emmisions.

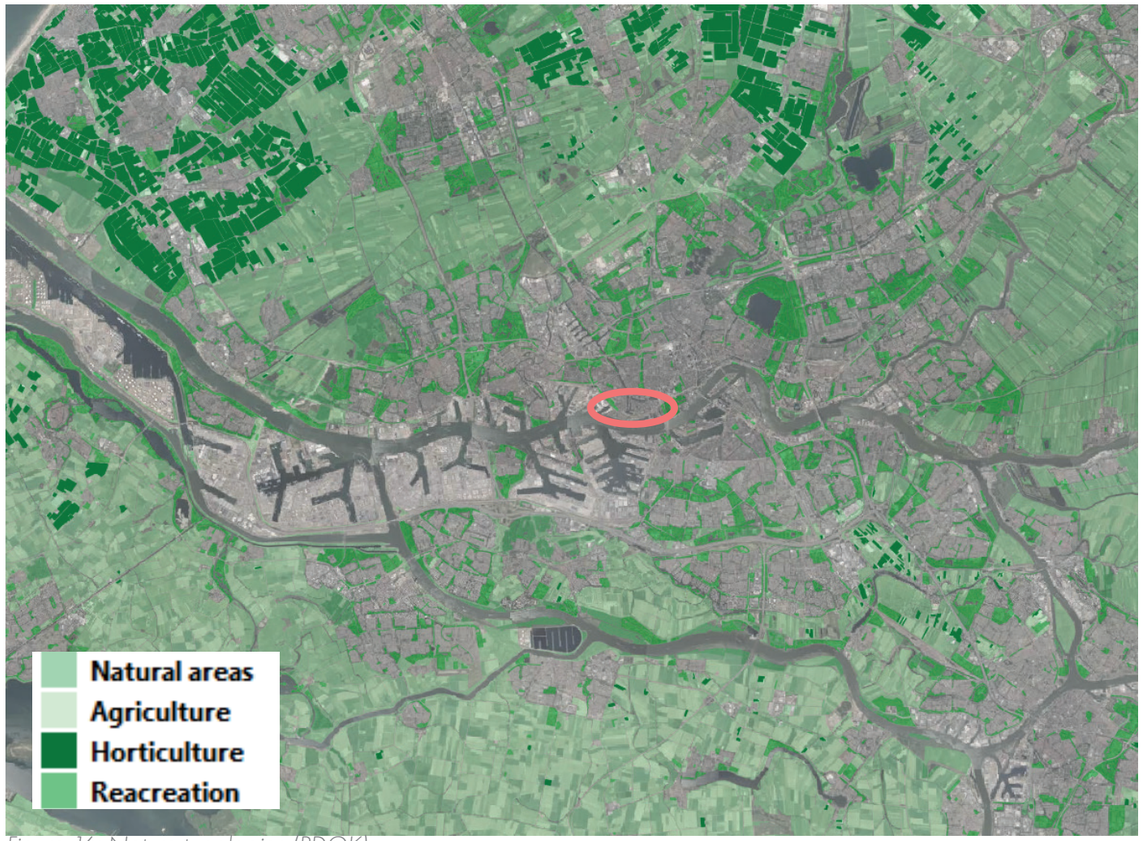


Figure 16: Nature typologies (PDOK)

Meso scale

Zooming in again we see some lineair green areas connected to the neighbourhood of Delfshaven. On the east is Het Park, a relative large ecological area with elements that create different habitats. The data set suggest that all natural areas are similar and function as recreational space. Visiting the place and looking at imagery however shows that some of the marked areas exist of grasslands and have very little variety in plant and tree species. The ecological value of those places has to be assessed individually.



Figure 17: Nature typologies Rotterdam Noord (PDOK)

The neighbourhood is connected by different mobility networks including many modes of public transport. Increasing accessibility for pedestrians, cyclists and public transport can create a good foundation to introduce a mobility shift away from cars. To serve a larger proportion of the population by public transport, this network might have to be extended or frequency has to be increased.

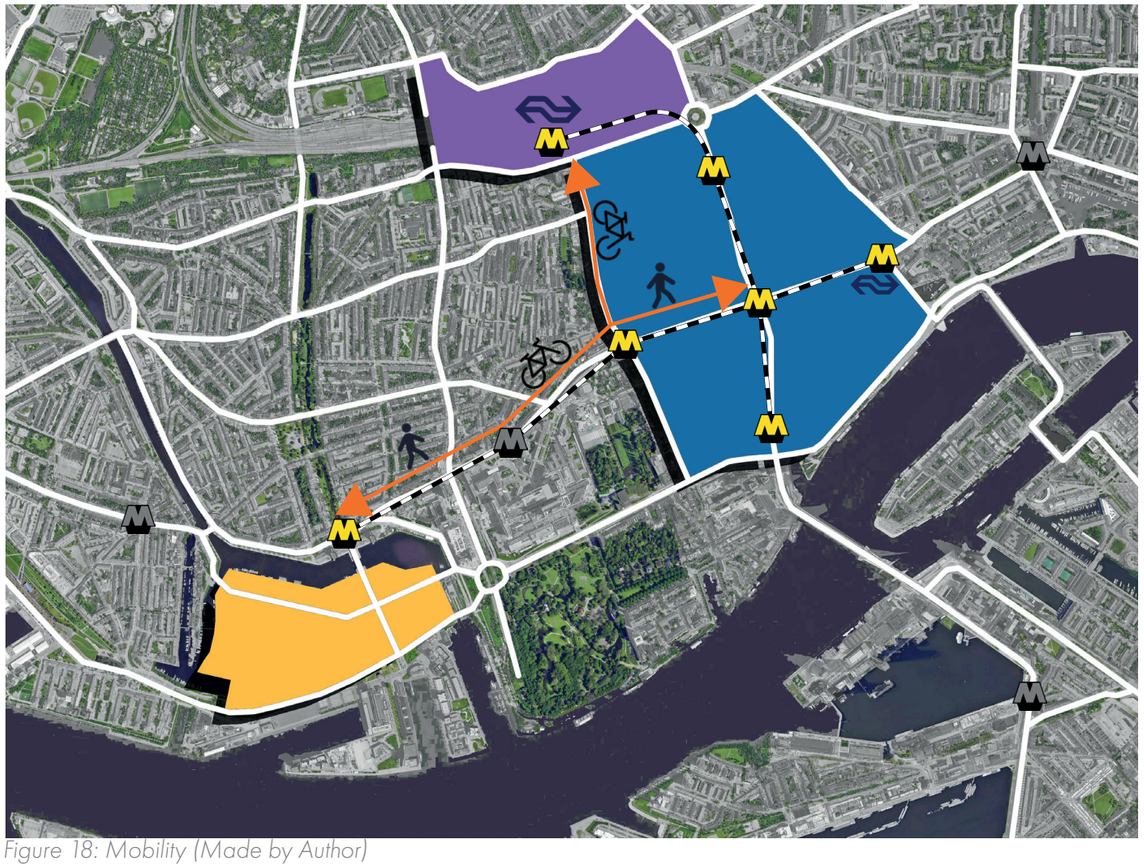


Figure 18: Mobility (Made by Author)

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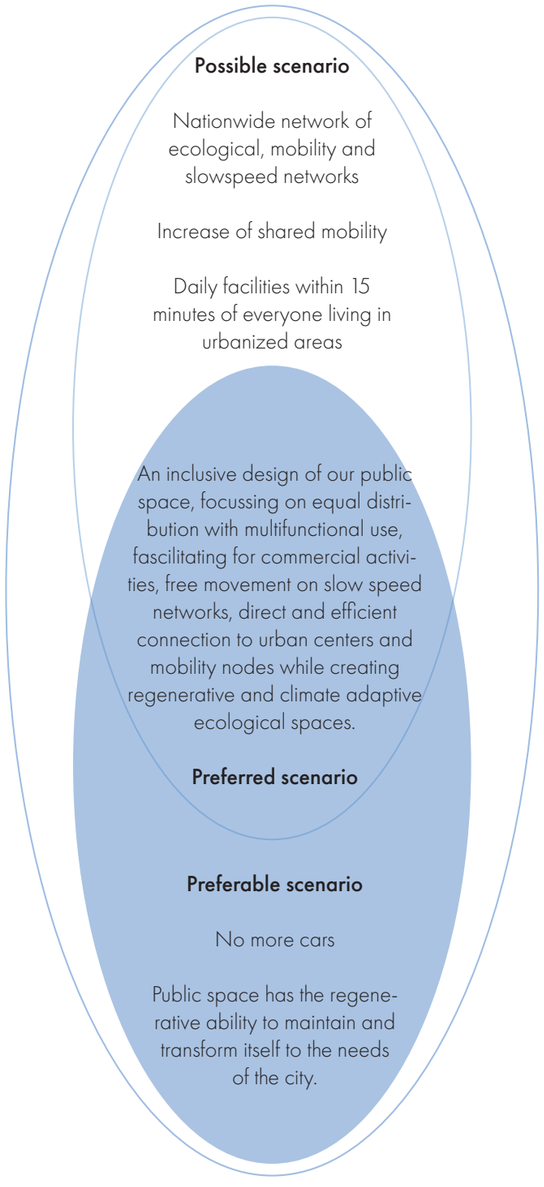
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Project aim

Project Aim

The project aims to create a new spatial design for public space in dense urban environments, in which it can contribute maximally to adapt to climate change, restore urban ecological systems, improve human well-being and in which the car will have a less prominent role. The research and design can form an example for future projects that aim for maximizing sustainability goals.



Research questions

1. How can we use public space more sustainable in terms of climate adaptation, ecology, human well-being and mobility?

a. What is the role of public space and how do people use and value it?
b. How can public space be used to improve mobility?
c. How can public space improve ecological systems?
d. How can public space help adapting and mitigating climate change effects?
e. How can public space improve human well-being?

Conceptual framework

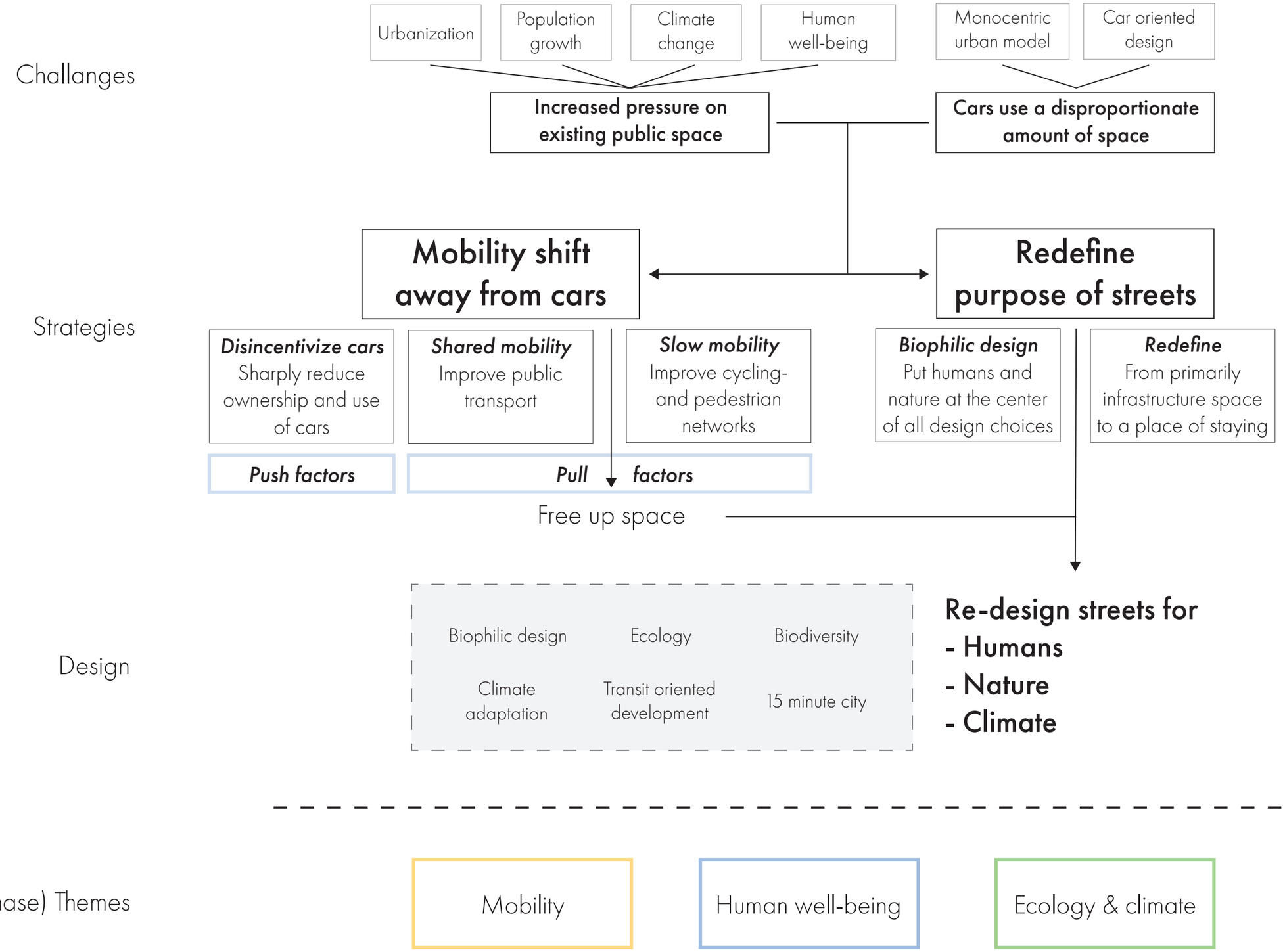


Figure 19: Conceptual framework (Made by Author)

Design focusses

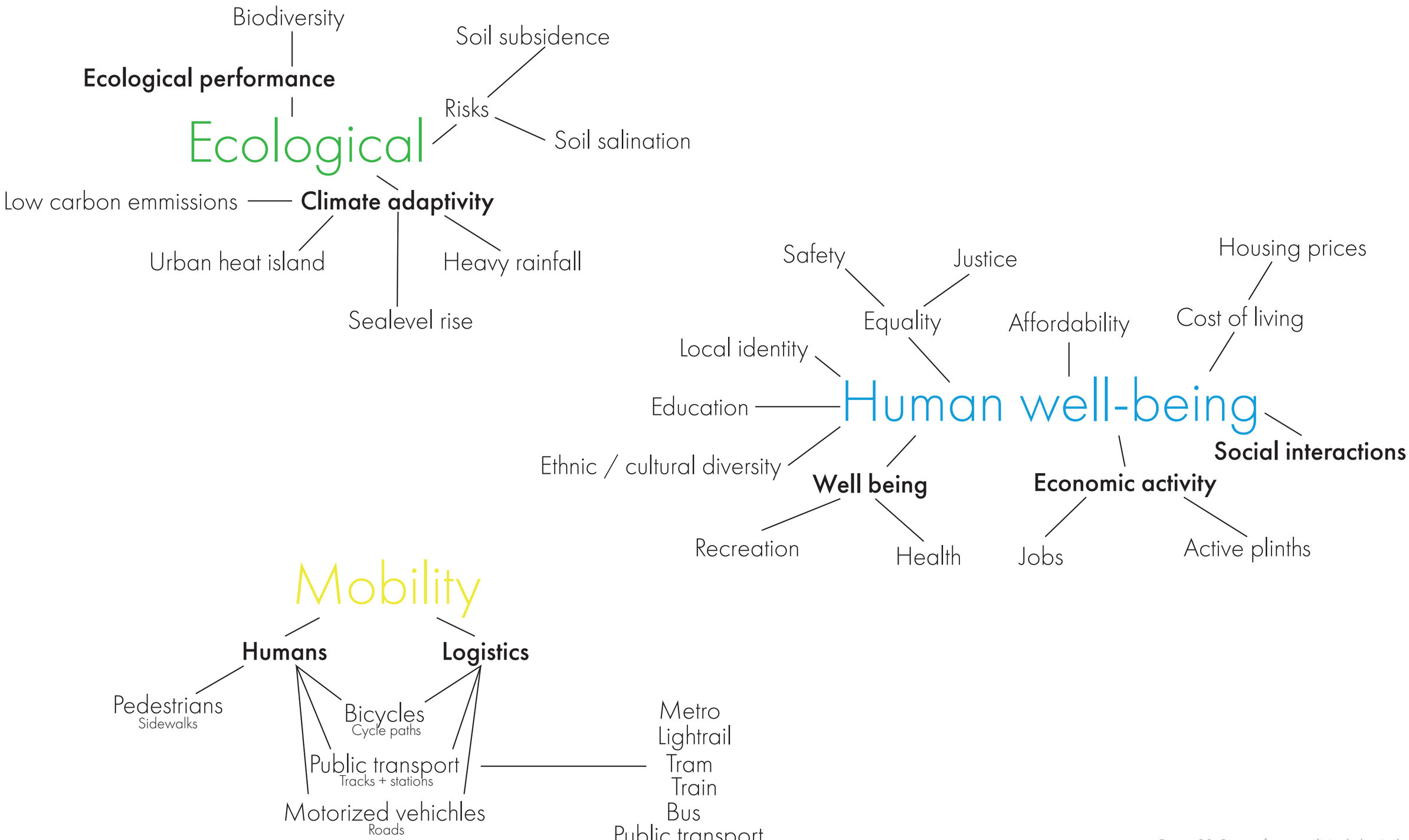


Figure 20: Design focusses (Made by Author)

Vision

Current situation
Currently much of our build environment is designed in a way that allows cars to conveniently access any part of it, meaning many paved surfaces are present. As described before in the problemization, space is becoming scarce and the needs of residents are changing because of trends that are unavoidable. Walkability is decreasing as scarce available space is given away to new car lanes, public transport or parking. Climate change is showing increasingly more and hazardous effects. Biodiversity loss is slowly starting to affect systems like agriculture, and vegetation (IPCC, 2022).

Recently, and amplified by the covid 19 lockdowns, we see that pressure on existing public space is increasing. More and more people wish to use it and it is becoming harder to facilitate enough space (Honey-Rosés et al., 2020). Public space is important for social interaction and can help with problems that many urban areas are coping with such as social inequality, loneliness and personal development.

Currently around 70% of our public space in cities is occupied by cars (PDOK dataset, 2022). Heatwaves, in combination with heat islands caused by large urbanized areas with lots of hard pavements causes cities to get unbearably hot and low amounts of natural areas causes areas to be unable to cool down significantly during night (Li & Bou-Zeid, 2013).

Vision
In this project a different approach to use of public space is proposed. The project envisions a design of our public space that focusses on creating space for humans and nature, without primarily trying to optimize for humans (and their incredibly unnecesary fast motorized mobility). The project proposes to do this by reducing pavement, increasing and diversifying natural areas, by creating more space for social interaction and by realizing a sustainable mobility system that is accessible by all.

What this will look like and what this means in detail will be explained eleborately in this report.

Why is this change important?
We are at a unique point in history where many problems are becoming increasingly tangible for most humans living in urban areas. If you've lived in a city for over 20 years you have undoubtedly witnessed the urban expansion and reduction of surrounding nature in your city. Climate change effects are now showing their impact and it is very hard to deny it will become worse if we don't take the steps neccesary to reduce our impact and to combat the dangers that climate change brings.

Space within our cities can only be designed in one way and it is unsustainable to keep designing excessively for accessability of the car and their parking needs. We should use our space efficiently and multi purposely. So that more people can enjoy the space that is available.

This change doesn't only give space to people and nature that really needs it, it also decreases our use of fossil fuels and can increase our health by reducing air pollution and contribute to a more healthy way of living with daily physical movement and social interaction (Sarkar et al., 2015).

This report will show in many ways how changing our cities is beneficial for our living experience, health and even the direct and indirect costs of life. Cleaner air and more physical movement can contribute to less costs related to health and more nature could mean less costs of constructing expensive intersections, road maintenance and reduces use of car related subsidies. By moving to more collective systems, more interactions are likely to happen. With a more resilient ecology and with the neccesary climate adaptation interventions the area will perform much better in periods of extreme weather.

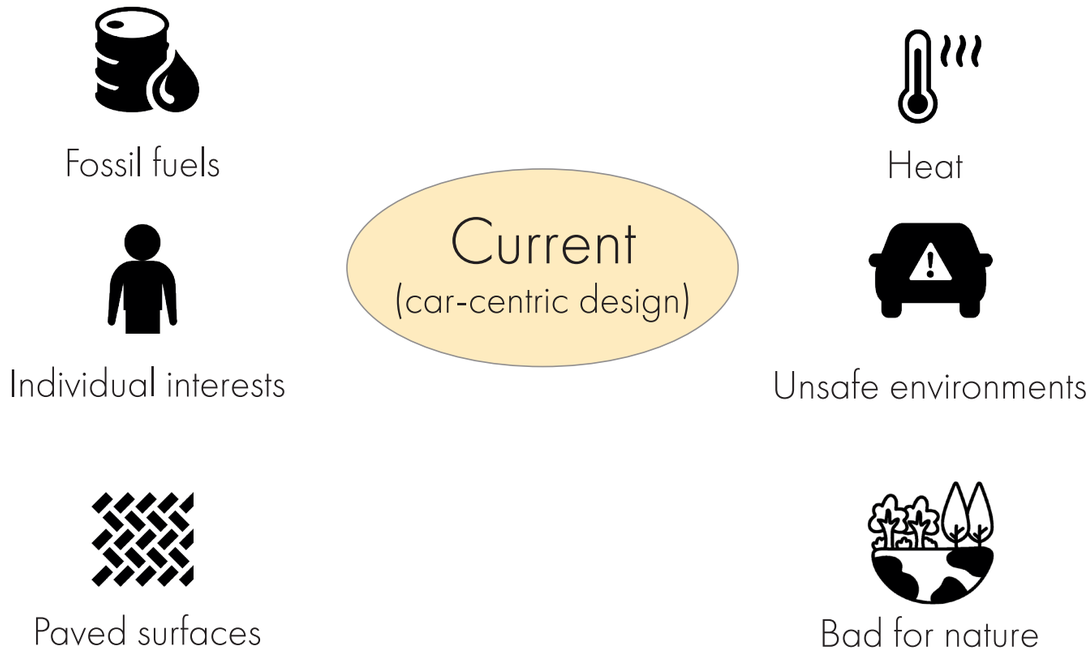


Figure 21: Vision (Made by Author)

Design methodology

Maximalization
Designing such a complex project where integration of climate, ecology and human well-being is the goal requires a clear and systematic design approach. To achieve the combined maximum result we have to look into all the possibilities and see where different themes strengthen eachother and where friction may appear between goals.

In the first phase of designing the maximalization method will be applied. In this phase all the themes of mobility, climate adaptation, ecological performance and human wellbeing will be designed with primarily the goal of maximizing outcome for this specific theme. In the final phase the themes will be combined and the final design should facilitate qualities for all the themes while still achieving the maximum cummulative qualitative result.

Mobility
To maintain accessibility and not cause big disconsent with the transformation, alternatives for using a car have to be added and improved.

First we start of by defining what the most important connection in and through the neighbourhood are, what infrastructure is neccesary at the minimum and if different modes of transportation need to have seperate lanes.

Secondly a couple streets are picked that are unique and represent the entirety of the neighbourhood. For these street types, options are designed and assesed with use of the definition of the importance of a connection and the amount of space left for other interventions related to climate, ecology and human wellbeing.

Finally these streetprofiles are applied to the neighborhoud and give an overview of the potential amount of space left for other interventions. In this mobility design, solutions for waste collection, post distribution, loading heavy items from a car and more are discussed.

Ecology
For ecology literature research has been done to assess qualities of different types of (urban) ecosystems. Those results lead to design principles that can be ranked in order of importance and feasability. It is also important to set up goals such as whether the project aims for specific species or what climate effects are wished to be mitigated.

Human well-being
To design for human wellbeing we will look into the current distribution of playgrounds, squares, facilities, shops, etc. The current amount of facilities can form a basis and research or interviews on location can point out the needs of residents on what is currently not sufficiently present.

Integrate
Eventually all maximalized options have to be combined. This will also create multiple options that have to be assessed. Overall the goal is to achieve a sustainable eco-system that is relatively self-regenerative and that provides residents with an appealing and healthy living environment.

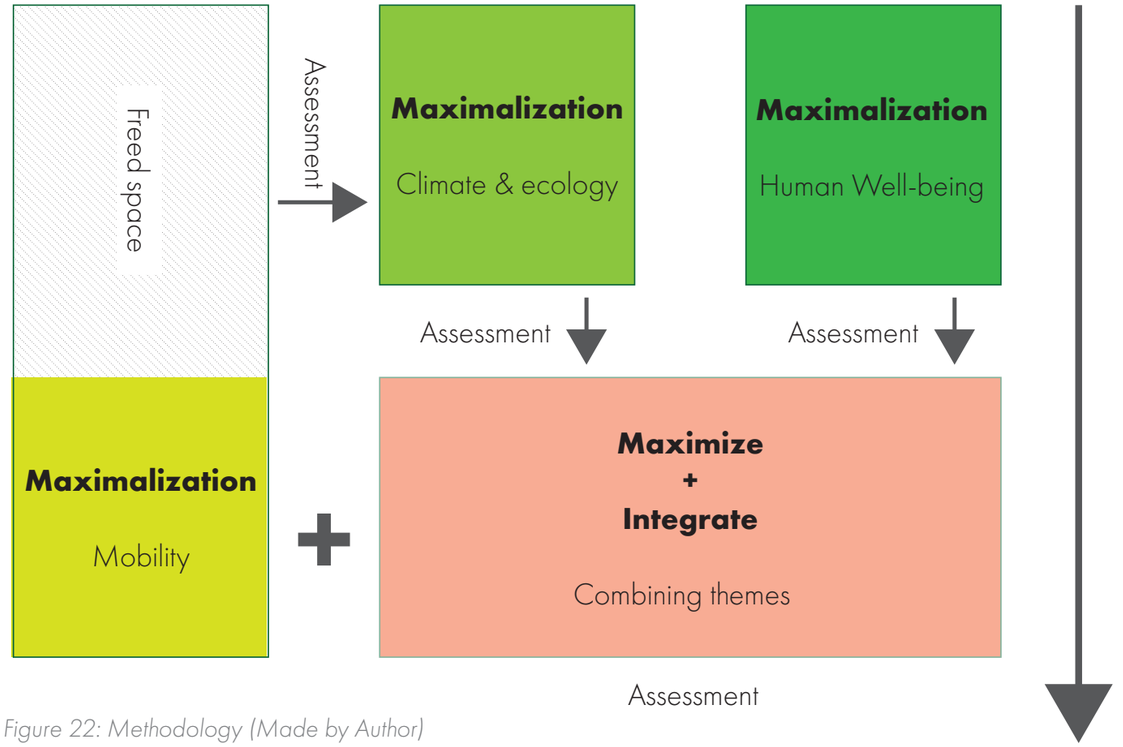


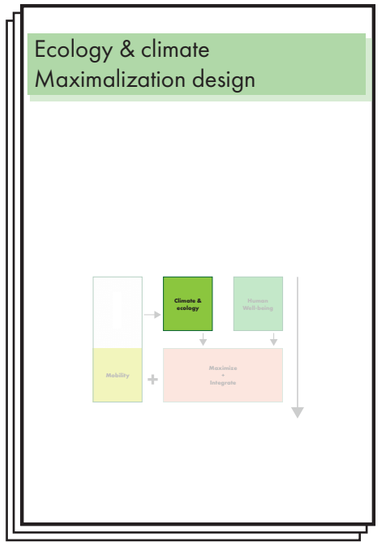
Figure 22: Methodology (Made by Author)

Report structure

The report consist of the following parts:

- **Introduction**
  - Problemization
  - Location
  - Theory & methodology
- **Mobility**
  - Research
  - Maximalization design
- **Climate & ecology**
  - Research
  - Maximalization design
- **Human Well-being**
  - Research
  - Maximalization design
- **Final Design**
  - Process
  - Design

At the beginning of each chapter a clear overview of content is given. In the chapters about the 3 design focusses (mobility, human well-being, climate & ecology) and for the final design the following page is shown to indicate the beginning of the maximalization design.



Appendix references can be found in an additional document.

4

Mobility

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Mobility

The network
To achieve a (almost) car free neighbourhood a transformation of the street network has to be made. The proposed transformation exists of the network layout, three focusses on street design and the implementation and expansion of the 15 minute city concept.

The network layout
Examples of different types of travel are shown in figure 23. Within walkable distance are multiple mobility nodes. People go here by foot or bike and can take public transport to continue there travel. From these nodes, mobility corridors will run trough the city with access in all directions. Around places where more people will travel to and where social interaction is likely to happen, a human well-being focussed design is included to create clusters within the network where people can meet each other, go shopping or go to work. Other space will be designed with ecology and climate adaptation as a primary goal, however this doesn't mean that goals of other focusses don't apply. Only the ranking of importance differs per location and typology.

The 15 minute city
To achieve this (almost) car free urban area, many facilities have to be in close proximity for everyone so they can acces them by bike or by foot. The concept of the 15 minute city will be applied to distribute important daily functions within 15 minute walking from their dwellings.

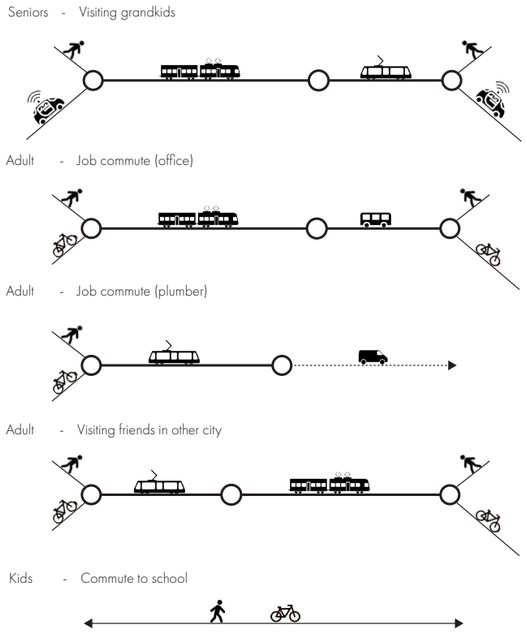


Figure 23: Modes of mobility (Made by Author)

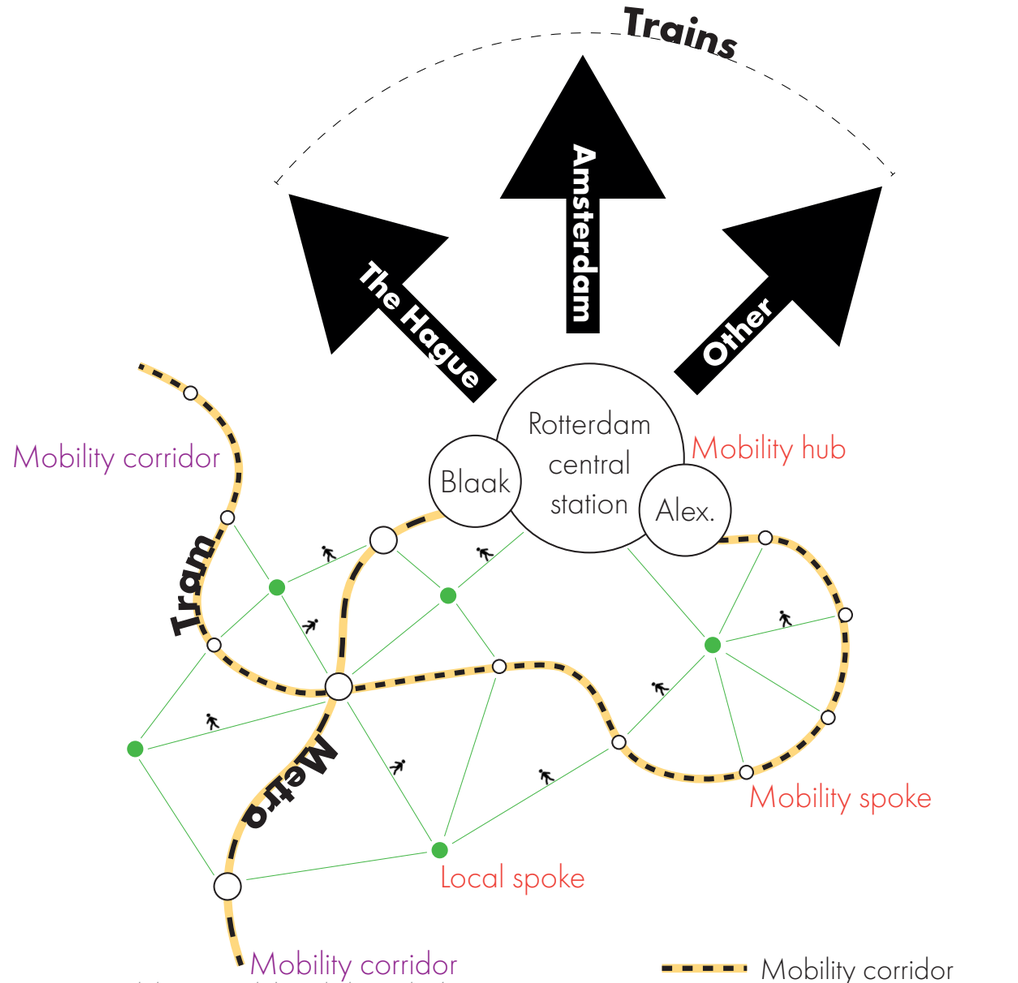


Figure 24: Mobility network (Made by Author)

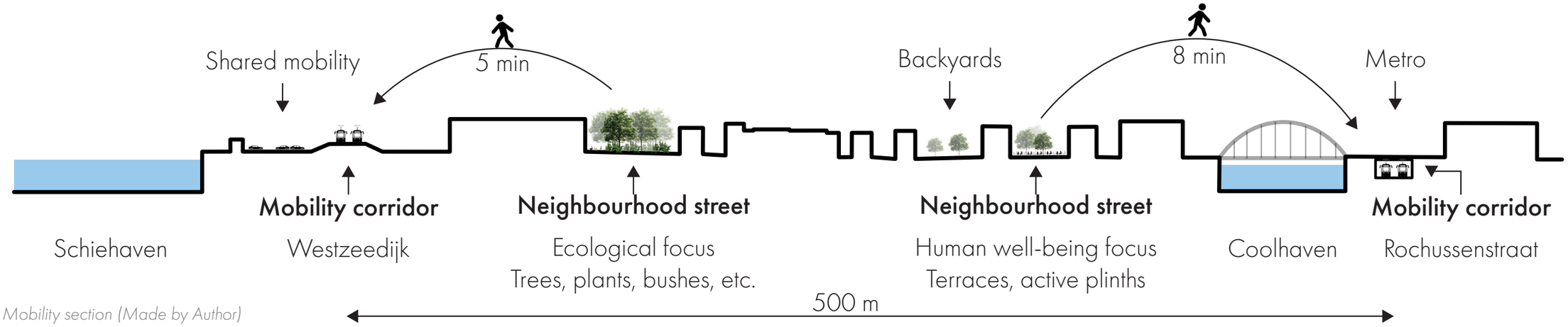


Figure 25: Mobility section (Made by Author)

Shared mobility

Current situation
Currently within the densest neighbourhoods of Rotterdam, half of our public space is used by cars (PDOK dataset, 2022). While only 35% of residents in Delfshaven say they use the car as their primary mode of transportation for trips longer than 30 minutes and only 5% say it's their primary mode of transportation for shorter trips (research by author, Appendix 3). This disproportionate use of space is making it very hard to free up space for other interventions such as creating places for social interaction, ecology and climate adaptation.

Shared cars
Shared mobility has existed for over a decade and is primarily used in city centers where parking fees are high and parking spots are scarce. Residents can subscribe to or occasionally rent cars that are located near their residence. By sharing cars with multiple residents the amount of cars can be heavily decreased. Experience shows that in dense areas as low as 1 car per 14 users is sufficient to facilitate for most necessary car trips (Greenwheels, 2019). The low coverage ratio means that occasionaly their might not be a car available. In practise this only happens on days like christmas or new years.

Improved networks
Because of the previously mentioned improved networks for walking, cycling and public transport, less people might desire to use a car. Currently around 55% of the residents of Delfshaven own a car (research by author, Appendix 3). In the design project an estimation has been made that all 55% of the residents would like to occasionally use a shared car and 45% will not be using cars at all.

Parking options
Using our previous estimation that 55% of the residents will use shared cars and that we need 1 car per 14 users, we can calculate that we need to be able to park 138 shared cars within the neighbourhood. Parking can be done on ground level in one or many levels which reduces the amount of available space for interventions, it can be done half underground within the courtyards which raises the courtyard level and prohibits big vegetation to grow here or it can be done underground which keeps ground level free but is very expensive. The decision for parking solutions will be explained on the next pages.

Delfshaven

Adresses	3506
Current parking situation	
Parking norm (current)	1
Parking spots (current)	3506
New parking situation	
Parking norm (new)	1
Participation rate shared cars	55%
Percentage of people living without using cars	45%
Private car ownership rate	0%
Adresses subrscribed to shared cars	1928
Subscribers per shared car	14
Total private parking spots	0
Total shared cars	138
Parking garage size	
Space per parking spot	30
Parking spots (private + shared)	138
1 layer	4132
2 layers	2066
3 layers	1377
4 layers	1033
5 layers	826

Infra

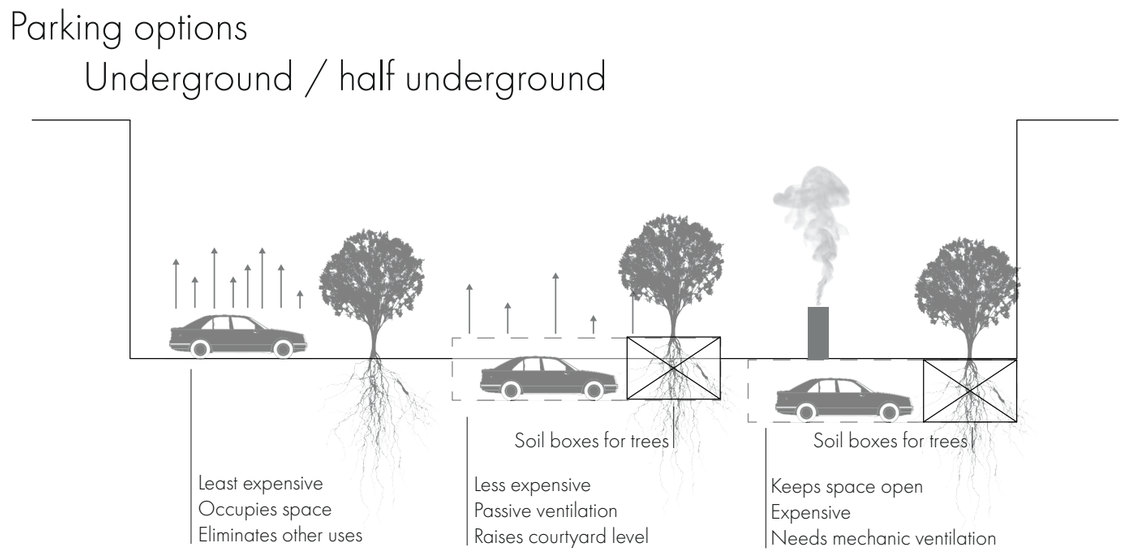
€	79,00	€/m2 BVO	Ontsluitingsweg
€	1.320,00	€/m2 BVO	Parkeren ondergr.
	23%	% tov bouw	Investeringskosten
€	1.785,00	€/m2 BVO	>2 verd. diep
	28%	% tov bouw	Investeringskosten
€	325,00	€/m2 BVO	Parkeren bovengr.
	22%	% tov bouw	Investeringskosten
€	405,00	€/m2 BVO	>4 verd. Hoog
	27%	% tov bouw	Investeringskosten
€	87,00	€/m2 BVO	Fietspad
	0,7	Milj./km	Spoor
	28%	% tov bouw	Investeringsrisico
	11,0	Milj./km	Tram
	159%	% tov bouw	Investeringsrisico

ON5 kostentabel (Bouwkunde TU Delft, 2021)

Costs

	Underground	Above ground
1 layer	€ 5.454.334	€ 1.342.923
2 layers	€ 7.375.748	x
3 layers	x	x
4 layers	x	€ 1.673.489
5 layers	x	x

Figure 26: Parking calculations (Made by Author)



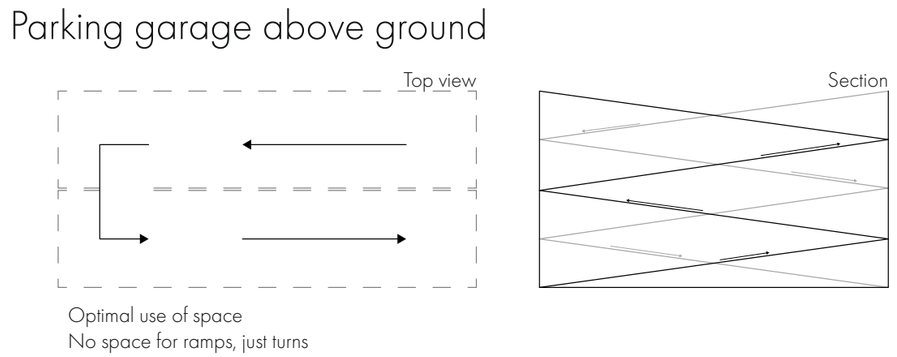


Figure 27: Parking options (Made by Author)

Locations
The map on the right shows the spatial implications of parking. Parking on ground level requires a lot of space but costs the least. With unsure future prospects this might be the safest option as cars might become less necessary or popular as public transport and cycling networks keep improving. However creating many parking spots on ground level will take away much needed space for interventions for social interaction, ecology and climate adaptation. These parking spaces can't be build in central places within the neighbourhood as space is simply not available here. In figure 28, either the orange patch (left top corner), the pink patch (center left) or the multiple red patches all are sized to accommodate for 150 parking spots at one level. The yellow patches are also sized to accommodate for 150 cars but are half underground to still keep a courtyard inside the building block for the residents. Realizing this type of parking is hard since ownership of the courtyards is mostlty private and highly fragmented. Without any new developments in the area, financing an underground parking is almost impossible.

The project
To achieve the goals as mentioned in the vision before and to keep the public space open for interventions, the half undergroud parkings marked in yellow on multiple courtyards are chosen as the best option. They dont occupy the public space and are also not the most expensive of all the options.

Autonomous cars
Autonomous cars are still in development and will probably not be seen on public roads very soon. Research on those vehichles is abundant, but barely any research estimates when we will see them on our roads. There is a lot unsure about safety and ethics around self driving cars. A research done in Pensylvania (US) has said that widespread implementation of self driving cars could happen as soon as 2040 (Hendrickson et al., 2014), however this is questionable since so much is still unsure. It is important to keep in mind future technologies since they may impact the urban areas we are designing today. Autonomous cars can drive without driver and pick up people without anyone in the car.

This means that cars would not have to be parked nearby since they can come to you when you need them. For this project it would mean that parking can be located in less dense neighbourhoods or even at the edge of the city.

New generations
Finally it is good to look at how different generations look at mobility. Interviews have shown that 75% of people under the age of 30 within Delfshaven prefere to primarily use a mode of transportation other than the car. While only 58% of residents older than 30 say they would primarily use another mode of transportation (research by author).

Education and worldwide trends can change the demand for driving. Worsening climate and rising oil prices might just be enough to push younger people to not buy a car or drive less with the one they have. Improved walking, cycling and public transport can also attract more people that would otherwise have chosen to use the car. All these changes together might significantly reduce the amount of users for the car and thus the amount of space needed for its infrastructure.

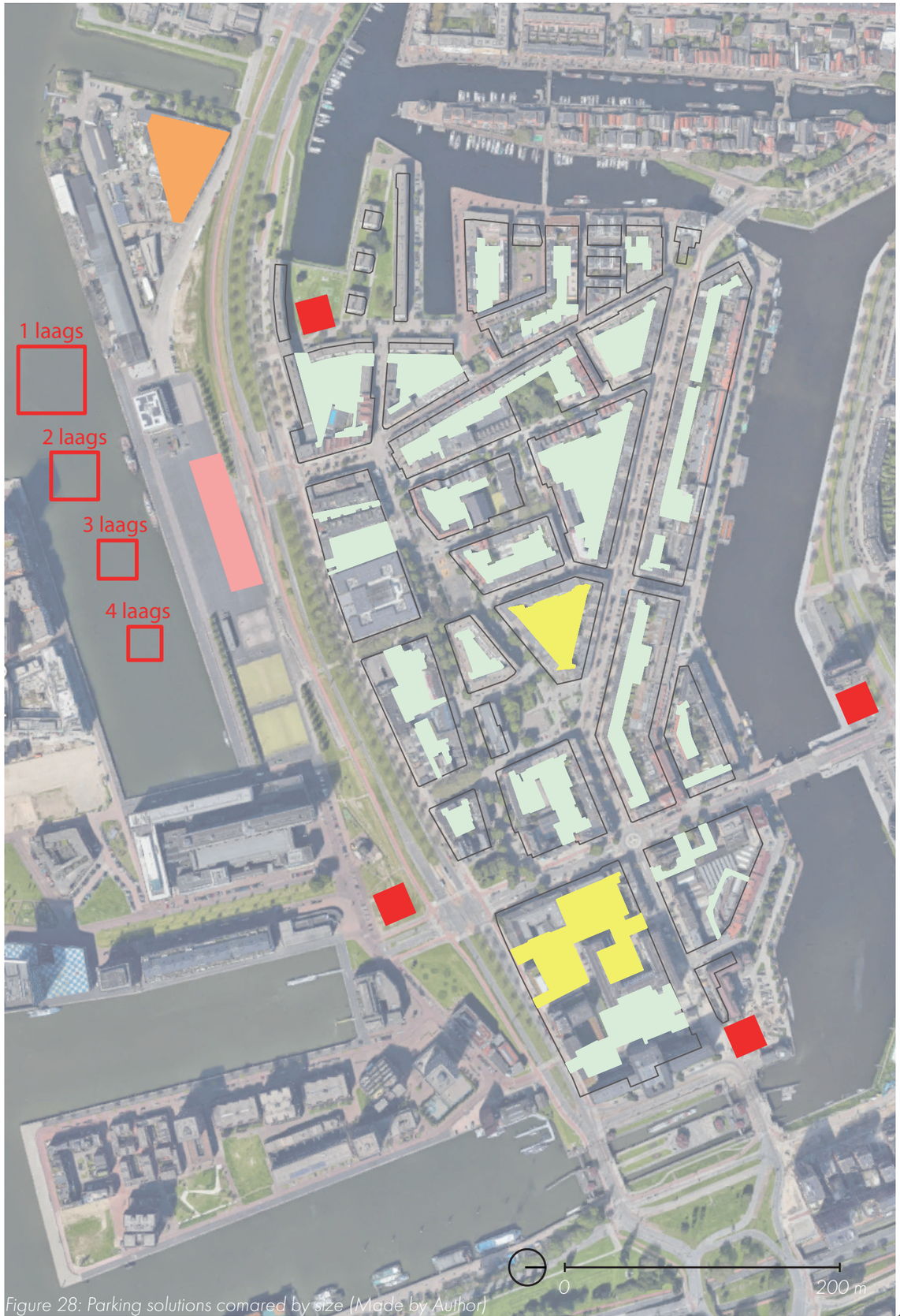


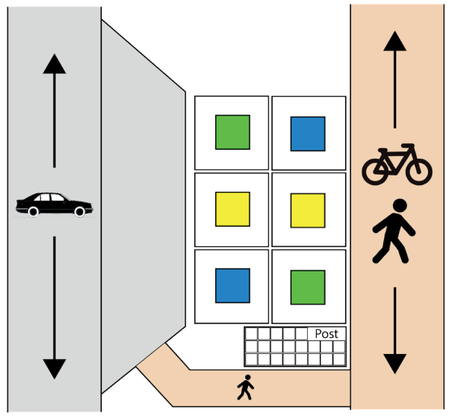
Figure 28: Parking solutions comared by size (Made by Author)

Waste & post

Waste collection
Waste collection and processing is a big task for municipalities and with increasing amounts of waste it is becoming a logistical problem. By reducing the amount of dedicated lanes for motorized traffic it is un favorable to have trucks driving on shared spaces such as bicycle paths or sidewalks. However waste has to be collected somewhere. In figure 29, three options for waste collection are illustrated. The first one is based on the current system where collection boxes are spread equally over the area. This means collection vehichles will have to move into the neighbourhood. Due to the higher amount of collection points, municipalities will only have to collect the waste at some moments each week. The second option shows the locations surrounding dedicated motorized traffic routes. This would mean people have to walk a little further, but collection vehichles would interfere less with other modes of mobility. The last option shows a central point where all garbage will be collected. This option would require the least amount of space, would not interfere with other modes of mobility and would make the process of collecting waste highly efficient for municipality services. It however also means some people would have to walk even further to drop off their waste. Based on the current average output of waste per household this isn't a favorable option. However, it is not unlikely that the production of waste materials such as plastic packages can decrease in the future and that more biodegradable alternatives will be used, thus reducing the amount of waste. When waste amounts are reduced significantly, walking once or twice a week to a central point might not be that bad of a solution.

Post distribution
Post delivery currently happens at your doorstep. This logistical system adds a lot of vehichles to the road that when decreasing the amount of motorized vehichle lanes can cause congestion. For this reason the project proposes to use post boxes that are located near other facilities such as waste collection, so people can pick up their packages here and trucks don't have to enter the smaller neighbourhood streets. Letters can still be delivered by bikes.

The system of post package boxes is already used in multiple cities, either as a whole or for particular areas. Examples for this are Singapore, Los Angelos and London.



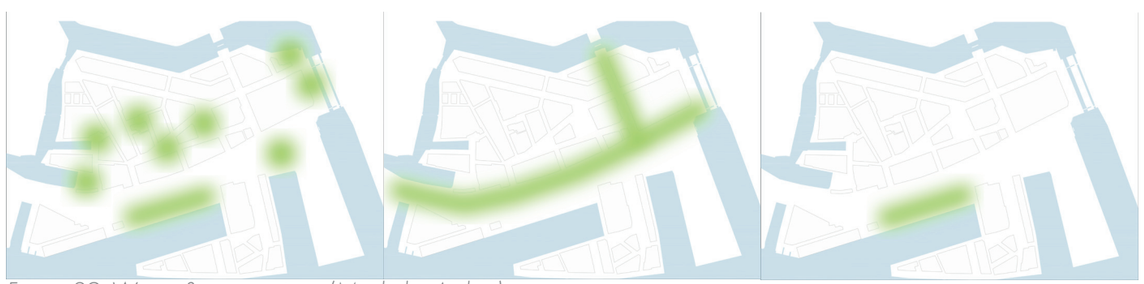


Figure 29: Waste & post options (Made by Author)

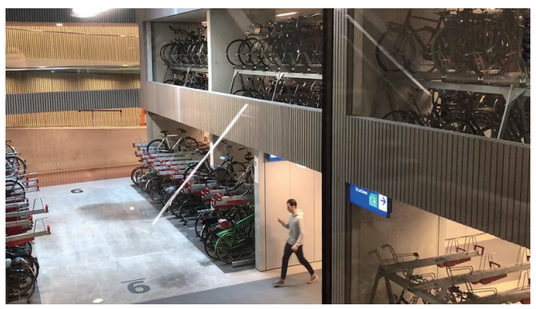
Bicycle parking

Bicycle parking
With the proposed mobility shift it is likely that bicycle use and ownership will increase. Where car parking can mostly be removed, bicycle parking has to be expanded. There are multiple ways to store bikes that all have their positive and negative effects. In this subchapter multiple options for parking bikes are discussed.

Parking strips along streets
The first option is currently the most used solution for bicycle parking. It exists of little strips of parking racks along streets, normally positioned between the cars and the sidewalk. This solution allows for equal and frequent placement of racks over the whole area. It however causes other land uses such as rows of trees or patches of grass to be disconnected at some point.

Plinths
The second option is to park bicycles inside buildings, preferable at the ground level. This will create an active plinth in the building and also provides protection that is increasingly important as prices for electrical bikes can be really high. This solution is more expensive than normal bike racks outside.





Former parking lots
The last option is to create bicycle parking lots or garages on empty plots. Within the Delfshaven neighbourhood there are multiple areas where parking lots are present that will be freed for interventions after cars are averted from the area. Those areas are large and can create parking for many bicycles. The downside of this is that some people might have to walk a minute or two after parking their bike before reaching their home. This can cause people to (illegally) park their bike somewhere closer or be less drawn to choosing the bike as preferred mode of mobility. This solution also means that the space can not be used multifunctionally, where as parking on the ground level of buildings allows other functions to occupy other parts of the building.

Figure 30: Bicycle parking options (Made by Author)

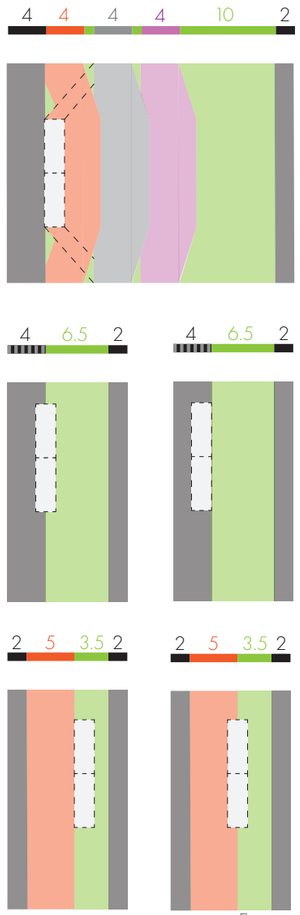
Car-free exceptions

Exceptions to the no car policy
Overall the mobility system will see very few cars. For any trip that doesn't require a car, use of cars will be prohibited on the inner neighbourhood streets. However there are exceptions where users may use the shared space provided as accessibility to individual buildings within the neighbourhood. Shared spaces include wide sidewalks and bicycle paths. Exceptions include emergency vehichles, people with disabilities or people with a profession that requires a lot of heavy tools such as a plumber. For those user groups it would be very hard to live their life and do their work without using a car when neccessary.

It is however demanded that employers, residents and other groups that fit the exception look into alternatives to their cars or little trucks. Exceptions can be a cargo bike or a small electric vehichle.

Network for cars
Within the network prioritizing pedestrians, cyclist and public transport there is also space reserved for neccessary individual motorized vehichles. Those spaces connect to important connections and will also have through traffic on them. The different networks will be elaborated more on the next page.

Loading bays
To avoid that neccessary individual vehichles having to stop on the cycle path, sidewalk or road, some places to park have to remain. Those parking spots will cause incontinuity in the street profile and much attention needs to go to upholding the aimed qualities of the streetscape. Decisions on loading bays may differ per street according to its width, importance in the ecological structure and its importance for connecting human and logistical flows.



In figure 31, three profiles are showing solutions to integrate the loading bays. In the first profile the loading bays are located next to the sidewalk so unloading activities dont interfere with cyclists.

In the second profile, the 4 meter wide sidewalk functions as a shared space for pedestrians and occasional individual motorized vehichles. Because of the low intensity of users of a road, the choice could be made to partly or fully locate the loading bays on the sidewalk to minimize the decrease of ecology in the profile. The pavement of those loading bays should clearly indicate that this space can occasionally be used to load and unload.

The third profile exists of sidewalks with a cycleroad (shared with cars). Depending on the expected occupancy of the loading bays the dicision can be made to put them partly on the cycle path since it is already made wider to allow oncoming bikes to pass cars easily.

Pavement
Finally it is important to mention that pavement of shared spaces meant for occasional motorized vehichles should be clearly distinguishable so that residents can keep those spaces free of objects. Due to the importance of response time in an emergency, those spaces should be accessible immediately at all times by emergency vehichles.

Figure 31: Loading bay options (Made by Author)

Ecology and climate
To reduce the negative effect of loading bays on the continuity of strips of greenery, materialization of these loading bays could be chosen specifically to mitigate this discontinuity. By using permeable surfaces like the one shown in figure 32, we can achieve relatively good climate adaptive and ecological performance, while still creating a solid pavement to occasionally be used to load or unload.

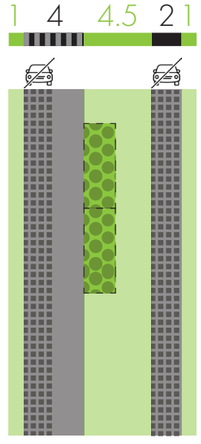
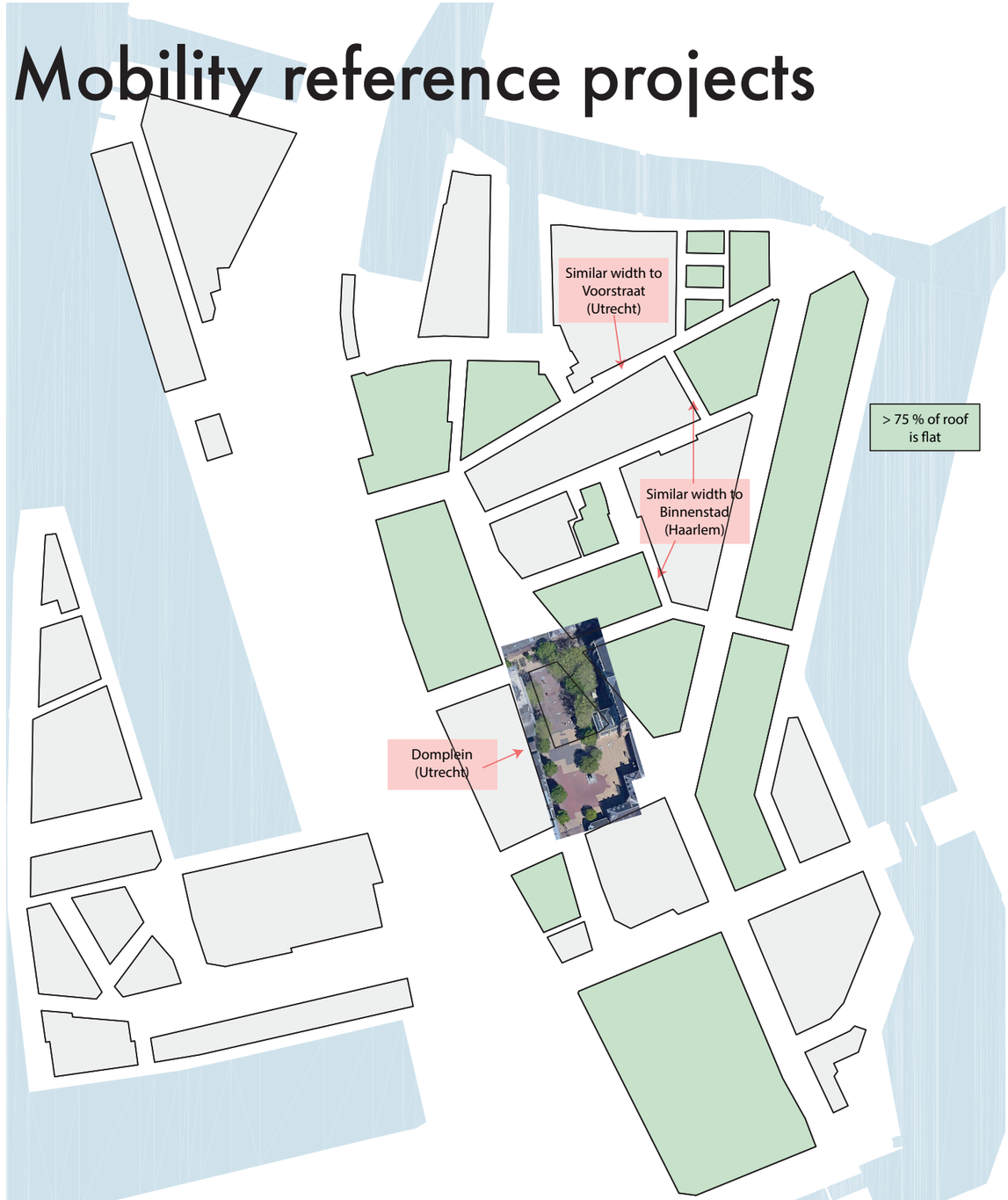




Figure 32: Materialization options (Made by Author)

Mobility reference projects



In this map references from the next page are shown on scale to indicate how they can be used as input for designing specific streets within the neighbourhood of Delfshaven.

Figure 33: Mobility references (Made by Author)

Voorstraat (Utrecht)

- Narrow sidewalks
- Cyclestreet width: 5m
- Single sidewalk width: 2.5m
- Utility strip (one side): 2m



The Voorstraat in Utrecht is an example of a narrow street in a city center where (occasionaly) cars share space with bikes. There are many activities in the plinths and sidewalks on both sides. Trees are present along side the street, but there are no permeable surfaces.

Inner city (Haarlem)

- Narrow street
- Car-free / shared space
- Vertical green
- No front yards
- Possible solution for narrow streets in west/mid Delfshaven



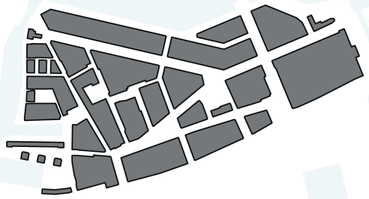
The inner city of Haarlem has multiple narrow alleys. The facade gardens and greenery in pots provide the street with shade, create an interesting path to walk and combats the urban heat island effect.

Domplein (Utrecht)

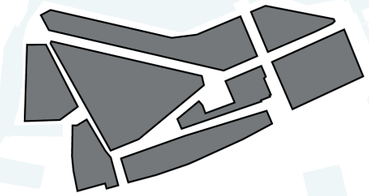
- Pedestrians & cyclists
- local & logistical traffic
- Emergency vehichles
- Mono pavement
- Impoprtent central location
- Many trees
- Few permeable surfaces



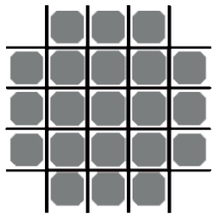
Domplein is a square in the city center of Utrecht. The pavement is the same everywhere but can be used by pedestrians, cyclists and emergency vehichles. The uniformity forces people to slow down and pay attention.

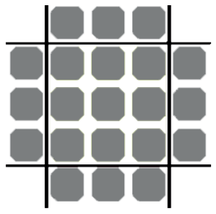


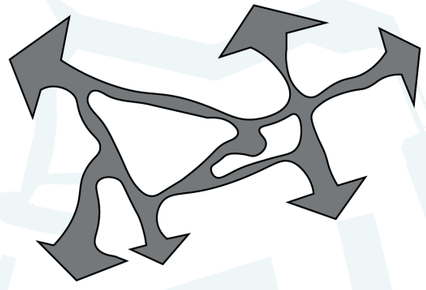
Building blocks
Delfshaven exists of multiple closed building blocks with inner courtyards. The public space and streets are often narrow and completely paved. Towards the west side there is some development from the 80's, but most of the neighbourhood was built between 1900 and 1925. Here the courtyards are open and facades exist of grey bricks instead of the classic Dutch red brick-stone.



Superblocks
To get a better feeling of the morphology of Delfshaven an abstraction of the building blocks is made. Those blocks function as small superblocks. Superblocks are multiple building blocks that only allow traffic to enter the superblocks in small loops and thus fend off most through traffic. In this way accessibility remains while the narrow streets won't get congested with cars.



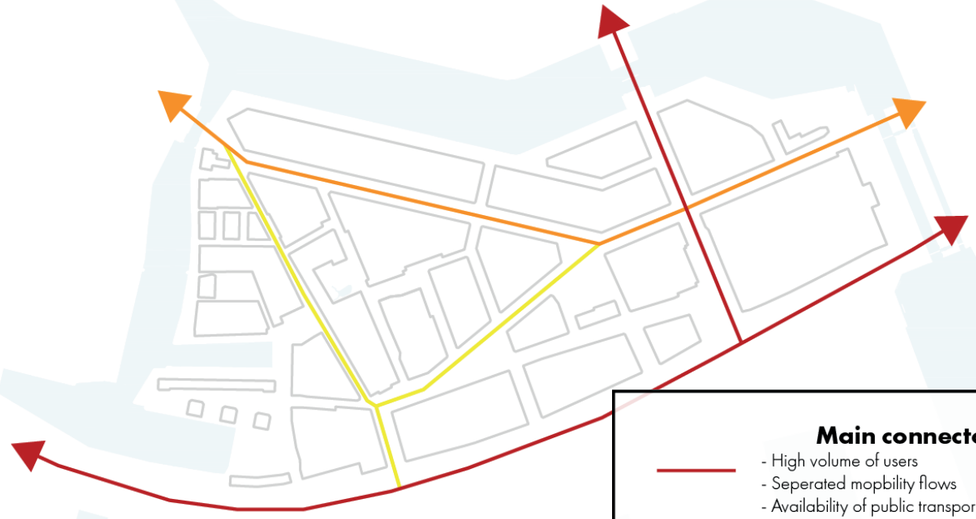




People flows
If we invert the superblocks we get a view of the most important connections in the area. Those streets function either as through connection, collector or just for residents to move around the area. The bridges surrounding the area limit the amount of connections that are possible in and out of the area. These connections will be translated into a mobility design over the next view pages.

Figure 34: Various morphology diagrams (Made by Author)

Street profiles

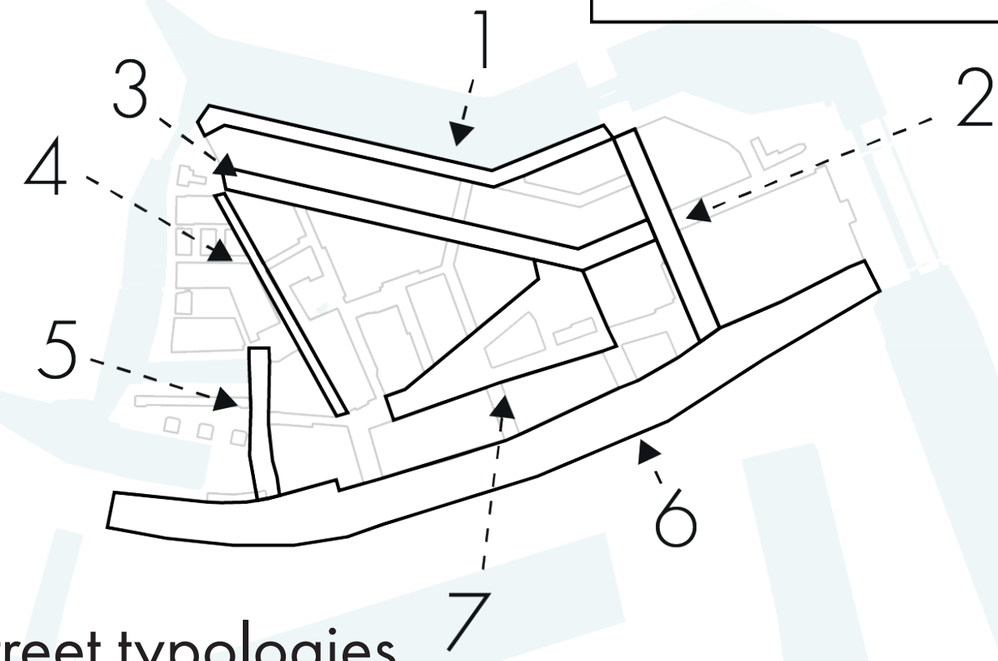


Main connector
- High volume of users
- Seperated mopbility flows
- Availability of public transport

Secondary connector
- Medium/high volume of users
- Seperated cycling & pedestrian paths
- Availability of public transport

Tertiary connector
- Low volume of users
- Accessable for destination cyclists

Important connections



Street typologies

Figure 35: Selection of streetscapes (Made by Author)

1 Coolhaven



2 Pieter de Hoochweg



3 Willem Buytewechstraat



4 Havenstraat



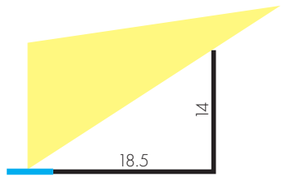
5 Kapiteinsbuurt



6 Westzeedijk



Figure 36: Various streetviews (Google Maps, 2022)



1

10 2.5 4 2
One way road

11.5 5 2
Cycle street

1 10.5 5 2
Waterfront walk

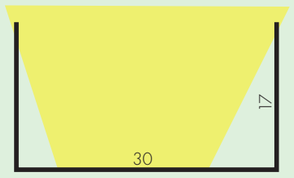
4 7.5 5 2
Boulevard

1 5 1 4 6.5 2
Seperated flows

2 14.5 2
Max. green (two side)

16.5 2
Max. green (one side)

14 2.5 2
One way only



2

4 4 2.5 6.5 2.5 4 4
Max. mobility

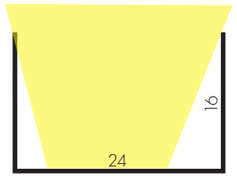
2 4 4 4 10 2
Seperated flows

2 4 4 17 2
Max. green + bus and/or cars

2 4 22 2
Max. green + only slow traffic

2 4 18.5 2.5 2
One way cars + cycling

4 4 4 4 10 2
Max. mobility (west oriented)



3

4 5 4 4 4
Max. mobility

4 5 4 6 4
Max. mobility (car + bus)

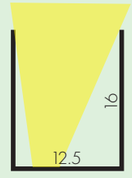
2 4 4 11 2
Max. green + bus and/or cars

2 4 16 2
Max. green + only slow traffic

2 4 12.5 2.5 2
One way cars + cycling

2 5 15 2
Cycle street

4 4 4 9 2
Max. green + mobility



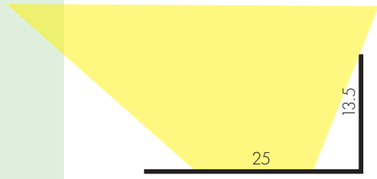
4

2 4 2.5 2
Max. mobility

2 4 4.5 2
Narrow cycle street

2 8.5 2
Max. green

4 6.5 2
Sidewalk + emergency access



5

4 5 4 7 4
Max. mobility

4 5 12 4
Prioritize slow traffic + cycle street

2 4 17 2
Narrow cycle street

2 21 2
Max green

4 19 2
Sidewalk + emergency access

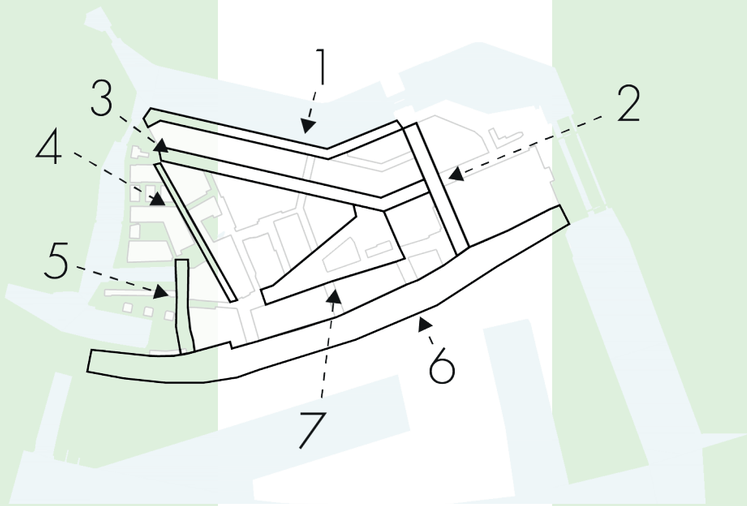


6

4 5 6.5 4 4 25.5 4 4
Max. mobility

4 5 6.5 4 36.5 2
Reduced mobility

2 4 6.5 47
Max green + tram & cars combined



Pedestrian
+ occasional cars
Cycling
Public transport
+ occasional cars
Cars
Natural

Maximize green
Maximize accessibility
Balanced / preferred

Figure 37: Street profile options (Made by Author)

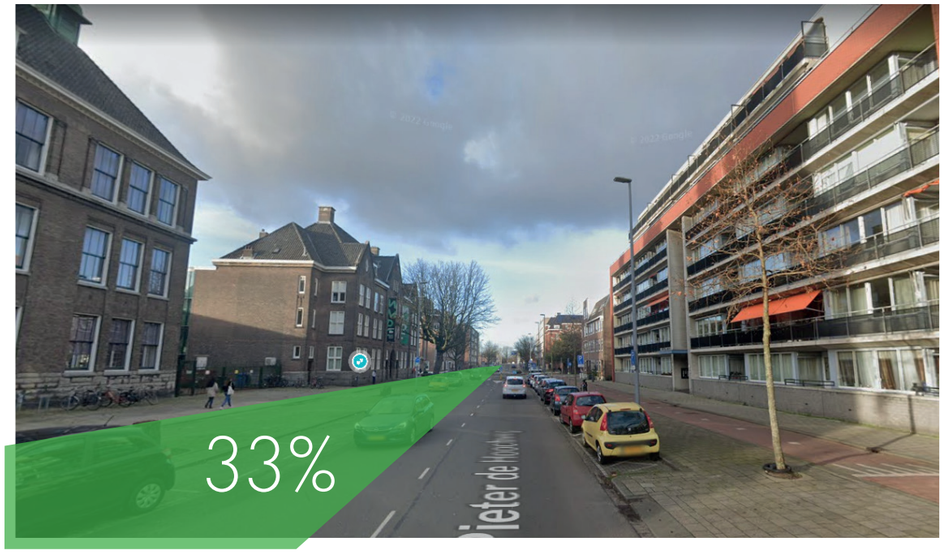
1

Coolhaven



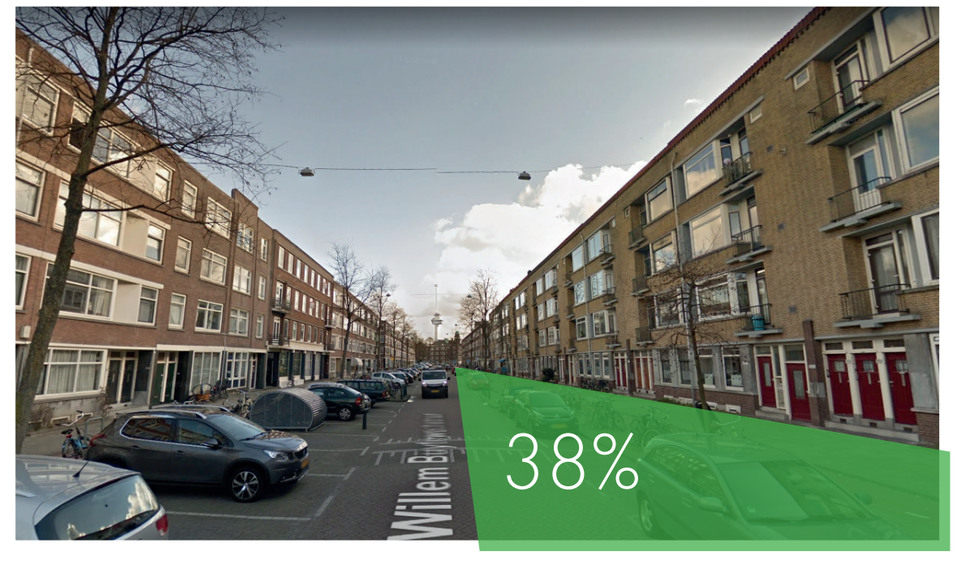
2

Pieter de Hoochweg



3

Willem Buytewechstraat



4

Havenstraat



5

Kapiteinsbuurt



6

Westzeedijk

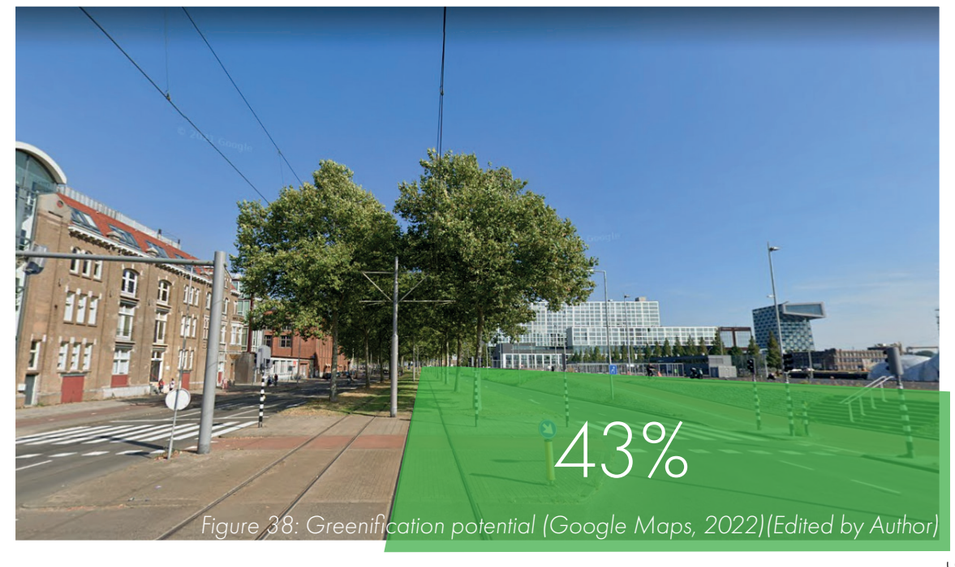


Figure 38: Greenification potential (Google Maps, 2022)(Edited by Author)

Continuity

Streets widen when approaching intersections. Extra lanes are added to allow car drivers to presort in front of the traffic lights, depending on the direction they need to go. This sytem of presorting for traffic lights or priority intersections works very well for the traffic flow and makes sure congestion is less likely to happen. However this widening of streets at intersections causes some other issues.

Ecological corridors

In the next chapter we will be designing the ecological network and climate adaptive solutions. Without going to deep into the theory, it can be said that ecology thrives when natural spaces and corridors are connected. In urban environments, connections are often made within the streetspace. When extra driver lanes are added, ecological strips consequentially become narrower which limits the ecological performance.

Sidewalks

When intersections are redesigned and traffic flow has to increase, lanes are added. Because space between buildings stays constant, space from other uses has to be taken to allow these extra lanes to be constructed. In history this often meant that sidewalks are narrowed. However this narrowing of sidewalks makes walking less pleasent and discourages people to walk. This in turn can lead to more people choosing the car over walking which will worsen the traffic flow again. The best way to increase traffic flow is to reduce the amount of cars on the road.

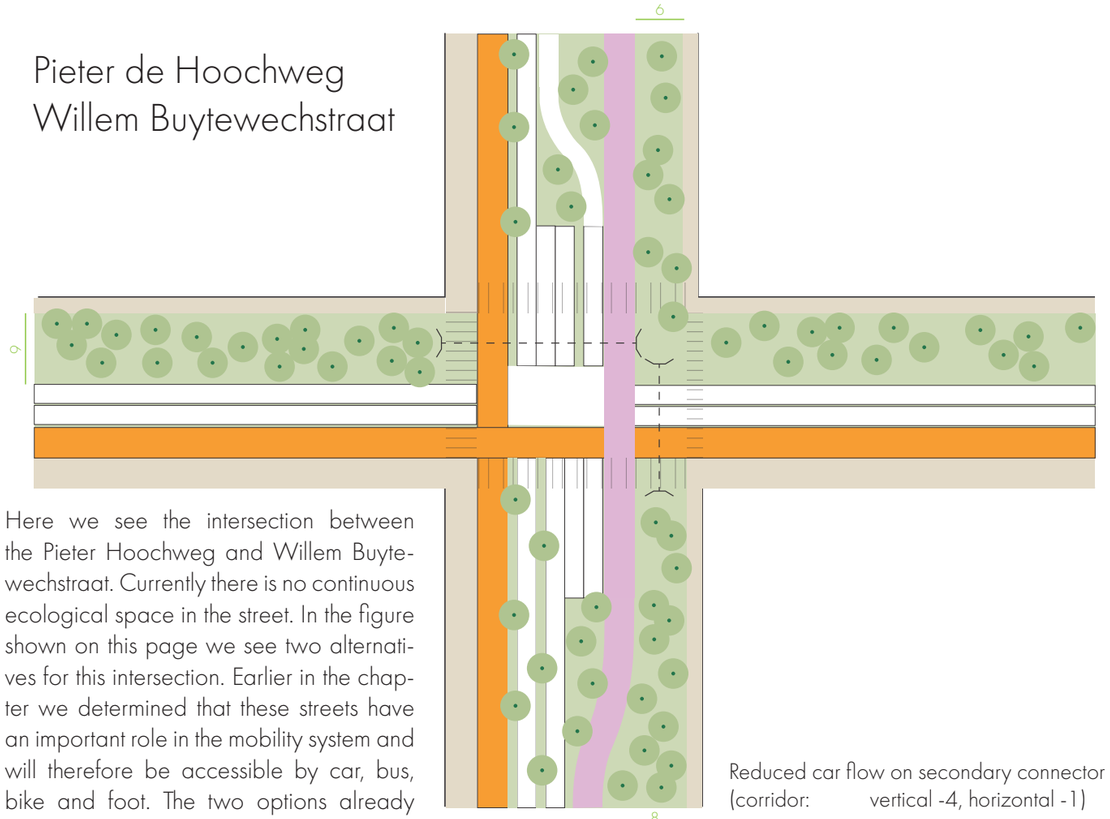
Sustainable mobility

In the last 4 pages the new mobility system (as proposed) was explained. Many private cars will disappear and occasional shared cars will share the road with public transport and cyclists. Cars will have to adjust to the speed of other (slow) road users and are not able to take over. This reduction in car users, the closing of some specific streets and the abolition of private car ownership will cause intersections to require significantly less space to maintain traffic flow. For some major important intersections traffic lights and some presorting lanes still have to be present. But overall way less space is used and is left to allow ecological corridors to be continuous and sidewalks to be wider. To allow wildlife to cross at intersections, animal tunnels have to be added.



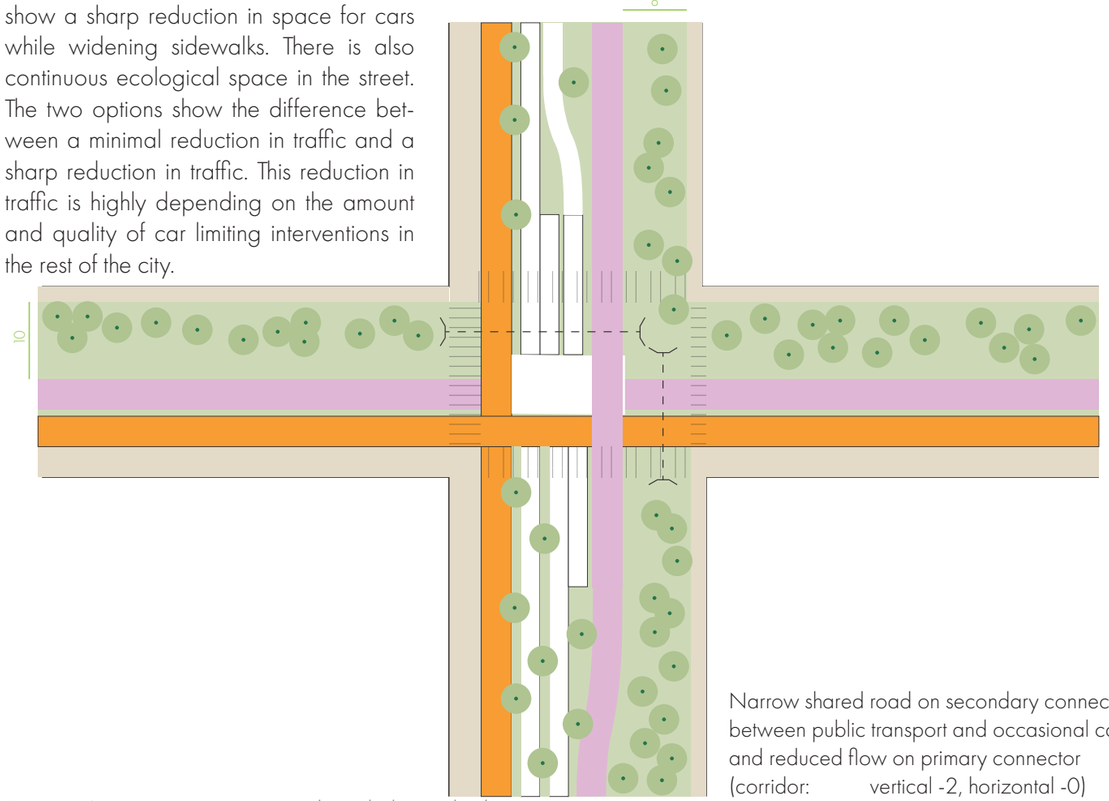
Figure 39: Intersection highlighted (Made by Author)

Pieter de Hoochweg
Willem Buytewechstraat



Here we see the intersection between the Pieter Hoochweg and Willem Buytewechstraat. Currently there is no continuous ecological space in the street. In the figure shown on this page we see two alternatives for this intersection. Earlier in the chapter we determined that these streets have an important role in the mobility system and will therefore be accessible by car, bus, bike and foot. The two options already show a sharp reduction in space for cars while widening sidewalks. There is also continuous ecological space in the street. The two options show the difference between a minimal reduction in traffic and a sharp reduction in traffic. This reduction in traffic is highly depending on the amount and quality of car limiting interventions in the rest of the city.

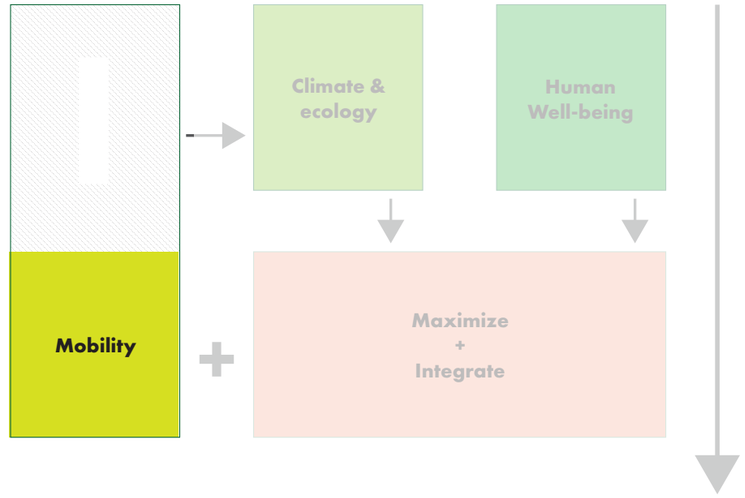
Reduced car flow on secondary connector
(corridor: vertical -4, horizontal -1)



Narrow shared road on secondary connector between public transport and occasional cars and reduced flow on primary connector
(corridor: vertical -2, horizontal -0)

Figure 40: Intersection top view (Made by Author)

Mobility
Maximalization design



The layout
Based on the chosen street profiles, a map has been made showing the different land uses and their sizes on the neighbourhood scale. In this map the streets are seen as homogeneous spaces that have the same profile over the entire length of the street. In reality however this will not be the case. Due to traffic cues, intersections often require more space and amenities like waste collection and bicycle parking also partly have to be solved in the streetscapes. On the next page these additional spaces are analized and discussed.

Shared space
The new mobility system will shift current car users towards other modes of mobility such as bikes, public transport and walking. This means that current car infrastructure can partly be taken out and the space can be used for other land uses. To accommodate the increase in bike, public transport and sidewalk users those spaces have to be enlarged while also enough space remaining to achieve the climate and ecological goals. For this reason different types of mobility share movement space to allow more space to be used for social, climate and ecological goals. Depending on the importance of the connection (page 57; figure 35) a seperated way for motorized traffic is neccessary or not. If not neccessary occasional neccessary car trips are merged with cyclists or public transport and if not present in the street they can occasionally use sidewalks to reach the loading bay proximate to their building.

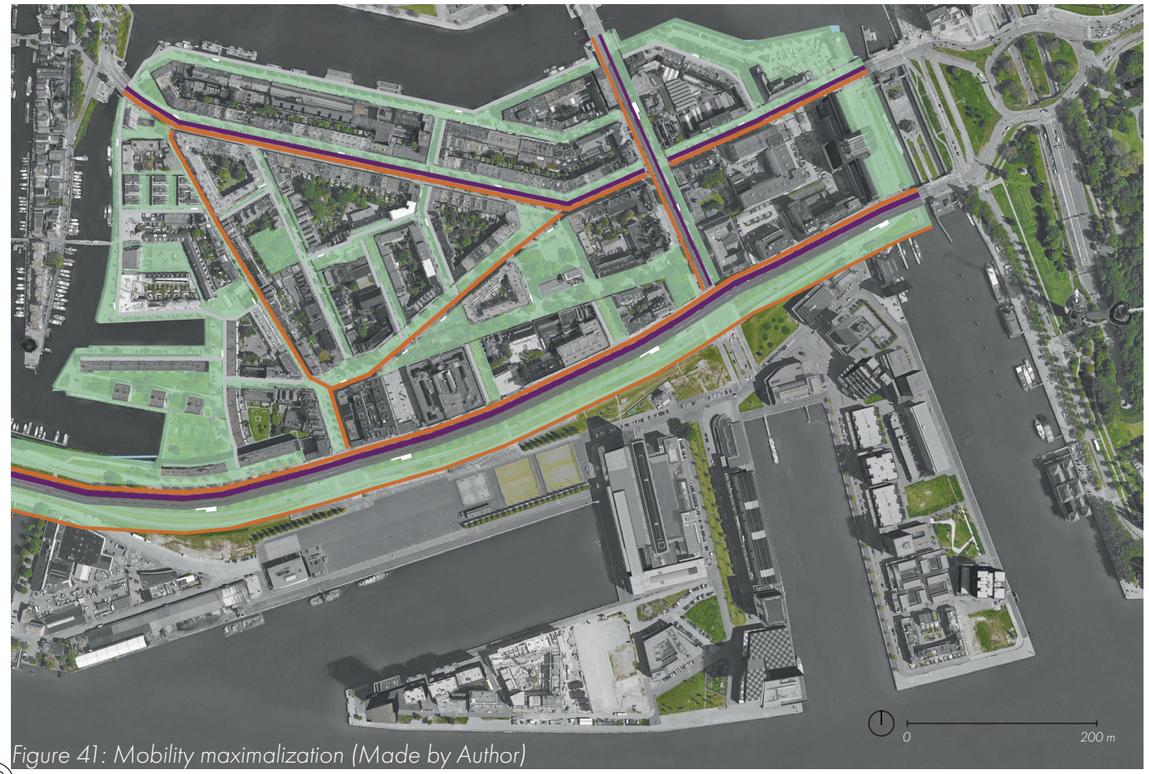
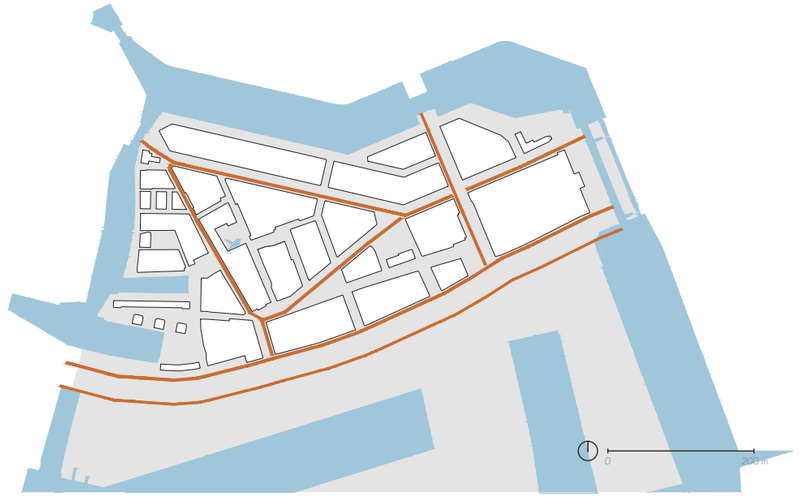
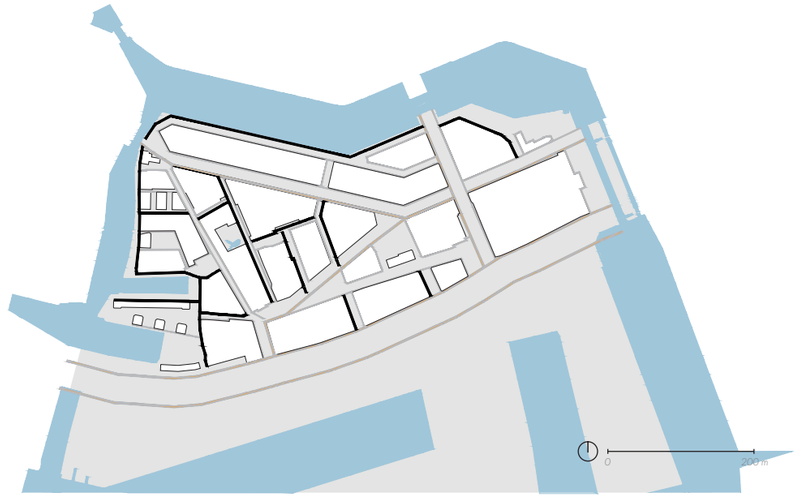


Figure 41: Mobility maximalization (Made by Author)

Cycling
The cycling network provides direct connections between key destinations and bridge connections. Some cycleways are shared by motorized vehichles due to the limited space in some of the streets. Cycleways are wider here and allow cars to pass oncoming cycling traffic.



Walking
As one of the priority flows a lot of sidewalks will stay present in the area. Every building with entrances on the roadside has atleast a 2 meters wide sidewalk to maintain accessibility. On important connections the sidewalk is widened to atleast 4 meters. In secondary streets, the sidewalk is also widened to 4 meters to allow for incidental use by motorized vehichles such as emergency vehicles.



Public transport
The most important connections that also connect the area to the wider city area have dedicated public transport lanes. For trams the width is 6.5 meters and allows for a 2 way connection. The buslanes are relatively narrow 5 meters and are sometimes shared with motorized vehichles.

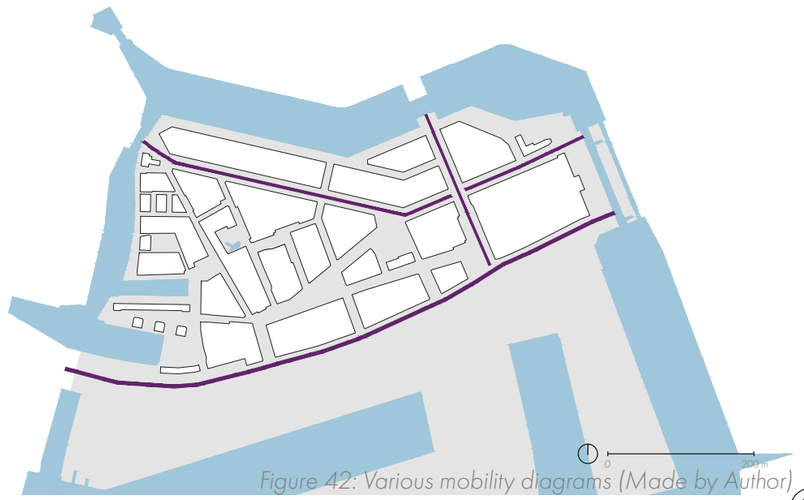
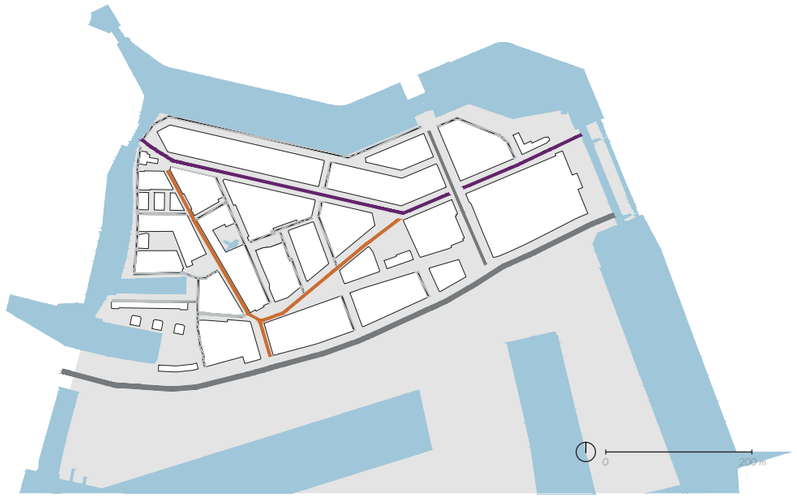
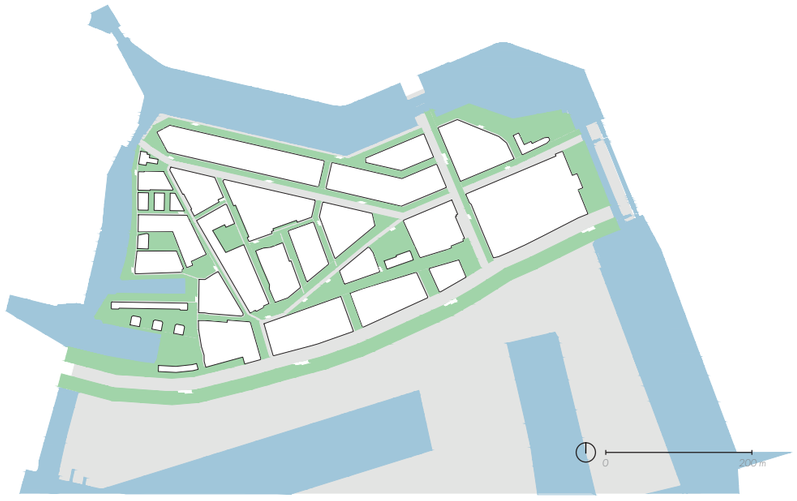


Figure 42: Various mobility diagrams (Made by Author)

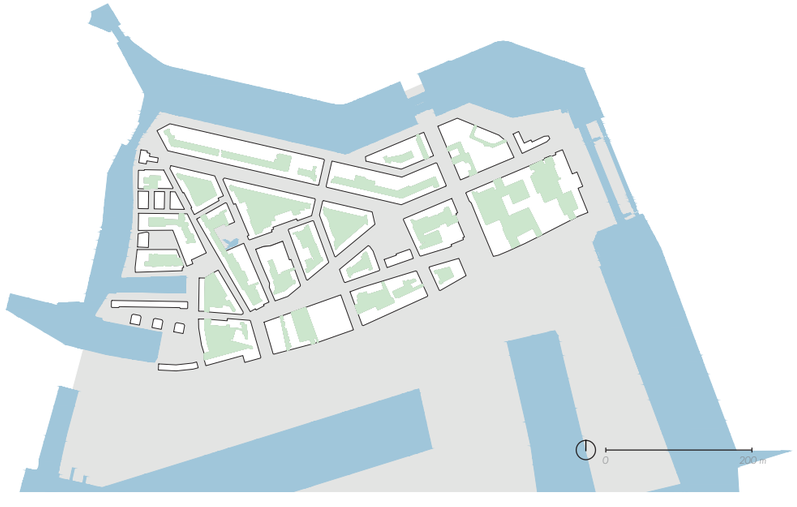
Motorized vehichles
Motorized vehichles such as logistical vehichles, emergency vehichles, etc. can access almost every street within the neighbourhood. Due to the expectation that this will only be neccessary in specific situations. The car shares a lot of space with either cyclists, busses or pedestrians. The most used connections have separated lanes for motorized vehichles.



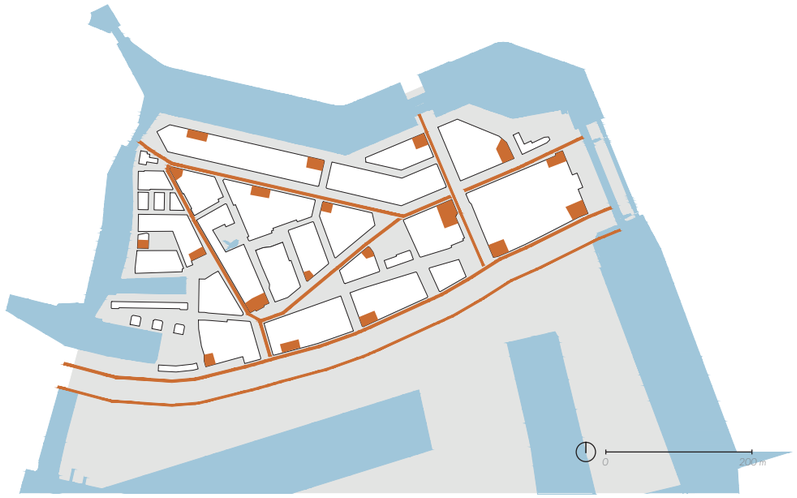
Ecology (streetscapes)
As one of the main goals is to create a ecological and biodiverse ecosystem within the build environment, a lot of the streetscapes will be changed from paved surfaces to natural permeable surfaces. The aim is to free up as much space as possible to counter climate change effects, increase ecological value and biodiversity and improve the quality of life for residents.



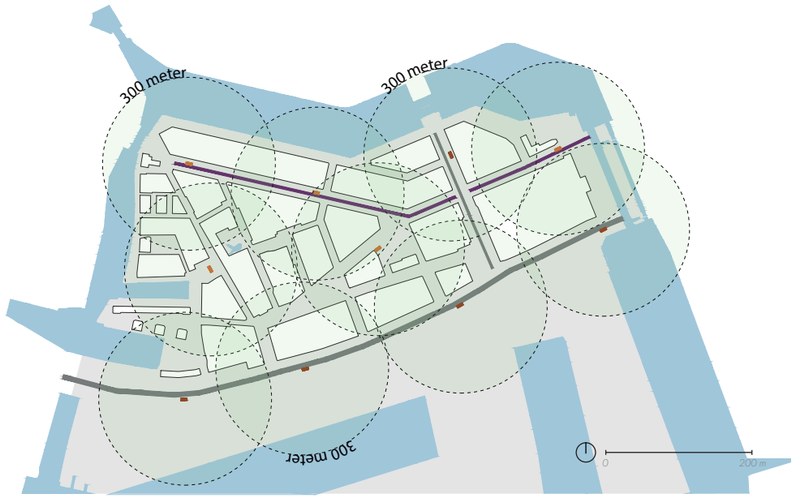
Ecology (courtyards)
It would be simplistic to only look at streets in terms of ecological performance. Courtyards, brownfields and green edges play a significant role in ecology and biodiversity (Norton, 2016). Intense management however limits effectiveness of these 'natural spaces'.



Bicycle parking
In the map you see the cycling network. The network exists of dedicated cycle paths and cycle streets (shared with cars). At the busy intersections bicycle parking garages will be created within the plinths of the building. This requires some people to walk a little to their bike, but this will keep a lot of space within the streets free for other uses.



Waste collection
To collect waste, multiple collection hubs are located alongside the dedicated car lanes and shared spaces. This will cause the least interaction with other modes of mobility and thus reduce nuisance. For this project waste output is expected to decrease over time.



Loading bays
For some specific situations individual motorized vehichles may enter the area. To facilitate these vehichles with space to load and unload without hindering other traffic, loading bays are created. They are spread equally over the are and will be within 50 meters of most residents and always within 100 meters.

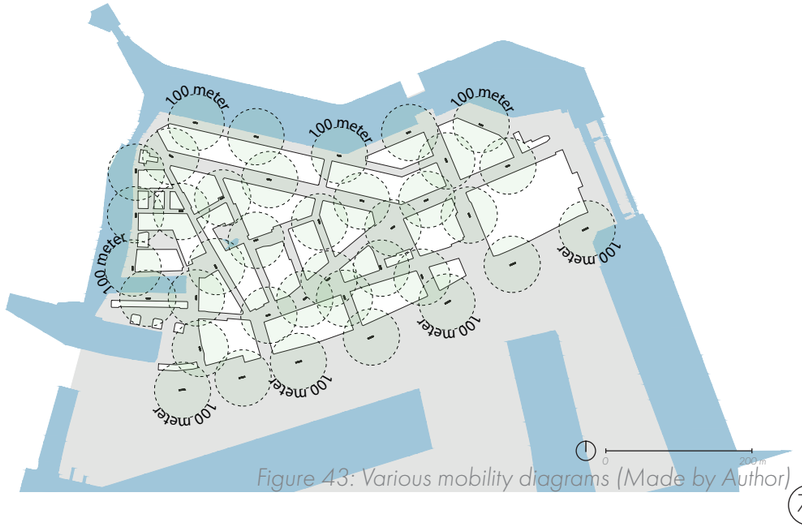


Figure 43: Various mobility diagrams (Made by Author)

5

Ecology

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Neighbourhood ecosystem

‘Cultuurrijk, stadswijken’
Delfshaven is one of the 19th century neighbourhoods that lie around the city center. The neighbourhood exists mostly out of closed building blocks with inner gardens. In these inner gardens you can often find old large trees. There is not much public green in the streets and public spaces. There are some playgrounds and since recently, greenification efforts have taken place and turned some sidewalks spaces into green space. Buildings are often old and due to different methods of insulation nowadays, bats can access the facades of these buildings. Renovated parts of the neighbourhood and their buildings are less accessible to animals. Many residents in the neighbourhood have added green facades and little front gardens. These attract multiple species such as butterflies and bees.

The municipality wants to improve the water quality of the canals to increase fish populations. They do this by adding vegetation alongside the canals and by sanitizing waterflows that enter the canals (Rotterdam, 2014).

Ambassador species
(Gemeente Rotterdam, 2014):

Swift



Horse Chestnut

Figure 44: Neighbourhood green typologies (Rotterdam, 2014)

Biodiversity

Biodiversity, how does it work?
Biodiversity is an umbrella term for everything that is related to the diversity and abundance of nature and animal species in an area. Diversity and abundance of species is highly related and one species can not survive without the support of a well functioning and resillient ecosystem. A basic abstraction of an ecosystem is shown below (figure 45). Plants and trees grow by extracting CO^2 from the air and nutritions from the soil rich of biologic remains. Animals (consumers) eat fruits and leaves from those trees and in return produce more CO^2. Decomposers or reducers such as worms live of the feces of animals and are themselves food for the animals.

What does this mean for the project?
All parts of the ecosystem are related and reduction of one, means inevitably also a reduction in the other parts. Ecological corridors, parks and other areas should therefore be designed with this complicated system in mind. Consumers, reducers and producers should be present in all parts of the ecological system.

Further on in this chapter, an analysis has been done on the types of producers in the area of Delfshaven (page 84 - 91) to determine what animal (consumer) species are likely to be living here or could be attracted.

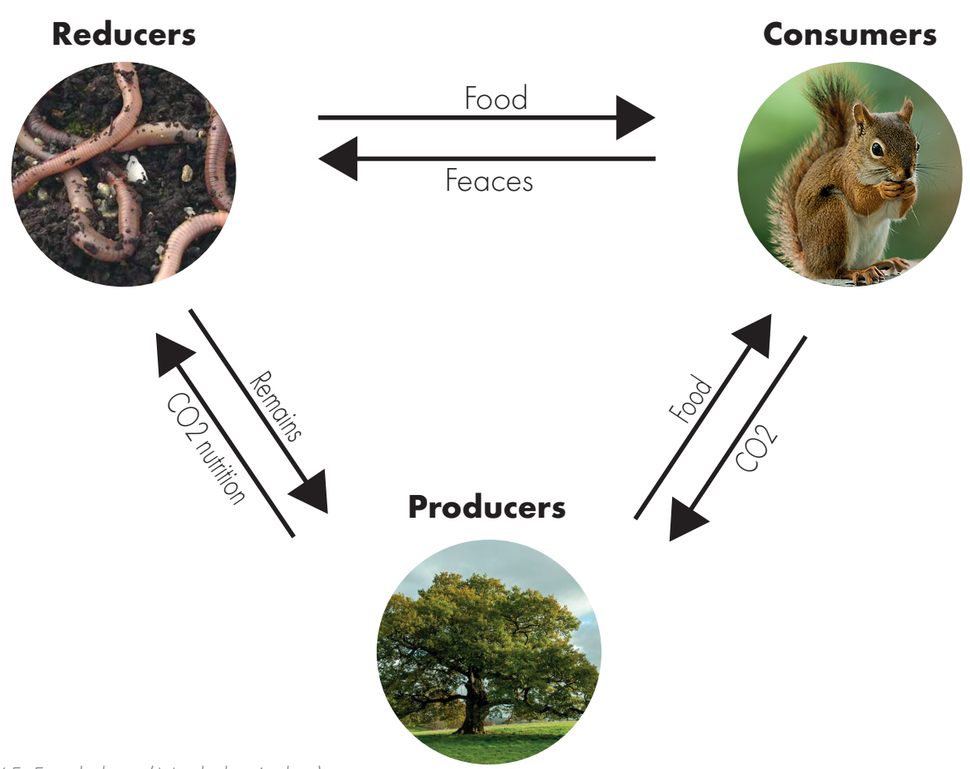


Figure 45: Food chain (Made by Author)

Urban habitats

Effectiveness of nature distribution

To talk about effectiveness of ecology we first have to determine what effects we strive for. Nature can help by solving many issues from humans mental and physical health to strenghtening end expanding animal habitats. For this chapter about ecology, the aim is to find conclusions on nature distrubution related to biodiversity and species migration.

Urban biodiversity consists of many different species such as mammals, birds, insects, etc. It also includes vegatation such as trees and plants. Mammals are a big part of our animal populations. Mammals often don't move over long distances, but move around a well known area to find food and shelter. They can move around in narrow corridors, but noise and smell disturbance should be minimal. They also need little parks to rest, if not they will most likely migrate out of the area (Norton et al., 2016).

We can see birds in many parts of our urban environments. They often move around via trees. They need specific types of vegetation to feed from, but those are often already present in Dutch cities. Bird populations can be limited when large areas have no trees and function as a barrier.

Animals with low daily movement such as snails and various types of insects don't need specific habitats or ecological networks. Small patches of nature and different types of vegetation already support this part of biodiversity significantly. It is thus important to conclude that small unconnected ecological interventions can already improve biodiversity (Norton et al., 2016).

Animals with high daily movement such as reindeers are not typically seen in urban environments. They are less likely to coexist with humans in the same space. However, if wished for they require larger ecological corridors to move and large parks to rest and feed in (Norton et al., 2016). It is very unlikely that this type of animals can be attracted to highly urbanized areas areas like Delfshaven.



Figure 46: Effectiveness of ecology distribution (Made by Author)

Urban ecosystems

Besides the habitat requirements of specific types of species, the research also describes more general findings on urban habitats (figure 47). Some of the findings will be explained further below.

Different ecosystems create different habitats for different species. Some animals can survive in different habitats and some need to feed on species coming from other habitats. For multiple reasons a variety in habitat types enriches the species diversity and increases their populations. Quality and size of surrounding nature also positively impacts biodiversity.

In general the research also mentions that large urban areas have a negative effect on species migration, but that those negative effects can be mitigated by bigger portions of nature and by connecting nature via ecological corridors. It also mentions how individual management of backyards create poor habitats, while collectively or even unmanaged small plots of nature support biodiversity considerably.

Finally it mentions how the urban heat island effect and manually feeding bird populations can influence migration patterns.

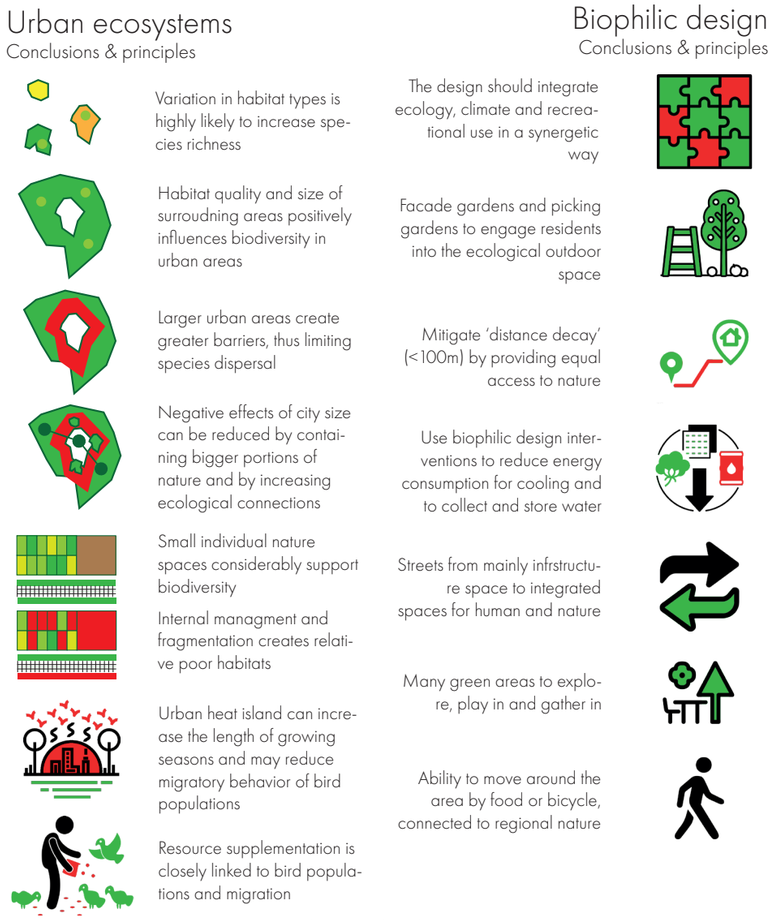


Figure 47: Urban Ecosystems and Biophilic design (Made by Author)

Biophilic design

Biophilic design is a term used for designing with the relation between humans and nature in mind. Biophilic design is about integrating ecology, climate and humans to create synergetic solutions.

A paper by Kothencz (2017) reviews multiple biophilic interventions and suggest guidelines to secure a synergetic outcome. These guidelines include access to nature by residents, function of streets and the ability to move around by foot or bike.

Delfshaven

For the ecological maximalization design it is important that all these characteristics of habitats, migration patterns and biophilic guidelines are taken into consideration to get the best and most integrated final result.

Plans from the municipality

Municipality plan
The municipality of Rotterdam has made an Urban Nature plan for the city in 2016. In the plan they discuss the origin of the city, the many paved surfaces and the sparcely spread patchworks of nature. In their plan they explain about their vision to change this patchwork into a network of ecological corridors. In figure 51 we see this 2016 Nature Map. All natural areas in the city are highlighted and proposed connections and corridors are marked by purple lines.

Delfshaven neighbourhood
In the neighbourhood of Delfshaven we see that the Westzeedijk is marked as a main ecological corridor. The westzeedijk connects Het Park (image 2) to the west side of the city. Within the area are a couple natural areas marked such as De Schat van Schoonderloo (image 1) and Landgoed van Cool tot Terhave.

In relation to the design assignment
The municipal vision of creating an ecological network and connecting patches into this networks connects really well to the vision of the design project since it is neccessary for many species to have natural spaces connected to each other. Connecting nature and combining pedestrian and cycling routes also improves users experience and can change perception of time and distance and make it more likely as an alternative mode of transportation (Beatley, 2011).


Figure 49: De Schat van Schoonderloo (Rotterdam, 2021)


Figure 50: Het Park (wikipedia, 2021)

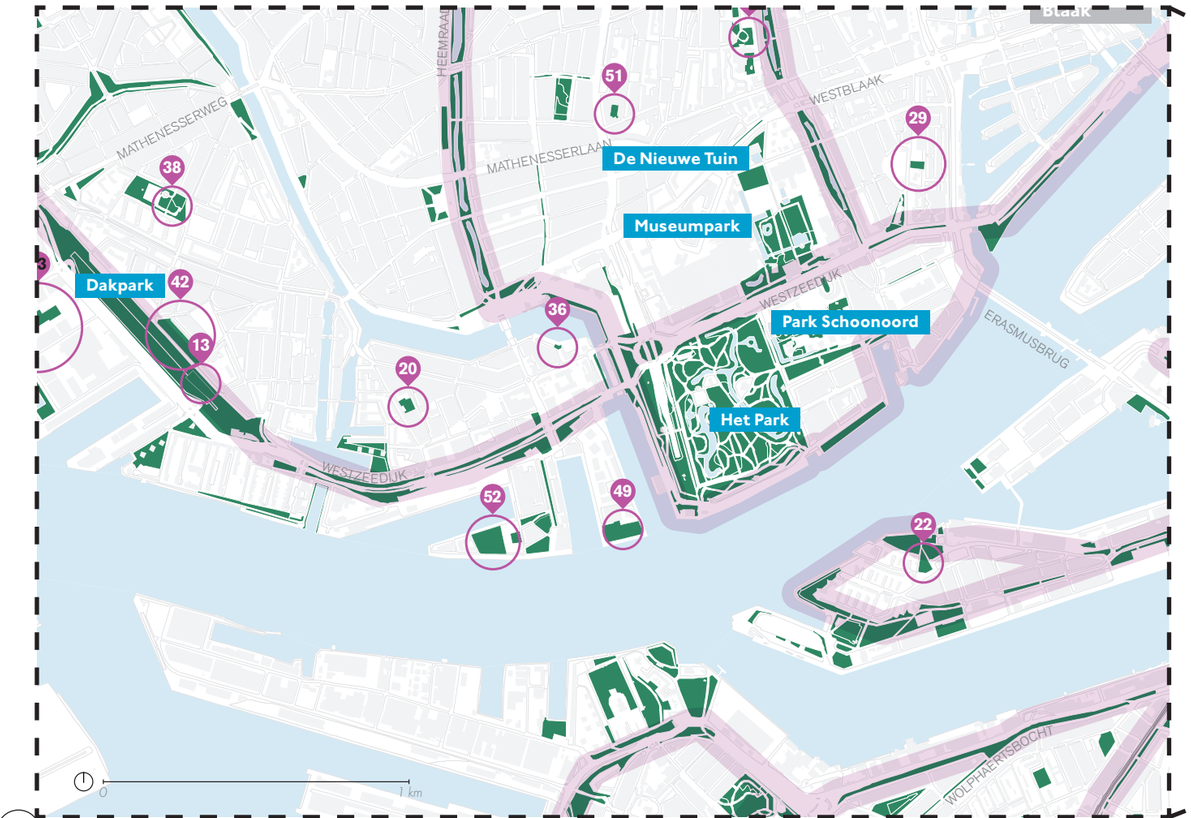


Figure 48: Urban Nature Map, Delfshaven (Rotterdam, 2016)

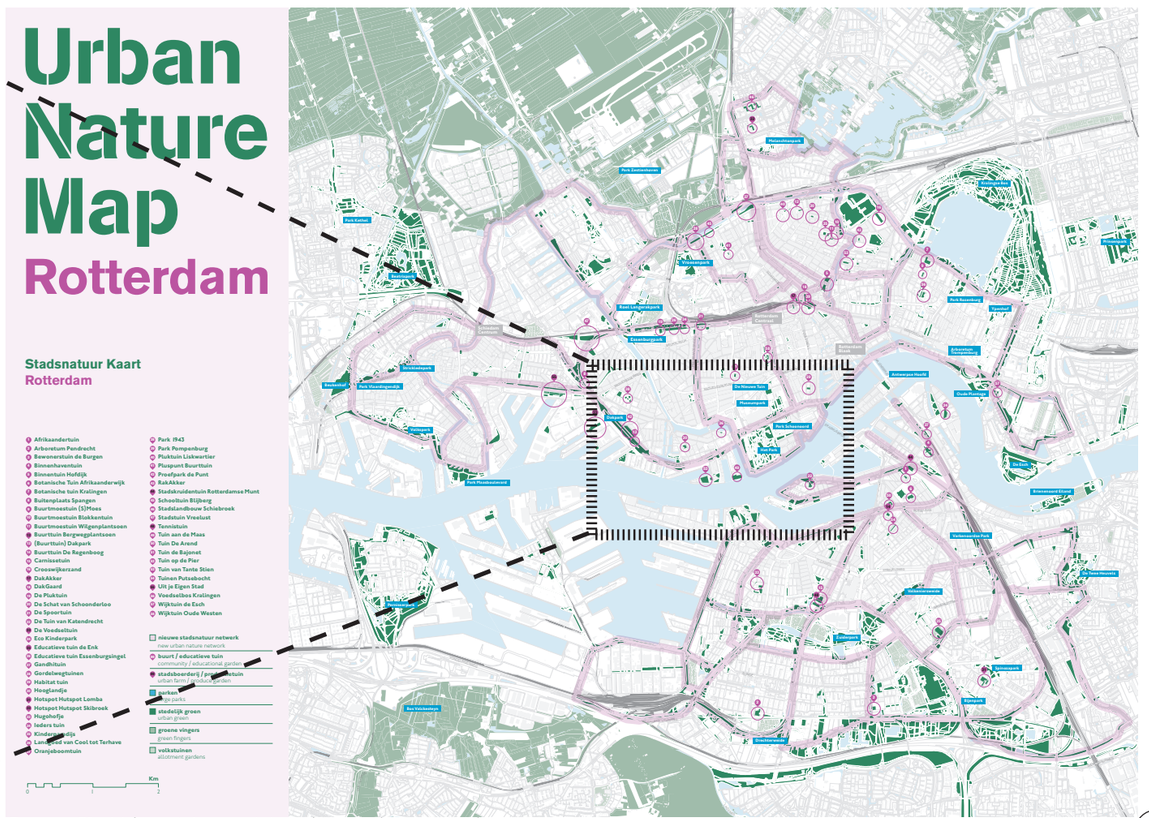


Figure 51: Urban Nature Map (Rotterdam, 2016)

Reflection
The plan of the municipality is very ambitious. It proposes over 190 kilometers of ecological corridors, many of them on locations that are currently nearly completely filled with busy intersections, squares or even buildings. All together the project has a lot of challenges and the costs can easily become very high.

The costs
Creating the ecological network means demolishing a lot of infrastructure, buildings and other facilities such as sportsfields and parking facilities. These infrastructure connections have to be rerouted, tunneled or connections have to be shut of completely. To allow for trees to grow on these ecological corridors, underground infrastructure also has to be changed. All these changes increase the price and will drastically change logistics and mobility systems within the city. Calculated with the help of a table showing construction related costs the full ecological network will cost an estimated €46 million euros (figure 54). Since this is a 2050 vision, this means that on average 3.6% of the costs have to be paid annually. This puts the project at a cost of €1.65 million euros per year.

The financing
The municipality has fixed budgets for its annual spending. These budgets are tightly managed and many costs return annually. To allow for new investments, previous budgets often have to be reduced.

Within the budgets are 'gebiedsontwikkeling', which means the development of urban areas and the 'stedelijke inrichting en ontwikkeling' which means city layout and development, but which is more of a maintenance budget than a new development one.

If we only consider the first budget of 'gebiedsontwikkeling' to be suitable for this ecological network vision. This consequently means that annually 6.1% of the budget will have to be paid to construct and transform all the proposed ecological connections. Within an already tightly managed and overused budget this is a very high amount.

The benefits
It would be wrong to exclusively look at the financial burden of the project. Creating a ecological network that boosts ecology and biodiversity performances has many qualities that directly and indirectly benefits budget spendings, quality of life and health of residents. They bring down noise pollution, reduce greenhouse-gas emmisions, improve air quality and decrease obesity rates (Allam et al., 2022). For example, the budget for 'volksgezondheid en zorg'(healthcare) was 856 million dollars in 2022 (Gemeente Rotterdam, 2022). One of the biggest costs related to healthcare are treatment of people with cardiovescular diseases (Erasmus MC, 2019). These diseases are caused by breathing polluted air, smoking cigarettes or working in heavy industries. A 2020 research conducted in Europe shows that people living in ecological urban areas are less likely to get cardiovescular diseases (Dalton & Jones, 2020). Creating a city wide ecological system can increase health and reduce healthcare costs citywide. Even if it only reduces healthcare costs by 0.19%, it would be enough to finance the whole corridor system.

Even when it is hard to know exactly what the effects of an ecological network like this would be, it is very plausable that the high costs can earn itself back and not put extra burdens on the municipal spendings in the long term. It is also interesting to look at the benefits for residents. How ecological spaces exactly benefit residents will be explained more eleborately later, but what is clear is that ecological environments allow people to live healthier, excercise more, spend less time waiting for traffic lights and breathing less polluted air. Ecological environments also positively effect the amount of physical movement in comparison to car use as mode of transportation (Sarkar et al., 2015). There is also an economic benefit for residents living close to nature. Research done at the university of Groningen shows that dwellings within a range of 500 meter of natural areas averagely cost 5% more than similar dwellings without nearby nature (Hulshoff, 2008).

Vague description
It is hard to figure out what these ecological corridors will look like. The municipality isn't very specific on the types of vegetation, species they want to attract or any other detail that is of vital importance to estimate the effect of the network on the ecology of the city. The design of the corridors and especially the amount of trees heavily influence the costs and can thus decrease or increase the estimated budget. The nature patches that are highlighted on the map in figure 51 also are not all similar. Some are great ecological places with high variety in plant species, while some others are just patches of nature with barely any ecological value. Connecting these places does make very little sense.

Lasten: € 4.150 - € 3.722
Bedragen in miljoenen

Programma	2022	2025
Algemene middelen	€ 72	€ 122
Beheer van de stad	€ 404	€ 409
Bestuur en dienstverlening	€ 87	€ 80
Cultuur, sport en recreatie	€ 239	€ 232
Economische zaken	€ 38	€ 26
Maatschappelijke ondersteuning	€ 225	€ 194
Onderwijs	€ 208	€ 191
Openbare orde en veiligheid	€ 165	€ 149
Overhead	€ 496	€ 469
Stedelijke inrichting en ontwikkeling	€ 406	€ 269
Verkeer en vervoer	€ 162	€ 103
Volksgezondheid en zorg	€ 856	€ 686
Werk en inkomen	€ 794	€ 791
Totaal	**€ 4.150**	**€ 3.722**

Bestemmingsreserves
Bedragen in miljoenen

Bestemmingsreserves (top 10)	2022	2025
Rotterdamse Investeringsmotor	€ 1.658	€ 1.728
Algemene Reserve*	€ 106	€ 161
Nationaal Programma Rotterdam Zuid	€ 82	€ 111
Tweedelijns WMO en Jeugdhulp*	€ 33	€ 33
Gebiedsontwikkeling	€ 30	€ 23
BUIG*	€ 27	€ 27
Bodem	€ 21	€ 12
Kredietrisicoreserve*	€ 19	€ 19
Regiodeal onderwijs	€ 14	€ 14
Energietransitie	€ 10	€ 3
Overig	€ 53	€ 49
Totaal	**€ 2.053**	**€ 2.180**

*** Onderdeel van het beschikbare weerstandsvermogen**

Figure 52: Financial budgets municipality of rotterdam 2022 (Rotterdam, 2022)

Selection of the plan

Reduced municipality plan
The scale of the municipality ecological network is very ambitious and costly. It is also vague in its design and can therefore easily become a network of generic grasslike areas when budgets are too tight and expenses have to be cut. In this project a selection of the network on the north part of the city will be shown as an example to reduce costs and maintain a high quality of ecology. The selected corridors are picked on the importance of their connection between existing ecological patches and to the outside the city, on their width (and therefore availability of space) and connections that have the greatest importance for mobility and accessibility are not included in this network so that they can remain as mobility corridors. An east west corridor following much of the Westzeedijk is the main corridor. This ecological strip will follow the river and connect many nature patches including 'Het Park'. This corridor is shown in red in the image below (figure 53). The remaining selected corridors are highlighted in purple and connect all the major ecological areas and connect the east west corridor with the nature on the north side of the city.

The costs and financing
The selection in the network costs significantly less than the full scale network. In contrast to €46 million euros estimated for the whole network, this reduction will only cost around €12 million euros (figure 54). When we again compare this to the development budget, this means it will cost around 1.6% of the budget annually. Since the chosen connections don't include the most busy infrastructure, changes in the network could cost way less and therefore reduce the price even more, while benefits such as a healthier environment and more incentives to walk and cycle might still significantly reduce healtcare budgets.

Delfshaven neighbourhood
For the project area, these conclusions mean that the east west ecological connections are very important to create a city wide ecological network. Migration of species will be more likely to occur when everything is well connected and designed with ecological performance as one of the main principles. However the focus should not only be on attributing to this network, but also to create a local ecosystem thats is self-reliant.

After 2050
The municipal plan envisions to complete an ecological network in 2050. However expending the network more and improving urban ecosystems within the whole city of Rotterdam should be pursued continuously. Effects named earlier in this chapter on reducing healthcare costs and increasing the quality of living can still be improved more after finishing this project.

The design for Delfshaven can function as an example of nature oriented development while still remaining a high quality of living for its residents.

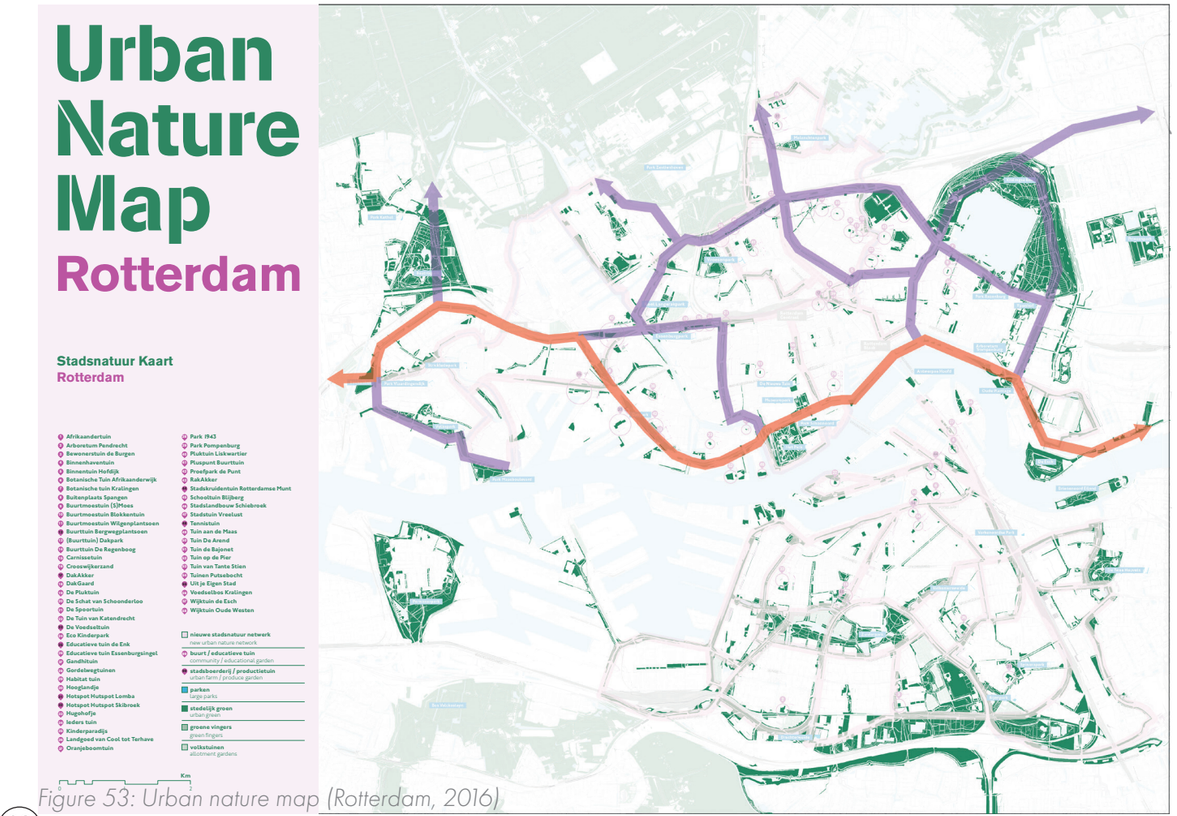


Figure 53: Urban nature map (Rotterdam, 2016)

Demolishion costs (€/m2)	36		For example:	Removing pavements, demolishing structures, etc.		
Cost of changing underground infrastructure (€/m2)	50	Est.	For example:	Utility tunnels, rerouting, etc.		
Average cost of mobility solutions (€/m2)	175	Est.	For example:	Rerouting, tunneling, building alternative mobility, etc.		
Cost of ecological transformation (€/m2)	76		For example:	Planting trees, decontaminating soil, adding water bodies		
Total cost of transformation (€/m2)	€ 301,00					
Avarage width corridor	50					
Year of completion	2050			Surface to transform	Costs	Price per year
Current year	2022					
Total length corridors (m)	191.808		Percentage green (%)	20%	153446	€ 46.187.366,40	€ 1.649.548,80
East-west corridor (m)	15120		Percentage green (%)	15%	12852	€ 3.868.452,00	€ 138.159,00
Purple network (m)	38160		Percentage green (%)	30%	26712	€ 8.040.312,00	€ 287.154,00
Total preferred network (m)	53280				39564	€ 11.908.764,00	€ 425.313,00

Figure 54: Cost calculation for urban ecological network (Made by Author)

Biotopes - Parks

All the nature patches and corridors within Rotterdam consist of different biotopes. Biotopes are homogeneous ecosystems that over a larger area have similar plants, trees and animal species. Between biotopes are transitional zones or barriers. In the urban context of Rotterdam most biotopes end with barriers like roads, building blocks or canals. Researching biotopes can help by determining which animal species live in the area and which might be able to live here if attracted.

Plant & tree species research

To determine which biotopes are surrounding our project area, research is done on site. With help of an app called Picture This (Picture This, 2022), plants are inventoried and counted for 5 park areas and 13 streetscapes. The 5 parks are; Heemraadspark, Dakpark, Schat van Schoonderloo, Museumpark en Het Park. In this subchapter results and conclusions on the research in these parks will be shown.

Results

On september 1st 2022, over 60 different plant and tree species have been inventored and counted in the previously stated 5 areas (Appendix 1). Over 300 plants and trees have been counted and have given insight into the ecosystems. By looking at overlapping species, we can see in figure 56 that area B, D and E are very similar, although area B has a significantly higher variety in species than the other two areas. We can also see that area A has a relatively low variety in species compared to the other areas and we can see that area C has no overlapping species and mostly houses plants that are far from native here.



Figure 55: Biotopes - Parks (Made by Author)

Biodiversity

The biodiversity surrounding Delfshaven is shown in figure 56. Different trees and plants attract different species and grow best in different conditions. For example, the Weeping Willow and Hairy Willowherb grow well in wet conditions and close to the waterfront, while the Bald Cypress and Oriental Sycamore grow less well in wet conditions but are known for having a strong root system and those trees can grow relatively old. Most analyzed species attract small mammals like squirrels. Multiple species attract birds and smaller insects like moths, caterpillars, butterflies and wasp-like insects.

As said before, the area of the Schat van Schoonderloo has no overlapping species with the other areas. The area, although looking wild, is highly managed and fragmented. Many bugs, butterflies and bees live here but it is unlikely that much migration between the area and its surroundings happening.

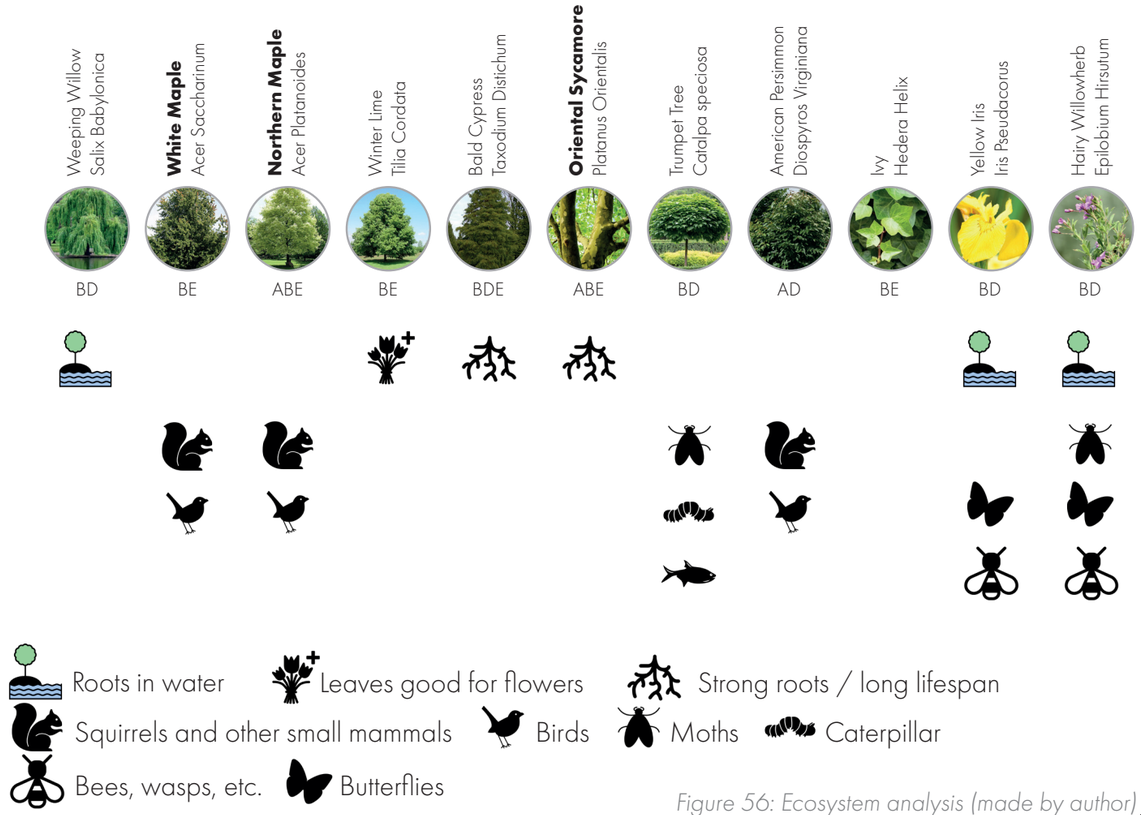


Figure 56: Ecosystem analysis (made by author)





















Figure 57: Various images of parks (Made by Author)

Biotopes - Streets

Streets do, just like parks, function as biotopes. Often a street has similar vegetation and design over its length. Street biotopes often end at big intersections or when connecting to another road. Researching those streets can give valuable insight in the ecosystems that exist.

Plant & tree species research

To determine which biotopes are present in the streets surrounding the Delfshaven Neighbourhood, a research is done on site just like the one done for parks on the previous pages. 9 streets are selected that both vary in type, width, vegetation and location related to Delfshaven. In the same order as the numbers in figure 58, the streets are: Graaf Florisstraat, 2e Middellandstraat, Claes de Vrieselaan, Mathenesserlaan, Hooidrift, Aelbrechtskade, Wijdesteeg, 1e Schansstraat, Spanjaardstraat, 2e Schansstraat, Piet Heynsplein, Willem Buytewechstraat, Schoonderloostraat, Pieter de Hoochstraat, GJ. de Jonghweg & Westerkade

Results

On september 28th 2022, almost 60 different plant and tree species have been inventoried and counted in the 13 different streetscapes (Appendix 1). Almost 700 plants and trees have been counted and have given insight into the ecosystems of those streetscapes. From the results of this research we can conclude that some streets are more biodiverse than others and some have only few vegetation while others have an abundance. What was also immediatly noticeable was the amount of vegetation in the pavement and on the facades. Much of this vegetation is added by residents or in collaboration with the municipality (Rotterdam, 2019). We also see that some tree species that were abundantly present in parks are also often present in streets. Examples of those are the White Maple, Northern Maple and the Oriental Sycamore. Maple trees are very beneficial for biodiversity as they attracts many animal species (Picture this, 2022). Plants and trees that were less abundant, but are also very beneficial for biodiversity are the American Lime and the Snowball.

Design project

All this surrounding ecology in parks and streets impacts the possibilities for the ecology in the project area. To increase biodiversity, animal populations have to expand, but attracting new species of animals would be hard to achieve since animal migration can hardly be forced on the smaller scale (Norton et al., 2016). Therefore the focus will be on expanding existing populations of small mammals, birds and insects by expending existing ecosystems. Plants and trees that support biodiversity significantly should be added abundantly in newly created natural areas. Below is a list of trees and plants from both parks and street analyses that occur frequently and support biodiversity significantly (Picture this, 2022):

Trees

- White Maple
- Northern Maple
- American Lime
- Western Sycamore

Plants

- Hairy Willowherb

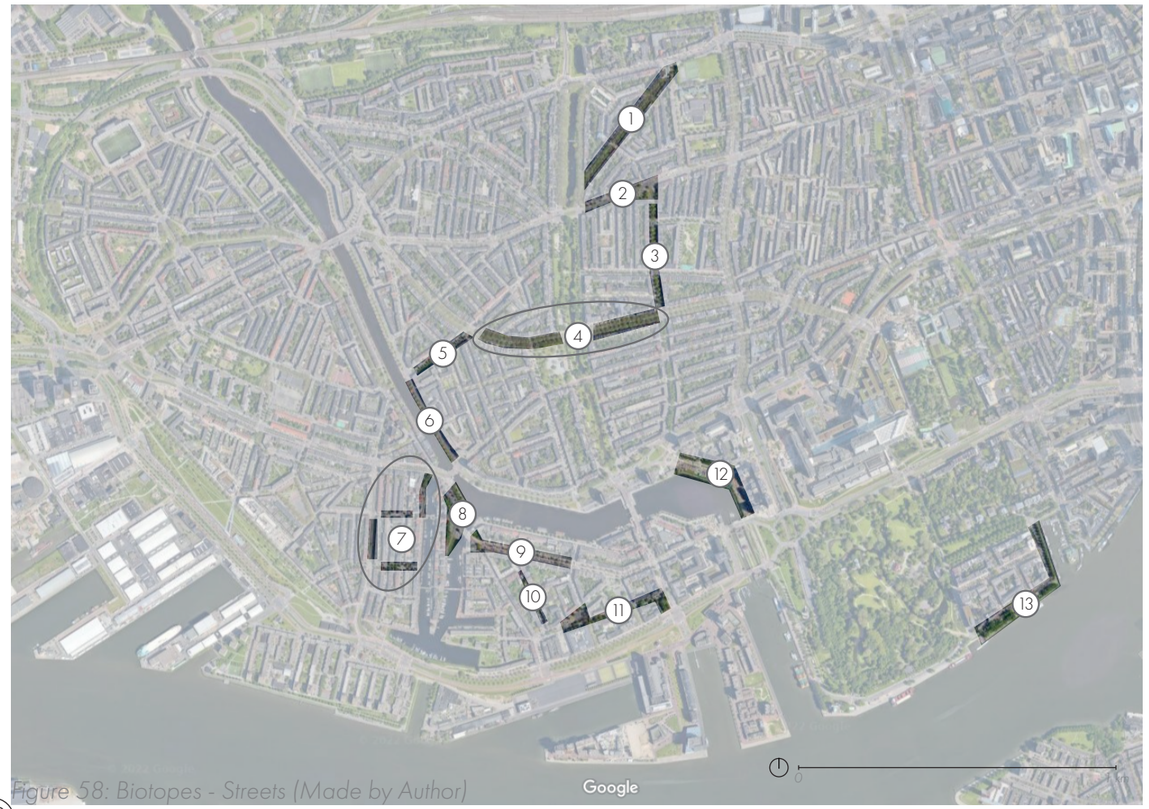


Figure 58: Biotopes - Streets (Made by Author)

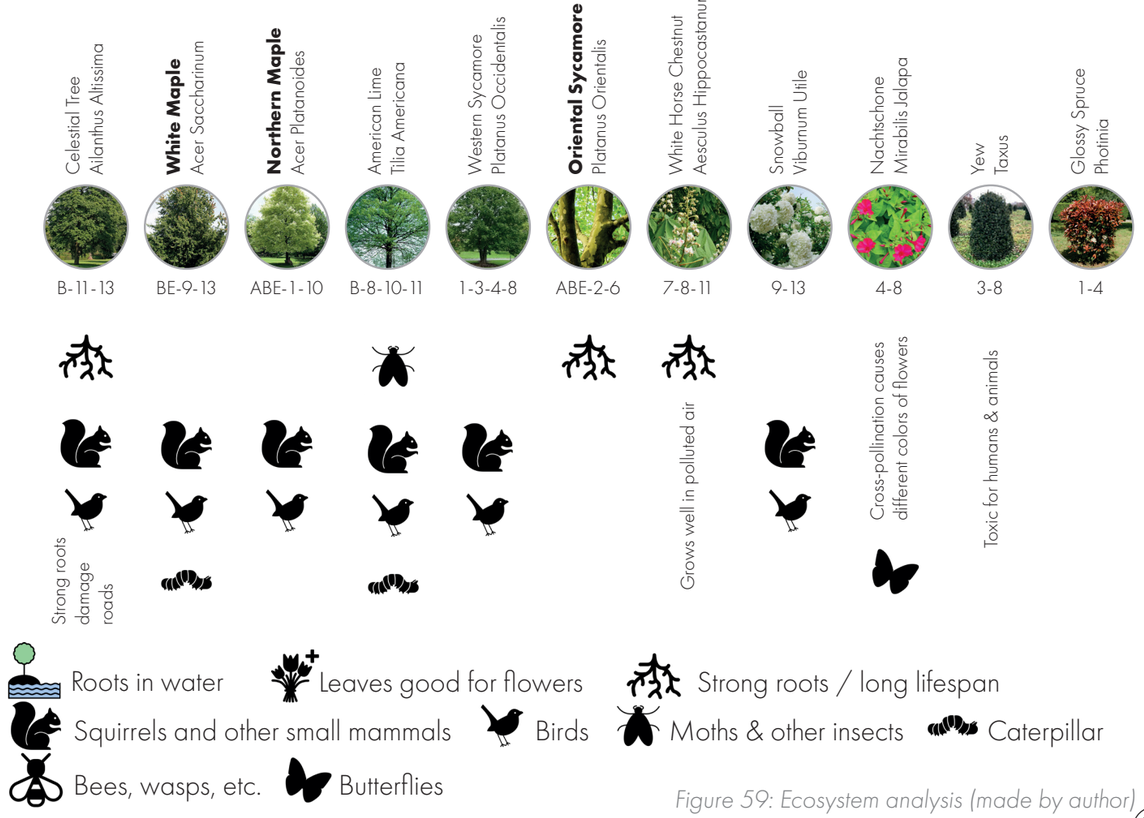


Figure 59: Ecosystem analysis (made by author)









Figure 60: Various images of streets (Made by Author)

Delfshaven habitat

Delfshaven is located on the crossing of two proposed ecological corridors. The corridors are both included in the municipal plan from 2016, as well as in the selection made in a previous subchapter. The Westzeedijk forming the most important and significant east west corridor. From the project area it connects to the north via the Heemraadspark.

Growing animal populations

To improve the ecological performance and biodiversity, animal populations need to increase. Animal species can increase by forcing migration from nearby areas or by increasing size and connectivity between habitats (Norton et al., 2016). Worsening ecology and decreasing biodiversity is a city wide problem and should therefore be solved without comprimizing biodiversity in other places.

Growing habitats

For the benefit of the whole city and to create an interconnected biodiverse ecosystem the approach of expanding and connecting ecological places is chosen. This strategy is in line with the municipal plan to connect the sparcely spread ecological patches all over the city (Rotterdam, 2016). Connecting and expanding habitats exponentially increases species populations and decrease the risk of migration and habitat disturbance and thus create a more resillient ecosystem (Norton et al., 2016).

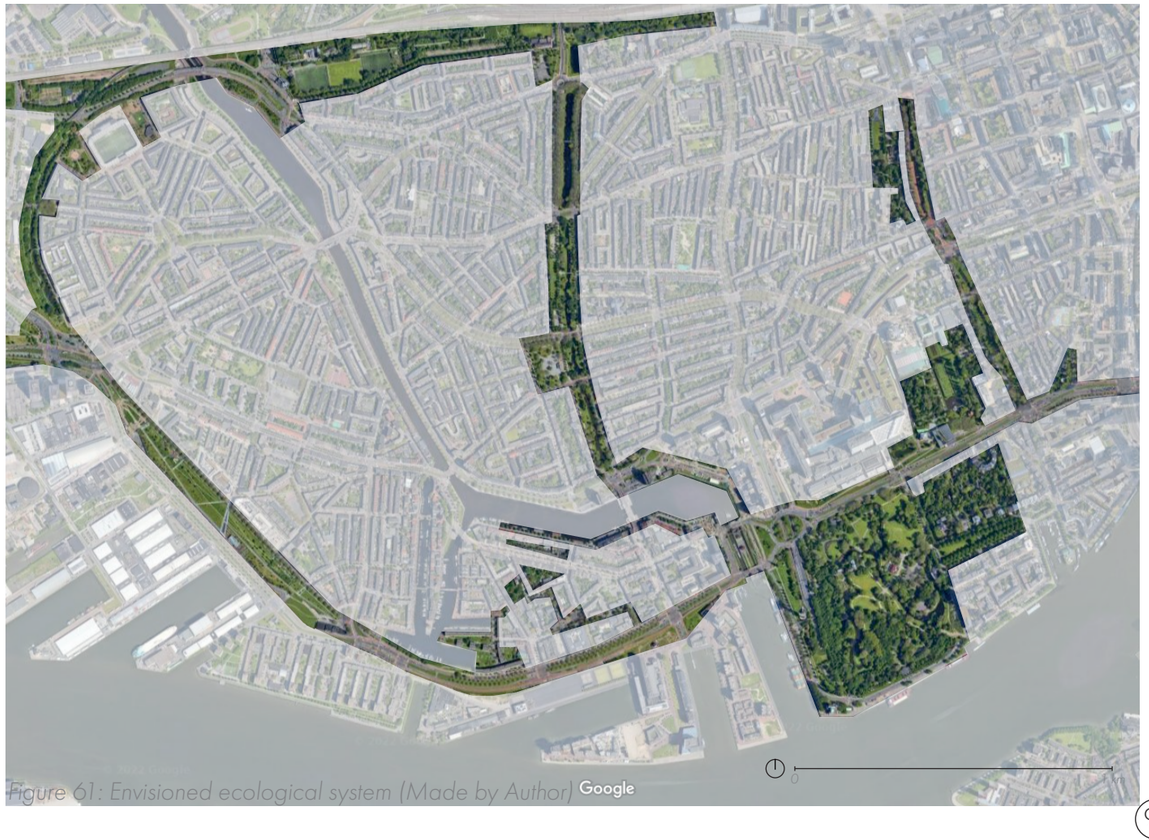


Figure 61: Envisioned ecological system (Made by Author)

Decontamination

Most parts of the neighbourhood are contaminated lightly and are sufficiently clean to allow for residential development and public space.

One part of the neighbourhood is slightly more contaminated, prohibiting any development by law except for industrial development (Gemeente Rotterdam, z.d.). There are a couple options to decontaminate the soil and make interventions feasable. The options are listed subsequently (Contaminated Soil Treatment Methods | Enva, z.d.).

Remediation using vegetation (A)
For this method specific vegetation is added to the soil and slowly pushes its roots into the ground. The life cycle of the vegetation helps creating clean soil and even boosts the fertility of the soil. This method usually takes up to 30 years to complete .

+ It's a natural process
+ Low cost

- Takes up to 30 years to decontaminate

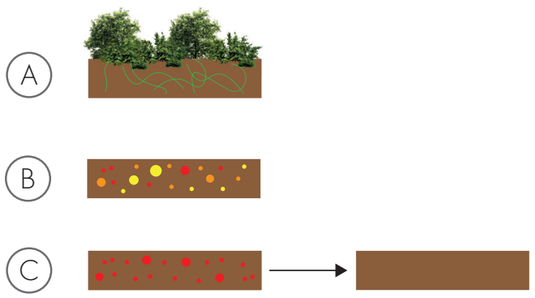


Figure 62: Decontamination methods (Made by Author)

Biological remediation (B)
This method uses bacteria or microbes to break down substances in the soil (Alpha Cleantec AG & European Union, 2019). The bacteria are strong and the top soil should not be in direct contact with humans or animals. The time period over which the soil will be remediated is not specifically clear, but according to one website, it takes about 5 to 10 years to remediate lightly contaminated soil to be suitable for residential use (Layfield, z.d.).

+ It's a natural process
+ Low costs

- Unable to use the land during decontamination

Soil replacement (C)
The contaminated soil gets taken out and moved to a decontamination facility. New uncontaminated soil is brought to the location and put in the ground. This is an expensive method, but does not require a period of time to decontaminate like other methods.

+ Soil is immediately available for interventions
+ Does not require time to decontaminate

- High costs
- Unsustainable to move soil around (especially if applied on larger scale)

Decontaminating Delfshaven
Decontamination by soil replacement happens almost immediately, but at a high cost. Importing clean soil and moving contaminated soil is not sustainable and only moves the problem elsewhere. This option should not be applied unless it is important for the success of the project to decontamninate certain areas in the first phases of the project. Biological decontamination in contrast to contamination by vegetation requires the area to be unused during the proces. Therefore, contamination by vegetation is preferred. Exceptions can be made for key areas within the project. Most of the area is only slightly contaminated and therefore does not neccessary need to be decontaminated.

Contamination at 1 meter depth



Figure 63: Soil contamination at 1 meter depth (Edited by Author) (Appendix 5; Rotterdam, 2022)

Contamination at 2 meter depth



Figure 64: Soil contamination at 2 meter depth (Edited by Author) (Appendix 5; Rotterdam, 2022)

Slightly contaminated
Residential development allowed

Moderately contaminated
Industrial development allowed

Subsoil infrastructure

Delfshaven is densily build. Not only above ground, but also below. A complicated network of infrastructure consisting of many cables and pipes are below pavements providing each building with water, electricity, sewage connections, etc. What we can build above ground highly depends on what exists underground. The figure below shows all the registered underground infrastructure (Gemeente Rotterdam, 2022).

Trees

Trees need 50 to 80 cubic meters of soil to root sufficiently (Appeltern, 2021). Trees with less room to grow in the subsoil will either die younger or will not grow as big as they potientially could. This means that because of the underground infrastructure, many places are currently unsuitable for adding trees. Streets like the Pieter de Hoochweg, Willem Buytewechstraat and the 1st Ijzerstraat are almost completely full of subsoil infratsructure. There are some trees that have smaller root systems like the Adams Crabapple, Trident Maple or the Japanese Dogwood (mrtreeservices, z.d.), but they are far from native and will not ecologically perform as well as native tree species. Trees with smaller root systems could be implemented where soil can impossibly be freed up, but native trees are prefered when possible.

Solutions for the subsoil infrastructure

Subsoil infrastructure has historically always been below our streets. Pipes and cables run underneath the pavement because this often is municipal space and therefore ownership rights can be handled more practically. It also allows for maintenance and new development to easily access the infrastructure. Reducing use of underground space by subsoil infrastructure can be done in different ways. Two solutions are described subsequently.

Utility tunnels

Utility tunnels are tunnels in which the subsoil infrastructure is placed. The tunnels allow for pipes and cables to be placed above eachother, requiring significantly less space horizontally. Utility tunnels are expensive and are therefore not frequently build yet.

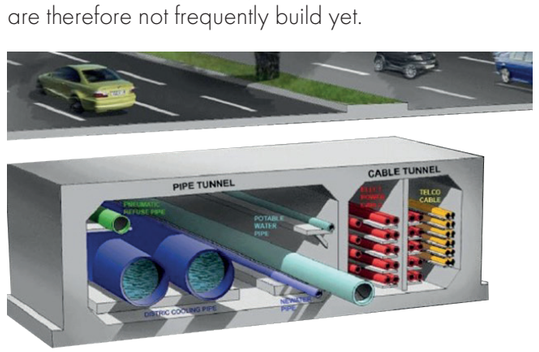


Figure 65: Utility tunnel (Alaghbandrad et al., 2020)

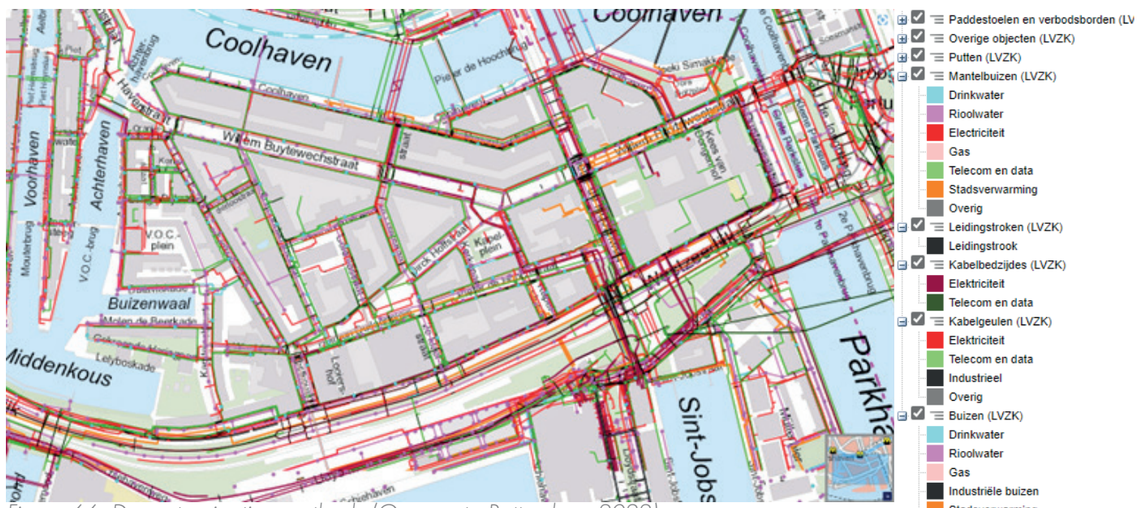


Figure 66: Decontamination methods (Gemeente Rotterdam, 2022)

Bioswales

Rainwater drainage currently happens within our sewage system. This puts a lot of pressure on our waste water treatment installations at peek rainfall periods. In many places a second 'sewage' is added to allow for rainwater to directly go to a body of water like the river (Jeznach et al., 2018). However, this only takes more space. To reduce use of subsoil space, water drainage should happen above ground by creating enough permeable surfaces so that water can seep into the ground. Large trees also absorb high amounts of water and can therefore increase the water absorption of an area significantly (Kane, 2014). Figure 67 shows how bioswales can help store water in peek rainfall periods. The water collects in the pit and slowly seeps into the ground. Surrounding vegetation absorbs part of this water over a longer period of time and the remaining water slowly seeps deeper untill it adds to the groundwater aquifer.

Subsoil interventions Delfshaven

Subsoil interventions are expensive. Utility tunnels have a lot to offer but are not neccessarily needed in every street. To minimize the costs, utility tunnels should only be added to the streets with the densest subsoil infrastructure. Streets where otherwise no trees could grow. In other streets, subsoil infratsructure should be designed in a way that it only occupies space below pavements and spaces that are designed as ecological spaces should also have open soil below ground. Sewage takes up a big amount of underground space. Rainwater should be collected, stored and absorbed by natural systems and interventions like bioswales. By doing this, space required for sewage pipes can be minimized and does not have to have a very high peak capacity because of the possibility of heavy rainfall.

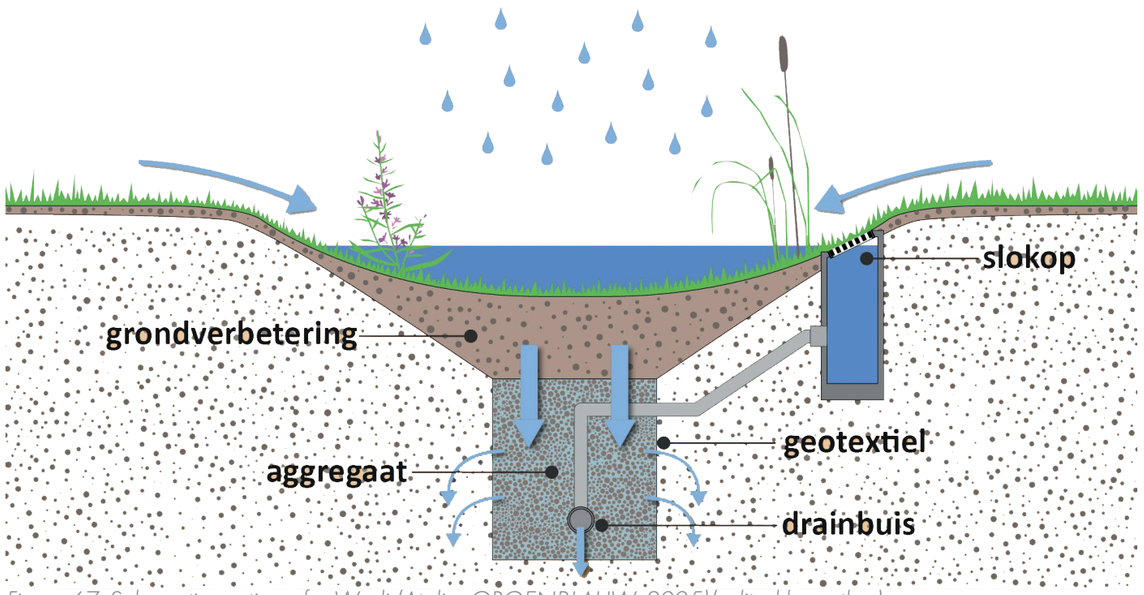


Figure 67: Schematic section of a Wadi (Atelier GROENBLAUW, 2005)(edited by author)

Climate adaptation

Reducing emmissions
Worldwide cities are accountable for 70% of the CO^2 emissions, of which 78% is created by vehicular transportation. Finding solutions to reduce emissions are therefore highly important in urban areas. Historic ways of expanding cities, relying on car accessibility will only make the problem worse (Allam et al., 2022). To decrease emissions car usage has to go down and more sustainable modes of transportation should be available as an alternative to car use. Sustainable modes of transportation include public transport or active forms of mobility such as walking and cycling. Walk- and cyclobility can be achieved by having daily life functions close to peoples dwellings and by having sufficient densities to keep those functions economically viable. Combined with density and diversity, multifunction neighbourhoods are formed that allow people to live, work, shop and recreate in close proximity of their dwelling. Greenery can also extract CO^2 from the air, further decreasing net emissions.

Storing water
Climate change is causing our local climates to become hotter on average and also to appear in more frequent extreme weather conditions such as heavy rainfall (IPCC, 2022). As mentioned before, rainfall puts a lot of pressure on our sewage system and takes up a lot of our undergound space. Water should therefore be captured, stored and used by nature and with interventions such as bioswales.

Cooling down
Our climate is heating up and our cities are currently experiencing the worst heatwaves in history. Many people that have underlying illness can die because of this heat and younger people experience negative impacts especially as night temperatures are high. To keep our cities livable, we need to design our cities in a way that cools down instead of increasing the heat. A street with grass and trees for example can cool down the physical equivalent temperature (PET) by 2-4 degrees, while a biodiverse park can cool it surrounding area by as much as 12 to 19 degrees PET (Gemeente Utrecht, 2022). Pavements should be less, while water, shade, nature and especially trees need to be added as much as possible.

Carbon capture
Besides reducing carbon emissions, it is also important to look for ways to capture or turn back our emissions into oxygen. This can be done in varying ways. For example, one tree can capture 10 - 40 kg carbon-dioxide annually (Ecotree, z.d.). Another great way to capture carbon dioxide is to create and maintain wetland areas. While wetlands only cover 8% of total global land mass, they account for 29-45% of carbon storage (Xu et al., 2021). This means that retaining or expanding wetland areas can increase the capacity to capture our emissions back from the air and store them in our soil.

Biophilic design

Biophilic principles
Biophilic design can be found at many different scales. From region and city, to building and street scale. The effect of the implementation of biophilic design depends on the cummulative interventions. Many small scale interventions such as greening empty plots, combined with large interventions such as creating ecological corridors can induce a big impact on ecological, climate and health related issues. Biophilic design strengthens the relation of humans with nature and puts designing with nature in mind as one of the main principles. Biophilic designing can serve many purposes such as climate adaptation, urban heat island mitigation, maintaining ecological habitats, improving water quality, filtering carbon emmisions and creating recreational benefits for residents.

Biophilic design elements
Biophilic design elements differ from removing small parts of pavement to allow water to infiltrate into the ground and to facilitate for little ecosystems to emerge to large interventions such as transforming brownfields into parks or transforming car dominated streets into ecological corridors. Sometimes it can also just be to look for opportunities where nature can restore itself without much intervention.

As nature exists out of many complex systems, it is hard to specifically conclude what works well and what does not in terms of ecological or climate performance. However by targetting specific types of species that originally (or desirably) live here we can create habitats that serve those species. The same goes for interventions aimed at climate adaptation where specific issues that are most urgent for the location are targetted to be solved or reduced by implementing biophilic designs.

Climate change
The introduction of this report has shown the problems facing us in terms of climate change. The amount of carbon emissions, the excessive use of energy and our urbanizing landscape increase the risks that we are already facing. With biophilic design the aim is to reduce movement by carbon emitting mobility, create space to adapt to the effects of climate change and to reduce energy use by cooling down and collectiong water by using ecosystems and low energy consuming systems. A great example of this is that a large mature tree has the potential to provide a similar amount of cooling as 10 room sized air conditioning units operating 20 hours a day (Beatley, 2011).

Green streetlights
Street lighting is an essential part of our streets. It keeps the path visible and provides security after sunset. Some animals need shade and darkness to rest. Dutch biologist Kamiel Spoelstra says that, although not all animals, many species like birds are repelled by bright environments and that intensity and color influence this effect. More intense light like blue or white light have a more negative effect than softer light like green light (NEMO, 2019). This means that switching our streetlights from white to green can positively influence the migration of birds and might also improve the habitat conditions for other species. Green street lighting has also proven to be more energy efficient. The effect of green lighting on residents hasn't been researched much yet, but implementation of green streetlights has already happened in multiple Dutch cities.


Figure 68: Green streetlights (B&C)

Overall, street lighting has the potential to improve habitat conditions, while also reducing energy consumption.

Biophilic reference projects

Promonade Plantée (Paris, FR)

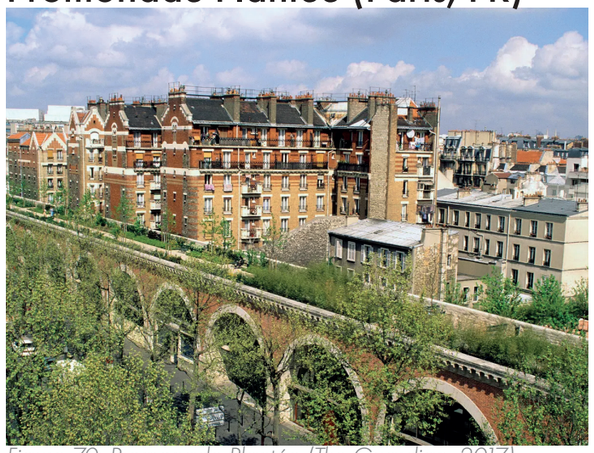


Figure 70: Promonade Plantée (The Guardian, 2017)

Teardrop park (New York, US)



Figure 71: Teardrop Park (Ann Hamilton, 2014)

Tanner springs (Portland, US)



Figure 72: Tanner Springs (Ramboll, 2020)

Promonade Plantée (Paris, FR)

The promonade Plantée is a linear park located on top of an old railway track. It is transformed into a park in 1988 and has kept its function as park and pedestrian connection ever since. The park is around 4.7 km long and has both elevated and ground level segments in it.

An important and usefull element of this design is that the pedestrian route is elevated from the (car dominated) roads below. This means that walking here can feel more relaxed and removes the sight (and part of the noise) of cars. This in turn can change the perception of time and distance while walking here. The linearity of the park also helps by giving larger parts of the neighbourhood access to the park within close proximity.

Goal - Creating a pleasent connection between some of the main green areas and to create green space in close proximity for many residents.
Size - 3,7ha (connects to 3,3ha park space)
Construction - 1993 (transformation of former train track)
Budget - Unknown (municipal funds)
Elements - Linear elevated walking path, diverse green, adjecent parks.
Success - The Promonade can be seen as a success. Many people use it to walk on and different animal and plant species can be found here. Multiple projects such as the Highline in New York are derived from this example (Atlantic, 2011).

Teardrop park (New York, US)

Teardrop park is located between high rise buildings on the edge of the Manhattan peninsula. The park has many natural design elements such as rocks, a variety of trees and many height differences. The height differences serve as a natural way to hold and distribute water to the plants and trees over longer periods of time. The higher elements also give people shade and facilitate for places to sit down or lean against. There is also a playground integrated with these elements.

For the Delfshaven project we want to take inspiration from using natural elements to create recreational and playfull uses. The park however is relatively large and is therefore not related to Delfshaven in scale.

Goal - Creating a central green space in the development of 3 new residential towers.
Size - 0,73ha
Construction - 2004
Budget - $17 million dollar (development fund)
Elements - Natural elements (water, plants, rocks and sand), playground, different elevations, natural water preservation and distribution.
Success - The park and playground are well used according to a news article (Moore, 2007). However, critics say there are too few things to do in the park (Project for Public Spaces (PPS), 2006).

Tanner Springs (Portland, US)

Tanner Springs park is located in the center of Portland. The grid layout of the center exists of medium to high rise buildings with flat single layer parking lots in between. Many of those parking lots have been transformed into green spaces. Most noticably in terms of ecology and climate adapatation is Tanner Springs. This former parking lot is transformed into a wetland that represents the nature of the area before urbanization happened. The wetland is accessible by low lying bridges and is home to variety of plant and animal species. The wetlands also absorb a lot of carbon emissions.

For the design of Delfshaven I want to use the elements of creating wild nature with access for people to watch and experience the impacts of this nature to the natural environment.

Goal - Creating a network of open spaces. The park, combined with two more natural spaces was part of one effort to elevate public space quality in the area. This specific part was meant to refer to the original landscape of the area; wetlands.
Size - 0,37ha
Construction - 2003
Budget - Unknown (municipal funds)
Elements - (Historic)Wetlands, different elevations, water storage, pedestrian duckboards, regenerative ecosystem
Success - The park is well used according to the municipality (Portland, 2016). The landscape features many elements that formed the previously existing wetlands of this area and there are many animal species present.

Green/blue network (Ypenburg, NL)



Figure 73: Ypenburg (The Hague, 2021)

De Woerd (Houten, NL)



Figure 74: De Woerd (Houten, 2019)

Greenacre park (New York, US)



Figure 75: Greenacre Park (Sasaki, 2018)

Green / blue network (Ypenburg, NL)
Ypenburg is a relatively new neighbourhood of The Hague. It consists of many low rise buildings with an extensive network of little waterways and green strips through it. This network of waterways and green strips form a foundation for species to live and forage. The green and spacious public space also provides residents with multiple options to walk around the area, to let their kids play outside and to be less prone to climate change effects such as heavy rainfall.

Goal - Facilitating a well functioning urban biodiversity. Ecologically connecting the urban development to the adjacent green area and creating high value residential developments.
Size - ~7ha (PDOK, 2022)
Construction - 2002
Budget - Unknown / unclear budget distribution
Elements - Water, native plant species, different ecosystems
Success - Different ecosystems cause the area to have a relative high biodiversity and copes relatively good with dry and wet climate periods (Gemeente Den Haag, 2009).

De Woerd (Houten, NL)
De Woerd is a residential development in a Vinex neighbourhood of the Netherlands. It was build to house families moving out of the big cities. The development focusses on limited car access, good cycling accessibility and integration of green into the little squares and streets. The waterbanks are designed to be animal friendly and the hellefites improve water quality.

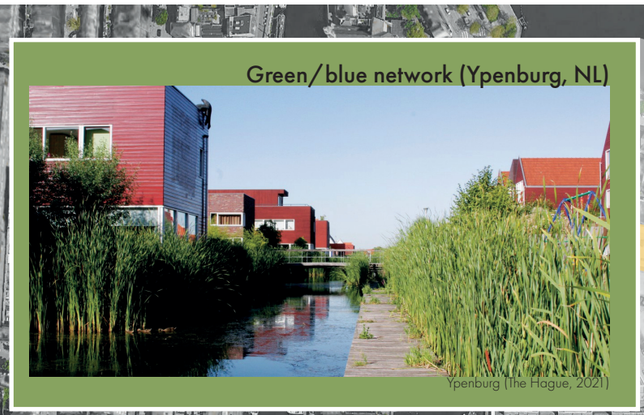
Goal - Creating a sustainable neighbourhood with high value single family homes in a suburb of one of the bigger Dutch cities.
Size - ...ha
Construction - Unknown
Budget - Unknown
Elements - Water, native plant species, different ecosystems
Success - Unknown

Greenacre park (New York, US)
Greenacre park is located in Manhattan surrounded by an area with a very high density. The small and tightly surrounded park is unique for its kind. The space is defined by a U shape of green walls and a waterfall. The waterfall provides the space with a continuous background noise that supresses the noise coming from the street and creates a relaxed and natural feeling when staying inside the park. For many New Yorkers from the area the place provides peacefulness in a place where it is always noisy and busy.

For the design project of Delfshaven, inspiration is taken from using natural noises such as a waterfall to create a continous natural background noise that makes humans feel more relaxed and that makes it more likely for animals sensitive to noise to go here and create a habitat.

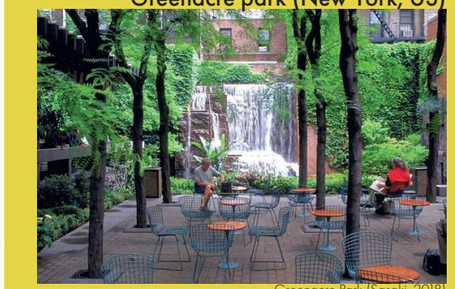
Goal - Creating a pocket park that gives the visitor the feeling they are not in a busy urban core anymore. Elements of the city such as noise and views have been hidden or covered by natural sounds and views.
Size - ...ha
Construction - 1971
Budget - Unknown
Elements - Natural sound of a waterfall, shade, enclosed on 3 sides
Success - The park has 200.000 visitors annually (New York, 2021). It is also frequently mentioned in articles online as well as in scientific papers. The designers have managed to almost completely block off the noise from the street and when the leaves are on the trees a visual blockade is also present.

References pinpointed



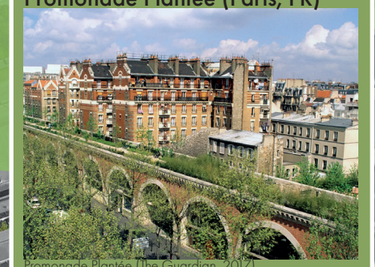
Green/blue network (Ypenburg, NL)

Ypenburg (The Hague, 2021)



Greenacre park (New York, US)

Greenacre Park (Sasaki, 2018)



Promonade Plantée (Paris, FR)

Promonade Plantée (The Guardian, 2017)



Teardrop park (New York, US)

Teardrop Park (Ann Hamilton, 2014)



Tanner springs (Portland, US)

Tanner Springs (Ramboll, 2020)

Within ecological main structure

Prioritizes social interaction

Mobility corridor with active plinths

Google Earth

Design principles

All conclusions and principles are important
As shown in this chapter, all conclusions from the research and analyses are important input for the design of Delfshaven. Many small interventions can be equally impactfull as a single big intervention. Depending on the target species different interventions might be needed to achieve the goal of an ecological and climate adaptive public space with high recreational and health improving qualities.

Main principles
For the design phase a couple principles have been picked to focus on. These are the main principles that are to be applied over the whole neighbourhood. After applying all the main principles successfully, additional biophilic elements can be added or more eco-systems can be created or improved.

The design should integrate ecology, climate and recreational use in a synergetic way



Mitigate 'distance decay' (<100m) by providing equal access to nature



Use biophilic design interventions to reduce energy consumption for cooling and to collect and store water



Streets from mainly infrstructure space to integrated spaces for human and nature



Many green areas to explore, play in and gather in



Ability to move around the area by food or bicycle, connected to regional nature



Create a variety of habitat types



Include large qualitative ecological areas



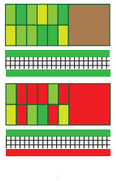
Reduce barriers



Conenct nature



Promote collective managment of private gardens

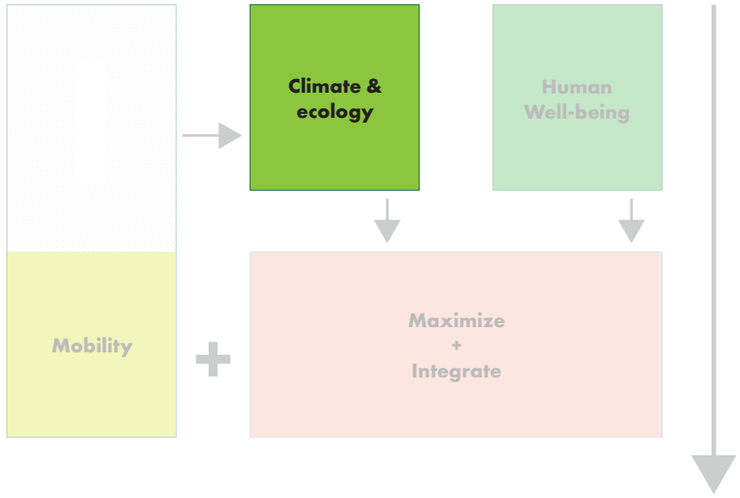


Ecology & climate
Maximalization design

Approach

Similar to the approach of designing the maximalization of mobility, principles for qualitative ecological and climate adaptive spaces have been formulated. From the mobility maximalization design, a requirement of space is shown that leaves us with an area to use for other interventions. This area is shown at the bottom of this page.

The preliminary ecological maximalization design is shown on the next four pages. The first 2 pages focus on the perspective of animal species. How they move around, what habitats they need to rest or find food in. The second two pages show the maximalization design from the perspective of humans. Where do they socially interact, where does noise occur and how does the mobility system relate to the ecological one.



Unpaved space after applying mobility

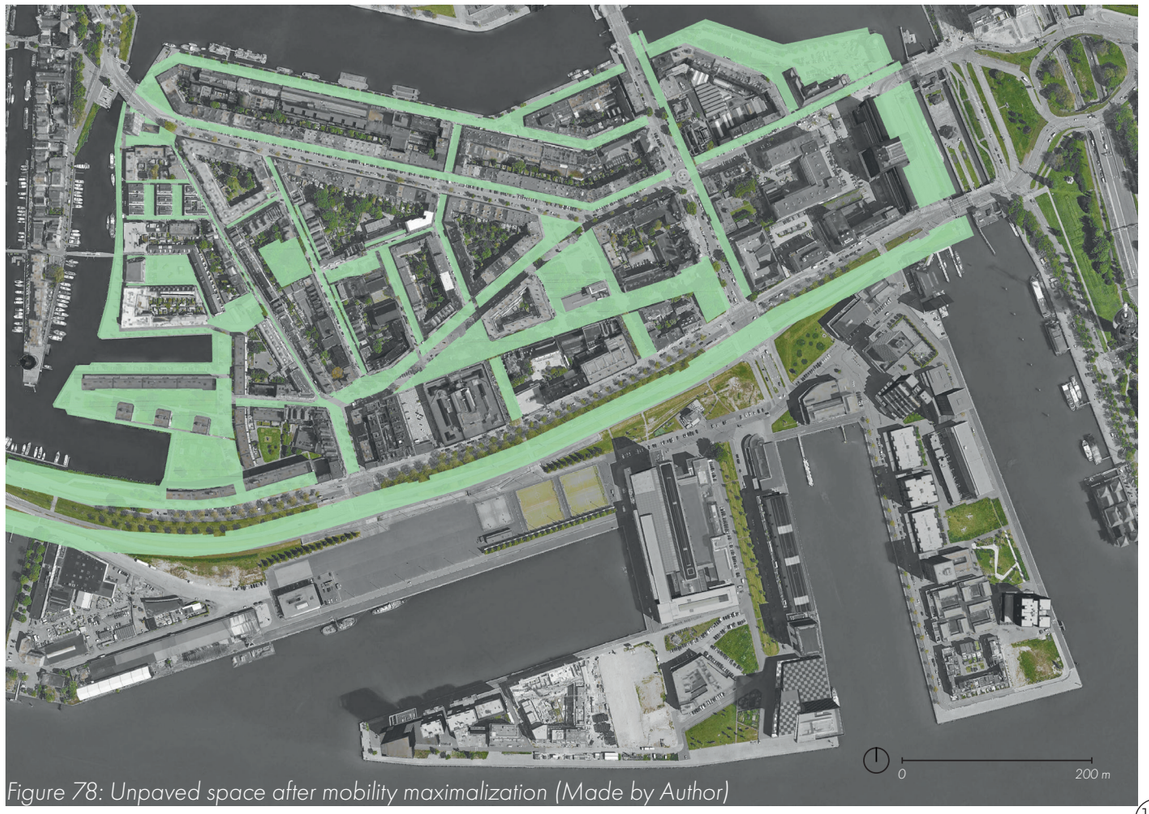
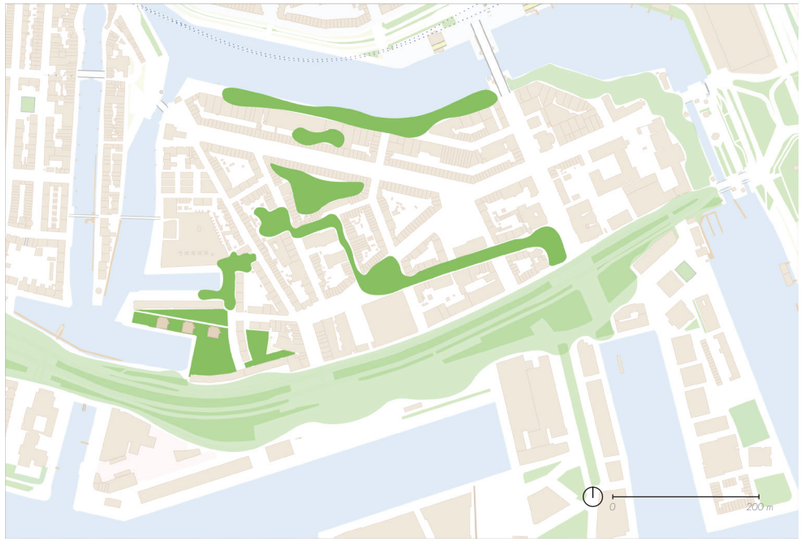


Figure 78: Unpaved space after mobility maximalization (Made by Author)

Current situation
The neighbourhood currently has no significant ecological areas. Alongside the Westzeedijk and towards the water quays are some grass patches.



Narrow corridors
Literature research shows that for multiple species it is neccessary to create ecological corridors for them to move around the area. Many animals can forest food and migrate through these narrow corridors.



Small parks
For some species (specifically mammals) animals require larger ecological spaces to rest and are vulnerable to noise and smell polution. For this reason small parks are located alongside the narrow corridors.



Wide corridors
Some animals (especially those from forest like environments) require wide ecological corridors and big parks to rest. The Westzeedijk and parts of Coolhaven are suitable for those corridors and connect directly to the city park at the Euromast. This big park can facilitate a pleasent resting environment for larger animals with high daily movement patterns. Due to the high level of urbanity it is debatable if such species should be attracted to this area.



The full ecosystem
To summarize all the nature typologies are shown together.



Species
This map shows how the different species can use the area and how different parts of the ecology facilitate for different species.

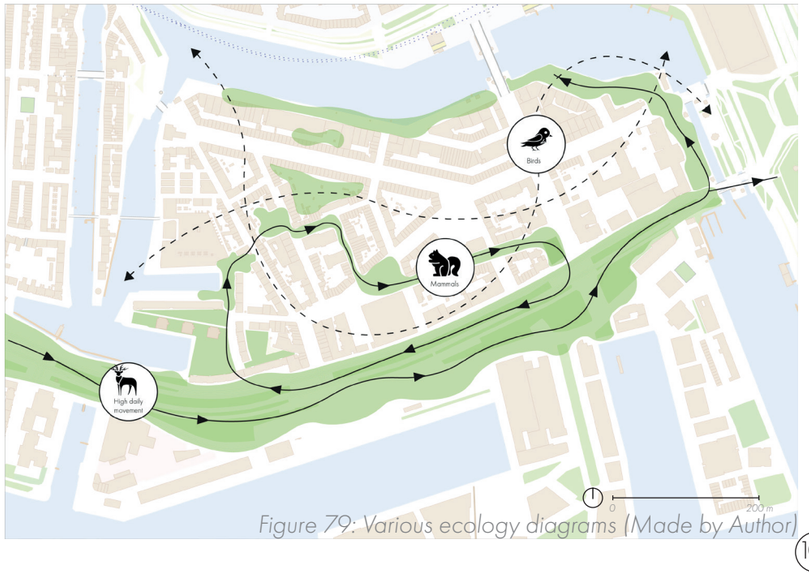
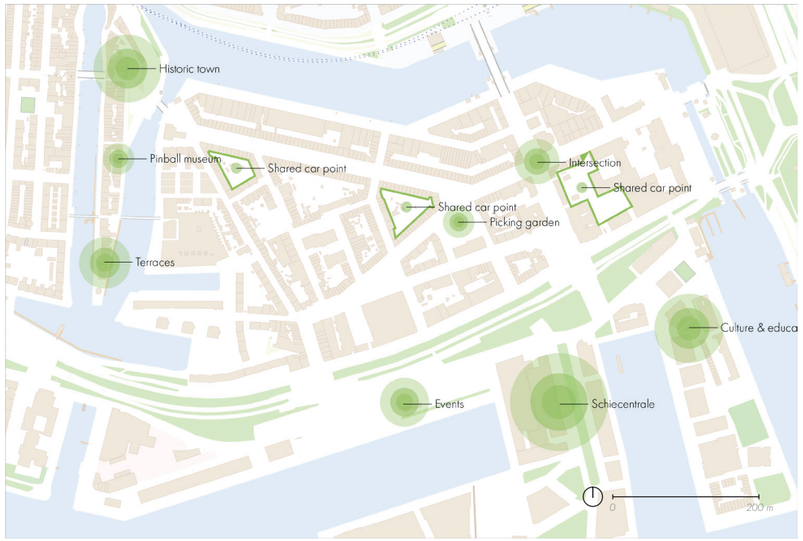
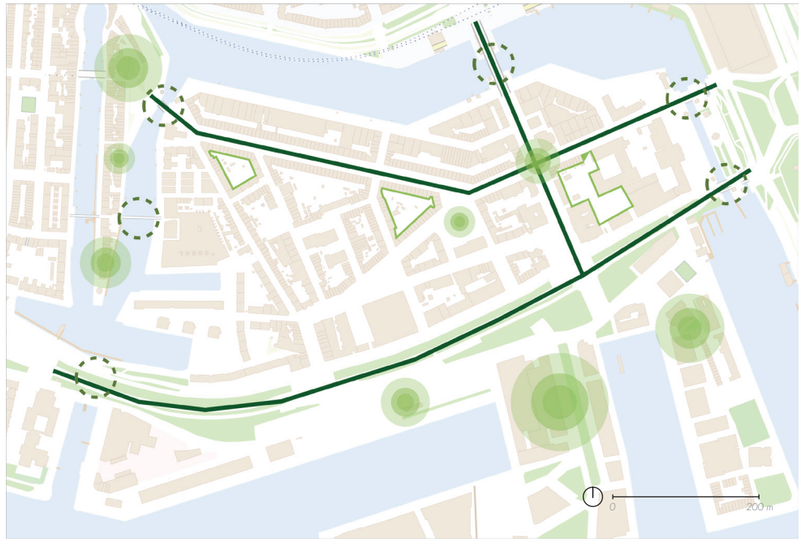


Figure 79: Various ecology diagrams (Made by Author)

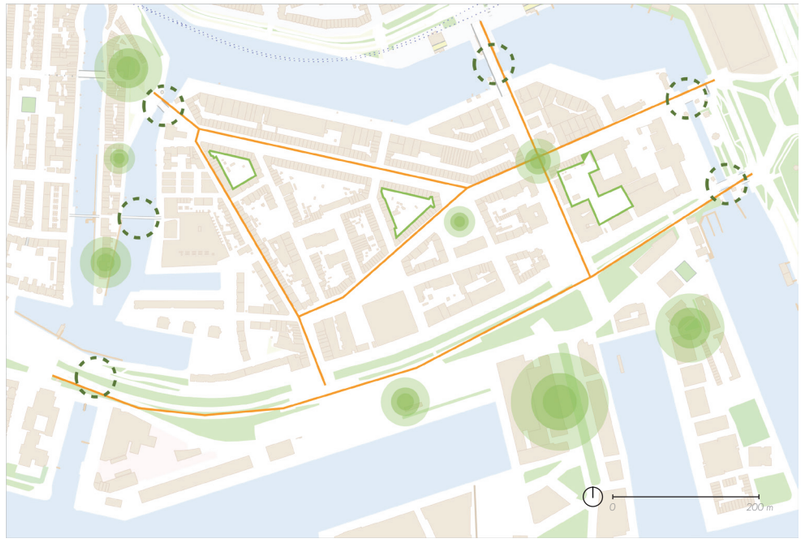
Hotspots
Within and around the neighbourhood are multiple facilities that attract visitors such as terraces, a historic town and parking for shared mobility. These should be easy accessible by different modes of mobility and they might generate relatively more noise and disturbence that negatively impacts ecological performance.



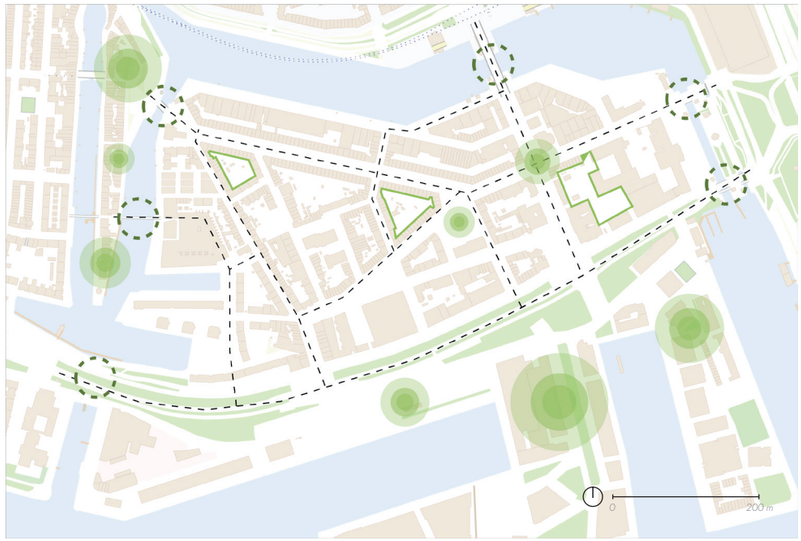
Motorized vehichles
To keep the neighbourhood and earlier named facilities accessible, they are located alongside the streets that function as mobility corridors. In these corridors there is space for cyclists, pedestrians, public transport and occasionally a car. They connect directly to multiple bridges that form connections with surrounding areas.



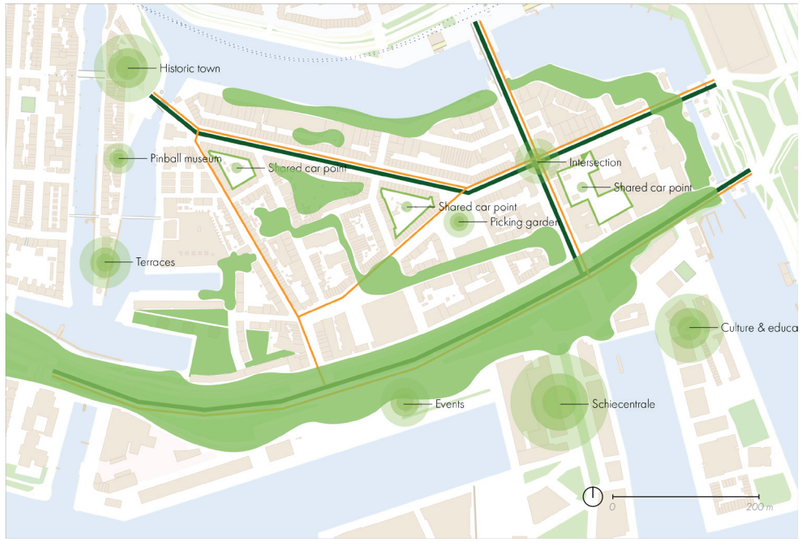
Bikes
In allignment with the vision, bike infrastructure will be expanded. All building blocks will be within close proximity of a seperated bicycle path. Those bicycle paths also connect all the earlier named hotspots and bike trips will often be the fastest connection since cars have to drive around and can only drive slowly on the space shared with other modes of mobility.



Pedestrians
Walking will be easy, accessible and above all pleasent in this area. More and wider sidewalks will create space for people to walk around or commute quickly to a public transport stop or a shared mobility garage.



The ecosystem
Plant and animal species often thrive best if there is low noise and smell polution. The ecological structure is located (mostly) away from motorized traffic and bicycle infrastructure only crosses the ecological structure occasionally. For some species, little changes or disturbances might cause them to migrate away from the area. For this reason it is good to keep intense human activity away from those areas.



Mainstreets
Mainstreets are areas where many shops and public facilities are located. They cause people to socially interact and create economic possibilities such as jobs and workspaces. Mainstreets should be easy accessible and businesses thrive best if located near busy streets. Therefore the yellow highlighted area is picked since it is accessible by all modes of transportation and is alongside a connection that will assumable carry a lot of (through)traffic

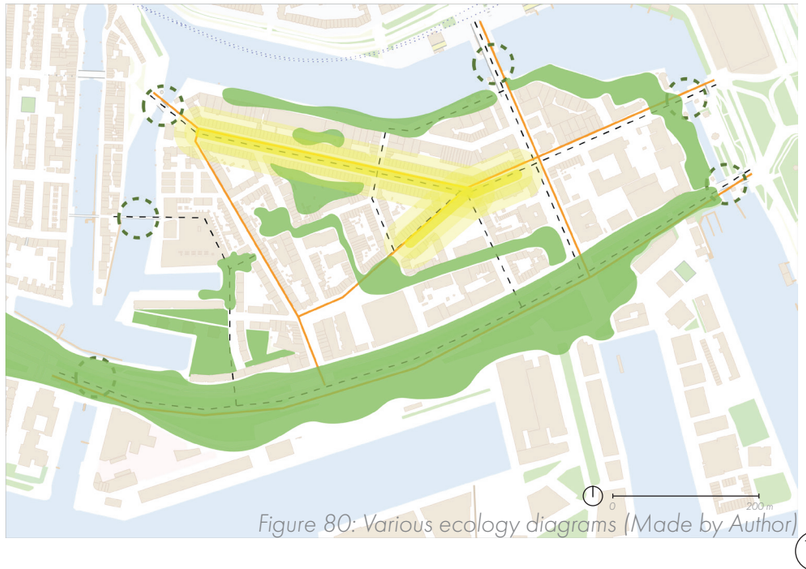


Figure 80: Various ecology diagrams (Made by Author)

6

Human Well-being

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Human Well-being

What does human well-being mean?
Human well-being refers to everything that improves the quality of life for people. Human well-being ranges from having easy access to public transport and education to living healthy and having strong social relations with other people. Even economic activity and opportunities have impact on human well-being.

Research
In this chapter we will research how design of public space can help improve human well-being. We will assess what is possible within the neighbourhood of Delfshaven and where human well-being solutions have symbiotic relations with ecology and mobility solutions.

Design
At the end of this chapter a human well-being focussed design will be given. Eventually all designs will be combined into a masterplan.



Space refers to the physical presence and geography of a location, while the term place is used to refer to use or identity of a space. To create vibrant and well functioning spaces, designers should use elements to turn space into place. The four main elements of placemaking are; sociability, activity, comfort and access. Each of those elements is subdivided into different characteristics that strengten this element further (Figure 81).

To create a vibrant neighbourhood all public spaces suchs as parks, squares and playgrounds should include all four elements.

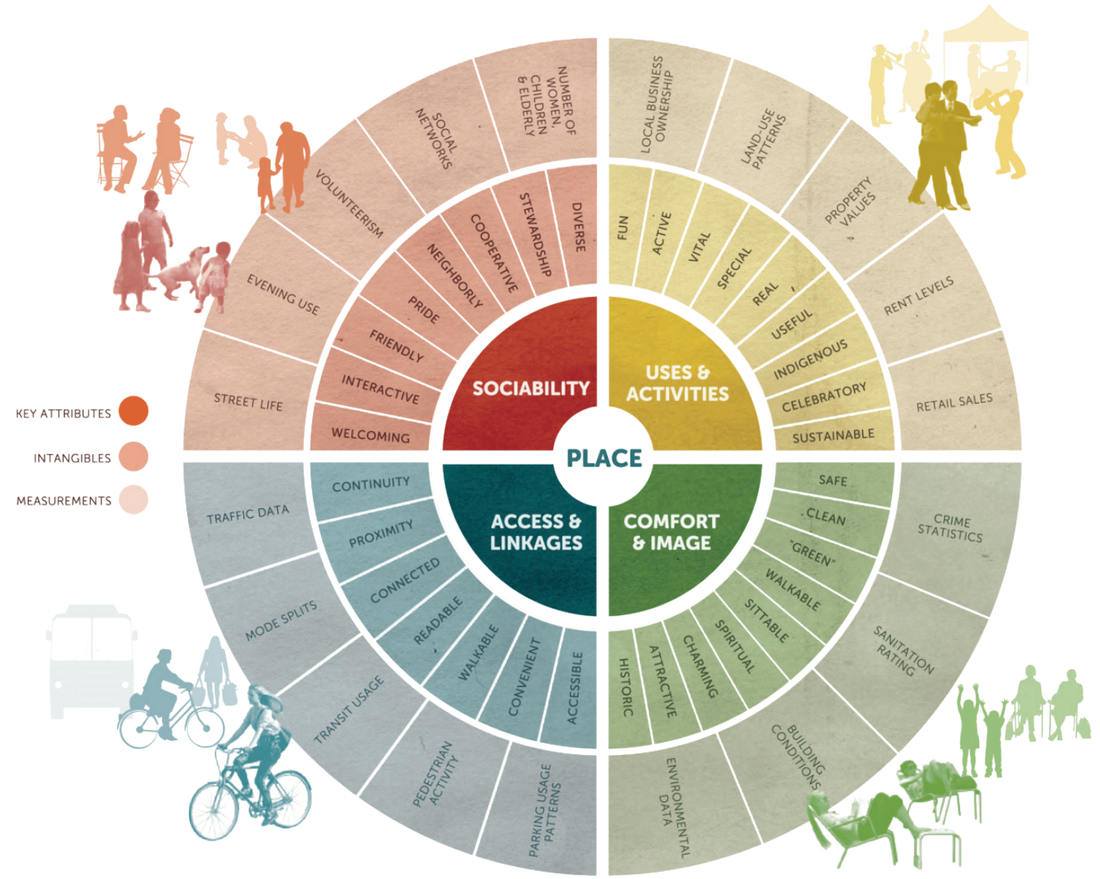


Figure 81: Place Space diagram (Projet for Public Space, 2000)

Comfort & access

Safety
Safety plays a big role in how much people enjoy life in a city. Safer environments often mean that people experience less stress and feel more invited to spend time outside and to let their kids play freely without parent supervision (Karsten & Felder, 2016). A feeling of safety is achieved when people do not feel like they have to pay close attention to their surroundings at all times, because of existing risks. Examples of how this can be achieved are seperating or removing (fast) motorized traffic, or by social control created by buildings facing open space, or by limiting dangers (Pucher & Dijkstra, 2003).

People walking and cycling are very vulnerable when infrastructure does not protect them. Mixing cars with them increases the chance of accidents. Seperating those flows and limiting the amount of motorized vehichles decreases the chance of accidents happening (Pucher & Dijkstra, 2003). As mentioned in previoius chapters, reducing motorized traffic (especially private cars) also help to free up space and improve ecological and climate adaptive performance. This type of interventions can thus create positive effects on all of the three main focusses of this design project.

Mobility
Walking or cycling is much safer than motorized vehichles. Higher speeds mean more serious accidents and mixing wide ranging speeds also increases likelyness of collisions (Pucher & Dijkstra, 2003). We should therefore focus primarily on facilitating those safe modes of transportation. Walking and cycling can easily be combined with public transport by including tram, bus and metro stops into the active mobility networks. Public transport should be more appealing than cars to incentivise people to choose this mode of transportation. This can be done by taxing car users, subsidizing public transport and creating faster public transport connections. Research on the acceptability of car-reduction measures has shown that push factors such as taxing car users are significantly more effective than pull factors such as cheaper public transport. It also shows that personal norms influence decisions more strongly when costs are more moderate (Keizer et al., 2019).

Therefore effective car reduction meassures should be significant, while alternatives should be efficient and affordable. When public transport is innefiecient and mixes with regular traffic, people are more appealed to take the car (Keizer et al., 2019).

As is mentioned previously, biophilic design is about taking space from less nature oriented uses and transforming it into space that serves both nature and humans in a healthy and sustainable way. By designing a street for humans and nature it also becomes more attractive to walk or cycle, which in turn again reduces the desirability of having a private car and using it for day to day trips. In many countries policies are also implemented to increase the costs of having a car, compared to public transport (Beatley, 2011). Integration of meeting places, active plinths and facilities such as bicylce parking spaces, bus stops and health facilities can further increase attractiveness of walking through a place instead of driving. “A livelier, more active mixed-use street will make walking easier and may even change the perception of distance; walking trips will feel shorter, more manageable and more enjoyable” (Beatley, 2011). A good network of car limited streets, networks of greenspace and nature are all very important for the walkability of a neighbourhood. As Beatley mentions here, the perception of distance and the readiness to walk depends strongly on the liveliness and attractiveness of the street itself, meaning a car dominated fully paved street will less likely be used by pedestrians while a vibrant green spacious street is more likely to be used.

With the introduction of the car, more and more space was taken away from pedestrians. The development of the sidewalk and the possible future prospect is shown on the next pages.

Greenery & surroundings
Greenery and easthetics of surroundings can influence peoples experience of space. Multiple researches have shown evidence that urban nature improves physical and mental health of residents living within close proximity (Lee & Maheswaran, 2010). This means that providing a more ecological environment is not only beneficial for ecosystems and climate adaptation, but also significantly benefits people living in and around it. Another reasearch shows that ecological areas have a high potential to contribute to the well being of humans and are considered to be enjoyable to be in or around (Kothencz et al., 2017).

When we look at streets we can see a clear misconception that streets are primarily a space for infrastructure, providing convenient accessibility for cars. However, to succesfully integrate walkability and biophilic design elements, the street has to be interpreted as a space that facilitates human interaction and recreational use with nature while strengtening biodiversity, ecological performance and climate adaptation all together.

Picking gardens are a good example of engaging residents with their natural environments. The trees increase local food production and people are more likely to interact with eachother while collecting fruits. A project in Boulder Colorade has implemented fruit yards on empty plots scattered around a neighbourhood. The production of a single suburban plot is much higher than most imagine (Beatley, 2011). This means that picking gardens could even contribute to a higher local food security for the city.

Kids
Kids often have to be accompanied by a parent when traveling to a friend, sports club or school. If and when kids are accompanied is strongly influenced by their age, the distance and amount of risk along the way. When staying within a (by a parent) considered safe area, kids are often allowed to move freely (Karsten & Felder, 2016).

15 minute city & density
To achieve a walkable area, necessary functions have be located nearby as people will only walk when distances are acceptable. To achieve walkable distances the 15 minute city concept is applied. By having many daily life functions (such as supermarkets, general practisioners, pharmacies, gyms, etc.) within a 15 minute walk from each resident, people are much more likely to go there by foot (Allam et al., 2022). Many functions require a minimum amount of users to be economically viable. A 15 minute walkable neighbourhood performs best when densities are relatively high.

Delfshaven
Delfshaven has a high density and within close proximity of residents are many daily functions such as supermarkets, dentists and childcare are present. This makes Delfshaven already very suitable for implementing the 15 minute city concept. The area however is designed in a very car oriented way. Many streets are paved and there is lots of groundlevel parking. To create green pleasent pedestrian routes the layout of the streets has to change. By using biophilic design principles, synergetic solutions can be implemented that increase human appeal as well as ecology and sustainable mobility. Examples of this are adding natural elements, removing cars and replacing them with high quality cycle paths and public transport.

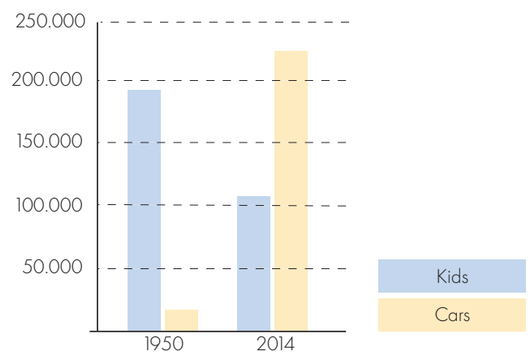
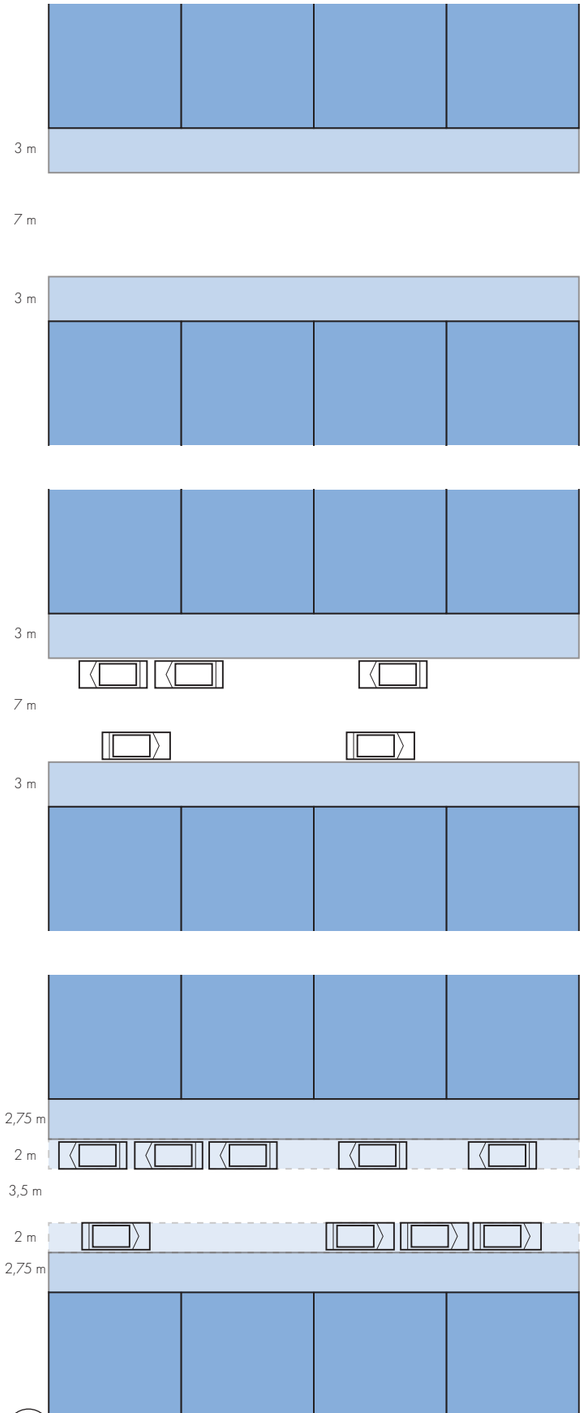


Figure 82: Changing relation between the amount of kids and cars in Rotterdam (edited by author)

Sidewalk development



~1900
Streets used to be very wide. There was no designated space for parking. Horse-drawn carriages moved through the streets carrying goods while streetcars were moving people around. Sidewalks were also considarably wider than they currently are.

Sidewalk ~ **3m**

~1950
With the introduction of the car, space slowly became occupied by them. Either when moving through a street or while parked at the edges.

Sidewalk ~ **3m**

~1980
While car ownership increased, cities became crowded with cars and municipalities allocated space specifically for parking within their streets.

Sidewalk ~ **2,75m**

~2015
To keep up with the increased use and ownership of cars, more parking had to be realised.

Sidewalk ~ **1,5m**

~2020
The last decade has shown a shift in this transformation. Parking is often being removed to make space for wider sidewalks, bike parking or greenery.

Sidewalk ~ **3,5m**

Now
Some streets are becoming car limited. Car lanes and parking are taken away to make space for wide pedestrian areas. There is much space to add bike parking, greenery and places for social interaction.

Sidewalk ~ **9m/ 13m**

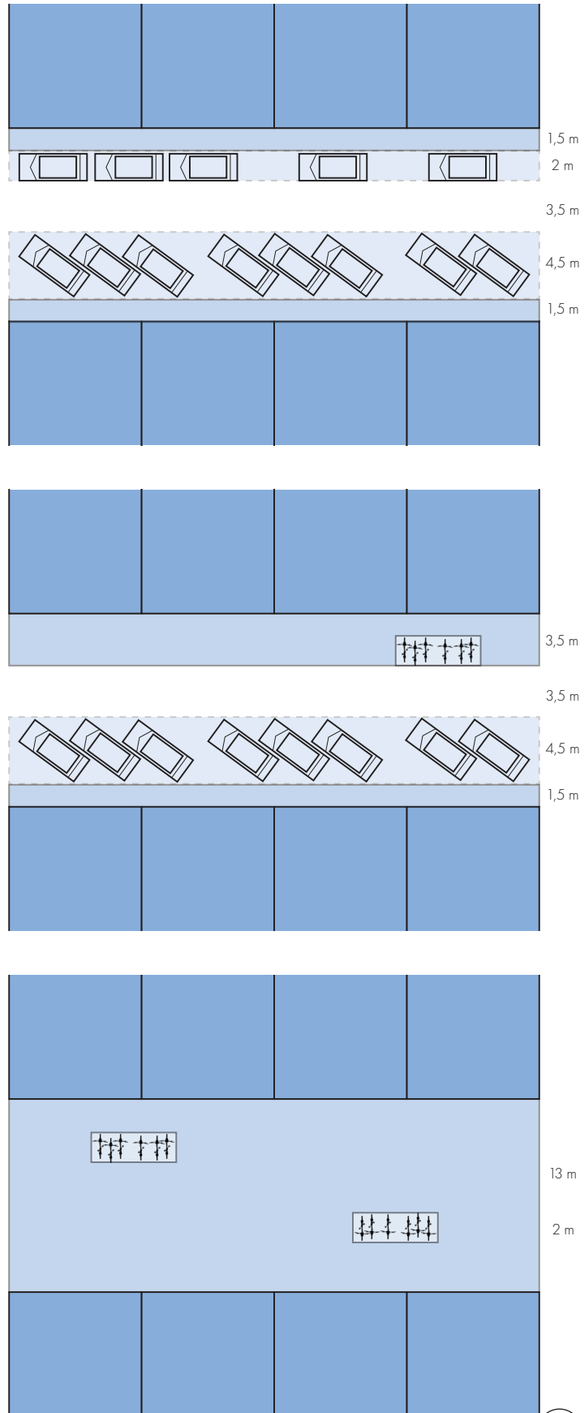


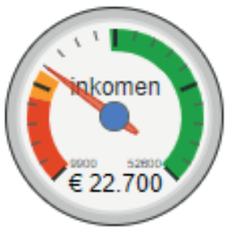
Figure 83: Streetscape development (Felder & Karsten, 2016)(editted by author)

Economic activity

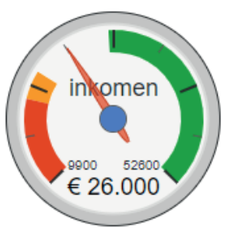
Income
In 2021, residents of Delfshaven earned an average income of €22.700 euros before taxes. This is lower than the municipal average of €26.000 euros and the provincial average of €43.300 euros (AlleCijfers, 2022). Within Rotterdam there are many areas that perform worse in terms of income. These neighbourhoods are mostly located on the south bank of the river. On the north bank of the river most neighbourhoods perform slightly better than Delfshaven.

Figure 84: Avarage incomes (Allecijfers, 2022)

Delfshaven



Rotterdam



Accessibility of work
For a 15-minute city, it is important that a variety of day to day functions are in proximity of each resident. The same goes for jobs. Residents will often pick their mode of mobility depending on the distance and accessibility of their job.

In figure 85 we see a heatmap of full time jobs. We can clearly see that most jobs are located in either the Hoboken district (regional medical center and museum cluster), the city center, shopping district and 'Kop van Zuid' (recent mixed use development)(Lisa, 2018). Additionally there are smaller clusters such as Zuidplein and Alexander. Most of those clusters are in close proximity of Delfshaven, they are easily accessible walking, cycling or by public transport.It is therefore very feasable to have those employees travel to work by either active mobility or public transport.

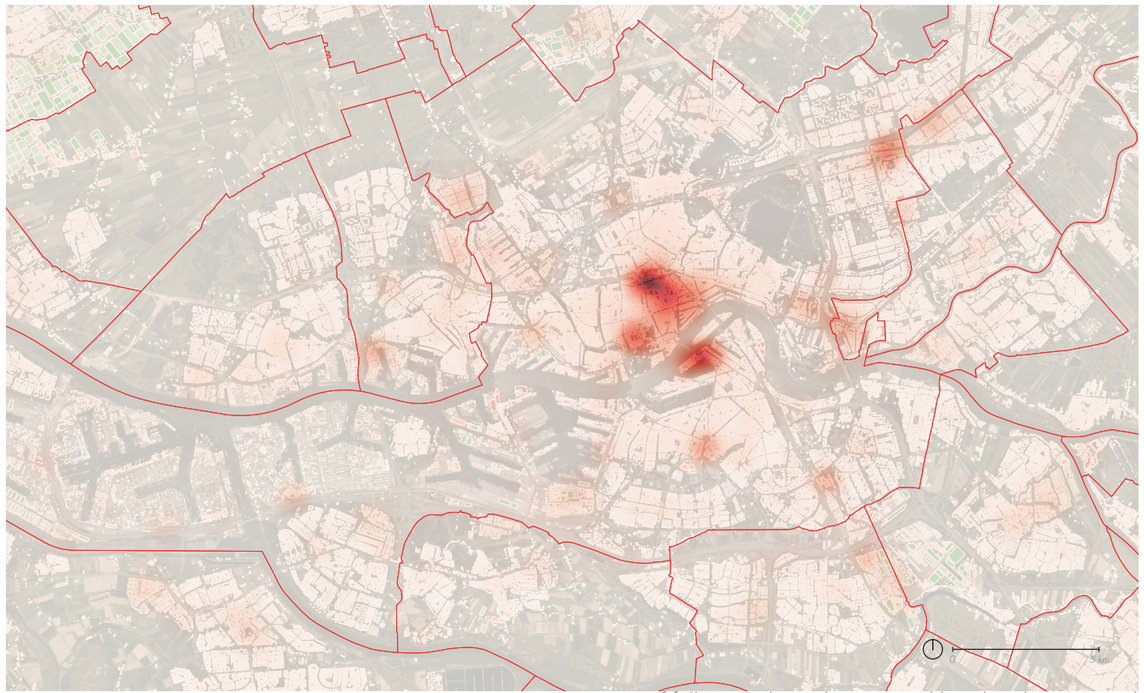


Figure 85: Heatmap of full time jobs with municipal borders (LISA, 2018)

As previously mentioned, research done by Felder & Karsten (2016) shows that 85% of families with kids in Rotterdam either have one or both parents working in Rotterdam (figure 86). It is not clear whether those numbers are also representitive for the whole population.

There are also jobs that are less easily accessible by car such as jobs in the remote parts of the harbor or on the surrounding agricultural land. Residents that work on those types of location could use active mobility and public transport in combination with shared mobility.

Delfshaven
Compared to many other parts of Rotterdam, In Delfshaven jobs are already in close proximity. From our literature research it seems that most people living here also work within Rotterdam. The main clusters where jobs are located are already very well connected by active mobility and public transport. It is important that a good balance of work and residential should be maintained.

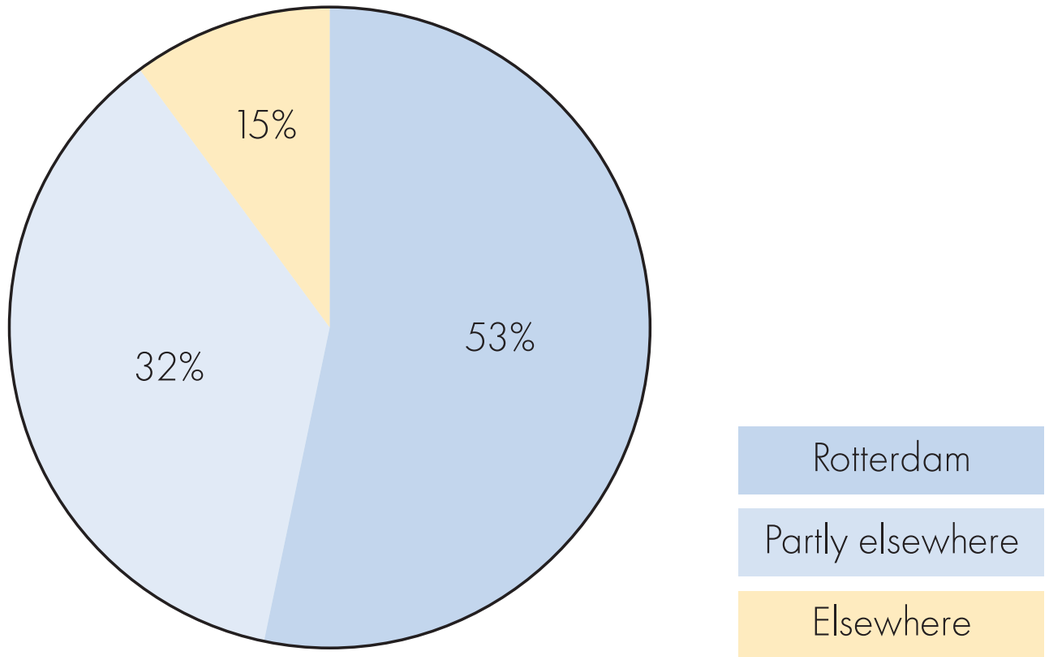


Figure 86: Job location of parents in Rotterdan (Felder & Karsten, 2016)(edited by author)

Childhood network

Neighbourhood
Kids form an important part of daily life. Having good networks and facilities in place can greatly improve a kids life and take away time consuming burdens from parents. In Delfshaven 16% of the residents are between 0 and 15 years old. This is slightly above the national average of 15% (Allecijfers, 2022).

School & chilhood friends
There are four elementary schools and two highschools in Delfshaven. In addition there are three elementary schools and two highschools within 1km from the neighbourhood. Research done by Karsten & Felder (2016) shows that if we compare Rotterdam to Amsterdam, schools are relatively further away from peoples dwellings. In Rotterdam 11 of the 15 (73%) participants in the research lived more than a kilometer away from their school, compared to amsterdam where this was only 3 out of 27 (11%)(figure x)(Karsten & Felder, 2016). Consequentially, this means that kids in Rotterdam need to be accompanied more often by a parent when going to school and that childhood friends, that are often friends from school, live relatively further away (figure 90).

Parents
Parents of young kids often have multiple social connections with parents of other kids. Those kids might be from their kids school or they live nearby. When living further away from each other those connections are less strong and are less likely to remain over time (Karsten & Felder, 2016).

Delfshaven
It is thus desirable that kids live in proximity of their school. This enables them to go to school and visit friends unaccompanied. It also causes parents to have stronger and longer lasting connections (Karsten & Felder, 2016).

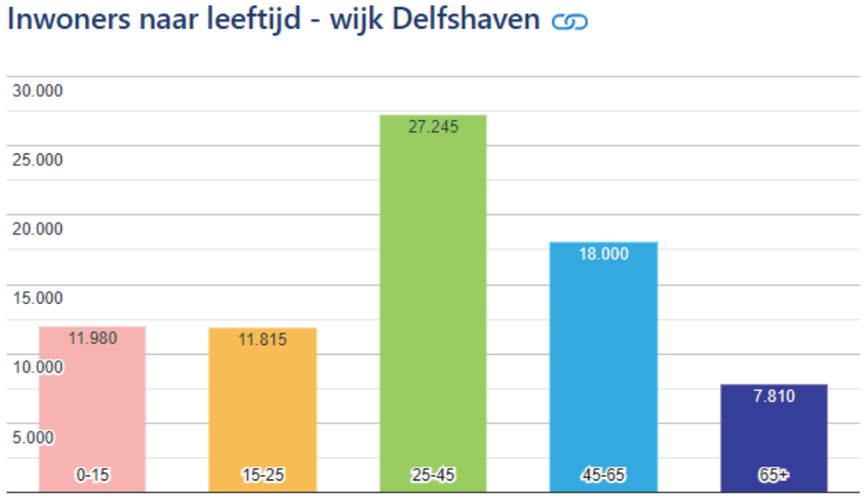


Figure 87: Population Delfshaven by age (Allecijfers, 2022)

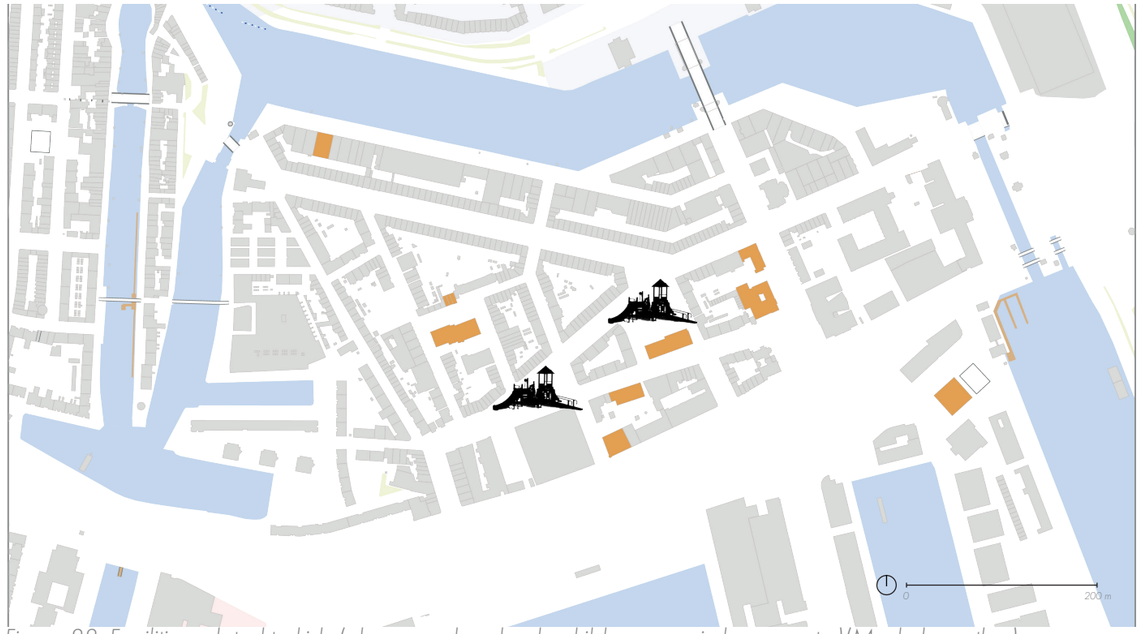


Figure 88: Facilities related to kids (playgrounds, schools, childcare, music lessons, etc.)(Made by author)

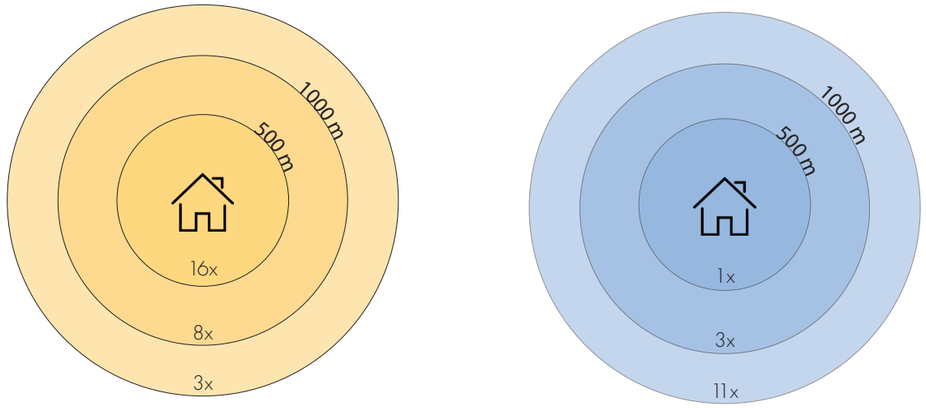


Figure 89: Distance between home and elementary school (Karsten, 1998)(edited by author)

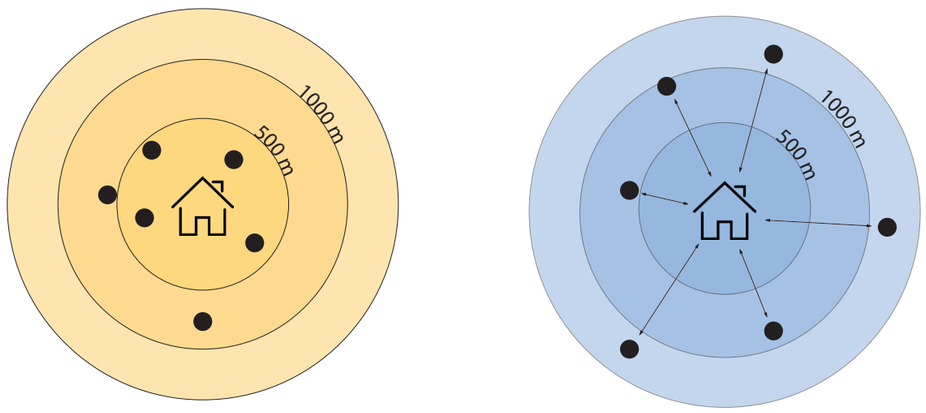


Figure 90: Distance between home and childhood friends (Karsten, 1998)(made by author)

Playing outside

Growing up
The first years in a kids life are very important for its social skills and school readiness (Brown et al., 2018). During a kids childhood screentime is averagely more than two hours a day Screentime negatively affects many aspects of early life development. Examples of this are less physical activity, less participation in organized sports, sleeping problems, being overweight, unfavorable relation to family and bad performance at school (Burghard et al., 2018). Research done among 575 kids (0-5 years & 54% boys) has shown that screen time has a significant negative effect on the progress of kids on those matters while playing outside improves the ability of a kid to learn and improve social skills (Brown et al., 2018).

Playgrounds
To increase likeliness of kids playing outside it is obvious that space has to be designed for kids. During the growing up period, kids change a lot and that means their wishes for quality outdoor playing space also changes. Playgrounds should be implemented in a variety of forms so that kids have different options to choose from during their childhood period. To ensure social security, playgrounds should be visible from residential units, but nuisance in the form of noise pollution should be limited. The right distance and location for playgrounds depends highly on the targeted age groups. Spaces for little kids require space for parents, where they can sit, watch over them and talk with other parents. Older kids often want to play away from little kids and parents, but social security should still be safeguarded (Karsten, 1998).

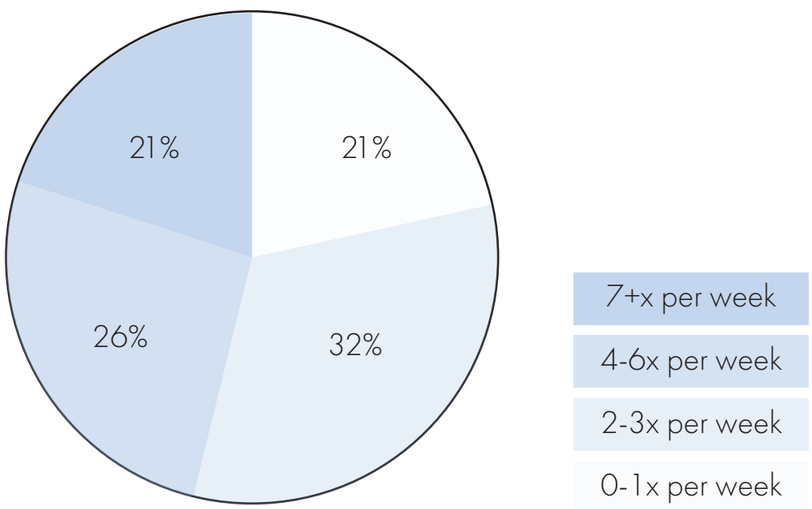


Figure 91: Frequency of kids playing outside (Karsten, 1998)(edited by author)

Accessibility
The area in which kids can play depends on different factors. As described earlier, barriers such as big roads limit the space in which kids are allowed to move freely without supervision. However, barriers also limit the space in which parents frequently move with their kids. Playgrounds should be in proximity and have no barriers surrounding it. The less barriers there are, the more likely it is that people will use the playground (Karsten, 1998).

Squares
Squares are places where people socially interact, relax themselves or simply find distraction from daily life. Squares often include little places to buy drinks, gather or enjoy views of nature or elements like sculptures. Like playgrounds, squares should also be designed in a varying way since people have different wishes. Some might look for activity while others enjoy peace and quietness. By occasionally combining squares with playgrounds, different groups can meet and socially interact, while more people add to the social security of public space.

Delfshaven
Research done by Karsten & Felder (2016) in Rotterdam has shown that parents often overestimate how much time their kids play outside. They asked kids and have found that less than half the kids play outside four or more times a week. It does not say specific durations of play time, but previously looked at research shows that screentime amoung Dutch kids sits at at least 2 hours per day (Burghard et al., 2018). The more a kid plays outside in its early years, the more likely it is to develop social skills and avoid screentime effects. To improve this situation, all conclusions on variety, proximity and availability of places for kids have to be taken very seriously.

The neighbourhood is very crowded and I have seen collisions multiple times. However, I enjoy living here, everything I need is nearby.

I don't know a lot about this part of the neighbourhood. Most of my daily trips are across the water.

The new playground is very nice for the children. But they should have added more trees since this is such a big space.

0

200 m

Figure 92: Quotes from interviews (Made by Author)

The green connection

The green connection is an initiative from the allotment gardens association together with the municipality. It will further integrate existing green networks and improve connections with adjecent developments and natural spaces. The initiative was launched in 2017 and aims to achieve goals without much public or private funding. It originated from many individual ideas that collectively have more chance of succeeding. Most elements are done by volunteering residents and even new ideas are coming from local volunteers. The project aims for local residents to engage more strongly with their (nature) surroundings and to boost interaction and narrow the gap between municipality and residents.

Big developments
The green connection forms a large 8.5 kilometer loop. Along this loop are multiple big developments. Some are finished, while some are still in the final planning stages. Three of the developments are shown on the right.

Schiehaven Noord (2040)
Potential future development, mixed-use

Little C (2021)
Dense residential and office district

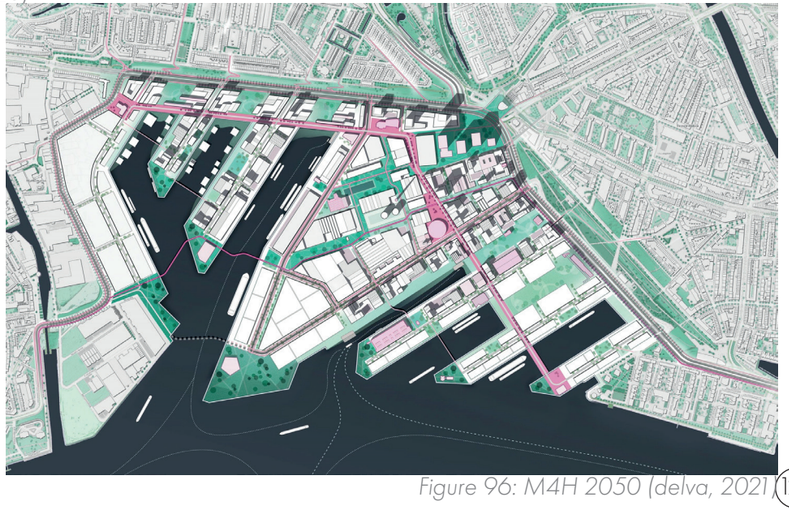
M4H (2050)
Large mixed-use harbor transformation



Figure 93: De Groene Connectie (Volkstuinvereniging SNV, 2017)


Figure 94: Schiehaven noord (AD, 2022)


Figure 95: Little C (cera-systeem, 2020)


Figure 96: M4H 2050 (delva, 2021)

Human well-being Maximalization design

The maximalization design for human well-being includes lots of squares, playgrounds and public facilities. These facilities are spread over the area so that they are in close proximity to all residents. Playgrounds and squares will be designed in a variety of ways so that people with different wishes have multiple options to go to. The area also has and will remain home to many child related facilities. These facilities will be connected to squares and playgrounds to promote double use of space and to strengthen social relations between kids, parents and other residents.

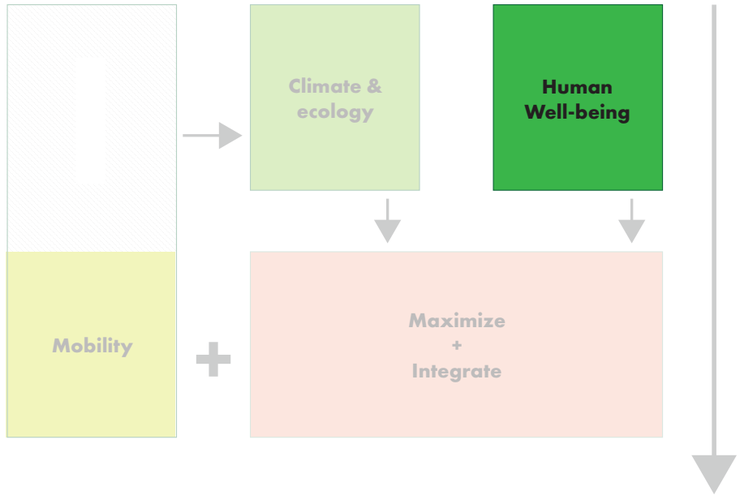




Image 97: Human Well-being maximalization (Made by Author)

7

Integrated design phase

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Biophilic design

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Ecosystems & connectiveness

Ecological

Biodiversity

Ecological environments

Ecological network

Minimize paved surfaces

Cooling the city

Emmisions

Climate

Parks with local based ecosystems

Rainwater storages & drainage

Happines

Human well-being

Quality of city life

Health

Accessibility

Mobility

Efficiency

Less pollution

Prioritizing active and collective mobility

Less space consuming

Functions evenly spread / in close proximity to every part of the area

Walkable neighbourhood network

Mobility shift

Figure 98: Design focusses and synergetic relations (Made by Author)

Design process

MESO SCALE

Methodology
To start designing many drawings have been made to inventory as many possible design options as possible. In a period of approximately three weeks, over 100 drawings have been made. The drawings are made on sketch paper so that they could be layered over each other to show relations between different options of different design choices. In this subchapter the process of drawings, conclusions and design outcomes is shown in a chronological order. You will see raw drawings on the pages on the right and conclusional or collective drawings on the left bottom page.

Heights
The heights in the area of Delfshaven vary quite a lot. The Westzeedijk forms the heighest area at four meter above NAP. This dike defends the urban area of Rotterdam against floods from the Maas. This dike is very important and heights can not be lowered. Within Delfshaven the height differs between zero and four meters. With stairs to overcome the height difference present in many parts.

Connectors & destinations
After drawing some mobility connections we can see a clear corrolation with the higher areas within the neighbourhoods. The roads follow the higher areas, possibly to avoid steep ramps. It is likely that these areas have been raised when the neighbourhood was constructed.

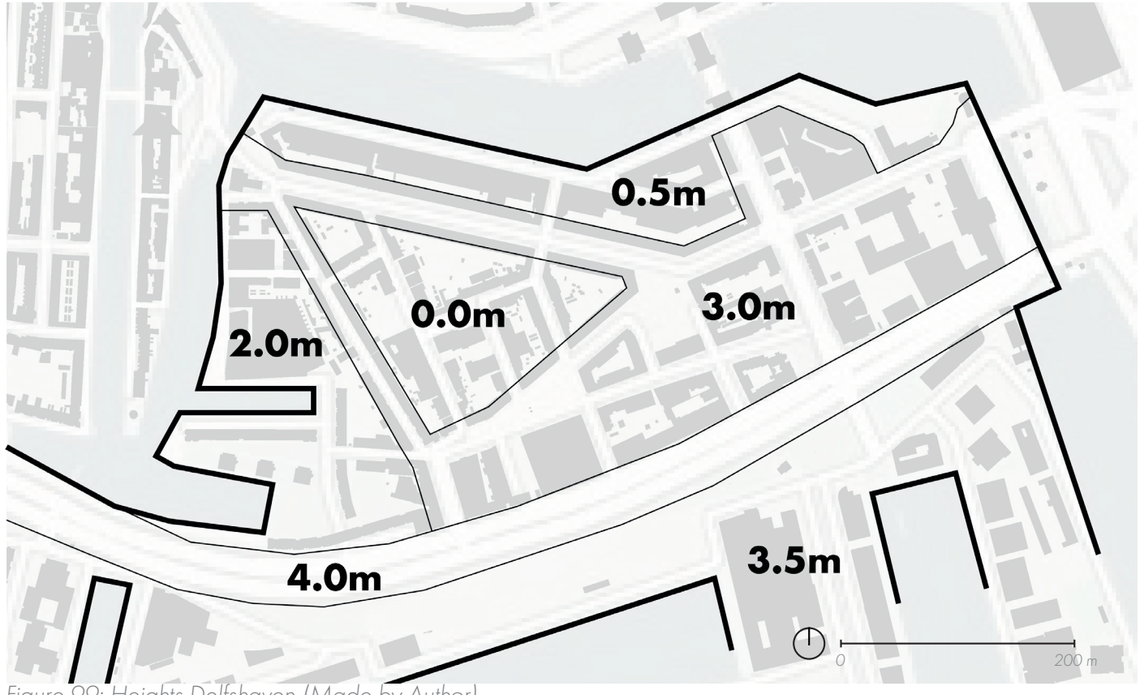


Figure 99: Heights Delfshaven (Made by Author)



Figure 100: Heights + cars (Made by Author)


Figure 101: Modes of mobility (Made by Author)



Figure 102: Heights + bikes (Made by Author)



Figure 103: Squares + bikes (Made by Author)

Ecology
For ecology all options have been tested in combination with plazas, mobility systems, parking solutions, etc. From the research done in previous chapters it has become clear that animals need routes to migrate and gather food. These routes don't necessarily have to be the shortest or the widest routes, as long as they provide characteristics necessary for a thriving ecology. These characteristics are described more thoroughly in the previous chapter but include low noise levels, wild vegetation, shade and cover. After looking at all options, a ring park and a not yet specified inner neighbourhood ecological network fit well with both mobility and places for social gathering. Animal species would still need to cross minor crossings with cyclist and occasional public transport but do barely cross path with motorized vehichles.

Social activity
From earlier research we can conclude that people living close to places for social gathering use it more often and generally have a more enjoyable living environment (Kothencz et al., 2017). Social gathering can take place in either plazas or parks and can differ in size. In figure 104, parks and plazas are spread evenly distributed while still corrolating with the required characteristics for ecological perfomance.

Accessibility
Each dwelling in a neighbourhood should be very easily accessible by bike or walking. When user intensity is low these types of mobility can be combined easily. Parking and public transport should be, just like plazas and parks, within close proximity of every building and is therefore evenly distributed.



Figure 104: Ecology + squares + bikes + cars (Made by Author)

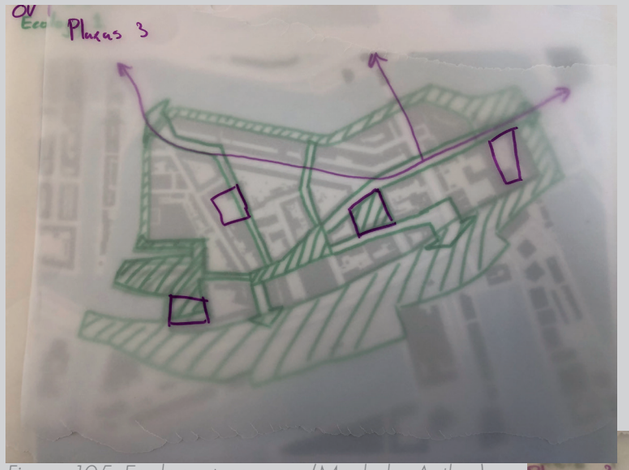
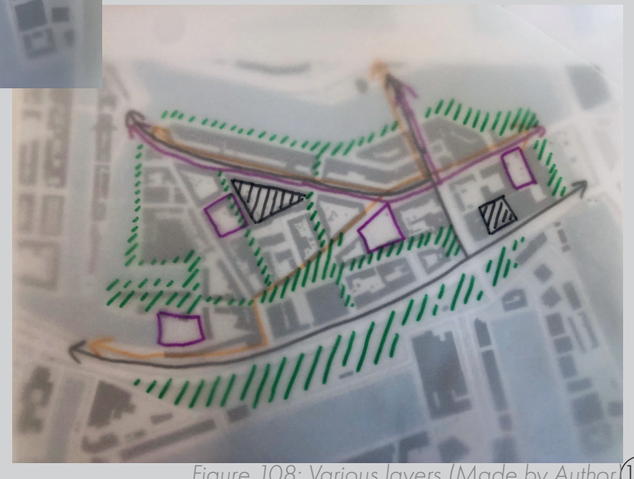


Figure 105: Ecology + squares (Made by Author)


Figure 106: Parking + squares (Made by Author)


Figure 107: Various layers (Made by Author)


Figure 108: Various layers (Made by Author)

Cycling
As car use and ownership is highly decreased, it is likely that cycling will increase. Convenience and safety should be taken in mind and problems from the past concerning too much car traffic should not be repeated with bikes in the near future. To improve cyling efficiency, direct routes should be unobstructed, bikes should have priority and bicycle parkings should be located near dwellings and bigger ones close to busy locations. Connections to dwellings can sometimes combine pedestrians and cyclists as mentioned before.

Barriers
We all know that big roads or waterways form barriers in our urban environments. However not many people see cycle paths as such. But in practice we see that busy cycle paths like the one at the Stadsschouwburg in Utrecht or the Coolsingel in Rotterdam can make it very hard for pedestrians to cross.

Freedom of movement
To ensure free movement within the neighbourhood not only for adults but also vulnerable elderly, kids or people with disabilities, we should try to redirect cycling through traffic to the paths where we want them to go and disincentivize people from using local paths by adding different pavements, more curves or other limiting objects. However, we have to make sure that residents living in this area can still easily access paths that lead to these bigger cycling routes. From different drawings, a conclusion is made to choose a partial cycling ring. This way all important external connections are still in place, people within the area are always in proximity of the loop and pedestrians within the loop have less disturbance from busy cyclepaths.

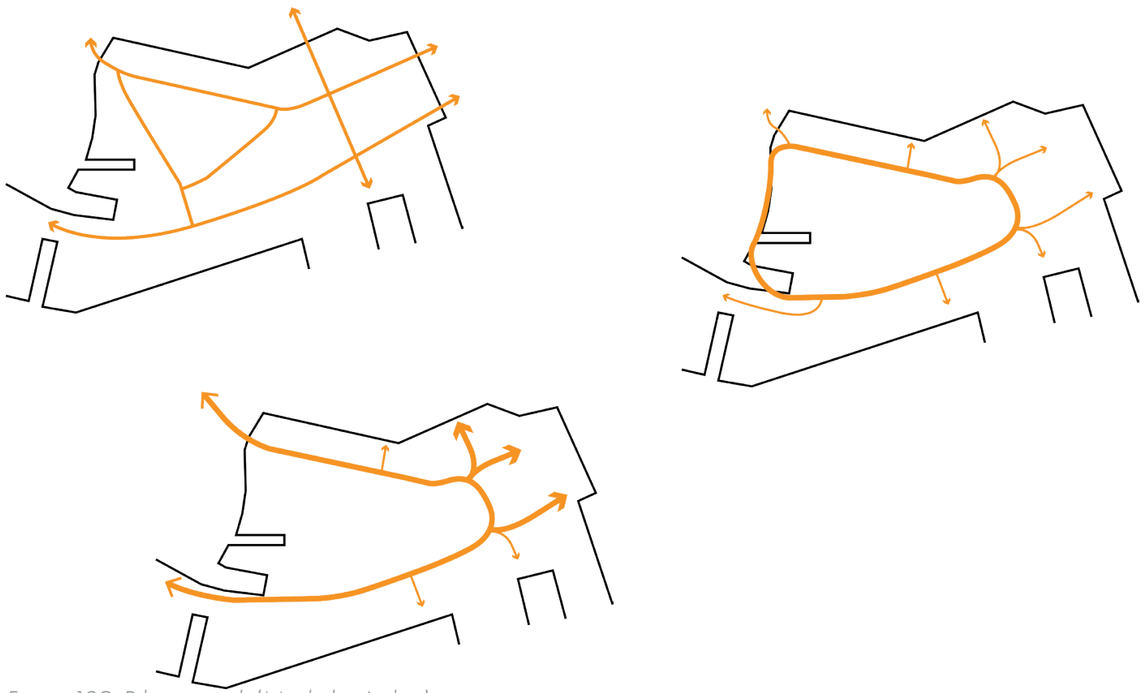


Figure 109: Bike network (Made by Author)

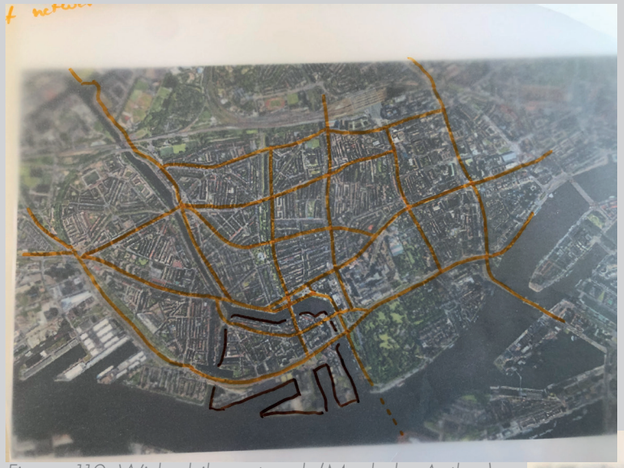


Figure 110: Wider bike network (Made by Author)



Figure 111: Connections options (Made by Author)



Figure 112: Important through routes (Made by Author)



Figure 113: Superblock / car limited area (Made by Author)

Shared spaces
As described in the chapter of mobility, shared space only works when user intensities and speed differences are relatively low. Through traffic should have seperated routes as much as possible where pedestrians and cyclists have top priority. Roads that connect to dwellings and parts deeper within the neighbourhood can be used by pedestrians, cyclists and occasional cars all in the same space as they will move slowly (<20km/h) and there will be few cars and bikes.

Parking
Parking for shared mobility should be evenly spread so people are in acceptable distance of a parking facility. The acceptable distance is hard to specify but it should be walkable within 5 minutes. For some people this means walking 400 meters is acceptable, but to include all of the population a distance of 300 meter is chosen. Putting parking to close to people will disincentivize other modes of mobility such as cycling and public transport. Parking should also be located where cars are already allowed to go. In these places cars will have seperated lanes from slower mobility, but might, depending on the busyness, share the road with public transport.

Heights
Overlaying our options with the heights shows that the lowest part of the neighbourhood is at a three meter difference with its surroudings. Creating a parking garage here that connects to the higher laying road is therefore a difficult task and might not give the preferred spatial quality.

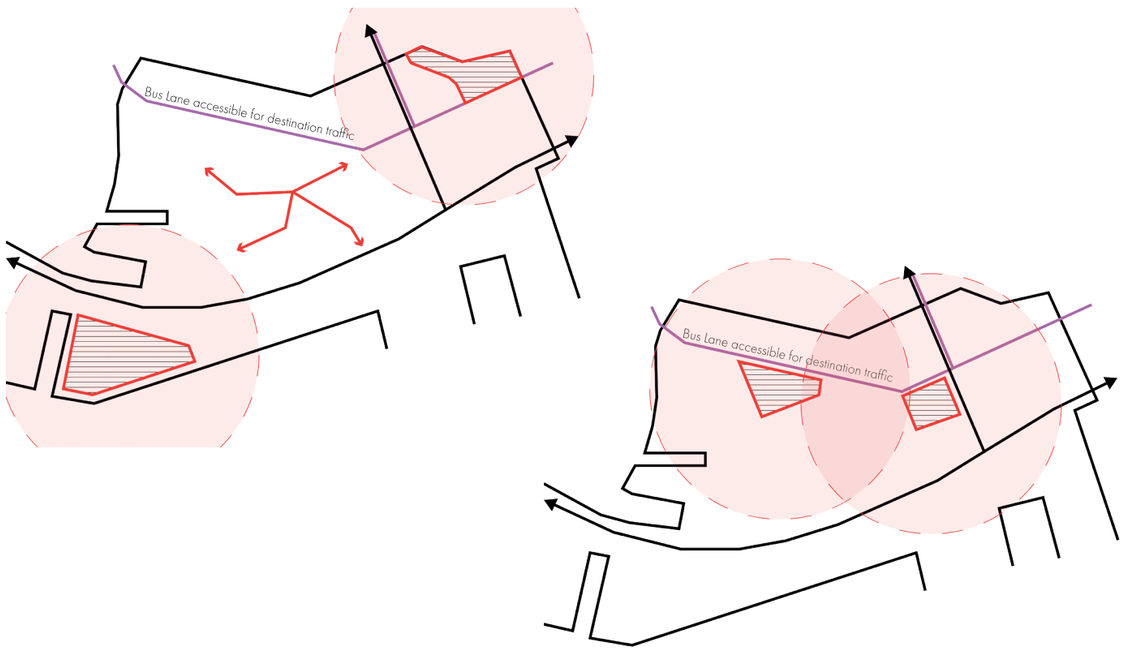


Figure 114: Ecology + squares + bikes + cars (Made by Author)


Figure 115: Car + bus (Made by Author)


Figure 116: Bike + shared space (Made by Author)



Figure 117: Heights + parking (Made by Author)



Figure 118: Heights + parking (Made by Author)

Buildings condition

Below we see a map of all the construction years and energy labels of all the buildings. Over 80% of the buildings is build before 1980 (figure 120) and the quality of some of these is relatively low (figure 119). It might therefore be beneficial to renovate or rebuild some of these buildings.

Morphology

The morphology of the area exists of a linear grid to the north along the water, big plots along the Westzeedijk, varying grid in the inner triangle and '80s transformation to the west (figure 122). To increase walkability and reshape public space, height differences and morphology of the inner triangle can be changed. Some ideas for this are shown in the drawings on the next page. When removing or renovating buildings, special attention should go to its historical value, iconic appearance and added value of the change. More parks and plazas are of course beneficial for residents, but lower densities are bad for the feasability of affordable public transport, enough housing supply and to create enough critical mass to allow economic functions to locate within the area.



Figure 119: Energylabels of buildings in Delfshaven (Nationale Energie Atlas, z.d.)

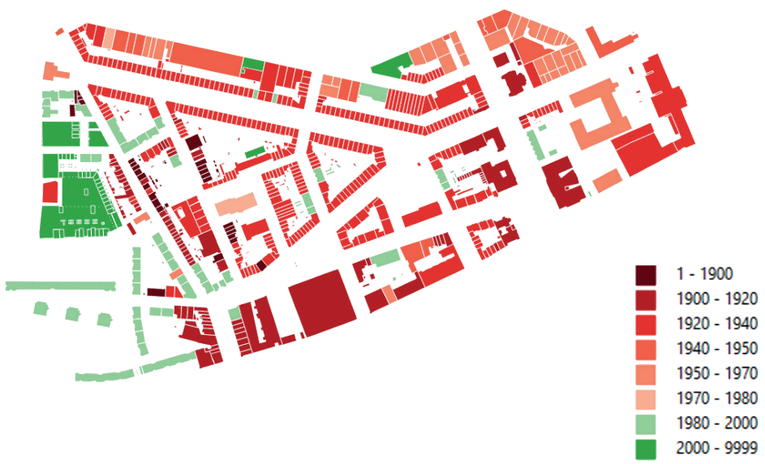


Figure 120: Construction years of buildings in Delfshaven (PDOK 2022)

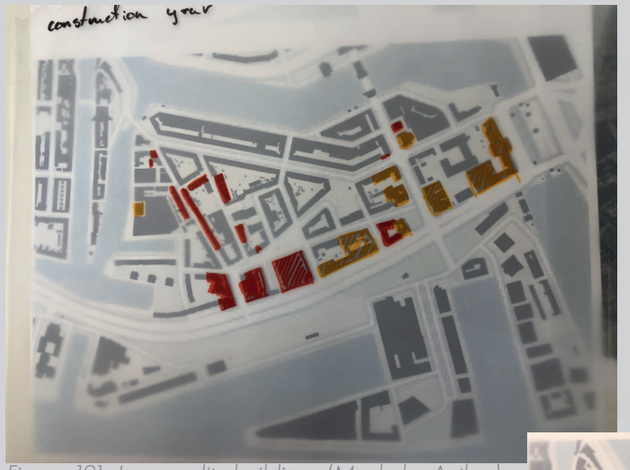


Figure 121: Low quality buildings (Made by Author)

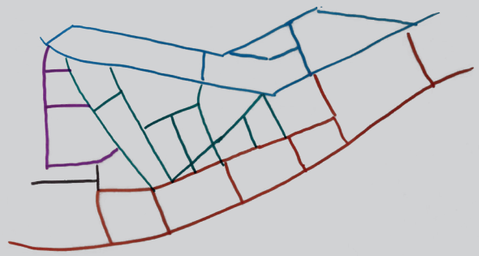


Figure 122: Morphology (Made by Author)

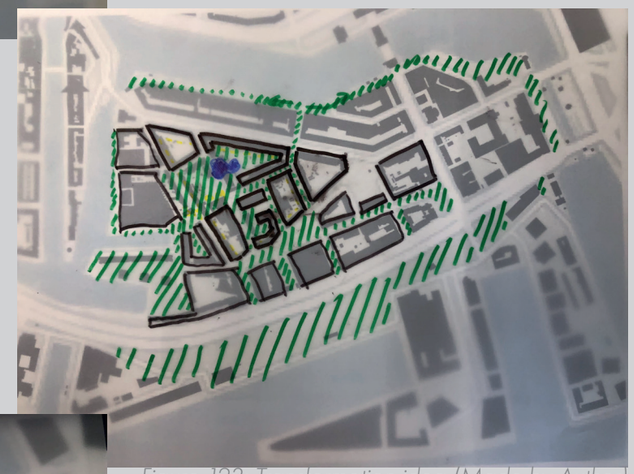


Figure 123: Transformation idea (Made by Author)



Figure 124: Transformation idea (Made by Author)

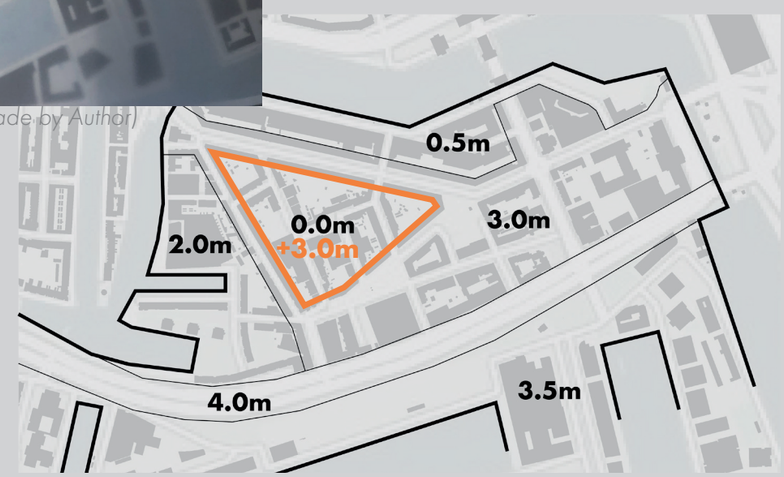


Figure 125: Heights (Made by Author)

Transformation

As mentioned, ideas for transforming the inner triangle (figure 126) are drawn and compared (figure 127). Options include denser blocks with more public space, less buildings, opening up building blocks and removing old or energy inefficient buildings to create green plots.

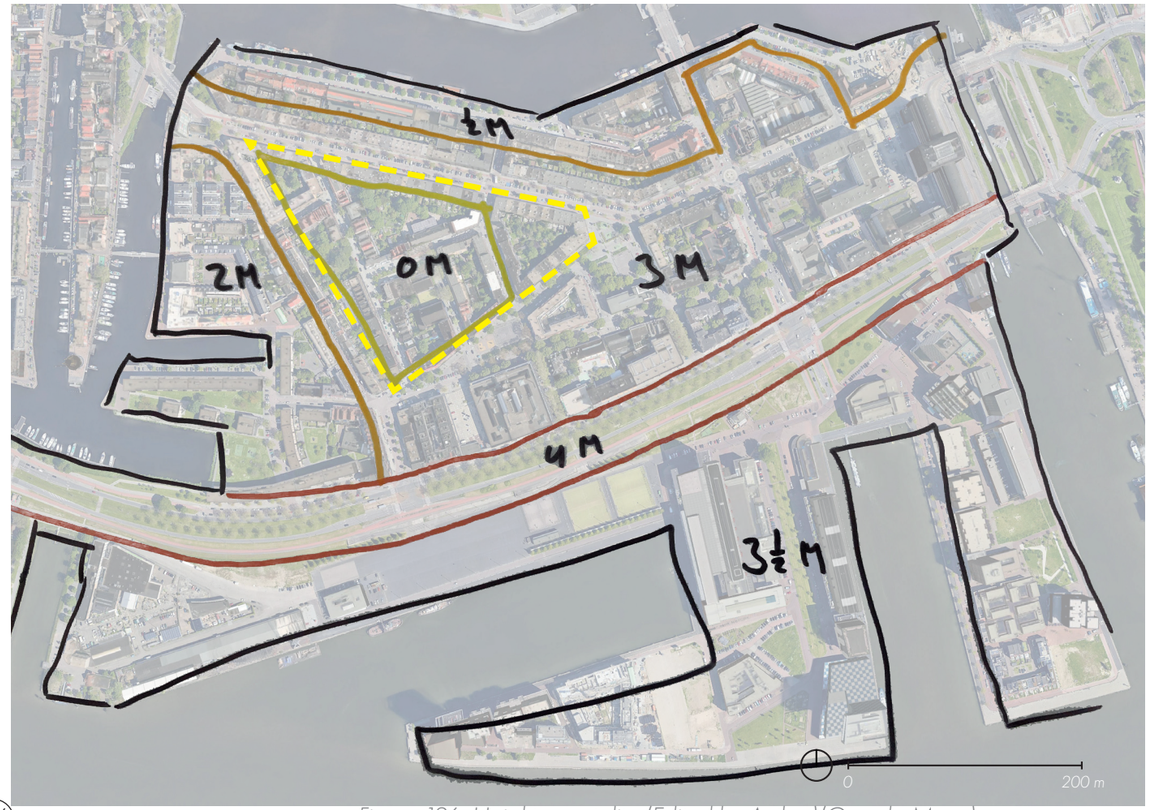


Figure 126: Heights + satalite (Edited by Author)(Google Maps)

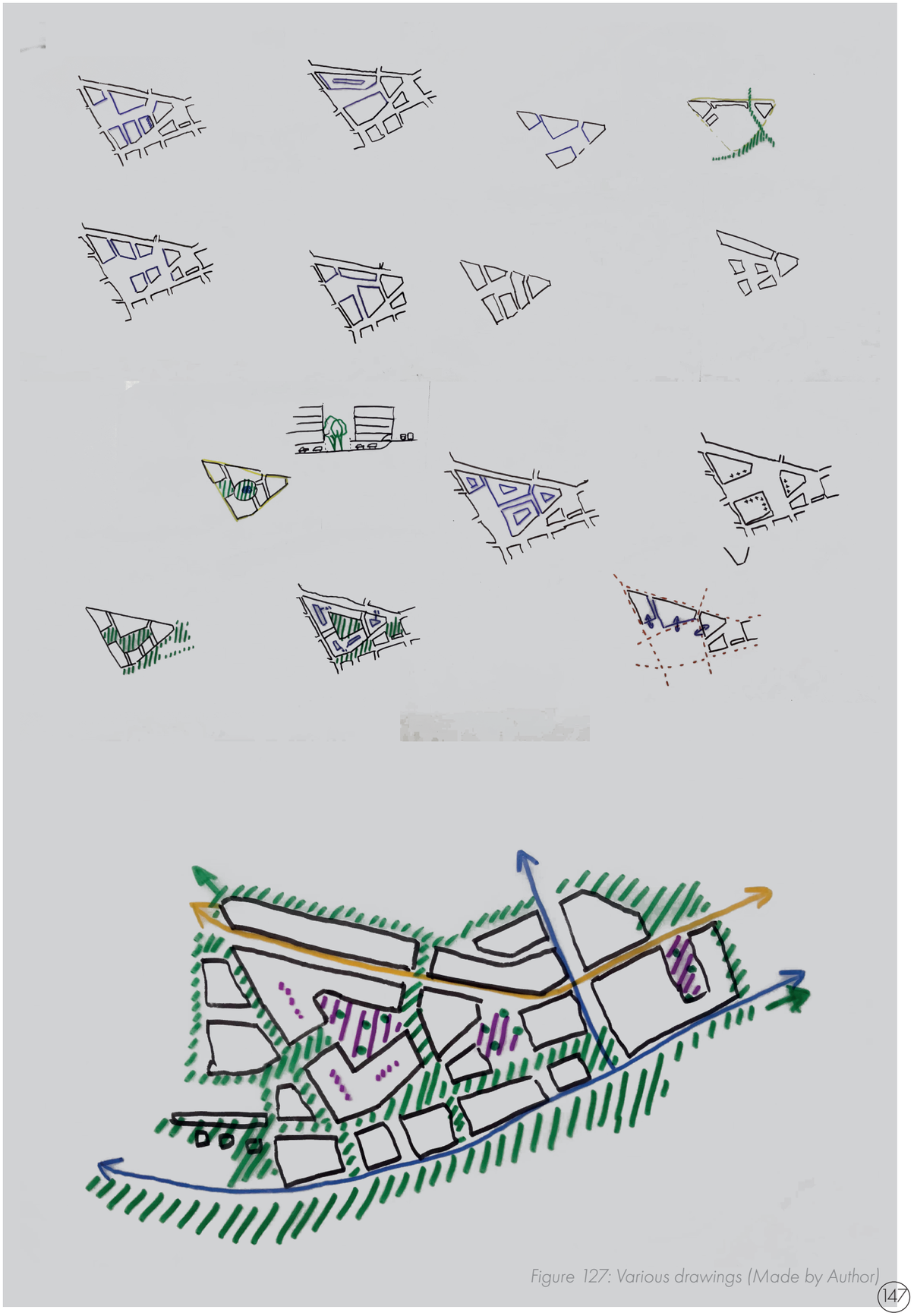


Figure 127: Various drawings (Made by Author)

The design includes two new cornershaped buildings. The two buildings together with an existing building form a triangle superblock. The superblock embraces a large inner park and has multiple entrances to this park. The buildings are wider and towards the middle they increase in height. They have a rooftop garden that allows for more green and for sunlight to reach the more centrally located parts of the building. The height on the street sides is kept the same to maintain a recognizable environment and to allow sunlight to reach these streets. The design of the building includes interventions that allow animals like bats to nest in the facades, just like they were able to in the older buildings.

The buildings sit next to the street at three meter elevation. The park in the middle is at a zero meter elevation. Lower elevated parts of the buildings will have parking for shared mobility and bicycles and edges of the park will be sloped against the buildings. The sloped park can capture, store and slowly allow water to seep into the ground in periods of heavy rainfall.

The new design maintains the amount of floor space while reducing the amount of ground space that is used. This causes the public space to expand noticably in an area that currently is very dense.



Figure 128: Final transformation idea (Edited by Author)(Google Maps)



Figure 129: Final transformation idea (Edited by Author)(Google Maps)

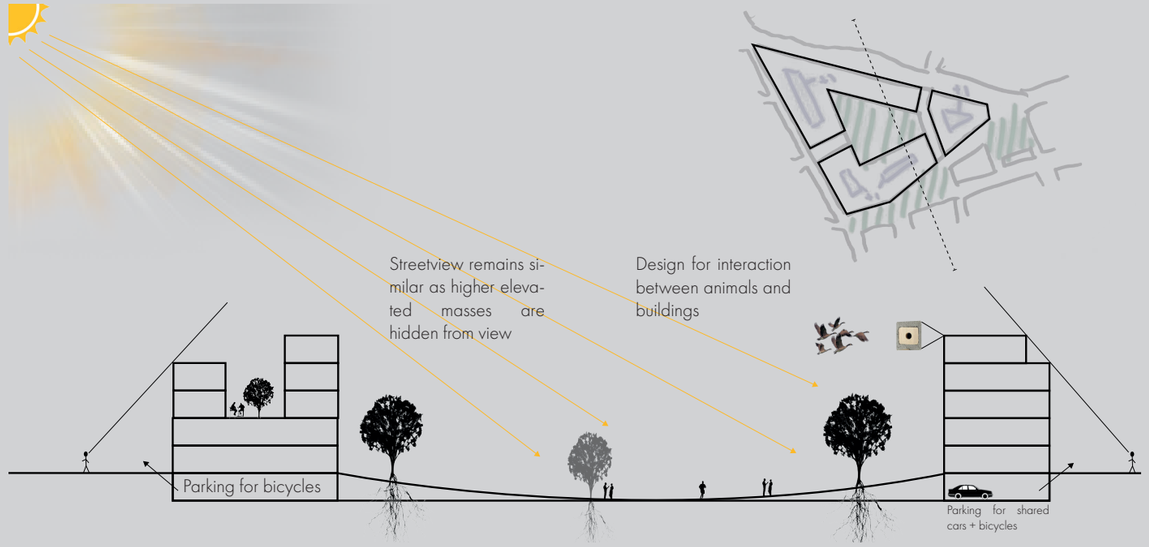


Figure 130: Transformation section 1 (Made by Author)

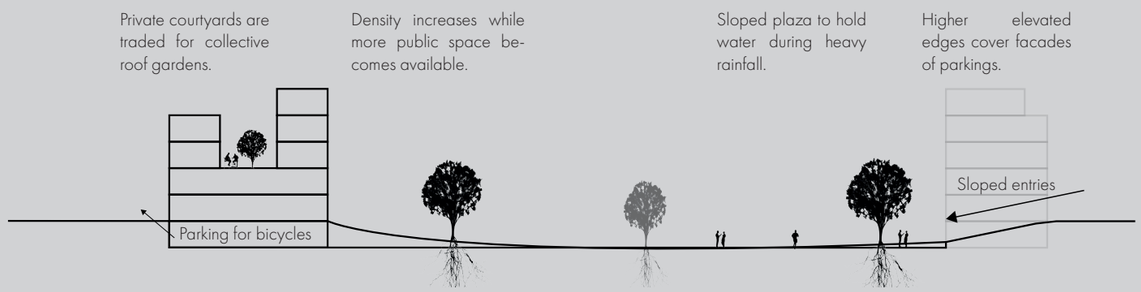


Figure 131: Transformation section 2 (Made by Author)

Design process

MICRO SCALE

During the design process drawings have also been made on a lower scale. Choices made on a larger scale can have many implications on lower scales and it is important to think about these and to base choices on a multi-scale approach.

Drawings for the smaller scales have been made on five locations. These locations are highlighted in figure 132 and include a central square, a busy intersection, a bridge over the canal slots, a quay near the water and a more detailed design for the newly created park in the center. The locations will be shown in this same order as figure 132.

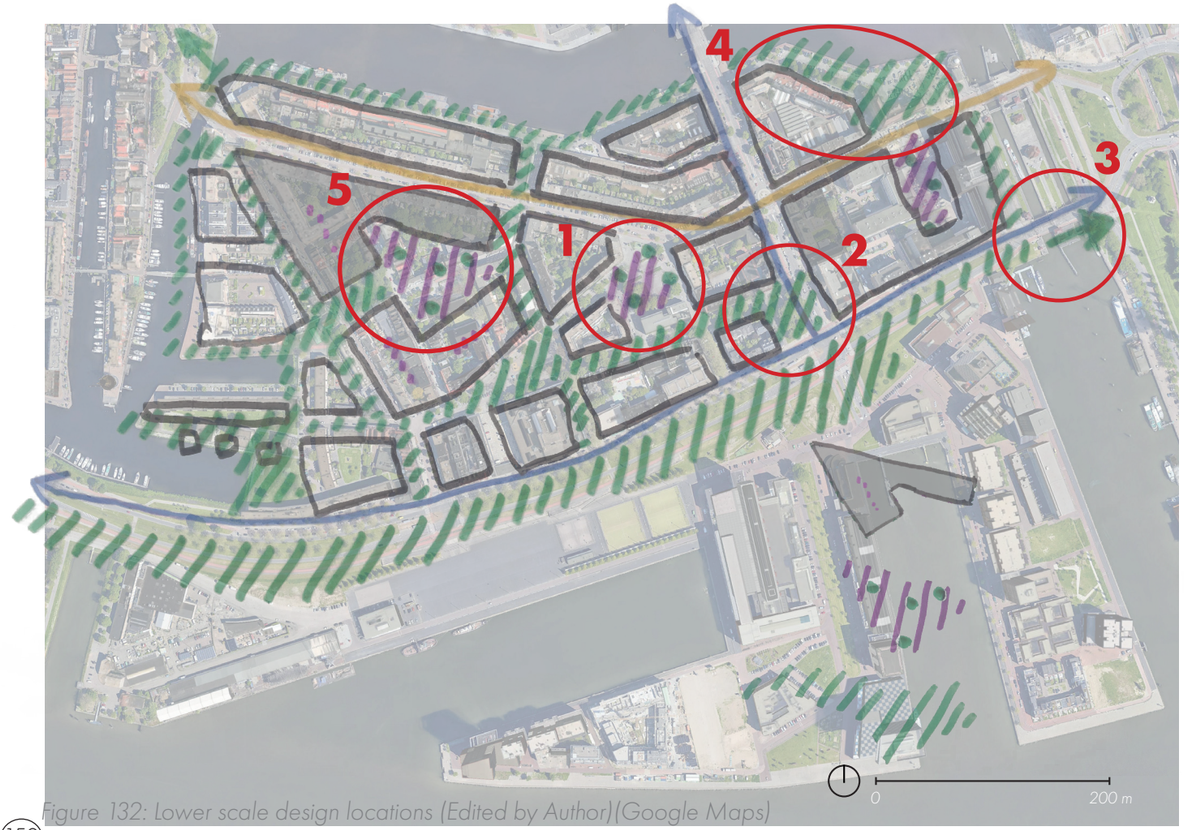


Figure 132: Lower scale design locations (Edited by Author)(Google Maps)

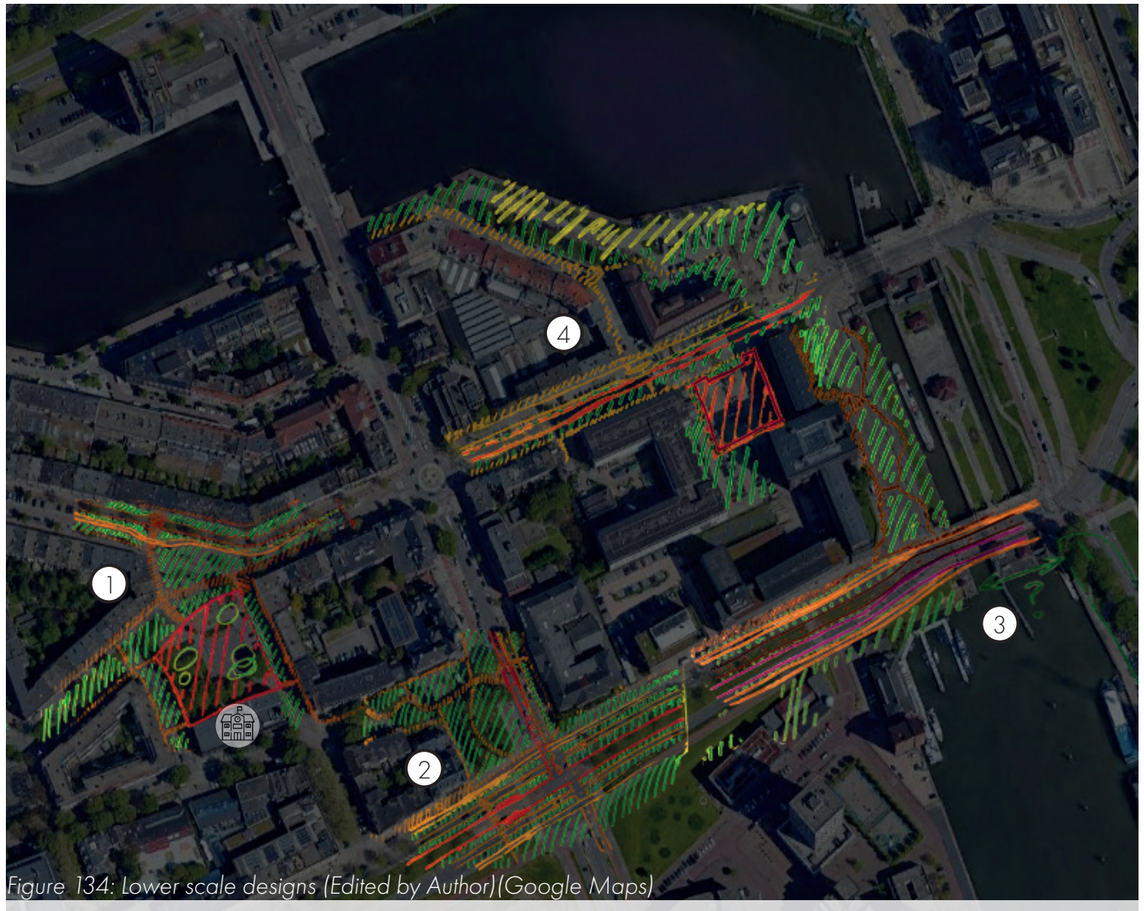


Figure 134: Lower scale designs (Edited by Author)(Google Maps)



Figure 135: Vegetation distribution (Made by Author)

1. Central square

This square is located near the Willem Buytewechstraat. It connects this street through the square to multiple alleys and streets that go in different directions into the neighbourhood. The area they connect to is part of the pedestrianized triangle and the main ecological structure.

Located next to the square is a high school. The square functions as a schoolyard during school hours and can be publically used by the neighbourhood afterwards. In this way, the space is used multipurposely and more residents can use and enjoy this space.

In figure 135, a visualization of the surfaces that are either covered by grass or more ecological vegetation are shown. We can see that the square connects multiply ecological corridors. For this reason the choice is made to keep the north part of the square unpaved so that different strips of nature are connected.

2. Major intersection

The intersection between the Pieter de Hoochweg and the Westzeedijk is currently the busiest intersection in the project area. There are traffic lights and many lanes to queue for different directions. With the expected reduction of local car users as well as city wide policies that reduce car use, the intersection can be scaled down.

A first design for this was drawn (appendix 2), Lanes are reduced while greenery and more space for pedestrians and cyclists are added. If we look at the distribution of green (figure 135; 2.1) we still see a large white gap at the intersection. Wider gaps form barriers that are hard for animal species to cross.

To reduce the width of the gap in greenery, a reference project is used and applied to the project area. The Papsouwselaan in Delft is a busy corridor (Figure 136). It includes multiple rows of trees and is easy to cross without traffic lights due to the space between lanes to cueue for turning traffic. In figure 135; 2.2 we see the design of the Papsouwselaan applied to the project area. If we compare the distribution of vegetation between the previous design and the new reference based design, we can clearly see a reduction in width of the barrier.

3. New bridge

The slots over the canal are located in the south east of the neighbourhood. They connect Delfshaven to Het Park and many of the city center areas. Currently space for mobility consumes the whole bridge and this creates a large gap in the ecological corridor. The sidewalks and bicycle paths are also narrowed to fit the narrow profile.

The new design proposes to create an extra bridge. This bridge allows for greenery accross the water and can add a pleasent pedestrian conenction that is not located next to a busy road. The current sidewalk space on the old bridge can be used for widening the narrow bicycle path.

4. The beach

The canal quay is at the north east corner of the project area. It has a large paved area that is currently used for parking. In the new design, cars will be parked in central facilities and the amount of cars will be reduced. This space along the water is part of a long pedestrianized zone from east to west of the area and is therefore designed with a wide pedestrian path. Due to overcrowded public spaces and beaches that are overcrowded on hot summer days, this location will be transformed into a city beach. Beaches are great places where many different people socially interact during summer days. Towards the buildings there will be vegetation to add to the ecological performance of the waterfront.



Figure 136: Papsouwselaan, Delft (Google Maps, 2022)

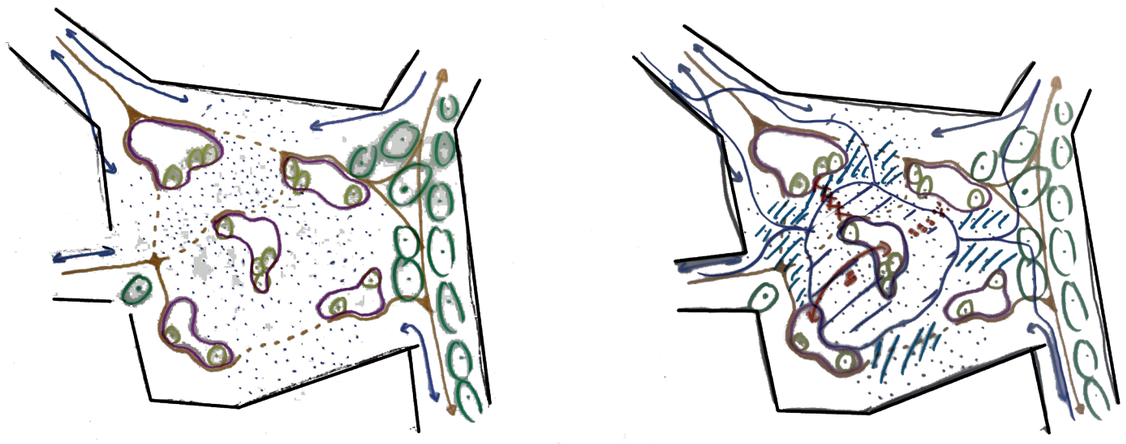


Figure 137: Final wetland design drawings (Made by Author)

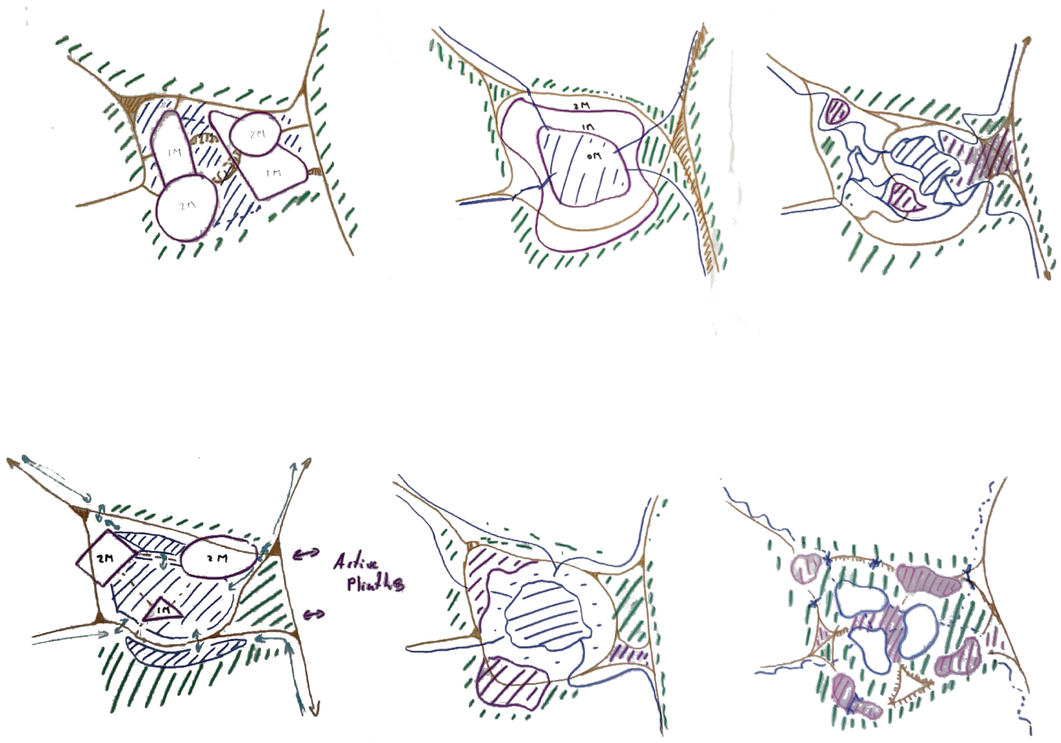


Figure 138: Various drawings for central triangle park (Made by Author)

5. Wetland park

In the middle of the newly transformed building blocks is a large open space of around 2.8 hectares. Due to the earlier mentioned height difference, the space is prone to flooding. In the design phase different approaches are tried to include the water in the design. Some options are shown on the left bottom. The final design drawings are shown in figure 137. A set of smaller squares with natural shapes is picked for this. The squares surround a body of water and an island in the middle is accessible and creates an interesting and adventurous landscape for kids. The design uses the difference in water levels to create a landscape that can soak up water during heavy rainfall and retain water during droughts.

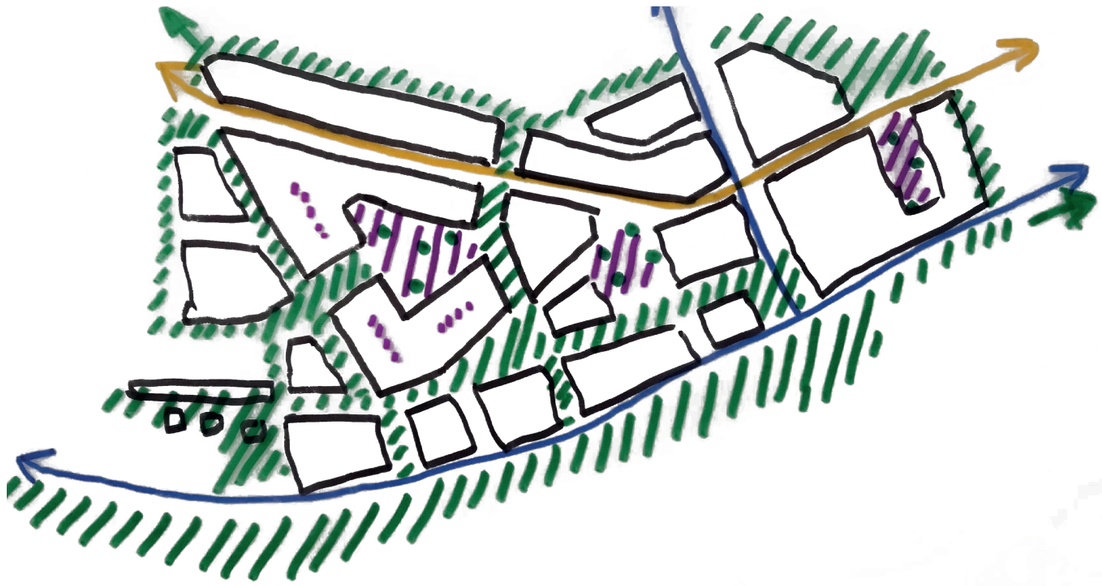
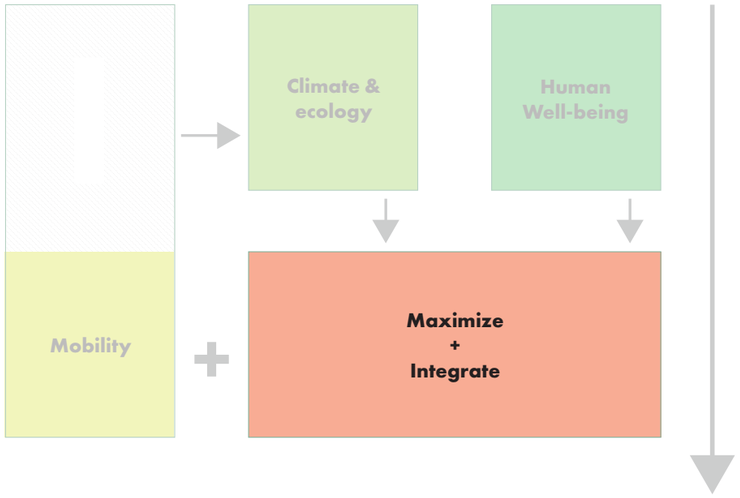


Figure 139: Ecological network, squares and mobility (Made by Author)

Delfshaven
Integrated design



This last chapter shows the final design for Delfshaven. It integrates the exploratory designs of ecology, climate, mobility and human well-being in a balanced way. The chapter includes various maps, sections, streetscapes and conclusional texts to give a full overview on the project.

On the next page you will find the design principles. They are divided per theme and specific guidelines are given for most of the principles. The guidelines are based on the research done in the earlier chapters and are therefore not eleborately repeated here.

Principles and guidelines

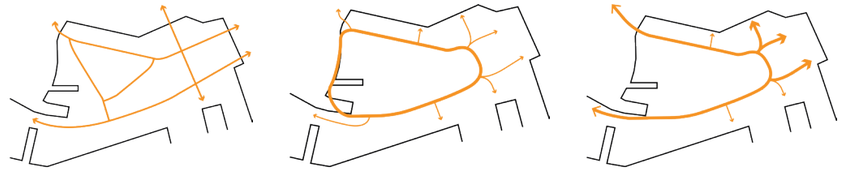
Theme	Principles	Guidelines
Human Well-being 	**Social space** Interactive, inviting, friendly, diverse	- Public space includes a variety of spaces to meet and interact
	Active space Active, fun, adventurous, useful	- Parks and squares have unique designs - Public space includes elements where residents can interact with nature
	Comfort space Safe, 'green', walkable, attractive	- Dwellings facing public space - Wide and attractive walking routes
	Accessible space Connected, continuous, proximity	- Park or square within 300 meters - Atleast two parks or squares accessible without crossing any barrier
Ecology 	**Habitat variety**	- The neighbourhood includes a variety of habitat types - Habitat types on page 160
	Large ecological areas Qualitative	- Ecological corridors are connected to large nature inclusive areas
	Connective Reduce barriers	- Limit barriers on corridors - Pedestrians have priority and other modes of mobility are limited in most of the neighbourhood
	Collective Maintenance, garden management	- Participation in design and maintenance by residents
Climate 	**Cooling down** Surface nature, tree cover	- 40+% surface vegetation - 30+% tree crown cover
	Reduce flood risk Draining & retaining water	100mm rain (38.000m^3) - Capacity to drain 40% to canals - Capacity to retain 60% in area (23.000m^3)
Mobility 	**Sustainable**	- Electric
	Collective	- No private car ownership
	Appealing Comfort, efficiency, costs	- Cheaper & faster than cars - 15 minute schedule - Ample peak capacity

Design process

Some conclusional diagrams from the design phase

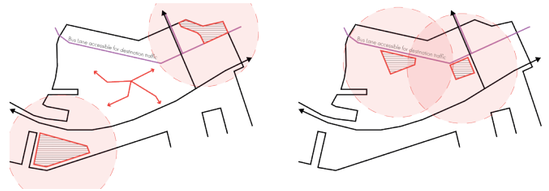
Cycle network

Reducing mobility barriers
Connecting important routes



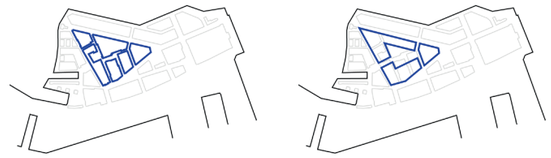
Shared cars

In proximity to all residents
Alongside mobility corridors



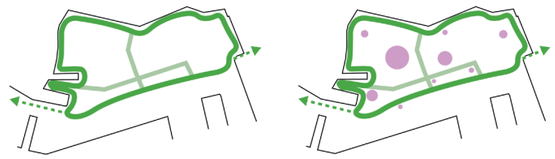
Transformation

Low elevation and bad energy labels
Creating denser buildings for more public space



Squares and parks

Ringpark with inner neighbourhood spokes
Squares outside, but connected to the ecology



Variety

Squares and playgrounds have diverse designs to fit different preferences

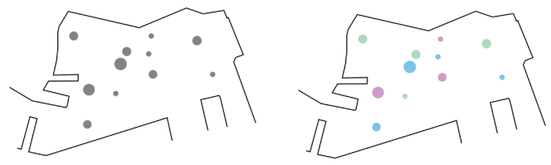
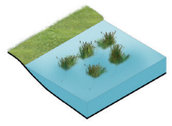
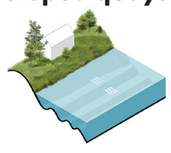


Figure 140: Various conclusional design digrams (Made by Author)

Ecology

Types	Condition	Species
Parks 	Large trees, wide dense tree crowns, spontaneous vegetation	White Maple, Northern Maple, American Lime, Western Sycamore, Tullip Tree, Prunus, Horse Chestnut, Oak, Walnut tree, schrubs, flowerbeds
Primary corridor (1) Wide > 20m (2) Narrow < 20m 	1. Medium to large trees, dense high tree crowns, deciduous	White Maple, Northern Maple, Western Sycamore, Horse Chestnut, prunus, Tullip tree, Oak, Schrubs, flowerbeds
	2. Medium trees, dense high tree crowns, deciduous	Northern Maple, Western Sycamore, schrubs
Secondary corridor (1) Wide > 20m (2) Narrow < 20m 	1. Medium trees, dense high tree crowns, deciduous, sitable grass	Northern Maple, Western Sycamore, Oak, Lime, Hornbeam, schrubs, sitable grass, hawthorn
	2. Small trees, dense high tree crowns, deciduous	Northern Maple, Oak, American Lime, Hornbeam
Wetland 	Temporarily wetland, water resistant vegetation, water purifying vegetation	Reeds, Willowherb, Lilies, Woolgrass, Blue Vervain
Sloped quays 	Water resistent vegetation, water purifying vegetation	Weeping willow, reeds, Willowherb, Woolgrass
Mobility corridor 	Small to medium trees, dense high tree crowns, road salt-resistent, pollution resistent	Northern maple, Oak, American Lime, Hornbeam

Trees	Specification	Requirements
	**General**	1m³ roots space / year 1/2 m³ groundwater / year 1/3 m³ high quality soil/ year
	Large > 18m height ~15m crown diameter	~60 years 60m³ root space 30m³ groundwater 20m³ high quality soil
	**Medium** 9-18m height ~9m crown diameter	~30 years 30m³ root space 15m³ groundwater 10m³ high quality soil
	**Small** < 9m height ~4m crown diameter	~10 years 10m³ root space 5m³ groundwater 3m³ high quality soil

Ecology principles

As shown at the beginning of this chapter, the main principles for ecology are the creation of a variety of habitat types, large qualitative ecological areas, connections between ecological areas and collective participation in design and maintenance. Collective maintenance reduces costs and creates higher quality habitats than individual management (like backyards in their current form) (Norton et al., 2016). Collective participation in design can also increase acceptence for big changes in the living environments of residents (Kothencz., 2017). When applied together, the principles will create a well performing ecological neighbourhood and species richness and populations are likely to increase significantly.

Page 160 shows different urban ecological types in the neighbourhood. Conditions are described and matching tree and plant species are named as example vegetation. Above, requirements for unconstrained and healthy grow of large trees is shown.

Climate principles

When talking about climate change, our project area is facing two main problems. Climate is expected to change and it is likely that heavier and more frequent rainstorms will appear. It is therefore important to have enough capacity to drain and store water in the area. Secondly, the climate is expected to get warmer and more heatwaves will occur (IPCC, 2022). To reduce heat stress, enough places with shade have to be created and vegetation should be added to help cool down our cities. A big part of solving our climate problems can be solved by adding, and growing, large trees. Large trees extract a lot of water, create alot of shade to hide from the heat and significantly cool down the area (Beatley, 2011). As you can see above, trees need significant amount of time to grow big, so solving urgent problems in 50 years requires interventions to be done now.

Ecology and climate interventions are often synergetic, as they benefit both goals of reducing climate risks and increasing ecological performance at the same time.

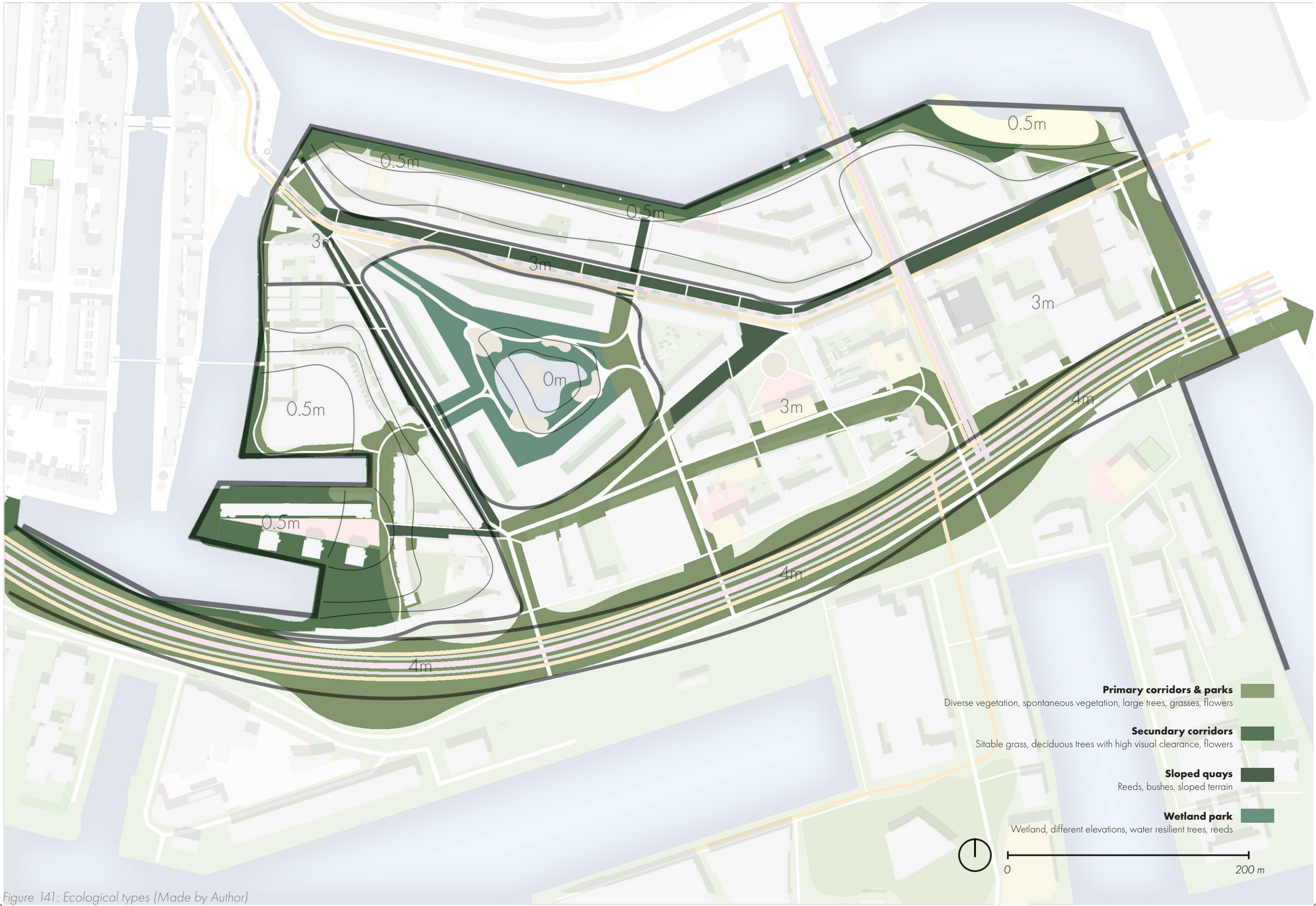


Figure 141: Ecological types (Made by Author)

Human Well-being

Group	Specification	Preferences
Toddler 	0 to 4 years old	Toddlers are in the development phase of basic skills like walking and speaking. They are always accompanied by adults. Playgrounds should be simple and in proximity.
Primary schoolers 	4 to 9 years old	Primary schoolers are entering the main learning phase in their life. While they learn to read and calculate, they also develop the wish to play and develop their first significant social skills. It is important that public space allows kids to play together and facilitates a challenging, but approachable design.
	9 to 13 years old	Towards the end of primary school, kids develop the need to have more adventurous environments to play in. They are likely to play with friends without an adult accompanying them.
High schoolers 	13 to 18 years old	The switch between primary school and high school is a big step in growing up. In this new phase of life, kids are likely to get new friends, develop new interests and are less eager to spend time with their parents. They like to do their own thing and are often attracted to spaces without adults or little kids present.
Adults 	18 to 67 years old	Adults are at work during day hours and like to have a comfortable living environment. In the early adult years, they often spend time outdoors, but are less likely to stay in the neighbourhood like kids. In later years, adults like to spend time with their kids or they appreciate to have nice places to go for a walk or to bike through attractive routes.

Group	Specification	Preferences
Elderly 	67+ years old	The elderly are in the last (big) phase of their life. Their work stopped, kids are out of the house and physically they are in decay. They often like to spend their time outside cycling or walking. They enjoy peacefull environments and are often moving out of the city during daytime. Once physically imcapable of moving longer distances, elderly are often limited to a smaller area. Functions should always be nearby and in exceptional circumstances, elderly should have the possibility to be picked up by a vehichle at home.

Human well-being

As mentioned previously in this report, human well-being is about the physical and mental well-being of the population. The well-being of the population can be facilitated by creating places that are in line with four main principles. These are that spaces need to be social, active, comfortable and accessible to become 'places' (Robertson, 2017). These principles are then translated into guidelines for the design. The guidelines are repeated below:

Social space
- Public space includes a variety of spaces to meet and interact

Active space
- Parks and squares have unique designs
- Public space includes elements where residents can interact with nature

Comfort space
- Dwellings facing public space
- Wide and attractive walking routes

Accesible space
- Park or square within 300 meters
- Atleast two parks or squares accessible without crossing any barrier

Residents of different age or gender need different spaces. Although humans live through many different phases during the entirety of their life, it is less likely for older people to require different types of public space. For this reason the division in age groups widens after the childhood period.

Clidhood period

The childhood period is an important period in life where many social and physical skills are learned. Those skills are learned best when characteristics of space and proximity of childhood related functions (schools, sports, etc.) are present (Karsten, 1998).

Change of culture

Kids are often more adaptable to change and have less problems with imagining utopian futures. While adults often reason if something is feasable by applying their own experiences, kids can look beyond these limitation and try to fit the ideas in their wide imagination. Because of this, kids can help by creating acceptence for these kinds of changes and can form an example for older people. Limiting car use and allowing kids to experience the benefits of sustainable mobility can increase the likeliness that they won't want a car when they grow up. By creating adventurous spaces that allow interaction between humans and nature, people become more aware of their green surroundings and start to understand natural systems better.

Since the project proposes a big change in use of public space and because of the size and complexity of the project it is likely that the change will happen over multiple decades. Interventions that promote this change of culture among kids in the starting phases of the transformation, can benefit acceptance in later phases.



Figure 142: Human Well-being & Public Space Distribution (Made by Author)

Masterplan

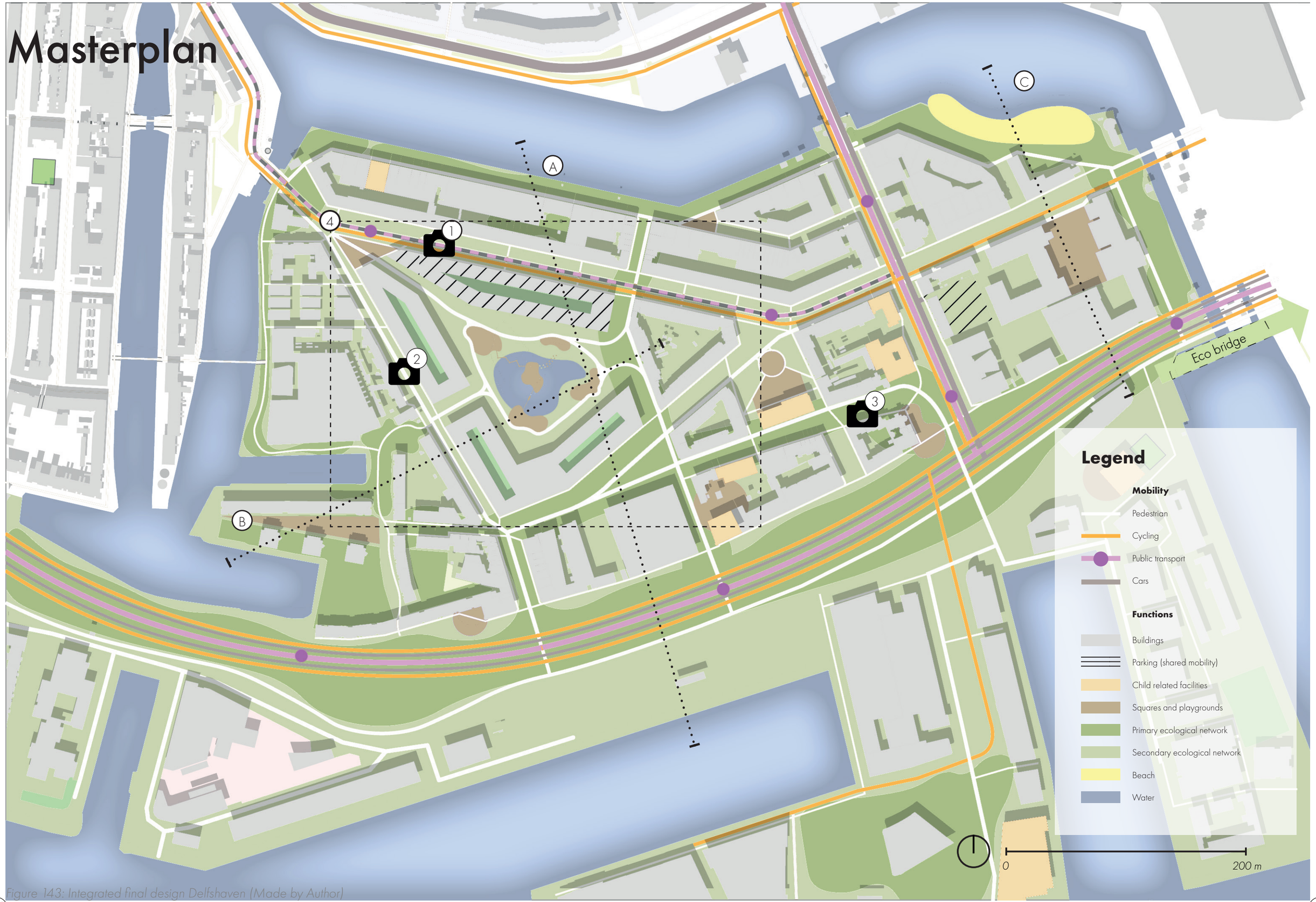


Figure 143: Integrated final design Delfshaven (Made by Author)

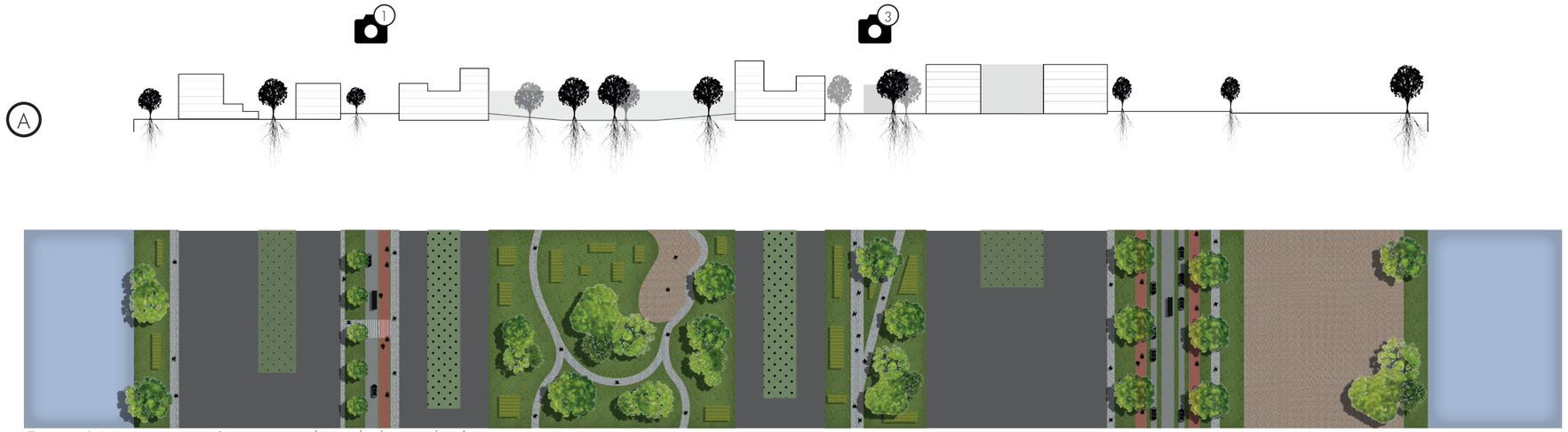


Figure 144: A section & top view (Made by Author)

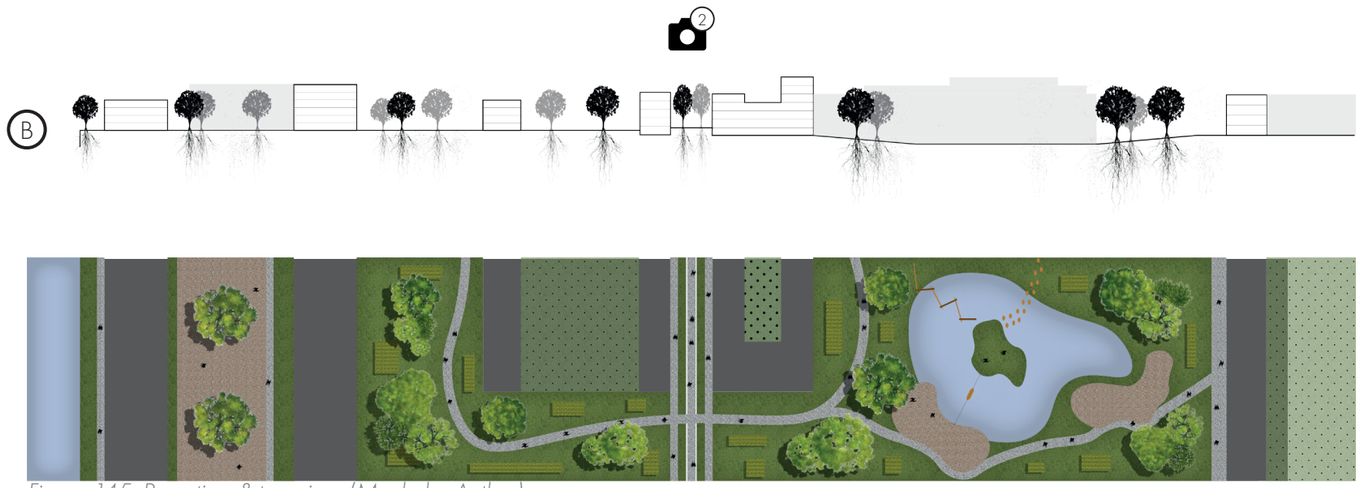


Figure 145: B section & top view (Made by Author)

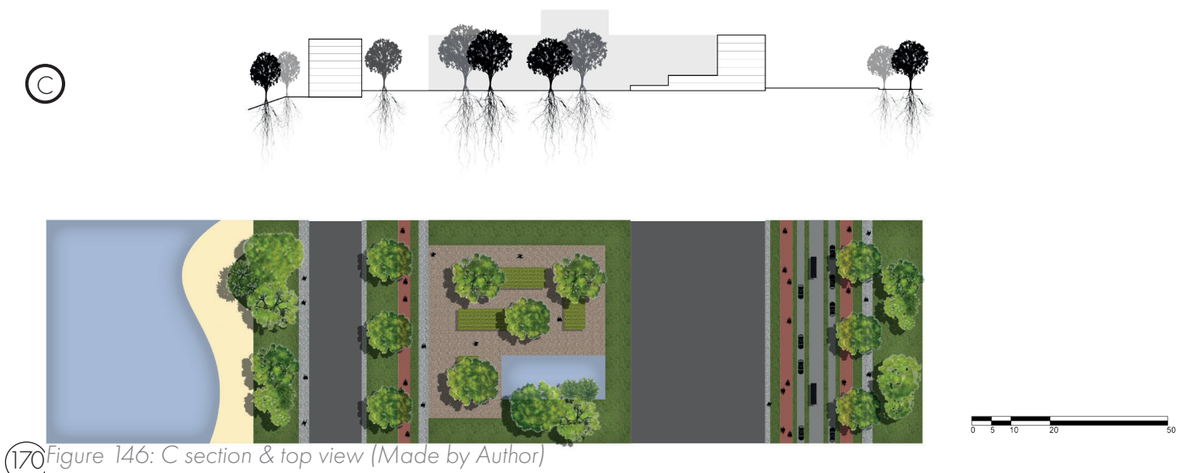
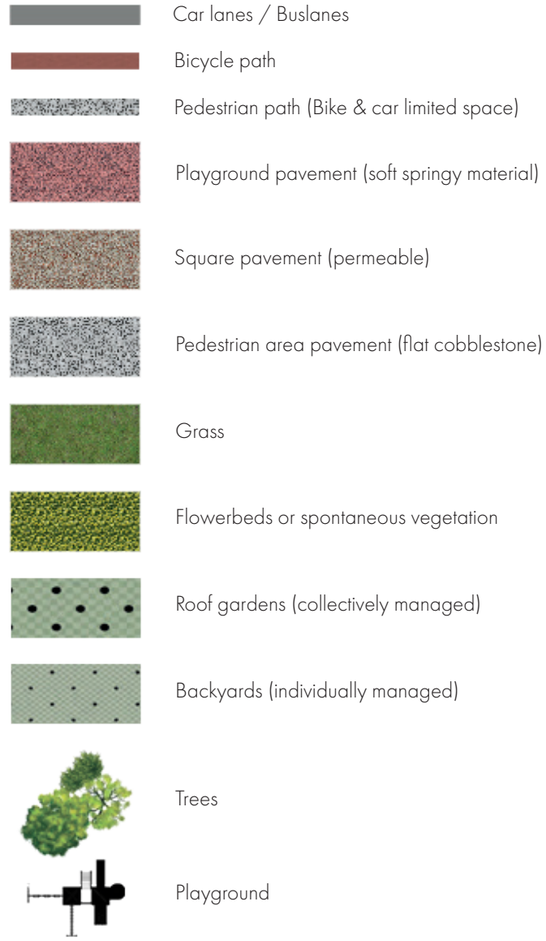
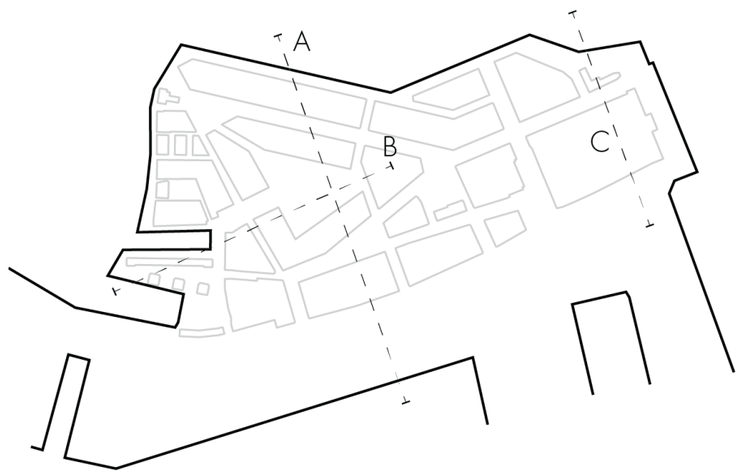


Figure 146: C section & top view (Made by Author)



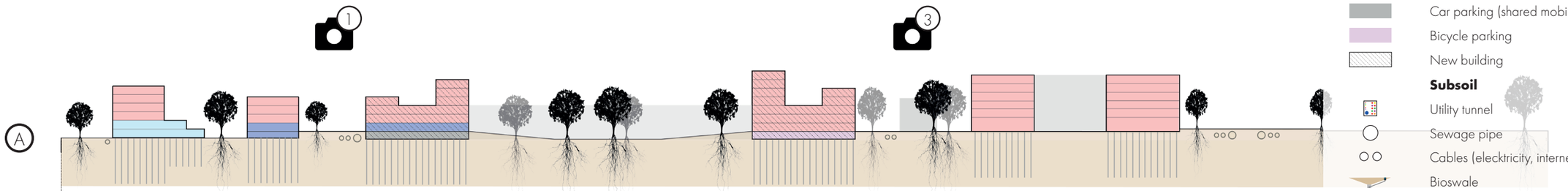


Subsoil infrastructure is located below the paved surfaces

Rainwater flows from higher elevated places to the wetland

Sewage pipes removed, due to many permeable surfaces and discharge to wetland

Westzeedijk subsoil remains similar due to many paved surfaces



Collective roofgardens considerably add to ecological performance

Functions
- Residential
- Commercial (shops, cafés, restaurants...)
- Workspaces (offices, flex workplaces...)
- Car parking (shared mobility)
- Bicycle parking
- New building

Subsoil
- Utility tunnel
- Sewage pipe
- Cables (elecktricity, internet...)
- Bioswale
- Contaminated soil
- Decontamination by vegetation
- Decontamination by soil replacement

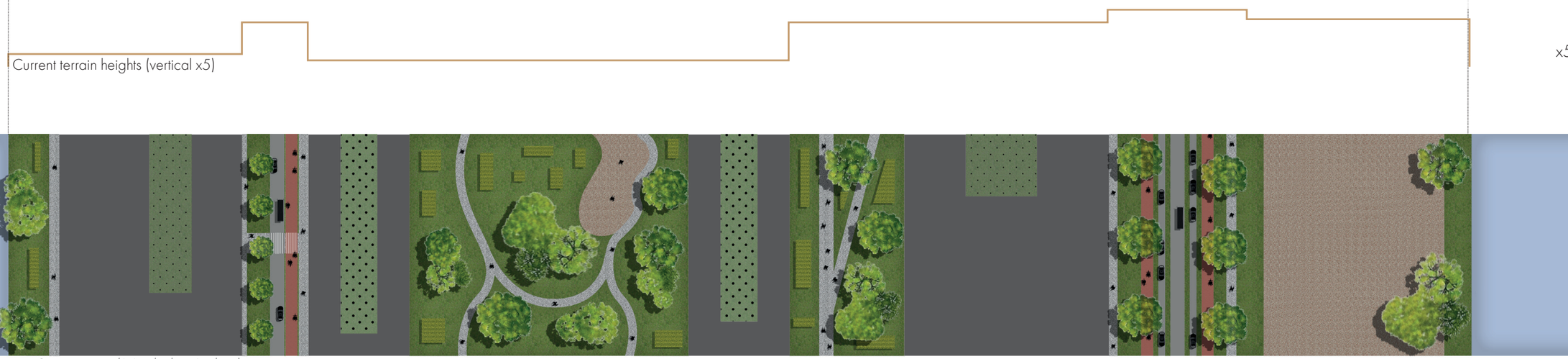
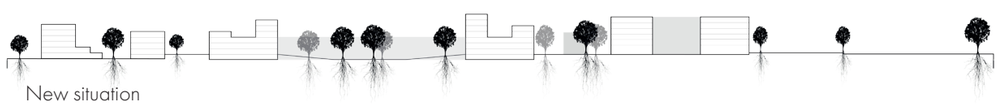
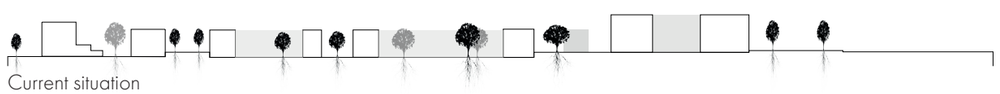
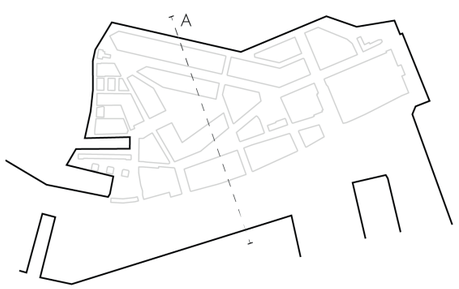


Figure 147: A section & top view (Made by Author)



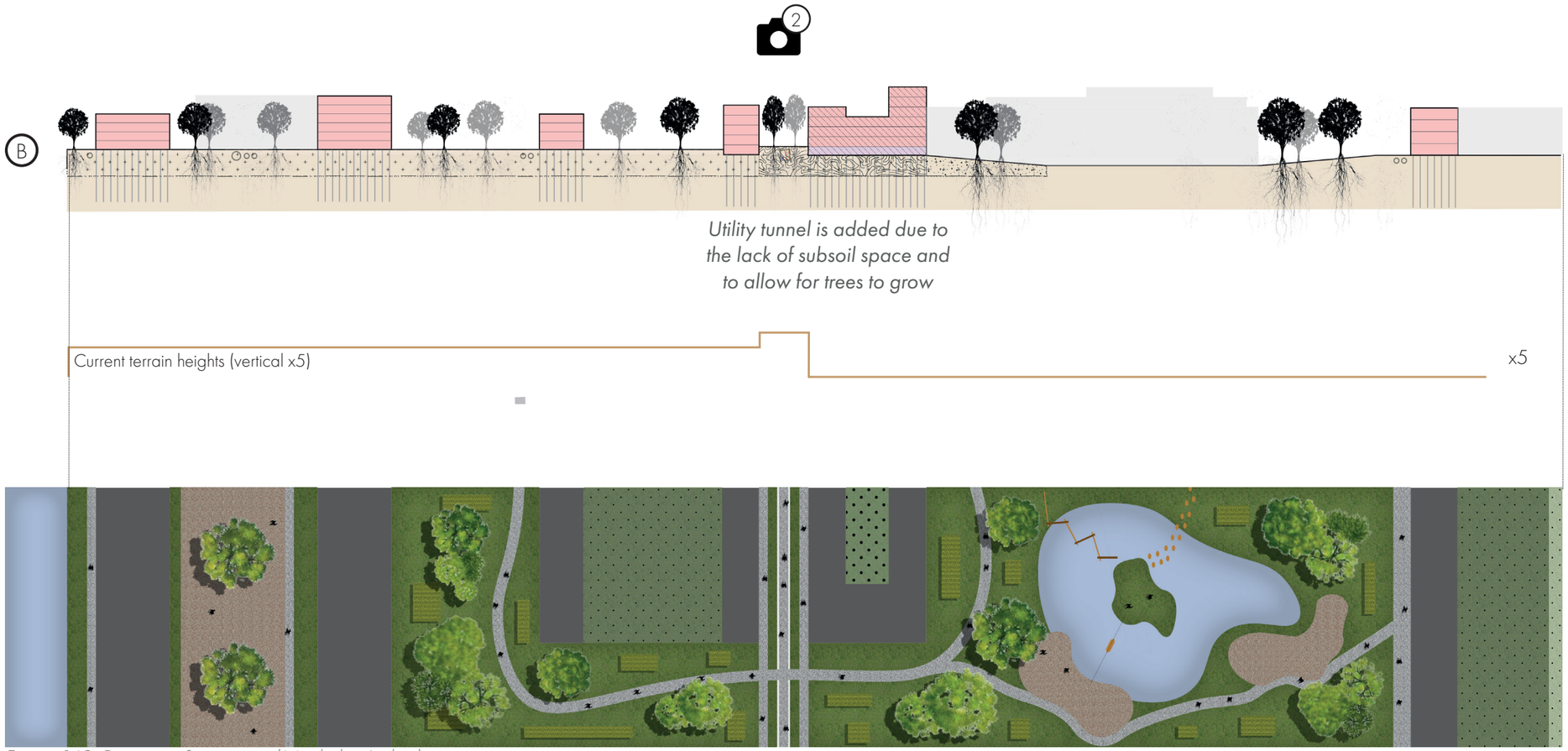




- Car lanes / Buslanes
- Bicycle path
- Pedestrian path (Bike & car limited space)
- Playground pavement (soft springy material)
- Square pavement (permeable)
- Pedestrian area pavement (flat cobblestone)
- Grass
- Flowerbeds or spontaneous vegetation
- Roof gardens (collectively managed)
- Backyards (individually managed)
- Trees
- Playground

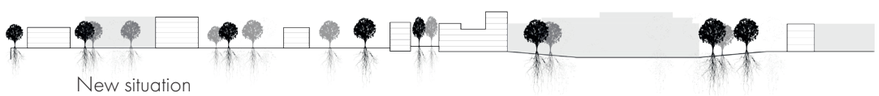
Soil below the building is being decontaminated by the use of soil replacement

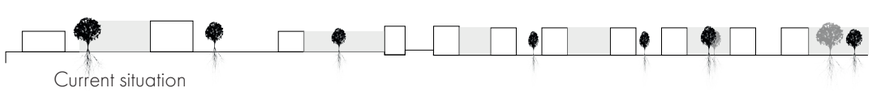
Soil below the park is being decontaminated by the use of special vegetation

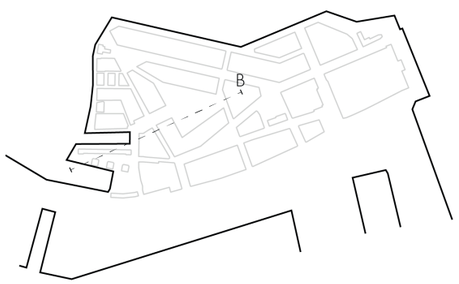


Utility tunnel is added due to the lack of subsoil space and to allow for trees to grow

Figure 148: B section & top view (Made by Author)







Functions

- Residential
- Commercial (shops, cafés, restaurants...)
- Workspaces (offices, flex workplaces...)
- Car parking (shared mobility)
- Bicycle parking
- New building

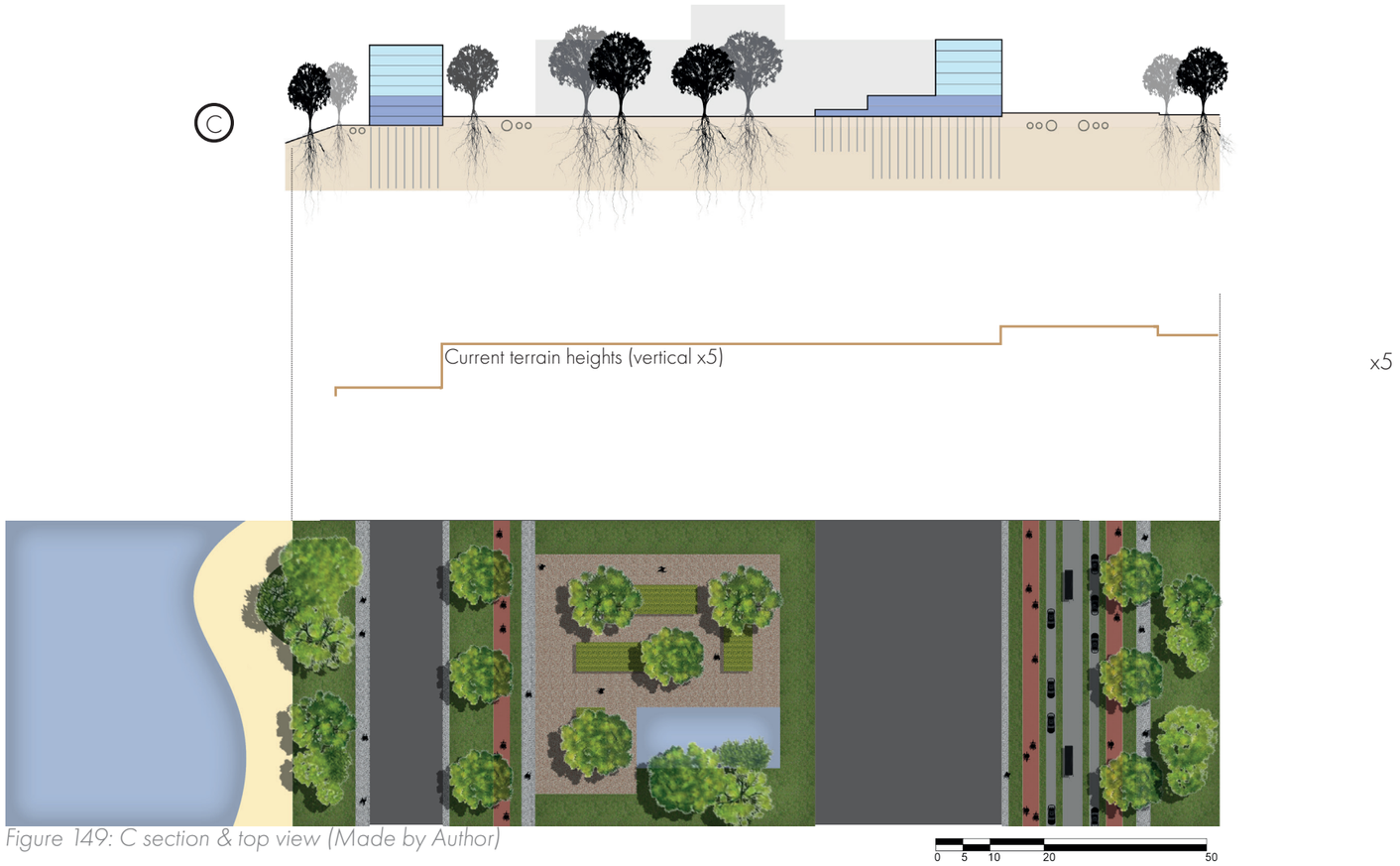
Subsoil

- Utility tunnel
- Sewage pipe
- Cables (elecktricity, internet...)
- Bioswale
- Contaminated soil
- Decontamination by vegetation
- Decontamination by soil replacement

- Car lanes / Buslanes
- Bicycle path
- Pedestrian path (Bike & car limited space)
- Playground pavement (soft springy material)
- Square pavement (permeable)
- Pedestrian area pavement (flat cobblestone)
- Grass
- Flowerbeds or spontaneous vegetation
- Roof gardens (collectively managed)
- Backyards (individually managed)
- Trees
- Playground

Square contains flowerbeds, water and spontaneous vegetation

Different flows of mobility are seperated at the Westzeedijk



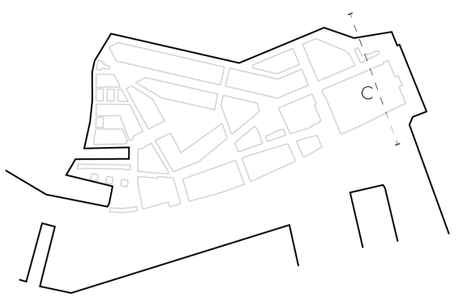
Functions
- Residential
- Commercial (shops, cafés, restaurants...)
- Workspaces (offices, flex workplaces...)
- Car parking (shared mobility)
- Bicycle parking
- New building

Subsoil
- Utility tunnel
- Sewage pipe
- Cables (elecktricity, internet...)
- Bioswale
- Contaminated soil
- Decontamination by vegetation
- Decontamination by soil replacement

Figure 149: C section & top view (Made by Author)







- Car lanes / Buslanes
- Bicycle path
- Pedestrian path (Bike & car limited space)
- Playground pavement (soft springy material)
- Square pavement (permeable)
- Pedestrian area pavement (flat cobblestone)
- Grass
- Flowerbeds or spontaneous vegetation
- Roof gardens (collectively managed)
- Backyards (individually managed)
- Trees
- Playground

1 Willem Buytewechstraat 28m

The Willem Buytewechstraat is one of the mobility streets within the neighbourhood. In this street noise reducing asphalt is used and the space is shared between cars and public transport.

Cyclists are provided with a wide two-way cycle path. This cycle path is important in the larger cycle network.

Sidewalks are made of flat cobblestone and differ in width depending on the predicted intensity of users. The pavement allows for a pleasent walk, while discouraging cyclists to use it.

A continuous strip of nature allows the street to be more climate adaptive, support biodiversity, create a healthy athmosphere for residents and looks pleasent for people staying or walking by.

30 60

25

5



Figure 151: Willem Buytewechstraat (Google Maps, 2022)

Figure 150: Section Willem Buytewechstraat (Made by Author)



Figure 152: Impression Willem Buytewechstraat (Made by Author)

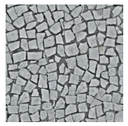


2 Havenstraat

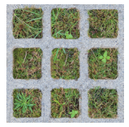
11 m



The Havenstraat is one of the narrowest streets in the neighbourhood. Due to its location, the street occasionally needs to be accessible for bikes (destination traffic) and emergency vehichles.



Sidewalks are made of flat cobblestone and differ in width depending on the predicted intensity of users. The pavement allows for a pleasent walk, while discouraging cyclists to use it.



Because the Havenstraat is so narrow, pavement is kept at a narrow width. However, strips of permeable surfaces are added to the sides to allow vehichles to (occasionally) pass by a cyclist or pedestrian.



A continuous strip of nature allows the street to be more climate adaptive, support biodiversity, create a healthy athmosphere for residents and looks pleasent for people staying or walking by.

15 30

5



Figure 154: Havenstraat (Google Maps, 2022)

Figure 153: Section Havenstraat (Made by Author)

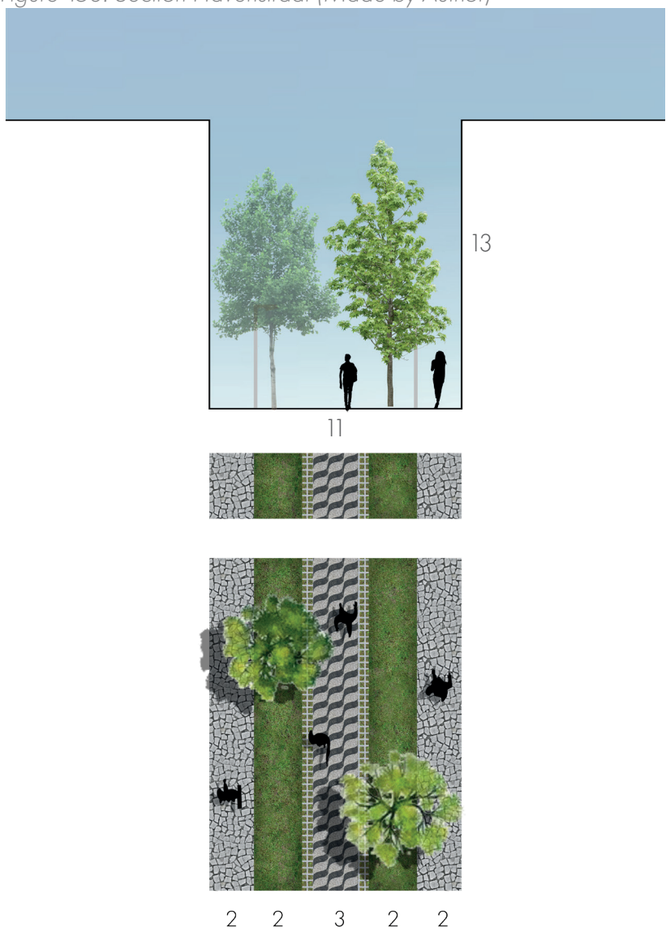
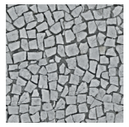


Figure 155: Impression Havenstraat (Made by Author)



3 Pieter de Hoochstraat 27m



Sidewalks are made of flat cobblestone and differ in width depending on the predicted intensity of users. The pavement allows for a pleasent walk, while discouraging cyclists to use it.



Exterior furniture is made out of natural elements. Residents sitting outside or kids playing in nature can experience a nature-inclusive design.



A continuous strip of nature allows the street to be more climate adaptive, support biodiversity, create a healthy athmosphere for residents and looks pleasent for people staying or walking by.



In the Pieter de Hoochstraat green streetlights are added. Green streetlights are less repelling to animals and use less electricity than conventional street lighting (NEMO, 2019).

5



Figure 157: Pieter de Hoochstraat (Google Maps, 2022)

Figure 156: Section Pieter de Hoochstraat (Made by Author)



Figure 158: Impression Pieter de Hoochstraat (Made by Author)



Wetland park
(dry season)

4

In the center of the neighbourhood the wetland park is located. The park is surrounded by residential buildings and all cars, bikes and public transport is excluded from this space. The space is designed to benefit ecology, climate and human well-being all together. The park exists of a wetland ecology with four small squares and one island. The squares are raised and connected by elevated pathways that allow water and vegetation to continue below. The island in the center is accessible in different ways such as by boat, by walking on wooden logs or by stepping on small platforms sprawling over the water. All together this area creates an adventurous environment for kids to play in, socially interact with eachother and learn to appreciate playing outside. This gives multiple benefits such as better social skill development and less health related risks (Brown et al., 2018). On east side of the park, the north south connection is part of the main ecological network. All entrances to the square have relative wide and gradually sloped sidewalks to create welcoming entry points.



Figure 160: Wetland park - dry season (Made by Author)

Wetland park
(wet season)

4

During periods of heavy rainfall, the wetland park functions as a water storage. Water flows into the area due to its elevation at zero meters, while its surrounding areas are mostly at three meters elevation. The soil and vegetation of the area slowly soak up the water over time and allow for different water levels to be present. The moisty soil and vegetation store the water over time and can cool down the surrounding area significantly in periods of drought. While the benefits for climate adaptation and ecology are big, it is also interesting for residents to see how real nature behaves in different seasons. Residents can, due to the elevated pathways and squares, enjoy the changing nature in the area, while remaining safe and dry. The observations can give knowledge to residents that is necessary to create a mindset of accepting change, because of the natural systems that require adaptive space to change. A current in the water is created by a solar motor. During sunny dry weather the motor creates a current in the water, while cold rainy days already create a current naturally. Finally wetlands have a considerable capacity to capture and store carbon-dioxide emmisions (Xu et al., 2021).



Figure 161: Wetland park - wet season (Made by Author)

Wetland park

Wetlands are unique ecosystems that thrive on the fluctuations of rainfall and water level. Different vegetation types need different levels of moisty soil or even standing water at the roots. A wetland has different elevations causing some areas to be permanently wet, while others only occasionally are in the water. Figure 162 illustrates how different types of vegetation exists at different elevations in the wetland. The design for Delfshaven includes these elevations and therefore the conditions necessary to grow a wide variety of vegetation types are present. Two sections of the wetland park are shown on the following pages. One showing the park in dry conditions, while the other shows it in wet conditions.

The human connection

The island in the middle of the wetland presents a unique environment for kids to play in. The different levels cause the area to look different over time and present an endlessly changing playground. The squares surrounding the permanent body of water are connected by elevated pathways that are located at a maximum of three meters above ground level. These pathways give people the experience of being in wild nature and the changing water levels are clearly visible from here.

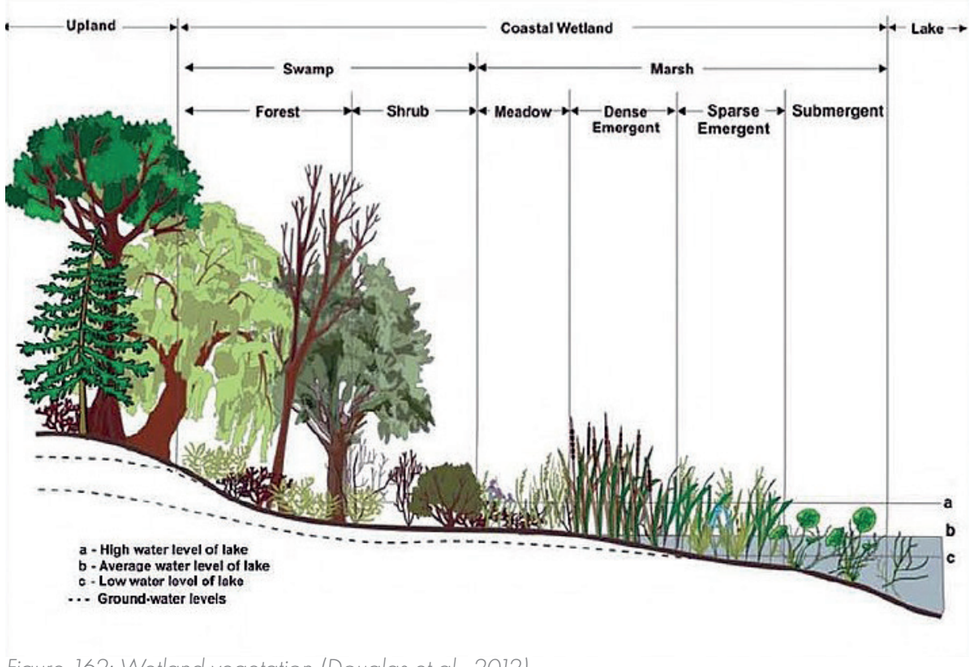


Figure 162: Wetland vegetation (Douglas et al., 2012)

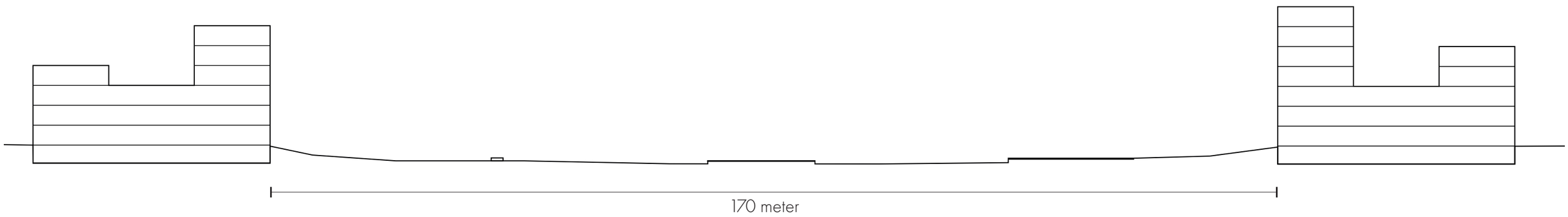


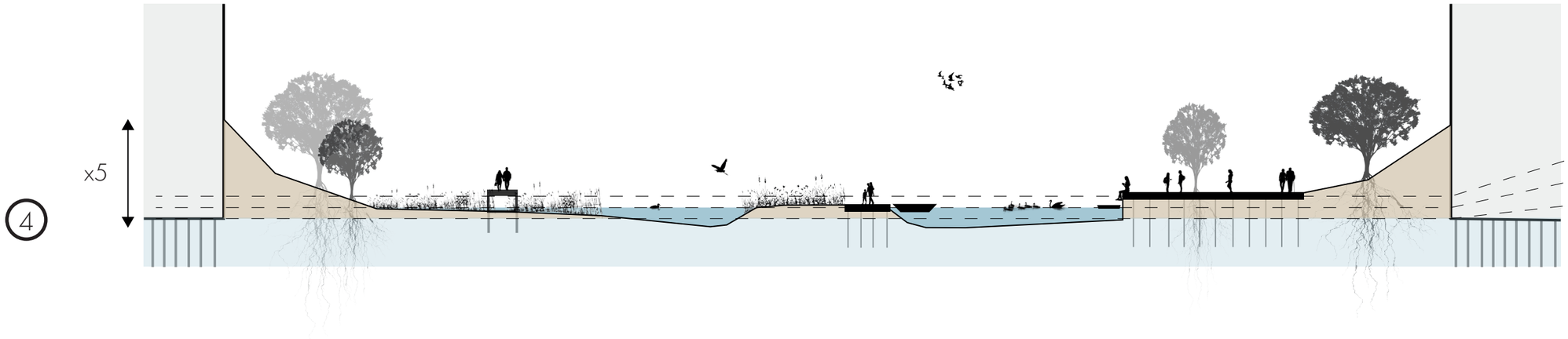
Figure 163: Bioswale park (Climatescan, 2017)



Figure 164: Qunli Stormwater Wetland Park (Turenscape, 2019)

Wetland park
(dry season)





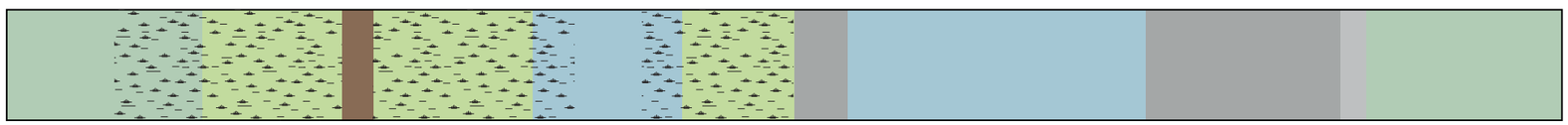
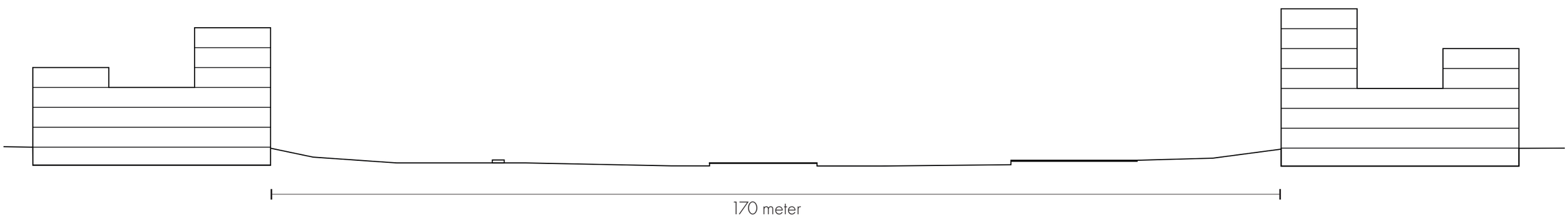


Figure 165: Wetland park section - dry season (Made by Author)

Wetland park
(wet season)



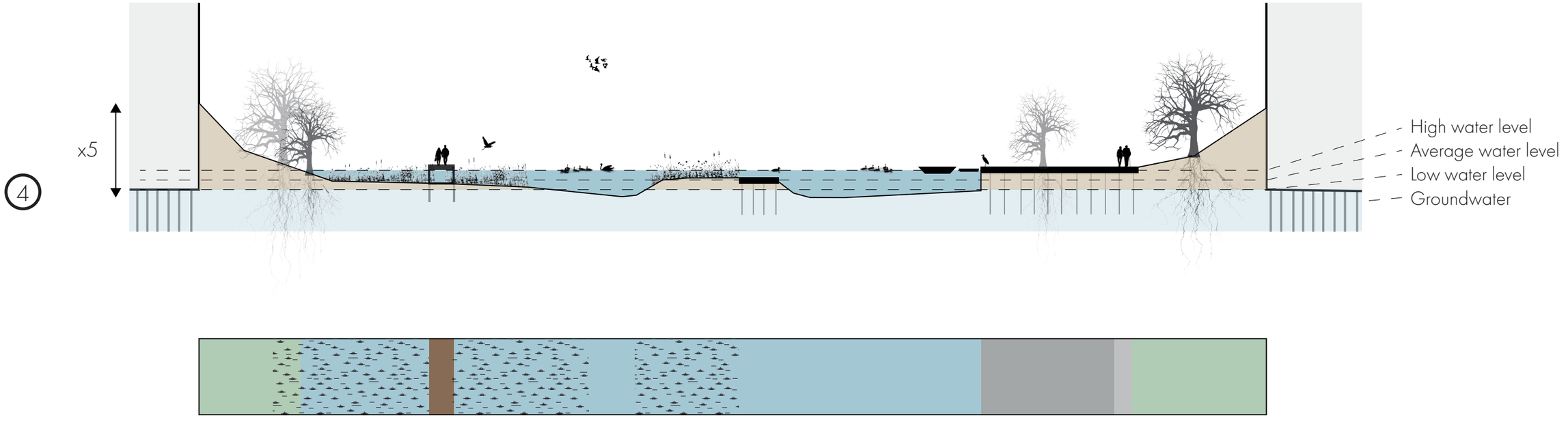


Figure 166: Wetland park section - wet season (Made by Author)

Human-environmental interaction

CONLCUSION ON SYNERGETIC RELATION OF INTERVENTION

Newly added ecological corridors and parks allow animals to move around, find shelter and have a food source. These ecological areas decrease the urban heat island effect and can absorb rain during heavy rainfall. Animals are however repelled by disturbances in noise or smell (Norton et al., 2016), while humans can be repelled by wild and unorganized looking nature (Cameron et al., 2020). Humans might consider these spaces dirty and unsafe, while animals like it because it provides shelter and attracts many different species. While humans might not enjoy this wild type of nature directly, they do benefit from the many ecosystem services that it provides (figure 169). A report on global ecosystems and connection to human well-being highlights the critical importance of having a thriving ecosystem to achieve sustainable human well-being (Millenium Ecosystem Assessment, 2005). While this research mostly speaks about ecosystems in general, instead of urban ecosystems, it is still good to keep in mind that much of the Netherlands is already urbanized. To achieve these ecosystem services, we have to improve ecosystems in our cities as well as outside.

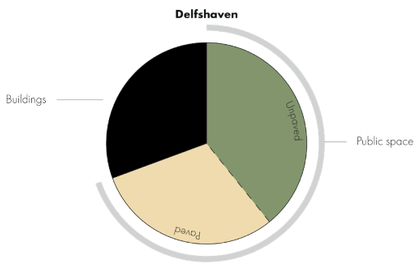


Figure 167: Delfshaven land use (Made by Author)

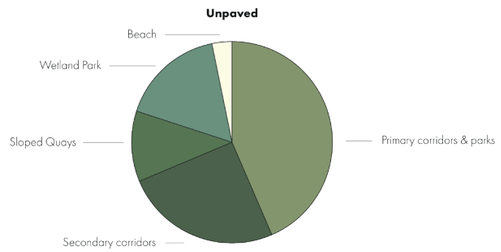


Figure 168: Delfshaven ecology typologies (Made by Author)

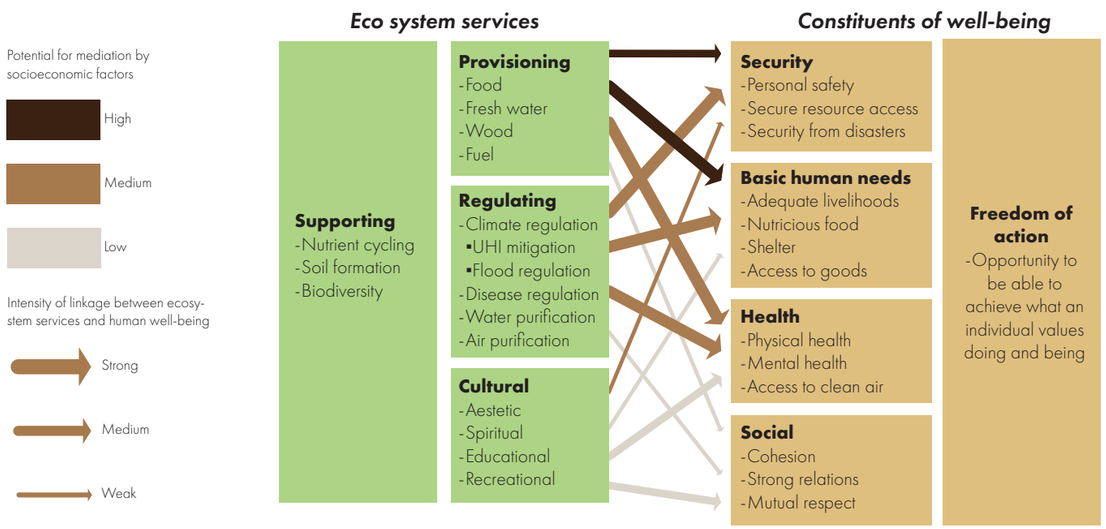


Figure 169: Ecosystem services and relation to human well-being (Edited by Author) (Millenium Ecosystem Assessment, 2005)

First of all it is important to note that the primary aim for a dense urban area like Delfshaven should always be the quality of life for the population. This means that although aiming for a much better ecological and climate adaptive performance, the aim should still primarily be to facilitate all neccessities to allow for daily life to go on and be enjoyable.

In the new design, about 45% of Delshaven is unpaved (figure 167). This area is divided in multiple ecological typologies that have different aims and characteristics (figure 168)(overview of characteristics on page 160). Primary corridors and parks form the main ecological structure. The aim of these areas is to create a variety of connected habitats that will improve the biodiversity within Delfshaven. Sloped quays are added to allow animals to get in or out of water and vegetation helps purifying the water. A wetland serves as a water buffer during heavy rainfall and can store alot of carbon emissions over time (Xu et al., 2021). And finally, secondary- and mobility corridors are primarily designed for human use and have relatively fewer plants and trees in them.

As mentioned before, humans tend to dislike wild nature and animals are repelled by human disturbance. It is therefore preferable to limit interaction between them. Humans are able to walk by and watch primary ecological areas, but squares and playgrounds are located away from them to avoid habitat disturbance. In contrast to ecology, climate adaptive solutions often can be designed so that space has multiple functions. For example, a water square can allow people to gather on dry days, while it can be used to store water during heavy rainfall. Wild ecology also improves climate adaptability as the presence of a variety of biotopes is much more resilient to climate extremes (United Nations, 2021).

In conclusion, human disturbance of habitats in primary ecological areas should be limited while climate adaptive spaces can serve as transition between the main ecological structure and more human oriented nature.

A more concrete example is shown on the next page.

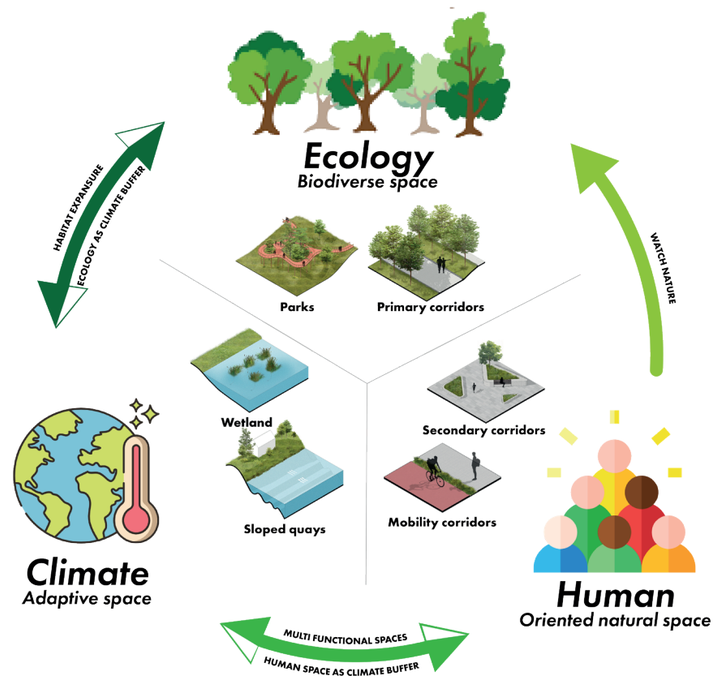


Figure 170: Relation between ecology, climate and human well-being interventions (Made by Author)

In the design, 45% of delfshaven is unpaved (figure 167). This is done to improve ecology, climate adaptability and human well-being. On the previous pages limitations are discussed on the relation between humans and animals. To show the spatial implications of these limitations, the following illustration is made (figure 171).

The main ecological structure will integrate a variety of habitats that are likely to increase existing animal populations and have the potential to attract new species as well (chapter 5). To limit human disturbance there are only few paths going through and they are sometimes set apart physically by elevation or materialization.

Human oriented spaces such as secondary corridors, mobility corridors, playgrounds and squares are designed primarily for human use. Trees are added to provide shade and bioswales are created to store water over time. This improves the drainage during more extreme weather events as predicted by the IPCC report (IPCC, 2022), but it is also necessary to allow newly planted trees to grow big (page 161).

Adding alot of trees in both ecological space and human oriented nature provides the whole area with benefits such as a cooler outdoor temperatures, better flood prevention and better air quality. The project however goes further by adding a wetland that stores relatively high amounts of carbon (Xu et al., 2021) and can store huge amounts of water. Interventions aiming for maximum climate adaptability often form less attractive habitats for animals, but can still be used as a link to connect ecological areas. By designing climate adaptive interventions such as trees and water squares, space can be used by humans as well as occasionally be flooded to avoid bigger problems elsewhere in the neighborhood.

Overall all interventions that include removing pavements or adding vegetation improve both ecology and climate adaptability, while ecosystem services indirectly improve the well-being of citizens (Millenium Ecosystem Assessment, 2005).

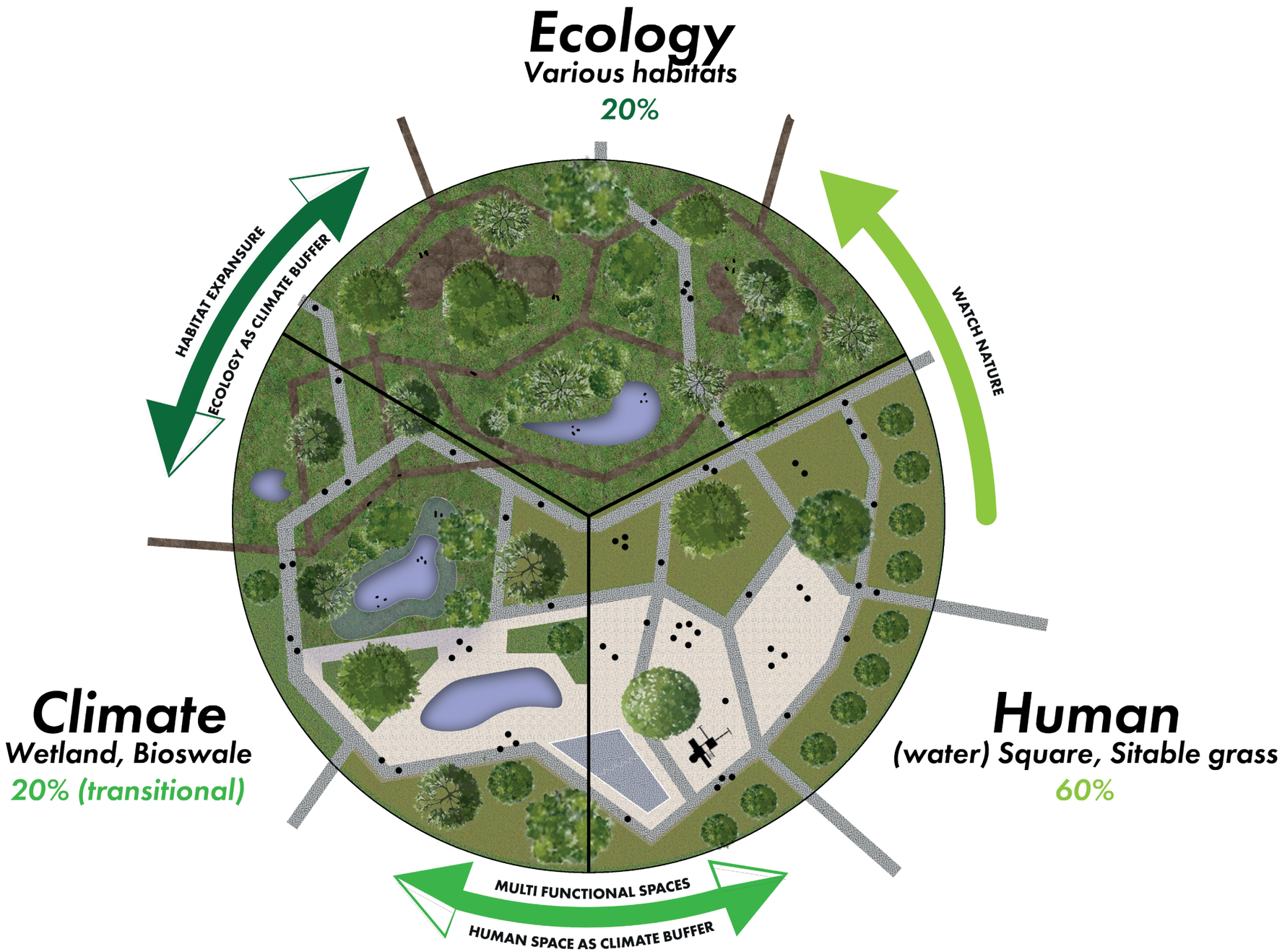


Figure 171: Relation between ecology, climate and human well-being interventions in Delfshaven (Made by Author)

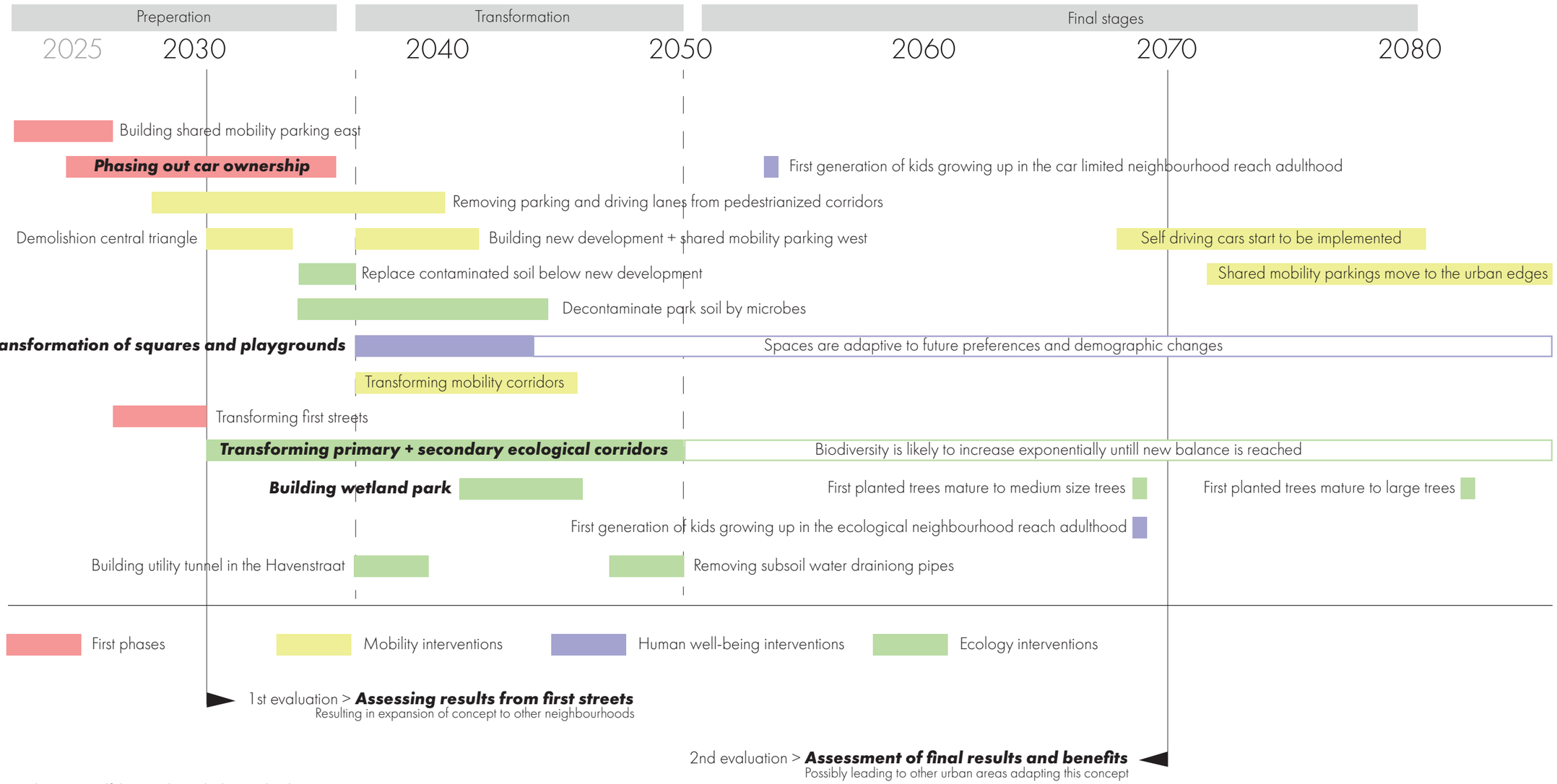


Figure 172: Project phasing Delfshaven (Made by Author)

Preperation phase (~10 years)
Present to 2035

In the first phase, preperations will have to be made to make the proposed transformation possible. Shared mobility parking garages will allow for the outphasing of private car ownership in the area and the demolishion of the buildings within the central triangle will prepare the area for the new development.

To start testing the concept, a couple streets will be transformed early in the process. After this, streets will be continously transformed one after the other. This process is shown on page 200 (figure 173).

Transformation phase (~15 years)
2035 to 2050

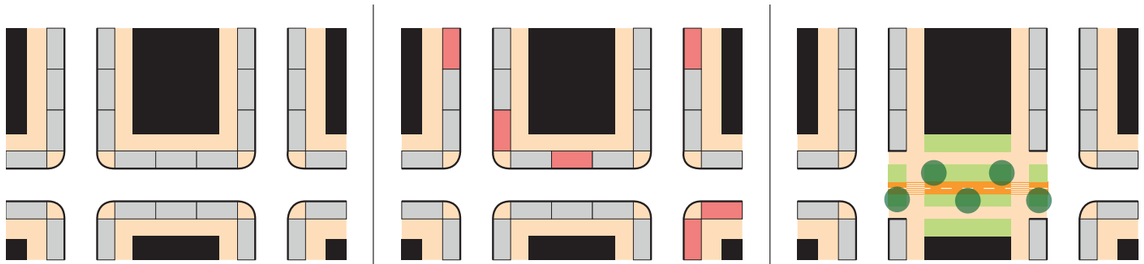
The transformation phase is the main phase where most significant changes happen to the area. These include the transformation of streets, squares and parks and the construction of the new residential buildings, the wetland park and the ecological network.

It is important to note that some interventions like the ecological network need time to allow vegetation to grow to the preferred size and for biodiversity to actually increase.

Final phase (~20 years)
2050 to 2070

In the final phase, construction has almost stopped entirely. In this phase most work is done by nature itself. Trees will grow, animal populations are likely to increase and residents will start reaking the benefits of living in a natural environment. Kids reaching adulthood will have grown up in a car-limited and nature inclusive neighbourhood and will probably have a more open mindset towards a sustainable future of our cities.

It is also likely that new innovations such as autonomous vehichles will be implemented during this period of time (Hendrickson et al., 2014). This allows for more (shared mobility) parking spaces to be removed from the project area.



Current situation

- Most streets have side parking
- All streets are accessible by car

Parking reduction

- Parking voluntarily reduces by providing:
  - Low cost alternative distant parking
  - Low cost shared mobility
  - Improved public transport
  - High trade-in value for cars
- Parking forcibly reduces by:
  - Not giving out new parking permits
  - Increasing parking tariffs

Existing parking permits will not be taken away

Street transformation

- Streets transform when:
  - Parking demand is reduced suffieciently
- Neighbourhood is fully transformed when:
  - All parking is voluntarily reduced 'or'
  - All parking permits expire

Figure 173: Reducing parking strategy (Made by Author)

As mentioned before, some streets will be transformed early in the project to test the concept and to anticipate bigger problems in later stages. To avoid having to forcibly take away private car ownership, a combination of incentives is given to voluntarily give up your car. These incentives are cheap alternative parking (distant from the project area), cheap shared mobility, improved public transport and high trade-in values for people handing in their car(s). When demand for parking reduces sufficiently, a street can be closed of and transformed (Figure 173).

Voluntary incentives are combined with more enforcing methods to ensure that all private car ownership will disappair over time, but preferably most of the reduction should happen voluntarily. These more enforcing measures are the increasing of parking tariffs and not giving out new parking permits for residents (Figure 173).

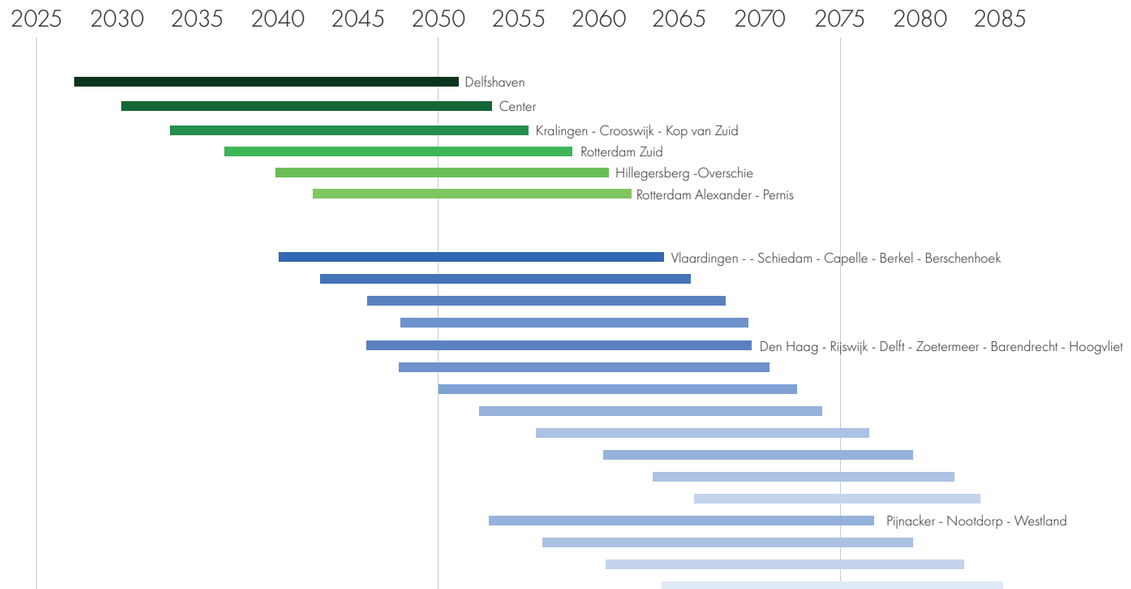


Figure 174: Project phasing Rotterdam, the Hague and surroundings (Made by Author)

Expansion of the project (~55 years)
2030 to 2085

In chapter one the problems of climate change, decreasing biodiversity, car-oriented development and mobility and the lack of human oriented public space have been explained (page 8-13). While this project gives a possible solution for many of these problems, it is unlikely that such a small area alone can make a significant difference. Therefore, it is important to expand the concept to other areas to increase the impact. It is also important to keep in mind that many interventions such as growing trees or phasing out car ownership take a lot of time, while problems might become increasingly worse soon. This emphasizes that we should act fast and try to get other areas to transform in the near future as well.

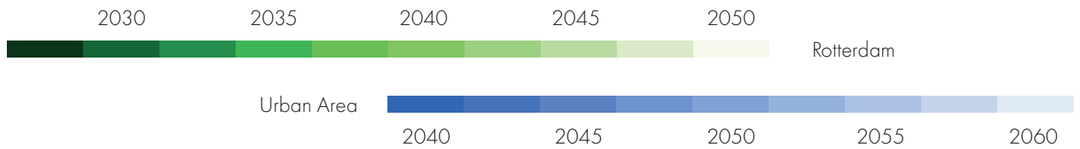
On the following pages a possible expansion over time is illustrated and elaborated on.

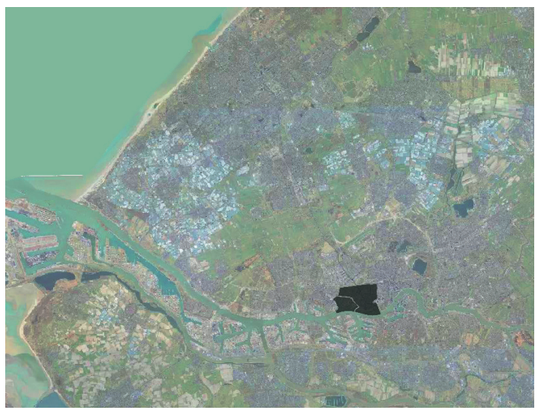
It is likely that surrounding neighborhoods in Rotterdam could be among the first to follow. By already implementing parking reducing incentives and by relocating facilities to be within walkable distance from the beginning of the Delfshaven transformation, preparation phases of later neighborhoods can be shorter and speed up the process overall.

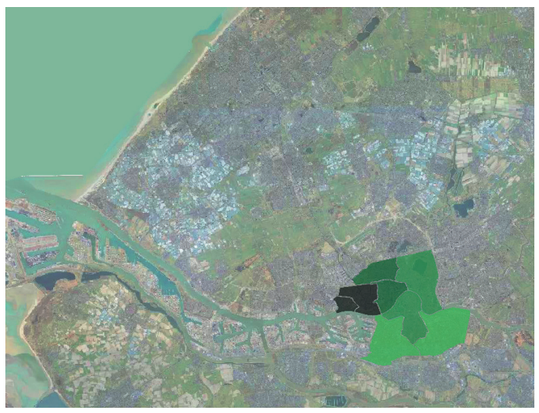
During the transformation of Rotterdam it is likely that surrounding suburbs will follow, since they can connect more easily to the improved public transport network. After success is proven in early adaptors, other large urban areas are likely to follow such as the Hague, Delft and Zoetermeer. Much later areas with lower densities and more distant from urban centers will follow. Public transport is less viable in these places and problems of urban heat and biodiversity loss are often less critical here.

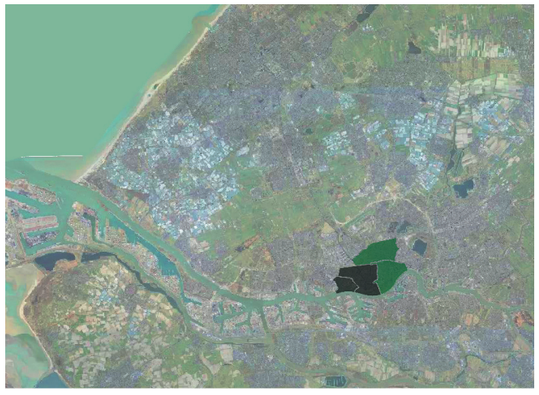
Since cities have to politically decide to start preparation measures it can be assumed that the time benefit of later neighborhoods will only appear in relation to transformations within the same city.

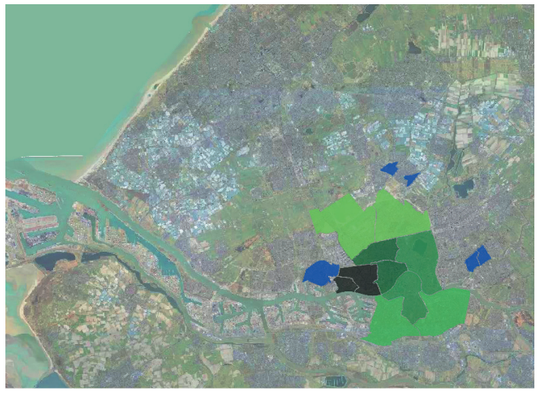
The maps below show a possible development and expansion of the concept over time. The expansion depends highly on local politics and outcomes of early transformations and is therefore very uncertain.

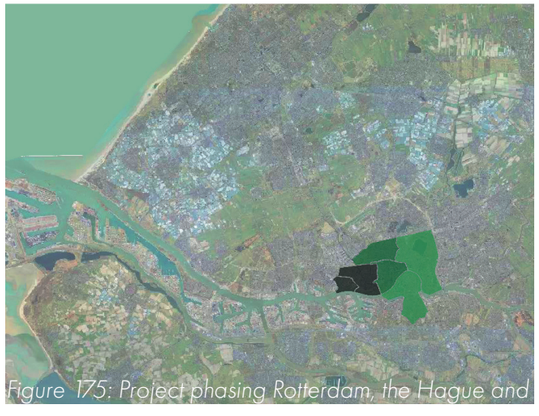












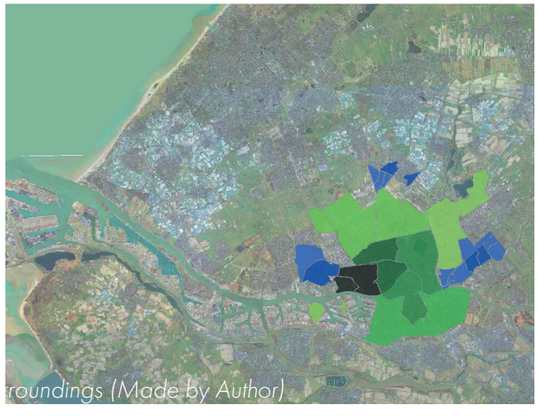
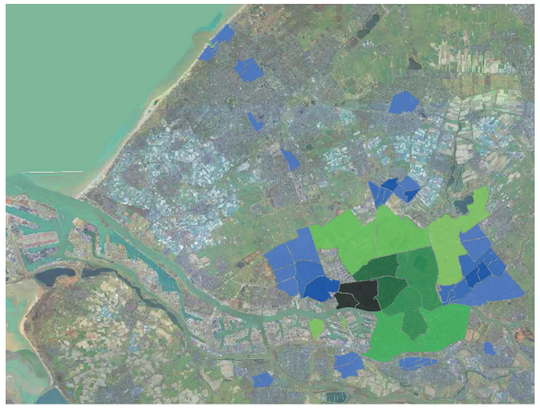
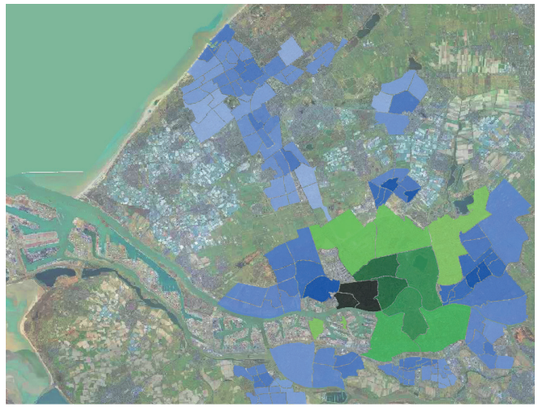
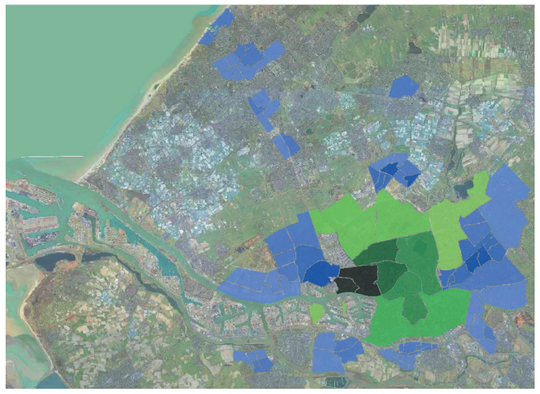
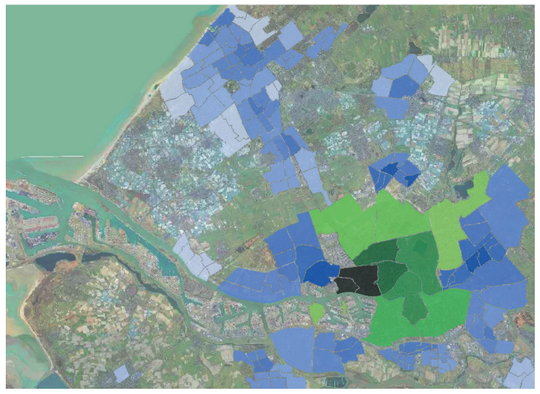


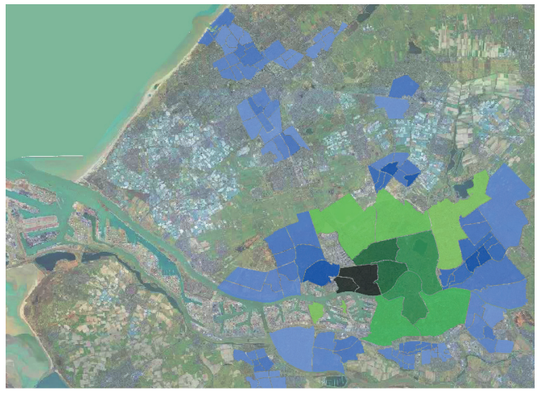
Figure 175: Project phasing Rotterdam, the Hague and roundings (Made by Author)

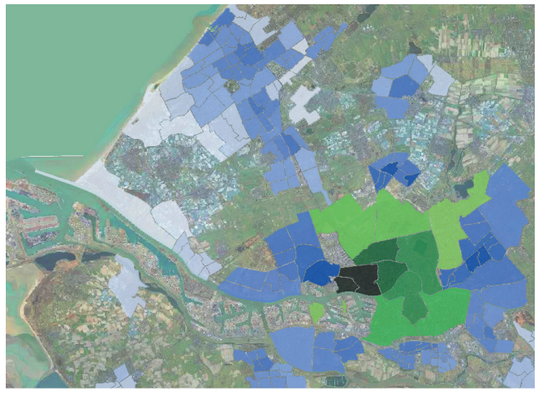


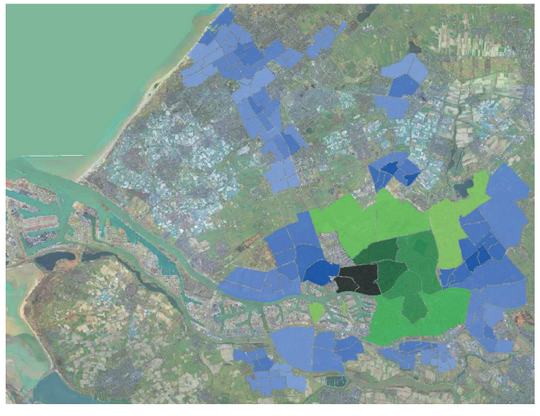


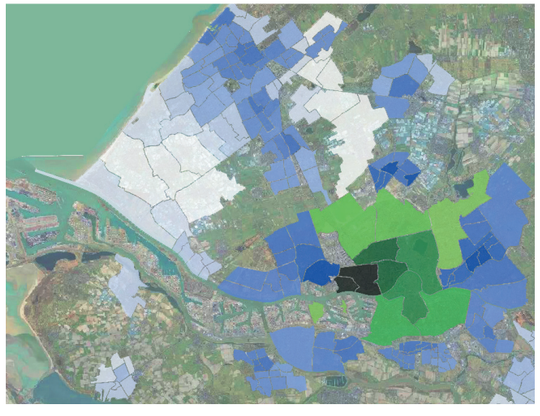












Costs

Transforming an urban area of this size is incredibly expensive. Costs are also very susceptible to economic trends. And with a transformation project this size, it might even influence the cost of labor and materials directly as a consequence of high demand. To give an idea of the costs, an estimated calculation is made (figure 176-a).

In chapter 5 we have already discussed the costs of transforming a selection of ecological corridors in Rotterdam. For the following calculation we use the same cost per m^2, which is €301 (figure 177). For less dense urban areas the cost is reduced by €175 per m^2 since solving mobility in less dense areas can be done much cheaper. For the calculation, unpaved areas remain untouched and only paved surfaces are included as areas to be transformed.

Transforming Rotterdam (without the harbor area) will cost around 6.6 billion euros (figure 176-a). To put this in perspective, this is almost 6 times the allocated area development budget of the municipality if we spread the financing over 50 years. Compared to the total municipal budget, this is around 6% per year (figure 176-b).

Looking purely at the costs of the project neglects the fact that the proposed transformation is expected to reduce healthcare costs (Allam et al., 2022) and private and collective costs related to car ownership, maintenace, parking and other infrastructure (chapter 5). For example, the healthcare budget of Rotterdam is 856 million euros (Gemeente Rotterdam, 2022). This is 39% of the required annual budget if spread over 50 years and benefits are only expected to increase as mental and physical health of the population will improve as a result of living in or close to a natural environment (Lee & Maheswaran, 2010).

If we look at the costs of transforming an area as shown on the previous page (figure 175), the costs become even higher. A project like this would cost close to 26 billion euros. If we take in mind the combined benefits over the long term it might be reasonable to rely on financing from the national government as well. Improving ecology and climate has benefits that go beyond the municipal borders and can serve as a catalyst for future sustainability interventions in other areas. The municipal budget allocated for municipalities is 44.6 billion euros (Rijksoverheid, 2022). If we spread the project over 50 years, this means it will only use 1% of this budget annually (figure 176-b).

Overall, we can conclude that financing a project like this can only happen if we change the financing structure. We need to have an open debate about our way of living and relocate budgets if we want to make this happen. Innovation might lead to cost reductions when applied on a large scale, but these costs can also go up because of disruption in the economy.

	City	1/1000	m2	GSI	open	%unpaved	paved	€ / m2		
1	Rotterdam		31005	31005000	0,084	28400580	23%	21868447	€ 301,00	€ 6.582.402.426,60
2	Den Haag		45806	45806000	0,177	37698338	18%	30912637	€ 301,00	€ 9.304.703.785,16
3	Schiedam		6943	6943000	0,138	5984866	20%	4787893	€ 301,00	€ 1.441.155.732,80
4	Delft		9430	9430000	0,14	8109800	41%	4784782	€ 301,00	€ 1.440.219.382,00
5	Zoetermeer		10783	10783000	0,119	9499823	52%	4559915	€ 301,00	€ 1.372.534.427,04
6	Rijswijk		7928	7928000	0,134	6865648	37%	4325358	€ 301,00	€ 1.301.932.830,24
							Avg.			
7	Vlaardingen		6558	6558000	0,09	5967780	38%	3688088	€ 126,00	€ 464.699.093,04
8	Capelle a/d Ijsel		5763	5763000	0,144	4933128	38%	3048673	€ 126,00	€ 384.132.811,10
9	Lansingerland		13806	13806000	0,227	10672038	38%	6595319	€ 126,00	€ 831.010.254,98
10	Barendrecht		4970	4970000	0,109	4428270	38%	2736671	€ 126,00	€ 344.820.528,36
11	Pijnacker Nootdorp		8127	8127000	0,162	6810426	38%	4208843	€ 126,00	€ 530.314.251,77
12	Westland		41197	41197000	0,436	23235108	38%	14359297	€ 126,00	€ 1.809.271.389,74
									Total	€ 25.807.196.912,84
	Source			RUDIFUN 2021	RUDIFUN 2021		PDOK 2022			

Figure 176-a: Project costs and financing calculation (Made by Author)

Demolishion costs (€/m2)	36		For example:	Removing pavements, demolishing structures, etc.
Cost of changing underground infrastructure (€/m2)	50	Est.	For example:	Utility tunnels, rerouting, etc.
Average cost of mobility solutions (€/m2)	175	Est.	For example:	Rerouting, tunneling, building alternative mobility, etc.
Cost of ecological transformation (€/m2)	76		For example:	Planting trees, decontaminating soil, adding water bodies
Total cost of transformation (€/m2)	€ 301,00			

Figure 177: Cost calculation for urban ecological network (Made by Author)

Municipal allocated budget (2022)	%	10yr /yr	20yr /yr	50yr /yr
€ 23.000.000,00	28619%	2862%	1431%	572%
National allocated budget (2022) (budget towards municipalities)				
€ 44.635.000.000,00	58%	6%	3%	1%

Total municipal budget (2022)	%	10yr /yr	20yr /yr	50yr /yr
€ 2.053.000.000,00	321%	32%	16%	6%

Govermental websites
https://www.rotterdam.nl/begroting-2022
https://www.rijksoverheid.nl/onderwerpen/prinsjesdag/inkomsten-en-uitgaven

Figure 176-b: Project costs and financing calculation (Made by Author)

Project outcomes

8% → +37% → **45%** … of area is unpaved

68% → +2% → **70%** … of area is public space

48% → - 44% → **4%** Public space used by cars

26% → +1% → **27%** Public space used by active mobility

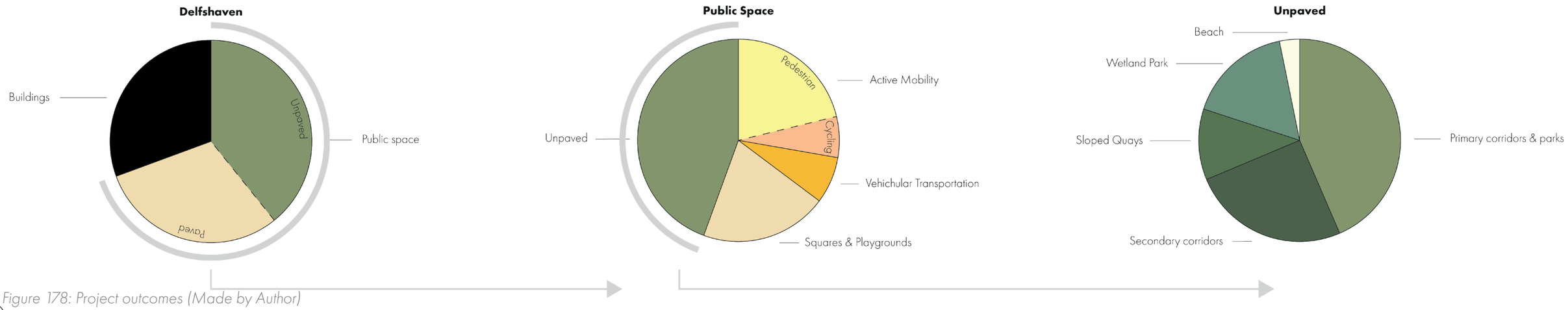


Figure 178: Project outcomes (Made by Author)

Discussion

Societal relevance
A wide range of problems is facing our urban environments. Cities will experience increasing climate and ecological decay, while urbanization and socio-economic inequality will continue to increase. The amount of available space will keep decreasing and the necessity to use space more efficiently will grow even further. Without a new approach to our public space, as proposed in this research, we will not be able to tackle all these problems.

Scientific relevance
A lot of research has been done on interventions that positively influence ecology, climate or socio-economic problems. However, there hasn't been much research combing all these themes together. This research gives a unique insight in the benefits of combing interventions on these themes and has been executed on an area that has many limiting factors such as availability of space, density, level of urbanity and current socio-economic problems. The outcomes of this project can, due to this limiting context of Delfshaven, practically serve as an example for other highly urbanized areas that want to transform their public space into a more sustainable design.

The chosen method of maximizing design on specific themes before integrating them together has shown that much is feasible if we try to envision beyond limitations. Researching specific themes has also repeatedly shown that interventions on one theme, often benefit multiple themes. The integration of themes with the aim of obtaining maximum result in general has shown to have a high degree of feasibility and can theoretically have far reaching positive impacts on all problems stated in the beginning of the research.

The methods and knowledge required to catch the completeness of this project have been developed partly during my master Urbanism track at the TU Delft, however in contrast to the Urbanism track, much of this research has been based on topics that have not elaborately been educated to me. The project includes many aspects of landscape architecture, climate and biology, while the mobility includes much more from the Urbanism master track. The guidance during my graduation process have helped me develop skills and knowledge to include all topics sufficiently into the project.

Limitations
There's a lot of research on ecology, climate and socio-economic interventions, however much of it has been theoretical. Only few projects have yet been built, causing essential data on performance and side-effects to be absent. It is also important to acknowledge that combining far reaching interventions on all these problems together has barely been researched before.

The research combines a lot of knowledge on the systems of ecology, climate adaptation, sustainable mobility and improving and maintaining human well-being. This knowledge is very complex and interrelated. It is impossible to cover every aspect of these systems and determining their functionality before and after proposed interventions. There is just simply not enough time. To tackle this issue, topics that are of less importance are discussed and researched less elaborately than topics that are of high importance to the viability and completeness of the project.

Finally, it is good to mention that executing a project like this in an existing neighbourhood brings a lot of problems that hinder feasibility. Residents are generally not in favour of big changes and politicians don't want to take the risk of supporting a big experimental project. Financing must happen upfront, while benefits will pay out over a decades long period of time. It is unlikely that a project of this complexity and scale will be executed in the near future. Instead, it will be a theoretical example of what our cities could look like in the future.

Ethical considerations
The research proposes a transformation of the living environment that to a high degree changes daily life for the whole population. The design partly removes history and culture related to our current way of living and is likely to be conceived by many residents as unwelcome. The aim of the project is not primarily to satisfy current populations, but to create a sustainable set of requirements to make our public space sustainable for future generations.

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